RESTRICTED

# BUSHIPS Electron


JUNE • 1949

NavShips 900,100

RESTRICTED

BUSHIPS Electron

A MONTHLY MAGAZINE FOR ELECTRONICS TECHNICIANS

JUNE · VOLUME 4 · NUMBER 12

*Electronics Work at Long Beach* ..... 1
*Standardized Shore Station Design* ..... 3
*Model VF Coincidence Gate* ..... 8
*Versatility of Sonar Equipment* ..... 9
*Electronics Cable Tracer* ..... 10
*Teletype Repair* ..... 11
*U.S. Naval Reserve in the 11th Naval District* ..... 13
*GCA Box Score* ..... 13
*Some Formulas for Calculating the Ranges of Radar Sets* ..... 14
*Attention—Marines, Coast Guardsmen, Reserves* ..... 20
*The Replaceable Subassembly and its Effect on Naval Electronics* ..... 21
*Development of the Cathode-Ray Tube* ..... 24
*Tuning Models SU/-1 Transmitter-Receivers* ..... 25
*Increased Distribution of NavShips 4110* ..... 25
*Maintenance of Model DBM/-1 Antennas* ..... 26
*Repair of Radar Mattress Type Antenna Arrays* ..... 27
*The Mon-Key, Electronic Monitor and Transmitting Key* ..... 28
*Reporting on the Maintenance Repair Parts Program* ..... 29
*Monthly Performance and Operational Reports, Sonar Equipment* ..... 30
*Monthly Performance and Operational Reports, Communication and Countermeasures Equipment* ..... 32
*Basic Physics, Part 18* ..... 34

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Bureau of Ships (Code 993-b)
The Editor BuShips Electron
Navy Department
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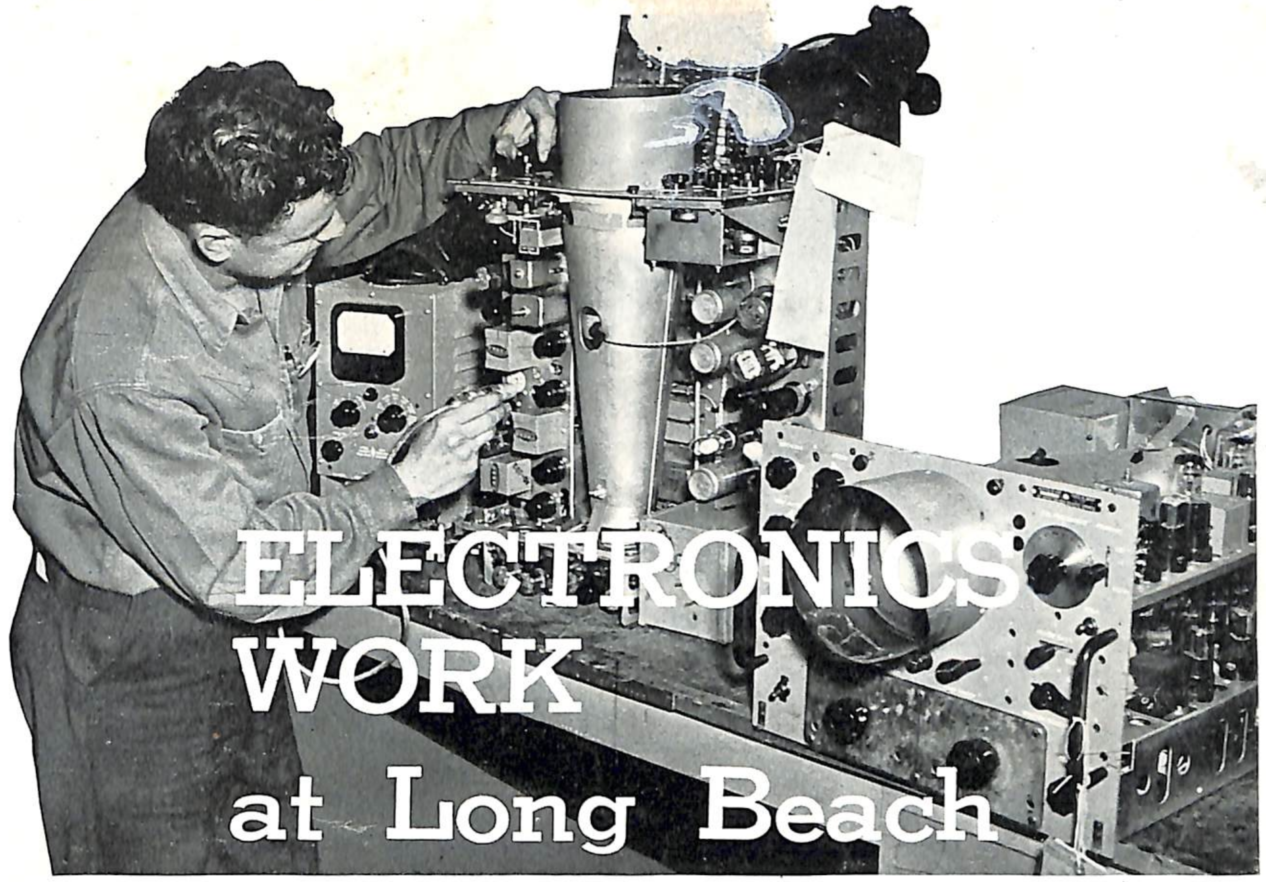


# ELECTRONICS WORK at Long Beach

*by* C. F. Taylor, *Foreman Electronics Mechanic, Long Beach Naval Shipyard*

Unlike other U. S. Naval Shipyards, the Long Beach Naval Shipyard might be termed a "war baby"—World War II being well on its way before the yard was dedicated. Practically every Naval station in the United States and its possessions is represented by personnel who made the decision to transfer to the Long Beach Naval Shipyard as career employees.

Our goal "to keep our customers satisfied" is the "must" item. Among those who keep us on our toes in our attempt to satisfy are:

1—The 19th Fleet's preservation program representatives. An average of twenty Shop 67 radio mechanics and electricians per day are assigned to this project.

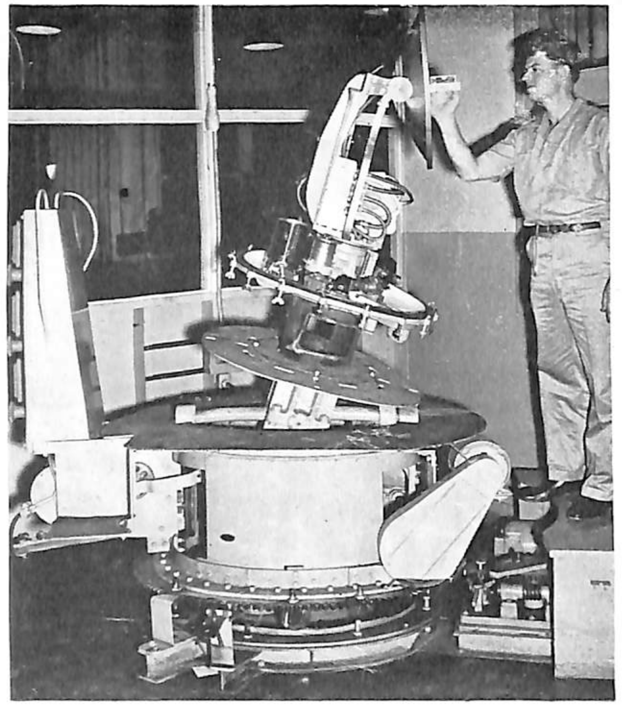
2—Another who can always be counted on to supply a large amount of work is the Long Beach Naval Shipyard Electronics Officer. Thirty-three Shop 67 men per day are kept busy repairing, maintaining, manufacturing and installing electronic equipment throughout the Eleventh Naval District Shore Establishment (including the Naval Reserve Armories), for which he is responsible.

3—One customer in particular that offers much interesting work is the Navy Electronics Laboratory, San Diego, California. The Long Beach ... Shipyard recently contracted with N.E.L. to ... a large number of sonar trainers for use with an advanced sonar system.

4—Needless to say, the Pacific Fleet is our largest customer. Shop 67 averages 105 men per day on shipboard job orders, including installation, repair, shipboard operational check and calibration.

5—The local Naval Supply Depot also can be relied upon to keep the shop busy in the repair of BuShips material in store and general electronic equipment requiring overhaul, now termed "Zebra Program."

Fortunately, Shop 67 has a goodly number of electronics mechanics, radio mechanics, and electricians of above average ability. However, there is still a small number whose ability is at a level below average. Training courses were initiated two years ago (under Shop 51) for the betterment of three major weaknesses of the electronics personnel. The courses included teletype maintenance and repair, fire control radar repair, and search radar repair. Also, during this period, several radio mechanics were sent to the West Coast Sound School in San Diego for sonar training. At the present time, under the auspices of the Long Beach City College, a total of three extra-curricular courses are in progress cove...g the subjects of sonar, radio, and teletype. One radar and one radio course were completed last semester. Through the efforts of the shipyard training personnel ... the interest shown by the radio mechanics, electronics



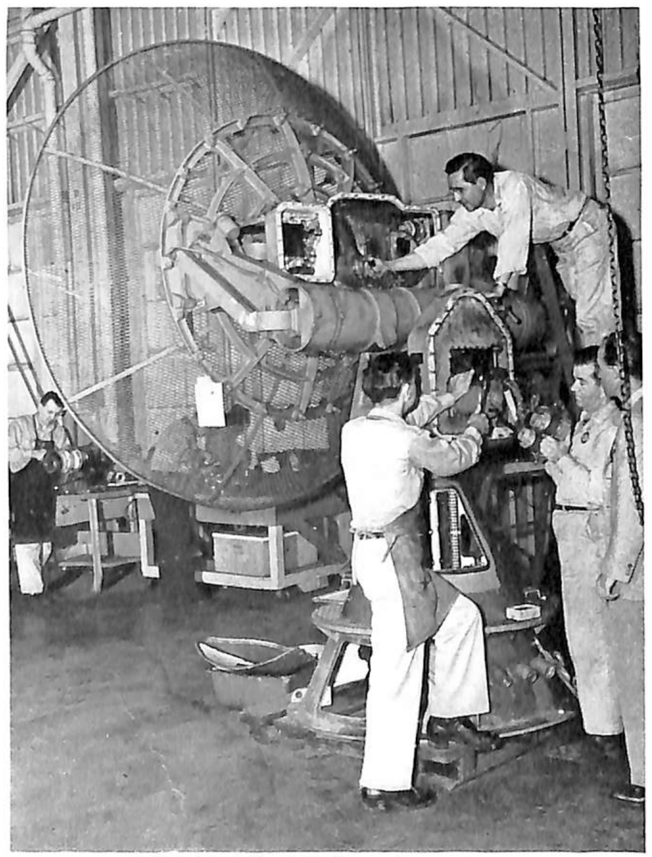
TEST OF SU RADAR ANTENNA on gyro shop Scorsby equipment.

mechanics and electricians, Shop 67 is fast becoming a versatile organization.

In addition to the BuShips electronic test equipment allowance, several units of test equipment have been devised by shop personnel to expedite repair and calibration of equipments. Among these time savers are: A portable synthetic gyro system from which is obtained OSC information, both 1× and 36× (used aboard ship and in shop); a cleaning tank and drier patterned after the one used by the Bell Telephone Company for cleaning teletype equipment; special canvas covers to be placed around electronic equipment aboard ship to prevent damage from assist trades; a remote control radiophone panel from which a number of receivers and transmitters are controlled for the purpose of ship to shop testing of repaired and newly installed equipments; a test panel with indicator for the bench testing of the channel selector units used in Models RDZ/TDZ equipments; a power output meter to measure zero audio level for 600-ohm output terminals of receivers (the conventional Type 22195 meter is designed for 500 ohms); a grid dip meter for determining the approximate frequencies of frequency multiplier stages in receivers and transmitters; and a method by which 100-kc or 1000-kc markers are added to the output of a Model LP Signal Generator throughout its entire frequency range, thus increasing the versatility of the LP and allowing the mechanic to have a constant check on its frequency calibration.

Radar, radio and sonar pilot equipments are an integral part of the shop facilities. At the present time there are three shop issues at the development stage (on which some action has been taken) which are considered necessary for an efficient productive organization. These issues are: Uniform approved shop practices in the repair, calibration and alignment of all electronic equipment; a method of rotating the employees through the three major phases of electronics—radio, radar, and sonar; and the use of production line principles in repair and overhaul of electronic equipment.

The following is an example of one of our shop practices. Following the overhaul of stabilized antennas, such as used with the Model SU radar, or Mark 8 stable elements as used with the Model SP radar, it has become a shop practice to test the antennas and the associated stable elements on the gyro shop's Scorsby equipment. In the case of the SU, the entire antenna is mounted on the Scorsby and power applied to all control and stabilizing circuits. The Scorsby is set in motion and an indicating bubble level is secured to the antenna to determine whether deficiencies exist in its stabilizing unit. The testing of Mark 8 stable elements associated with the SP also requires that they be mounted on the Scorsby. The level, cross level and training voltages are then fed into a dummy director recorder to determine whether the synchro control voltages are within allowable tolerances. Much unnecessary work aboard ship has been prevented by utilizing the knowledge and facilities of gyro shop personnel.



OVERHAUL OF SP radar antenna.





# STANDARDIZED SHORE STATION DESIGN

*by* L. H. Appleman, *Supervising Engineer, Shore Station Section, Long Beach Naval Shipyard*

Rapid wartime expansion and a heavy postwar modernization program within the Eleventh Naval District created an engineering, fabrication and installation work load which could only be handled through standardization. It has been found necessary to standardize not only the accessory equipments, but also systems, circuits and even design procedures. Standardized design was first instituted when the Shore Section was confronted with a sudden expansion from two prewar to twenty-four wartime air stations. Classification of the various activities by size and mission and the design of standard systems and accessories appeared to be the only method of attack which would ensure high quality communication within the limits of engineering and installation manpower. Although elapsed time between inception and final test was the wartime criterion, standardization has been fundamental in accomplishing a large postwar program under budgetary limitations.

Progress toward standardization of planning, design and installation procedures has been steady throughout the seven-year period since 1942. Implementation of the program has resulted in cognizance as follows:

*Planning Engineer:* Provides systems and equipment requirements both on a broad scale and for individual stations.

*Design Engineer:* Develops systems, circuits and

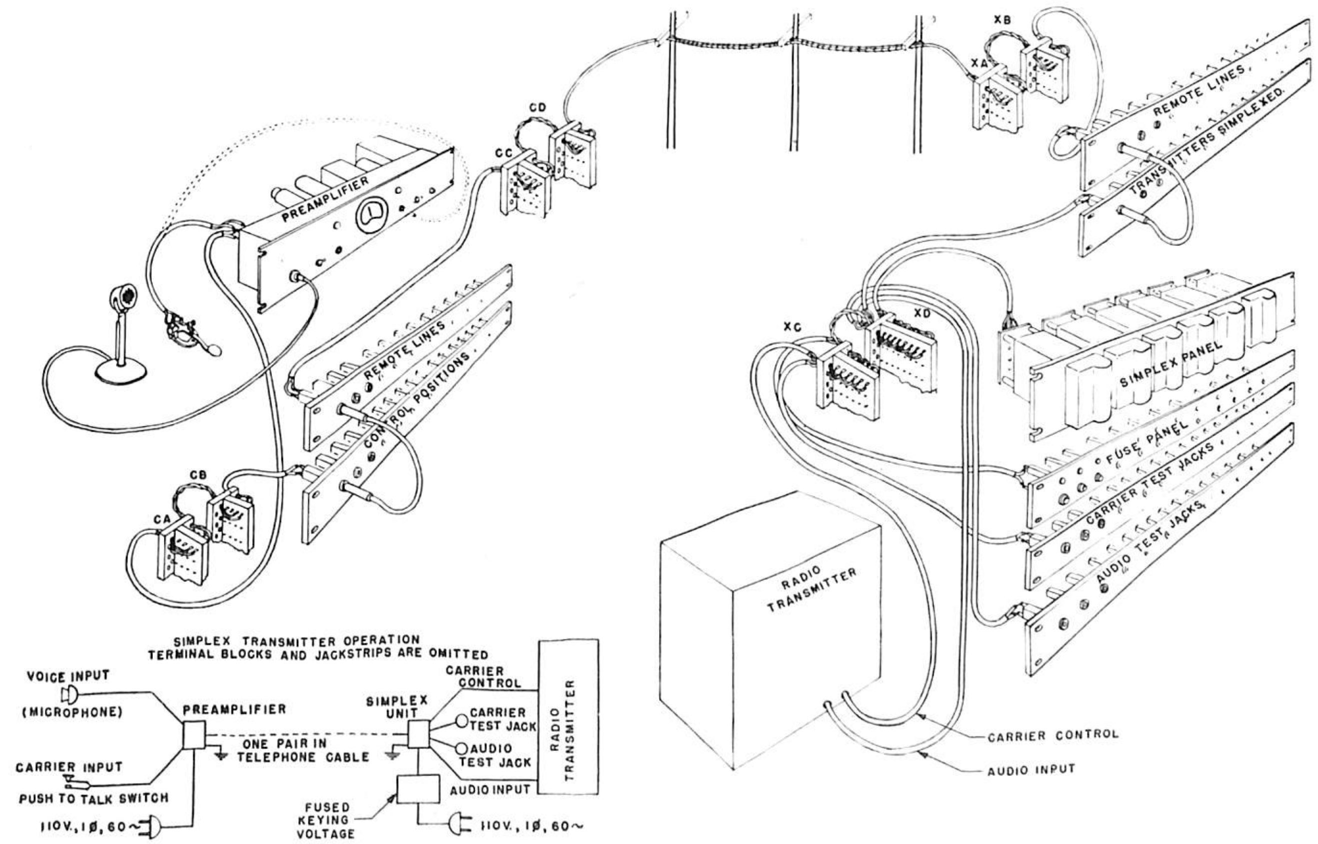



FIGURE 1—*Simplex control system.*

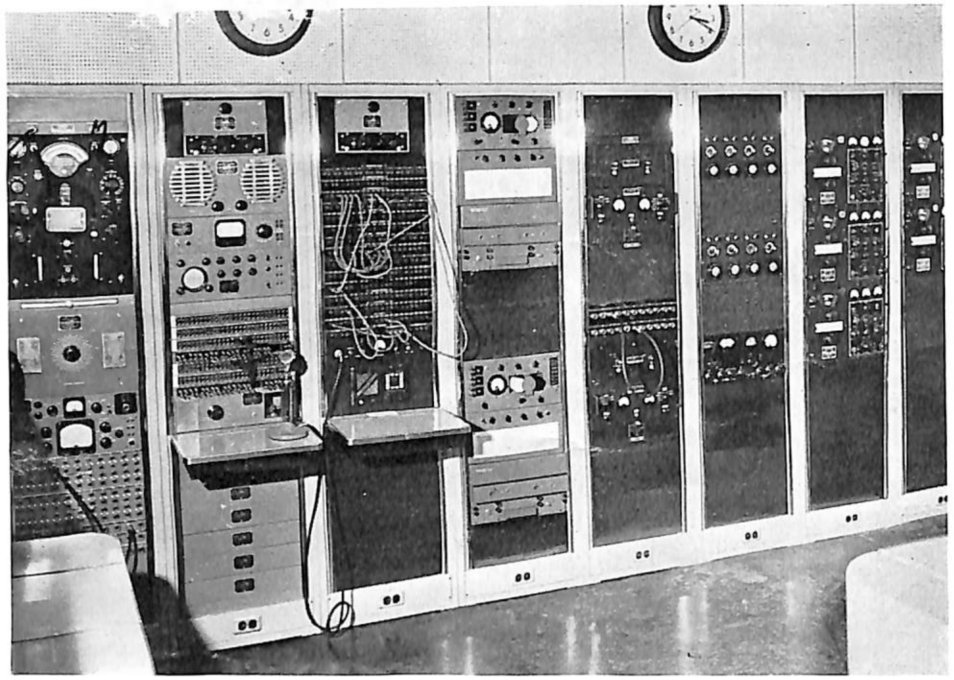


FIGURE 2—*Control and receiver bays at the receiving station, Naval Station, Long Beach.*

equipment with constant attention to simplification of installations and multiple use of new equipment; provides production designs for all accessory equipments; and develops and illustrates, when required, installation techniques.

*Project Engineer:* Reduces planning information to equipment lists (cabinets, operating tables, preamplifiers, simplex panels, etc.); prepares circuit block diagrams, terminal assignment sheets, work requests; and provides overall supervision of installation and test.

## Systems

The basic principle behind planning operations, not new to the communication station field, is concentration of transmitters and receivers in adequately spaced buildings. This principle has not in the past been rigidly applied to air stations and other dispersed activities. Centralization of transmitters has been an accepted practice, but too often numerous receiving activities spring up in locations providing poor reception resulting in substandard communications. Airport control towers, operations radio, administrative radio and airways communications stations are generally plagued by limitations on antenna height and space and by high noise levels. Emphasis has therefore been placed in recent years on improvement of receiving systems through isolation and centralization. Isolation has been achieved by three methods depending on individual situations and availability of funds:

1—The establishment of an isolated central receiving station for service to all activities by new construction or by the conversion of an existing structure.

2—Centralization of receivers at an existing radio room sufficiently close to an acceptable site for an antenna park, to permit employment of buried RG–85/U coaxial cable for connection to the remote antennas.

3—Installation of fixed frequency h-f and v-h-f receivers in weather-proof enclosures mounted on one or more of the antenna poles, and employment of buried telephone cable for interconnection with the central receiving room. In this case it is necessary to install tunable standby and CW circuit receivers in the radio room. At airways stations primarily interested in voice circuits, this makes an economical yet highly satisfactory solution.

Every attempt is made to rack mount all equipment in central receiving stations, even to the extent of fabricating adapters when necessary, for the various equipments encountered. The availability of signal distribution units has decreased the quantity of accessory equipments requiring local fabrication. Expansion of the distribution units is generally necessary, however, since the average central receiving station employs from 30 to 45 receivers. Standard 7-foot rack cabinets, Type CY–597/G, are employed extensively throughout the entire system. Attenuator units are mounted in each receiver cabinet for reduction of average output level to zero. This has the advantage over attenuation in the jack field in that common cables can be employed throughout the bays for all circuits. Rack-mounted AM–215/U line amplifiers are used at all remote receiving locations. Type–50272 amplifiers were employed in early installations for amplification at remote control points. Due to its small size this unit is preferred. However, due to the short supply of these units, the larger r adapted Type AM–215/U has been substituted. Local operating positions are provided, when required,





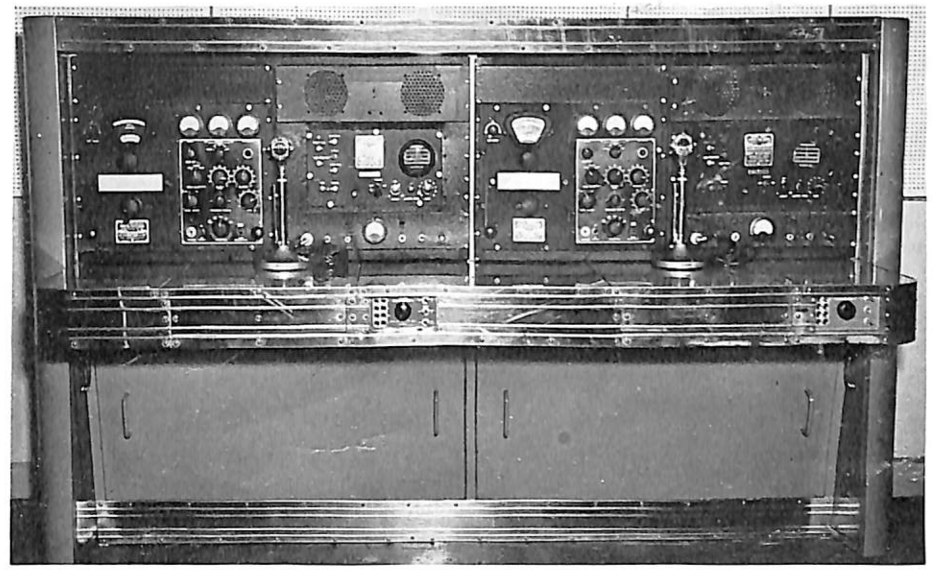


FIGURE 3—*Two-position operating table.*

by the installation of special rack-mounting tables, which are treated as remote stations with zero level tone channels (receiver audio output) supplied to each position from the control bays. When local operating positions are installed, a transmitter patch bay is included for remote transmitter control. Receivers in operating tables are connected with the signal distribution unit for antenna service.

Transmitter control has gone through a period of evolution resulting in the present simplexed system. It became apparent early that all transmitting equipment should "look" the same to all remote control locations. This meant terminal equipment to accomplish the match for both the carrier and audio circuits. Working from the transmitter back, the following conditions are maintained:

1—*Transmitter terminals:* Carrier operated by 48 volts d.c., positive grounded, externally supplied. Audio input, balanced, 500 ohms, —5 db input for 100% modulation (additional amplification, required only on TCS equipment, is supplied by a local preamplifier which is powered by receiver receptacle of TCS power supply).

2—*Transmitter test jacks:* Carrier is keyed by shorting the circuit (48 volts d. c. from indicating fuse strip applied at same terminal block). Audio, —5 db input maximum, across 500 ohms.

3—*Transmitter simplex strip:* Carrier, simplexed on 500-ohm balanced line (operating voltage applied on same terminal block through an indicating fuse strip).

4—*Remote control position:* Carrier control by grounding center tap of preamplifier output winding. Audio level across the balanced line, zero (average line loss = 5 db).

Figure 1 illustrates, in a simplified manner, the overall transmitter control system which is based on simplex operation. This system is favored because of the simplicity in patching voice transmitters, and the reduction in government control cable requirements and reduced cost where leased control lines are involved.

The equipment requirement and the installation involved in setting up a communication activity using the system are therefore small. For each position the bare essentials are:

1—Line amplifier (AM–215/U).
1—Speaker and/or headphones.
1—Tone channel unit.
1—Preamplifier (115 volts a. c.).
1—Dynamic microphone.
1—Hand key.
1—Telephone pair to the receiving center.
1—Telephone pair to the transmitting center.

Remote control installations are multiplied as required, installing the necessary equipment either in existing fixtures (e. g. control tower consoles), rack-mounting tables in communication centers, or in rack cabinets in special types of installations, such as tactical air control centers. The combination of foresight in reserving radio control pairs in a station telephone system, and the packaged nature of the prewired remote control units, tables and cabinets, makes it relatively simple to accommodate changing communication plans.

## Typical Installations

The receiving station at Naval Base, Long Beach, is an example of a medium-sized central receiving station where remote antennas feed the r-f section of the signal distribution unit.

The station is located in the communication wing of the Administration Building. Figure 2 shows the control and receiver bays as follows:

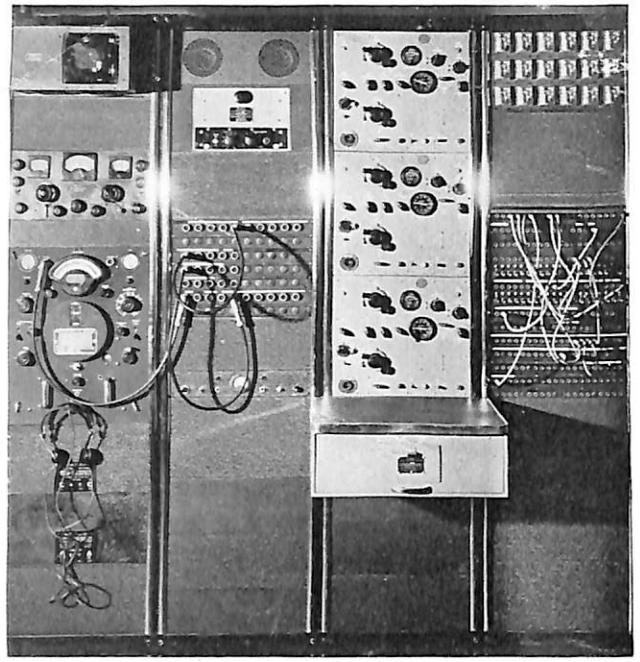


Figure 4—*Transmitter control bay at the Naval Station, Long Beach.*

Bays 1 & 2—Expanded Type *B* signal distribution unit.
Bay 3—Transmitter remote patch bay.
Bay 4—U-H-F RATT terminal equipment.
Bay 5—H-F RATT terminal equipment.
Bay 6—Remote control for unattended TDZ/RDZ installation in signal tower.
Bays 7 & 8—RBB & RBC receivers in special adapters (power supplies below, rear access).

Six local operating positions are available in the receiving room proper, with four additional positions in the adjacent ComSecAct receiving room. Receivers in ComSecAct are connected with the signal distribution unit for r-f input and a-f output distribution. Two remote operating locations, the Port Director and the Harbor Craft Base, are also served from the receiving room.

Figure 3 shows Positions 5 and 6 in the receiving room. The table is a standard two-position unit, and houses two RBB receivers, two RBU panoramic adapters and the usual preamplifier simplex units. These positions are normally employed on the 2–3 Mc harbor circuits; the panoramic adapters being provided to eliminate the need for periodic "rocking" of receiver tuning on the ship-shore guard frequencies.

Figure 4 shows the Naval Base transmitting station control bays containing:

Bay 1—Automatic keyer for RDF calibration, SX-28, LR-1 and two 48-volt control power units.
Bay 2—AM–215/U, coaxial patchbay and preamplifier for local test.
Bay 3—Three FSA keyers.
Bay 4—Three simplex panels and the usual jack field.

The coaxial patch bay terminates runs of RG–59/U from the oscillators of all master oscillator type transmitters and inputs to the first IPA stage on all equipment adapted for FSK. These coaxial interconnections serve for frequency meter pickup and permit permanent installation of the FSA keyers.

A typical large remote control unit is shown on figure 5. This completely assembled and wired unit was photographed in the Electronics Shop prior to delivery to the Naval Air Missile Test Center, Point Mugu. The unit has been installed in the launching area for service to both Flight Test Control and Sea Range Clearance. Provision is made for guarding 15 receiving circuits while transmitting on 12 circuits simultaneously. Provision is also made for control from a maximum of 20 locations in each room, for bridging any or all circuits, and for intercommunication between control points. The communication plan for each launching problem is set up in the patch bay as required, to serve the Clearance Officer, radar plots, AEW, etc.

## Equipment

A description of a few of the accessory equipments may be of interest to complete the picture of standardized design:

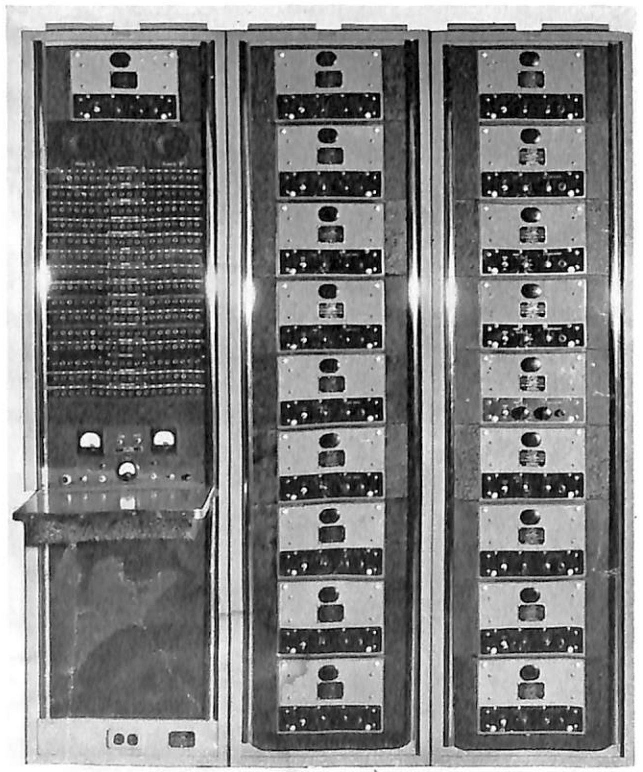


Figure 5—*Remote control cabinets for flight test control NAMTC, Pt. Mugu.*





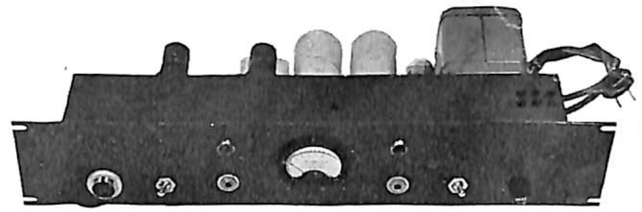


Figure 6—*Preamplifier simplex unit.*

Figure 7—*Transmitter simplex unit.*

*Operating Table*—(*Figure 3*) (*Plan RJ–23F–1056*).
1—Welded steel construction.
2—Two positions per unit, available in left-hand, center or right-hand units (e. g. 6–position table composed of L, C and R sections and left and right ends).
3—One duplex rack per position, rolls out on tracks for servicing of equipment; self indexing plug connectors for power and control/tone circuits.
4—Typewriter well covers slide back, eliminating stowage.
5—End section is separate unit; continuous hinge at rear; handle (under table) releases lock for access to unit terminals.
6—Space for power supplies (viz. RBA series) in space below racks (access by lift-off covers).
7—Table top of grey Formica (cigarette and stain proof).
8—Trim, and points of wear are of stainless steel.
9—Panel lighting provided by recessed lumaline units.

*Preamplifier*—(*Figure 6*) (*Plan RJ–50D–1073*).
1—Rack panel, 3½″ x 19″.
2—Input: Dynamic or carbon microphone.
3—Output: Simplexed, balanced 500-ohm line to +5 db.
4—Power input 115 volts, single phase, 50/60 cycles, 20 watts.
5—Multiple relay provides carrier simplex, receiver muting, connects preamplifier to line (allows multiple operation of several units on same line), and loads output in OFF position to protect power level meter.
6—Contains special low flux density, triple shielded power transformer.
7—Tube complement: 1 each 6SJ7, 6C5, 6X5.
8—Telegraph key connects to terminal board on rear, or plugs into jack on panel.

*Simplex Panel*—(*Figure 7*) (*Plan RJ–23F–881*).
1—Converts simplexed line to carrier and audio lines.
2—Six lines per strip; 3½″ x 19″ panel.
3—High speed relay (Advance No. 1200), panel-mounted for inspection and adjustment; molded plastic cover.

*TCS Rack Adapter* (*Plan RJ–10F–1061*).
1—Rack mounts either TCS transmitter or receiver.
2—Panel, 10½″ x 19″.
3—Power supply mounts on intermediate frame.

*TCS Preamplifier* (*Plan RJ–50AA–927A*).
1—Installed with remote control TCS transmitters.
2—Provides conversion from 12-volt TCS carrier control circuit to standard 48-volt d. c. operation.
3—Provides 25 db of gain, if required, ahead of TCS modulator.
4—Plugs into TCS power supply receiver receptacle for power and input connections.
5—Single stage, 12A6.

*VRF Rack Adapter* (*Plan RJ–10D–1338*).
1—Panel, 17½″ x 19″.
2—Recorder recessed, controls flush.

*VRF Control Panel* (*Plan RJ–23E–1373*).
1—Panel, 5½″ x 19″.
2—Used with each pair of rack-mounted VRF recorders.
3—Provides for automatic transfer, and for eight isolated input lines.
4—Local and remote warning lights indicate need for film replacement.

*AM–215/U Rack Adapter* (*Plan RJ–23F–1079*).
1—Details CEMB, Supp. No. 25.

*Relay Rack Table*—(*Figure 2*) *Bays 2 & 3* (*Plan RJ–23F–1071A*).
1—Panel, 3½″ x 19″; saves considerable panel space over Type FN–28G (8¾″ x 19″).
2—Top of grey Formica (cigarette and stain proof); hinged for access to compartment for log books, patch cords, etc.

*Control Power Supply*—(*Figure 4*) *Bay 1* (*Plan RJ–20AA–715*).
1—Panel, 8¾″ x 19″.
2—Input 115 volts, single phase, 50/60 cycles, 200 watts.
3—Output 48-volt d. c. at 3 amps.
4—Employs 4B24 rectifier.

# MODEL VF COINCIDENCE GATE

*by* J. L. PLOOF, *Fire Control Group, Long Beach Naval Shipyard*

Numerous ships entering this yard equipped with VF PPI repeaters have experienced difficulty in keeping these equipments operating satisfactorily. Since most of this trouble centers around the operation of the B-scope and especially the coincidence gate, V–314, a brief discussion of the functions of the coincidence gate and its major troubles, together with their causes and corrections, may be of some value to the Fleet.

A coincidence gate is basically a very simple circuit. It consists of a tube to which two signals are applied. The tube is so biased that neither signal alone will cause the tube to conduct, but when both signals are applied simultaneously, their combined voltages are sufficient to overcome the tube's bias and cause the tube to conduct.

In the case of the VF, the coincidence gate, V–314, is a 6SJ7 tube. The two coincidence voltages are applied, one to the No. 3 grid and the other to the No. 4 grid. Negative bias voltages are applied to these grids from the power supply.

The signal voltage applied to the No. 3 grid is a square wave pulse 6 microseconds wide. Its repetition rate is identical with the repetition rate of the radar energizing the VF.

The signal voltage applied to the No. 4 grid is a series of approximately 50 marker pips spaced at 6.1-microsecond intervals. A series of pips is started by each sync pulse from the master radar.

A phase shifting network capable of shifting the phase of these markers 360° is so geared to the Veeder range counter that for each 360° phase shift the Veeder counter shows 1000 yards change in range.

The 6-microsecond pulse is capable of being linearly delayed approximately 300 microseconds by means of a helipot and pick-off diode. The helipot is so geared to the Veeder counter that for each change of 1000 yards of the counter, the pulse delay will change 6.1 microseconds.

Normally one of the marker pips applied to the No. 4 grid of the coincidence tube will occur at approximately the middle of the 6-microsecond pulse applied to the No. 3 grid. The tube will then conduct, triggering the B-circuits. This condition should prevail at any setting of the range counter.

When movement of the 6-microsecond pulse is not linear, the pulse will move faster or slower than the shift in phase of the *B* marker pulses. Under this condition, after the range crank has been moved several turns, the 6-microsecond pulse will have been advanced or retarded in respect to the *B* marker pulse sufficiently to allow it to occur between *B* marker pulses, thus causing the *B* gating multivibrator to remain in a steady state condition. This is the most common cause of loss of the B-scope presentation. It is easily recognized by the fact that the B-sweep will disappear and then reappear as the range crank is turned through its entire range. The correction for this trouble is the proper adjustment of R–325 and R–320.

When the *B* marker oscillator is operated at a higher frequency than normal, the spacing between marker pulses becomes less than 6.1 microseconds. When the spacing between marks decreases to 6 microseconds or less, it is possible for two marker pulses to occur during the 6-microsecond pulse. When two marker pulses are "riding" the 6-microsecond pulse, the leading marker will trigger the *B* gating multivibrator but the following marker will have no effect. However, any slight deviation in linearity of movement of the 6-microsecond pulse will allow the leading marker to "drop off the pulse." This allows the following marker to trigger the *B* gate. This trouble can be recognized by a sudden jump of approximately 1000 yards in range. The remedy is adjustment of the oscillator oven thermostat for correct oven temperature and readjustment of the oscillator L–301 to the correct frequency.

Most ships do not have a special thermometer for measuring the oscillator oven temperature. However, nearly every ship which has a VF installation also has a VJ installation. Component M–501 of the VJ is a Navy Type–40253 thermometer. It is carried in VJ equipment spares as Tag No. 1497, and this thermometer will serve for measuring the VF oscillator oven temperature.

Section V, par. 4, part 3 of the VF instruction book outlines the procedure for adjusting the oscillator frequency by use of the Model 60ACZ circular sweep scope. Because the number of these scopes procured by the Navy was very limited, very few ships are fortunate enough to possess one. When a Model 60ACZ scope is not available, a Model TS–239/UP synchroscope used as outlined below will prove to be a satisfactory substitute.

The frequency of the oscillator can be adjusted in the following manner:

With the synchroscope sweep set at 10 microseconds and triggered by the applied signal, apply the phase shifted markers from pin 4 of V–314 to the signal input jack of the synchroscope. By using the 0.2 microsecond markers an accurate measurement of the distance between marker pulses can be obtained. Coil L–301 of the oscillator should be adjusted until the distance between marker pulses is exactly 6.1 microseconds. (This should not be attempted until the oven has reached its normal temperature.)

In some VF units trouble is experienced in adjusting the slope of the pick-off diode cathode voltage as outlined in Sec. V, par. 4, part 3j of the VF instruction book, so that linear movement of the 6-microsecond pulse will ensue.

The Model TS–239/UP synchroscope can be used in the following manner to make this adjustment:

Couple the 6-microsecond pulse from pin 3 of V–314 to the signal input jack of the Model TS–239/UP. Couple the marker pulses from pin 4 of V–314 to the Z-axis jack. Set the sweep at 10 microseconds and trigger it from the signal. Adjust the signal attenuator until a well defined pulse appears on the scope. Turn the intensity down until a series of breaks appear in the sweep trace. These breaks are the marker pulses.

Set the VF range at 3000 yds. Adjust R–325 until one of the breaks occurs squarely in the center of the pulse. Advance the range crank several thousand yards and note if any shift in position of the break occurs. If so, make compensating adjustments by means of R–320. Repeat this operation at least three times because there is a certain amount of interaction between R–325 and R–320.

# VERSATILITY OF SONAR EQUIPMENT

*by* MR. H. H. WAIR, *Head Sonar Group, Ship Section, Long Beach Naval Shipyard*

The Bureau of Reclamation has for some time been utilizing ultrasonic depth recording equipment to measure the silt deposits in Lake Mead, which is the great reservoir formed behind Hoover Dam in Nevada by the waters of the Colorado and Virgin Rivers.

Models NJ–8 and NK–6 Echo Sounding Equipments furnished by the Bureau of Ships and maintained by this shipyard are being used in plotting the growth of these subsurface deposits.

The recording of the actual silt depth directly on the equipment recorder rather than obtaining the depth by comparing the new depths with the original survey is particularly advantageous. It was found previously through comparison of the various equipments, that the Models NJ–8 and NK–6 would register the total depth of the silt deposit, indicating both the top and bottom. The depth of the silt was found to be as great as 100 feet in certain locations. The ability of the above equipments to measure such great depths of silt is laid to the fact that a low operating frequency of 14.25 kc is used.

A commercial model sounding equipment was used as a check on the Model NJ–8, and as a standby unit. In comparing the two equipments, it was interesting to note that the commercial unit indicated a depth of approximately one to two fathoms greater than the Model NJ–8 when readings were taken over silt deposits; however, no indication of the bottom of the silt deposit was presented. These differences in indications between the two equipments are believed to exist primarily because of the different operating frequencies employed. The operating frequency of the commercial model was 50 kc.

Core samples taken of silt deposits showed approximately the first two fathoms of the deposit to consist of silt in suspension in the water. Chain soundings were compared with commercial model and NJ–8 recordings taken at locations where core samples were obtained. These comparisons brought out the fact that the Model NJ–8 registered the top of the silt suspension, whereas the commercial unit indicated the beginning of the solid silt. Corrections for salinity and for temperature gradients of the water were made in establishing the accuracy of the soundings.

The above application of standard Navy sonar equipment to a special assignment illustrates the versatility of these units.

# ELECTRONICS CABLE TRACER

*by* George F. Masin, *Search Radar Group, Long Beach Naval Shipyard*

Occasionally the Ship Section of the Electronics Office is called upon to cope with a situation without apparent precedent, necessitating devising an equipment or developing an idea with which to solve the problem.

One such problem concerned a defective interconnecting cable supplying the high-voltage anode potentials to the Mk 13 radar forward fire control indicator scope on a cruiser. These potentials originated from a rectifier power unit developing 5000 volts, which was located in the after fire control equipment compartment. The outgoing cable conductors were fed through 500,000-ohm isolation resistors and since the insulation resistance of each conductor was in the order of 100,000 to 200,000 ohms to ground, it was obvious that approximately one-sixth of the normal potentials were available at the remote indicator.

Since this cable passed through a compartment which had been flooded, resistance checks using a bridge as a Varley loop would produce uninterpretable readings, for, as was found later, the resistance-to-ground was not concentrated in one area, but was continuously distributed throughout one hundred and fifty feet of cable.

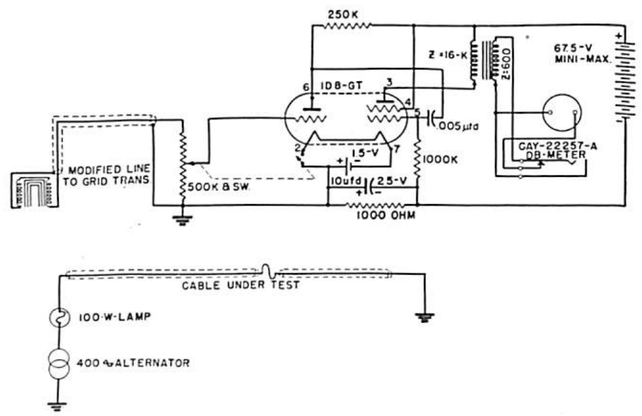
At the time this problem was presented to the Ship Section, others had attempted to physically and visibly trace this cable, with no success. In fairness to the others, it may be stated that this cable was subsequently found to contain twenty-eight *different* cable identification tags.

The problem was attacked from the standpoint of the utilization of an influence field which would emanate from this cable, be of positive identification, and which would not suffer undue attenuation throughout the cable's length.

The electrostatic field (r-f) method was tried and found unsuccessful.

The theory utilized was that of a magnetic field varying at an audible rate (i.e., 60 to 1000 cps), knowing this variable field would lend itself most readily to detection.

A pick-up device tailored from a line-to-grid transformer, modified by restacking the core laminations to produce an open end or air gap, was rapidly fashioned. A portable two-stage electronic amplifier was developed, operating entirely from a 1.5-volt flashlight cell and a 67.5-volt minimax battery, and utilizing a single 1D8GT tube. This amplifier incorporated an output meter for visual indication and an earphone jack for audible detection. To develop the influence field, the output of a Mk 22 radar 400-cycle alternator was connected to one of the conductors in the cable through a 100-watt lamp, to act as a current limiting device. The other output lead from the alternator was connected to the bulkhead securely for an effective electrical ground. The far end of the inner cable conductor was also securely grounded, thus resulting in a closed loop circuit carrying approximately 1 ampere of 400-cycle a. c.




MAGNETIC CABLE TRACER ELECTRONIC AMPLIFIER.

It was found, as had been surmised, that there was little if any attenuation of the signal with progressively increasing cable length, since the current through the cable and the resultant magnetic field was constant.

In less than an hour aboard ship, the complete cable had been traced, down through the forward director tube, through several compartments and bulkheads, to the after director tube.

It may be pointed out that identification of the cable under test was positive and rapid, even though it was located, in many cases, in a group wireway with 20 to 30 other cables. The 400-cycle tone could be picked up at from 6 inches to 1 foot from the conductor, and positive identification was accomplished through rotation of the pickup transformer to obtain minimum signal, under which condition the air gap was at right angles to the influence field.

Here was an instance of an unusual problem quickly surmounted and overcome by the Ship Section, and which resulted in the saving of time and material.





# TELETYPE REPAIR

*by* K. C. Gresowski, Lieut. (J. G.), USN, *Long Beach Naval Shipyard*

A teletype repair facility was established in this shipyard on 1 December 1946 to provide the necessary services for installation, maintenance, repair and limited overhaul on teletype equipments located at shore activities and on ships in the San Pedro area. A subsidiary activity was established in the Electronics Repair Unit at San Diego for similar services to shore activities in that area.

In September 1947 the Shipyard facility was expanded, with an increase in personnel, additional work benches and a fully equipped cleaning department. This cleaning department, developed in collaboration with the Fire Marshal, includes a spray booth, two cleaning baths and a drying oven. The procedure developed at this shipyard is as follows:

1—After disassembly the units are placed in the spray booth and sprayed with cleaning solvent which removes excessive accumulation of grease and dirt. This procedure prolongs the life of the cleansing agent used in the "Agitor" bath—the cleaning solvent is strained and reclaimed.

2—The units are next placed in an Agitor cleansing bath made up of one part Pentone Major and seven parts high grade kerosene where they remain for 45 minutes under constant agitation—this insures a thorough cleansing of all tight spots. The cleansing bath is under continuous filtering through a Fram automobile filtering element replaced by folded cheese cloth. By continuous filtering it has been found necessary to add only one gallon of Pentone Major and seven gallons of kerosene every six weeks. The bath unit is manufactured by Gary Mills, Evanston, Illinois, under trade name Agitor.

3—The next step is to place the units in a hot water bath maintained at a constant temperature of 160° F. This bath is also agitated by air pressure. The bath water is removed and the excess water blown off by air pressure.

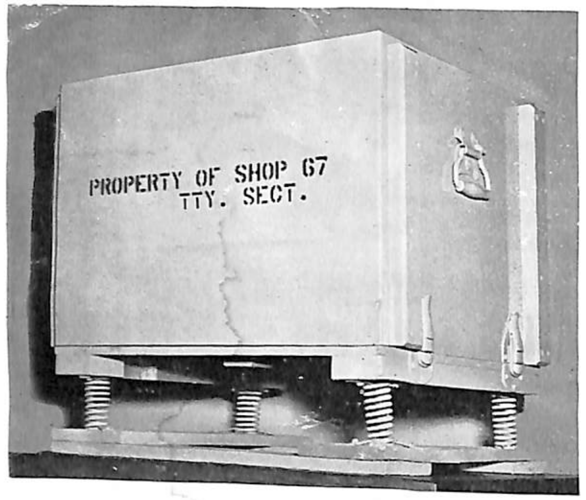
4—When all visible water has been removed, the unit is placed in an oven heated by eight infrared lamps and dried for 45 minutes at a temperature of 250° F. The unit is then placed in the spray booth and sprayed with light teletypewriter oil to prevent rust from condensation when the warm unit is removed to the work bench for reassembly and replacement of worn parts.

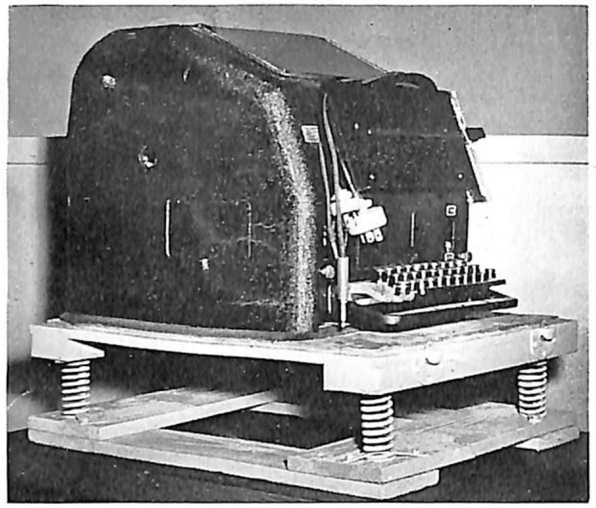
Concurrent with this expansion a scheduled major overhaul program was established for all teletype equipment installed ashore in the Eleventh Naval District. Exclusive of routine maintenance and emergency repair the capacity of the present facility for complete breakdown overhaul and reassembly is approximately 500 teletypewriters and 100 crypto machines per year.

DISASSEMBLED TELETYPE UNITS being sprayed with cleaning solvent.

The man-hours presently required are as follows:

| | |
|---|---|
| Breakdown and clean any unit | 2 man-hours |
| Overhaul, reassemble, adjust and test Mod 14 and Mod 15 TTY | 40-48 man-hours |
| Overhaul, reassemble, adjust and test Mod 19 TTY | 80-88 man-hours |



POSITION of teletype machine IN TRANSPORTING CHEST.

Overhaul, reassemble, adjust and
test Crypto[1] and components 40-48 man-hours

A routine preventive maintenance procedure and technique has been developed by the shipyard together with the most desirable features used by the Bell System repair shop in this area, and is applied to all government-owned teletypes in the District on a 10–14 day schedule. A copy of the maintenance pamphlet will be furnished any activity upon request.

By experiment it was found satisfactory and particularly economical to schedule machines recently overhauled (first sixth-month period) on a 14-day schedule and others at 10 days.

In connection with maintenance, the shipyard developed a carrying case as a protection against shock and dust which are invariably encountered when transporting teletype machines over long distances.

[1] Handled in a secured section of the shop by cleared personnel.

This was a particular problem of this shipyard as machines must be transported to activities remote from the shipyard, such as Inyokern (165 miles), Barstow (110 miles), San Diego (103 miles) and Litchfield Park (375 miles), which necessitated an extensive recheck for maladjustments, broken parts and dust.

Construction of this case is relatively simple and inexpensive. The following parts are used:

One chest, Type CH–50–B (transporting cover for TG/7B Model Teletypewriter).
Four plunger springs, Part No. 5227067, used in Model 278 Diesel Engine Spring Injector.
One rectangular wooden base, dimensions to conform with the chest base.

The assembly will be obvious from the photographs, and firm mounting of the teletype machine is amply provided by the four holding-down bolts provided in the chest.

## MODEL SR–2 T–201 TRANSFORMERS

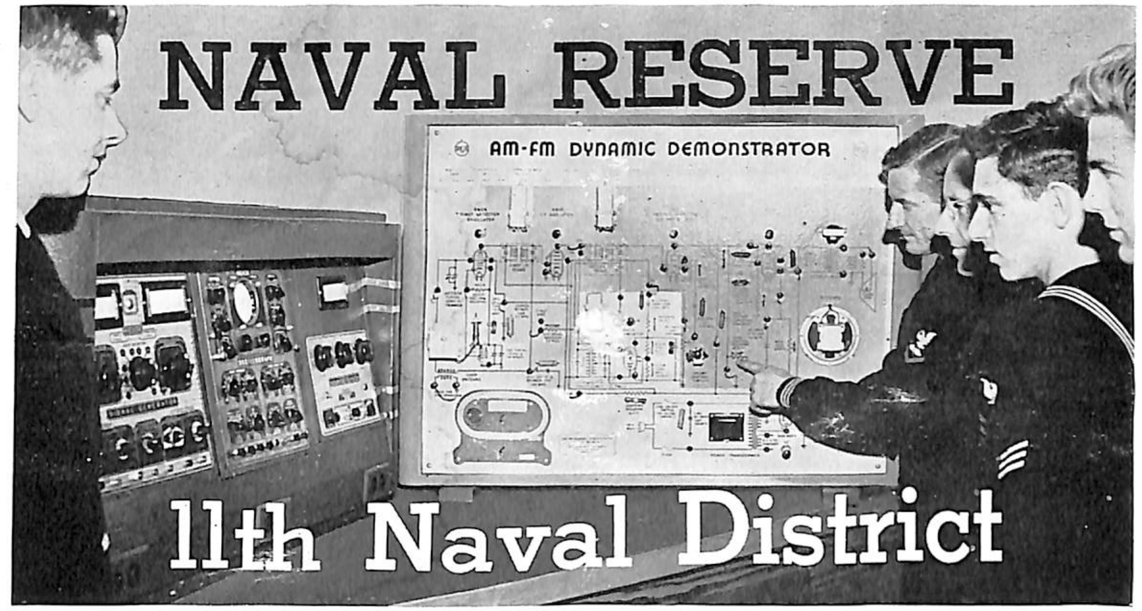
A recent Fleet Performance and Operational Report advised that transformer T–201 in the receiver unit of the Model SR–2 Radar Equipment had failed. The following excerpt is taken from this report:

"Fuse F–202A in the receiver unit failed. Transformer T–201 was found with secondary No. 3 open and secondaries Nos. 1 and 4 shorted. The transformer was swollen, apparently due to overheating. The replacement transformer from spare parts had a note stating that secondaries Nos. 2 and 3 were reversed. It is believed that the original transformer had the same reversal but had not been wired to compensate for the error. The result was that all 6.3-volt tubes were supplied with a filament voltage of 5 volts and vice versa. In addition, the 5-volt, 3-ampere secondary was overloaded 300% to 400% and probably caused the overheating and final failure of T–201. The transformer was replaced and correctly wired. The receiver then operated normally."

It is suggested that if other ships with Model SR–2 Radar Equipments encounter similar failures, the T–201 transformer filament voltages be checked for proper terminal connections.








In the summer of 1946 were heard the orders of "single up—cast off!" as the Eleventh Naval District Naval Reserve Electronics Program moved slowly from limbo and got underway for what has proven to be a long and interesting cruise.

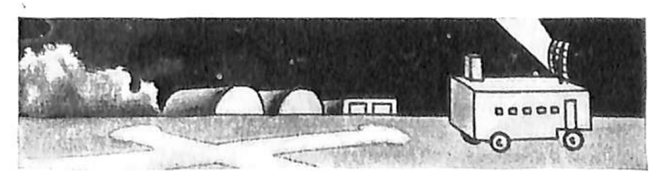
Three Naval Reserve Officers were placed on the staff of the Commandant, Eleventh Naval District, to administer to the particular needs of this phase of the new Naval Reserve. The grind of procurement of personnel and material consumed every waking (and some sleeping) moments of all three of these officers. Suffice it to say that theirs was indeed a Herculean task. The first step was the establishment of Naval Reserve Fox broadcasts. These arrangements were completed with the assistance of the District Communications Officer, and emitted from a spare transmitter at NPL, by remote control from the old receiving station at Point Loma.

In the interim, selection of sites for eighteen authorized Naval Reserve Training Centers went forward. Each site was given the benefit of an actual radio survey by the DREO, with the end result that all NRTC's are favored with better-than-average radio locations.

Seven complete installations have thus far been made, and two additional ones are in progress. Complementing these training centers are twelve Electronics Warfare Companies and fifty-two Electronics Warfare Stations which have been established. In addition, the District boasts of the possession of one DD, two DE's, two LCI(L)'s and two SS's which are in constant use by the Naval Reserve in underway training.

Planning for all but one training center has been accomplished by Naval Reservists. The entire procurement program has been directly in the hands of the Assistant Electronics Officer for Naval Reserve, and his staff, consisting of one Reserve Chief Radio Electrician and one Reserve enlisted yeoman. All M&P's, work order requests and other usual paper details have been handled "by the Reserve, for the Reserve." With the guiding hand of experienced planners, shop design and shop superintendents and their staffs, the Reserve has designed special racks, tables, pole struts, antenna mounts, communication consoles and a special platform-mounting for gyro compasses, and the various shops have fabricated same, in addition to having reconditioned many items of electronic gear. All in all, it might well be said that every shop in the Long Beach Naval Shipyard has contributed its full share of support and interest in the realization of the completion of the Eleventh Naval District Reserve Electronics Program.


| Type of Approach | Last Month | To Date |
|---|---|---|
| Practice Landings | 10,238 | 202,966 |
| Landings Under Instrument Conditions | 373 | 8,896 |



# SOME FORMULAS for Calculating the Ranges of Radar Sets

*by* E. V. PERRY, JR., *Search Radar Design Section, Bureau of Ships*

## Introduction

A collection of formulas for calculating the range of radar sets is contained in this article. Radar is by now such an essential part of a modern Navy that the basic formulas for calculating radar ranges are reasonably well-known. Less familiar to most personnel, however, are the methods for calculating these ranges for radars with complex scans. Less familiar to most personnel, too, are the methods for computing radar ranges when variables other than those presented in the commonly-presented radar formulas must be considered. Consequently, there is need for empirical information of this type, and for the formulas presented in this article. No implication is intended that this group of formulas is all-inclusive, but it is felt that they may be of value to those who may have to calculate radar ranges, or to those who may desire to find the effect on radar range of varying certain of the parameters.

## List of Symbols Used in the Formulas

$\beta$ = I-F bandwidth of receiver in cycles per second

F = Repetition rate in pulses per second.

f = Transmitter frequency in megacycles per second.

$G_r$ = Gain of receiving antenna, expressed as a power ratio, relative to the radiation reception characteristics of an isotropic receiving antenna (one which receives equally well in all directions).

$G_t$ = Gain of the transmitting antenna, expressed as a power ratio, relative to an isotropic radiator.

G = Gain of the antenna expressed as a power ratio, relative to the gain of an isotropic antenna, when the same antenna is used for transmitting and receiving.

$\lambda = \frac{300}{f}$ = Transmitting wavelength in meters.

h = Height of antenna above the sea in meters.

K = Boltzmann's constant, with a numerical value of $1.37 \times 10^{-23}$ watt-seconds per degree Kelvin.

$L_{TR}$ = Power loss, expressed as a ratio, due to TR and pre-TR tubes.

$L_{wg}$ = Twice the product of the power loss per foot of waveguide expressed as a ratio, and the length of waveguide used.

$L_C$ = Indicator collapsing loss.

$L_{s\tau}$ = Loss due to product of sweep speed and pulse length not being optimum.

$L_I$ = Loss due to closing (incoming) target.

$L_s$ = Scanning loss.

$\overline{NF}$ = Noise factor of the receiver power expressed as a ratio.

$N_{H8}$ = Number of hits on the target made by the radar beam in eight seconds.

$N_{P8}$ = Number of transmitter pulses in eight seconds.

$O_k$ = Operator constant, with an approximate value for the average operator of 2.5, when expressed as a ratio, and 4 db, when expressed in decibel units.

$P_F$ = A factor in the expression for the minimum detectable signal which indicates the effect of varying the repetition rate.

$P_{\tau\beta}$ = A factor in the expression for the minimum detectable signal which indicates the effect of varying the product $\tau\beta$ from its optimum value.

$P_t$ = Peak power transmitted during each pulse.

$RPM_H$ = Azimuth rotation rate of the antenna in revolutions per minute.

$R_{max}$ = Maximum reliable radar range in meters.

S = Indicator sweep speed in seconds per millimeter.

$S_{min}$ = Minimum detectable signal in watts of power.

$SPM_v$ = Vertical antenna scanning rate in scans per minute.

$\sigma$ = Effective cross-section of target to radar set in square meters.

$\Theta$ = Target elevation from ship in degrees above horizontal plane.

$\Theta_H$ = Horizontal beamwidth in degrees.

$\Theta_v$ = Vertical beamwidth in degrees.

T = Temperature of 300° Kelvin.

$T_R$ = Time in seconds between completion of one azimuth sector scan and start of the next sector scan.

$T_S$ = Time in seconds required to scan a complete azimuth sector.

$T_v$ = Fraction of vertical scan actually used (a portion of the scan is lost because the antenna is returning to the point where it will begin the next scan; this fraction is the remainder).

$\tau$ = Pulse length in seconds = pulse length in microseconds x $10^{-6}$.

V = Vertical angle scanned in degrees.

## Basic Formulas

The basic formulas for computing the range of radar sets and containing the more important of the design parameters of the equipments are as follows:

1—For a searchlighting radar with an A-scope presentation:

$$R_{max} = \left[\frac{4.84\, P_t \tau^2 \beta G_t G_r \sigma \lambda^2}{(4\pi)^3 (\overline{NF}) KT(\tau\beta+1)^2} \cdot \left(\frac{F}{50}\right)^{1/2}\right]^{1/4} \text{meters.}$$

2—For a searchlighting radar with a PPI-scope presentation:

$$R_{max} = \left[\frac{4.84\, P_t \tau^2 \beta G_t G_r \sigma \lambda^2}{(4\pi)^3 (\overline{NF}) KT(\tau\beta+1)^2} \cdot \left(\frac{F}{12.5}\right)^{1/2}\right]^{1/4} \text{meters.}$$

These formulas do not include the effects of the "operator factor" ($O_k$), the power loss in the waveguide ($L_{wg}$), the power loss in the duplexer system (TR and pre-TR losses, $L_{TR}$), or the effect of departure from the optimum value of the product of the sweep speed and the pulse width on the oscilloscope used ($L_{s\tau}$).

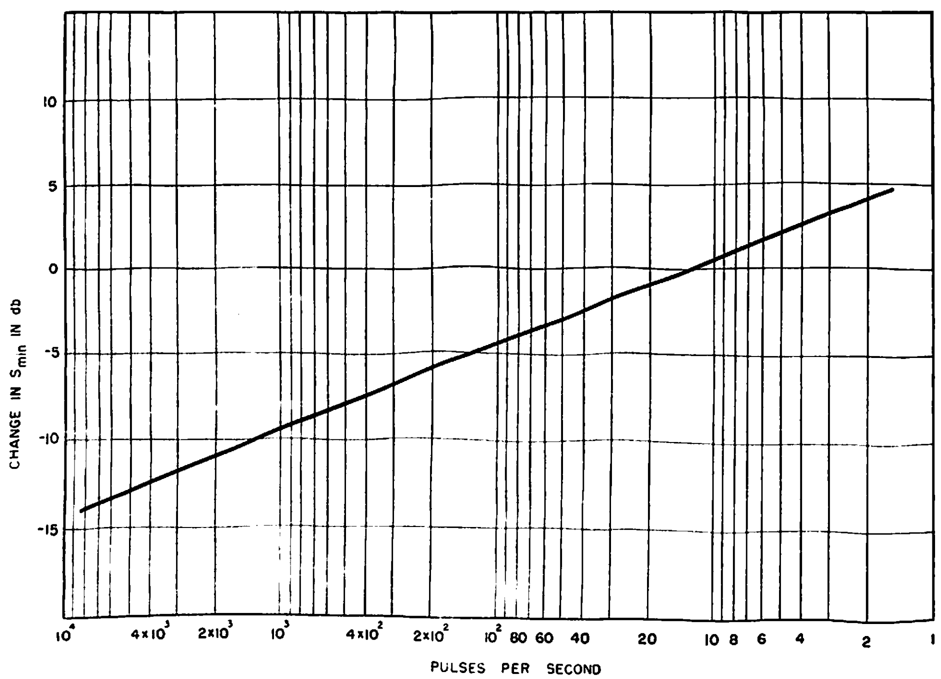



FIGURE 1—*Effect of pulse repetition frequency F on the minimum detectable signal $S_{min}$ (from figure 20 of U. S. Naval Research Laboratory Report R-3007).*

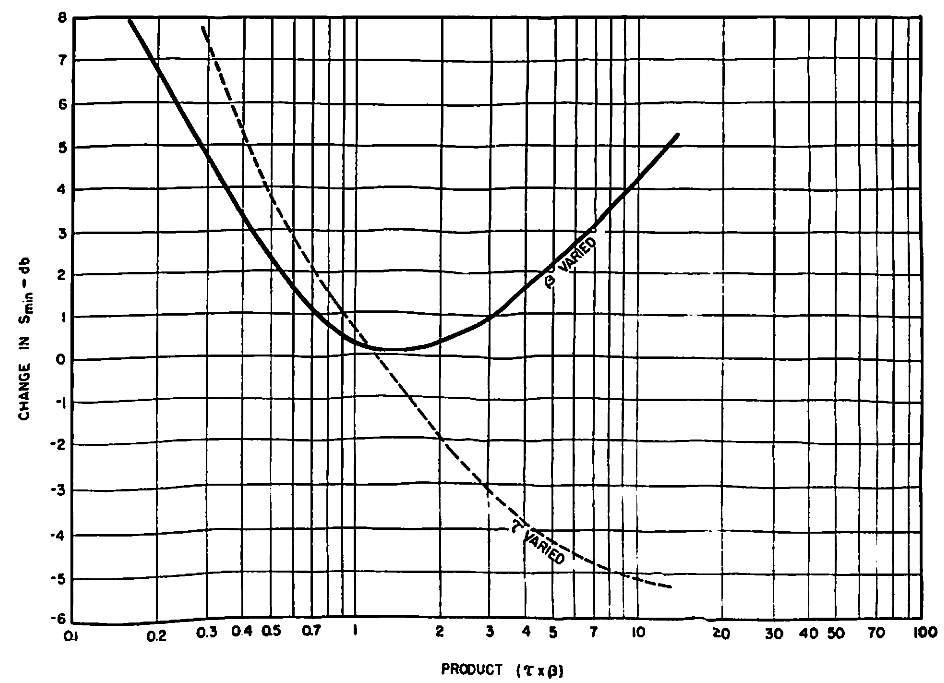



FIGURE 2—*Effect of variation of either the pulse length τ or the I-F bandwidth β on the minimum detectable signal $S_{min}$, with the other of these two (β, τ) maintained constant.*

## Radar Range Calculations Incorporating Experimental Data

There is another form of the basic radar equation which we shall use in conjunction with certain auxiliary formulas and experimental data to permit us to compute ranges for certain types of scanning radars, using a PPI presentation. This form of the equation, which is for installations in which the same antenna is used for both transmitting and receiving, is as follows:

3— $$R_{max} = \left[\frac{P_t G^2 \sigma \lambda^2}{(4\pi)^3 S_{min}}\right]^{1/4} \text{ meters.}$$

The minimum detectable signal $S_{min}$ may be expressed in terms of a number of other factors:

4— $$S_{min} = KT\beta(\overline{NF}) P_F P_{\tau\beta} O_k L_{wg} L_{TR} L_c L_{ST} L_I L_s$$

The factor in minimum detectable signal which depends on the pulse repetition rate, $P_F$ may be obtained from the graph in figure 1.

If either $\tau$ or $\beta$ is varied this variation will cause a change in the minimum detectable signal $P_{\tau\beta}$. Figure 2 displays the approximate effect on $S_{min}$ for deviation of either $\tau$ or $\beta$ when the other is maintained constant.

The operator factor results from the fact that the operator is human and will not peform at 100% efficiency, thus lowering the value of the minimum detectable signal still further. Tests have shown that the operator factor $O_k$ may be taken as 4 db for the average experienced operator.

The waveguide in the radar set has a finite though small resistance, and it is necessary to include the factor from this cause, $L_{wg}$. This quantity is twice the power loss ratio per foot of waveguide times the length of waveguide involved. There are, of course, additional losses in the TR and pre-TR tubes in the duplexer. The loss from these latter causes is lumped into the quantity $L_{TR}$ and usually is approximately 1 db.

Any presentation of radar information which superimposes sweeps containing no signal on sweeps containing an echo will cause this "extra noise" to be integrated with the echo, resulting in a loss of signal visibility. In a scanning radar, for example, if the beam sweeps vertically we will receive no signal where the beam does not intercept a target, but will be receiving noise all the time. When the beam sweeps across a target, we will receive both an echo signal and noise. Since PPI sweeps at any azimuth contain all the vertical sweeps, the "extra noise" will tend to mask the signal by lowering the signal-to-noise ratio. Such a loss of signal visibility may be termed the "indicator collapsing loss," $L_c$. This may be estimated with the aid of figure 3(a). A formula which may be used for calculating the collapsing loss of a vertically-scanning radar with a PPI presentation is:

5— $$L_c = \sqrt{\frac{V}{\Theta_v}} = 10 \log_{10} \sqrt{\frac{V}{\Theta_v}} \text{ db.}$$

Variation of the pulse length on a PPI screen will vary the minimum detectable signal, producing a loss $L_{ST}$. It has been determined by test that optimum discernibility is achieved when the product of the sweep speed S in millimeters per microsecond and the pulse width $\tau$ in microseconds is approximately 0.8 mm. Deviations from the optimum will vary the minimum detectable signal according to figure 4.

If a target is close enough to the radar so that it has previously been detected, then that target has "recognition value" for us at the time, and, as it moves out from the location of the radar, we can still identify and detect it when the echo is weak because it is known to us. For a target coming in, the target has to get close enough that the echo signal will become strong enough to force its attention on us and by its prominence indicate without question that it is from a new target and is not just noise. The range at which we can still detect and identify a retreating target is greater than the range at which an incoming target is first recognized as such. We may express this effect on the minimum detectable signal when the target is coming in on the radar as $L_I$. It depends on the percentage of the total oscilloscope face watched, and on the azimuth scan rate. The curves in figure 5 approximate the loss from each of these factors; the total loss $L_I$ in db is the sum of the effects of these two factors.

As the great majority of modern equipments scan in azimuth, in elevation, or in both, we have a loss due to the fact that we only get echo pulses when the beam sweeps across some sort of reflecting target. A portion of the output energy is lost when no reflection occurs. This loss is the "scanning loss," $L_s$. It may be calculated by using the following formula, which holds fairly well down to a minimum of approximately five hits in eight seconds (eight seconds is the average time in which the eye and the scope integrate in such a manner that the eye cannot distinguish the particular way in which the echo pulses were received):

6— $$\text{Scanning loss} = \sqrt{\frac{N_{PS}}{N_{HS}}} \text{ or } 10 \log_{10} \sqrt{\frac{N_{PS}}{N_{HS}}} \text{ db.}$$

The number of hits in eight seconds for a radar scanning both in azimuth and in elevation is given in the formulas below which are derived in the Appendix:

7—(Continuous scan)

$$N_{HS} = \frac{FT_v\Theta_v\Theta_H}{60V(RPM_H)} \cdot \left(\frac{RPM_H}{.5} + 1\right)$$

8—(Sector scan) $$N_{HS} = \frac{FT_v\Theta_v\Theta_H}{7.5V(RPM_H)(T_s + T_R)}$$

Figure 3 may be used to aid in calculating the scanning loss.

## Additional Factors Influencing Radar Ranges

Oxygen and water vapor will absorb r-f energy and will decrease the range of radar sets when the transmitter frequency is high enough. Although the curves in figure 7 do not show us directly how to compute the loss from this attenuation, they do show us the frequencies at which it must be reckoned with, and show us its frequency dependence.

If the beam is searchlighting with its nose on the horizon, there will be reflection from the ocean. The approximate effective range in case of such reflection may be obtained from the relation:

9— $R_{max}$ with reflection =

$$(R_{max} \text{ without reflection}) \left(2 \sin \frac{2\pi h \sin \Theta}{\lambda}\right)$$

## Calculating Radar Range by Extrapolation from Radars of Known Characteristics

It is possible to estimate the effects of varying any parameter, thereby permitting extrapolation from the existing radars of similar characteristics. Those parameters which enter into the basic formulas to the ¼-power are "one-way losses," influencing either the transmitting or receiving system. Those entering in to the ½-power are "two-way losses," influencing both the transmitting

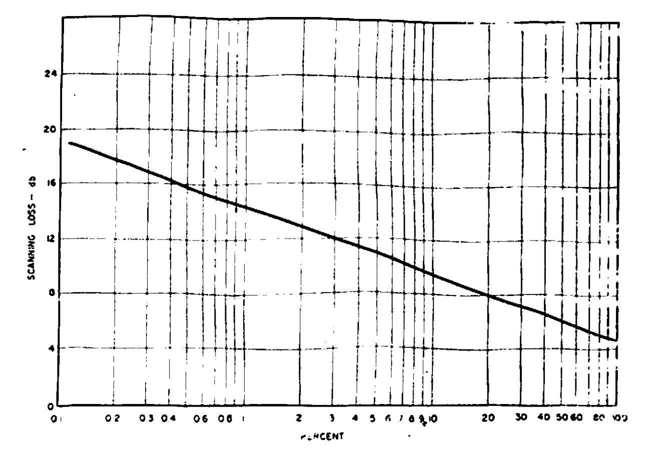



FIGURE 3—*The scanning loss in db as a function of the number of hits in eight seconds $N_{PS}$ (expressed as a percentage of the repetition rate F in pulses per second $\left(\frac{N_{HS}}{F} \times 100\right)$).*

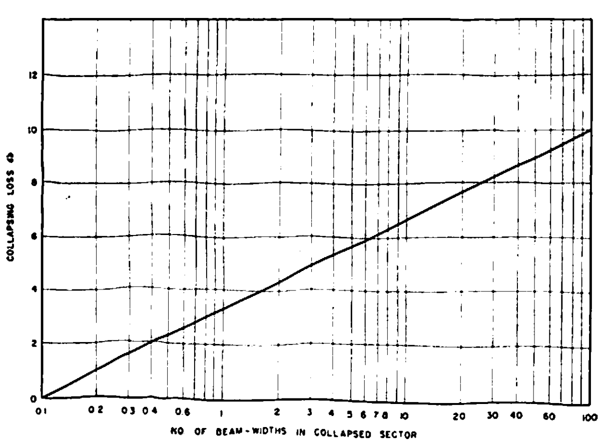



FIGURE 3(a)—*The indicator collapsing loss in db as a function of the number of beam-widths in the collapsed sector.*

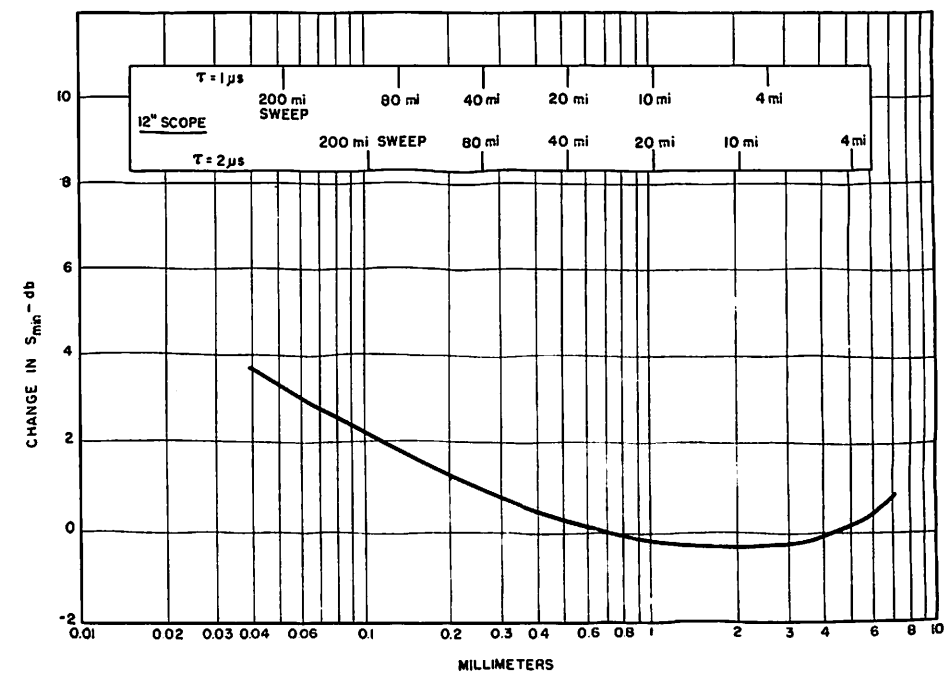



FIGURE 4—*Effect on the minimum detectable signal $S_{min}$ of variation of the pulse length on the PPI screen in millimeters (from figure 12 of U. S. Naval Research Laboratory Report R-3007).*

and receiving systems. If the necessary test information is available, the method of extrapolating is the most accurate means of computing radar performance. Certain parameters are independent, and the effect on the range of their variation can be determined from figure 6. These parameters are:

1—The peak power $P_t$, which is a one-way loss.

2—The waveguide loss $L_{wg}$, which is a two-way loss.

3—The TR-loss $L_{TR}$, which is a one-way loss.

4—The receiver noise $\overline{NF}$, which is a one-way loss.

5—The target echoing area $\sigma$, which is a one-way loss. The target echoing areas for some common aircraft are:

| *Target* | *$\sigma$ (square meters)* | *Variation (db)* |
|---|---|---|
| B17 | 75 | 5.7 |
| PBY | 50 | 4.0 |
| SNB | 20 | 0.0 |
| F8F | 8 | –4.0 |
| P81 | 4 | –7.0 |

If any of the remaining parameters ($\lambda$, G, $\beta$, $\tau$, F) are varied, correction will be required on the other parameters as listed below:

1—Wavelength $\lambda$.

a—Wavelength variation effect is shown in figure 6, and is a two-way loss.

b—Antenna gain variation, a two-way loss, see figure 6.

c—Number of hits (formulas 6, 7, and 8), resulting in a change in $S_{min}$ (one-way loss, see figure 6).

2—Antenna gain G.

a—Antenna gain variation from figure 6, a two-way loss.

b—Number of hits (formulas 6, 7, and 8), and resulting effect on $S_{min}$ (one-way loss, see figure 6).

3—I-F bandwidth $\beta$.

a—I-F bandwidth, see figure 2 for change in $L_{\tau\beta}$.

b—Change in $10 \log_{10} (\beta \pm \Delta\beta)/\beta$ and resulting effect on $S_{min}$ of the change in $L_{\tau\beta}$ and of this change (see figure 6, one-way loss).

4—Pulse width $\tau$.

a—Pulse width variation, see figure 2 for change in $L_{\tau\beta}$.

b—Pulse length on PPI screen ($S \times \tau$), see figure 4.

5—Pulse repetition rate F.

a—Pulse repetition rate, see figure 1.

b—Number of hits (formulas 6, 7, and 8) and resulting effect on $S_{min}$ (see figure 6, one-way loss).

## Appendix—Derivation of Formula for Scanning Loss

The number of hits is considered to be the number of pulses transmitted while the target is on or between the 3 db points of the radar beam.

10—Hits per vertical scan $= F \dfrac{\Theta_v}{V} . T_v . \dfrac{60}{SPM_v}$

11—Fraction of azimuth beamwidth moved per vertical scan. (This should never be more than one or coverage is incomplete)

$$= \frac{360\ (RPM_H)}{\Theta_H\,(SPM_v)}$$

12—Hits per frame = area bounded by $\Theta_H$ and V = Formula 10 divided by formula 11 =

$$\frac{60\ F\Theta_v T_v}{V(SPM_v)} \cdot \frac{\Theta_H\,(SPM_v)}{360\ (RPM_H)} = \frac{FT_v\Theta_v\Theta_H}{60V\,(RPM_H)}$$

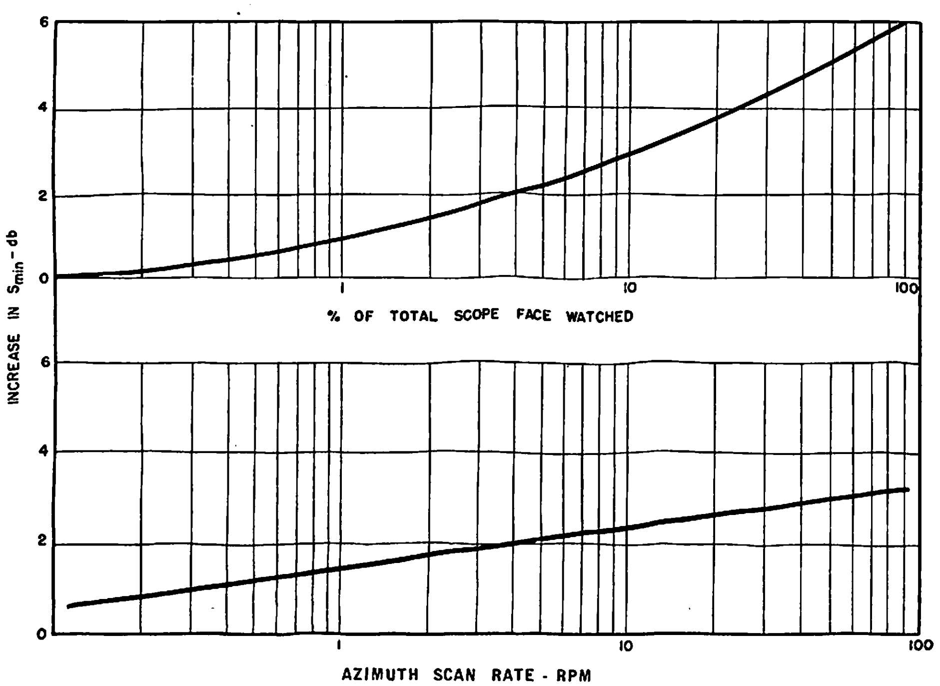



FIGURE 5—*Effect on the minimum detectable signal $S_{min}$ of the percentage of the total oscilloscope face watched and the azimuth scan rate in revolutions per minute (from figures 8 and 9 of U. S. Naval Research Laboratory Report R-3007).*

13—Number of frames in eight seconds for continuous scanning =

$$\frac{RPM_H}{7.5} + 1$$

14—Number of frames in eight seconds for sector scanning =

$$\frac{8}{T_S + T_R}$$

7—Number of hits in eight seconds for continuous scanning = Formula 12 multiplied by formula 13 =

$$N_{HS} = \frac{FT_v\Theta_v\Theta_H}{60V\,(RPM_H)} \cdot \left(\frac{RPM_H}{7.5} + 1\right)$$

8—Number of hits in eight seconds for sector scanning = Formula 12 multiplied by formula 14 =

$$N_{HS} = \frac{FT_v\Theta_v\Theta_H}{7.5V\,(RPM_H)\,(T_S + T_R)}$$

## Sample Calculations

The following sample calculations are for the height finding system of the SX radar. The calculated $R_{max}$ of 46.5 miles, scanning, compares favorably with the reports from the fleet on the SX, although it is somewhat optimistic as no factor is included for system performance being less than peak.

I. Searchlighting range on PPI ($S_\tau$ = .8mm.)—Formulas 3 and 4.

| | | |
|---|---|---|
| $P_t$ | $= .6 \times 10^6$ watts | $= 10^{5.78}$ |
| G | = 37 db | $= 10^{7.40}$ |
| $\sigma$ | = 10 square meters | $= 10^{1.0}$ |
| $\lambda$ | = 0.085 meters = $10^{-2} \times 10^{0.93}$ squared | $= 10^{-4.0}$ |
| | | $10^{1.86}$ |
| $(4\pi)^3$ | $= 10^{3.3}$, inverted | $= 10^{-3.3}$ |
| $KT\beta$ | $= (1.37 \times 10^{-23})\ (300)\ (1.2 \times 10^6)$ | |
| | $= 4.9 \times 10^{-15}$ watts, | |
| | $= 10^{-15} \times 10^{0.69}$, inverted | $= 10^{15.0}$ |
| | | $10^{-0.69}$ |
| $\overline{NF}$ | = 12 db, inverted | $= 10^{-1.2}$ |
| $P_F$ | = 1170 pps = —10 db, inverted | $= 10^{1.0}$ |
| $O_k$ | = 4 db, inverted | $= 10^{-0.4}$ |
| $P_{\tau\beta}$ | = 1.2 (Optimum) | $= 10^{0.0}$ |
| $L_{wg}$ | = 1 db × 2, inverted | $= 10^{-0.2}$ |
| $L_{TR}$ | = 1 db | $= 10^{-0.1}$ |
| | | $4)\,10^{32.04} \times 10^{-9.89} = 10^{22.15}$ |
| | | $10^{5.54}$ |

$$10^{5.54} = 345{,}000 \text{ meters} = 188 \text{ miles} \left(\frac{\text{meters}}{1828} = \text{miles}\right)$$

II. Scanning loss (4 rpm, 10 scans/sec vertically) —Formula 6

Hits/vert scan $= 1170 \times \dfrac{1.1}{11} \times 0.89 \times 0.10$

= 10.4—Formula 10

Azimuth beamwidth moved/vert scan $= \dfrac{360 \times 4}{3.5 \times 600}$

= 0.68—Formula 11

Hits/frame $= \dfrac{10.4}{0.68} = 15.3$—Formula 12

No. of frames in 8 sec $= \dfrac{4}{7.5} + 1 = 1.53$

—Formula 13

No. of hits in 8 sec = 15.3 × 1.53 = 23.4

—Formula 13

Scanning loss = 13.6 db—Figure 3

(for $\dfrac{23.4}{1170} \times 100 = 2\%$) = 46% of range

—Figure 6

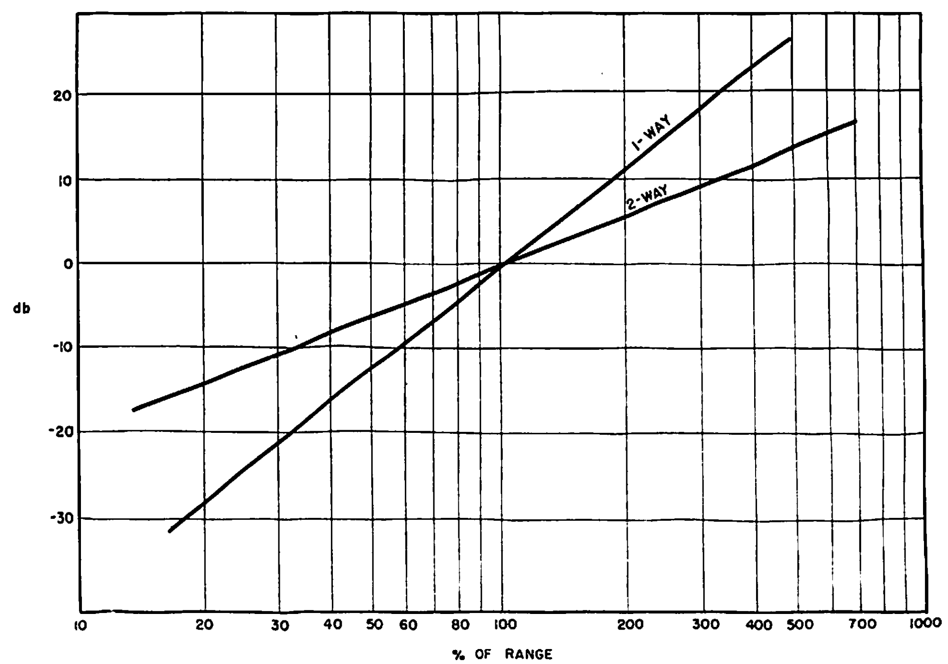



FIGURE 6—*Effect on the maximum range of losses or gains in one-way factors (entering into the basic formula to the one-fourth power) and of two-way factors (entering to the one-half power).*

$R_{max}$ scanning $= 188 \times 0.46 = 86.5$ miles

III. Indicator Collapsing Loss—Formula 5

$$L_c = 10 \log_{10} \sqrt{\frac{11}{1.1}} = 10 \log_{10} 3.16 = 5 \text{ db}$$

From figure 6 (one-way loss) 5 db = 75% of range

$R_{max} = 86.5 \times 0.75 = 65$ miles

IV. Presentation loss (7″ scope 50-mile range)—Figure 4

$$\tau \times S = 1 \times 10 \times \frac{0.3 \times 25.4}{50 \times 12.2 \times 10} O = .124$$

$= 1.1$ db $= 95\%$ of range

$R_{max} = 65 \times 0.95 = 62$ miles

V. Loss due to a closing target—Figure 5

$= 5$ db $= 75\%$ of range

$62 \times 0.75 = 46.5$ miles

NOTE: Information is gathered from the following sources:

N.R.L. Report R–3007
Dr. R. M. Ashby—N.R.L. Field Station, Boston
Mr. L. V. Blake—N.R.L.
Mr. R. S. Sargent—BuAer

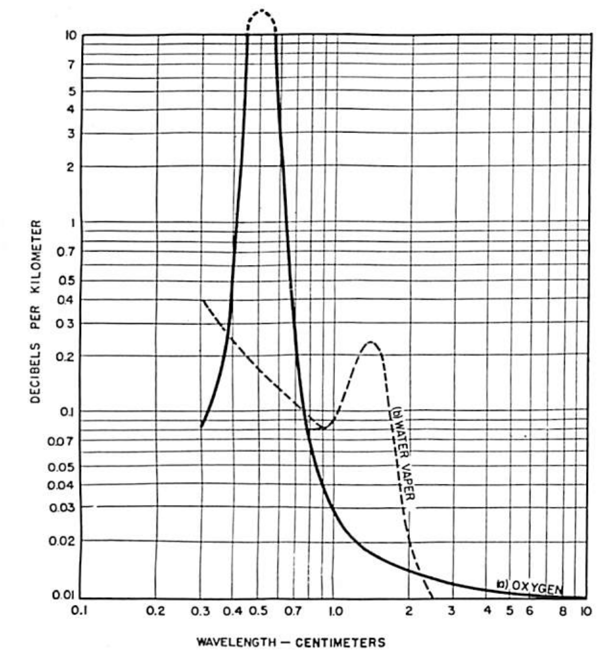



FIGURE 7—*Power attenuation in decibels per kilometer of an r-f signal transmitted through the atmosphere (one-fifth by weight of oxygen at 76 mm. Hg pressure, and containing 10 grams of water vapor per cubic meter). From Volume I of the M.I.T. Laboratory Series.*


Distribution of BuShips ELECTRON is not limited to Naval activities alone. Many copies of the magazine go each month to Marine Corps, Coast Guard, and Naval Reserve activities as well.

It is Bureau policy to deliver this magazine to as many activities within those services as we can.

Distribution lists must be kept current, however; they must be altered from month to month as activities come and go and as requests are received.

Requests from regular Navy activities are screened and acted upon by the Bureau. Requests from Marine Corps, Coast Guard, and Naval Reserve activities are screened by key agencies within the respective services. These agencies keep their own distribution lists. They are shipped bulk quantities of ELECTRON and in turn distribute copies to individual activities.

Copies of the magazine intended for Naval Reserve activities are shipped to the Commandant of each Naval District, marked Attention, District Reserve Electronics Warfare Training Officer. Each Reserve command in turn distributes to individual activities within its own district.

Copies consigned to Marine Corps activities are sent to the Depot Quartermaster (Stationery), U.S. Marine Corps, 734 Schuylkill Avenue, Philadelphia, Pennsylvania. All requests from Marine Corps activities should be sent to that address.

Coast Guard activities are served by the Coast Guard District Headquarters. Individual Coast Guard ships and stations should address correspondence concerning distribution to the District Coast Guard Officer within their own district.

Experience has shown that this is the best way to handle this phase of the distribution of ELECTRON. By doing so we are actually cutting red tape, not adding it, so that in the end all activities are more effectively served.





# THE REPLACEABLE SUBASSEMBLY AND ITS EFFECT ON NAVAL ELECTRONICS

*by* FRANK S. QUINN, JR., LIEUT. COMDR., USN,
*Systems Branch Head, Electronics Design Division,*
*Bureau of Ships*

Twenty-five years ago the electronic equipment aboard a combat vessel, though bulky and inefficient by present standards, was small in quantity and the problem of where to put it was minor. So great has been the growth, in number and complexity, of the electronic instruments now considered necessary for the prosecution of Naval warfare that today there are those who are seriously proposing that a new type ship be created. The primary mission of this proposed type would be to carry electronic equipment and engage in "electronic warfare."

Faced by the problem of how to get the necessary electronic equipment aboard ships and combat vehicles, many have turned to "miniaturizations" as a possible answer. The *size* of electronic equipment has constantly become smaller over the years—the electronic portion of the radio in your living room is a midget beside a comparable receiver of twenty-five years ago.. Research and development with the specific end of making electronic assemblies as small as possible has produced some remarkable results. The use of printed circuitry and other techniques has made possible the proximity fuse, a complete transmitter and receiver in the nose of a five-inch shell. The two-way wrist radio used by Dick Tracy, of comic strip fame, is but one step beyond today's achievements and perhaps will become a reality tomorrow.

The prospect of making electronic equipments smaller and thereby making it possible to place the needed instruments aboard our ships, aircraft, and tanks, and at the same time saving important quantities of critical materials, has fired our imaginations and brought forth "miniaturization programs." But let us be wary. The miniaturization programs to date consist of a catalogue of commercially available small parts; research and development programs investigating printed circuitry, assembly techniques, etc.; the use of commercially available small components by design engineers where these hold some promise of meeting service requirements; the development of a very few miniature equipments and subassemblies. In truth, there is an awareness among engineers of the advantages to be gained by reducing size and an effort to realize these advantages, but there is no true program. By such means we can eventually get the small equipment we need, after a sufficient number of years have elapsed for this evolutionary process to produce its effect. However, to continue in this way offers little hope of solving our immediate problems and loses some of the greatest advantages to be gained from the present trends in the electronics art.

There are two other things that it would be most desirable to do to our electronic equipment at the same time that we make it smaller and lighter: first, reduce the number of repair parts which must be stocked for maintenance purposes and second, make the equipment easier to maintain. As you probably know, it used to be the custom to allow a manufacturer making equipment for the Navy to use components of any shape, size and color that pleased him so long as the equipment was serviceable and did the job for which designed. This played hob with supply. When the last war ended the Navy was procuring and stocking some three-quarters of a million different electronic items, and electronic spare parts boxes were so numerous aboard ship that their proper storage was a real problem.

We are greatly reducing the number of items which it is necessary to stock for maintenance purposes by requiring that electrically similar components have the same physical dimensions so that they may be used interchangeably, and the supply system has been remodeled to meet the problem of the spare parts boxes. This program, however, is at present being applied only to normal-sized components. If we don't get started pretty soon on the little ones, we are going to find ourselves in the same situation with them that obtained for those of normal size at the end of the war.

It is not necessary to dwell on the need for simplifying maintenance. It is a matter of common knowledge that it takes two or three years to train a man to be a competent maintenance man for one or two equipments

—and then he does not reenlist. It takes thorough training and more years of experience to produce general purpose maintenance men who can service most of the electronic equipment aboard a ship.

There is a development in the electronics art, closely connected with the effort to make equipment even smaller and lighter, that holds promise of alleviating both of these conditions. This is the concept of "subassemblies." As anyone who has studied electronics at all is aware, for the purposes of study and analysis the circuit of any but the simplest equipment is broken down into subcircuits and these are studied individually. For example, a conventional superheterodyne receiver circuit may be broken down into a radio-frequency section, a first detector or mixer, intermediate-frequency section, a second detector, and an audio-frequency section. As the engineers made equipments smaller and smaller, the point was reached where the size was so small and the wiring so involved that the skill of a watchmaker was required to work on them. To simplify the job, they began building the subcircuits as units and then connecting them together to form the complete equipment. They called these units "subassemblies." In some cases they embedded the whole subassembly in plastic to protect the small parts and intricate wiring and attached a plug so that the whole subassembly could be plugged in like a tube. In other cases the subassembly was enclosed in a box, or left open on an individual chassis which could be connected or disconnected at will. These are "packaged subassemblies." We thus arrive at a definition of a packaged subassembly as a portion of a complete circuit which is constructed, and may be replaced, as a unit. Such packaged subassemblies may also be procured, stocked and issued as units.

Now it is clear that if we break the circuit of a radio receiver into five subcircuits and construct each of these as a packaged subassembly, then (aside from such accessories as antenna, speaker and power supply), the receiver has but five major, replaceable components. The power supply might easily be another packaged subassembly. Moreover, whereas it takes a skilled technician to locate and replace a defective capacitor or resistor in a conventional receiver, the average housewife could replace packaged subassemblies in such a receiver until it worked again. She does something comparable every Christmas when she finds and replaces the bulb that has burnt out in the string of lights on the Christmas tree.

At about this point the reader must be asking how I propose to achieve these wonderful results. Let us return to our radio receiver. There are many like it in use in the Navy. They differ in output powers and fidelity of audio-reproduction, and they cover different bands of radio frequencies, but they all have the same five subcircuits which may be built as five packaged subassemblies. Moreover, each subassembly may be completely described electrically by a limited number of parameters. For an audio amplifier these would be input impedance, output impedance, upper and lower half-power frequencies, required driving signal level, gain and power output.

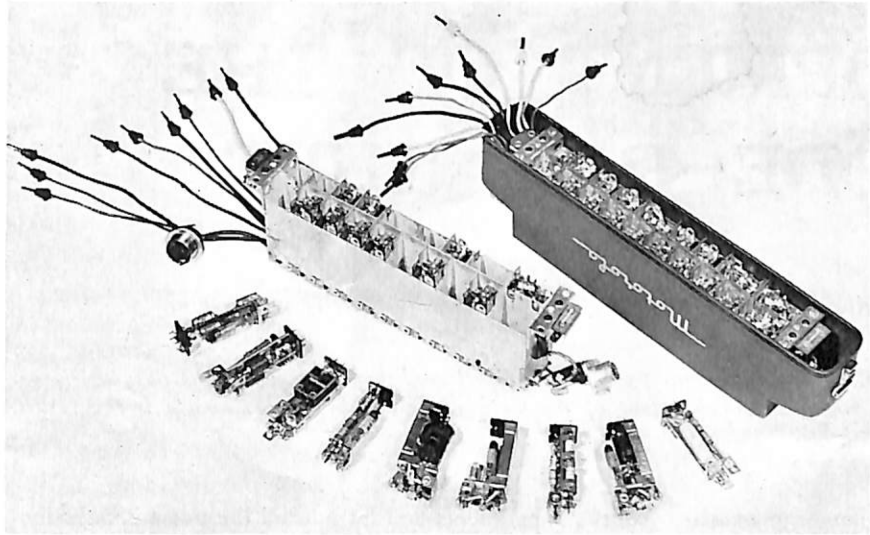
If we formulate a set of parameters for each of the five subcircuits, we may then describe any superheterodyne receiver in terms of these parameters. If we were to collect such descriptions of all the receivers of this type in use in the Navy and analyze them, we would

One of the many operating positions possible with the Motorola FM HANDIE-TALKIE UNIT.

find that, in spite of the differences in the detailed circuitry, the parametric descriptions of any one subcircuit would fall into a comparatively small number of groups within which the differences would be small. It is then possible to build a packaged subassembly, making it as small as available techniques will permit, which will be representative of the subcircuits in any particular group. If the analysis and design are properly carried out, this representative subassembly will be







EXPLODED VIEW of the standard Motorola FM HANDIE-TALKIE UNIT.

capable of performing all the electrical functions required of any number of the group which it represents.

In designing our subassemblies we should also do some standardizing on physical shape and size. We might require, for example, that all audio amplifiers for communications use be capable of fitting into a rectangular solid two by three by six inches and be fitted with a standard plug at one end. They would then all be physically interchangeable. Such standardization should be carried out for each class of subassembly, with due regard to desired physical configuration of the completed equipment and recognizing that it may be desirable to have more than one standard shape and size for a particular class.

There are those who will object that such standardization would freeze the design of electronic equipments and prevent progress in the future. This is not true. It would still be possible to design better and smaller audio amplifiers within the size limits established as standard, and as further advances justified it, standard sizes could be modified, new subassemblies introduced and new groupings developed to perform new functions or to perform old functions better.

The advantages to be gained from such a program are tremendous:

1—Electronic equipment would be made as small and light as possible utilizing presently known techniques. This would go far toward solving the problem of how to get the necessary instruments and weapons aboard our ships and aircraft.

2—The multiplicity of components at present necessary for maintenance would largely be replaced by a comparatively few standardized subassemblies. In many cases these could be manufactured at so little cost that it would be economically preferable to discard them when they became defective. They could be procured, stocked and distributed in the same manner that tubes are now handled.

3—Shipboard maintenance of electronic equipment would be greatly simplified. Much of the present difficult and time-consuming trouble shooting would be accomplished by simply replacing subassemblies until the defective one was found. These defective subassemblies could be either discarded, or in the case of subassemblies the cost of which justified repair, turned in to a shipyard or a central repair depot. At a central repair depot the numbers of assemblies to be repaired would justify specialized test equipment, permanent test setups and specialization of personnel. One man might well work on only one type subassembly, and whereas it takes years to train a man to service complete equipments, he could be trained to service one or two type subassemblies in a matter of months. This would be a tremendous advantage in time of war or national emergency when it becomes necessary to expand the armed forces greatly. Years could be saved in training repairmen.

One manufacturer of commercial communications equipment has produced a small two-way radio set utilizing the packaged subassembly technique and has set up a servicing system closely parallel to the supply and repair system proposed here. The company claims lower production costs, greater ease of maintenance, and greater flexibility of equipment as compared with conventional designs.

It should be recognized that not all electronic equipment can be broken into replaceable subassemblies, nor can all shipboard maintenance be reduced to the plugging in of new subassemblies until the defective one is found. Enough can be accomplished, however, to make a program such as that outlined here very worth while. Such a program would in effect require the redesign of all our electronic equipment. This is a tremendous job requiring years and large sums of money—but can we afford not to undertake it?

# DEVELOPMENT OF THE CATHODE-RAY TUBE

*by* E. C. GARRISON, *Electronics Engineer, Office Supships and NIO, Newport News, Virginia*

*In the December 1948* ELECTRON *ORBIT, we offered to publish, with full credit to the author, the best article received from the field on "The Antecedents and Development of the Cathode-Ray Tube." This article is the result. Congratulations and thanks, Mr. Garrison—*Ed.

The achievements and international language of science so transcend national political boundaries that it is extremely difficult to say that any one man was the sole originator of a device.

The above is particularly true in the case of the cathode-ray tube. Although most writers credit Crookes as the inventor, to those whose criterion for credit is constructive use of the results of an experiment, this may not be acceptable. With this in mind, this article intends only to show the development of the cathode-ray tube by listing the major experimenters and their contributions.

The first step in the development of the cathode-ray tube began in 1752 when Watson discovered that electricity passes more easily through a partial vacuum than through air at atmospheric pressure. Morgan added to this in 1785, referring to the glow obtained when electricity was passed through an evacuated glass vessel.

The second step began in 1831 with Farraday's invention of the induction coil and his subsequent experiments with magnetism and the luminiferous ether, recording a phosphorescent glow in 1838. He also introduced the terms "anode," "cathode" and "electrode."

The third step began in 1855 when Geissler developed a better vacuum pump and consequently obtained a greater degree of evacuation in tubes. He developed this idea commercially and began making tubes in all shapes and sizes, which by electrical discharge in rarefied gases produced nearly all colors except the red of present-day neon tubes. His tubes were widely used in laboratories and were known as "Geissler Tubes."

From here, the actual development of the cathode-ray tube began by successive stages. In 1859 J. Gassiot described an experiment in which he undoubtedly obtained a beam (cathode-ray). In 1869 J. Hittdorf published experiments on electrical conductivity in gases, showing that the current flowed in a straight line, could throw a shadow, could be deviated by magnetic fields, and could be focused. He also discovered the use of the incandescent cathode. In 1876 Goldstein confirmed Hittdorf's experiments and introduced the name "Kathodenstrahlen" or cathode rays. He also discovered, in 1886, the corresponding positive rays from the anode.

Crookes achieved the first fluorescence of a tube and determined that zinc sulphide gave the brightest glow. In 1870 he invented a target type tube and proved that the rays came from the negatively charged electrode or cathode. In this same year he devised another tube which contained a small paddlewheel, free to rotate, and demonstrated the mechanical properties of cathode radiation. In 1879 he demonstrated that a narrow beam of rays could be obtained by passing them through a slit.

Varley, in 1871, had suggested that cathode rays consisted of charged particles and in 1892, H. A. Lorentz formulated the electron theory. In 1895, J. Perrin reviewed previous experiments and devised a tube, using a perforated metal disc in lieu of the target of Crookes tube, obtaining a glowing spot on the anode. Possibly as a result of these experiments, interest in cathode rays revived and Wiechert, Kaufmann and J. J. Thomson began experiments.

J. J. Thomson in 1897 proved the cathode ray to be composed of "electrons," a name first proposed by J. Stoney, and founded the theory of thermionic emission. About 1908 K. F. Braun developed the Braun Tube. He produced a narrow guided stream of electrons, deflected it electrostatically and made it trace patterns on a fluorescent screen. The tube was further modified by B. von Rosing who modulated the electron stream to follow lights and shadows of the image. The evolution and development continued through, among others, Zworykin, Dumont and Farnsworth to the present-day cathode-ray tube.

Since so many scientists have contributed to the development of the modern cathode-ray tube, the assignment of credit is left to the reader. Even in this account it must be remembered that the names of many experimenters have been omitted, including the first Russian whose name, up to the date of this account, has not been released by Tass.





# TUNING MODELS SU/–1 TRANSMITTER-RECEIVERS

Tuning the transmitter-receivers of the Models SU/–1 Radar Equipments requires two men. While one man tunes the transmitter-receiver, the second man observes the scope on the indicator. Due to lack of communications or other reasons, it is often unsatisfactory to tune the equipment even when two men are available. To provide a tuning indicator for use at the transmitter-receiver, an adapter was devised for tuning the Model SO series transmitter-receivers where a similar situation exists. It was distributed as Navy Field Change No. 103—SO. This field change is also applicable to the Models SU/–1 Radar Equipments.

The adapter furnished in the field change kit must be used in conjunction with an a-c output voltmeter having a sensitivity of 1000 ohms-per-volt. If the meter does have an "output" position, it will be necessary to use a blocking capacitor (.005 mf) in series with the center conductor of the adapter output cord so that the d-c plate voltage will not be impressed on the meter.

The receiver output cathode-follower tube V–3111 is removed from socket X–3111 and inserted in the adapter. The adapter is then inserted in the X–3111 output socket. The output cathode-follower tube has now been converted to an amplifier tube by the insertion of a resistor in the plate circuit as shown in figure 1, and is ready for operation.

The Bureau of Ships approves the issuing of Field Change No. 103—SO for use with Models SU/–1 Radar Equipments. However, since there is only a limited quantity of SO field change kits available in stock, it is suggested that, where the supply is short and time is available, these adapters be fabricated for the Models SU/–1 equipments.

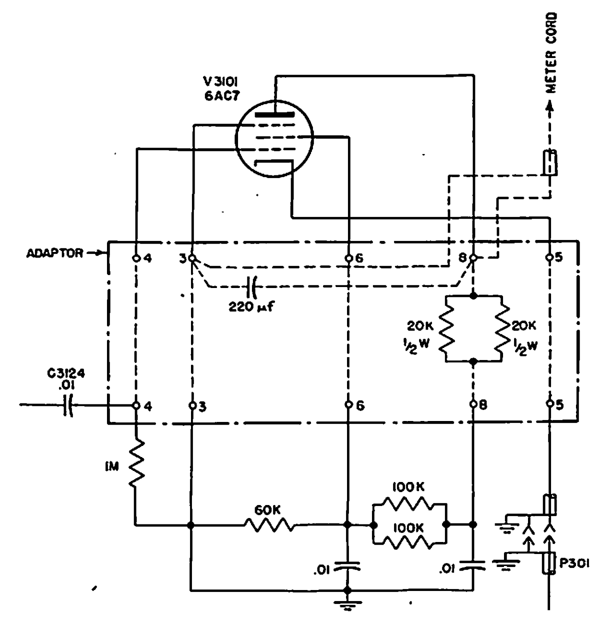



FIGURE 1.

# INCREASED DISTRIBUTION of NavShips 4110

Previously the distribution of the Ship Electronics Installation Record, NavShips 4110, was limited to eight copies because this was the maximum number that could be produced by the tabulating machines in one printing without seriously impairing legibility.

A new duplicating process which makes additional copies available has now been put into effect in the Bureau. The following is the new distribution of NavShips 4110 for Active Fleet ships. No change has been made in the distribution of copies for Reserve Fleet ships.

| *Copies* | *Activity* |
|---|---|
| 3 | Ship (one for Operational Commander) |
| 5 | Type Commander (3 for overhaul yard to be forwarded with ship's work list) |
| 1 | Home Yard |
| 1 | Each Service Force Commander |
| 2 | Atlantic Fleet Ships: 1—CinCLantFlt; 1—ComSecond Task Fleet. Pacific Fleet Ships: 1—ComFirst Task Fleet; 1—Held for future disposition |
| 3 | Bureau of Ships (one copy for ComOp DevFor ships) |
| 15 | TOTAL |

# MAINTENANCE OF MODEL DBM/–1 ANTENNAS

A number of the Model DBM Radar Direction Finder quipment antennas have been found with the hub on he spinner base completely broken off. This failure has een attributed to weak construction and the type of naterial used. It has necessitated the replacement of antennas which were otherwise in good condition.

Mr. Chester J. Brox of the Puget Sound Naval Shipyard has developed a simple method of repairing these broken spinner bases. It requires the expenditure of approximately eight man-hours labor and shipyard availability.

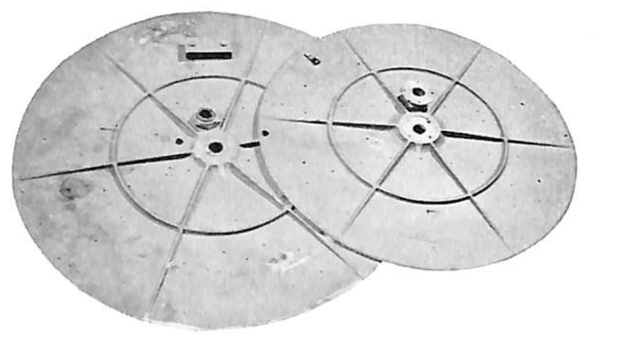


FIGURE 1.

The spinner base on the left of figure 1 shows the broken hub and contracting locking nut arrangement. The spinner base on the right shows the boss on the base after being machined and drilled to take a new flange with the original contracting locking nut. Figure 2 is the design drawing of the new flange and original locking nut, both of which are machined from solid CRES stock. Whenever possible, this repair should be effected rather than the replacement of the entire unit.

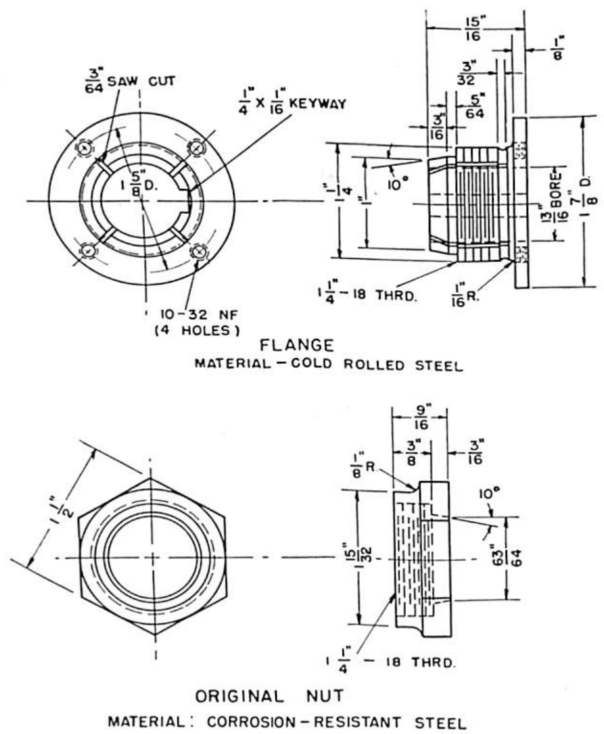



FIGURE 2.

# MODELS SR–3, SR–6 AND AN/SPS–6 SERIES STANDING WAVE RATIO TUNER ASSEMBLY

Bureau of Ships Drawing RE 10F 627B is a plan showing constructional details for fabricating a standing wave ratio tuner assembly for the Models SR–3, SR–6 and AN/SPS–6 Series Radar Equipments. Blueprints of this drawing have been distributed to all concerned activities.

The following instructions are additional to those given under "Note" on the drawing and should be considered as part of the procedure outlined thereon:

1—If the SWRT is to be built into the section of waveguide already attached to the directional coupler, this section should be removed to prevent small particles of metal from falling into the waveguide. All inside and outside edges and corners of the waveguide slots and irises should be clean and smooth. All burrs should be removed with crocus cloth.

2—Each time a new magnetron is replaced, the SWRT should be readjusted.





# REPAIR OF RADAR MATTRESS TYPE ANTENNA ARRAYS

Recent reports received by the Bureau of Ships indicate that all antenna arrays of the Models SA, SC and SK series Radar Equipments subjected to one year or more service in the weather, have the parallel hollow members of the array completely disintegrated leaving only the paint. Inspections have disclosed that these members have corroded from the inside due to excessive condensation of moisture.

In order that this disintegration may be retarded, it is recommended that ali hollow members of these antenna arrays be treated with raw linseed oil. This may be accomplished as follows:

1—Drill and tap a hole (3/16" bolt) at lowest point (bottom side) of each hollow member.

2—Drill and tap a hole (3/16" bolt)* at highest point (top side) of each hollow member.

3—The hollow member can now be filled by introducing raw linseed oil through the bottom hole by pressure pump, or by stopping up the bottom hole and introducing the oil through the top hole.

4—The oil should be retained in the hollow member for one hour and then drained off.

5—Next allow the raw linseed oil to dry for thirty-six hours.

6—Stop up the hole at the highest point of each hollow member with a 3/16" bolt.

7—Leave the bottom hole of each hollow member open. This will permit any water that may get in to drain.

The Bureau of Ships letter Serial C–982–790 (982) over C EN28/A2-11 dated 7 August 1945 outlined a procedure for the inspection and repair of Models SA, SC and SK series radar equipment antenna arrays. Enclosure (A) of this letter is being republished in part as follows:

"(a) Standard inch size red or yellow brass tubing cut to length should be used for the dipoles. If tubing of this size is not available, red brass pipe tubing I.P.S. or SAE 1030 steel tubing may be turned down to obtain the proper size. Sheet brass and brass rods should be used for the bazookas. Parts should be joined by silver brazing.

"(b) The increased failure rate of antenna arrays indicates that all antenna array framework and dipoles should be inspected quarterly and those installed directly aft of the stack should be inspected monthly by the Radar Officer. The stack gases contain sulfur compounds which form sulfuric acid. The combination of hot stack gases and a salt atmosphere creates a very corrosive condition, which combined with vibration accelerates deterioration of the paint film. Further, any break in the paint film permits almost immediate rusting of the base metal.

"(c) When it has been noticed that the paint has started to crack or rust on the dipoles or framework of the antenna, immediate action should be taken to clean the entire surrounding surface from old paint, soot, rust, etc., using a good strong power wire brush. The cleaned surface should then be wiped with a cloth containing linseed oil so as to produce a light oil film, and then repainted, using a hand brush, with two coats of 52P18 zinc chromate primer, and with not less than two nor more than four coats of haze gray paint, formula 5H. Brass dipoles need not be coated with a primer."

*Larger hole may be drilled in hollow member provided member is not weakened.

# ERRORS IN MODELS LAF/–3 INSTRUCTION BOOKS

The instruction book for R-F Signal Generators Models LAF and LAF–3 (NavShips 900,516) contains an error in the title of Tables 8–2 and 8–3. Table 8–2 should be entitled "Combined Parts and Spare Parts List by Symbol Designation for Model LAF Signal Generator." Table 8–3 should be entitled "Combined Parts and Spare Parts List by Symbol Designation for Model LAF–3 Signal Generator." The titles were inadvertently reversed. The table of contents, however, shows the correct titles. Pen and ink corrections should be made to copies already in the field.

This instruction book supersedes the "Preliminary Instruction Book for Navy Model LAF Signal Generator" (Contract No. NXsr–39273) and "Preliminary Instruction Book for Navy Model LAF–3 Signal Generator" (Contract NXsr–53363). The final book is available and should be requisitioned in the usual manner if only the preliminary books are aboard.

# THE MON-KEY . . . .

## ELECTRONIC MONITOR AND TRANSMITTING KEY

The Bureau of Ships in its continuing efforts to improve from a technical standpoint the quality of manual transmission of communications, has carefully examined the Mon-Key, an electronic monitor and transmitting key. A quantity of 25 of these electronic monitor and transmitting keys are being made available to the following activities under Contract NObsr–44726 for trial and evaluation tests and comparison with conventional speed keys:

OINC, NAVAL COMMUNICATION STATION, CHELTENHAM, MD.

CINCLANTFLT

CINPACFLT

COMFIRSTTASKFLT

COMSECONDTASKFLT ON U.S.S. MISSOURI (BB–63)

COMSIXTHTASKFLT ON U.S.S. ALBANY (CA–123)

COMOPDEVFOR ON U.S.S. ADIRONDACK (AGC–15)

COMNAVFORCESWESPAC ON U.S.S. ESTES (AGC–12)

COMDESLANT ON U.S.S. YELLOWSTONE (AD–27)

COMDESPAC ON U.S.S. DIXIE (AD–14)

CINC, NAVAL COMMUNICATION STATION, GUANTANAMO BAY, CUBA

CINC, NAVAL COMMUNICATION STATION, PORT LYAUTEY, F.M.

CINC, NAVAL COMMUNICATION STATION, ADAK, ALASKA

CINC, NAVAL COMMUNICATION STATION, GUAM

S.O., NAVAL SHIPYARD, NEW YORK FOR COM 3 RADIO NEW YORK

S.O., NORFOLK NAVAL SHIPYARD FOR COM 5 RADIO NORFOLK

S.O., NAVAL SHIPYARD, CHARLESTON FOR COM 6 RADIO CHARLESTON

S.O., NAVAL STATION, SAN JUAN FOR COM 10 RADIO SAN JUAN

S.O., MARE ISLAND NAVAL SHIPYARD FOR COM 12 RADIO SAN FRANCISCO

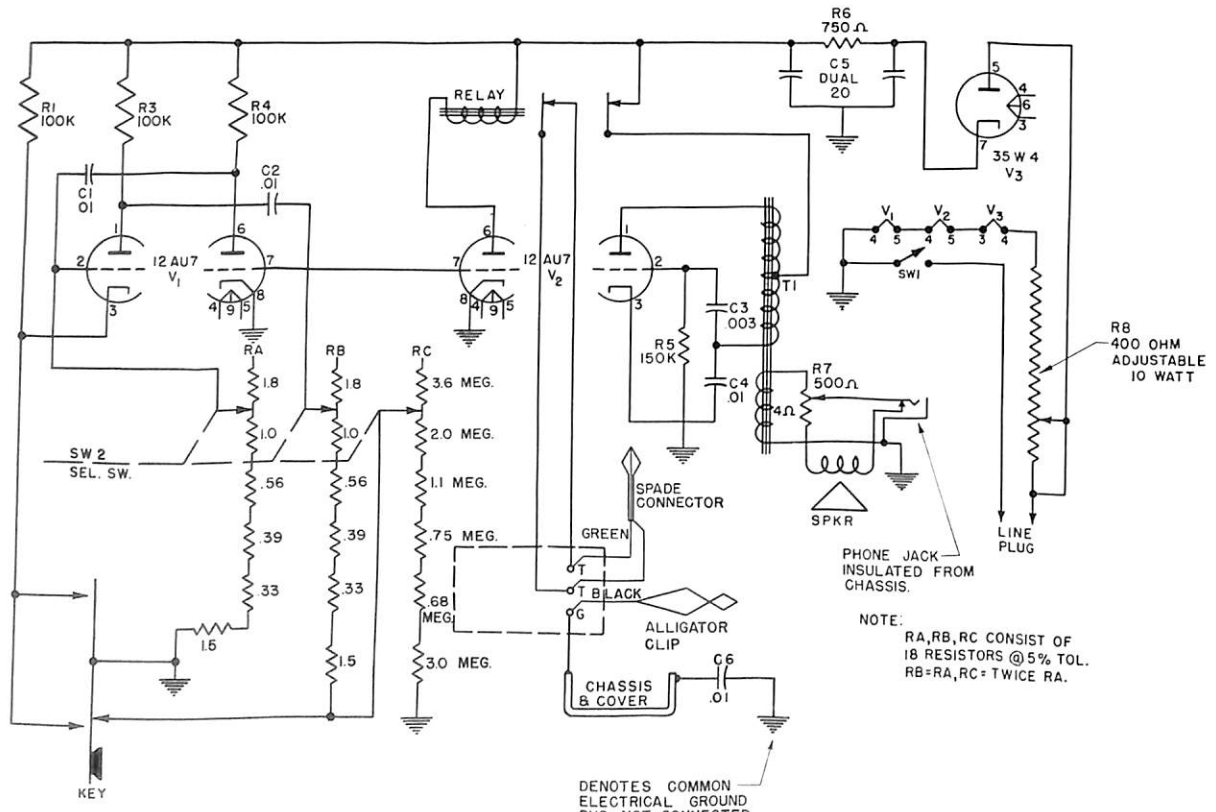



FIGURE 1.





S.O., PUGET SOUND NAVAL SHIPYARD TRIAL & EVALUATION FOR COM 13 RADIO SEATTLE

S.O., NAVSHIPYD PEARL HARBOR FOR COM 14 RADIO HONOLULU

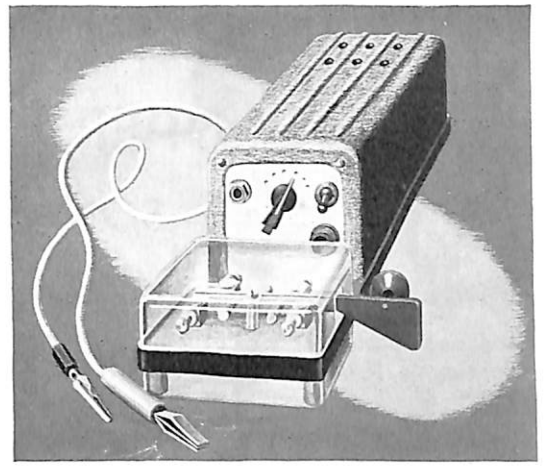
S.O., NAVAL SUPPLY DEPOT BALBOA FOR COM 15 RADIO BALBOA

S.O., NOB, KODIAK FOR COM 17 RADIO KODIAK

The Mon-Key, as illustrated, serves a dual purpose—that of keying a transmitter and of monitoring the actual keying. Similarly, the unit can be used as an audio oscillator for code practice and instruction. It is suggested that the Mon-Key be operated by itself at first while becoming familiar with the functions of the unit and the action of the key. After a little practice, operators, including speed key artists, will be able to use the key to full advantage. Holding the key paddle to the left, a series of "dashes" will be heard coming from the relay or speaker (depending on the location of the tone control knob). Holding the key paddle to the right a series of "dots" will be heard. By holding the key in one position and turning the speed switch, an increase or decrease of the keying speed will result. The dashes will always be three times as long as the dots, however, and the spaces between successive dots or dashes will be equal in length to a dot. This is good because most operators tend to make dashes too long when using a Vibroplex type key. Letting the key make its own series of dashes is the hardest operation, and many a "CQ" is emitted with more than a couple of dashes on the end. Releasing the dash contact when a perfect letter has been made, however, is soon learned. There is no "swing" possible with the Mon-Key. By practicing the alphabet a few times and noticing the letters which have been sent incorrectly, operators will soon be using the key perfectly.

In comparing the Mon-Key with the Vibroplex type of semi-automatic transmission key, it will be found that the undesirable characteristic of the Vibroplex, namely high speed transmission of dots and slow speed transmission of dashes, is not present in the Mon-Key. The Mon-Key's relationship of dot, dash and space is always proper, regardless of the speed of transmission. The highest nominal keying speed for the Mon-Key is 45 to 50 wpm.

Operation from 110 volts a. c. or d. c. is possible. A multivibrator (see figure 1) controlled and triggered by the key, emits pulses of proper length and spacing to form accurately timed dots and dashes. These pulses, in turn, control a keying relay tube which actuates a sensitive keying relay. The keying relay has two sets of contacts, one set being brought out to the terminals on the bottom of the key marked "T" "T." A ground terminal marked "G" is connected to the aluminum case cover and chassis of the unit. These parts of the Mon-Key, when connected to a non-inductive keying circuit of a transmitter, will replace any standard hand-operated key. The relay contacts will safely handle 2 amperes in a non-inductive circuit.



The other set of contacts on the relay controls the plate current of a triode vacuum tube audio oscillator which actuates a 2-inch dynamic speaker (or headphones when connected).

A flexible insulated ground wire, about 3 feet long, is connected to the ground terminal with an alligator clip on the loose end.

One end of a flexible double conductor cable is connected to the relay contacts "T" "T." The other end is terminated in a two-contact, flat surface plug for connection to the shorting switch receptacle of a hand key.

The following controls and jacks are located on the front panel:

1—An ON and OFF switch controlling the filaments of the three tubes.

2—A six-position switch for adjusting the speed of the dots and dashes while maintaining proper ratio of length to speed.

3—A tone control for the audio monitor which also serves to switch off the audio tone.

4—A phone jack. By connecting headphones, the loudspeaker will be disconnected. The tone control also operates with the headphones.

Activities receiving these Mon-Keys are requested to forward test information, data, comments, and recommendations to the Bureau of Ships, Code 983. Comments on the comparison of the operation of the Mon-Key with conventional hand keys and speed keys are especially invited.

### MAINTENANCE REPAIR PARTS

*Reports and comments on the Maintenance Repair Parts Program, as requested in the May* ELECTRON, *should be addressed to Code 960 (formerly 995).*

# MONTHLY PERFORMANCE AND OPERATIONAL REPORTS

## SONAR EQUIPMENT

All sonar-equipped vessels will submit by *confidential* letter a Monthly Performance and Operational Report on certain sonar equipments.

It is essential that the Bureau of Ships receive these reports in order to keep informed on sonar equipment performance and operation. These reports provide the Bureau with first-hand information under actual operating conditions and are, therefore, of extreme value to the sonar program. Some of the details for the report may be obtained from the ship's Electronic History Cards and Installation Records, which should be accurately kept. The remainder of the form is to be filled in from operational data and bathythermograph slides or cards.

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

An outline of a sample form is included with this article. In general, it is not intended that the reports be confined to the spaces indicated, but rather that the sample be used as a guide. An explanation of items (a), (b), (c), (d), (e), (f), (g), (h) and (i), as referred to in the form, follows:

(*a*) *Transducer(s) Information.* (1) Distance of transducer from bow (frame number). This data can be obtained from the installation records and plans. (2) Depth of transducer—above keel for submarines and below keel for surface craft and submarines.

(*b*) *Field Changes Accomplished.* This data can be taken directly from the Electronic History Cards if they are up to date. Give only the numbers of the field changes that have been completed.

(*c*) *Total Hours of Operation. To Date——During this Period.* If possible, indicate the total hours the equipment has been in operation from the date of installation to the date of the report. Also, indicate the hours the equipment has been in operation since the last monthly sonar report.

(*d*) *Total Hours of Operation Lost During Period of this Report.* The time lost refers to equipment shutdowns due to component and tube failures and other troubles which prevented normal operation.

(*e*) *General Performance.* Comments pertaining to general performance are required. Errors in ranges and bearings, sloppy train, etc. should be listed. Equipment performance is to be rated as follows:

*Excellent*

(1) Echo Ranging Equipment—100% return echoes from target for all "ping" transmissions during normal search speed and at limiting range for the day.

(2) Listening Equipment—Continuous contact at limiting range for the day.

(3) Echo Sounding—100% return echoes for all "ping" transmissions at all depths within the scale limits of the indicator and recorder.

*Good*

80 to 90% of that listed for excellent.

*Fair*

60 to 70% of that listed for excellent.

*Poor*

Less than 60% of that listed for excellent.

This should be followed by a statement of the general reasons which contributed to the description given such as "Equipment is very reliable, steady, easily tuned and put into operation," or "Equipment is more dependable since personnel has become more familiar with it," etc. If the equipment has a PPI, state whether target was readily discernible, persistent, clear, etc.

(*f*) *Operational Difficulties.* Describe the nature of all interference encountered; that is, tell the amount and what effect it had on the scope pattern and the relative arc in which the interference occurred. If possible, state the causes of all operational difficulties encountered and what steps, if any, were taken to remedy them and the results obtained. State what interference the ship's sonar caused to other equipment, and what preventive steps, if any, were taken to reduce it. Own ship's screws are always a source of noise and their arc of interference is fairly well known but "spokes" sometimes appear due to dome reflections. Any voltage fluctuation or frequency change of the power supply which affects the sonar equipment should be reported.

(*g*) *Range Table: Maximum Range Obtained.* This will be the maximum range at which a target was obtained and identified as a target. *Sonar Message.* This will be the sonar message at the time of run on obtained target. *Type of Target.* This will be "SS," "AP," "DD,"





### SONAR—MONTHLY PERFORMANCE AND OPERATIONAL REPORT

Ship ______________________ (Name) ______ (Type) ______ (Hull No.)

Equipment Model ________ Ser. No. 381 Date Installed Oct. ____ By Tacoma Boat Bldg.

(a) Transducer(s) Located at Frame(s) ____________

Distance of Transducer(s): Below Keel in Operating Position ____________

Above Keel in Operating Position ____________

(b) Field Changes Accomplished ____________

Period of Report ____________ to ____________

(c) Total Hours of Operation, To Date X ________ During this Period ____________

(d) Total Hours of Operation Lost During Period of this Report ____________

(e) General Performance: Excellent ( ), Good ( ), Fair (✓), Poor ( )

(f) Operational Difficulties ________ No True Bearing ________ Record kept of total operating time

(g) Range Table:

| Maximum Range Obtained (yards) | | Sonar Message | Type of Target | Depth | | Sea Condition | Operating Frequency (kc) | |
|---|---|---|---|---|---|---|---|---|
| Ranging Eqpt. | Listening Eqpt. | | | Target (estimated) | Own (if SS) | | Echo Ranging Eqpt. (tuned to) | Listening Eqpt. (bandwidth) |
| | | | | | | | | |

(h) Sonar Personnel

Name(s) and Rating(s): Operating ____________

Maintenance ____________

(i) General Remarks ____________

Copies to:

BuShips (1—Attention Code 983)

Comdt. Coast Guard (1—When report is submitted by a Coast Guard vessel)

(Other copies as directed by fleet or type commanders) etc., as identified. *Depth.* Surface ships will report the estimated depth of a target that is submerged. Submarines will report own depth and estimated target depth. *Sea Condition.* This will be the average sea condition at the time of contact. *Operating Frequency.* (a) Echo Ranging Equipment—Driver and receiver tuned to . . . . .kc. (b) Listening Equipment—Bandwidth . . . . .kc.

(*h*) *Sonar Personnel.* Identify by name and rating the men with sonar training, either as operators or maintenance men.

(*i*) *General Remarks.* Add here any remarks not covered in the above items. Include new uses of equipment or suggested changes in use of equipment to achieve better results. Some of these uses may be happened upon by chance or come from proposals by operators or maintenance men. This is not to be construed as authority to modify the gear in any way. Commanding Officer's remarks are specifically requested.

Information concerning the newer sonar equipments is desired for comparison with other types and as a check on their troubles, usefulness, etc. *It is not desired that reports be made on all sonar.* The list below covers sonar equipments on which reports should be submitted. This list will be changed from time to time as older equipments are dropped and new ones added.

JT
NAC/NAD
NGA/NGA-1
NGB
OKA
OMA
QDA
QHB/QHBa/QHB-1
QLA/QLA-1
QXB
WFA/WFAa/WFA-1

*It is not required that a report be submitted for the equipments listed above if the equipment has not been in operation.*

This report is not to be confused with the failure report form NavShips 383. All activities should continue to report all failures of electronic equipment on the NavShips 383 failure report form, whether or not a special operational report is submitted.

# MONTHLY PERFORMANCE AND OPERATIONAL REPORTS

## COMMUNICATION AND COUNTERMEASURES EQUIPMENT

In order to facilitate the preparation of monthly performance and operational reports for communication and countermeasures equipment, the Bureau of Ships will supply a form, Navships 3642(3-49), a sample of which is included with this article. A pad of fifty has been furnished to each active vessel in the fleet, and additional forms may be obtained from District Publication and Printing Offices.

Note that six separate equipments may be reported on a single form, and that the classification has been reduced to *restricted.*

The explanation of the items on the form are contained in the March issue of BuShips Electron, the only exception being that under the heading "Total Hours In Operation" it is necessary to report only the hours of operation for the period of the report. The total hours of operation since the date of installation of the equipment are not required.

The March issue of Electron also carried a list of equipments for which P & O reports were required. This list is cancelled. Beginning immediately, reports should be forwarded to the Bureau of Ships, Code 983, on the following equipments:

- Model TDZ Radio Transmitting Equipment
- Model RDZ Radio Receiving Equipment
- Model MAR Radio Transmitting and Receiving Equipment
- Model RDR Portable Radio Receiving Equipment
- TS-587/U Noise-Field Intensity Meter (only when used during the month)
- ME-11/U R-F Wattmeter
- AN/USM-3 Test-Tool Set (only for suggested new applications and general remarks)





COMMUNICATION AND COUNTERMEASURES EQUIPMENT
MONTHLY PERFORMANCE AND OPERATION REPORT
NAVSHIPS 3642 (3-49)

RESTRICTED

*Submit original only to Bureau of Ships*

SHIP USS BLIND LANDING (XXX-30) PERIOD OF REPORT 1 March thru 31 March 1949

| EQUIPMENT MODEL | TDZ | RDZ | RDZ | | | |
|---|---|---|---|---|---|---|
| SERIAL NO. | 725 | 850 | 853 | | | |
| DATE OF INSTALLATION | 12 Jan 1949 | 12 Jan 1949 | 12 Jan 1949 | | | |
| INSTALLED BY | Boston | Boston | Boston | | | |
| ① TOTAL HOURS IN OPERATION | 105 | 125 | 120 | | | |
| *NOTE 1 - Report only the hours lost as a direct result of equipment deficiency during this period on the following line:* | | | | | | |
| ② HOURS LOST DURING PERIOD *(See Note 1)* | 20 | 0 | 5 | | | |
| *NOTE 2 -* KEY TO PERFORMANCE | 100%-EXCELLENT | 90%-VERY GOOD | 75%-GOOD | 60%-FAIR | 50%-POOR BUT OPERATING | 0%-INOPERABLE |
| ③ GENERAL PERFORMANCE *(See Note 2 - Enter Percentage)* | 60 | 100 | 90 | | | |
| ④ MAXIMUM RELIABLE RANGE *(State Frequency)* | 10(277.8) | 15(282.4) | 12(268.8) | | | |
| ⑤ ANTENNA LOCATION | Type-66147 132' above waterline, peak of mainmast (Port) | Type-66147 132' above waterline, peak of mainmast (Port) | Type-66147 136' above waterline, foremast SG-6 platform level | | | |
| ⑥ FIELD CHANGES ACCOMPLISHED | 3 & 4 | 1, 3 & 4 | 1 & 3 | | | |
| ⑦ ELECTRONIC MAINTENANCE PERSONNEL | Jones, F. L.<br>Adams, A. D. | ET1<br>ET2 | 1 1/2 yrs.<br>1 yr. | | | |

SUGGESTED NEW APPLICATIONS

⑧ None

GENERAL REMARKS *(If additional space is required use reverse side)*

⑨ One (1) type 2C39 tube burned out after 230 hours operation. Tuning difficulties previously encountered with TDZ corrected since last report.

Field Change No. 4-RDZ for RDZ #853 has been requested and will be installed upon receipt.

SIGNATURE

RESTRICTED
8-12222

*STOCKED IN CDS*

REPORT-SHIPS-66

# BASIC meter MOVEMENTS

## BASIC PHYSICS PART 18

The tremendous field of electricity and electronics encompasses many varied types of measuring devices to visually indicate the current and voltage in vital parts of electrical circuits. The actual type of instrument encountered will depend upon the particular application. In laboratories, electrical measuring and indicating instruments will be capable of much greater precision than those normally utilized in equipment such as power switchboards, radio or radar transmitters and thousands of other electronic equipments.

Although official definitions vary from usage somewhat, in electronics practice the words "meter" and "instrument" are employed almost interchangeably to refer to a device which indicates and measures the value of some physical quantity under observation. The quantity is usually an electrical one in electronics, of course. Superimposed upon this general equivalence of the words, however, are several fine distinctions. When in practice in electronics we think of a "meter," we usually conjure up a picture of a rather small-sized device, more-or-less self-contained, indicating the values of the more-common electrical units, such as voltage and current. The common, three-inch milliammeter is an example. The word "instrument" brings to mind a somewhat larger, somewhat more delicate and precise device, more elaborate in outlay and often more complex in operation, consisting of several separate electronic components, which may include meters. Instruments in this sense tend to be employed to measure the less-common physical quantities. In any case, these are somewhat fine distinctions, rather loosely applied in practice; generally, the words are more-or-less interchangeable.

### Fundamental Principles of Meters

Electrical measuring devices are designed to utilize the effects produced by current, voltage, etc. in an electrical circuit to furnish a measure of the quantity under measurement. There are instruments based on the effects manifested by both current and voltage, but in practical applications in the field of electricity we will find that the greater majority of measuring devices are of the type which depend upon the effects of currents. The definite relationship given by Ohm's Law between the current, voltage, and resistance of any circuit makes possible the measurement of voltage and resistance as well as current by current-operated meters, as explained later.

An electric current may be detected and measured by a device designed to utilize any of the previously-studied effects a current produces. These are the magnetic effect, the heating effect, and the electrolytic effect.

### The Magnetic Effect of Current

When a conductor of any kind carries an electric current a magnetic field always appears about the conductor. It has been previously shown that a mechanical force acts on such a current-carrying conductor when it lies in another magnetic field, and that the force acting on the conductor is directly proportional to three quantities: 1—the strength of the field, 2—the magnitude of the current, and 3—the length of the conductor lying in the field. This mechanical force can easily be measured and used as an indication of the amount of current in the conductor. The D'Arsonval and other types of instruments operating on this principle are described later.

### The Heating Effect of Current

A metallic conductor becomes heated and continues to develop heat as long as current flows. This is attributed to thermal agitation by the electron flow within the metal itself. When a current $I$ flows in a wire between two points in an electrical circuit whose potential difference is $E$, we have $I$ units of electricity falling each second through a potential difference $E$. This represents a loss of potential energy, according to the laws of physics, equal to $EI$ units per second. Since, by Ohm's Law, $E = IR$, the rate at which energy is expended in the wire is $P = I^2R$ units per second. This transformation of electrical to heat energy is called the expended power and is dissipated as heat from the wire as fast as it is produced, when a steady current state is reached. This heat energy can easily be measured and used as an indication of the amount of current flow in the conductor. Meters depending on this principle are *hot wire* and *thermo-couple* meters (described later on).

### The Electrolytic Effect of Current Flow

During the study of electrical conduction through liquids, it was found that an electric current, when passing through certain metallic salts in solution, will liberate a mass of a substance which is proportional to the quantity of electric current. Methods of electrical measurement utilizing this principle require so much auxiliary equipment that it is not applicable to ordinary electrical measurements.

### Utilizing the Magnetic Effect of Current

To illustrate and describe the instruments that are actuated by the magnetic effect of an electric current, some principles learned in previous parts of this course will be briefly reviewed.

Ampere derived the fundamental relation between the direction of current flow, its attendant magnetic field, and the force that would be exerted through the interaction with another magnetic field. This principle was used in explaining the theoretical operation of the electric motor described in *Basic Physics*, Part 14. Arsène D'Arsonval is generally credited with the first application of these magnetic relationships to a device which will indicate the presence of current flow by its magnetic effect, hence the name D'Arsonval movement is used when describing a meter of this type.

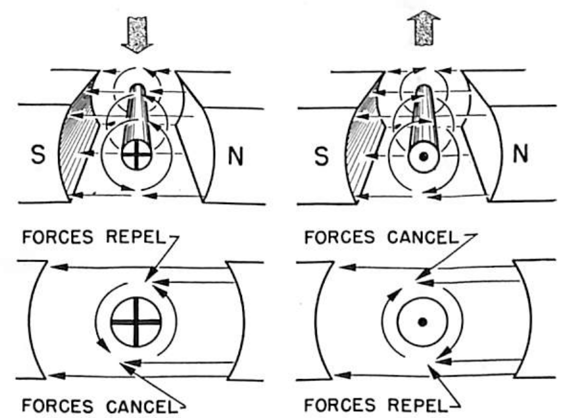



FIGURE 1—*The direction of force shown as a result of cancellation of flux lines in a D'Arsonval meter. A weaker field results.*

When a wire is placed in a magnetic field and an electric current is passed through the wire, it experiences a force tending to force it out of the field. As illustrated in figure 1, the reaction between the magnetic field of the magnet and the lines of force produced by the wire is such that the field is strengthened on one side of the wire and weakened on the other, and the wire is accordingly forced in the direction of the weaker field. This force is directed in such a manner that the conductor will tend to move at right angles to the lines of flux produced by the permanent magnet. The force in dynes may be expressed:

$$F = \frac{B \times I \times L}{10}$$

where $B$ is the flux density in lines per square centimeter, $I$ the current in amperes, and $L$ the active length of the conductor in centimeters.

If a single-turn coil is placed in the magnetic field as shown in figure 2A, and is free to rotate much the same as a simple motor, the interaction of magnetic fields produced by current flow in the coil will cause a force to be exerted as shown in the sketch. This is the familiar motor action, but when applied to electrical measuring instruments, it is known as the D'Arsonval principle.

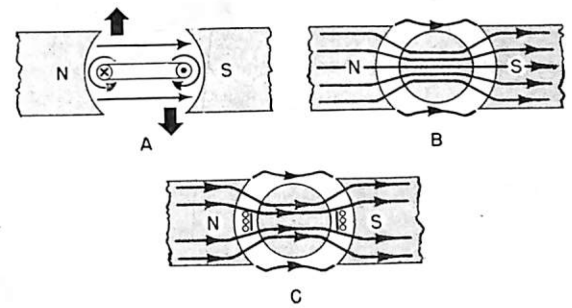



FIGURE 2—*A method for obtaining a uniformly-radial magnetic field.*

The forces acting in the manner shown in figure 2A will tend to rotate the coil about its pivot axis. Since the combination of force acting on each conductor tends to produce rotary motion, it is in actuality a torque. The value of a torque is expressed in units of force and distance; the distance in this case is the perpendicular distance from the pivot axis to the conductor upon which the force is exerted. The torque or turning effect is proportional to the current only when the conductor is passing the flux lines at right angles, but it will be noted that as rotation continues from the position shown in figure 2A, the angle between the flux produced by the field and the motion of the conductors will become less than 90 degrees. Therefore, since the force on a conductor varies as the sine function of the angle at which the flux lines are cut, the torque in the example shown will decrease. This feature is undesirable in an indicating device because of complications that arise when a scale is to be calibrated.

Figure 2B shows the method used in the D'Arsonval-type meter which permits a constant-flux field that is radially perpendicular to the axis about which the moving coil rotates. The core material is constructed of soft iron in the form of a cylinder which is fixed in position between the pole pieces of the permanent magnet, so that there is an air-gap of uniform dimensions opposite each pole face. The flux lines are perpendicular between opposite faces of the air gap, as shown in figure 2B, because flux lines have the property of assuming any shape that will shorten the flux path in air.

When a current-carrying coil is placed with freedom to rotate in the air-gap of figure 2C, any movement of the coil will move it at right angles to the flux in the air-gap. Thus, the force and resultant torque developed will be proportional to the strength of the permanent-magnet field and the ampere-turns of the coil. The torque will not depend upon the angle of displacement opposite the pole faces, but, when the turns of the coil reach the interpolar regions at the top and bottom of the sketch, the distortion of the magnetic field will cause a decrease in the torque.

The direction in which the force acts will be determined by the direction of the current flow in the conductor and the direction of the flux in the magnetic field. Hence, as shown in figure 1, for a reversal of current flow, the magnitude of the force remains unchanged so long as the same field exists and the same quantity of current flows.

Since the magnetic field about a current-carrying conductor is concentric and counter-clockwise (when one looks in the direction of current flow), a measuring device of the moving-coil permanent-magnet type can be used to indicate the direction of current flow as well as the magnitude.

The flux across the air-gap in a moving-coil meter-movement must be as constant as possible over long periods of time, if calibration is to be reliable. To meet this requirement, the permanent magnets used in meters are artificially-aged so that their strength will not appreciably change with time. Artificial aging is necessary because the rapid quenching of permanent magnets during heat treatment produces sudden changes in their molecular structure, and it may be several weeks before the magnet becomes adjusted to a stable magnetic condition, because a change in magnetic properties accompanies any molecular change.

Methods of aging vary. For instance, one method is to immerse the magnets in oil at 120° C. for one hour, during which the magnets are sometimes subjected to mechanical vibration or an alternating magnetizing and demagnetizing force. However a magnet is aged, the process reduces the residual magnetism by possibly 20%, but tends to bring the magnet to a more permanent state. When permanent magnets are used for instruments and meters it is most important that their strength shall not change with time.

## The D'Arsonval Galvanometer

A galvanometer is defined as an electrical apparatus for measuring current strength. It is usually inserted directly in the circuit to be measured, since its current requirements are quite small. The D'Arsonval galvanometer depends for its operation on the force acting on conductors in a magnetic field. This instrument is very important because most direct-current measurements of current (and voltage) are made with it. It is also used in conjunction with thermocouples, copper-oxide rectifier units, and vacuum tubes to make many alternating-current measurements.

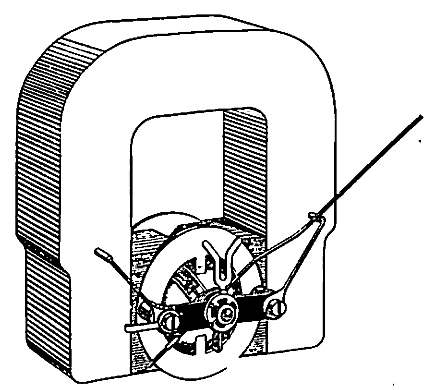


FIGURE 3—*Basic D'Arsonval or moving-coil meter movement shown without scale or protective case.*

A sketch of a D'Arsonval-type meter is shown in figure 3. A permanent magnet made of an alloy such as tungsten steel, cobalt steel, or aluminum-nickel-cobalt (Alnico) produces a strong magnetic field. The current to be measured or a known portion of it is passed through the moving coil which is situated in the constant field of the permanent magnet. The motor action resulting from the magnetic reactions of the field about the turns of the moving coil and the field produced by the permanent magnet causes the coil and the attached pointer to turn; the strength of the current is thus indicated on a suitably-calibrated scale.

## The Operation of the Permanent-Magnet Moving-Coil Mechanism

The simple explanation just given is the basis for a large majority of electrical measuring instruments. Of course, the different manufacturing details and variations for different applications cause instruments of different manufacturers to vary in size and physical shape. The D'Arsonval instrument shown in figure 3 is typical of most permanent-magnet moving-coil mechanisms.

The pole-pieces serve to intensify the field at the ends of the permanent magnet and concentrate the magnetic lines of force within the region desired. The cylindrical soft-iron core provides a good magnetic path for the flux between poles of the magnet, thus producing a uniform field in which the moving coil travels. This combination materially lengthens the life of the meter magnet because the actual air-gap is very short, and since the field is concentrated about the moving coil, stray external magnetic fields will have little effect.

This uniform air-gap is visible in figure 3 as the space through which the moving coil rotates. Reference to figure 2C should clarify the physical relationship of the moving coil to the air-gap between the pole faces of the magnet and the soft-iron core.

The moving-coil is usually wound of from twenty to fifty turns of fine copper wire on a rectangular frame as shown in figure 4. The frame is lightly constructed of thin aluminum, and is fastened to the shaft which is pivoted at each end in jewel bearings to minimize mechanical friction. A pointer attached to the shaft provides external, visual indication of the displacement of the moving coil. The shaft is counter-balanced.

A flat, spiral spring at each end of the shaft serves to conduct current to and away from the turns in the coil. These metal springs provide the opposing force against which the moving coil acts when current flows, and are also used to return the pointer to rest or zero on the scale when there is no current flow through the coil winding.

It is obvious that at zero current there must be zero force on the moving coil; hence, at zero on the scale, the needle rests at the relaxed position of the springs. The torque is actually working against the restraining force of the springs. This fact is accordingly taken into consideration during the design of the springs. An idea of the magnitude of this restraining force may be obtained by applying Ampere's Law to the coil of a galvanometer.

At any position of the coil in the air-gap where the flux is uniform and at right angles to the direction of coil movement, the torque is proportional to twice the force acting on the turns on one side of the coil. By restraining the coil movement with springs whose force is proportional to displacement, the movement of the coil will then be proportional to the current flow, and can be indicated on a uniform or equally-divided scale.

Since the moving element must be very lightly constructed, the use of this type of instrument as a series meter in which the total current is measured is limited to circuits involving very small currents. However, as will be shown later, by the use of appropriate shunts, the instrument may readily be adapted for use as an ammeter or voltmeter of practically any range.

An electrical instrument must be damped. If not, the

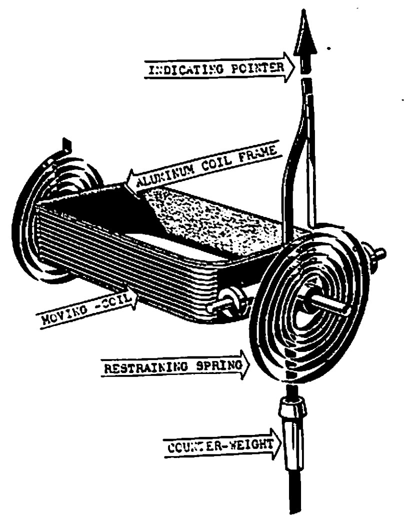



FIGURE 4—*An enlarged sketch of the moving coil of a D'Arsonval meter which is pivoted to move in the uniform-flux field between the pole-pieces and the cylindrical soft-iron core.*

pointer will not go directly to a given value of current and stop, but will swing to and fro, only coming to rest after a considerable period. To provide this damping or to make the instrument "dead-beat," the moving coil is wound on an aluminum frame. The edges of this frame are clearly visible in figures 3 and 4. When this frame moves in the air-gap, it cuts across the lines of force and a current will be induced as a result of the generator action. This induced current is called an *eddy current* and it likewise has its magnetic field, but the polarity of the field is opposite to that of the field in the air-gap; thus, the motion of the moving coil is opposed by a force which is proportional to the *speed* at which the moving coil cuts the flux lines.

The opposition to coil movement afforded by induced eddy currents in the aluminum framework causes the pointer to swing somewhat more slowly to a given position, but once it arrives there, there will be little tendency to oscillate about that position. This is electrical damping as compared to other methods (such as air friction damping) that are also used in electrical instruments. (The air-friction type has an enclosed air chamber in which a screened vane is swung against the air.)

## The Electrodynamic or Dynamometer Type Instrument

The American Institute of Electrical Engineers defines an electrodynamic instrument as an instrument which depends for its operation on the reaction between the current in one or more moving coils and the current in one or more fixed coils.

The basic difference between this instrument and the permanent-magnet moving-coil instrument is that no permanent magnet is used. The magnetic field which reacts against the moving coil is produced by field coils instead. These are large coils of many turns of wire and may be seen in figure 5 (one of the field coils has a portion removed for clarity). It will be noted that the rest of the meter is constructed much the same as the D'Arsonval movement, in that the moving coils are attached to a shaft which is restrained by springs and to which is affixed a pointer for external scale indication. As indicated in figure 5, there are two fixed-field coils and one movable coil.

The connections to the coil are made so that the magnetic fields produced by the fixed coils are of the same direction and directed along the axis through the field coils. The magnetic field produced by the moving coil will tend to align itself with the lines of force produced by the field coils. The reaction between the two magnetic fields produces a torque that overcomes the

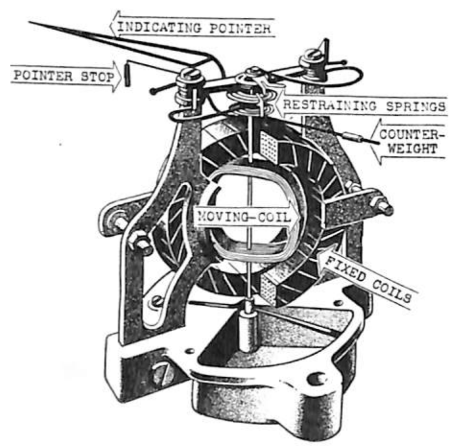



FIGURE 5—*The basic movement of the electrodynamic or dynamometer-type indicating instrument.*

restraining force of the springs and moves the indicating pointer accordingly.

The magnetic field produced by the fixed coil is proportional to the current flowing, as is the magnetic field produced by the movable coil. The force on the movable coil and the attached pointer is caused by the interaction of these two fields and is proportional to their product. Hence the force on the moving coil, or the deflection of the needle, is proportional to the current times the current, or current squared. For this reason, the scale marks of equal current differences are crowded together at the lower end and are widely separated at the upper end.

When the instrument is used to measure alternating currents, the magnetic fields of both the fixed and movable coils are reversed simultaneously with every reversal of current. Therefore, the direction of force acting between the coils remains unchanged in both halves of the a-c cycle, and the deflection of the pointer is always in the same direction and will be dependent only upon the magnitude of the current flow. There are no terminals marked "plus" and "minus" on an a-c meter, for which proper polarity must be observed when connections are made.

## The Concentric-Vane Type Meter

The soft-iron-vane type meter depends for its action on the deflection which takes place as a result of the

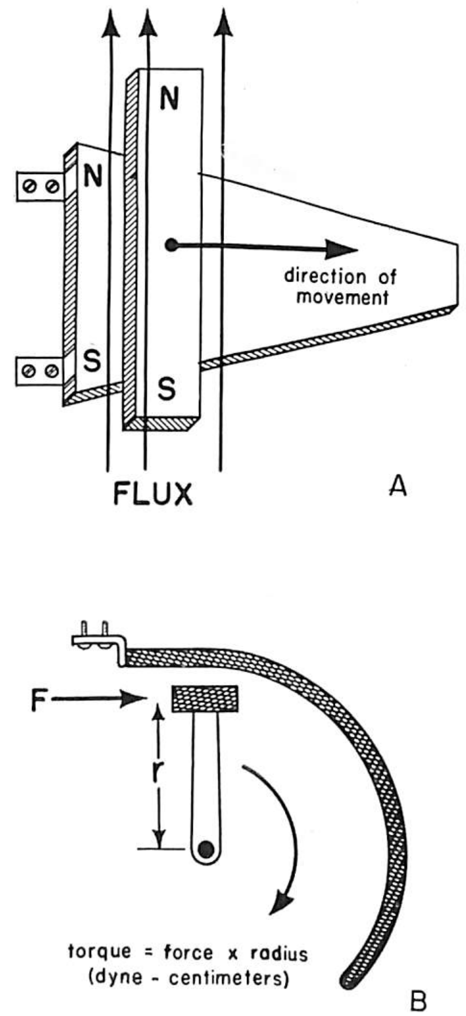



FIGURE 6—*A graphic example of the method by which the repulsion between like poles can be utilized to produce rotary movement.*

repulsion of two magnetized pieces of soft iron (see figure 6A). Figure 6B shows two pieces of soft iron of special shape. The larger is in the shape of a tongue and the smaller merely rectangular. In the position shown, a flux, as indicated by the vertical arrows, will cause both pieces of soft iron to be magnetized. If the tongue-shaped iron is fixed in position and the smaller rectangular piece of iron restricted to move at a fixed distance from the larger, the force of repulsion will be to the right. This restriction of movement is accomplished by curving the fixed vane in a cylindrical fashion and pivoting the movable iron piece on a shaft as shown in figure 6B.

The concentric-vane or moving-iron instrument (as shown in figure 7) depends for its action on the deflection which takes place between two pieces of soft iron bent concentrically and placed within a coil. Fastened to the inside of the coil is a fixed cylindrical piece of soft iron. This piece of iron is purposely made unsymmetrical so that the inner, movable, soft-iron pole-

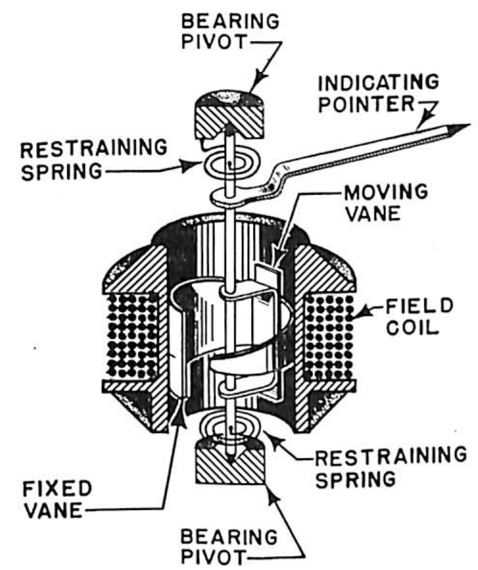



FIGURE 7—*Cut-away view of the repulsion-type or moving-iron meter.*

piece will deflect in a given direction. The movable pole-piece is attached to the shaft, which is pivoted in jewel bearings. The two pieces of iron are held but a small distance apart, and any movement is restrained by the coiled springs. When the coil is energized, it magnetizes both pieces of iron in the same direction, with the result that they repel one another. This repulsion causes a movement of the movable iron, and hence this meter is called a repulsion-type meter. The extent of movement depends on the amount of excitation produced by the coil and the tension of the springs.

The scale of this type of instrument is neither linear nor of the current-squared variety because the final shape of the scale can be modified by the shape of the fixed pole piece as well as the concentric vane. This instrument has the same advantage as the dynamometer type in that it may be used on alternating as well as direct current. When used on a. c., the reversals of magnetism due to the alternating current which occur in the coil also change the polarity of both pieces of iron so that the deflection remains constant in direction.

## Instruments That Utilize the Heating Effect of Current

Measuring devices that depend on the heating effect of an electric current are called thermoammeters. The heating effect is a function of the power expended and varies as the square of the current (hence a device actuated by temperature would have a non-linear scale calibration).

There are two general types of thermoammeters, the hot-wire ammeter and the thermocouple type. The hot-wire type depends for its operation upon the property possessed by all pure metals of expanding when subjected to heat. The thermocouple instrument utilizes the potential difference developed across a junction of two dissimilar metals when the junction is heated.

The explanation of the hot-wire type instrument is given, not as a detailed study of the meter itself, but rather to show by an example the manner in which the work done by any current varies with an increase or decrease of the current in a circuit.

Hot-wire instruments indicate current magnitude by mechanical coupling to a metallic wire whose coefficient of linear expansion is accurately known, such as platinum

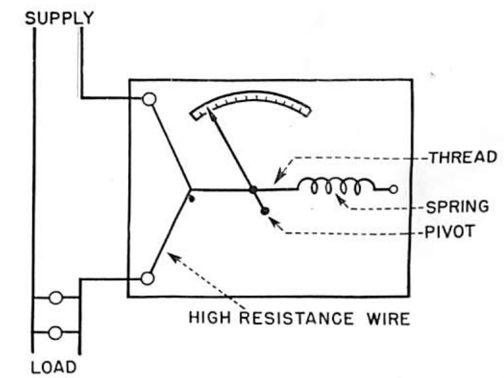



FIGURE 8—*Working sketch of a hot-wire type thermoammeter.*

wire of constant cross section. Figure 8 shows a working sketch of a hot-wire instrument. The platinum resistance wire is heated by the passage of current and expands or stretches. This allows the spring to contract and move the pivoted pointer across a suitably-calibrated scale. The scale is calibrated in terms of the square of the current.

The application of this type of instrument is limited in the field of present day electronics because of its mechanical complexity and the lack of permanence of its calibrations.

The thermocouple ammeter has practically replaced the hot-wire type of meter. The operation of the thermocouple meter depends upon the fact that when physical contact is made between two dissimilar metals and the junction is heated, a difference of potential is built up across the junction. The magnitude of the potential difference is a direct function of the types of dissimilar metals used and the temperature of the junction. This is the Seebeck Effect explained in Part 14 of *Basic Physics*. A sensitive D'Arsonval galvanometer is connected across the thermocouple and is activated by the current which flows as a result of the voltage developed across the heated junction.

Two types of thermocouple instruments will be discussed. They are the direct-contact and the separate-heater type. Both consist of thermocouples that are heated by the power expended in a resistance wire as a result of current flow.

The arrangement shown in figure 9A is employed in most thermocouple meters in use today. In contact with this heater element is the thermocouple junction. When the current to be measured is passed through the heater, power equal to $I^2R$ is dissipated in the heater, raising

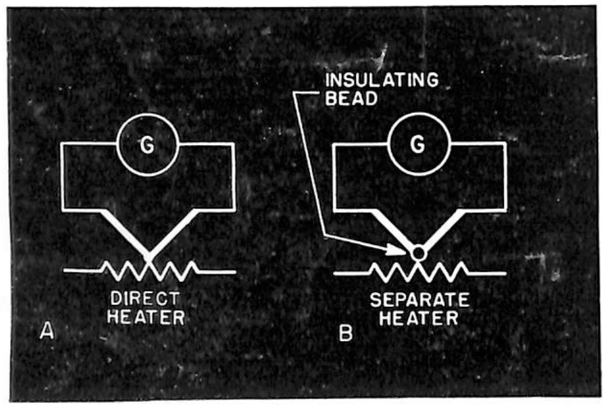



FIGURE 9—*The two types of thermocouple instruments commonly used.*

the temperature of the thermocouple junction. This causes a d-c potential difference to exist between the cold terminals of the thermocouple, and this voltage will force a direct current through the sensitive moving coil instrument. The amount of current through the meter will be determined by the voltage across the junction and the resistance of the coil movement.

Although special wires are used in high-grade thermocouples, a voltage will be produced between any two unlike wires in direct contact; for instance, at a junction between pieces of copper and iron at a temperature of 100° C. there will be produced approximately one-thousandth of a volt across the thermocouple. In sensitive thermocouples the wires are very delicate, so they are mounted in an evacuated glass bulb with the heater leads and the meter leads brought out through glass seals. This protects them from mechanical injury, prevents air from conducting heat away from the junction, and consequently makes the thermocouple more sensitive.

The separate-heater type of thermocouple, shown in figure 9B, is particularly well-suited for measurements in radio-frequency circuits. It has been specially designed to reduce the errors that thermocouples introduce into r-f circuits. Because of the importance of this meter in communication circuit measurements, it will be encountered quite often.

The insulating bead is placed between the heater and the thermocouple junction. This bead electrically insulates the thermocouple junction from the heater wire. The material chosen for the bead, however, has good heat conducting properties, so that the heat from the heater is readily conducted to the junction. By careful choice and construction of this bead, the separate-heater type thermocouple has been made almost as sensitive as the contact type in which the heater and junction are in metallic contact.

## Ammeters and Voltmeters

Instruments for measuring current and potential difference in commercial applications are galvanometers of a more substantial type than laboratory instruments. There is no structural difference between an ammeter and a voltmeter, and both deflect in proportion to the current in the moving coil. The difference between them is one of electrical resistance. The instruments are designed so that their introduction into a circuit for purposes of measurement will not change appreciably the quantities they are intended to measure.

In the ammeter the coil is provided with a by-pass called a *shunt*, connected directly across the meter terminals so that the current in the coil will be only a small but definite part of the entire current in the circuit. The ammeter has a very low resistance so that the potential drop across it will be small. Naturally, care must be taken to have enough resistance in the circuit associated with this meter so that the current will be limited to a value within its range. An ammeter should never be connected across the source of e.m.f., for it would almost certainly burn out immediately.

In the voltmeter, the movable coil is connected in series with a resistance, so that the instrument may be connected directly across a source of e.m.f., and yet take only a small current. A voltmeter has a high resistance so as to divert as little current as possible from the circuit to which it is connected. In a sense, the voltmeter protects itself because of its high resistance, but care must be exercised not to apply potential differences exceeding the range of the instrument. The range of a voltmeter can be extended if desired by the use of an additional series resistance external to the instrument. Such an auxiliary resistance is called a *multiplier*.

## Ammeter Shunts

A shunt is a conductor of low resistance designed to carry the bulk of the line current, while setting up a potential difference across the terminals of the meter sufficient to cause the proper value of current to flow through the instrument. The resistance of the shunt for a particular instrument can be found by calculations involving Ohm's Law. The scale may be, and usually is, graduated and marked in terms of the line current to which its indications are proportional. The meter and shunt must be properly suited to one another, and shunts are not interchangeable without due consideration being given to the resistance of the meter.

When calculating the shunt to be used with a meter movement to extend its range of measurement, all the laws that apply to parallel circuits are used. It must be borne in mind, however, that the current-carrying capacity of the moving coil is the governing factor. Before a shunt is designed, the resistance of the moving coil element and the current to produce a full scale deflection must be known. The resistance of a moving coil used in typical one-milliampere meters produced by several manufacturers is twenty-seven ohms. Applying Ohm's Law, we find that the voltage across the meter terminals necessary to obtain a full-scale deflection of one milliampere will be 0.027 volts. Suppose it were desired to extend the range of such a meter to a full-scale deflection at 50 milliamperes line current. This will require a meter shunt that will by-pass all except the one milliampere needed by the moving coil for a full-scale deflection. By Ohm's Law, it was found that 0.027 volts would cause one milliampere to flow through the moving coil; therefore, the resistance of the shunt must develop an *IR*-drop of 0.027 volts when 50–1, or 49 milliamperes flows. By Ohm's Law:

$$\textit{Shunt resistance} = \frac{0.027}{0.049} = 0.551 \textit{ ohms.}$$

This shunt can be made from ordinary cotton-covered copper wire. According to A.I.E.E. standards, 1,500 circular-mils for each ampere of current should be allowed, to avoid serious variation in the shunt resistance due to temperature change. By consulting a wire table we find that the size of wire that will most nearly carry 49 milliamperes without exceeding its capacity is 31 gauge, which is rated at 53 ma, and has a resistance of 132.7 ohms per 1000 feet. The length of 31-gauge wire for a shunt with a resistance of 0.551 ohms would be:

$$\frac{0.551}{132.7} \times 1000 \times 12 = 49.7 \textit{ inches}$$

This length of wire may be conveniently wound on a wooden spool and connected across the meter terminals.

Similar calculations can be used to find the resistance of any shunt to extend the range of an ammeter. Of course, when the shunt must carry currents in the vicinity of 100 amperes, extreme care must be taken to insure that the contact resistance is low, and that the heat developed may be adequately dissipated in air.

## Voltmeter Multipliers

A multiplier or external resistance to extend the range of a voltmeter, is a series resistance whose value is great enough to limit the current through the moving coil to its rated value. For instance, a typical one-milliampere meter with an internal resistance of twenty-seven ohms can be made into a voltmeter of practically any range and the scale calibrated in terms of voltage.

The calculation of the values of resistance of a suitable multiplier can be handled the same as that of a simple series circuit where one resistance is known. Suppose a multiplier is desired that will enable the above meter to be used for voltage measurements up to 250 volts. The total resistance that will limit the current to one milliampere at a potential difference of 250 volts can be calculated through Ohm's Law:

$$R = \frac{250}{0.001} = 250{,}000 \textit{ ohms.}$$

Therefore, the resistance required in series with the meter would be 250,000 –27, or 249,973 ohms. Usually the resistance of the meter is neglected when the value of the multiplier is over 100 times as great.

Ordinary voltmeters used for circuit indication or for test purposes are designed around a meter and multiplier that will provide a resistance of 1000 ohms per volt across the source of e.m.f.

In using voltmeters thus based on
of ammeters, the user must be sure t
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## Combination Ammeter and

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possible to mount a single mil
and switch in the shunt or mult
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a multirange scale is provide

Answers to *Bas*

1.—Equivalent delta resistance

$R_1 = 4.71$ ohms.

$R_2 = 4.00$ ohms.

$R_3 = 15.7$ ohms.

2.—Equivalent resistance is 2.391 ohm

3.—Current flow through five-volt batte

Direction of current is up.

# GOT MORE Electrons THAN YOU NEED?

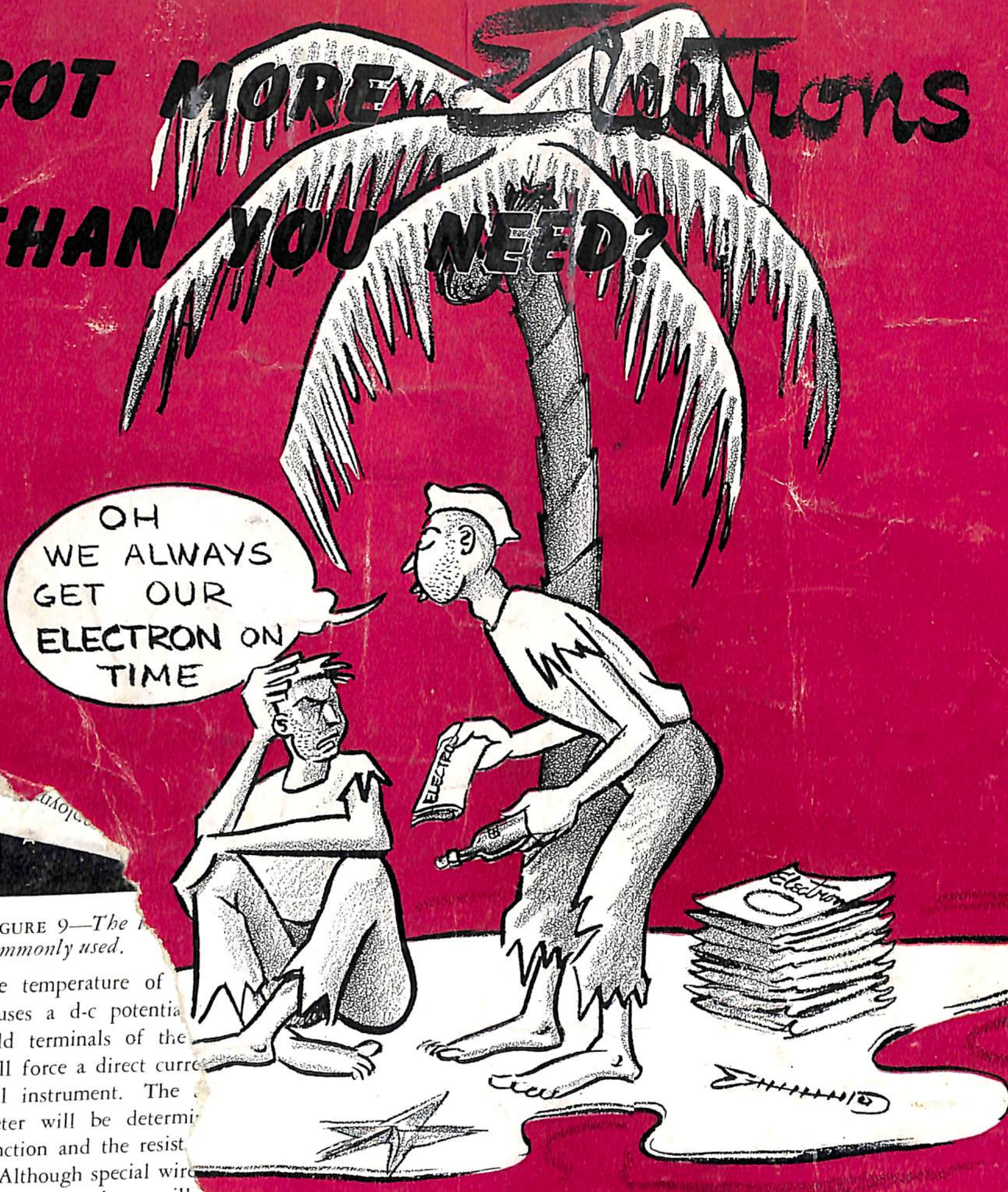


FIGURE 9—*The* ...
*commonly used.*

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