CONFIDENTIAL

DECEMBER 1947

BUSHIPS Electron

NavShips 900,100

DECEMBER 1947 • VOLUME 3 • NUMBER 6

FRONT COVER. The editor explained the confused shipboard antenna situation to the artist and asked for a pictorial representation of the confusion. The result is a diagram of conflicting radiation patterns. In this issue of ELECTRON appears the first of a series of articles explaining what is being done to improve antenna systems.

BUSHIPS Electron

A MONTHLY MAGAZINE FOR ELECTRONICS TECHNICIANS

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

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

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

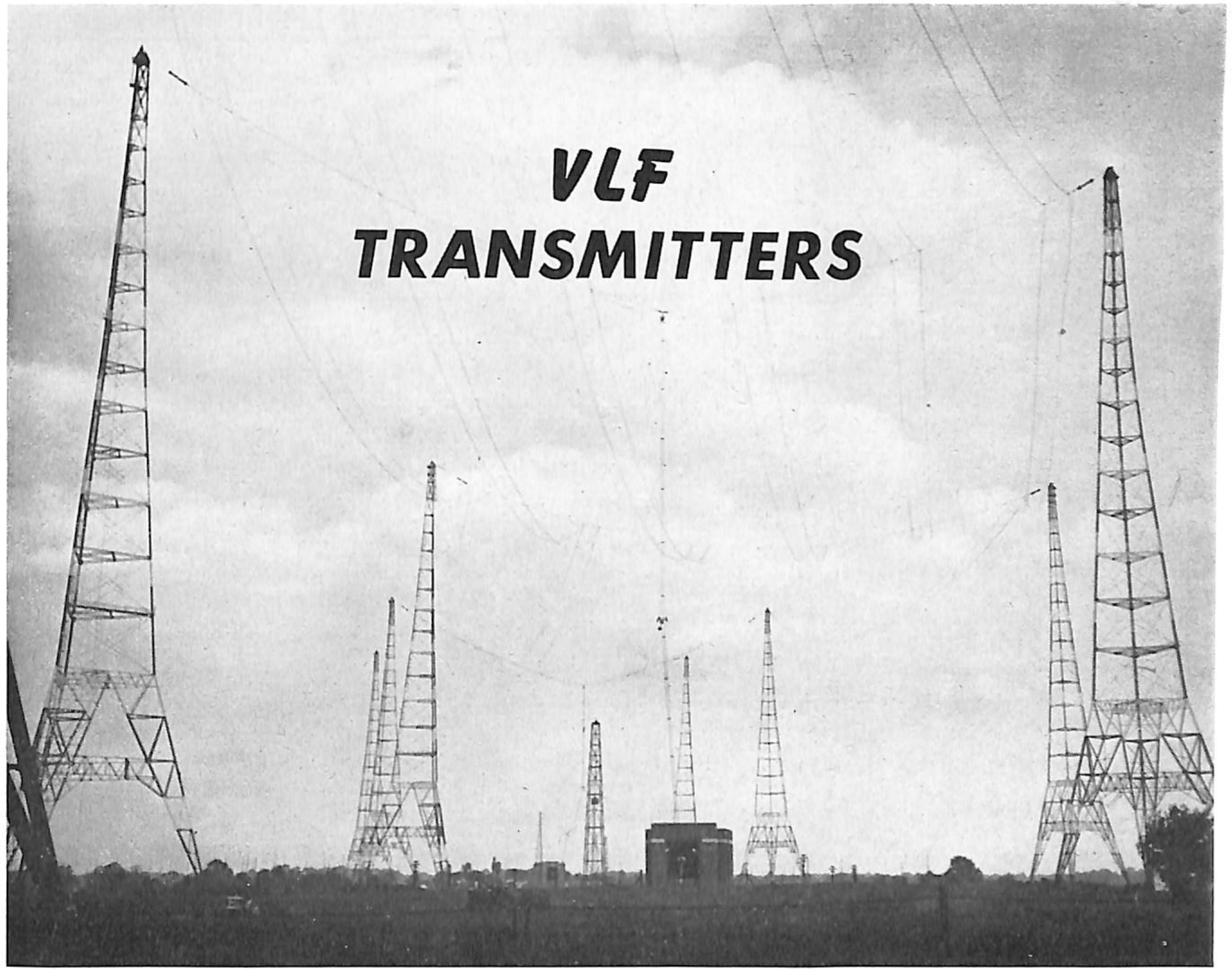
and forwarded via the commanding officer. Whenever possible articles should be accompanied by appropriate sketches, diagrams, or photographs (preferably negatives).

CONFIDENTIAL: BUSHIPS ELECTRON has been classified confidential in order that information on all types of equipment may be included. It should be shown only to concerned personnel as provided in the U.S. Navy Regulations. Don't forget this includes enlisted personnel!!

BUSHIPS ELECTRON contains information affecting the national defense of the United States within the meaning of the Espionage Act (U.S.C. 50; 31, 32) as amended.

BUREAU OF SHIPS — NAVY DEPARTMENT

VLF TRANSMITTERS



V-l-f antenna towers at Annapolis. At extreme left may be seen one leg of the ninth tower. The Annapolis antenna covers 120 acres of land.

By DAVID M. JONES
Lieutenant (EDO), U. S. Navy. Shore Electronics, Installation and Maintenance Branch, Bureau of Ships

■ Very low frequency is the band of radio frequencies from 10 to 30 kc. The navy employs very low frequencies for the fleet broadcasts, and for time, weather and hydrographic broadcasts in concert with various high frequencies. All of the v-l-f transmitters in use for these broadcasts are of high power output, ranging from 200 kw to 500 kw delivered to the antenna system. These high power, very low frequency transmitters radiate signals that have omni-directional coverage to distances of several thousands of miles. Vessels are thus assured reception regardless of their direction from the transmitter. The power radiated by these transmitters is principally in the form of vertically polarized waves that bend with the curvature of the earth to form a ground wave. V.l.f is essentially immune from fading characteristics and provides reliable coverage on a twenty-four hour per day basis. It is difficult for an enemy to jam v-l-f transmission except by the use of other high power v-l-f transmitters, which cost millions of dollars and require a period of years to design, build, and install.

High power v-l-f transmitters, while not entirely immune to sun-spot activity and magnetic storms, which are the cause of some of the high frequency disturbances, are affected only to a minor degree by them. Consequently, coverage is consistently reliable. Submarines, when properly equipped, are able to receive v-l-f transmissions when completely submerged. Frequencies below 25 kc penetrate the surface of the ocean to depths of 25 or more feet at great distances from the transmitter location. Other things being equal, the lower the frequency, the better the submerged reception.

Reliability is paramount in naval communica-

Table I—*Vlf Transmitters in Operation*

Station	*Frequency*	*Power*	*Location*	*Model Eqpt.*	*Use*	*Service Area*
NPM	16.68 Kc	200 Kw	Haiku, Oahu, T. H.	Alexanderson Alternator	Haiku FOX	Central Pacific
NPM	26.10 Kc	500 Kw	Lualualei, T. H.	TAW-a	How FOX	Central Pacific
NBA	32.60 Kc	300 Kw	Summit, C. Z.	TAW-1	Baker FOX	Pacific side Central and South America
NSS	18.00 Kc	500 Kw	Annapolis, Md.	TBJ	Wm. FOX	North and South Atlantic

tions. During disturbed high frequency conditions, the inherent stability and reliability of v-l-f transmissions is of vital importance. Many FOX schedule operators have complained of the monotony attending the reception of high power v-l-f transmissions. These complaints constitute some of the best evidence of the reliability of v-l-f reception. At certain times during Arctic Operation NANOOK and Antarctic Operation HIGHJUMP only the v-l-f transmissions of the FOX series provided usable copy. In the high latitudes of the auroral and polar zones high frequencies may be particularly erratic at times, whereas v.l.f is quite stable. The use of v-l-f and l-f bands is therefore particularly advantageous for naval communications in polar regions.

V-l-f transmission from naval radio stations is by means of either Alexanderson alternators or vacuum tube transmitters. An Alexanderson alternator is essentially a large motor generator set in which the output of the generator is telegraphically keyed. These machines employ a driving motor of about 500 horsepower geared to a special generator having a very large number of pole pieces. For example, one machine is equipped with 976 poles. The driving motors normally rotate about 900 r.p.m. Gears to step up the speed of the generator are proportioned according to the assigned operating frequency and the number of poles of the alternator. A rather elaborate keying, control and compensating system is employed to maintain frequency stability and clean keying. These alternators are rated at 200 kilowatts output of radio frequency energy to the antenna system. They require approximately 350 kw from the supply line. Figure 1 is an oblique view of the Haiku transmitter. Figure 2 is a view of the 600 kw emergency power plant, auxiliaries, keying and control panels for the Haiku transmitter.

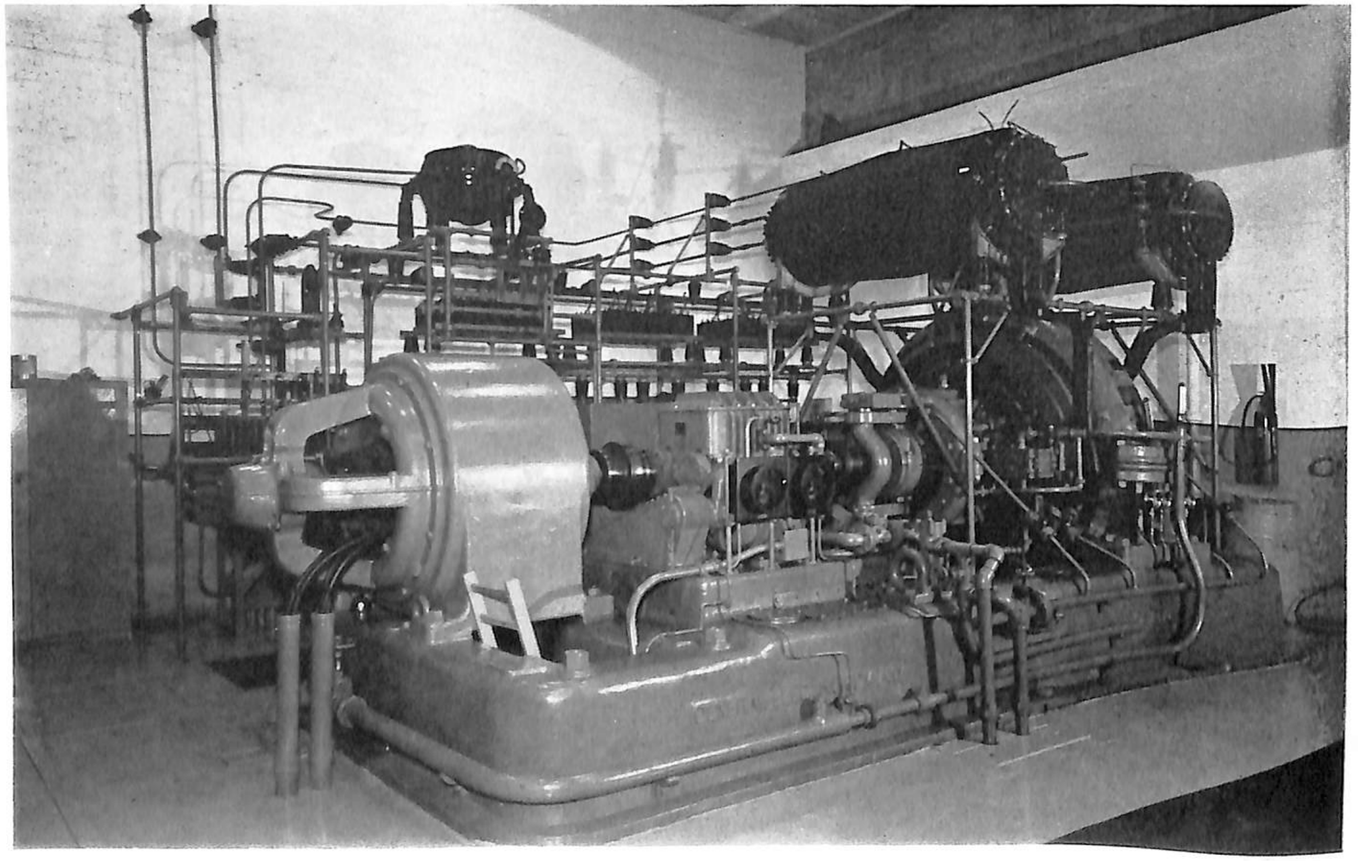


Figure 1—*Alexanderson alternator installed in Haiku Valley, Oahu, T. H. Radio NPM.*

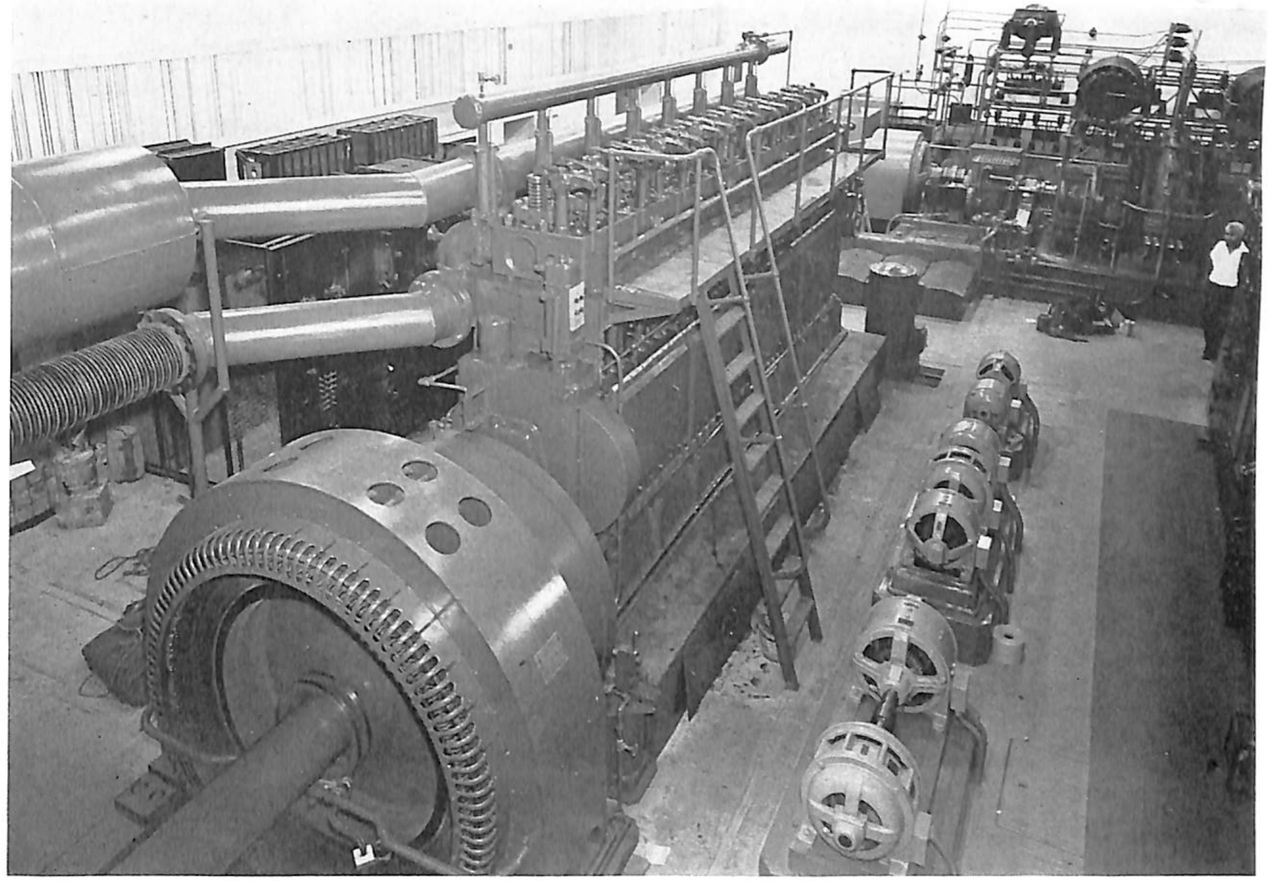


Figure 2—*Diesel power supply, control equipment and auxiliaries used with the Haiku alternator.*

The remainder of the v-l-f transmitters listed in the table above are of the vacuum tube type. All are of approximately the same basic design, although differing somewhat in power rating. A future modification is contemplated for the transmitter at Summit to increase its power output to 500 kw, to equal that of the transmitters at Annapolis and Lualualei.

Such a v-l-f vacuum tube transmitter is *BIG*. The transmitter proper, exclusive of power sub-station equipment and antenna tuning helics is 54 feet long, 15 feet high, and 26 feet deep. Figure 3 is a view of the Annapolis transmitter enclosure. The large size is necessary for two reasons: 1—the large size of the component coils and condensers necessary for v-l-f use; and 2—the high power and high voltages associated therewith.

These transmitters are of such size that separate buildings are required to house them. Associated with the transmitter building proper are one or two antenna tuning houses to house the antenna tuning inductances and the tuning variometer. These tuning coils are approximately 15 feet in diameter and about the same height. Usually three of these size coils are installed along with a motor driven variometer. The variometer tuning motor drives the variometer rotor through a gear arrangement similar to that used in the rear axle of an automobile. The tuning houses are often larger in size than the transmitter building, being about 80 feet square or octagon and about 60 feet high.

The trunk lead-out for the antenna is centered in a large opening about 30 feet in diameter, or square, to insulate the many thousands of r-f volts. Various means have been tried to insulate these trunk lead-out openings, but the 250,000 or so volts of r.f. have ultimately caused all of them to fail.

For 500 kw output, the total power drawn from the supply line is around 900 kw. All but about 100 kw of this power is fed into the main rectifier systems. Filament power, plus pumps and other auxiliaries consume about 100 kw. For example,

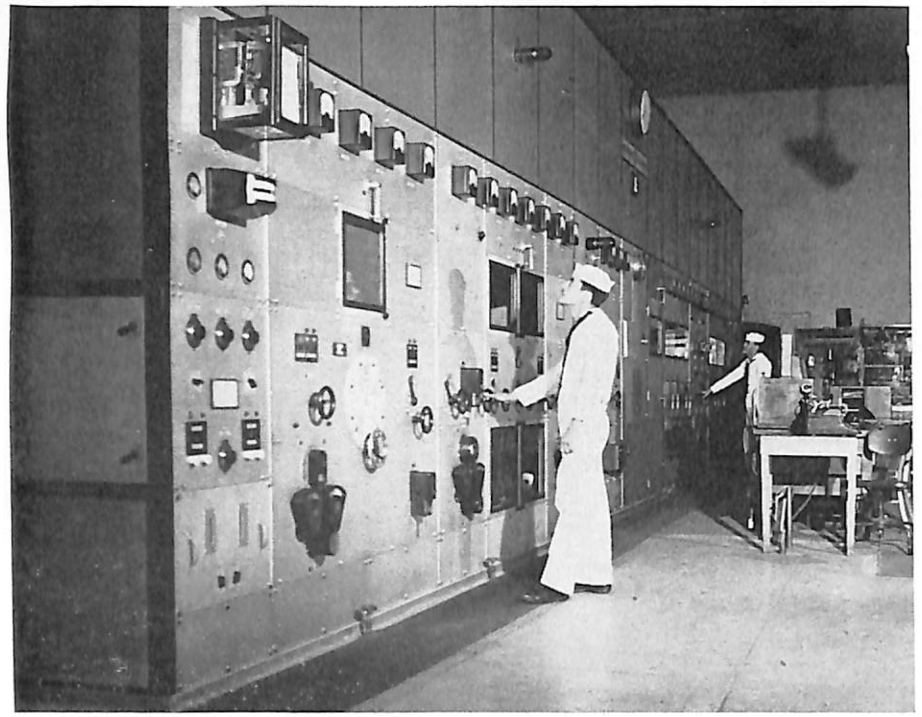


Figure 3—*Front panel of model TBJ transmitter at Annapolis.*

one of the eight water cooled tubes in the power amplifier requires 207 amperes at 33.5 volts, or just under 7000 watts to light the filament. The filaments alone of the power amplifier consume about 55 kw.

The Annapolis TBJ transmitter has two vertical down-lead sections and two helix tuning houses. Each vertical section has about 600 amperes flowing for a total of about 1200 amperes of antenna current. This current from the antenna must ultimately flow also into the ground to complete the antenna circuit. If all of this current were collected at one ground connection point the I^2R power loss would be enormous and the antenna efficiency would be so low that only a few kilowatts of power would be radiated for the full 500 kw of transmitter power.

To reduce the losses very elaborate ground systems are employed. These are of two general types. Buried copper wires are used where it is easy to plow in the wires to a depth of 1 or 2 feet. Many hundreds of wires are used and are placed under the antenna proper and extend out radially for several hundred feet as the terrain permits. From various points in this mesh of ground wires, connections are made and the current is conveyed to the antenna tuning house via overhead wires quite similar to telephone wire construction. As many as 40 such connections may be made, with overhead conductors carrying the current to the helix.

Where buried wires are impracticable, copper-clad steel rods about $\frac{1}{2}$ inch in diameter and from 8 to 10 feet in length are driven into the ground. As many as 5000 to 7000 such rods are used. These rods are usually placed in circular patterns with radial overhead conductors carrying the current to the tuning helix. Equalizing coils are placed in these radial conductors and the inductance is adjusted to produce an essentially-even distribution of the current in each of the conductors. The even distribution of ground current assures minimum loss. The resistance of a single rod to the earth may be many ohms, but the use of several thousand rods makes the joint resistance of the system but a very small fraction of an ohm. Thus the ground losses are reduced and the radiation efficiency of the antenna is much improved. Antenna efficiencies vary considerably, with different installations and with frequency and range, from about 20 percent to about 70 percent.

Figure 4 is a view of the 50 kw intermediate power amplifier stage of the TBJ. These coils demonstrate the large size of the components associated with v.l.f.

Plate voltages used with the tubes in v-l-f transmitters are commonly from 13,000 to 15,000 volts d.c. Total plate current for the power amplifier stage may exceed 50 amperes. The circulating tank current in the power amplifier tuned circuit may be from 300 to 400 amperes. Antenna currents for each vertical down-lead section, depending upon frequency and antenna arrangements, approximate 600 amperes. These figures serve to illustrate why v-l-f transmitters are large from the point of view of high power.

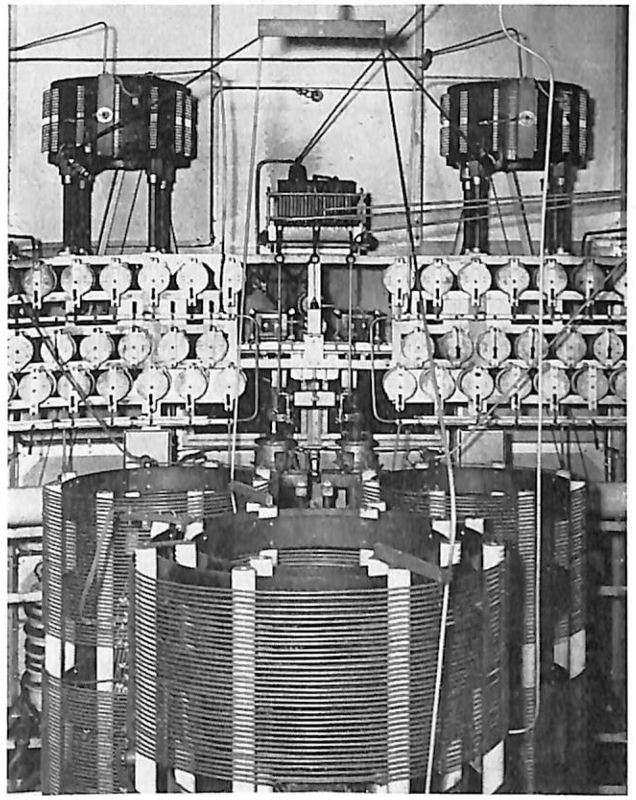


Figure 4—*TBJ 50-kw intermediate power amplifier. Coils in foreground are about four feet high.*

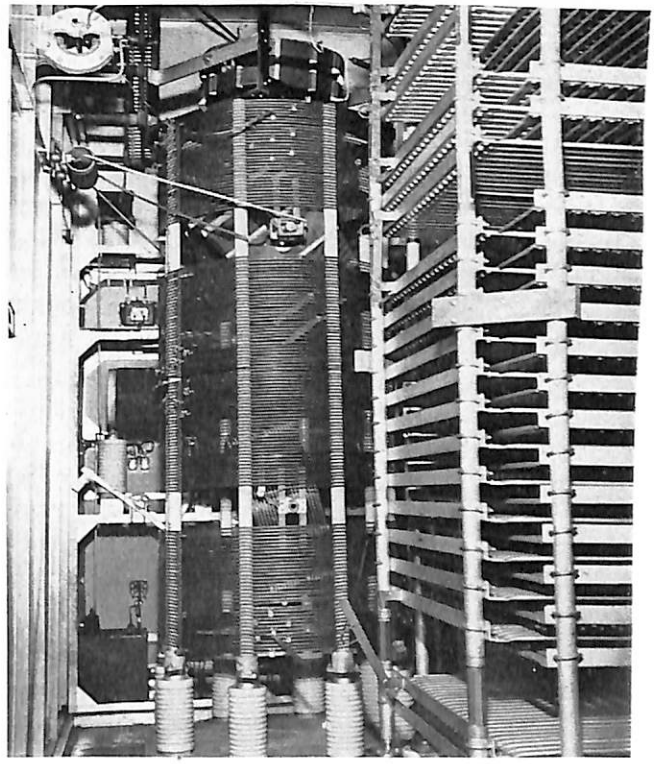


Figure 5—*TBJ 25-kw master-oscillator tank circuit. The central coil is about seven feet high. Air-dielectric capacitor at right.*

By comparison, a search radar may radiate pulses of 500 kw, but since the repetition rate is slow and the pulse length short, the *average* power radiated may not exceed 200 watts. The v-l-f transmitter, on the other hand, is often tested with continuous locked key, in which case the average power generated is the full 500,000 watts.

Where radio frequency circuits are concerned, v-l-f transmitters are quite simple. The usual arrangement is a master oscillator driving a push-pull intermediate power amplifier, which in turn drives a push-pull power amplifier. The power amplifier is inductively coupled to the antenna tuning helix.

The master oscillator employs a type 858, 25-kw water-cooled triode tube in a conventional Hartley oscillator circuit. The master oscillator is continuously variable over the frequency range of 15 to 34 kc. The oscillator runs continuously while the transmitter is in operation. The oscillator is very lightly loaded and actually furnishes only about one kw to drive the intermediate amplifier. This light coupling to the succeeding stage allows the circuit Q of the frequency-determining copper tubing coil and air dielectric condenser to be quite high. The result is excellent frequency stability. As a general rule the frequency stays within 2 to 3 cycles of the assigned value day after day. Figure 5 is a view of the TBJ master oscillator coil and air capacitor units.

Adjustable inductive couplers convey r-f energy from the master oscillator to the grids of the push-pull type 858 water-cooled tubes in the intermediate power amplifier. Telegraph keying of the transmitter is accomplished by means of a cascade of vacuum tubes and power supplies which alter the grid bias of the intermediate amplifier from an operating value of bias for key down condition to a blocking bias for key up condition. The plate tank circuit of the intermediate amplifier is composed of copper tubing coils and mica dielectric condensers. Attention is invited to figure 4 for a view of this stage.

The intermediate amplifier is inductively coupled to the grids of the type 862, 100-kw water-cooled power amplifier tubes. The power amplifier tubes are grouped in two clusters of 3 tubes at Summit and two clusters of 4 tubes at Annapolis and Lualualei. In each cluster the grids and plates of the tubes are paralleled. The two clusters of tubes are operated in push-pull.

The power amplifier tank circuit capacitance is made up of two banks of oil-mica condensers. Each bank contains 20 condensers of 0.0275 microfarad each, with an individual switch for connecting each unit into or out of the circuit. The actual number connected in parallel in each bank depends upon frequency; the lower the frequency, the greater number in use. These condensers are cylindrical in shape, approximately 30 inches high and 18 inches in diameter, and weigh slightly over 275 pounds per unit.

The power amplifier tank circuit inductance is made up of two Litzendraught cable variometers connected in series via the turns of the output inductive coupler. Each variometer is about 5 feet in diameter. The output inductive coupling turns are arranged in two sections to permit loading each half of the power amplifier evenly. Figure 6 is a view of the power amplifier.

The energy from the power amplifier tank circuit is inductively coupled to the antenna tuning variometer and inductances, and to the ground system.

At this point it is believed that a brief description of the Litzendraught cable used in the power amplifier variometers and the antenna helices would be interesting. The Litz cable as used in these v-l-f power transmitters is an r-f conductor made up of about 90,000 individual strands of enameled copper wire, each strand 0.005 inch in diameter. The cable is about 2 inches in diameter and is made up of a hemp center of slightly more than an inch diameter, around which, in cross section, are the major strands of the conductor. The major strands also have hemp centers around which are grouped the minor strands. In turn, the minor strands have very small hemp centers around which are grouped the individual 0.005-inch enameled copper conductors. Each of these tiny conductors is thus insulated from all others along the length of the cable, being connected in parallel in a special terminal fitting at each end of the cable. The individual, minor, and major strands are woven in a lay such that in a length of several feet, each of the individual strands will have the same percentage of its length extending from the exterior to the interior of the completed cable. This amounts to taking a given cross section of copper conductor and subdividing it many times to obtain the maximum practicable surface area. Since radio frequency currents travel principally on the surface of a conductor, the Litzendraught cable, possessing very great surface area, has very low radio frequency loss resistance. Litzendraught cable is less efficient as frequency is raised, however, and is about equal electrically to hollow copper tubing at about 2500 kc. Litzendraught is at its best in the v-l-f and l-f range of frequencies.

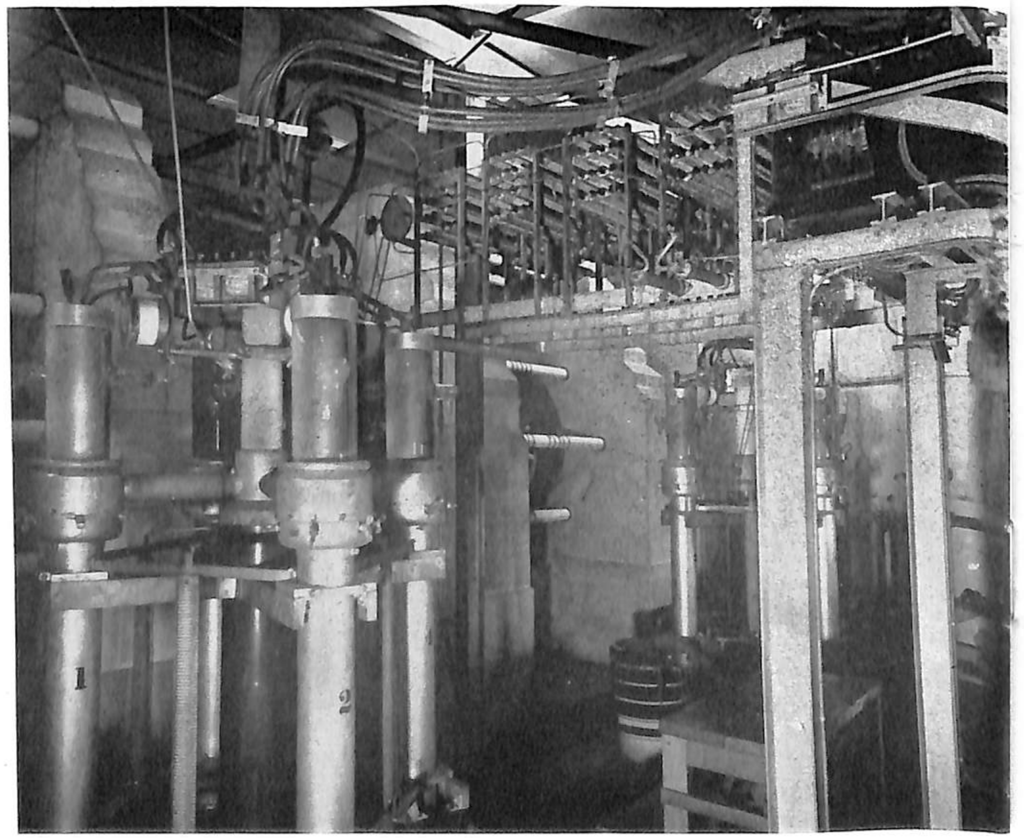


FIGURE 6—*TBJ 500-kw power amplifier. Water-cooled tubes are rated at 100 kw each and stand about five feet high.*

The power amplifier tank variometers are constructed of a single 2-inch Litz cable rated to carry continuously 400 amperes of radio frequency current. The antenna variometer and tuning helices are constructed of two 2-inch cables paralleled which will permit up to 800 amperes of antenna current within the rating of the cables.

At Annapolis and Lualualei the primary a-c power within the station for use of the v-l-f equipment is from 11.5 to 13.2 kilovolts, 3 phase, 60 cycles. Transformers step this voltage down to 400/220 volts for use of filament lighting and auxiliaries of various kinds, including water and air pumps. Multi-tapped oil-cooled transformers adjust the incoming high voltage as necessary for use in a 3-phase, full wave rectifier which supplies up to 15,000 volts d. c. for use on the plates of all tubes. Type 870-a mercury vapor rectifier tubes are used in the plate supply rectifier. The primary power at Summit is alternating at 25 instead of 60 cycles. Due to the use of 25-cycle power, a 12-phase rectifier system is used in order that the power supply ripple of the rectified d-c voltage may be more easily filtered.

The large water-cooled tubes employed in these high power transmitters cost several hundred dollars each. To obtain quick servicing and minimum casualty off-the-air time, self-protecting control measures and indicating devices are very extensively employed in these equipments. Each high power water-cooled tube is equipped with a tube life meter, plate current overload relay, interlocked grid current overload relay, water overtemperature relay, water flow interlock, water pressure gauge and air flow interlock.

The nominal efficiency of these class C power amplifiers is in the order of 65 percent. Thus, to have 500 kw of radio frequency power output, about 800 kw of plate input power must be drawn from the plate rectifier system. The difference between the 500 kw output and the 800 kw plate input, 300 kw, is manifest in heating of the plates of the water-cooled tubes. To dissipate this waste heat, distilled cooling water in a closed circulatory system is pumped through water jackets in which the tubes are mounted. Water flow per tube is from 15 to 20 gallons per minute. The heat from the plates of the tubes is transferred to the distilled water flowing through the tube jackets. The distilled water flows through a water-to-water heat exchanger to 1000-gallon surge tanks. The distilled water pumps take their suction from the surge tanks and recirculate the water continuously. The heat from the distilled water is given up through the walls of the heat exchanger to the raw water system. The heat thus given to the raw water system is finally given up to the earth and air in cooling wells or ponds. In some cases the raw water is sprayed over the cooling ponds for supplemental air cooling.

The distilled water is conducted from the electrically grounded tank, pump, and piping system to the tube plates and tube water jackets via insulated distilled water columns. These water columns are made up of rubber, plastic, or ceramic hose reels having a column length of about 30 feet. Distilled water has very high resistance per inch in such a column; the total resistance of each column, therefore, is several megohms. The power leakage through these distilled water columns is very minor when compared to the quantity of power being handled by the tubes.

V-l-f antennas are necessarily very large. For comparison, a vertical quarter wavelength antenna for 2000 kc would be close to 120 feet high, whereas a vertical quarter wavelength antenna for 20 kc would have to be some 12,000 feet high or a height of well over 2 miles. This height is obviously impracticable. Actual v-l-f antennas are of a catenary type suspended from mountain tops or are of a T or ⫪ configuration, elevated upon 600-foot towers. Distant reception of v.l.f is primarily by means of the vertically-polarized ground wave. This ground wave is radiated from the vertical section of the antenna. The top of the T antenna structure is a means of top loading to increase the current, and therefore the radiation, from the vertical section. The top of the T is an electrical substitute for physical height.

The transmitter at Haiku is an example employing a multi-span catenary antenna. This antenna is supported by mountain top anchorages between peaks located about 8000 feet apart. Approximately 4500 of the 8000 feet span is the horizontal top loading section of the T antenna proper, with a vertical section extending from the center downward some 1200 feet to the transmitter building on the floor of the valley. An elaborate distributed ground system is installed in the valley floor to conduct the ground currents to the ground terminal of the antenna tuning inductance.

Of the tower supported antennas, Summit has six 600-foot towers arranged in two rows of three each to form a rectangle about 1200 x 2400 feet, and has a single vertical section and antenna tuning helix. Lualualei has seven 600-foot towers, six of which form a rectangle with the seventh tower extended on the center line at one end. Annapolis

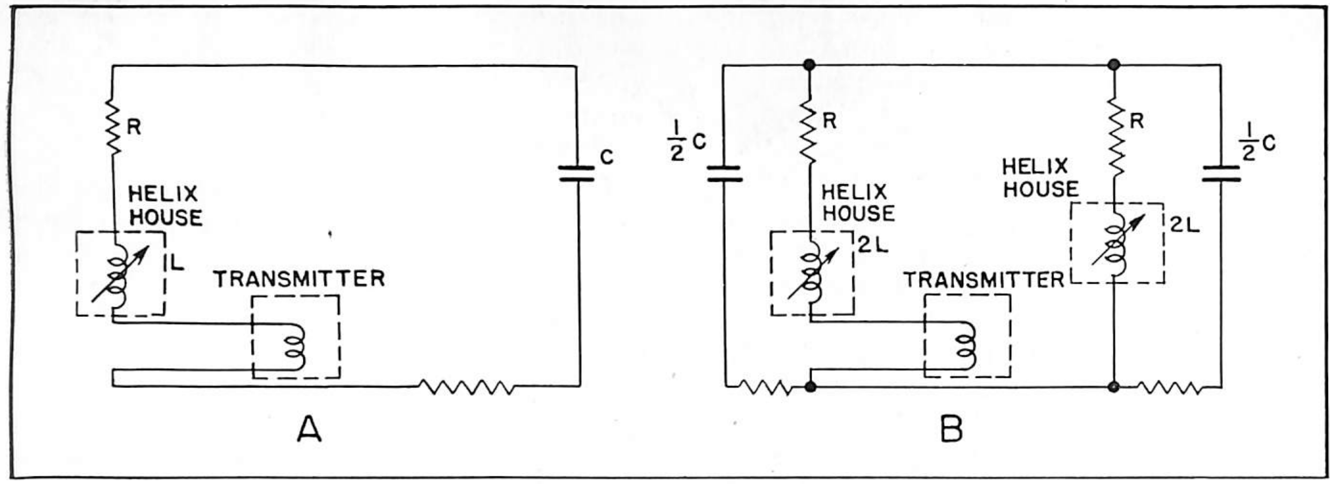


FIGURE 8—*At A, the equivalent circuit diagram for single-point tuning of a v-l-f antenna. At B, the 2-point multiple tuning arrangement. Using the latter, more power is radiated with less loss and lower antenna voltages.*

has nine 600-foot towers situated upon an irregularly shaped point of land extending into Chesapeake Bay. The Annapolis antenna covers approximately 120 acres of land. Extensive ground systems are employed with all of the tower v-l-f antennas.

The radiation resistance of a quarter-wavelength antenna approximates 36 ohms and is non-reactive. If, for the same frequency, the antenna is appreciably shortened to the point that it becomes a very small fraction of a quarter wavelength, the radiation resistance is markedly reduced and may become but a fraction of one ohm. The shortened antenna will become capacitively reactive, values of capacitive reactance becoming as much as 400 ohms. If an inductive reactance equal to the capacitive reactance of the antenna is placed in series with the shortened antenna, the reactance of the antenna is cancelled, the antenna plus tuning coil make the whole system resonant to the original frequency, and the impedance of the antenna is equal to the resistance of the antenna system.

The wavelength corresponding to 20 kc is 15,000 meters, about 9 miles. A quarter-wavelength then, is approximately 2¼ miles. Because of sag, due to the weight of conductors, the 600-foot tower-supported antennas are effectively about 400 feet high. At 20 kc a v-l-f antenna will be but a very small fraction of a quarter-wavelength high. The top loading contributed by the horizontal top section will help some, but even so the antenna will be quite small in terms of wavelengths at v.l.f.

Suppose, for example, that a v-l-f antenna operated at 20 kc has an antenna terminal capacitive reactance of 400 ohms and that the resistance is exactly 1 ohm. For I^2R power of 500 kw the antenna current would be 707 amperes, and the voltage on the antenna terminal, built up across the 400 ohms of inductive reactance of the tuning helix through which the antenna current must flow $(E = IZ)$, would be 282,800 volts.

Above about 300 kilovolts, depending upon atmospheric conditions, corona discharge commences. Corona discharge literally "burns the air," consuming many kilowatts of r-f power but without producing strong signals at a distance. The power that a v-l-f antenna can radiate without reaching the corona voltage limitations may be increased by "multiple tuning" the antenna. This is accomplished by having two vertical sections resonated by two helices so that for the same voltages on the antenna the currents in the vertical sections may be added together for a greater antenna current than would be possible for single point tuning. Multiple tuning also reduces ground losses because the ground currents are returned to more than one tuning helix, thereby providing a multiple of shorter paths for these currents.

Figure 8A is a schematic diagram for a v-l-f antenna having a given antenna capacity C, radiation resistance R, and tuning inductance L for single-point tuning. Figure 8B is a schematic diagram for the same size antenna with two-point multiple tuning. Here ½ of the antenna's total capacity is tuned to resonance for the same operating frequency by the use of a tuning helix having twice the inductance of figure 8A. The two halves of the antenna are thus independently tuned to the same frequency and operate in parallel. The transmitter need couple to only one of the helices since the second section is excited due to its close proximity to the driven section. The transmitters can be operated to furnish about 500 kw to the multiple tuned antenna, whereas the same antenna, if single-point tuned, would limit transmitter power to approximately 300 kw before corona starting voltages would be reached. Figure 9 is a view of the antenna tuning inductances of one helix house used with the TBJ transmitter.

The transmitters at Annapolis and Lualualei operate into multiple-tuned antennæ and may, therefore, be operated at 500 kw with increased antenna efficiency and with some safety factor under corona-starting antenna voltages.

These high power v-l-f transmitters are very large, very reliable, have omni-directional antenna radiation characteristics, have an effective range of several thousand miles, can be received by submarines running under the surface, and are effective during times when other long distance radio communications are subject to limitations or elimination due to magnetic storms and sun-spot disturbances. Despite the emphasis being placed on high frequencies in these modern times, the v-l-f transmitters continue to bang out solid copy for thousands of miles in all directions, having been tried by the ordeal of time and proven their worth for a good place in the sun.

Should opportunity present itself for navy communications and electronics personnel to visit any of the navy's major v-l-f transmitters, this opportunity should not be missed. Prior to such a visit, arrangements should be made with the Officer-in-Charge of the station.

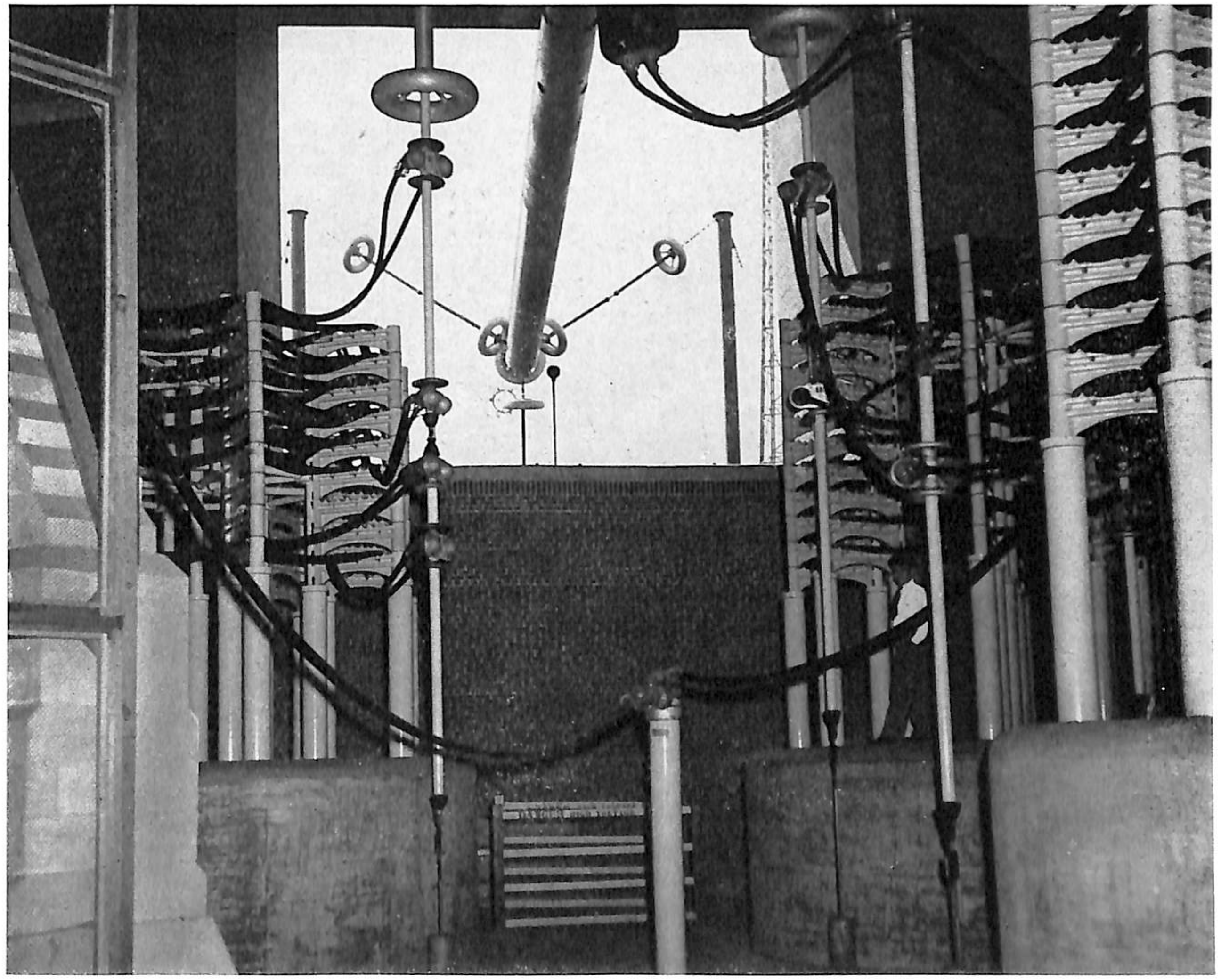


FIGURE 9—*One of the TBJ antenna tuning houses. Note man standing on coil base at lower right. This building can not be occupied with equipment in operation.*

early antenna program at NEL

By R. T. Brackett
U. S. Navy Electronics Laboratory

■ *During the recent war a maze of antennas of all types—radar, IFF, countermeasure, beacon, u-h-f, whip and long wire antennas—seemed to sprout overnight on the superstructures of naval vessels. These antennas, although carefully designed to rigid and satisfactory specifications individually, were found, when placed in the maze on shipboard, to act in an erratic fashion which hampered fleet operations. It became evident that antenna design would need to be based on the overall system performance rather than individual "free-space" antenna performance.*

Realizing this, the Bureau of Ships set about to establish a long-range program of study and development of antenna systems. The best personnel and laboratory facilities were made available, new facilities were added, and unique new measuring techniques were developed.

Among the agencies intimately associated with this program are the U. S. Navy Electronics Laboratory at San Diego, the U. S. Navy Underwater Sound Laboratory at New London, the Naval Research Laboratory at Washington, D. C., and various commercial contractors.

The following article is the first of a series of four articles which will appear in BuShips Electron *on this subject. These articles will deal with the problems imposed by modern shipboard electronic antennas and the methods employed which have led and are leading to the improvement of individual antennas, and to the development of standard and integrated system arrangements for each class of naval vessel.*

World War II, which has been called the "technician's war," was characterized by an astonishingly rapid development in all phases of combat technology. The greatest expansion occurred in Electronics, and accomplishments in this field contributed greatly to the final defeat of the enemy. At the outset, however, the ultimate importance of electronics was not immediately appreciated.

In the face of the impending early crises, it became necessary to develop and install aboard naval vessels huge quantities of naval combat equipments. Preference naturally went to those weapons which could inflict damage upon the enemy or contribute directly to the protection of the vessel. It is reported that at this time one commanding officer remarked, "You can fight 'em without radio, but you can't fight 'em without guns."

Perhaps no one single weapon created more difficulties for electronics than the aircraft. The development of aerial warfare required us to protect our vessels with anti-aircraft batteries capable of high-angle fire, and also to establish additional tactical communication circuits to maintain control of our own air units. Thus, one single factor not only required the clearing of overhead spaces in which antennas could be installed, but at the same time necessitated the employment of additional antennas.

While engineering technology was entirely adequate for the production of new high-frequency equipments, the urgency of overall antenna engineering was not at first appreciated, particularly in the radio communication field. Primarily this was due to a lack of suitable test equipment for employment at these frequencies. Moreover, several naval organizations, in particular the Naval Research Laboratory, had made extensive investigations at medium frequencies and below, and their results aroused no serious apprehension about the overall performance of shipboard high-frequency antennas.

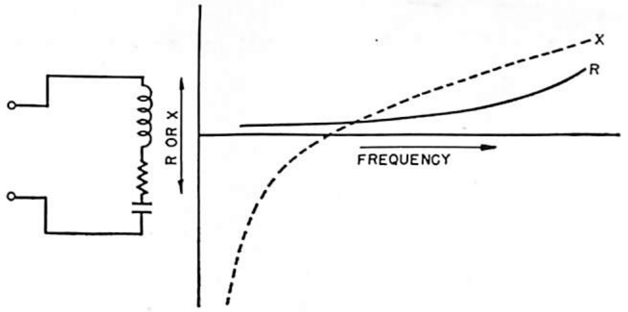


Figure 1A—*Series LC circuit. The antenna impedance looks like this near the odd-numbered resonances.*

It therefore came about that the five-thousand-dollar high-frequency equipments were well designed and thoroughly tested, and their operation was well understood. At the same time the associated five-dollar high-frequency antennas were installed without adequate design or test, and (as was subsequently ascertained) very little was known about their operation.

When the Navy Electronics Laboratory was first commissioned as the Navy Radio and Sound Laboratory at San Diego in 1940, a Radio Division was among those first activated. This group at once initiated an investigation into the characteristics of the then-current high-frequency antenna installations. Fortunately, new measurement equipments became available, and the nature and scope of the shipboard high-frequency antenna problem soon came to be better appreciated.

It was well known that when an antenna is operated over a sufficiently wide frequency range, it becomes resonant at many frequencies. As the frequency is increased, the first resonance occurs for that frequency at which the antenna length is roughly one-quarter wavelength, and near this frequency the antenna behaves much like a series LC

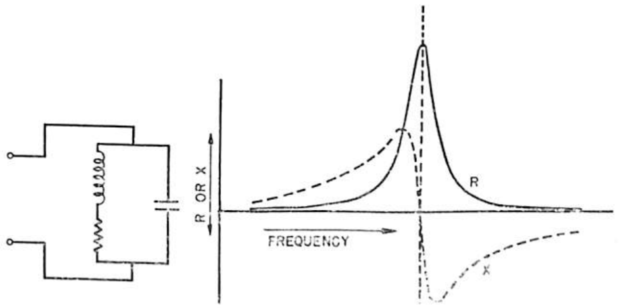


Figure 1B—*Parallel LC circuit. The antenna impendance looks like this near even-numbered resonances.*

or resonant circuit (see impedance characteristics of figure 1A). As the frequency is further increased, the second resonance occurs when the antenna is one-half (i. e., two-quarters) wavelength, and near this frequency the antenna behaves like a parallel LC or anti-resonant circuit (see impedance characteristics of figure 1B). Near the third, the fifth, and all the other odd-numbered resonances (where the antenna is electrically an odd number of quarter wavelengths long) the impedance properties resemble those near the first resonance, while near all the remaining even-numbered resonances the properties are like those near the second resonance.

Figure 2 shows part of a typical impedance characteristic obtained by the Radio Division for the TBL antenna on the *Long Island* (CVE-1).

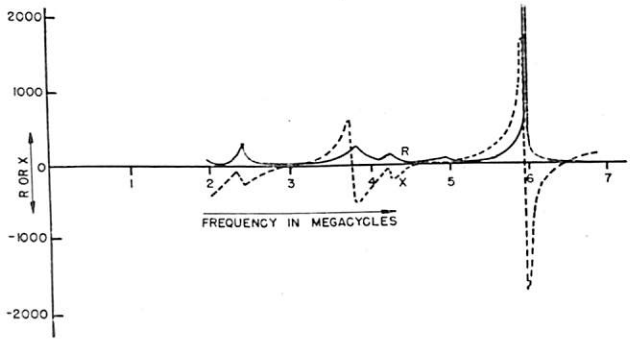


Figure 2—*Typical antenna impedance characteristic for the Long Island (CVE-1) TBL antenna. The first and third resonances appear at 3.0 and 4.8 Mc. while the second and fourth are at 3.75 and 5.95 Mc. The irregularities at 2.4 and 4.2 Mc are due to coupling to other antennas resonant at these frequencies.*

In a few cases the impedance was found to be so erratic and unstable as to account fully for anomalies in the behavior of the associated equipments. The impedance properties were not in general found to be unsatisfactory. However, a much more serious situation was disclosed by investigation of the directivity properties of shipboard antennas at high frequencies and above.

A moment's reflection will show that the surroundings of a shipboard antenna are electrically quite complex, involving an irregularly-stepped ground plane and, usually, a large number of parasitic conductors. These conditions had been appreciated, and it was realized that at high frequencies and above, the radiation from a shipboard antenna would be impaired along certain relative bearings, and perhaps enhanced along others.

Measurements disclosed the above to be true. For many antennas measured, sectors were found in which the signal intensity dropped to ten per cent of the maximum observed, sometimes to complete extinction. In the autumn of 1941 the old *Saratoga* (CV-3) proved that one communication failure was due solely to directivity in a transmitting antenna. Subsequently, it was observed that receiving antennas also possess directivity, sometimes so marked as to impair their efficiency seriously.

Figure 3 shows a typical antenna directivity pattern obtained by the Radio Division for the TBM antenna No. 2 on the *Saratoga*.

In 1942 some of the first aircraft carrier escorts appeared in the San Diego area and appealed to the Laboratory for assistance in establishing satisfactory radio communication. It had been ascertained that equipments were not at fault, personnel were properly trained, procedures were correct, yet day after day flight operations had to be canceled because of radio communication failures.

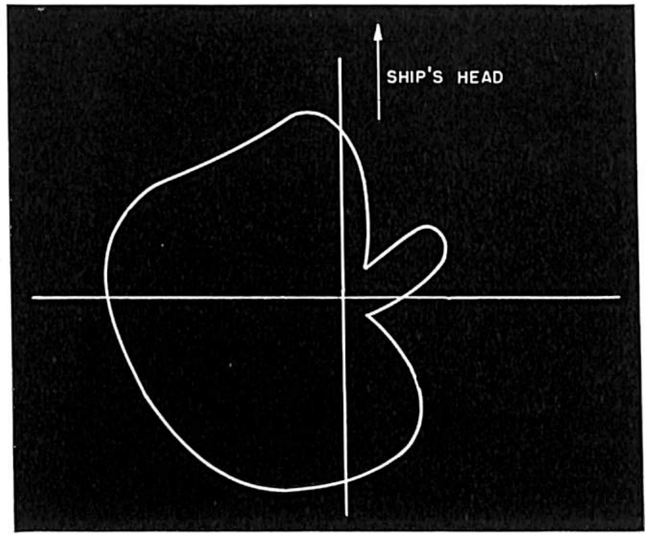


Figure 3—*Typical antenna directivity pattern for the Saratoga (CV-3) TBM antenna No. 2 at 2210 kc. The antenna was installed on the starboard side of the stack and transmitted more effectively through the obstruction.*

The radio antenna arrangement appeared conservative and sound in the light of experience and currently-available information. However, laboratory measurements showed that this antenna arrangement suffered from extreme directivity. In fact, one antenna operating at a popular frequency was found to have extremely weak low-angle radiation throughout a total arc of nearly 240 degrees. Vertical radiation patterns showed wide cones of silence, into which very little power was radiated.

The work of the Laboratory's Radio Division on this problem led to the braced tilting whip and the "lazy tee" antennas. Although these structures displayed some poor characteristics, they proved operable and were adopted as interim devices for the duration of combat operations.

About this time the Laboratory's Special Developments Department began to investigate antennas used at v.h.f. and higher. Techniques were developed for obtaining the effective coverage patterns of radars, and for determining the reduction in range of submarine SJ's when looking through the periscope shears. Relative coverage patterns were also obtained for IFF and beacon equipments.

By 1943 the Bureau of Ships was working feverishly on the expansion program, involving construction or conversion for the many new auxiliary classes and types. To assist in the program, the Laboratory detailed an engineer from its radio division for temporary additional duty in the Bureau. The results of the Laboratory's influence upon antenna arrangements were much in evidence among the auxiliaries joining the fleet in late 1943 and 1944.

By this time it had been ascertained that the simple laboratory, or textbook, theories were incapable of forecasting the directivity of shipboard antennas. While some general principles had been found to give a better expectation of good results, it still remained necessary to check a proposed arrangement in an actual installation and to make cut-and-try adjustments. In the case of new construction or conversions not completed, this obviously could not be done. Moreover, such work sheds little light upon the nature of the antennas and the causes of their shortcomings.

In 1944, the Laboratory initiated a study of small-scale ship models, whose antennas operated at proportionately small wavelengths. A destroyer model procured from the David Taylor Model Basin was followed by other models constructed by the Laboratory. A full account of the model technique, the facilities, difficulties and accomplishments, will be covered in another article.

In mid-1944, the Laboratory's Radio Division was reorganized as the Test and Measurement Department, and the personnel complement was somewhat expanded. By this time the measurement techniques had become fairly well established. Work of this department had resulted in improvements to antenna arrangements for some seaplane tender, submarine, and light cruiser types. The Laboratory's Special Developments Department also effected improvements in antenna arrangements for v-h-f and u-h-f equipments under their cognizance.

With the ever-accelerating growth of the electronic arts, more and more equipments were appearing on our vessels, with more and more antennas. As the clamor grew from different sources for favored locations for these antennas, it finally became necessary for the Bureau of Ships to designate a neutral arbiter to hear conflicting demands.

This was accomplished by organizing the Systems Engineering Section, BuShips Code 911, whose functions were to assemble all available and pertinent engineering information, to consider the space requirements for each antenna assembly, to decide between conflicting space allocations and, in the name of the Bureau of Ships' Electronics Division, to make final recommendations regarding antenna arrangements.

Because of the liaison already established between N.E.L. and the forces afloat, and the unusual facilities for continuation there of the antenna studies already begun, the Bureau of Ships Systems Engineering Section proposed that the Laboratory engineering activities should be centered in the Test and Measurement Department, at the U. S. Navy Radio and Sound Laboratory.

Accordingly, in the summer of 1945 a conference was held between representatives of the Chief of Naval Operations, the Bureau of Ships, the U.S. Navy Radio and Sound Laboratory (now the U.S. Navy Electronics Laboratory), the Naval Research Laboratory, and the National Defense Research Council Divisions 13, 14, and 15. At this time a systems engineering doctrine was formulated, which, in effect, stated that the assemblage of antennas on a naval vessel must be considered an electronic system, whose performance is to be evaluated in terms of the contribution of the whole system to the combat efficiency of the vessel. Regardless of potential enhancement to performance of a particular antenna, no concessions should be made to any one antenna in matters of design or location at the expense of efficiency of the system as a whole.

The conference also initiated a program for implementing the systems engineering doctrine. The technical activities were to be centered at the Laboratory, while matters of administration and policy were to be handled in the Bureau. The latter agency was also to effect liaison between the Laboratory and supporting agencies, including other naval laboratories and private contractors.

The Test and Measurement Department, now reorganized as the Systems Engineering Department, assumed responsibility for all antenna measurements, including v-h-f and u-h-f assemblies formerly under the cognizance of the Special Development Department. Personnel requirements were met partly by personnel expansion at NEL and partly by the negotiation of a contract with Naval Electronic Research under the auspices of the University of California.

With minor modifications, the original plan remains in effect. The U.S. Navy Underwater Sound Laboratory at New London, Connecticut, has been assigned cognizance of submarine antenna systems installations, the Radio and Sound Laboratory, now redesignated as the United States Navy Electronics Laboratory, has been assigned cognizance over shore-station and shipborne antenna systems.

In following articles more details will be given concerning the antenna systems engineering program at the U.S. Navy Electronics Laboratory.

DBM ANTENNA COUPLING FAILURE

The Puget Sound Naval Shipyard has reported by letter the following mechanical defects in the construction of the model DBM-1 low-frequency direction finder antenna. The letter is quoted as follows:

"Inspections of electronics equipment on vessels arriving at this yard have revealed a serious mechanical defect in the antenna-drive mechanism of model DBM-1 direction-finders. In two instances the coupling for securing the antenna to the drive shaft has failed, permitting the rotating antenna to come off at the shaft, resulting in considerable damage to the antenna. Failure of these couplings, in at least two cases, was due to breaking of a threaded collar which is an integral part of the antenna subbase casting. This collar is of aluminum, and the threaded portion is split lengthwise in two directions. The collar fits over the top end of the drive shaft, and is secured thereto by a steel locknut having a tapered pipe thread. Because of the soft material and small dimensions of this collar, it has insufficient strength to withstand the mechanical shocks to which a combat vessel is subjected.

"In other instances, the aluminum collar did not break, but the antenna came loose from the shaft because of loosening of the locknut, due apparently to vibration or to differences in thermal expansion of the steel nut and the aluminum collar. The design of these parts is such that clearances are not sufficient to permit use of a locknut. Locking of the nut by means of a tapered drive pin cannot be accomplished, as the hollow drive shaft contains the antenna coax cable.

"The casualties described above have been observed only in low-frequency DBM-1 antennas (CBM-66141). This is probably due to the fact that, while the drive mechanism and couplings are of the same design, the antenna elements are somewhat heavier in the low-frequency antenna than the high-frequency antenna."

It is requested that all ships, naval shipyards or other activities having this equipment installed and whose findings are similar, report them immediately to the Bureau of Ships, Code 982, thus enabling the Bureau to initiate remedial action accordingly. It is not necessary that these findings be submitted in formal letter. The usual Failure Report, NavShips 383, will suffice.

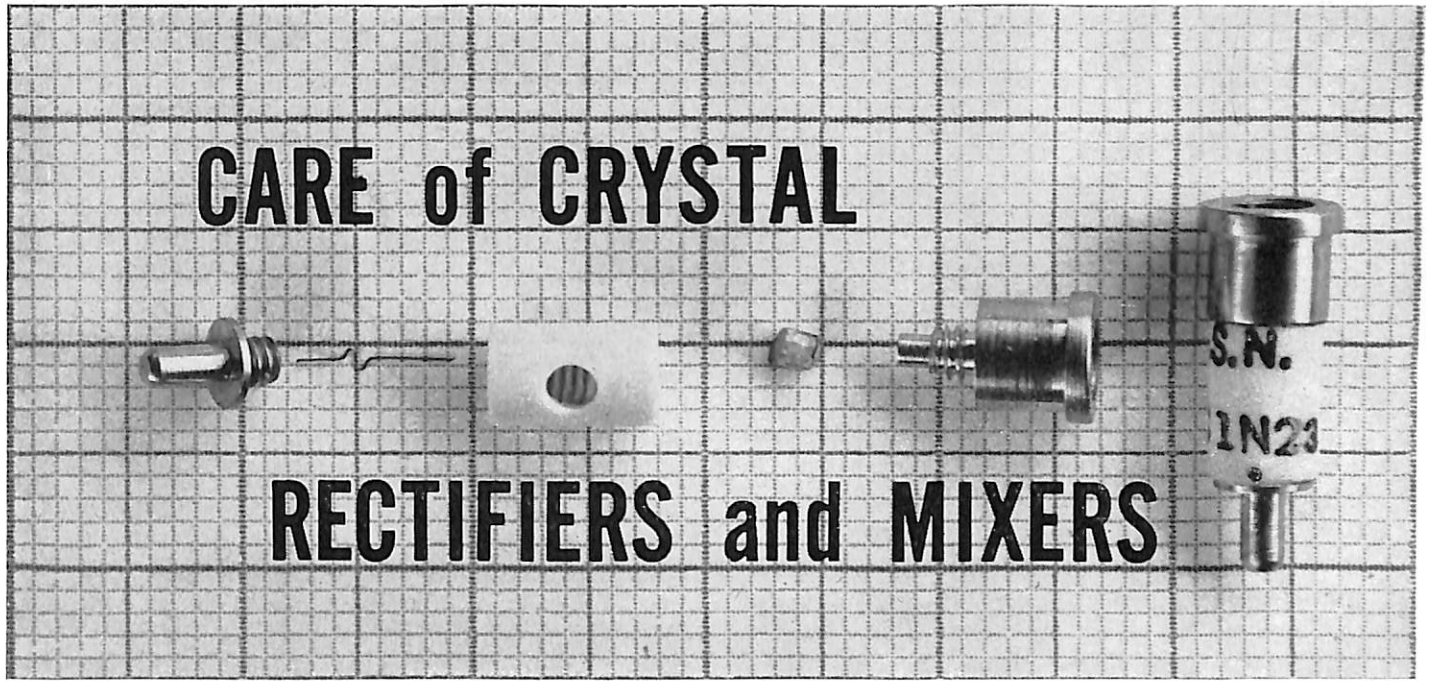
AS-45A/SPR-2 ANTENNA COUPLER

The manufacturer has recently completed 200 couplers for adapting RG-48/U waveguide to RG-8/U solid dielectric cable. These units, formerly referred to as the navy type -49890 but now designated UG-340/U, have been shipped to the Navy Supply Depots at Clearfield, Utah, and Mechanicsburg, Pennsylvania, for further distribution. Electronics Officers should request these coax couplers from the Naval Supply Depot and have them available for installation, distribution and stock.

Ships having the AS-45A/SPR-2 "Y" antenna installed should contact the nearest E.O. at the earliest opportunity to determine the availability of this item. It can be installed by the ship's crew in a few hours, and consequently will not require a navy yard availability. In making the installation it is recommended that the length of the solid dielectric RG-8/U between the coupler and the receiver be maintained as short as practicable, to minimize the attendant db losses inherent to this type of cable.

The approved BuShips drawing for this coax coupler is now RE49F449A, entitled "Adaptor, UG-340/U, Coaxial Line to Waveguide (RG-8/U to RG-48/U)."

CARE of CRYSTAL RECTIFIERS and MIXERS



■ Since crystal rectifiers can easily be damaged by careless handling, an effort should be made to insure that all personnel handling these units have some knowledge of their construction and are acquainted with the recommended storage and handling precautions.

Most crystals (especially those used as mixers in radar receivers) are mounted in a cartridge, the external dimensions of which have been standardized so that different makes of crystals all fit into the same holders. Although the internal arrangement differs, depending on the manufacturer, all cartridges contain a nearly pure crystal of the element silicon, mounted so that a fine tungsten wire with a sharpened point can be brought into contact with the broken surface of the crystal. After adjustment at the factory, the cartridge is impregnated with a filler that increases the mechanical stability of the contact and renders the unit impervious to moisture. Crystals of this type are therefore not ordinarily adjustable and should not be confused with piezo-electric crystals used to control the frequency of oscillators.

Crystal units will stand only a limited amount of mechanical shock, and should not be dropped or tapped unnecessarily. Furthermore, during the time when a crystal is not installed in an equipment, it must be protected from r-f fields, and currents induced by sudden current changes in neighboring wires. It is also necessary to exercise care in installing crystals, to prevent the discharge through the crystal of static electricity accumulated either by the operator or by ungrounded apparatus. Relatively small static discharges through a crystal can reduce its sensitivity to a great extent.

Through the exercise of a few precautions, however, these difficulties can be avoided:

1—Ground all equipment and check system grounds.

2—Handle the crystal cartridge by the base end only. Contact the equipment through this end before touching the top end, and maintain hand-contact with the equipment (crystal holder) until the crystal unit is in place.

3—Store crystal cartridges in metal containers or wrap them in metal foil until they are to be inserted in the equipment or until it is necessary to remove them for testing.

4—Avoid exposing open-end waveguide sections containing crystal rectifiers to intense r-f fields.

5—When electrical measurements are being made on crystals, employ only short shielded leads to minimize pickup. Also avoid subjecting the crystal units to overloads or transients, such as those caused by interrupting the circuits.

6—Do not tamper with the crystal unit set screws.

It is good policy to store crystals in their original cartons, which provide good protection from mechanical shock. Extremes of humidity, and temperature below -40°F or above 160°F are to be avoided. Many units tested have shown no appreciable deterioration over periods of months when stored properly.

NEW VALUES OF ELECTRICAL UNITS OF MEASUREMENT

■ As a consequence of recommendations by the International Committee on Weights and Measures the Bureau of Standards on January 1, 1948, will inaugurate a new system of electrical units, similar organizations in other countries following suit. The change is to be from the present so-called "international" system to the so-called "absolute" system, and has the purpose of eliminating certain inconsistencies in the relationship of the electrical units to other physical units. Both the units and the methods of measuring them will be altered. The change was to have been promulgated in 1940, but was interrupted by the war. Practically, the change in the size of the electrical units amounts to a fraction of one percent, and is negligible for most purposes, but is or may be important in both civilian and military applications for certain others.

In the scientific realm it is desirable to simplify theories whenever it is possible to do so and still maintain consistency with the facts which the theories are attempting to explain. As a result of the extensive theoretical and experimental investigations of the world and the universe which has been carried out in the past few centuries, it has been found possible to reduce all purely physical units to those of mass, length, time and some unit representative of electric or magnetic behavior. From this simplification, an elegant overall unity of man's physical knowledge of the universe is obtained, and practical benefits ensue in the standardization of units, for the number of fundamental, primary standards on which our whole system of physical measurements is based is thus kept at a minimum.

At the time that the first international attempt was made to set up a satisfactory system of electrical units in 1893, almost no laboratories were maintained by governments for the purpose of standardization. Most laboratories had to maintain their own standards, and facility of reproduction of primary standards was deemed more important than basing electrical units on other, more fundamental units. Therefore, it was decided, the values of the electrical units were to be obtained from direct measurement on primary physical standards, which were chiefly electrical in nature as follows: 1—The *ampere* would be defined by measurement in the silver voltameter, where electric current flowing for a known period of time electrolytically deposits a certain quantity of silver, 2—the *ohm* would be determined from the resistance of a specified column of mercury, and 3—the *volt* would be determined from the electromotive force of a standard battery, the Clark Cell. In the ensuing years, national laboratories have appeared in several of the larger countries, and facility of reproduction of the units has lost its original emphasis. The present change is in recognition of this fact. The electrical units will now, in the "absolute" system, be based on the primary units of mass, length, and time, and for the electromagnetic unit, the permeability (or magnetic inductive capacity, as it is also called) of free space, to be taken as unity in the centimeter-gram-second system of mechanical units and 10^{-7} in the equivalent meter-kilogram-second system. (See "Basic Physics," Part 1, in ELECTRON, July, 1947.) All electrical units will be exact multiples of these units—a great simplification in calculations. The electrical units are now subsidiary to the primary standards of these four units, and are to be derived from them by secondary measurements based on accepted principles of electromagnetism. Very precise methods have been developed for so doing these last years. Work has been progressing in the national laboratories of the United States, France, Great Britain, Germany, Japan, and Russia on the secondary measurements, and precise average values have been obtained. Standard resistors and cells maintained at the Bureau of Standards will be used in the actual scientific and industrial calibration within this country.

For completeness it should be mentioned that in 1911 the three electrical standards had been redefined more exactly, and the Weston Normal Cell substituted for the Clark Cell, in order to bring the volt, ampere, and ohm in exact agreement with Ohm's law.

TABLE I—*Conversion from Mean to Absolute Units*

Mean International Unit	*Absolute Unit*
1 ohm*	1.00049 ohms
1 volt*	1.00034 volts
1 ampere	0.999835 ampere
1 coulomb	0.999835 coulomb
1 henry	1.000495 henries
1 farad	0.999505 farad
1 watt	1.000165 watts
1 joule	1.000165 joules

* The legal United States units are slightly different from the mean value, so that 1 international ohm (U. S.) = 1.000495 absolute ohms, and 1 international volt (U. S.) = 1.00033 absolute volts.

As will be seen from table I, the change in the units of resistance, inductance, and capacitance is about 0.05 percent. In electrical measurements involving these quantities the change in units should not, therefore, be neglected in calibrations guaranteed to 0.1 or 0.25 percent. For most indicating instruments, however, the change is negligible.

—L. M. F.

TYPE –23497 SELECTOR CONTROL UNIT

Due to some misinformation, an error appeared in the article entitled "U-h-f Selector Control Unit", on page 10 of the August, 1947 ELECTRON. In that article it was stated that difficulty was encountered in making the subject control unit operate with the TDZ transmitter when the type –20409 power supply unit was not used. The mention of the TDZ transmitter was incorrect, as the intention was to refer to the RDZ receiver. Moreover the article did not clearly state that the trouble was not due to the lack of a type –20409 power supply unit.

The type –20409 power unit is used to provide power for a radiophone unit or type –23496 control indicator unit, and also to provide the power necessary for effecting the change-over from reception to transmission in the controlled equipment when the "push-to-talk" button on the handset is pressed. The RDR and RDZ receivers have none of the above controls which require this source of power, and the TDZ transmitter supplies its own power for such purposes. Consequently this unit is not required for the operation of these equipments. However, in each case it is necessary that the two jumpers connecting J to A and K to L in Plug-102 be in place as mentioned in the previous article, as these jumpers provide continuity through the type –23497 selector control unit for the audio circuits from the receiver.

When the type –23497 selector control unit is used with the Model MAR transmitting-receiving equipment, the –20409 power supply unit must be used, as it is needed to supply both relay and microphone current for the associated radiophone unit and handset. In this case the above mentioned jumpers should be removed.

Type of Approach	Last Month	To Date
Practice Landings	6,835	64,561
Landings Under Instrument Conditions	183	3,388

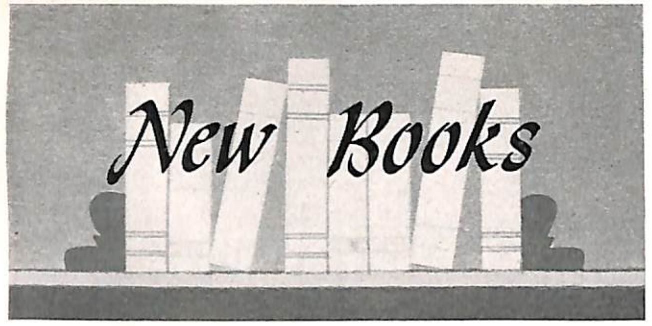
MORE THAN TWO HUNDRED THOUSAND

At each naval district in continental United States there is a Publications and Printing Office whose most important function is to provide *you* with all kinds of forms: long ones, short ones, simple ones and complex ones—and NBS 383 failure report forms. Each of these publications offices has stacks and stacks of the failure report forms—a total of more than 200,000 copies!

Despite this, however, a few activities are reporting failures on mimeographed or other makeshift facsimilies. This effort is admired, but wasted.

Get your forms the easy way! Ask the Supply Department for a Stock Form and Publications Requisition (NAVGEN-47). Write on it the number of failure report forms you will need for six months. Be sure to get the name right: FAILURE REPORT—ELECTRONIC EQUIPMENT—NAVSHIPS (NBS) 383. Then mail it to the Publications and Printing Office at the nearest Naval District Headquarters.

Two hundred thousand are too many! Let's use them up!



New Books

■ The following pages list all instruction books distributed since 1 Oct., 1945. The first list includes all equipments bearing a navy model letter, a navy type number, or a joint army-navy designation. The second list includes equipments bearing only commercial designations. The key to the abbreviations appearing in the third column of each list is given on page 22.

LIST 1

Model	Short Title	Edition
ABK through ABK-8	NAVSHIPS 900,909	PL
AN/APA-6/-6A	NAVSHIPS 900,768	F
AN/APR-1	NAVSHIPS 900,483.4	SP
AN/APR-5X/-5A/-5AX/-5AY/-6X	NAVSHIPS 900,655	F
AN/APT-3	NAVSHIPS 900,280	MI
AN/APX-7 (XN21)	NAVSHIPS 91,001	MI
AN/CPN-6	NAVSHIPS 900,838	F
AN/CPN-6	NAVSHIPS 900,771	IH
AN/CPN-6	SHIPS 291-1	SP
AN/CPX-3	NAVSHIPS 900,940	F
AN/CPX-4 (XN-21)	NAVSHIPS 900,941	F
AN/FGC-1A	NAVSHIPS 95,583	F
AN/GPN-2	NAVSHIPS 900,934	F
AN/GPN-2	NAVSHIPS 900,934.4	SP
AN/MPN-1A	SHIPS 316 (A)	F
AN/SPA-1	NAVSHIPS 900,768	F
AN/SPR-1	NAVSHIPS 900,483 (A)	F
AN/SPR-2	NAVSHIPS 900,654	F
AN/SPR-2A	NAVSHIPS 900,599	F
AN/SPT-2	NAVSHIPS 900,281-IB	OI
AN/SPT-6A	SHIPS 383	F
AN/TPS-1B	SHIPS 296	F
AN/TPS-1B	NAVSHIPS 900,901.4 (A)	SP
AN/UPA-1	SHIPS 271 (A)	F
AN/UPM-1/-1A/-1B	NAVSHIPS 900,845	MI
AN/UPM-2	NAVSHIPS 900,452	F
AN/UPM-4 (XN21)	NAVSHIPS 900,949	F
AN/UPM-6 (XN21)	NAVSHIPS 900,951	F
AN/UPM-7	SHIPS 344 (A)	F
AN/UPT-T3	NAVSHIPS 900,844	F
AN/UPX-T1	NAVSHIPS 900,785	F
AN/URA-T2A	SHIPS 361	F
Army-Navy Manual of Standard Descriptions	JANP-109	F
AS-177/UPX	NAVSHIPS 900,954	F
AS-236/SPT	NAVSHIPS 900,837	F
AS-263/UPT	NAVSHIPS 900,871	F
AS-330/TPX	SHIPS 390	F
BM IFF Coordination Assembly	NAVSHIPS 900,340 (A)	IH
BM-1	NAVSHIPS 900,240	IH
BM-1/-2	SHIPS 298	F
BN Data Sheets	300,662-2	P
BN-1	SHIPS 323 (A)	F
BN-1	NAVSHIPS 900,449	IH
BN-1	SHIPS 324-1	RPL
BO	NAVSHIPS 900,340 (A) - IB	IH
BO-1	SHIPS 298	F
BO-1	NAVSHIPS 900,239 (A) - IB	IH
CXFF	NAVSHIPS 95,053	F
CXFM	NAVSHIPS 95,054	F
CXFW	NAVSHIPS 900,200	F
CXGG-1/-2	NAVSHIPS 95,058	F
CXGG-2	NAVSHIPS 900,796	ES
CXGH-2	NAVSHIPS 95,060	F
CXGJ-2	NAVSHIPS 95,062	F
CXGJ-4	NAVSHIPS 95,064	F
CXGJ-5	NAVSHIPS 95,065	F
CXGZ	NAVSHIPS 95,068	F
CXJC-1	NAVSHIPS 900,923	F
CXJG	NAVSHIPS 900,846	F
CXKA	NAVSHIPS 95,070	F
CXKX	NAVSHIPS 900,936	F
DAB/-1/-3	NAVSHIPS 900,893	PL
DAH	NAVSHIPS 900,757	F
DAH-2	NAVSHIPS 900,758	F
DAJ	SHIPS 382	F
DAK-2	NAVSHIPS 900,277	F
DAQ	SHIPS 233	F
DAS-1/-3	NAVSHIPS 900,752	F
DAU	SHIPS 301	F
DAU	SHIPS 302-1	SP
DAU/-1	NAVSHIPS 900,907	PL
DBB	NAVSHIPS 900,769	F
DBD	NAVSHIPS 900,851	F
DBE	NAVSHIPS 900,659	F
DBE	NAVSHIPS 900,659.2	OH
DBE	NAVSHIPS 900,659.2	Ch. #2 to OH
DBM-1	NAVSHIPS 900,587 (A)	F
DBS	NAVSHIPS 900,306	F
DCRI	NAVSHIPS 365-1583	F
DXA	SHIPS 384	F
FOA	NAVSHIPS 95,004	F
FOC	NAVSHIPS 95,005	F
FQB	NAVSHIPS 95,003	F
FRA	NAVSHIPS 900,613	F
FRB	NAVSHIPS 95,002	F
FRC	NAVSHIPS 900,078	F
FRE	NAVSHIPS 95,100	F
FRF	NAVSHIPS 900,208	F
FRH	NAVSHIPS 900,358	F
FSA	NAVSHIPS 900,754	F
FSJ	NAVSHIPS 95,002	F
F-26/UPR	NAVSHIPS 900,906	F
F-27/UPR	NAVSHIPS 900,713	F
JR-1	NAVSHIPS 900,245	F
JT	NAVSHIPS 900,424 (A)	F
LAE-3	NAVSHIPS 900,806	F
LAE-3	NAVSHIPS 900,806	Ch. #1 to F
LAF-1	NAVSHIPS 900,585 (A)	F
LAG/-1	NAVSHIPS 900,645	F
LAJ	NAVSHIPS 900,378 (A)	F
LAJ-1	NAVSHIPS 900,956	F
LM Series	NAVSHIPS 900,921	PL
LM-18	NAVSHIPS 900,002-IB	F
LO/-1/-2/-3/-4	NAVSHIPS 900,886	PL
LP/-1/-2/-3/-4	NAVSHIPS 900,897	PL
LP-5	NAVSHIPS 900,425	F
LR/-1/-2/-3	NAVSHIPS 900,890	PL
LU-3	SHIPS 309	F
LX	NAVSHIPS 900,913	SPL
LX-1	NAVSHIPS 900,643	F
MAM	NAVSHIPS 900,588	F
MAR	1B-38397	Sheet
MAR	1B-38398	Sheet
Mk 2, Mod 0	SHIPS 352	F
Mk 2, Mod 1	SHIPS 385	F
Mk 2, Mod 2	NAVSHIPS 900,926	F
Mk 6, Mod 0	SHIPS 359	F
Mk 13, Mod 0	SHIPS 327 (A)	F
Mk 20, Mod 3	NAVSHIPS 900,925	F
Mk 22, Mod 0	SHIPS 252 (A) -1	S #1 to F
Mk 22, Mod 1	NAVSHIPS 900,850	F
Mk 22, Mod 1	NAVSHIPS 900,930	MD
Mk 22, Mod 2	NAVSHIPS 900,926	F
Mk 26, Mod 3	NAVSHIPS 900,316-IB	MD
Mk 32, Mod 1	SHIPS 350	F
Mk 34, Mod 2	NAVSHIPS 900,848	F
Mk 34, Mods 3 and 4	NAVSHIPS 900,883	F
MAW	NAVSHIPS 900,734	F
MBF	NAVSHIPS 900,508	F
MX-565/GPS	NAVSHIPS 900,738	F
NAD-10A	NAVSHIPS 95,542	P
NJ-7	NAVSHIPS 900,409	F
NJ-8	NAVSHIPS 900,333 (A)	F
NK-5	NAVSHIPS 900,219 (A)	F
NK-7	NAVSHIPS 900,407 (A)	F
NMC	NAVSHIPS 900-251-IB-1	PL
NMC-1	NAVSHIPS 900,443 (A)	F
NMC-1	NAVSHIPS 900,443 (A) -1	S #1 to F
NMC-2	NAVSHIPS 900,595 (A)	F
O-30/CPN	NAVSHIPS 900,824	F
OAE	NAVSHIPS 95,157	F
OAH	NAVSHIPS 95,159	F
OAP-1	NAVSHIPS 900,001-IB	F
OAW-1	NAVSHIPS 900,722	F
OAX	NAVSHIPS 900,419	F
OBJ	NAVSHIPS 900,241	F
OBL-1	NAVSHIPS 900,227 (A)	F
OBL-2	NAVSHIPS 900,576	F
OBQ	NAVSHIPS 900,496	F
OBQ-2	NAVSHIPS 900,641	F
OBT	NAVSHIPS 900,296	F
OCA	NAVSHIPS 900,376 (A)	F
OCD	NAVSHIPS 900,646	F
OCF	NAVSHIPS 900,204	F
OCK	NAVSHIPS 95,169	F
OCL	NAVSHIPS 900,807	F
OCN	NAVSHIPS 900,235	F
OCP Hydrophone Mount 10600	NAVSHIPS 900,878	F
OCP-1	NAVSHIPS 900,811	F
OCQ-2	NAVSHIPS 900,046-1	S
OCR-1	NAVSHIPS 900,739	F
OCV	NAVSHIPS 900,203	F
OD	NAVSHIPS 900,918	PL
OE Series	NAVSHIPS 900,916	PL
OF-2	NAVSHIPS 900,572-IB	F
OFN	NAVSHIPS 900,880	F
OJ-3	NAVSHIPS 900,994	F
OKA	NAVSHIPS 900,791	F
OKA	NAVSHIPS 900,791	Ch. #1 to F
OSA	NAVSHIPS 900,937	F
PF	NAVSHIPS 900,922	F
PP-286/UR	NAVSHIPS 91,004	F
PR	NAVSHIPS 900,741	F
PU-51/TPS-1B	NAVSHIPS 95,211	F
QAA	NAVSHIPS 900,789	F
QBE-1A	NAVSHIPS 900,594	F
QBG/QBG-1	NAVSHIPS 900,405	F
QBH	NAVSHIPS 900,369	F
QCQ-2 Dome and Retracting Gear	NAVSHIPS 900,805	F
QCQ-2 Auxiliary Junction Box 62141	NAVSHIPS 900,393	II
QCU Auxiliary Junction Box 62141	NAVSHIPS 900,392	II
QDA	NAVSHIPS 900,700	F
QDA	NAVSHIPS 900,700.1	IH
QDA	NAVSHIPS 900,700.2	OH
QDA	NAVSHIPS 900,700.3	MH
QDA	NAVSHIPS 900,700.4	SP
QFA-5/-6	NAVSHIPS 900,795	F
QFM	NAVSHIPS 95,227	P
QFN	NAVSHIPS 900,780	Ch. #1 to F
QGB Dome and Retracting Gear	NAVSHIPS 900,805	F
QGB Auxiliary Junction Box 62141	NAVSHIPS 900,394	II
QJA	NAVSHIPS 95,229	F
QLA/-1	NAVSHIPS 900,790	F
RAO-2/-6	NAVSHIPS 900,351	F
RAO-7/-9	NAVSHIPS 900,356	F
RAX-1	NAVSHIPS 900,707	F
RBA-5	NAVSHIPS 900,708	F
RBG/-1/-2	NAVSHIPS 900,004-1	PL
RBH/-1/-2/-3	NAVSHIPS 900,411	F
RBK Series	NAVSHIPS 900,611	PL
RBK-12/-13/-14	NAVSHIPS 900,235	F
RBL/-1/-2	NAVSHIPS 900,353	F
RBL-5/-6	NAVSHIPS 900,350	F
RBQ-1	NAVSHIPS 900,621	F
RBS/-1/-2	NAVSHIPS 900,324	F
RBU	NAVSHIPS 900,501	P
RBU-2	NAVSHIPS 900,717	F
RBV	NAVSHIPS 900,501	P
RBV-2	NAVSHIPS 900,717	F
RBW/-2	NAVSHIPS 900,288	F
RBW-3	NAVSHIPS 900,717	F

Model	*Short Title*	*Edition*
RCO	NAVSHIPS 900,255	F
RCX	NAVSHIPS 900,288	F
RDC-1	NAVSHIPS 900,486	F
RDG	NAVSHIPS 900,515 (A)	F
RDG	NAVSHIPS 900,515-SP	SP
RDG	250-970-5	LC
RDJ	NAVSHIPS 900,253 (A)	F
RDJ-1	NAVSHIPS 900,823	F
RDO	NAVSHIPS 900,527	P
RDZ/-1	NAVSHIPS 900,617	F
REK	NAVSHIPS 900,961	F
REM	NAVSHIPS 91,003	F
RXA	NAVSHIPS 900,213	F
SA/-1/-2/-3	NAVSHIPS 900,911	SP
SA/-2/-3 Antenna Pedestal	NAVSHIPS 900,733	F
SA-2	SHIPS 276	F
SA-3	SHIPS 283	F
SF-1	SHIPS 363	F
SG-2S	NAVSHIPS 900,532	F
SG-3	SHIPS 367 (A)	F
SG-3	NAVSHIPS 900,899.1	IH
SG-3	NAVSHIPS 900,899.2	OH
SG-3	NAVSHIPS 900,899.3	MH
SG-3	NAVSHIPS 900,899.4	SP
SG-6	NAVSHIPS 900,861 (A)	F
SG-6	NAVSHIPS 900,861 (A) .1	IH
SG-6	NAVSHIPS 900,861 (A) .2	OH
SG-6	NAVSHIPS 900,861 (A) .3	MH
SG-6	NAVSHIPS 900,861 (A) .4	SP
SK-1M	NAVSHIPS 900,484	F
SM	NAVSHIPS 900,561	F
SM-1	NAVSHIPS 900,615	F
SO-3	SHIPS 260	F
SO-6/-10	NAVSHIPS 900,860	F
SO-6/-10	NAVSHIPS 900,860.1	IH
SO-6/-10	NAVSHIPS 900,860.2	OH
SO-6/-10	NAVSHIPS 900,860.3	MH
SO-6/-10	NAVSHIPS 900,860.4	SP
SO-12M/N	SHIPS 294	F
SO-13	SHIPS 237	F
SP	NAVSHIPS 900,534	F
SP-1M	NAVSHIPS 900,560.4	SP
SR-2	NAVSHIPS 900,577 (A)	F
SR-2 UHF Coaxial Line	NAVSHIPS 900,579 (A)	F
SR-3	NAVSHIPS 900,539	F
SR-3	NAVSHIPS 900,539.1	IH
SR-3	NAVSHIPS 900,539.2	OH
SR-3	NAVSHIPS 900,539.3	MH
SR-3	NAVSHIPS 900,539.4	SP
SS	SHIPS 335	F
SS	NAVSHIPS 900,746.1	IH
SS	NAVSHIPS 900,746.2	OH
SS	NAVSHIPS 900,746.3	MH
SS	NAVSHIPS 900,746.4	SP
SU	SHIPS 313-2	S #2 to F
SU/-1 Antenna Service Kit	NAVSHIPS 900,814	F
SV	NAVSHIPS 900,548 (A)	TB
SV-1	SHIPS 341	F
SV-1	NAVSHIPS 900,822.1	IH
SV-1	NAVSHIPS 900,822.2	OH
SV-1	NAVSHIPS 900,822.3	MH
SV-1	NAVSHIPS 900,822.4	SP
TAJ-10	NAVSHIPS 900,428	F
TAJ-11/-13/-16/-17	NAVSHIPS 900,863	F
TAJ-14/-15/-18	NAVSHIPS 900,833	F
TAJ-19	NAVSHIPS 900,492	F
TAQ-5/-5a/-6/-6a/ 6b/-7/-8	NAVSHIPS 900,248	F
TAQ-9	NAVSHIPS 900,273	F
TAQ-10	NAVSHIPS 900,549	F
TBA-6/-10	NAVSHIPS 900,406	F
TBA-9/-11/-12/-13	NAVSHIPS 900,454	F
TBC-4/-5	NAVSHIPS 900,856	F
TBK-9	NAVSHIPS 900,380	F
TBK-13/-18/-20	NAVSHIPS 900,388	F
TBK Speech Input and Modulator Equipment 50194	NAVSHIPS 900,778	F
TBL-4/-8/-9	NAVSHIPS 900,373-IB	F
TBL-10/-11	NAVSHIPS 900,390	F
TBM-4	NAVSHIPS 900,380	F
TBM-5/-7/-9/-11	NAVSHIPS 900,388	F
TBM-12	NAVSHIPS 900,763	F
TBS	NAVSHIPS 900,590.4	SP
TBS Adaptor Unit 23525	NAVSHIPS 900,357	F
TBS Power Unit 20417	NAVSHIPS 900,737	F
TBU-1/-2/-3	NAVSHIPS 900,384	F
TBU-4	NAVSHIPS 900,391	F
TBX-8	NAVSHIPS 900,706	F
TCG/-1	NAVSHIPS 95,311	F
TCG/-2	NAVSHIPS 95,312	F
TCJ-1	NAVSHIPS 900,402-IB	F
TCJ-2	NAVSHIPS 900,529-IB	P
TCK Series	NAVSHIPS 900,210	F
TCM	NAVSHIPS 900,401	F
TCN	NAVSHIPS 900,401	F
TCP/-1/-2/-3	NAVSHIPS 900,868	PL
TCS-6	NAVSHIPS 900,269-IB	F
TCS-7/-9/-10/-11/-12	NAVSHIPS 900,291 (A) -SP	SP
TCS-12	NAVSHIPS 900,291 (B) -SP	SP
TCS-14/-15	NAVSHIPS 900,705	F
TCU	NAVSHIPS 900,401	F
TCZ-1	NAVSHIPS 95,325	OH (Ed. #1)
TCZ-1/-2	NAVSHIPS 900,481 (A)	F
TDE/-1/-2	NAVSHIPS 900,389-IB	F
TDE/-1/-2/-3	NAVSHIPS 900,887	PL
TDF	NAVSHIPS 900,912	RPL
TDG-1	NAVSHIPS 900,620	F
TDH-2	NAVSHIPS 95,332	F
TDH-3	NAVSHIPS 900,904	F
TDH-4	NAVSHIPS 900,798	F
TDM-1	NAVSHIPS 900,832	F
TDN/-2/-3/-4	NAVSHIPS 95,335	P
TDO	NAVSHIPS 900,915	PL
TDP-1	NAVSHIPS 900,263 (A)	F
TDY-1	NAVSHIPS 900,342 (A)	F
TEB	NAVSHIPS 900,352 (A)	F
TEC	NAVSHIPS 900,212	F
TS-28/UPN	NAVSHIPS 900,521 (A)	F
TS-102/AP	NAVSHIPS 95,344	F
TS-102A/AP	NAVSHIPS 95,344	F
TS-107/TPM-1	NAVSHIPS 900,454-IB	P
TS-120/UP	SHIPS 386	F
TS-173/UR	NAVSHIPS 900,644	F
TS-182/UP	AN-08-35-TS182-2	F
TS-182/UP	NAVSHIPS 95,345	MH
TS-191/UP	SHIPS 386	F
TS-202/U	NAVSHIPS 900,864 (A)	F
TS-230/AP	SHIPS 372	F
TS-231/AP	NAVSHIPS 900,869	F
TS-251/UP	NAVSHIPS 900,652.4	SP
TS-268/U	NAVSHIPS 900,647	F
TS-270/UP	SHIPS 343 (A)	F
TS-275/UP	NAVSHIPS 900,825	F
TS-295/UP	SHIPS 311 (A)	F
TS-324/U	NAVSHIPS 91,006	F
TS-349/UP	NAVSHIPS 900,884	F
TS-358/UP	NAVSHIPS 900,817	F with Ch. #1 and 2
TS-358/UP	NAVSHIPS 900,817.4	SP
UE-1	NAVSHIPS 900,427 (A)	P
UF	NAVSHIPS 900,223	F
UG	NAVSHIPS 900,223	F
UH	NAVSHIPS 900,223	F
UM	NAVSHIPS 900,745	F
UN System	NAVSHIPS 900,840 (Vol. 1 & II)	F
UN Carrier Supply	NAVSHIPS 900,201	F
UN Voice Carrier	NAVSHIPS 900,202	F
UO	NAVSHIPS 95,355	F
VD-2	NAVSHIPS 900,933	F
VF	SHIPS 288	P
VF	NAVSHIPS 900,076	OH
VG/-1/-3	SHIPS 261	P
VG/-1/-3	SHIPS 261	Ch. #1, 2 and 3 to P
VH	NAVSHIPS 900,934	F
VJ	NAVSHIPS 900,829 (A)	F
VJ	NAVSHIPS 900,829 (A)	Ch. #1 to F
VJ	NAVSHIPS 900,829 (A) .1	IH
VJ	NAVSHIPS 900,829 (A) .2	OH
VJ	NAVSHIPS 900,829 (A) .3	MH
VJ	NAVSHIPS 900,829 (A) .4	SP
V-22/M	NAVSHIPS 95,357	DB
WCA/-1/-2/-3	NAVSHIPS 900,663	F
WCA/-1	NAVSHIPS 900,045.4	SP
WCA-2/-3	NAVSHIPS 900,525.4	SP
WDA/-1	NAVSHIPS 900,436	F
WEA-1	NAVSHIPS 900,507	F
X-DAX	NAVSHIPS 95,081	P
X-DAY	NAVSHIPS 95,082	P
X-DAZ	NAVSHIPS 95,083	P
XDW	NAVSHIPS 900,927	F
X-RDJ	NAVSHIPS 900,253 (A)	F
X-RDZ-2	NAVSHIPS 900,957	CI
YA-1/-2	NAVSHIPS 900,220	F
YG-1/-2	NAVSHIPS 900,252-IB-1	S #1 to F
YH/-1	NAVSHIPS 900,910	PL
YL	NAVSHIPS 900,249-IB	F
ZM-1/U	NAVSHIPS 900,948	F
10AEF	SHIPS 337	F
10AEX	NAVSHIPS 900,212	F
10AFJ	NAVSHIPS 900,728	F
14ABW	SHIPS 391	F
21ADL	NAVSHIPS 900,776	F
23AFL	NAVSHIPS 900,653 (A)	F
23AGU	NAVSHIPS 900,879 (A)	F
23AJG	NAVSHIPS 900,876	F
24AAL	NAVSHIPS 900,665 (A)	F
24AAP	NAVSHIPS 900,704	F
50ABM	NAVSHIPS 900,792	F
50ACU	SHIPS 354	F
50ACW	NAVSHIPS 900,344	
55ADP	SHIPS 354	F
55ADV/-1	SHIPS 375	F
55AGD	SHIPS 375	F
55AHM	NAVSHIPS 900,872	P
55AHP-1	NAVSHIPS 900,827.4	SP
60ABF	NAVSHIPS 900,862	F
66ALA	NAVSHIPS 900,731	F
66ALA	NAVSHIPS 900,731	Ch. #1 to F
66ALB	NAVSHIPS 900,731	F
66ALB	NAVSHIPS 900,731	Ch. #1 to F
66ALC	SHIPS 353	F
66AML	NAVSHIPS 900,830	F
10306	NAVSHIPS 95,366	F
10563	NAVSHIPS 900,747	F
10600	NAVSHIPS 900,878	F
10617	NAVSHIPS 900,881	IH
20312	NAVSHIPS 900,756	F
20409	NAVSHIPS 900,777	F
20417	NAVSHIPS 900,737	F
23304-A	NAVSHIPS 95,389	F
23445	NAVSHIPS 900,777	F
23496	NAVSHIPS 95,006	F
23497	NAVSHIPS 900,777	F
23510	NAVSHIPS 900,205	F
23525	NAVSHIPS 900,357	Pamphlet
24325	NAVSHIPS 900,637	F
35060	NAVSHIPS 900,754	F
46169	NAVSHIPS 900,804	F
49545	NAVSHIPS 900,853	F
50064A	NAVSHIPS 900,491	F
50101	NAVSHIPS 900,591	F
50103	NAVSHIPS 900,816	F
50124	NAVSHIPS 900,816	F
50127	NAVSHIPS 900,819	F
50149	NAVSHIPS 900,668	F
50194	NAVSHIPS 900,778	F
50202	NAVSHIPS 900,783	F
50254	NAVSHIPS 900,857	F
50262	NAVSHIPS 900,783	F
50272	NAVSHIPS 95,417	F
51095	NAVSHIPS 900,724	F
53191	NAVSHIPS 900,720	F
53212A	NAVSHIPS 900,382	F
53349	NAVSHIPS 900,880	Pamphlet
55149	NAVSHIPS 900,371 (A)	F

Model	*Short Title*	*Edition*
55180	NAVSHIPS 900,724	F
60007	NAVSHIPS 900,628	F
60089	NAVSHIPS 900,744	F
60094	NAVSHIPS 95,437	F
60140	NAVSHIPS 900,786	F
66131	NAVSHIPS 900,656	F
66132	NAVSHIPS 900,794	F
211135	NAVSHIPS 900,573	F
211303	NAVSHIPS 900,626	F
211304	NAVSHIPS 900,629 (A)	F
211305	NAVSHIPS 900,629 (A)	F
211347	NAVSHIPS 900,630	F
211348	NAVSHIPS 900,630	F
211414	NAVSHIPS 900,589	F
211574	NAVSHIPS 900,760	F
211575	NAVSHIPS 900,760	F
211627	NAVSHIPS 900,631	F
211757	NAVSHIPS 900,631	F
301227	NAVSHIPS 900,803	F
471138	NAVSHIPS 900,972	F
491120	NAVSHIPS 95,417	F
491481	NAVSHIPS 900,931	F

—G. L.

LIST 2

Model	*Short Title*	*Edition*
Boehme Automatic Keying Unit	NAVSHIPS 95,463	F
Expansion Dry-Air Adaptor 100A	NAVSHIPS 900,813	F
High-Frequency Sweep Generator Model 709B	NAVSHIPS 95,571	F
Q Meters 100A, 160A and 170A	NAVSHIPS 95,548	F
Teletype, Model 14	NAVSHIPS 95,450	F (M 66)
Teletype, Models 14, 15 and 19	NAVSHIPS 95,589	F (M 26)
Teletype Reperforator, Model 14	NAVSHIPS 95,445	F (M 9)
Volt-Ohm-Ma Meter, Model 202	NAVSHIPS 95,556	F

KEY TO ABBREVIATIONS

Ch.	Change
CI	Complimentary Instructions
DB	Descriptive Booklet
ES	Errata Sheets
F	Final Book
IH	Installation Handbook
II	Installation Instructions
LC	Lubrication Chart
MI	Maintenance Instructions
OH	Operators' Handbook
OI	Operating Instructions
P	Preliminary Instruction Book
PL	Parts List
RPL	Revised Parts List
S	Supplement
M	Manual
MD	Maintenance Drawings
MH	Maintenance Handbook
SP	Spare Parts Catalog
SPL	Supplementary Parts List
TB	Temporary Book

UHF CRYSTALS

Several reports have reached the Bureau recently from ships indicating difficulty in obtaining crystals for their u-h-f equipment. Crystals are now plentiful and distribution is regular.

U-h-f crystals are stocked by the Naval Gun Factory, Washington, D. C., and Electronic Supply Center, Naval Supply Depot, Oakland. Distribution is made by means of Bureau shipment orders upon the request of the Electronics Officer of the installing activity. Admittedly, manufacture and distribution was slow at the early part of the u-h-f program but now the situation is alleviated.

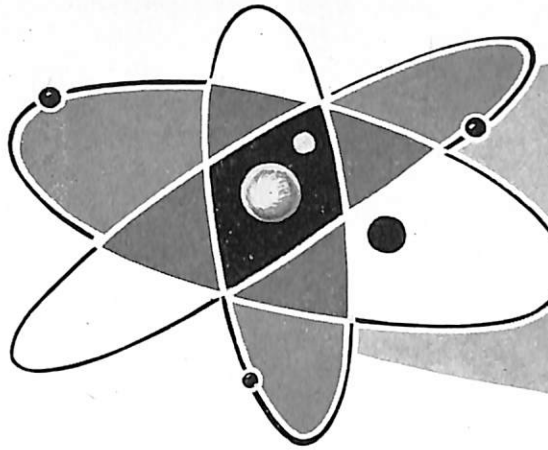
In January, 1946 the Chief of Naval Operations established Crystal Allowances for Models TDZ, RDZ, MAR and RDR equipments. In order that every ship will have available when needed a crystal for each operating frequency, complete sets of 100 crystals each are issued. One additional crystal will be furnished for TDZ and RDZ equipment. This is for the common watch frequency of 243.0 mc. Individual crystals can also be obtained to replace failures or breakage.

For TDZ, RDZ and MAR equipments, two sets of each type for each ship are allowed, regardless of the number of equipments installed.

For RDR equiqment, two sets of crystals are allowed for each ship, regardless of the number of equipments installed, except in those cases where MAR equipment is also installed. In such cases no crystals are allowed for RDR equipment.

Ships having u-h-f equipment installed and less than the authorized allowance of crystals, should apply to the nearest Electronics Officer.

If not near an Electronics Officer, a request should be forwarded to the Bureau of Ships giving the type of equipment installed and the number of sets of crystals aboard. Where ships have more than the allowed number of sets of crystals, the excess should be turned in to the nearest Electronics Officer for redistribution to the ships not having the required number.



the electrical nature of matter

BASIC PHYSICS-Part 6

■ This chapter is concerned with the nature and internal structure of atoms. Although, to physicists, atomic and nuclear physics is a complex subject about which much remains to be learned, the electronics student is fortunate in that he needs only a qualitative understanding of the subject in order to readily visualize electrical and electronics principles. Primary interest here will center in the planetary electrons of the atom—the internal structure of the nucleus and the energy stored therein being of little immediate interest.

Although the Greeks had visualized the world as being composed of minute primary or "building-block" particles called atoms, it remained for John Dalton, an English schoolmaster who worked early in the 19th century, to formulate the atomic hypothesis which eventually became the foundation of modern chemistry and physics. According to this hypothesis, all matter is made up of atoms. An atom is the smallest particle one can obtain by successive subdivision of a given piece of matter that will still retain all the properties of the matter.

Nature in her economy needs scarcely more than ninety kinds of atoms—which is to say ninety elements—to construct hundreds of thousands of different substances. These elements are given in table I. Those above No. 82 are radioactive, which means that the very atoms of which they are composed are undergoing individual disintegration, forming new atoms of lighter weight. Such formation of new atoms is known as *transmutation,* and leads us to believe that, although they no longer exist, millions of years ago elements above No. 92 were to be found in nature. It is to be noted that elements numbers 93 to 96 have been synthesized artificially in the manufacture of the atomic bomb. Some of the elements listed in the table are not believed to exist in natural form, while others are so rare as to have little economic significance.

Electrons, Protons, and Neutrons. Dalton conceived the atom as the ultimate indivisible particle, but atomic research has revealed that the atom may be subdivided into a variety of small particles, the most important of which are neutrons, protons, and electrons. An understanding of the nature and properties of these atomic particles reveals the fundamental electrical nature of all matter.

Neutrons, protons, and electrons are the building blocks of atoms and are believed to be individually distinct particles of pure electrical energy. Electricity, as a form of energy, is not expected to possess mass but, when considering the particles individually, mass becomes their most important physical property. The mass of any single particle is very small but, since it is customary to deal with such large numbers of them, their mass effects are appreciable. Much experimental work has been accomplished in establishing the mass of the proton and electron:

$$\text{Mass of proton} = 1.661 \times 10^{-24} \text{ gram.}$$

$$\text{Mass of electron} = 8.99 \times 10^{-28} \text{ gram.}$$

$$\frac{\text{Mass of proton}}{\text{Mass of electron}} = \frac{1.661 \times 10^{-24}}{8.99 \times 10^{-28}} = 1847$$

Although the mass of the proton is about 1847 times greater than that of the electron, modern theory indicates that the proton has a volume much less than that of the electron. The density of protons is great, so great in fact that a minute drop of them would weigh millions of tons. However, relatively speaking, the electron and the proton are so much smaller than particles of matter of ordinary size, indeed even atoms, that the student should consider them as being of about the same volume.

The neutron may be thought of as a proton and an electron in such a tight embrace that an inordinately large quantity of energy must be used to separate them. The mass of a neutron may be taken as the mass of a proton, the small additional mass of the electron being neglected.

A single atom is so small that there is little possibility that man will ever be able to view the internal structure directly. Present knowledge of atomic structure is based upon observation of the forces exerted by atomic particles and the electrical and mass effects observed when such particles are in motion.

Since all atomic particles possess mass, it would seem that gravitational forces might play an important part within the atom. The observed forces, however, are much larger than can be accounted for by gravitational forces alone. It is common experience that charged bodies attract or repel each other with forces that are purely electrical in nature. A fountain pen that has been charged by friction, for example, can be used to pick up bits of paper. Forces of this class, it is felt, play a large part in the atom, but even though much of our knowledge of the exact nature of sub-atomic forces is complete, still more is incomplete, observation showing us in many cases that sub-atomic behavior is not strictly analogous to similar large-scale behavior. Such questions, however, are beyond the scope of this work.

The study of the internal structure of atoms begins with certain fundamental concepts. Neutrons, protons and electrons are the fundamental building-blocks of all atoms, one atom differing from another only in the total number, kind, and arrangement of the particles. Neutrons, protons, and electrons differ primarily in their electrical properties. Each is identified in terms of the effects of its mass and the electrical force it exerts, the direction in which the force is exerted, and the way in which it reacts when subjected to an external electrical or magnetic force. All neutrons are identical, all protons are identical, all electrons are identical. By convention, electrons are said to be negatively-charged, and protons postively-charged. Neutrons are electrically neutral. A proton is identified by the fact that it exerts an electrical force of attraction for all electrons and an electrical force of repulsion against all other protons. An electron exerts an electrical force of attraction for all protons and an electrical force of repulsion against all other electrons.

The forces acting between an electron and a proton balance each other, which indicates that both particles represent the same quantity of electricity and hence possess equal charges, although the proton has a greater mass than the electron. A proton attracts an electron and repels a proton; an electron attracts a proton and repels an electron; hence, the two particles exert electrical forces in opposite directions. This is the condition which is covered in the concept of *polarity*. There are a variety of statements which may be made to indicate this polarity: 1—a proton has a positive, an electron negative polarity; 2—a proton represents an elementary charge of +1, and an electron an elementary charge of −1. 3—a proton exerts a positive electric force, and the electron a negative electric force. The fundamental law of charges, of which this is a special case, states that *charges of like polarity repel, charges of unlike polarity attract.*

Since protons and electrons exert equal forces in opposite directions, when two such particles combine to form a neutron the effective force is zero; the neutron is in electrical equilibrium and is electrically neutral. In the neutron, the electrical force of attraction between proton and electron binds the two particles tightly together but the force is entirely self-contained. Externally the neutron does not seem to be a quantity of electrical energy because it does not exhibit the characteristics of an electric charge. That is why the neutron is often said to be a particle of "mass without charge."

Electric Charges. It seems appropriate at this time before examining the structure of the atom to present more information on the behavior of electric charges, particularly with regard to charged bodies of matter.

Electrons and protons, and electrical charges on pieces of matter, are found to attract or repel in accordance with Coulomb's law which states that the electrical force of attraction or repulsion between two charges: *1—varies directly as the magnitude of the charges, 2—varies inversely as the square of the distance of separation between them, and 3—is a force of attraction if the charges are of opposite polarity, and a repulsive force if the charges possess the same polarity*. It is important that the inverse-square variation be understood fully. If the distance between charges is doubled, the force is reduced to one-fourth; if the distance is tripled, the force is only one-ninth as great. Conversely, if the distance is halved, the force is multiplied by a factor of four; if the distance is reduced to one-third, the force is increased nine times. When the distance of separation is relatively great, a small change in distance has little effect on the magnitude of the force. When the distance of separation is small, the slight change in distance produces a great change in the force. Theoretically, the force exerted by electric charge extends to infinity and hence is exerted against all other charges in the universe.

Normal matter is electrically neutral by virtue of two conditions: 1—it contains equal numbers of protons and electrons; and 2—the distribution of protons and electrons is uniform. Matter will exhibit the properties of an electric charge if either of the above conditions is disturbed. In normal matter, the ratio of protons to electrons is unity. If electrons are removed (or protons added) the ratio becomes greater than unity, protons predominate, and the matter acts like a positive charge. If electrons are added (or protons removed), the ratio is less than unity, electrons predominate, and the matter exhibits the characteristics of a negative charge.

Study of atomic structure shows that electrons have a greater degree of mobility than protons. In solids, protons are confined within a relatively small volume of space within each atom, but electrons may readily transfer from atom to atom. In liquids and gases, protons have some mobility (since the whole nucleus moves) but, being more massive than electrons, they move much more slowly. It is customary to define an electric charge in terms of an excess or deficiency of electrons, because the electrons possess the greater degree of mobility: a positively-charged body of matter is said to have a deficiency of electrons, a negatively-charged body, an excess of electrons.

When a glass rod is rubbed with cat's fur, some of the electrons in the glass are transferred to the fur. The glass becomes positively charged, the fur, negatively charged. The magnitude of either charge will vary directly according to the number of electrons transferred, and is measured in terms of the force it will exert on a standard unit charge. The standards for measuring such charges will be discussed in the next chapter.

In neutral matter equal numbers of protons and electrons are distributed uniformly throughout the substance. In such matter the force exerted by any given electron is counterbalanced by that exerted by an adjacent proton, so that externally there is no evidence of an electric charge. If this uniform distribution of electrons and protons is disturbed, the matter itself gives evidence of being electrically charged. How non-uniform distribution can be accomplished is demonstrated in figure 1. A glass rod is rubbed with cat's fur to give the rod a positive charge. When the rod is brought near a neutral pithball, the ball is attracted toward the rod. Electrons in the ball tend to move toward the glass rod, so that an excess of electrons appears on the right side of the ball, making that side negative. The left side of the ball has a deficiency of electrons and represents a positive charge. If the glass rod is removed from the vicinity of the pithball, the distribution of the electrons in the ball returns to normal and the ball is again neutral. However, if the rod touches the ball, electrons pass from the ball to the rod, decreasing the positive charge of the rod, but creating a deficiency of electrons in the ball. The rod and ball will then repel each other because both now have a deficiency of electrons (positive charge).

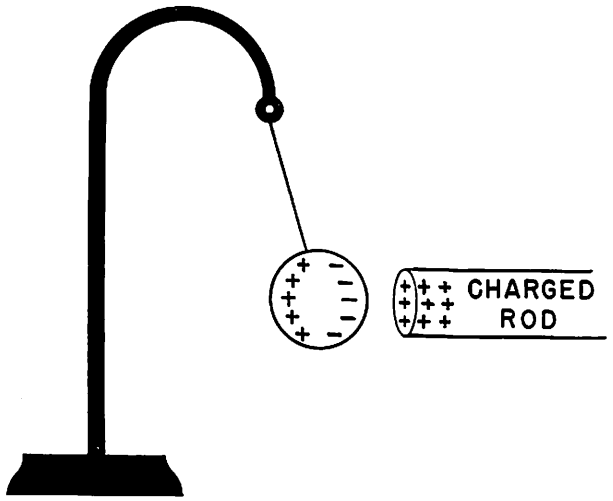


FIGURE 1—*Induced charges.*

Charges produced in neutral matter by the effect of an external charge are called *induced* charges, and the process by which they are produced is called *induction*. This process plays many important roles in electrical and electronic phenomena.

THE STRUCTURE OF ATOMS

It is customary and helpful to visualize an atom as a miniature solar system. Practically the entire mass of an atom is contained in a central core or nucleus composed of protons and neutrons tightly and intimately bound together. Around the nucleus rotate one or more planetary electrons, spinning on their axes in much the same manner as does the earth in its passage around the sun. The idea of a miniature solar system is more firmly grasped by considering the dimensions of an atom. Hydrogen, element No. 1, has the simplest internal

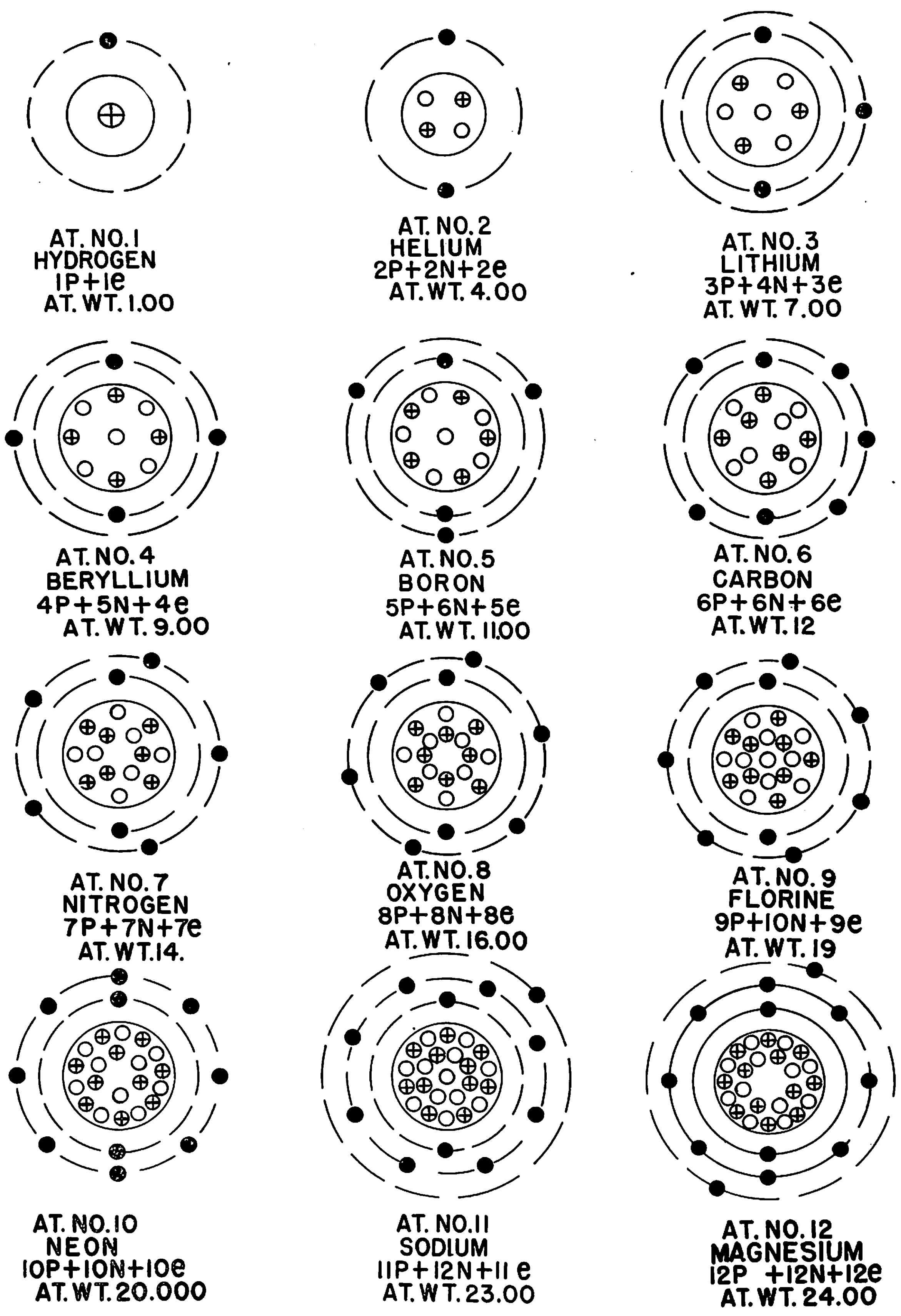


FIGURE 2—*Arrangement of planetary electrons, protons and neutrons in the nucleus, for the first twelve elements in the periodic table.*

structure. A hydrogen atom is composed of one proton around which rotates a single planetary electron. The diameter of the proton is about 10^{-12} cm, the diameter of the electron orbit about ten thousand times greater, or 10^{-8} cm. Such very small dimensions are difficult to visualize. This fact helps, however: if a hydrogen atom could be magnified until the proton had a diameter of one foot, the diameter of the electron orbit would be ten thousand feet, if a circular orbit is assumed. The electron would be spaced about 5000 feet from the proton. Since the volume of a sphere varies as the cube of the radius, it should be evident that the electron and proton occupy only a minute portion of the space bounded by the electron orbit. An atom, like the solar system, is practically all empty space.

Hydrogen, the lightest of all the elements, is a gas at normal temperature and pressure. Under normal conditions, hydrogen has a *diatomic* molecular composition, which means each molecule is composed of two hydrogen atoms. Apparently, two protons, by sharing their electrons, form a more stable combination than a single proton and electron. Oxygen, nitrogen, and chlorine are other gases that, under normal conditions, have a diatomic molecular composition. When hydrogen is solidified, it has the properties of a light metal similar to lithium.

Helium, element No. 2, has an atomic structure composed of two protons, two electrons, and two neutrons. The two neutrons and two protons are combined in the nucleus and together comprise what is known as an *alpha particle,* important in the study of nuclear physics and radioactivity. The helium atom always has a *monatomic* structure; that is, a molecule of helium is always composed of a single atom. Helium is called an inert gas because it will not combine chemically with any other element. Although a helium atom weighs about four times as much as a hydrogen atom, the fact that helium is monatomic, whereas hydrogen is diatomic, makes the molecular weight of helium only twice that of hydrogen.

Lithium, element No. 3, classified as a light metal, has an atomic structure composed of three protons, four neutrons and three electrons. Its atomic weight is about seven times that of hydrogen. Figure 2 is a crude representation of the atomic structure of elements Nos. 1 to 12 inclusive. A study of this figure will indicate that the *atomic number of an element is identical with the number of protons in its nucleus, and also with the number of planetary electrons in a neutral atom of the element.*

Atomic Weight. In general, the atomic weight is representative of the number of neutrons and protons in the nucleus, the very small mass of the electron being ignored. In measuring atomic weight it is customary to measure the weight of a given volume of the element and divide the result by the number of atoms in that volume. This yields the average atomic weight. For many years physicists were puzzled by the fact that such measurements did not yield whole number weights. Since the nucleus must contain a whole number of neutrons and protons, each atom should have a weight equal to a whole number times the weight of hydrogen. The puzzle was solved by the discovery of heavy hydrogen in 1932. The nucleus of a heavy hydrogen atom contains one neutron and one proton and hence weighs twice as much as a normal hydrogen atom. In any given volume of hydrogen about eight out of every one thousand atoms will be of the heavy type. The puzzle remained unsolved for so many years because all atoms of an element demonstrate identical chemical properties.

An atom that exhibits the same chemical properties as other atoms of the element but differs in weight is call an atom of an *isotope* of that element. The term isotope, like the term element, is used in reference to atoms or isotopes in bulk. Since the discovery of heavy hydrogen, isotopes of all the elements have been found. It is an odd fact that among the elements, as found in nature, the ratio of one isotope to another is a constant so that any measurement of atomic weight of different samples leads to the same average value. Chlorine, in natural form, has two isotopes. Three chlorine atoms out of four will have a relative weight of 35.00, but the fourth will have a weight of 37.00. The average atomic weight of chlorine works out to

$$\frac{(3 \times 35) + 37}{4} = 35.5$$

In nuclear physics a special form of notation is used to describe the exact atomic weight of an atom. The symbol ${}_{10}\mathrm{Ne}^{20}$ refers to an atom of element No. 10, neon, having a weight 20 times that of a normal hydrogen atom. When this method is used, the atomic weight is always a whole number.

The Nucleus. Just a brief word here about the internal arrangement of neutrons and protons in the nucleus and the energy stored therein. The atomic bomb is sufficient evidence that the nucleus represents potential energy. Since protons repel each other, it would seem that strong forces of repulsion between these particles would tend to disintegrate the nuclei of all atoms. It is now believed that this does not happen because some type of stabilizing influence within the nucleus is exerted by the neutrons. Some unknown type of force, analogous to surface tension in a drop of water, is believed to hold the nucleus together. The binding forces of this tension decrease much more rapidly with increase in nuclear radius than the decrease in the forces of repulsion with increased spacing between protons. In elements above No. 82, the radius of the nucleus becomes so great that sometimes a slight nuclear disturbance causes the forces of repulsion to exceed the "surface tension." When this occurs, the nucleus ejects a nuclear particle or a wave of energy which decreases the atomic weight of the atom. This wave of energy results from the conversion of some of the nuclear mass into energy, in accordance with one of the basic premises of nuclear physics. This law, due to Einstein, states that mass and energy are equivalent; that is to say, that mass can be converted to energy and energy to mass. Dramatic proof: Hiroshima.

The Periodic Law and the Bohr Atom Model. The first table of atomic weights was published about 1860, and shortly thereafter several investigators noted a peculiar relationship between properties of the elements and their atomic weights. Mendeleeff, a Russian chemist, summarized these findings in the *Periodic Law*, which states that the chemical properties of the elements are periodic functions of their atomic weights. The elements may be arranged in five distinct classes: light metals, heavy metals, non-metals, rare-earth metals, and inert gases. A sequence of elements beginning with a light metal and ending with an inert gas constitutes a period. If arrangements are made in this way, the following periods are obtained:

First Period—2 elements—H, and He.
Second Period—8 elements—Li to Ne.
Third Period—8 elements—Na to A.
Fourth Period—18 elements—K to Kr.
Fifth Period—18 elements—Rb to Xe.
Sixth Period—32 elements—Cs to Rn.

Since the chemical properties of an element are known to be a function of the planetary electrons, the 2-8-8-18-18-32 pattern must refer to the arrangement of planetary electrons around the nucleus. Ingenious work, so characteristic of modern physics, has proved this to be true. For practical purposes, the atom may be considered as a postively-charged nucleus surrounded by rotating electrons. This is essentially the atom model originally conceived by the Englishman, Rutherford, and brilliantly developed by the Danish physicist, Niels Bohr. The electrons, Bohr assumed, are arranged in concentric circular orbits about the nucleus, and are held in place by the Coulomb attraction of the nucleus which is just balanced by the centrifugal force of rotation. Bohr went further and said that only a limited number of orbits are possible. (The radii are to each other as the squares of the integers: 1^2, 2^2, 3^2, etc.) This restriction on the possible orbits was one of Bohr's most striking assumptions, and was completely at variance with previous theory.

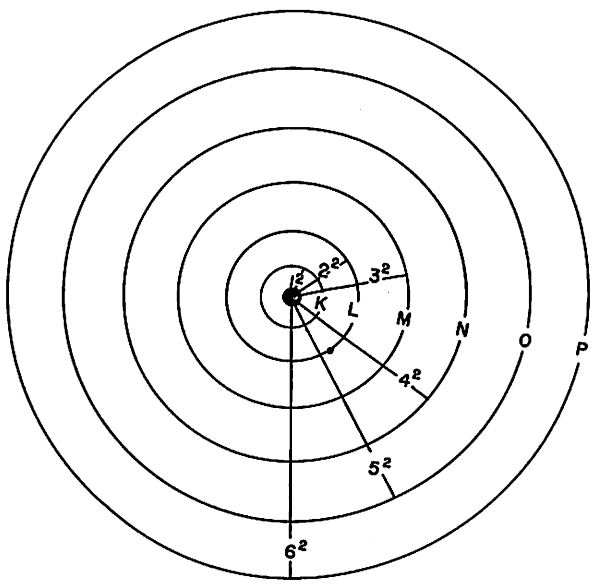


FIGURE 3—*Electron shells.*

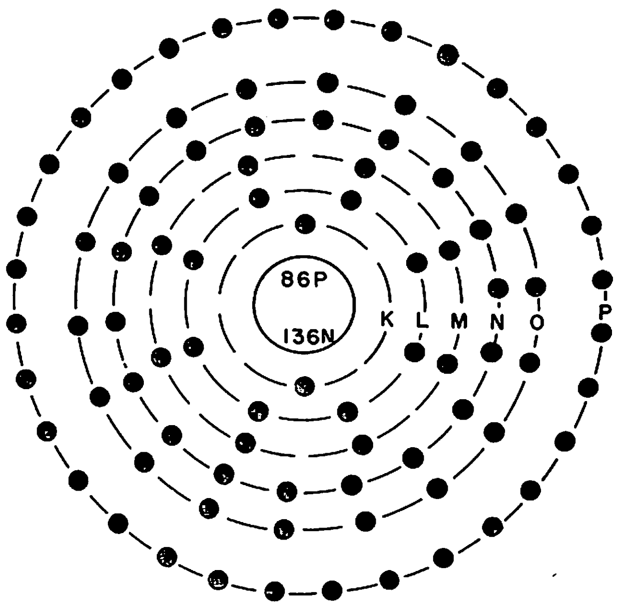


FIGURE 4—*Distribution of electrons in shells about an atom of radon.*

A given orbit may contain several electrons and is then said to constitute a "shell." These concentric shells are indicated in a crude manner in figure 3, where it may be noted that, in accordance with customary convention, they are designated by capital letters: K for the innermost shell, L for the next, then M, etc. In a given element, the K-shell is the most stable, and the electrons in it most tightly-bound to the nucleus, the L the next most stable, etc. The arrangement of shells for the element radon is shown in figure 4.

The explanation for the periodicity of the elements which is evidenced in the periodic table was given by Bohr and Pauli. Using the Bohr model, they assumed that Nature had placed a limit on the number of electrons which each shell could contain. Once a shell had been filled, no more electrons could be added, additional electrons being accommodated by fitting into the next-outermost shell. The maximum number permitted in the K-shell is 2, in the L-shell, 8, in the M-shell, also 8, in the N-shell, 18, etc., in accordance with the 2-8-8-18-32-etc. pattern already noted. Thus Nature builds up her whole series of elements. Let us see how this works, by referring to figure 2. Hydrogen has one electron which (under normal conditions) is in the K-shell. Helium has two electrons, both in the K-shell. The K-shell is now filled. Lithium, element No. 3 with three planetary electrons, has two in the filled K-shell, and one in the unfilled L-shell. The maximum number permitted in the L-shell is 8, so that we can expect seven more elements to be built up by successively adding more electrons to the L-shell. The L-shell is built up from lithium through berylium, boron, carbon, nitrogen, oxygen, fluorine, to neon. Sodium has both the K- and the L-shells completely filled, so that its additional electron must lie in the M-shell. In a similar manner are the remainder of the elements built up. An interesting fact appears: Whenever an atom is found where all the shells are completely filled, it is found to be an atom of one of the inert gases, helium, neon, argon, krypton, xenon, and radon, which do not combine chemically with other elements. These elements are chemically stable because their shells are completely filled. A second fact of importance also appears: All elements the atoms of which have the same number of electrons in their outermost shells—the shells which determine chemical activity—are found to have similar chemical properties. This is the real basis for the arrangement of elements according to similar chemical behavior which is inherent in the periodic table.

The Bohr model of the atom is very successful in explaining not only the periodic table, but also the phenomena of certain types of important radiant electromagnetic energy, and of chemical reactions.

Applications of Atomic Theory to Radiant Energy. Radiant energy is energy in the form of electromagnetic waves. The wavelength of these radiations varies over a very wide range. Their observed physical characteristics and their reactions on matter depends primarily upon wavelength and frequency. These difference in physical characteristics enable them to be classified into several distinct categories. The wide gamut encompassed by radiant energy is portrayed in figure 5, the so-called electromagnetic spectrum. It embraces: 1—very long electromagnetic waves, hundreds of miles in wavelength, occurring on public utility electric power transmission lines; 2—radio waves, the ETM's bread and butter; 3—infra-red or heat rays; 4—visible light rays; 5—ultra-violet ("black light") which causes sunburn; 6—X-rays; 7—gamma-rays, emitted by such radioactive materials as radium, and at least as small as 10^{-9} centimeters in wavelength. There is evidence of the existence of waves of even shorter wavelength (higher frequencies) associated with the so-called cosmic rays.

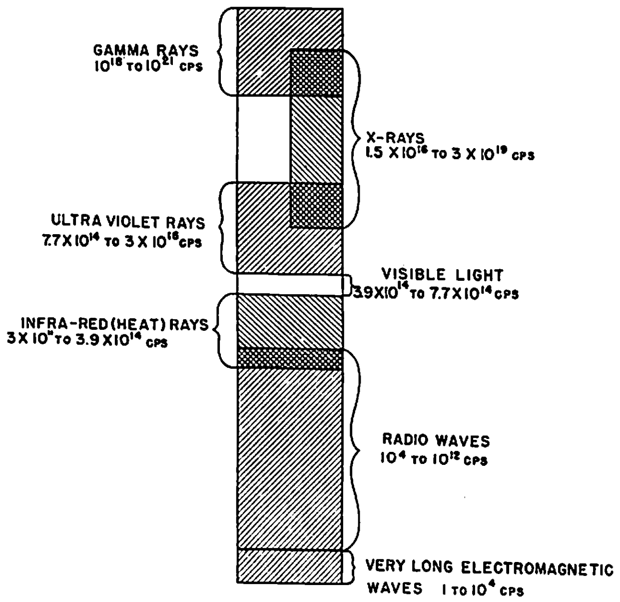


FIGURE 5—*Electromagnetic spectrum.*

The frequency, or the number of cycles per second, is related to the velocity of propagation of the waves (3×10^{10} cm/sec or 186,000 mi/sec for all electromagnetic waves) and the wavelength by the familiar equation:

$$\text{frequency in cycles/second} = \frac{3 \times 10^8 \text{ m/sec}}{\text{wavelength in meters}}$$

Physicists now know that the various classes of electromagnetic waves are produced by different fundamental physical mechanisms:

1—The very long electromagnetic and the radio waves are produced by the to-and-fro motion of electric charges.

2—Infra-red radiation is produced by oscillations and vibrations of molecules.

3—Light rays, ultra-violet rays, and X-rays are produced by the planetary electrons of individual atoms.

4—Gamma-rays are of nuclear origin.

It is in the quantitative application to visible, ultra-violet, and X-rays that the Bohr atom model has received its most brilliant substantiation.

We have stated that Bohr assumed that the planetary electrons could exist only in certain orbits or shells. This assumption means that: 1—the planetary electrons can possess only certain distinct values of energy, and 2—the electrons do not radiate electromagnetic energy when they are circulating about the nucleus in their allowed orbits. Otherwise, as their kinetic energy was lost by radiation, the electrons would spiral inward toward the nucleus and the entire atomic structure would eventually collapse. The second conclusion is contrary to the obvious fact that matter is permanent. How, then, is one to explain radiation?

Bohr felt that radiation occurred as a result of an electron changing its energy level by shifting from one electron orbit to another. In the case of neon, for example (see figure 2), one of the electrons in the L-shell may absorb external energy and jump into the M-shell, which is normally unoccupied. When this occurs the atom is said to be *excited*. An excited atom is unstable and shows a strong tendency to return to a more stable condition. To return to a normal unexcited condition the electron jumps inward to a more stable but lower energy orbit. The excess energy of the electron is radiated in the form of an electromagnetic wave, the frequency and energy of which is determined by the energy of the orbits involved in the electron shift. If the energy difference between orbits is relatively small, visible light is generated; if the energy difference is larger, ultra-violet rays will appear; if the energy difference has a still greater magnitude, X-rays will be emanated.

X-rays are usually produced by bombarding a tungsten target with high-velocity electrons in a special thermionic vacuum tube designed for the purpose.

It should be repeated that this type of mechanism in the atom is responsible only for the production of visible light, ultra-violet light, and X-rays. Production of the other types of radiation will be considered when it is desirable to do so under the appropriate heading.

Incidentally, if the electrons are excited strongly enough in the development of these types of radiations, they may gain enough kinetic energy to overcome the nuclear attraction, escape from the atom, and leave it with a preponderance of positive charge. The atom is then said to be ionized; in this case it is a positive ion.

Atomic Explanation of Chemical Reactions. The Bohr atom model is as helpful in understanding chemical behavior as it is in the field of radiant energy.

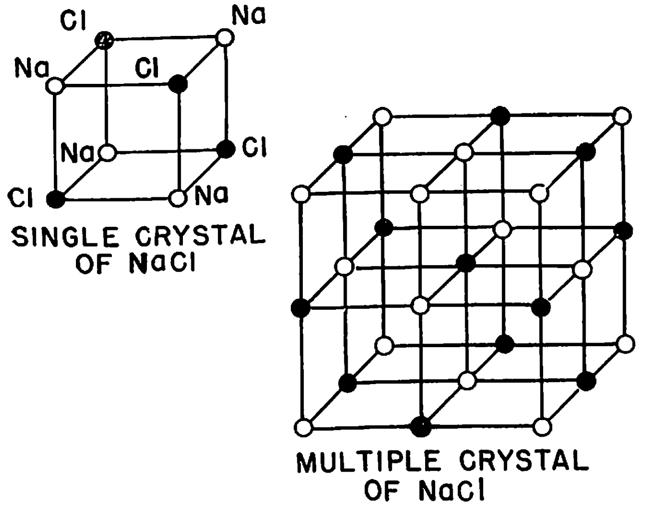
The chemical properties of an element are determined by the electrons in the outermost electron shell. A lithium atom has two electrons in the K-shell and one in the L-shell. The outer electron, being about four times more distant from the nucleus than the inner electrons, is held by a force of nuclear attraction only about one-sixteenth as great as that exerted on electrons in the K-shell. If energy is supplied in some way to a lithium atom, the outer electron will be the first to be affected because it is subject to the least nuclear attraction. If sufficient energy is supplied to an atom the outer electron may become sufficiently accelerated to overcome nuclear attraction and escape from the atom. The atom would then become a positive ion because the three protons in the nucleus would predominate over the two remaining planetary electrons. Elements whose atoms have outer shells less than half filled with electrons show strong tendencies to give up electrons when excited and to form positive ions. Such elements are said to be *electropositive*.

The fluorine atom contains seven electrons in its outer shell and shows a strong tendency to fill this outer shell by picking up any stray electrons. When the shell is filled, the atom contains an excess of electrons and hence acts like a negative charge. An atom that has gained an extra electron is called a *negative ion*, and atoms that are readily changed to negative ions are said to be *electronegative*.

It should be evident that, if lithium and fluorine are mixed and the mixture excited in some way, electrons may shift from lithium to the fluorine atom. The two atoms would then be bound together as a new unit (a molecule) by the attraction of unlike charges. The molecule formed by the positive lithium ion and the negative fluorine atom is the smallest chemical subdivision of the chemical compound lithium fluoride. This is the basic idea underlying most chemical reactions.

Chemical *valence* has a number of fine distinctions, but in general it refers to the number of electrons an atom will give up or accept in a chemical reaction. The valence of an ion is defined as the ratio of the charge of the ion to the charge of an electron. Lithium has a valence of −1 because it gives up one electron in forming a positive ion. Fluorine has a valence of +1. Elements like carbon which have their outer shells about half-filled with electrons may give up or accept electrons with equal ease. Such an element is both electropositive and electronegative, and hence can form great numbers of compounds. The chemical activity of carbon is apparent from the fact that over 500,000 carbon compounds are known.

The chemical symbols of the elements are useful in describing the chemical composition of matter and the action that takes place in a chemical reaction. They will be briefly discussed here. Chemical formulas are of two kinds, molecular and conventional. A molecular formula is an expression (composed of chemical symbols) which indicates the kind and number of atoms in a specific molecule. For example, an oxygen molecule contains two oxygen atoms, as indicated by the symbol O_2; a molecule of ammonia contains one nitrogen and three hydrogen atoms, as indicated by the symbol NH_3.



SINGLE CRYSTAL OF NaCl

MULTIPLE CRYSTAL OF NaCl

FIGURE 6—*Salt crystals.*

A conventional or empirical formula merely shows the relative number of different kinds of atoms in an indefinite quantity of a compound. NaCl is the symbol for common salt, but it does not mean that each salt molecule is composed of a single atom each of sodium and chlorine. A crystal of salt is composed of equal numbers of positive sodium ions and negative chlorine ions interlocked in a crystal-like structure in such a way that no one sodium atom is distinctly paired with any particular chlorine atom.

In general, molecular formulas apply to gases, conventional formulas to liquids and solids. There is no general method by which one type of formula can be distinguished from the other, and for our purposes the distinction is of no great import.

Chemical formulas are frequently used to describe a chemical reaction. Potassium chlorate is a compound represented by the symbol $KClO_3$. When potassium chlorate is decomposed to potassium chloride the reaction is described by the formula

$$KClO_3 \rightarrow KCl + O_2$$

where the arrow indicates that a chemical reaction has taken place. This formula is said to be unbalanced because the member to the left of the arrow contains five atoms (one potassium, one chlorine, and three oxygen) while the right-hand member contains only four. A balanced formula for the same reaction is obtained by indicating the proportional division of the substance into the correct member of molecules. Thus,

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

Note that a number preceding a chemical term multiplies all the atoms in that term. Both sides of this formula contain 10 atoms, so every atom is accounted for.

Chemical formulas are not to be taken as exact equations but rather as general statements of the reaction that occurs. The nature of the formula gives no indication of the energy conditions. Chemical changes that liberate energy in the form of heat are called *exothermic* reactions. Changes that absorb energy in some form are called *endothermic* reactions. Burning coal is a chemical reaction between carbon and oxygen which forms carbon dioxide, CO_2, and releases heat energy. Water, H_2O can be decomposed to hydrogen and oxygen by supplying a large quantity of heat energy.

Electron Movement in Solids. In order to obtain a reasonable degree of simplicity in explaining the atomic structure, it has been necessary to assume that electrons rotate around the nucleus in layers or groups. Although, as has been stated, the Bohr atom was very satisfactory in quantitatively explaining the lighter atoms, other researchers have refined the planetary atom model in closer conformance with the observed data on the heavier elements. Closer agreement, for example, is achieved when the electrons are thought of as rotating in elliptical orbits instead of circular. In figure 7 appears such a model for the copper atom. It will be noted that the electron orbits form a veritable maze about the nucleus.

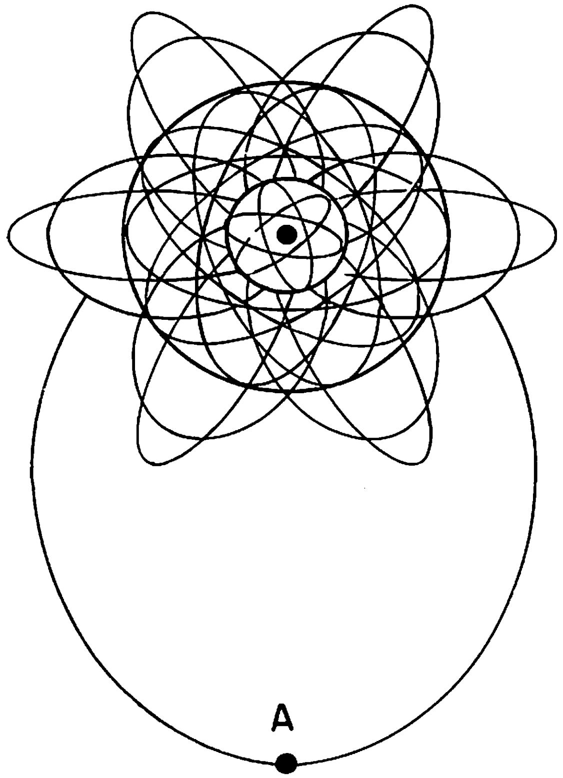


Figure 7—*Model of copper atom, with elliptical orbits assumed.*

The planetary model of the atom with elliptical orbits is helpful in understanding the behavior of electrons in solids, such as copper. Referring to the figure, it will be noted that the copper atom has one electron in the outer shell that follows an elliptic orbit of large major diameter. When the electron reaches position A in that orbit, the force of nuclear attraction is at a minimum. Only a slight force is required to remove the electron from its orbit at this point. At the instant that such separation occurs, the electron is momentarily free to move in any direction under the influence of an external electric charge. The electron remains free only for an instant before being captured by a nearby nucleus, but in that instant it has a very high degree of mobility. The number of highly-mobile electrons in a unit volume of any substance determines the electrical conductivity of that substance. A substance that has a large number of free electrons per unit volume is called a *conductor.* Substances that have relatively small number of free electrons per unit volume are called *non-conductors* or *insulators.* As would be expected, there is no sharp line of demarcation between conductors and non-conductors. Substances that might be classified as partial conductors or partial insulators are often called *resistances* or *semi-conductors.*

EXERCISES, PART 6

1. A proton is about ______ times more massive than an electron and has an electric charge the magnitude of which is ______ times the charge of the electron.

2. A group of 10 protons is separated by a distance of 1 cm from a group of 8 electrons. The force acting between the two groups, one of (attraction, repulsion) has a magnitude ______ times greater than the force between a single proton and electron separated by the same distance.

3. In problem 2, if the distance between charges is increased to 1.25 cm, the force will be (increased, decreased) to ______ of its original magnitude.

4. List the number of planetary electrons in a neutral atom of the following:
   (a) Carbon______
   (b) Element No. 29______
   (c) Element having an atomic weight of 181______
   (d) $_{80}Hg^{204}$______

5. Electromagnetic waves having a wavelength of 5 x 10^{-3} millimeters are being radiated from a certain substance. These waves would fall into what portion of the radiant energy spectrum?

ANSWERS TO EXERCISE PROBLEMS, PART 5

1. 4.4 ft.
2. 972 Btu.
3. 6.94 days.
4. 49%, approximately.
5. 1.5%, approximately.

Table I—*Table of Elements*

Atomic No.	*Element*	*Chem. Sym.*	*Atomic Wt.*	*Melt. Pt. °C*	*Boil. Pt. °C*	*Spec. Grav.*	*Valence*	*Description*
1.	Hydrogen	H	1.0080	–259.14	–258.7	—	1	Lightest of all gases.
2.	Helium	He	4.003	–272.2	–268.9	—	0	An inert, colorless, gaseous element first observed spectroscopically in the sun's atmosphere.
3.	Lithium	Li	6.94	186	1220	0.534	1	Soft, white metal, lightest metal known. Never found free in nature.
4.	Beryllium	Be	9.02	1350	1500	1.85	2	A rare, hard, whitish metal used in alloys where strength, light weight, and anti-corrosion qualities are desired.
5.	Boron	B	10.82	2300+	2550	2.5	3	Constituent of boric acid and borax. A non-metallic element occurring only in combination.
6.	Carbon	C	12.01	3500+	4200	1.88-2.25	2, 3, or 4	Occurs in very large number of compounds, usually in plant and animal substances, or in compounds synthesized from them. The diamond and graphite are pure forms occurring in nature.
7.	Nitrogen	N	14.008	–209.86	–195.8	—	3, 5, or 6	Gas. 78% of atmosphere.
8.	Oxygen	O	16.000	–218.4	–183	—	2	Most abundant element. Very active chemically. Forms about one-fifth of the atmosphere. Vital to life.
9.	Fluorine	F	19.000	–223	–187	—	1	Pale-yellow halogen gas, very active chemically, combining with many elements, but not with oxygen.
10.	Neon	Ne	20.18	–249.67	–245.9	—	0	Inert gas.
11.	Sodium	Na	22.997	97.5	880	0.971	1	Soft, silvery-white alkali metal that burns readily. Most common compound is salt (NaCl).
12.	Magnesium	Mg	24.32	651	1110	1.74	2	Light, fairly tough, white metal that burns with dazzling white heat.
13.	Aluminum	Al	26.97	659.7	1800	2.699	3	Most abundant element in earth's crust, and third most abundant among all elements.
14.	Silicon	Si	28.06	1420	2600	2.42	4	Non-metallic solid resembling graphite. Second most abundant element in earth's crust.
15.	Phosphorus	P	30.98	44.1	280	2.0	3 or 5	Waxy red, yellow, or black solid. Poisonous. Ignites spontaneously in air.
16.	Sulphur	S	32.06	112.8-119	444.6	2.0	2, 4, 6	Pale-yellow, brittle solid insoluble in water. Occurs widely.
17.	Chlorine	Cl	35.457	–101.6	–34.6	—	1, 3, 5, 7	Greenish-yellow halogen gas very active chemically. Has irritating and suffocating odor.
18.	Argon	A	39.944	–189.2	–185.17	—	0	Inert gas forming 0.8% of atmosphere.
19.	Potassium	K	39.096	62.3	760	0.87	1	Soft, white, alkali metal that burns readily.
20.	Calcium	Ca	40.08	810	1170	1.55	2	Alkali earth metal. Fifth most abundant element in earth's crust.
21.	Scandium	Sc	45.10	1200	2400	—	3	Rare-earth metal.
22.	Titanium	Ti	47.9	1800	3000	4.5	3 or 4	Lustrous, white metal used to harden steel and to obtain opacity in high-grade white paints.
23.	Vanadium	V	50.95	1710	3000	5.96	2, 3, 4, or 5	Infusible, grayish metal used to harden steel.
24.	Chromium	Cr	52.01	1615	2200	7.1	2, 3, or 6	Hard, grayish, infusible metal used in stainless steel to harden it; also used to harden certain other steels, and in plating.

TABLE I—*Table of Elements, continued*

Atomic No.	*Element*	*Chem. Sym.*	*Atomic Wt.*	*Melt. Pt. °C*	*Boil. Pt. °C*	*Spec. Grav.*	*Valence*	*Description*
25.	Manganese	Mn	54.93	1260	1900	7.2	2, 4, 6, or 7	Hard, brittle, gray-white metal used in many iron, copper, brass, and nickel alloys.
26.	Iron	Fe	55.85	1535	3000	7.85	2, 3, or 6	Cheapest and most useful of all metals. Ductile and malleable. Has useful magnetic properties. Basic constituent of steel.
27.	Cobalt	Co	58.94	1480	3000	8.9	2 or 3	Brittle, hard, very-magnetic metal of grayish color tinted with red. Used in many magnetic alloys and as blue coloring pigment.
28.	Nickel	Ni	58.69	1455	2900	8.9	2 or 3	Hard, malleable, ductile metal of high tenacity much used in plating and alloys.
29.	Copper	Cu	63.57	1083	2300	8.93	1 or 2	Metal. Excellent thermal and electrical conductor. Malleable and ductile. Most common electrical conductor.
30.	Zinc	Zn	65.38	419.5	907	7.14	2	Blue-white metal used in alloys, in galvanizing, and in electric dry-cells.
31.	Gallium	Ga	69.72	29.75	1600	5.91	2 or 3	Metal with low melting and high boiling point. Used in high temperature thermometers.
32.	Germanium	Ge	72.60	958	2700	5.36	4	Gray-white, brittle, crystalline metal.
33.	Arsenic	As	74.91	500	615	5.73	3 or 5	Brittle, crystalline semi-metallic solid. Forms very poisonous compounds. Much used in insecticides.
34.	Selenium	Se	78.96	220	688	4.8	2, 4, or 6	Semi-metallic, gray solid used in glass and ceramic manufacturing. Electrical conductivity varies with degree of illumination.
35.	Bromine	Br	79.916	–7.2	58.78	—	1, 3, 5, or 7	Only liquid non-metallic element. Highly volatile at normal room temperature and has very irritating effect on eyes and throat.
36.	Krypton	Kr	83.7	–157	–152.9	—	0	Rare inert gas.
37.	Rubidium	Rb	85.48	38.5	700	1.53	1	Soft, white, rare alkali metal having chemical properties similar to potassium.
38.	Stronium	Sr	87.63	752	1150	2.54	2	Hard, yellowish metal having chemical properties similar to calcium. Used in cathodes of vacuum tubes to increase emission.
39.	Yttrium	Yb	88.92	1490	2500	5.51	3	Rare-earth metal.
40.	Zirconium	Zr	91.22	1900	2900	6.4	4	Metal, semi-precious gem. Used in paints, insulators, and abrasives.
41.	Columbiun or Niobium	Cb Nb	92.91	1950	2900	8.4	3 or 5	Very rare metallic element. Extremely white and lustrous. Added to stainless steel, preserves its corrosion resistance even when heated.
42.	Molybdenum	Mo	95.95	2620	3700	10.2	2, 3, 4, 5, or 6	Hard, silvery metal used in vacuum tube manufacture, in tool steels, rifle barrels, crankshafts, etc.
43.	Masurium	Ma	98 (est.)	2300	—		2, 3, 4, or 6	Artificially-produced element. Natural existence doubtful.
44.	Ruthenium	Ru	101.7	2450	2700	12.2	3, 4, 6, or 8	Metal similar to platinum.
45.	Rhodium	Rh	102.91	1985	2500	12.5	3	Metal similar to platinum. In electroplating it gives a surface unaffected by exposure to air or to strong acids or alkalies.
46.	Palladium	Pd	106.7	1553	2200	12.16	2 or 4	Metal similar to platinum. Used in construction of non-magnetic watches, parts of delicate balances, and surgical instruments.

TABLE I—*Table of Elements, continued*

Atomic No.	*Element*	*Chem. Sym.*	*Atomic Wt.*	*Melt. Pt. °C*	*Boil. Pt. °C*	*Spec. Grav.*	*Valence*	*Description*
47.	Silver	Ag	107.88	960.5	1950	10.50	1	Metal. Best thermal and electrical conductor. Malleable and ductile.
48.	Cadmium	Cd	112.4	320.9	767	8.65	2	Metal used principally in plating, and in bearing alloys.
49.	Indium	In	114.76	155	1450	7.28	1 or 3	Very soft metal not affected by air or water. Used in plating.
50.	Tin	Sn	118.7	231.9	2260	5.75	2 or 4	Soft, malleable metal of low tenacity much used for cheap plating.
51.	Antimony	Sb	121.76	630.5	1380	6.691	3 or 5	Blue-white, brittle, lustrous metal used in many resistance alloys.
52.	Tellurium	Te	127.61	452	1390	6.24	2, 4, or 6	Semi-metallic, gray-white solid used in manufacture of ceramics.
53.	Iodine	I	126.92	113.5	184.35	4.93	1, 3, 5, or 7	Gray-black, lustrous solid. Volatile at normal temperature and pressure, producing irritating odor.
54.	Xenon	Xe	131.3	–112	–107.1	—	0	Rare, heavy, inert gas.
55.	Cesium	Cs	132.9	28.5	670	1.87	1	Alkali metal having great affinity for oxygen. Used in photo cells as light-sensitive element and as "getter" in vacuum tubes.
56.	Barium	Ba	137.36	850	1140	3.5	2	Soft, silvery metal resembling lead. Used in vacuum tube filament alloys.
57.	Lanthanum	La	138.92	826	1800	6.155	3	Rare-earth metal.
58.	Cerium	Ce	140.13	640	1400	6.9	3 or 4	Rare-earth metal.
59.	Praseodymium	Pr	140.92	940	—	6.5	3, 4, or 5	Rare-earth metal.
60.	Neodymium	Nd	144.27	840	—	6.95	3	Rare-earth metal.
61.	Illinium	Il	146	—	—	—	3	Artificially produced. Natural existence doubtful.
62.	Samarium	Sm	150.43	1350	—	7.7	2 or 3	Rare-earth metal.
63.	Europium	Eu	152.0	—	—	—	2 or 3	Rare-earth metal.
64.	Gadolinium	Gd	156.9	—	—	—	3	Rare-earth metal.
65.	terbium	Tb	159.2	—	—	—	3	Rare-earth metal.
66.	Dysprosium	Dy	—	—	—	—	3	Rare-earth metal.
67.	Holmium	Ho	164.94	—	—	—	3	Rare-earth metal.
68.	Erbium	Er	167.2	—	—	—	3	Rare-earth metal.
69.	Thulium	Tm	169.4	—	—	—	3	Rare-earth metal.
70.	Ytterbium	Yb	173.5	1800	—	—	3	Rare-earth metal.
71.	Lutecium	Lu	174.99	—	—	—	3	Rare-earth metal.
72.	Hafnium	Hf	178.6	1700	3200	13.3	4	Metal having chemical properties similar to zirconium.
73.	Tantalum	Ta	180.88	2996	4100	16.6	5	Metal. High ductility, tenacity and melting point. Used in lamp and vacuum tube filaments to resist more-than-ordinary vibration.
74.	Tungsten	W	183.92	3370	5900	19.3	2, 4, 5, or 6	Hard, brittle metal becoming ductile when worked. High melting point makes it useful as lamp and vacuum tube filament material. About 90% of world's production used in steel manufacture. Its various steel alloys used in armor plate projectiles, and high-speed cutting tools.
75.	Rhenium	Re	186.31	3000	—	20.53	2, 5, 6, 7, or 8	Metal with chemical properties similar to manganese.
76.	Osmium	Os	190.2	2700	—	22.48	2, 3, 4, or 8	Hardest and most dense of metals. Alloyed with iridium to produce fine machine bearings, pen tips, etc.

Table 1—*Table of Elements, continued*

Atomic No.	*Element*	*Chem. Sym.*	*Atomic Wt.*	*Melt. Pt. °C*	*Boil. Pt. °C*	*Spec. Grav.*	*Valence*	*Description*
77.	Iridium	Ir	193.1	2350	4800	22.42	3 or 4	Hard, brittle metal often alloyed with platinum or osmium.
78.	Platinum	Pt	195.23	1773.5	4300	21.37	2 or 4	Metal of high tenacity, malleability, and ductility. Has approximately same thermal coefficient of expansion as, glass.
79.	Gold	Au	197.2	1063	2600	19.32	1 or 3	Softest and most malleable metal. Used as base for currency.
80.	Mercury	Hg	200.61	–38.87	356.9	13.546	1 or 2	Metal. Liquid at room temperature. Dissolves many metals, forming amalgams.
81.	Thallium	Tl	204.39	303.4	1650	11.85	1 or 3	Metal with properties similar to those of lead.
82.	Lead	Pb	207.22	327.5	1620	11.35	2 or 4	Soft, malleable metal of low tenacity. Bottom of radioactive group.
83.	Bismuth	Bi	209.0	271.3	1450	9.78	3 or 5	Brittle metal resembling tin. Used in solders of low melting point. Poor conductor of electricity. Expands when cooled.
84.	Polonium	Po	210	—	—	—	—	Radioactive metal.
85.	Alabamine	Ab	221	—	—	—	1, 3, 5, or 7	Artificially produced. Natural existence doubtful.
86.	Radon	Rn	222	–110	–61.8	9.73	0	Inert gas. Radioactive. Heaviest of all gases. Used in cancer therapy.
87.	Virginium	Vi	224	—	—	—	1	Artificially produced. Radioactive.
88.	Radium	Ra	226.05	960	1140	—	2	Radioactive metal.
89.	Actinium	Ac	227	—	—	—	—	Radioactive metal.
90.	Thorium	Th	232.12	1845	3000	11.3	4	Radioactive metal. Used to improve emissivity of vacuum tube filaments.
91.	Protactinium	Pa.	231	—	—	—	—	Radioactive metal.
92.	Uranium	U	238.07	1150	—	18.68	3, 4, or 6	Radioactive metal. Source of U235.

FREQUENCY SHIFT CONVERTERS

The navy now has in stock twenty-two model FRF frequency shift converter equipments which have been set aside for shipboard use.

The FRF converter is the dual-channel i-f type, connected by means of r-f cables and a coupling unit. It is necessary that the RBB or RBC receivers selected to be used in conjunction with this converter be modified by the addition of coaxial connectors and coupling units. The modification parts will be supplied in a kit which will accompany each FRF equipment.

This equipment is decidedly superior to the only available shipboard converter, the FRA, and is immediately available. Due to the limited quantity, however, it will be distributed only upon recommendations of the Commanders in Chief of the U. S. Atlantic or Pacific fleets.

The equipments, being originally designed for shore installation, are not equipped to withstand the shocks and vibration encountered aboard ship, but steps are being taken by the Bureau to procure 40 sets of suitable shockmounts for the shipboard installations. The shockmounts will be shipped to Naval Supply Depot, Mechanicsburg, where they will be issued with the equipments. The installing activities will have the responsibility of mounting these shockmounts on the bottom of the FRF cabinets.

● ● ●

IBM ANALYSIS OF TUBE TYPE

Recently the question arose as to whether a certain type transmitter tube should be "ruggedized". Failure reports on that type tube were analyzed by the IBM machines in half an hour. A study of the tabulation, which would have taken several days to compile by hand methods, revealed that ruggedizing was unnecessary and thereby saved the navy and American taxpayers a neat $10,000.00.

THIS ONE "Rings the Bell"

■ An interesting but utterly impractical application of an electric current is in the ringing of a small bell at its fundamental mode. This serves but one purpose: to prove that currents—eddy currents—are induced in metal placed in a magnetic field.

It is well known that a bell struck a sharp blow with a hard instrument will make a sound different from that which it makes when struck with a soft, blunt instrument. Probably the difference in sound, or timbre, is caused by the fact that the hard instrument sets up vibrations in the bell at frequencies higher by many harmonics than the fundamental frequency, whereas the soft, blunt instrument, remaining in contact with the bell for a longer time, damps these higher-order harmonics and allows only the lower-order harmonics to be heard.

In neither case, however, is the bell excited at its true fundamental frequency, but rather at frequencies in the order of the second harmonic and higher. In figure 1A is shown a bell struck a single blow on its side, and the instantaneous distortion which takes place in its shape. Figure 1B shows distortion which must take place if the bell is to oscillate at its fundamental frequency.

By winding a coil of wire around the bell as in figure 1C and causing a single short pulse of high current to flow through the coil, a high-intensity magnetic field will be developed instantaneously which will cut through the bell longitudinally. This magnetic field cutting the metal shell of the bell will in turn induce currents of electricity in the two sides of the bell as shown by the dotted line in figure 1D. The mutual repulsion between the two current loops distorts the bell, and instantaneously it takes a shape as denoted in figure 1B. The currents then drop to zero, but the bell has been set into oscillation and, because it is a bell, rings.

The author tried it. It works. He wound about a hundred turns of hookup wire around his hand, taped it together and suspended the bell by a cord in the center of the coil. About 35 microfarads of capacitance were obtained by connecting miscellaneous paper capacitors—not electrolytics—in parallel. A 300-volt d-c power supply was connected through a 10,000-ohm, 2-watt resistor to the bank of capacitors, and one side of the coil to the capacitors as shown in figure 2. The other side of the coil was insulated with spaghetti (before the power supply was turned on!) and its bare end touched to the other side of the bank of capacitors. By listening carefully, the author was able to hear a weak but clear and deep-throated tone emanating from the bell, at a pitch a full octave below any other tone that had previously been heard from that bell. The bell was ringing at its fundamental mode.

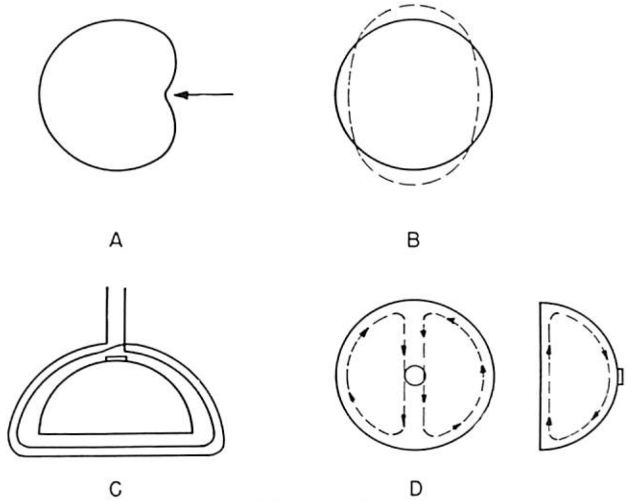


Figure 1

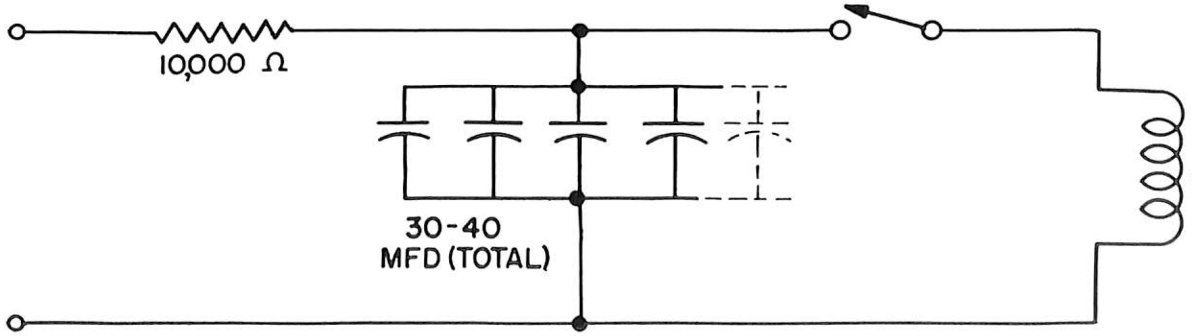
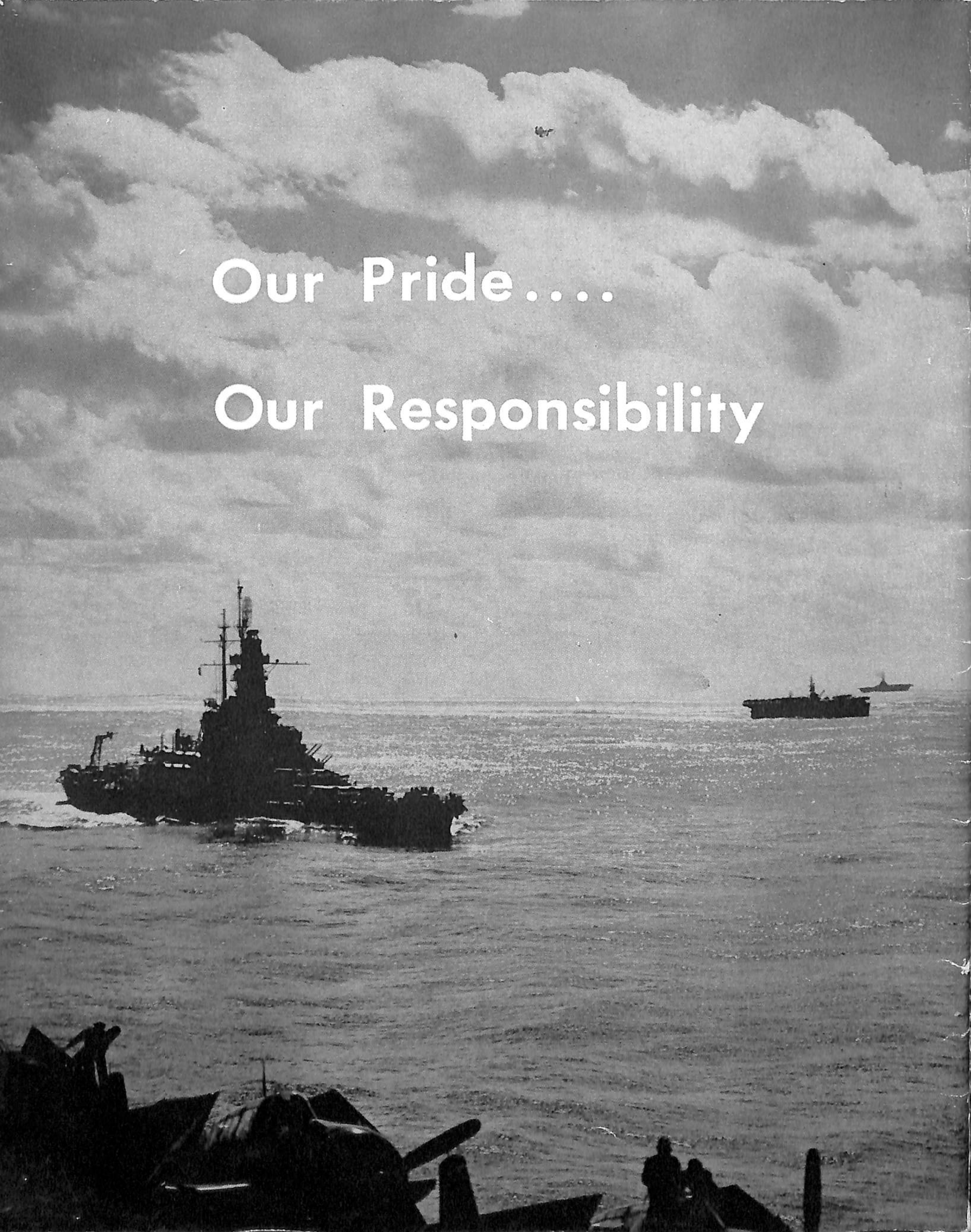


Figure 2


Our Pride....
Our Responsibility