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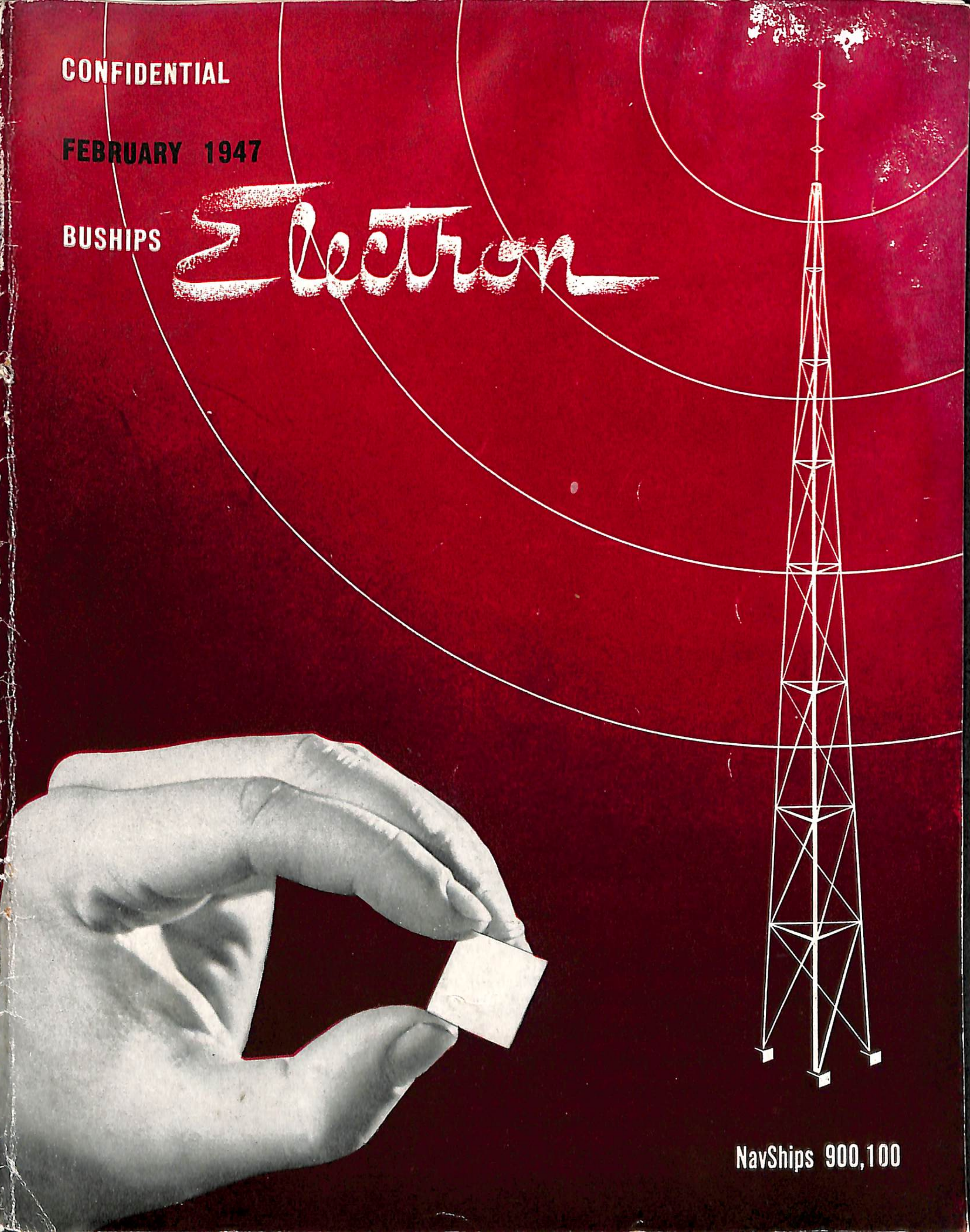
FEBRUARY 1947

BUSHIPS Electron



NavShips 900,100

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BUSHIPS Electron

A MONTHLY MAGAZINE FOR RADIO TECHNICIANS

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

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

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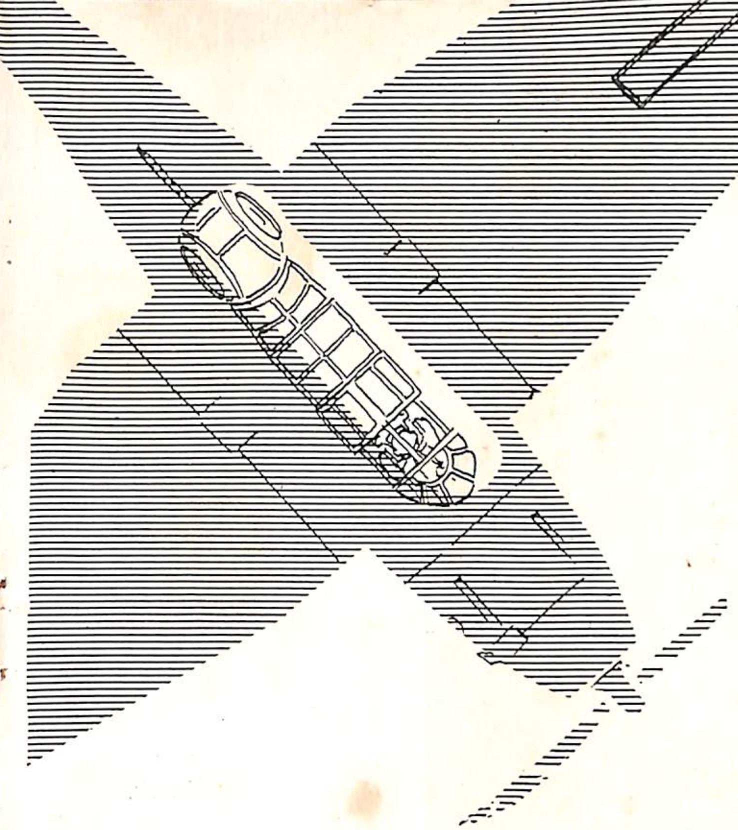
BUREAU OF SHIPS — NAVY DEPARTMENT

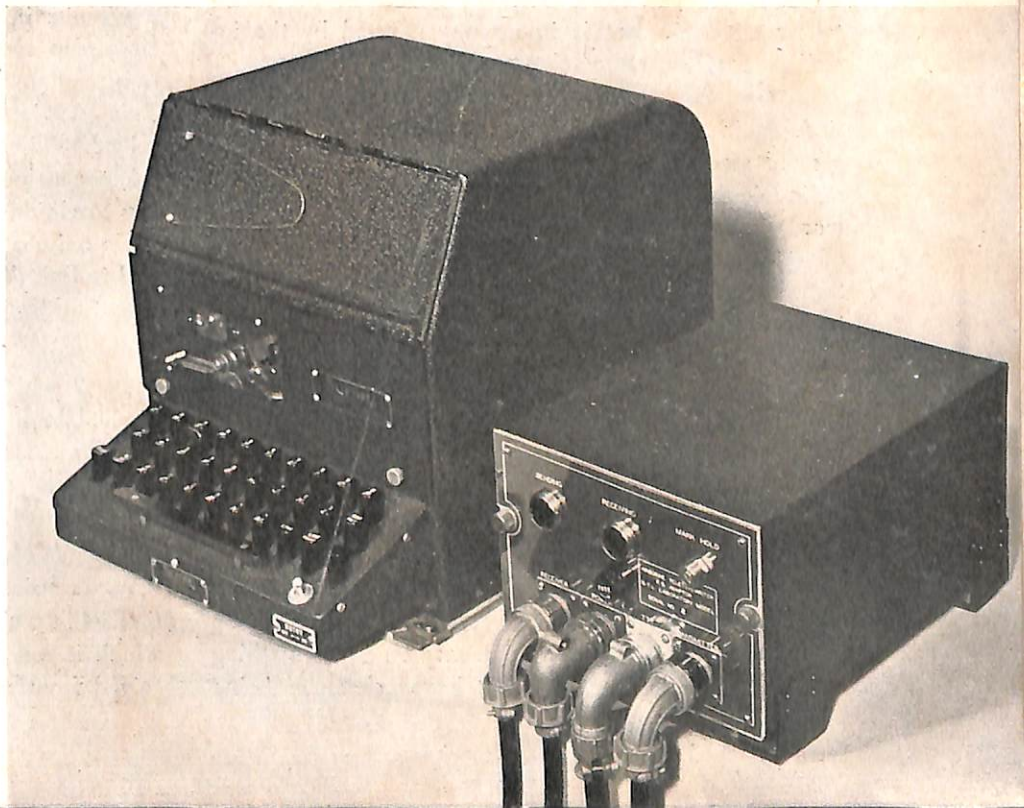


High-Flying Teletype

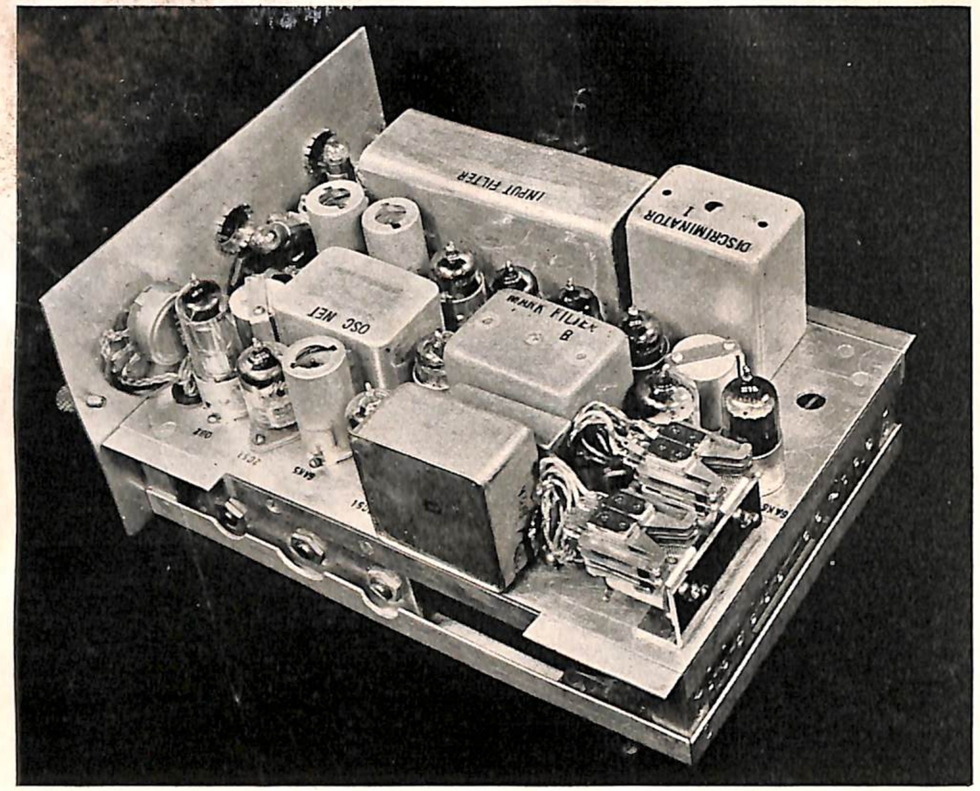
By R. A. Vanderlippe,
Bell Telephone Laboratories

■ Another milestone in the history of radio communications has been reached, for it is now practicable to send teletype messages to and from airplanes in flight. The equipment which makes this possible is the new lightweight Model 31 teletype printer, developed by the Teletype Corporation, and an associated converter-control unit, developed by Bell Telephone Laboratories.

Smaller and lighter than a standard typewriter, this printer uses the regular teletype keyboard and signaling code. The converter-control unit at a station which is sending, changes this code into frequency-shift signals in the audio-frequency range for transmission over existing radio-telephone equipment. At a station which is receiving, the converter-control unit changes these frequency shift signals into electrical impulses for operating the receiving-typing part of the printer.



Teletypewriter and converter-control unit for use with radio-telephone system.



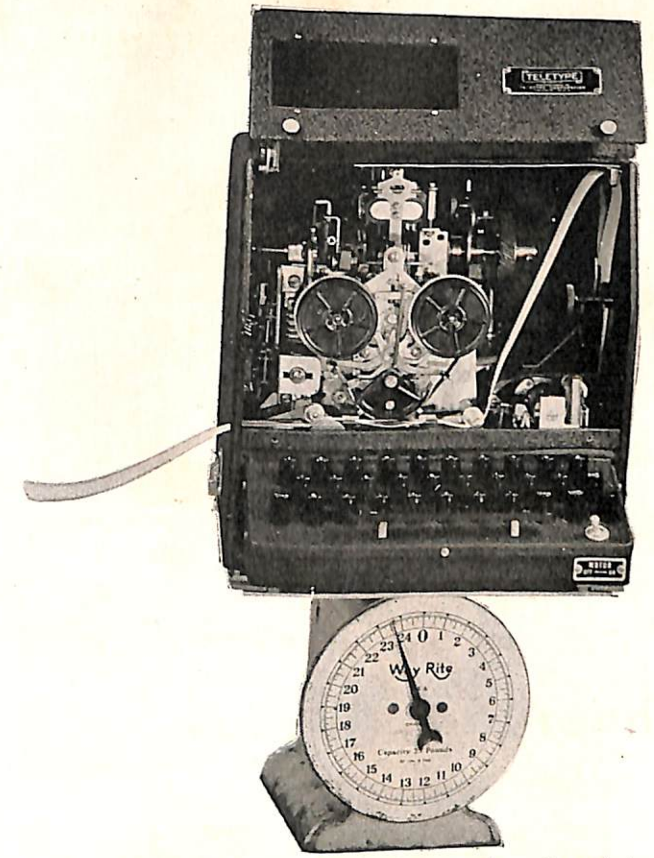
Interior view of the converter-control unit.

An interesting feature in connection with the use of this new instrument is that it will work with any existing radio-telephone installation capable of carrying on satisfactory two-way voice communication. This, of course, means that by the simple addition of the radio teletype equipment, weighing less than thirty-five pounds, and without any modification of the radio-telephone equipment, two-way, typed communication, with all its advantages, may be achieved. The normal use of the radio-telephone equipment is in no way affected by the installation of the radio teletype.

A radio teletype network installed in aircraft and ground stations operates very much like a press-to-talk radio-telephone network, except that instead of spoken words it handles typed messages. No manual operation of a "press-to-talk" control is required since the radio transmitter is turned on automatically when the first teletype character is sent. As in standard land-wire teletype equipment, two signaling conditions, commonly referred to as "marking" and "spacing," are used for transmission of teletype signals. The unit of time during which a character is transmitted is broken into seven intervals. Each character begins with a spacing "start" interval and ends with a marking "stop" interval. During these intervals all printers which are receiving are synchronized with the printer which is sending. During each of the five time intervals between the start and stop intervals, the signaling condition may be either marking or spacing, depending on the teletype character being transmitted, so that thirty-two different signaling combinations are possible. By assigning one combination for "upper case" and one for "lower case" functions, any or all of the remaining thirty combinations may be used for the transmission of either of two characters or symbols so that there are enough combinations for all characters and symbols on the keyboard of the teletypewriter.

Circuits in the converter unit provide an automatic closure to condition the radio-telephone equipment for transmission when the first teletype character is sent. This function is disabled when a message is being received. Other control circuits provide for holding the selector magnet circuit of the teletype printer in a marking condition during idle periods of the circuit, so that radio noise will not cause false characters to be printed, and to light lamps to indicate whether the terminal is in a transmitting or a receiving condition.

Openings and closures of the printer transmitting contacts which occur as the keyboard is operated are applied to the sending circuit and shift the frequency of an oscillator between two audio-frequency tones as required by the marking and spacing elements of the character to be transmitted. The output of the sending circuit modulates the radio transmitter in the same manner as a voice signal. A small amount of energy from the sending circuit is applied to the receiving circuit in which it functions in the same manner as a signal received from a distant station. In this way, a local copy



Interior view of the Model 31 teletypewriter. It weighs less than 24 lbs.

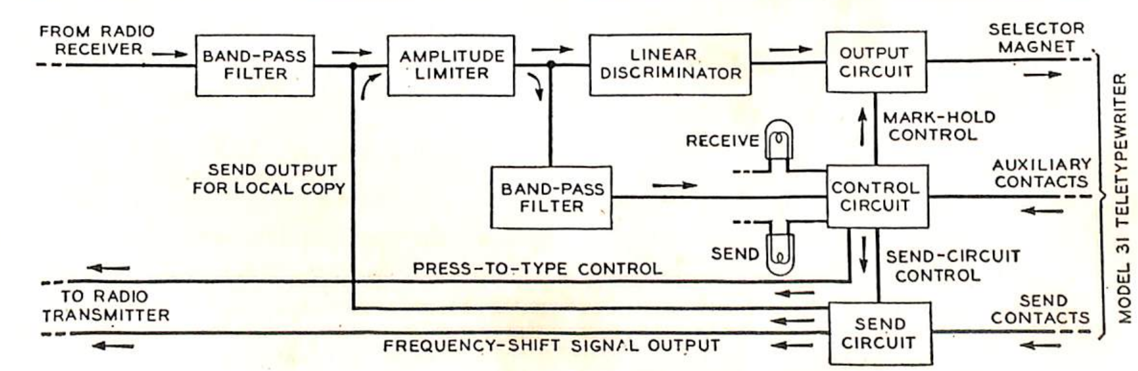
of the teletype characters being transmitted is obtained. During transmission, the auxiliary contacts of the teletypewriter close during each character and, operating through the control circuit, cause the press-to-talk control circuit of the radio transmitter to close at the beginning of transmission and remain closed as long as at least one character is sent every five seconds.

Release of the mark-hold circuit during a receiving condition causes a green-capped "receive" lamp to light. At the same time that the marking hold is released, the sending control circuit is disabled to prevent accidental operation of the keyboard from interfering with the incoming signals. During the transmitting condition, a red-capped "send" lamp is lighted and the circuit for lighting the "receive" lamp is disabled.

When signals are being received, the marking and spacing tones, together with the important side-band components resulting from signaling, are passed by the input band-pass filter to a fast-acting amplitude-limiting circuit and applied to a frequency-discrimination circuit. The output of the discriminator circuit is a positive voltage for marking and a negative voltage for spacing signals which result in a current of 20 milliamperes in the selector magnet for a marking condition and zero current for a spacing condition. The output of the amplitude limiter is also applied to the "mark-hold" circuit. The marking elements of the first teletype character to be received cause the marking hold on the output circuit to be released so that subsequent signals may pass through the output circuit to the printer selector magnet.

The primary source of power for the converter-control unit and the Model 31 teletype is the 26.5-volt battery commonly used in airplanes. Plate voltage supply of +250 volts for the converter-control unit is normally obtained from a generator winding on the teletype driving motor. This high-voltage supply is also used for an electronic speed regulating circuit that is incorporated in the printer.

Tubes having 6.3-volt heaters are used in the converter-control so that this unit could be adapted for vehicles having a 6-volt battery by reconnecting the filament circuits. A vibrator type high-voltage supply circuit operating from 6-volt battery has been constructed for supplying plate voltage to the converter-control unit.



Block schematic of a telegraph terminal

The Model 31 teletype printer is only 10½ inches high, 10 inches wide and 13½ inches deep, and weighs only 24 pounds. The converter-control unit is 5 inches high, 7 inches wide and 9 inches deep, and weighs 8 pounds. This makes it possible to provide teletype service over existing press-to-talk radio-telephone circuits by adding less than 35 pounds to the weight of the communications equipment. No modification of the radio-telephone equipment is necessary. An additional feature of importance to aircraft operation is the fact that this equipment will operate in any position, even upside down.

With teletype operation, a printed record of all communications is available at all stations in the network. Messages may be handled easily and accurately by inexperienced personnel, and are received without attention from the operator. Since a standard teletype code is used, messages may be sent from any other teletype station such as a land-wire "weather" network. In international service, code groups of teletype characters could be standardized to cover all routine phases of weather reporting, take-off, landing and other instructions to be given to the plane.

The new lightweight terminal equipment has special application to other fields in which the large size and weight of standard equipment has prevented the use of teletype methods of operation. These fields include mobile service to trucks, cars and harbor craft and military applications to landing operations and forward command posts of advanced echelons of a battle force. Of particular importance in these uses is the advantage of making a record of instructions or other data without continuous attention from an operator. Also of importance is the fact that messages may be handled easily and accurately by inexperienced operators.

Ship Electronic Inventory Report

The following questions on the Ship Electronics Inventory Report have been submitted to the Bureau. They are published here, together with the answers, so that other activities may be able to use the information:

1—Are inventories required for inactivation vessels?

Answer: Yes. However, because the Sixteenth and Nineteenth Fleets had already installed a fairly effective system of making inactivation reports, it was not desired to include inactive ships at this time. The equipment installed therein will be used in the Bureau's I.B.M. inventory system.

2—Should equipments modified to a later type be listed as a new installation? For example, should an SG-1b Radar when modified to an SG-1e be listed as a new installation? If so, would the SG-1b be listed under removals?

Answer: When modification changes the equipment to a later type, such as the SG-1b to an SG-1e, the information should be listed as a new installation of the SG-1e and listed as a removal of the SG-1b.

3—Should the relocation of a major unit of an equipment from one compartment to another be listed as an installation and a removal?

Answer: Yes.

4—Should a special piece of test equipment that comes with a specific equipment be listed separately under test equipment? (For example, the LAD included with an SP Radar).

Answer: Yes.

5—Should voltage-regulating transformers and line transformers be listed under power supplies?

Answer: Yes, unless this particular item is an integral part of the equipment.

6—Should items such as stable elements, synchro amplifiers, step-by-step converters, etc., when used exclusively with electronic equipment, be listed?

Answer: Yes.

7—Should an equipment that has only its major unit replaced be listed as an installation and removal?

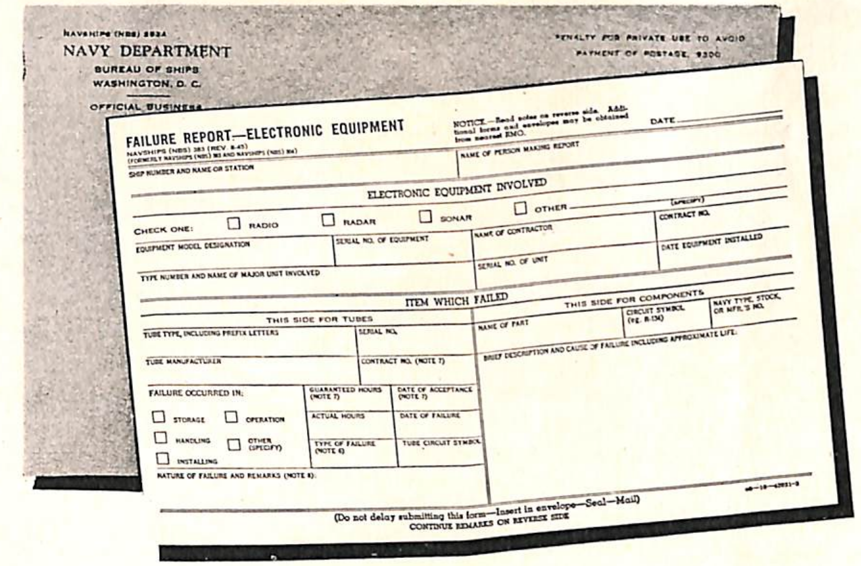
Answer: No, unless change involves use of new serial number, which should be listed on the I.B.M. inventory.

8—Should items that ordinarily would be listed as separate units, when included as part of a major unit, be listed separately? For example: A 23285 remote control unit comes with the MN-5 equipment. In addition an extra 23285 unit is installed. Should both of these remote units be listed or is the one that comes with the equipment considered as part of the MN-5 installation?

Answer: Items which are used with, but are not part of, the equipment should be listed separately. Here both of these remote units should be listed separately.

9—Shall inventory be taken on vessels in shipyard for fitting-out period?

Answer: Yes. Inventory should show equipment on board upon completion of fitting-out period.



FORMS AVAILABLE

The "technician's lifeline", as we call the new failure report card NBS-383 (described in the September ELECTRON) must be a pretty scarce item out in the fleet. The bureau is continually receiving failure reports recorded on improvised facsimiles of Form NBS-383. These reports do the job and the bureau appreciates the effort expended in their preparation. But it seems like a lot of wasted effort as the new official forms are available on request in any quantity desired. If your supply of these forms is low or depleted get yourself a Stock Form and Publications Requisition (NAVGEN-47), fill it out including identification number (NBS-383) and description (Failure Report—Electronic Equipment), and forward it to the nearest Publications and Printing Office. These offices have been set up in all the continental Naval Districts and also in the Fourteenth District at Pearl Harbor. See the article on page 14 of the July 1946 issue of ELECTRON for the correct mailing addresses. The offices in the First and Seventh Naval Districts are not yet complete so, for the present, vessels or activities in these localities will draw on the main East Coast stocking activity at Williamsburg, Virginia.

The above activities are the official stocking centers for forms, and it is requested that the requisitions be submitted directly to them. Requests sent to the bureau will cause unnecessary work and delay as they will then have to be rerouted to the appropriate activity for action. Remember that the bureau does not stock these forms. The form NAVGEN-47 should be available at your own supply office but if not you may also request them from the same activities.

QFA-SERIES TARGET SPEED

In view of the high speeds which submarines of the future will be capable of attaining, and the attendant higher attack speeds that will be required of anti-submarine vessels, it is desirable that applicable sonar equipment be modified to allow for these increased speeds. The Models QFA-5/-6 Attack Teachers were both provided with a 25-knot maximum submarine target speed by the manufacturer. Modification in the field for speeds in excess of this is not practical and would require alteration of the gearing. The Models QFA/-1/-2/-3/-4, however, were provided with a 15-knot maximum submarine speed, and can readily be modified for a 25-knot speed.

The modification consists of reducing the series resistance in the current circuit of the target coordinate motors, so that the current is increased for a given potential applied to the complete combination (this potential being full line voltage at maximum speed). The speed indicators are simply wattmeters with one set of coils connected to the line voltage and the other set connected to the variable voltage applied to the coordinate motor current circuit. Full scale on the wattmeter is, by calibration, the deflection when full line voltage is applied to the latter set of coils. Also, as a part of this modification, the dial of the wattmeter must be altered by substitution of a new scale.

Full instructions and authorization for making this modification will soon be released as "Field Change No. 1—QFA/-1/-2/-3/-4—Modification to Permit Submarine Speeds Up to 25 Knots."

RDZ TUNING INDUCTANCE

In the early production of model RDZ equipments the manufacturer had not developed accurate jigs for adjusting the tuning inductances prior to their actual attachment to the variable tuning gang. As a consequence, certain of these equipments in the group having serial numbers 1 through 500 have reached the field with the mixer tank slightly on the high-inductance side, which results in a loss in gain at high ambient temperatures. This condition appears to be most noticeable at approximately 258 megacycles.

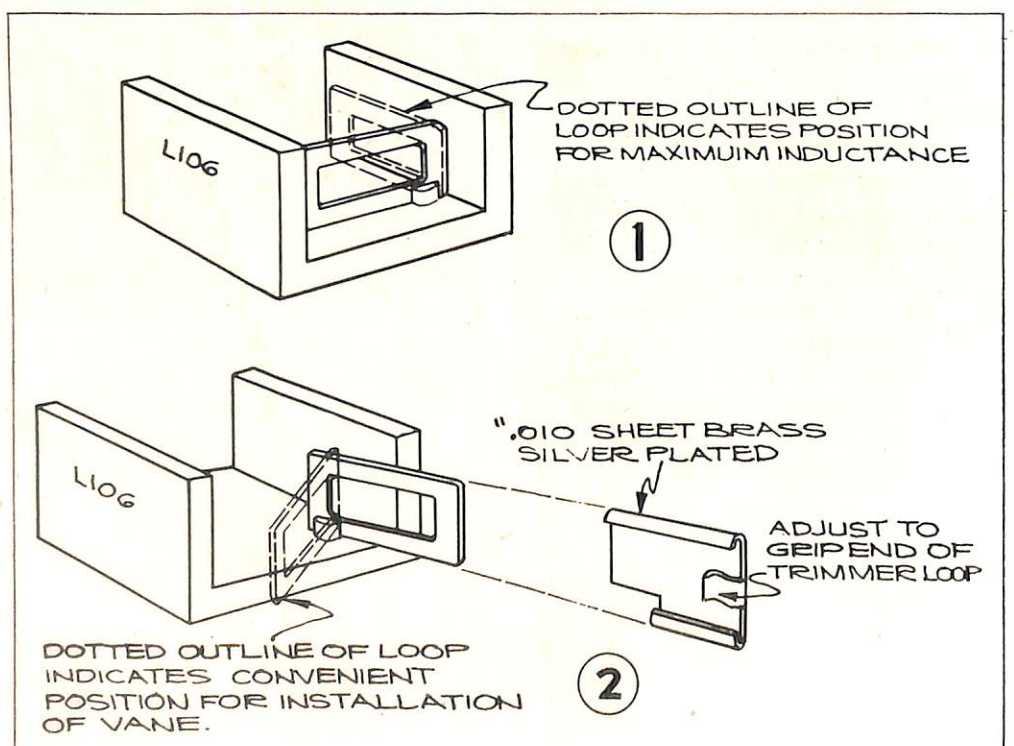
In order to decrease the tuning inductance in the mixer tank and thereby minimize the loss in gain at high ambient temperatures, it has been found necessary to insert an auxiliary absorption loop in the mixer tank of most of these equipments. This was necessary because investigation disclosed that the inductance trimmer was already set in its minimum inductance position, as shown in figure 1.

All model RDZ receivers in this group should be checked, and the following change accomplished in those that need it. First check the alignment of the receiver carefully in accordance with the procedure outlined in the instruction book. Then remove the shield plates from the last multiplier mixer compartment. Determine by inspection the setting of the mixer inductance. If this trimmer is at the minimum inductance setting (see figure 1) or within 30° of minimum (inside the inductance), it will be necessary to install the absorption vane on the trimmer as shown in figure 2. If the trimmer setting is 30° or more from the minimum position, the absorption vane is not necessary.

This change is known as "Field Change No. 2—Model RDZ Equipment—Adjustment Of Tuning Inductance". Field change kits are being made up in the Bureau of Ships and will be forwarded to the various Electronics Officers for distribution to the field in the usual manner. Full instructions will accompany the kits, and it will require approximately two hours to accomplish the change.

TDZ INSTALLATION

The attention of all activities concerned with the installation of Model TDZ transmitting equipments is invited to the fact that equipments bearing serial numbers 1 through 100, 107 through 109, 111, 113 through 124, 128 through 134, 136, 137 and 140 are not suitable for shipboard installation. Accordingly, activities in possession of any of these equipments are cautioned not to install them in vessels unless specifically authorized to do so by the Bureau of Ships. Model TDZ equipments, other than those listed above, have been distributed in sufficient quantities to meet present requirements.



Modification of Model RDZ mixer inductance trimmer to reduce the value of the tuning inductance.

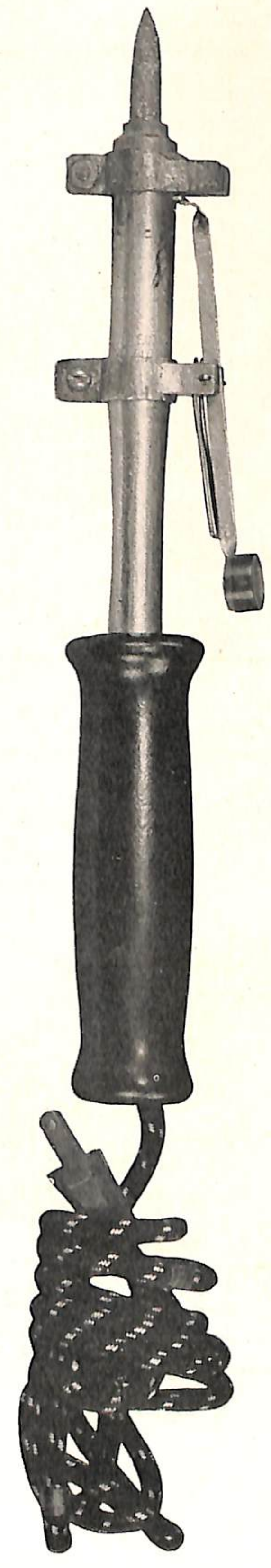
Stripping Insulation

■ The material laboratory of the New York Naval Shipyard, after conducting a series of tests on the preparation of telephone-type cable conductors, recommends the use of the following methods which are considered to be the safest and most practical for stripping insulation from the unit conductors of this type of cable.

The preferred method is applicable to both TTHFA and TTHFWA cable and is also satisfactory for fabric-served and resin-insulated wires. It consists of heating the end of the conductors with a match or electrician's alcohol torch and, when thus heated, immediately wiping the insulation off with a rough cloth or cotton waste.

A second method, also applicable to type TTHFA and type TTHFWA cable, entails the use of an ordinary electric soldering iron with a V-shaped brass block mounted directly over the heating unit. A lever arrangement holds the end of the conductor in the notch of the block, as shown in the figure. The conductor is inserted in the heated V, held in place by the lever arrangement, and withdrawn when the insulation is sufficiently heated. The end of the conductor is then wiped clean with a cloth or cotton waste. This method is very desirable where electric service is available, as it eliminates the use of an open flame.

The third and most common of these methods is one in which a pair of short-nosed pliers is used as the insulation remover. It is applicable to type TTHFA cable only. The length of insulation to be removed is gripped between the jaws of the pliers and sufficient pressure is applied to cut the insulation. The wire is then pulled through the jaws of the pliers thus stripping it free of insulation. In the case of enameled wire the conductor may have to be redrawn through the pliers two or three times to entirely clean it. Knives or diagonal pliers should not be used for this purpose.



Addition of accessories to an ordinary soldering iron makes an efficient stripper for enameled wire.

Fire-Control RADARS

Comparison of Characteristics

The Bureau of Ships, in conjunction with the Bureau of Ordnance, has compiled this table of technical and operational information on current and future fire-control radar equipments. Since there is such a large variety of these equipments, there will inevitably be questions as to operating frequency, power output, installation problems, types of guns controlled, etc. These questions confront interested technical personnel, not only about some of the more familiar equipments, but also about comparatively new types which are not yet in production.

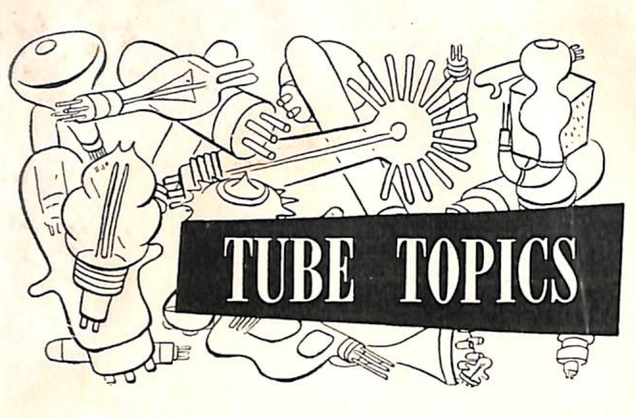
For example, the radar officer on a certain ship learns that he is to receive a new type of fire-control radar at the next yard availability. By referring to this table he will find the answers to many of the important questions associated with pre-installation planning. This table has been prepared with the intent of making available much of the information considered essential to radar personnel who are active in the fire-control program, as well as others who have need of such information in conjunction with strategic or tactical employment of a ship or force.

	Mark 4 Mods 0-1	Mark 8 Mod 2	Mark 8 Mod 3	Mark 12 Mod 0 and 1	Mark 13 Mod 0
Topside Weight	1200	5890	4585	2200	3100
Lower-deck Weight	1800	1200	1000	2100	3400
Peak Power Output(s)	20 kw	20 to 30 kw	35 to 45 kw	90 to 110 kw	35 to 45 kw
Frequency	700 Mc	3000 Mc	8800 Mc	920 to 970 Mc	8800 Mc
Pulse Width	1.5 Microsec.	0.4 Microsec.	0.3 Microsec.	1.2 Microsec.	0.3 Microsec.
Repetition Rate (PPS)	1640	1500 ±10%	1500 ±5%	480	1800 ±10%
Beam Width—Horizontal Beam Width—Vertical	12 degrees 12 degrees	2 degrees 6 degrees	0.9 degrees 3.5 degrees	10 degrees 10 degrees	0.9 degrees 3.5 degrees
Number of Operators	3	2	2	3	2
Types of Presentation	*A* for ranging, *K* for pip-match	*A* for slow scan, *B* for rapid scan	*B*-type	*A* with notch (*R*), *F* for pip-match	*B*-type
Maximum Range	50 miles	30 Miles	30 Miles	25 Miles	35 Miles
Minimum Range	1,000 Yds.	250 Yds.	200 Yds.	400 Yds.	350 Yds.
Range Accuracy	±40 Yds.	±15 Yds. (±0.1% measured range)	±15 Yds. (±0.1% measured range)	±20 Yds.	±15 Yds. (±0.1% measured range)
Bearing Accuracy	±15′	±7′	±4′	±10′	±4′
Elevation Accuracy	±15′ (above 10°)			±10′ (above 10°)	
Range Resolution	400 Yds.	120 Yds.	100 Yds.	300 Yds.	100 Yds.
Bearing Resolution	10°	1°	0.5°	8°	0.5°
Reliable Range—Aircraft Reliable Range—Surface	40,000 Yds. 30,000 Yds.	30,000 Yds. 40,000 Yds.	30,000 Yds. 40,000 Yds.	45,000 Yds. 40,000 Yds.	30,000 Yds. 45,000 Yds.
Directors Used With	Mark 33—Mark 37	Mark 34—Mark 38	Mark 34—Mark 38	Mark 37	Mark 34, 38, 54
Types of Guns Controlled	5″ 38 Cal.	Main battery	Main battery	5″ 38 Cal.	Main battery
Types of Antenna Scan(s)	Lobe switching 30 cps	±15° at 1.5 cpm or 10 cps	±5° at 10 scans per second	Lobe switching 60 cps	±5° at 10 scans per second

	Mark 27 Mod 0-1	Mark 28 Mod 0, 2, 3	Mark 29 Mod 2	Mark 32 Mod 1	Mark 34 Mod 2-12
Topside Weight	975—Mod 0 1100—Mod 1	453	150	Total installed weight of equipment 350	180
Lower-deck Weight	1350—Mod 0 1400—Mod 1	1800	1850		2150
Peak Power Output(s)	20 to 30 kw	30 kw	25-35 kw	1.0 kw	25 to 35 kw
Frequency	3000 Mc	3000 Mc	9200 Mc	157 to 187 Mc	8800 Mc
Pulse Width	0.4 Microsec.	0.5 Microsec.	0.6 Microsec.	5 to 9 Microsec.	0.3 Microsec.
Repetition Rate (PPS)	1500 ±10%	1800 ±10%	1800 ±10%	500 Max.	1800 ±10%
Beam Width—Horizontal Beam Width—Vertical	8° Mod 0, 4° Mod 1 18°″ 0; 6° Mod 1	6.5 degrees 6.5 degrees	3 degrees 3 degrees	46 degrees 50 degrees	3 degrees 3 degrees
Number of Operators	2	3	2	None additional	2
Types of Presentation	*A* with step (*M*)	*A* with step (*M*) *F*-type	*A* with step (*M*) *F*-type	*L*-type	*A* with step (*M*) *F*-type
Maximum Range	30 miles	20 miles	20 miles	25 miles	20 miles
Minimum Range	400 Yds.	400 Yds.	350 Yds.	1600 Yds.	350 Yds.
Range Accuracy	±15 Yds. (±0.1% measured range)	±15 Yds. (±0.1% measured range)	±15 Yds. (±0.1% measured range)	±250 Yds.	±15 Yds. (±0.1% measured range)
Bearing Accuracy	±10′ ±2.7° on PPI	±15′	±7′	±6°	±7′
Elevation Accuracy		±15′	±7′		±7′
Range Resolution	150 Yds.	150 Yds.	200 Yds.	500 Yds.	100 Yds.
Bearing Resolution	6° (Mod 0) 4° (Mod 1)	6°	2.5°	8°	2.5°
Reliable Range—Aircraft Reliable Range—Surface	30,000 Yds. 40,000 Yds.	20,000 Yds. 30,000 Yds.	25,000 Yds.	30,000 Yds. 30,000 Yds.	20,000 Yds.
Director(s) Used With	F.C. Tower, M.B. Turrets or Director	Mk 33 Mod 0 and 3 GFCS Mk 63, Mod 2	Gunfire control system Mark 57	Radars Mark 4 and Mark 12	GFCS Mk 63—Mod 2 and 6 GFCS Mk 57 Mod 3, 4, 7 and 12
Types of Guns Controlled	Main Battery	5″ 38 Cal.-Mod 0 and 3 Automatic Guns—Mod 2	Antiaircraft		Antiaircraft
Types of Antenna Scan(s)	Lobe switching at 30 cps	Conical scan at 30 cps	Conical—30 cps	Lobe switching at 30 cps	Conical—30 cps

Mark 22 Mod 0	Mark 22 Mod 1	Experimental Data Mark 25 Mod 2	Mark 26 Mod 3-4
725	725	Total weight of top-side and lower deck equipment—6000 lbs.	78
475	475		1044
25 to 35 kw	25 to 35 kw	50 kw	40 to 60 kw
9400 Mc	9400 Mc	8500—9600	3000 Mc
0.5 Microsec.	0.5 Microsec.	0.2 Microsec.	0.5 Microsec.
Same as associated radar	Same as associated radar	1800 to 2200 and random	600 ±10%
4.5 degrees 1.2 degrees	4.5 degrees 1.2 degrees	2 degrees 2 degrees	7 degrees 9 degrees
None additional	None additional	3	1
Intensity modulated	*E* for range and elevation	Range-*A*, *B*, *B′* Brg.-*B*, Elev.-*B′ E*	*J*-Type
20 miles	20 miles	25 miles	15 miles
600 Yds.	600 Yds.	350 Yds.	400 Yds.
	±20 Yds.	±15 Yds (±0.1% measured range)	±150 Yds.
		2-5′ Approx.	
±10′	±10′	2-5′ Approx.	
	200 Yds.	80 Yds.	200 Yds.
0.6° (Elevation)	0.6° (Elevation)	1.25° Approx.	
18,000 Yds. 40,000 Yds.	18,000 Yds. 40,000 Yds.	30,000 Yds.	15,000 Yds. 30,000 Yds.
Radars Mark 4 and 12 on Gun Dir. Mark 37	Radar Mark 12 on Gun Dir. Mark 37	Mark 37	Mark 52
5″ 38 Cal.	5″ 38 Cal.	5″ 38 Cal.	Automatic guns
+6° to −7° (vertical)	+6° to −7° (vertical)	Spiral and Conical	None

Mark 35 Mod 2 Experimental Data	Mark 39 Mod 3	MARINE Mark 20 Mod 1	MARINE AN/MSG-1
6500 (GFCS Mk 56)	120	Total weight of equipment—4575	Total weight of equipment—180,000
4500 (GFCS Mk 56)	1700		
50 kw	25 to 35 kw	100 kw	250 kw
8500 to 9600 Mc	9000 Mc	1250 Mc	3000 Mc
0.1 Microsec.	0.5 Microsec.	1.6 Microsec.	0.2 or 0.8 Microsec.
3000±5%	1800 ±10%	255 PPS	1100 PPS
2 degrees 2 degrees	3 degrees 3 degrees	10 degrees 10 degrees	5 degrees 5 degrees
2	3	3	1—Auto. Track 3—Man. Track
A/R scope, *B* and *E* scopes	*A/R*-type, *F*-type and double-*E*	5″ *A*-type and 2 3″ pip-match	*A*, *J*, *PPI* and 2 for pip-match
25 miles	15 miles	25 miles	40 miles
350 Yds.	350 Yds.	300 Yds.	500 Yds.
±10 Yds.	±30 Yds. (±0.5% measured range)	500 Yds. Absolute 300 Yds. Rel.	25 Yds.
±1.7′	±7′	±4′	±6′
±1.7′	±7′		
50 Yds.	200 Yds.	135 Yds.	25 Yds.
1.5°	2.5°	12.8°	7.2°
30,000 Yds. 30,000 Yds.	20,000 Yds.		
GFCS Mk 56	Gunfire Control System Mark 57		
Antiaircraft	Antiaircraft	Searchlights	90 Millimeter antiaircraft
Spiral (Search) Conical (Tracking)	Conical or elliptical at 30 cps	Conical	Conical



POST-WAR POLICY ON TUBES

The Bureau has revised its system of reporting and disposing of failed electron tubes with the intention of simplifying tube handling both ashore and afloat. Scrap your old methods and turn to on this new system.

As new tubes are received aboard ship they should be checked for obvious breakage or rough handling. If they are received in a damaged condition, do not fill out the failure report form but notify the activity from which the tube was requisitioned and send a copy of the correspondence to the Bureau of Ships, Code 962.

Where feasible check all new spare tubes in a tube tester or in the equipment before they are placed in stowage. Give the large tubes and tubes stocked in small quantities (2 or 3) at least an electrical test for filament continuity and shorted elements. An NBS 383 form must be filled out and sent to the Bureau for each tube that fails aboard ship (except those received in a damaged condition as referred to above) in stowage, handling, installation or in operation.

Incidentally only the new NBS-383 card form is to be used in the future for reporting all tube failures, as the old form "Report of Vacuum Tube Failures—NavShips (250) NBS-304" have been declared obsolete. All copies of this old multiple-copy form should be destroyed and the stock replaced with the new NBS-383 single-card form. A supply of NBS-383 forms may be obtained by requesting them on "NAVGEN 47—Publication and Forms Requisition" from the nearest District Publication and Printing Office. Tenders and Electronics Officers at Naval Shipyards usually maintain a limited stock of these forms and will supply them upon request.

One of the important changes in the tube set-up is the Bureau's present policy of not buying tubes used aboard ship under a service-life guarantee. This step will greatly simplify the tube handling job by doing away with the special reports and holdover periods called for in the regulations set up for these tubes. If you have any tubes which were bought under some of these old guarantees you are now authorized to treat them as non-guaranteed tubes. By the way, while speaking of old tubes being aboard, it may be well to point out that the Bureau has been receiving reports on unused tubes bearing acceptance dates of as far back as 1942 and 1943. This is a bad situation and we would like to bring to your attention the important rule of using the tubes in the order in which they are received. This rule was formulated to offset the inherent tendency of electron tubes to deteriorate with age, and it will be to your advantage to abide by it.

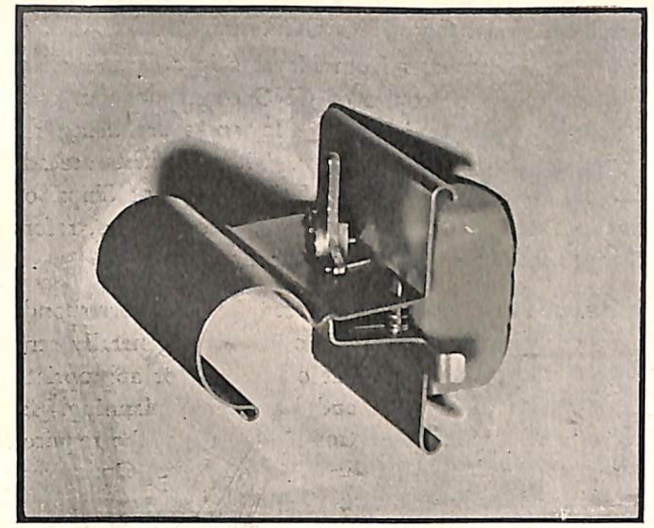
After complying with the report procedure and making surveys necessary to conform with existing regulations, the tubes may be disposed of. The disposal must be in accordance with existing security and salvage regulations unless specific instructions have been disseminated to the field by special correspondence and/or publication in the regular maintenance bulletins.

That's it, as far as the boys afloat are concerned. Nothing to remember but the new NBS-383 card form and the tube-use rule. Shore-station electronics supply officers and Naval inspectors also have a few duties in making this new system a success. The whole story on this new tube system is told in item 46-1954 of the Navy Department Bulletin for 30 September 1946.

DEFECTIVE TUBES

UHF miniature pentode tubes type 9003 manufactured by RCA prior to November 1946 are defective, as they develop positive grid bias with increased periods of operation. The defect, probably due to grid emission, is particularly troublesome in the Navy models MAR and RDR radio equipments, which use these tubes as r-f amplifiers. The tubes develop this trouble in less than 100 hours of operation, and the resulting decrease in bias causes the gain to increase beyond the maximum designed value for a given signal. This results in unstable AVC due to the fact that many tubes have the same supply voltage on their grids. In the MAR equipment the defect also causes a 5- to 15-second period of silence (blocking) when the equipment is switched from receive to transmit and back to receive. These troubles are not as predominant when similar types of tubes produced by other manufacturers are used.

To eliminate this source of trouble in the subject equipments the Bureau of Ships is taking action to curtail the use and purchase of defective tubes of this type in the future. All activities will be instructed to check RCA type 9003 tubes as to the acceptance date on the individual containers. If the date is prior to November, 1946, the tube is not to be used. To assure that defective tubes will not be purchased in the future, JAN specifications for this type of tube are to be revised to include a grid emission test.



UHF crystal oven extractor showing curved gripping edges. Note the convenient handle on the extractor.

UHF CRYSTAL-OVEN EXTRACTOR

Reports indicate that considerable difficulty has been encountered in removing the crystal ovens from models TDZ, RDZ, MAR, and RDR ultra-high-frequency equipments when servicing is necessary. This difficulty is in a large measure due to the tight fit of the oven in its holder, with the attendant problem of getting a grip on the oven so that it can be pulled clear of the equipment.

In order to overcome this difficulty, the Bureau of Ships has procured a quantity of Navy type 10552 crystal oven extractors which will facilitate the removal of these ovens. When the latch on the extractor is in its loosened position, the outer edges of the extractor can be slipped over opposite edges of the oven to be removed. When the latch is moved to its closed position, the edges of the extractor are pulled together tightly against the oven. A pull on the handle of the extractor will now remove the oven.

These extractors are now being shipped with the aforementioned UHF equipments, and a sufficient number of extractors will be stocked at a Naval activity on each coast to take care of the UHF equipments that were shipped before the extractors became available.

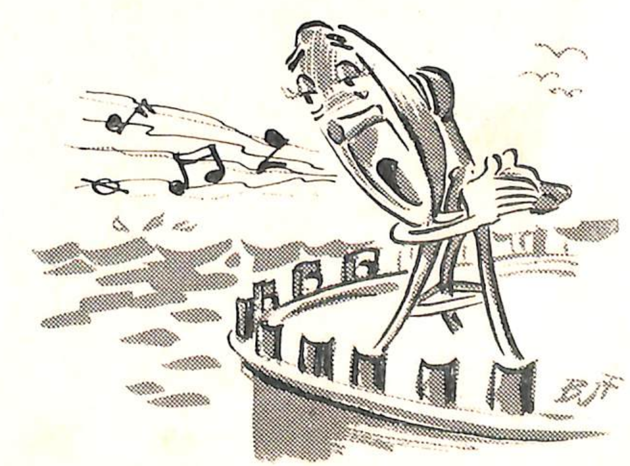
MONITOR SCOPE SWEEP LENGTHS

Reports from the field indicate that an additional sweep of approximately 50 microseconds duration would be desirable on the monitor scope of the XSG-4, XSG-3 and SG-3 radars. This sweep would be used for checking the echo-box ringing time of the complete system when operated near maximum gain. The Bureau of Ships has under consideration the future issue of a field-change kit which would permit the addition of a new sweep length of 50 microseconds to the monitor scope without disturbing the existing sweeps. Due to the time required to procure kits and distribute them to the field, however, the fleet is authorized to convert the present 10-microsecond sweep to a 50-microsecond sweep.

The main uses of the 10-microsecond sweep are to monitor the 1¼-microsecond main pulse and the receiver output immediately following the main pulse. After the 10-microsecond sweep has been increased to 50, the main pulse can be viewed on the 2-microsecond sweep, and the echo-box ringtime on the new 50-microsecond sweep. All that is needed to convert the 10-microsecond sweep to 50 microseconds is to replace the 220-$\mu\mu$f capacitor C-317 with a 1500-$\mu\mu$f $\pm 5\%$ capacitor, and alter the sweep range scale accordingly. After the modification has been made, it should be recorded in the appropriate log.

RADCM ANTENNA PERFORMANCE

It has come to the attention of the Bureau of Ships that some of the RADCM CAGW-66132 stubmast antennas have reached the fleet with two coats of Navy light grey enamel applied between the termination of their metal sheath and the coaxial conductor located on the end of the mast. In other cases, fleet maintenance crews have painted this section of the antenna. The presence of lead-base paint on this section under conditions of high humidity results in lowering the antenna-to-ground resistance, with a resultant loss in sensitivity of the antenna. In order to correct this condition the enamel paint should be scraped off and the phenolic section covered with two coats of grey spar varnish. This should effect an improvement in performance as soon as accomplished.



SG BEARING ERROR

A 7° bearing error has been reported in SG-3 and SG-4 radar installations by installation and maintenance personnel in the field. This error is probably the result of a slight misalignment of the 1-speed synchro, B-1312, with respect to the 36-speed synchro, B-1311. The same trouble has been encountered in the final test department of the manufacturer while running on relative bearing and was corrected by proper re-alignment of these antenna synchros. Investigation has revealed that there seems to be a possibility of slight phase differences between ship's OSC and the reference voltages of the radars in relation to the corresponding signal voltages. Even though the synchros appear to be properly aligned for satisfactory operation on relative bearing, it is possible that the relative alignment for OSC operation may be in error to the extent of allowing the 36-speed synchro to lock in on a bearing about 6° or 7° removed from the lock-in point on relative-bearing operation. It is recommended that any installation evidencing this trouble be checked for synchro alignment as explained in the following paragraphs.

With the TRUE-RELATIVE switch (S-801) in the relative position, carefully align the synchro system as outlined in the instruction book, Ships 367-A, pages 7-2, 7-3, and 7-4, adjusting for the minimum 1-speed error voltage (sum of error voltage plus bucking voltage).

This switch should then be placed in the TRUE position and the 1-speed error voltage noted when the antenna comes to rest. This voltage should be measured in the Ant. Control Unit from tap 3 on the secondary of the bucking transformer T-1210 to terminal 64 on terminal board E-1210, and should be nearly the same as that found in the preceding paragraph. If it is not, rotate the 1-speed synchro (B-1312) very slowly and carefully until the error voltage is minimum, noting the amount of rotation. Now turn the switch back to RELATIVE and re-check the 1-speed error voltage, which should now be greater than the first measurement. Rotate the 1-speed synchro, B-1312, until this error voltage is reduced to about half-way between the two RELATIVE 1-speed voltages found. Next check the error voltage when the switch is in TRUE position. Continue the above steps, cross-checking until the 1-speed error voltage obtained is nearly equal at both positions of the TRUE-RELATIVE switch.

REQUESTS FOR CNO CORRESPONDENCE

Numerous requests from Naval shipyards and other field activities for copies of CNO correspondence concerning shipboard electronic allowances are being received by the Bureau of Ships. These requests are addressed either to the Chief of the Bureau of Ships, or to the Chief of Naval Operations, who, in turn, refers them to the Bureau of Ships for action.

Attention is invited to the fact that CNO correspondence relating to shipboard allowances is generally sent only to the material Bureaus concerned for appropriate coordination of material and installation planning. In the case of shipboard electronic allowances, the requirements as transmitted by the Chief of Naval Operations are stated broadly in terms of military and operational characteristics. The Bureau of Ships interprets and translates these requirements into specific allowances and promulgates the new allowances through the medium of the Electronic Equipment Type Allowance Book (NavShips 900,115). When necessary, in order to avoid delay in initiating the development of installation plans, this information is forwarded by separate correspondence direct to the planning agencies concerned, prior to its publication in NavShips 900,115.

Many factors involving such things as the availability of equipment, the technical and physical characteristics of proposed new equipment under development, the effects of the new allowances on additional power requirements, weight and space allocation, and weight and moment compensation must be taken into account before allowances are finally established. Accordingly, it is not the policy of the Bureau of Ships to forward basic CNO directives of a generalized nature covering electronic equipment type allowances to field activities, since to do so might lead to confusion. This article is written in the hope that it will eliminate further requests from field activities for copies of CNO correspondence intended primarily for Bureau of Ships action.

RADAR

This is the final installment of a comprehensive story on Radar, by Dr. Edwin G. Schneider, appearing in four consecutive issues of ELECTRON.

RADAR SYSTEMS GENERAL DESIGN CONSIDERATIONS

The first step in the design of a radar system is to study the requirements of the particular application. Some of the major items to be considered are the range, vertical coverage, accuracy of determination of target position, weight and size limitations, radio frequency, and presentation of data. Since several different methods may be used to accomplish practically the same end result, the final choice is usually made on the basis of compromises between these factors. The following discussion of radar systems will be far from a complete survey of all existing sets and, furthermore, will not attempt to describe any one system in full detail. The emphasis will be on the reasons for the choice of design rather than on detailed description.

AIRCRAFT SEARCH SYSTEMS

The AN/TPS-3, as shown in figure 78, is a "lightweight" radar set used to give air-raid protection to troops on a beachhead. This set was designed to guide fighter planes to intercept raiding aircraft; therefore, a range of at least 60 miles on a single fighter was considered necessary, and coverage to 30,000 feet was desired. The maximum allowable weight including two gasoline-driven generators was set at 2000 pounds. In order to save transformer weight, a prime-power frequency of 400 cycles was used. The indicators were placed directly under the antenna so that minimum lengths of cable are needed and so that the operator may turn the antenna by a simple hand crank. A frequency of 600 megacycles was chosen because calculations showed that the desired coverage could be obtained by a

FIGURE 78—*AN/TPS-3 set placed on tower to clear surrounding obstacles.*

10-foot paraboloid with its center 12 feet above the ground. Weight and windage are reduced by using wire screen to form the paraboloid. By using ground reinforcement, the lowest lobe gives good coverage up to the desired altitude at the cost of blind regions at higher angle; but because a 20-foot-diameter antenna would be needed to obtain the range performance without using ground reflection, the lobes are a necessary evil. This use of ground reflection also makes the set unsatisfactory in mountainous country where a flat reflecting surface cannot be found. Echoes from the mountains would make the set practically useless in rough terrain, so this lack of a flat surface is not considered a serious drawback. A rotary spark-gap modulator was chosen as the lightest available type, the gap being mounted on the generator shaft. The pulse-repetition frequency was selected as 200 cycles in order to utilize alternating-current resonant charging of the pulse-forming network, the discharge taking place on alternate cycles. A PPI was selected for the main presentation because an undistorted map picture is required to direct fighter planes. An A-scope was also incorporated but is more often used as a test instrument than as a radar search presentation. Under heavy air traffic conditions, a single PPI is often inadequate to handle the traffic; but, since minimum weight of the set and size of the operating crew were the prime considerations, the components were designed to be as light and simple as possible and yet meet the essential military requirements.

The opposite extreme in air-search sets is the AN/CPS-1, which is commonly called MEW (microwave early warning). A solid search range of 150 miles on heavy bombers above the horizon and below 40,000 feet was requested. No limitation was placed on weight and size; but, since the antenna was required to withstand a 125-mile-an-hour wind, a maximum length of 25 feet was set as a practical limit by the mechanical designers. The radio frequency was chosen as 2800 megacycles, because this was the highest frequency allocated to ground equipment on which very high power could be obtained. As discussed in Section IX, both the beam width and the vertical aperture of an antenna for a given coverage decrease as the frequency is increased. Small vertical aperture was considered desirable to reduce wind loading, and the narrow azimuth beam width was needed to locate aircraft to better than 1 degree in azimuth. Since solid tracking was required, no use could be made of ground reflection; and calculations showed that the desired coverage could not be obtained with a single radar system. It was decided, therefore, that two sets should be built on a single antenna mount. An 8-foot vertical aperture was required for the long-range antenna, and a 5-foot aperture for the high-angle coverage. Because of the long, narrow aperture a line feed in a cylindrical reflector was chosen, a parabolic cylinder being used for the main beam and a "cosecant-squared" reflector to spread the energy to high angles for the upper beam. These two antennas were placed back to back, as shown in figure 57, to reduce windage. (It would have been better from an operational point of view if the two beams had been pointed in the same direction so that the video outputs of the two sets could have been combined on a single indicator.)

In order to simplify the radio-frequency system, the modulator, transmitter, and receiver were placed on the antenna and rotated with it. This avoided the necessity for radio-frequency rotating joints, which may introduce power loss, and allowed slip rings to be used to carry all voltages through the antenna axis. A rotary gap modulator was chosen because of light weight and simplicity of maintenance, since it was to be mounted on the antenna. Wave guide was chosen because of the high power (1000 kilowatts) and frequency.

A large number of indicators was provided because the set was to be used for reporting positions of large numbers of aircraft to an air-warning center as well as to control aircraft in flight. The B-scans, which display a limited section of the range scale and of the azimuth angle, are used to divide the area covered by the set, as indicated in figure 79. Since these indicators are of the type sketched in figure 72(b), the area covered by a given tube can be changed quickly. A PPI may be used as shown to cover a low traffic area. The division of area among the scopes is made on the basis of traffic, so that no one operator has more planes to report than he can handle. For control of aircraft, to intercept enemy planes, or to bring aircraft over a point on the ground, PPI tubes are provided. In this set every attempt has been made to provide maximum flexibility.

The cost of the performance and flexibility of the MEW is about 30 tons in weight and an operating crew of about 300 men, as compared with the AN/TPS-3, which weighs 1300 pounds and requires a crew of about 20 men. On the other hand, considerable advantage is gained by having all of these functions in a centralized spot. Since several AN/TPS-3 sets require a central coordinating organization to maintain on over-all air traffic picture and to assign raids to a given set, the apparent ratio of 15 to 1 (based on manpower required) does not give a true picture of the relative costs and values of the two sets. Furthermore, the solid coverage and the greater angular accuracy of the MEW makes the manpower basis of comparison a minor factor. These two sets were chosen as representing extremes. Many other sets have been built and used which fill intermediate requirements. On the other hand, these two extremes have their faults, and should not be considered as perfect answers, even for the purposes for which they were designed.

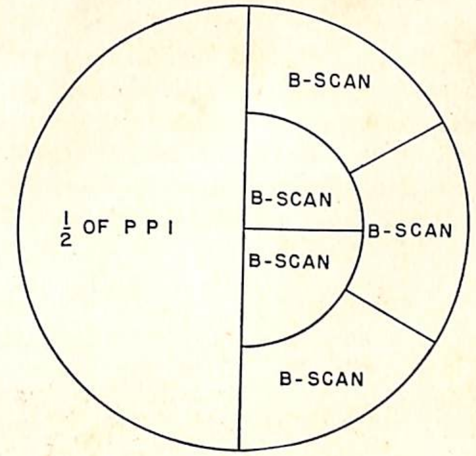


FIGURE 79—*Possible scope coverage*

HEIGHT FINDERS

The class of set discussed in the section on general design considerations shows only the range and bearing of the target and must, therefore, be supplemented by a height-finding radar.

The simplest height finder, from a technical point of view, is illustrated by the AN/TPS-10, as shown in figure 80. The antenna, which is continuously rocked in elevation by a motor, is turned by hand to point in the direction of a target discovered on a search set such as the AN/TPS-3. As the beam sweeps vertically across the target the echo appears on a range-height indicator, the height being read by noting the position of the center of the signal on a calibrated scale.

The antenna is 10 feet high and 3 feet wide, and is fed by a horn on the end of a wave guide. Since the set operates at 3 centimeters, the beam is about 0.7 degree high and 2 degrees wide. The 3-centimeter wavelength was chosen so that a very narrow vertical beam could be obtained with a reasonable size of antenna. The horizontal beamwidth had to be wide enough to make the target easy to find, and yet the antenna gain had to be great enough to give the desired range of 50 miles on a medium bomber. Since the horizontal aperture affects these two antenna characteristics in opposite directions, the 3-foot antenna width or 2-degree beamwidth represents a compromise.

This set may also be used for aircraft search if the azimuth rotation is controlled by the elevation rate to

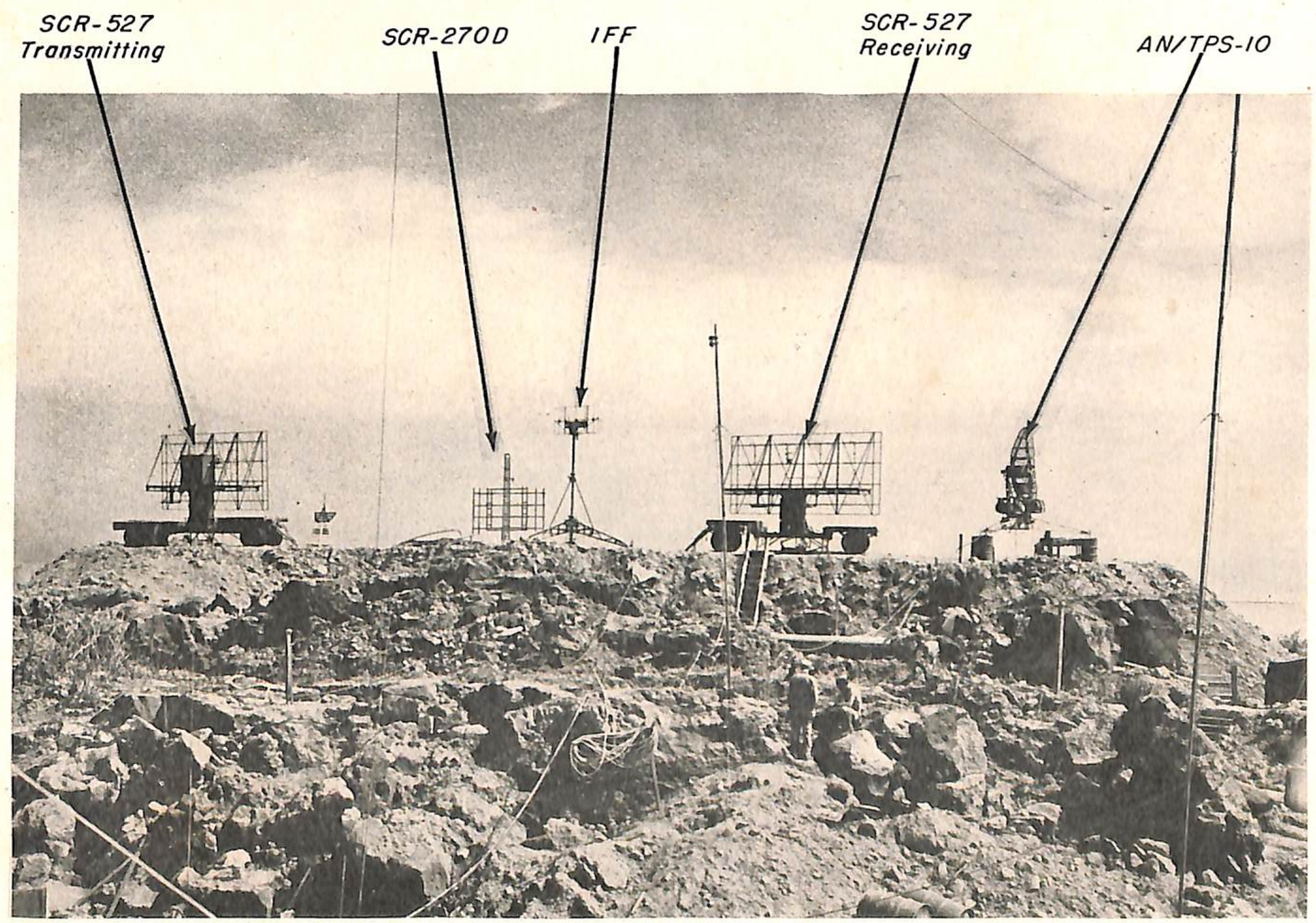


FIGURE 80—*Radar on Iwo Jima.*

give a saw-tooth scan, as discussed in paragraph 8 of Section IX. Since the elevation-scan rate is low, less than 2 cycles per second, a PPI presentation of the signals is very unsatisfactory because of the flash which occurs when the beam crosses and recrosses the target in elevation. On a search set, aircraft may be lost because the echo from the target and a hill at the same range are received simultaneously, the target echo being buried in the signal returned by the ground. Therefore, if a PPI is used with the AN/TPS-10, the echo may be masked by the afterglow of the ground return on the PPI. On the RHI this masking does not occur because an aircraft appears above the mountain on the tube. Therefore, the AN/TPS-10 offers one method of locating aircraft in mountainous country. It would be improved for this purpose, however, if the elevation-scan rate were increased.

A second method of height-finding is used in the SCR-527 (see figure 80). This set operates at 200 megacycles and uses ground reflection to obtain the range performance. When the set is perfectly sited, the vertical lobe pattern is the same at all azimuth angles. Since the ground must be level to within one foot for a radius of one-half mile around the antenna, it is not often that this uniformity of lobe pattern with azimuth angle is achieved. The antennas are arrays of dipoles, 8 wide and 4 high, mounted just a few feet above the ground. Separate transmitting and receiving antennas are used. By a switching device, the height of the center of the radiating area of the antenna can be changed by alternately feeding the top and bottom rows of dipoles. This effective change in antenna height shifts the lobe positions. Height is then measured by estimating on an A-scope the ratio of the signals received on the alternate antenna lobe positions. The square wave which switches the antenna is applied to the horizonal deflection of the A-scope to make the signals on alternate positions appear side by side. The signal ratio is converted to height by use of a calibration chart. If the radar site is not perfect, the calibration will vary with the azimuth angle.

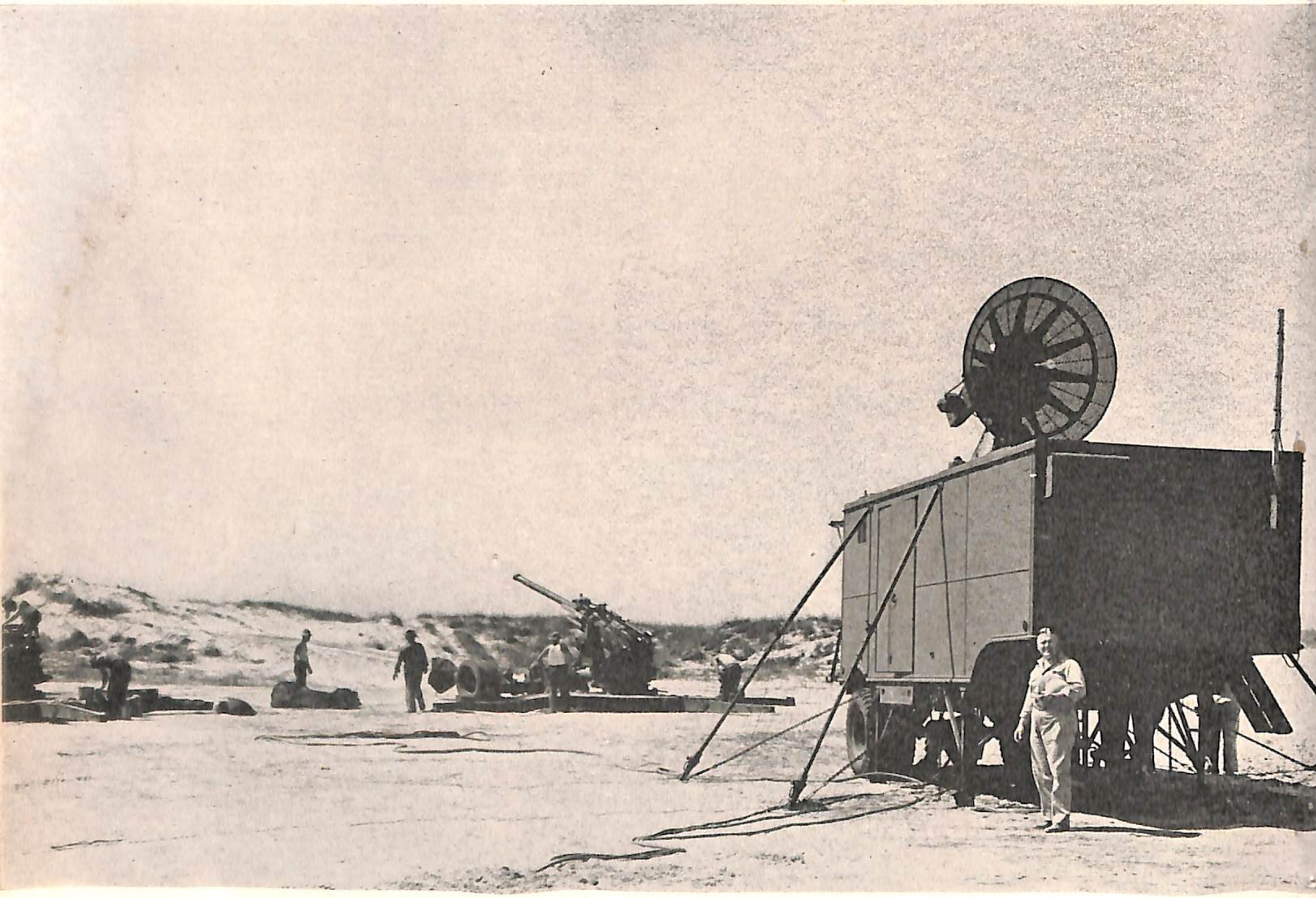


FIGURE 81—*SCR-584 with gun battery.*

A PPI is used to obtain range and azimuth. The SCR-527, therefore, gives complete co-ordinates of the target if properly sited to read height.

The SCR-584 shown in figure 81 also uses lobe switching to determine height but does not depend on estimation of signal ratios. Since this set was designed to aim antiaircraft guns at a target which could not be seen visually, the whole design of this set was guided by the need for accuracy in measuring the target position. For the operating frequency, 2800 megacycles was chosen because a narrow beam was required, and at the time of the design this was the highest frequency at which appreciable transmitter power was available. A stub-supported coaxial transmission line was used largely because wave-guide techniques were not well developed. A 6-foot paraboloid was chosen as a convenient antenna reflector for truck mounting. This gave considerably more gain that was needed to meet the required range performance and gave a sufficiently narrow beam, 4 degrees, to obtain the required average angular accuracy of 0.1 degree when used with a conical scan.

The antenna turns in both azimuth and elevation so that search may be carried out by using a helical scan. The signals are presented on a PPI as well as on a J-scan which covers the full range of the set; another J-scan covers any desired 2000-yard interval of range. When a target is located, the helical scan is stopped; and the antenna is pointed at the aircraft by using hand controls which operate servo drives to position the reflector.

The cross hair for measuring range on the full-scale J-scan is then put in position over the signal. This automatically sets the blanking gate to the proper range to allow the same signal to appear on the expanded J-scan, as described in paragraph 3 of Section X. Further adjustment of the hand crank places another crosshair over the front edge of the signal on the expanded J-scan. The target range can then be read from dials with an accuracy of better than 50 yards. In order to achieve this accuracy, the range circuit and transmitter pulse rate are controlled by a crystal oscillator.

By means of a phase-shift delay circuit a narrow gate is also positioned by the range handwheel. This gate is applied to a channel in the receiver different from that feeding the signals to the scopes and permits only the signal under the range cross hair to pass through the gated channel. This selected signal is used to automatically center the conical scan on the target. A reference generator attached to the rotating dipole feed gives a voltage in phase with the motion of the beam on the conical scan. This voltage is used to switch the signal from the narrow-gated receiver into four channels corresponding to the up, down, right, and left positions of the beam during a revolution of the conical scan. If the elevation angle of the antenna is wrong, the average direct-current output voltages of the "up" and "down" channels will not be equal because at one position of the conical scan the beam will be pointed more directly at the target. When the antenna is turned to equalize these two voltages, the elevation angle is correct. A similar equalizing of the "right" and "left" voltages brings the target to the center of the conical scan. These voltage differences may be displayed on meters with the antenna adjustment made manually by the operators; or may, as in the normal use of the SCR-584, be fed into the servo-control system as an "error voltage" to keep the antenna pointed automatically at the target.

With the antenna accurately pointed at the target in elevation, the height of the target may be computed from the elevation angle and the slant range. Automatic height computers operating on principles similar to those used in producing RHI sweeps are in use in the SCR-584.

SHIPBORNE SETS

Radar sets for shipboard differ from ground radar sets in only one major respect. Since the ship changes course and also rolls and pitches, the antenna must be stabilized.

Azimuth angles should be measured with respect to north in order to correlate readily the radar echoes with a map. There are two methods of north stabilization which may be illustrated by imagining a ground set placed on shipboard with the zero azimuth angle corresponding to the antenna pointing directly forward. When the ship is headed north, a PPI on this set will have north at the top of the tube, the normal orientation for reading a map. Now if the ship swings to a course due east, the top of the PPI will be east since the signals from straight ahead of the ship will appear at the top of the tube. If the whole PPI chassis is rotated through 90 degrees in a clockwise direction, north may again be brought to the top of the tube. The same effect can be obtained by rotating the PPI azimuth-sweep coils or the data take-off device on the mount. This general method of correction is known as "data stabilization" since only the data are corrected, the antenna still swinging with the ship.

Although data stabilization could be carried out by a man watching a compass, it is more satisfactory to use a gyrocompass which turns a selsyn as the ship's course changes. The output of this selsyn is then used to operate a servo unit which either mechanically rotates the azimuth data take-off or operates a phase-shifting device in the electrical circuit controlling the data output, thereby introducing the proper correction. For example, if the PPI is selsyn or servo driven, introducing a 90-degree phase shift between the two selsyns will cause the follower to rotate 90 degrees.

If the antenna of this data-stabilized system is stopped and pointed at some target, the azimuth data will always be correct; but the operator will be kept busy turning the hand control to keep the antenna on target as the ship changes course. This turning of the hand wheel can again be done by a servo drive operated from a gyrocompass. In order to avoid having the hand control continually whipping around and to allow the operator to change the antenna position, the ship's motion is normally put into the antenna-drive hand control by a differential. This enables the ship's motion and the hand drive to be added without interfering with each other. The differential may be a mechanical gear system or an electrical circuit, depending on the means used to control the antenna. With this "north-stabilized antenna" the ship turns without rotating the antenna with it. Therefore, the data stabilization previously inserted must be removed to give a correct presentation. A ship system should have either data or antenna stabilization, but not both.

Another stabilization problem arises from the roll and pitch of the ship. For a long-wave set in the 200-megacycle region which uses water reflection to obtain its vertical-coverage pattern, the roll and pitch of the ship has little effect other than causing a slight change in antenna height. On the other hand, when the vertical beamwidth of a radar set is narrow, the rolling of the ship may swing the beam off the target in the vertical direction. Stabilization in elevation is controlled by a "stable-vertical" gyro which introduces corrections in the antenna-elevation-control system for the roll and pitch of the ship. In order to obtain complete correction, two elevation axes at right angles must be provided. Sufficient stabilization for many purposes may, however, be obtained by a single elevation axis.

Since ship navigation is certain to be an important peacetime use of radar, a brief discussion of the probable form of such a set is in order. Only a small antenna gain is required, because the range at which other vessels and land may be seen is usually limited by the horizon rather than by the radar performance. On the other hand, since high resolution and accurate bearing measurements are needed, the beamwidth should be very narrow. In order to obtain a narrow beam with a small antenna, say 2 by 3 feet, the set should operate at 9000 megacycles or higher. Stabilization will also be required. Another advantage of this high frequency arises from the fact that the lobes caused by water reflection lie much closer to the surface than do those of a longer wavelength set at the same height. This improves the signal strength from buoys and small boats. The signals should be presented on a PPI so that a true map picture of the position of objects which cause echoes may be obtained.

AIRBORNE RADAR

Although weight and size, particularly of the antenna, must always be kept in mind when designing sets for ship use, in an aircraft virtually all other considerations play a role secondary to these factors. Light-weight, compact construction is required throughout. This requires the use of light-weight metals such as aluminum and magnesium and a frequency of 400 cycles or higher for the prime power source. Since power costs weight in the form of generators and transformers, every effort must be expended to keep the over-all power consumption to a minimum even to the extent of sacrificing items which would be helpful but are not essential. Furthermore, any safety factor in components costs weight; for example, a transformer or capacitor operated below the maximum rating is less apt to burn out but is larger and heavier than one built for this smaller operating current and voltage.

Because the antenna must be mounted inside the fuselage or in a streamlined housing, the maximum size of the antenna is seriously limited. The antenna may be mounted in the nose or in a nacelle on the wing when it is not necessary for the radar to see behind the plane. From these positions it is possible to scan the forward 180 degrees. To obtain 360-degree coverage the antenna must be put in a blister on the belly. In many cases, provision must be made for retracting this blister when the plane lands.

With the radar competing with other items for allowance of weight and space and for power from the plane's generator, a great deal of consideration must be given to the choice of antenna size, the transmitter power output, and the packaging of the components. As a rule, the installation is more satisfactory if the set is designed to fit the plane because the radar components may then be built to take full advantage of existing space. Even when the set is built for a particular aircraft, extensive modification of the plane may be necessary to make the installation.

The problems of airborne-radar design may be illustrated by two navigational sets. The AN/APS-10, as shown in figure 82, was designed as a navigational set. Since installation in fighter planes was anticipated, the total weight limit was set at 100 pounds. In order to be

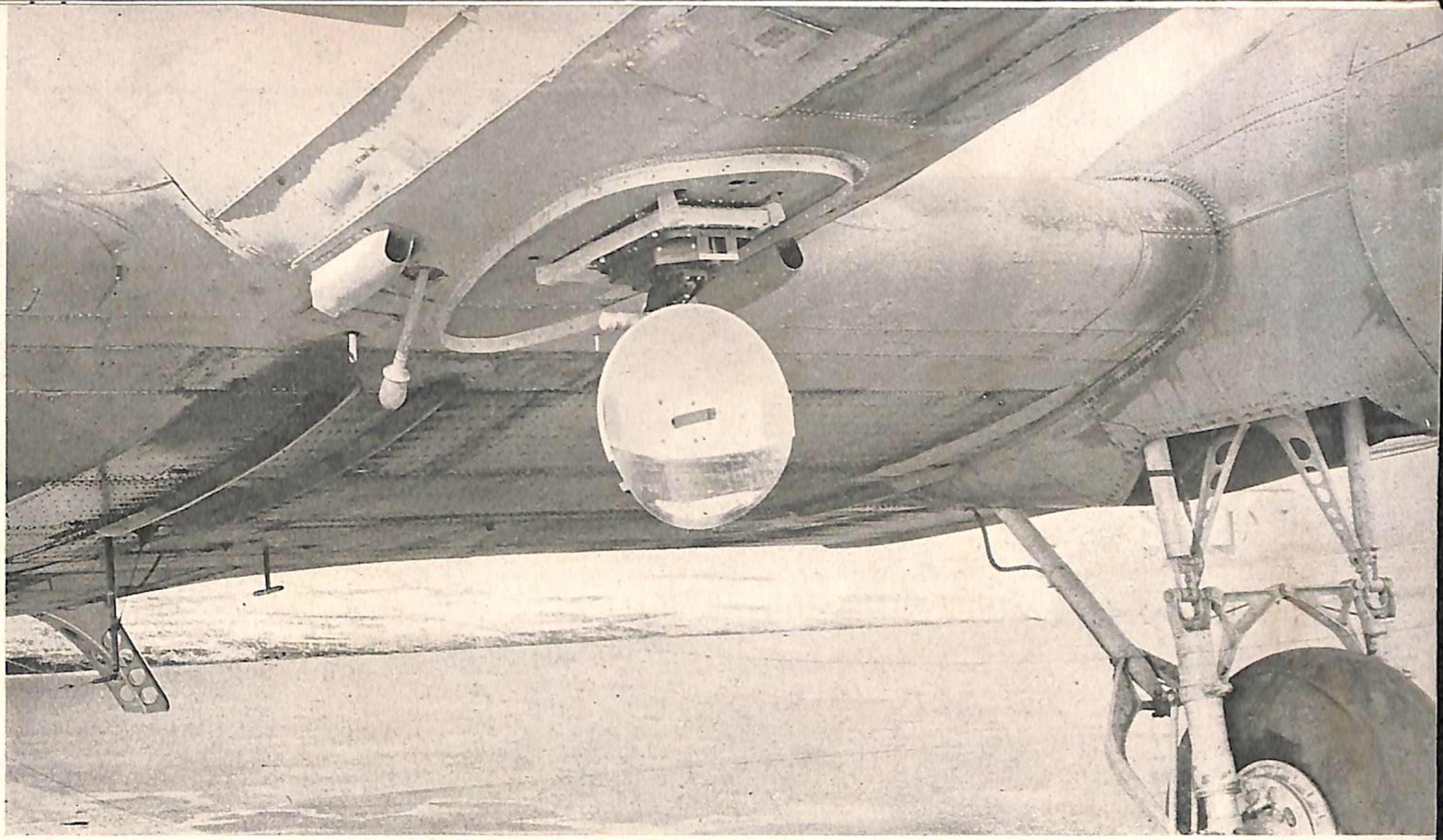


FIGURE 82—*AN/APS-10 antenna on C-47, antenna housing removed.*

useful for navigation, a range on land masses of at least 50 miles is needed. This is equivalent to a range of 3 to 5 miles on an aircraft. Furthermore, the beam must be narrow to allow rivers and other prominent landmarks to be seen. On the other hand, the largest antenna which may be fitted into a fighter is about 18 inches. At the time this set was designed, 3 centimeters was the highest usable frequency and was, therefore, used. The final design uses a peak output power of only 8 kilowatts, although the magnetron is capable of giving 50 kilowatts with a heavier modulator. The signals are displayed on a 5-inch PPI placed in front of the pilot. The total power consumption of the set is 500 watts. Although this set meets the requirements for which it was built, the pilots of the Fighter Commands were unwilling to sacrifice 100 pounds of ammunition or gasoline for a simplification of the problem of navigation. Even on the long flights from Iwo Jima to Japan, where navigation was a serious problem, 100 pounds more of gasoline was considered a better safety insurance than 100 pounds of radar.

Radar blind bombing, the application which has received the most publicity, is largely a navigational problem, and therefore requires the best possible radar navigation equipment. This factor has led to a continued improvement in resolution by going from 200 to 3000 megacycles, and then to as short a wavelength as possible with antennas as large as practical. Best results in picking out landmarks are obtained when the illumination of the ground is the same at all ranges; therefore, a "cosecant-squared" antenna pattern is used. Because the pattern of landmarks must be readily recognizable and therefore should correspond as closely as possible with the appearance of the map, a PPI presentation is used. The center of the PPI is rather badly distorted at the shorter ranges on account of the fact that slant range rather than ground range is used. Particularly noticeable is the "altitude circle," as in figure 83, which is formed by the nearest signal, the ground directly under the plane. Thus, the range of the first echo is the altitude of the plane. This fact is used as the basis for one type of radio altimeter.

In addition to the radar, a bomb-release computer is needed. In one form, this device may mark electronically the proper course and release point on the PPI tube, or in another form the signal on the tube may be tracked to feed data to the computer.

It is obvious from figure 83 that aircraft beyond the range of the altitude signal would be overlooked in the ground return. Therefore, a navigational set would be of relatively little value for collision avoidance. In air-to-air search applications, such as a night fighter after a bomber, the beam should be narrow enough so that it does not strike the ground. For example, the SCR-720 used in Army night fighters has a pencil beam which is

FIGURE 83—*Airborne radar photograph taken at low altitude over Duxbury Bay, Mass.*

used with a rapid helical scan. The azimuth scan rate is 360 revolutions per minute, and the vertical rate is 30 degrees per second. The signals are presented on a B-scan to determine range and direction of the target, and on a C-scan to determine altitude.

The AN/APS-13, which was designed to provide warning of a plane closing in from the rear, offers a possible solution to collision avoidance. This set, which weighs 20 pounds, operates at 415 megacycles and requires only 90 watts at 27 volts direct current. The antenna, which consists of two folded dipoles, is mounted in a fixed position and covers 60 degrees horizontally and 90 degrees vertically. When another aircraft enters this cone and is within 800 yards, a red light shows in front of the pilot and a bell rings. A modification, which uses the return signal from an object closer than 800 yards to trip the transmitter, can provide an audio tone which rises in pitch as the distance decreases. This gives the pilot a rough indication of range.

BEACONS AND RADAR NAVIGATIONAL SYSTEMS: RADAR BEACONS

Radar beacons, unlike the radio beacons now commonly in use, do not transmit continuously. The radar beacon is triggered or "interrogated" by the radar in order to show position rather than just direction. The beacon consists of an antenna, a receiver, a transmitter, and, usually, a coder. The radar transmitter pulse, if of the correct frequency and pulse length, is received and amplified so that it may be used to trip the beacon transmitter. The transmitter then sends out a pulse or series of pulses as determined by the coder. Since the time delay between the reception of the signal and the firing of the transmitter is extremely small, the beacon signal reaches the radar at essentially the same time as the echo from an object placed at the beacon. Thus, the beacon response may, in effect, be used to strengthen the echo from the target.

A wide-band crystal-video receiver may be used on the beacon where the band of frequencies of the interrogating sets is not too great. However, since the radar set has a narrow receiving band, the beacon response frequency cannot readily be spread sufficiently to be received on all of these sets. Two solutions to this problem exist. One is to make the frequency of the beacon transmitter sweep with time. This solution is adequate where a few seconds may be spent in interrogating the beacon, the time being spent in waiting for the beacon response frequency to sweep through the receiving band of the interrogating system.

The other solution to this beacon response problem is to have all beacons transmit on a particular frequency. The radar sets must then have a receiver for the beacon replies which is tuned to the beacon frequency. The video output of this receiver can then be mixed with the radar video for presentation on the scopes. Having the beacon respond on a separate frequency from the radar makes possible the presentation of beacon signals only. The major advantage of this lies in the fact that no ground echoes appear under these conditions.

Beacons have been used for extending the range of tracking, since the beacon response essentially is a radar signal "reinforcer." They have also been used for the obvious purpose of marking airfields for aircraft equipped with radar. Because beacons must receive radar pulses from any direction, beacon antennas are nondirectional. Therefore, the beacon antenna gain is quite low. This factor is more than compensated for, however, by the fact that the power in going from the source to the receiver need not make a round trip. Hence, the signal strength falls off as the inverse square rather than the inverse fourth power of the distance. Therefore, if the beacon receiver is reasonably sensitive and its transmitter power is of the order of a few watts, the range at which it may be seen is usually limited only by the horizon. When the beacon receiver is not sufficiently sensitive, the beacon may stop responding when the radar signal becomes too weak. When this happens, the beacon response will either be strong at the radar or will not appear. On the other hand, where the beacon power output limits the range, the beacon signal will become very faint before it is lost.

In some aircraft, the P-38 for example, two beacon antennas are required to achieve a nondirectional antenna pattern because in certain directions parts of the plane obstruct the radiation from a single antenna. Even on planes where a single antenna can be employed, considerable care must be used in selecting a satisfactory location.

The customary beacon antenna on an aircraft is a dipole, while on ground beacons the antenna may be a dipole or a short array similar to that shown in figure 55.

BEACON NAVIGATION SYSTEM

Beacon markers may obviously be used as known reference points for aircraft equipped with radar and have been used as runway markers for instrument landing.

Because radar range measurements may be made with an accuracy of 50 feet with suitably designed equipment, very precise position fixes may be made by triangulation, as indicated in figure 84. The ranges R_1 and R_2 from two beacons at accurately known ground points are measured. The plane is then known to be at the intersection of circles of radius R_1 and R_2 drawn about beacons 1 and 2, respectively. Since there are two intersections, the proper one is determined by a rough knowledge of position obtained by some other means.

In the "oboe" system two ground stations are used. The master station is a normal radar, while the other is merely a receiving station with its range circuits synchronized by a pulse from the master station. The aircraft carries a beacon which is interrogated by the master station. The beacon response is received on both stations, and the two ranges are accurately measured. Instructions are given to the pilot by suitable modulation of the radar beam. One pair of ground stations can handle only a single flight at a time.

In the gee-H, shoran, and micro-H systems, two ground beacons are used. These are interrogated by a radar set in the plane and reply on different frequencies

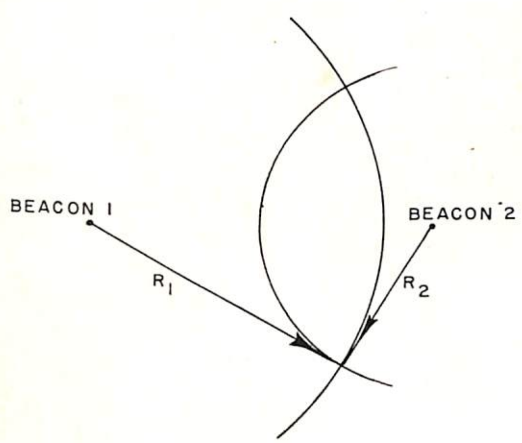


FIGURE 84—*Range triangulation.*

or with different codes to enable the operator in the plane to determine which signal belongs to a given beacon. Where precise navigation is not required, the plane's position may be determined by drawing circles on a map about the beacon position. However, where the position must be known as accurately as possible, such as in bombing, special indicators and computers must be used. An elaborate calculation making corrections for slant range and curvature of the earth must also be made. Since this requires considerable time, the calculations are made before the flight and the plane is kept on a predetermined path. For aerial mapping the calculations may be made after the flight if a record is kept of the range readings at the time a photograph was taken.

GEE AND LORAN

Although these navigational systems are not strictly radar, they do use pulse-transmission techniques. Both of these systems are based on the principle that a hyperbola is generated by keeping the difference in distance from two fixed points constant. If stations *A* and *B*, (see figure 85(a)), send out pulses simultaneously, a measurement of the difference in time of arrival of the

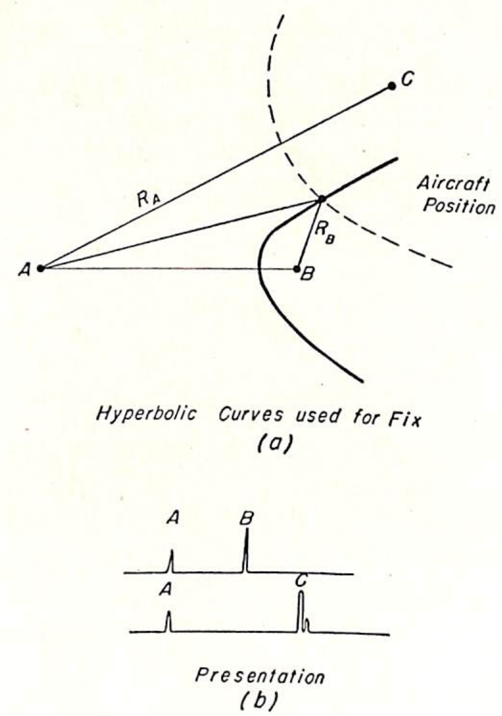


FIGURE 85—*"Gee" system for navigation.*

signal from *A* and from *B* will determine the difference in distance of the two stations from the receiver. The plane or ship is then known to lie on a given hyperbola corresponding to this difference in distance. Another such pair of stations will give a second line of position, the fix being determined by their intersection.

In the gee system, *A* is the master station which transmits at fixed repetition rate and alternately triggers two slave stations *B* and *C*. These stations all operate on the same frequency and are displayed on an A-scope, as indicated in figure 85(b), the trace from the pair *AC* being displaced vertically from that on which *AB* appears. The pulse from *B* or *C* may be coded to show which pair of stations corresponds to the lower trace. The two range intervals *AB* and *AC* are used to locate the position from a map on which families of hyperbolas have been drawn. Interpolation between these calculated hyperbolas is usually necessary. Navigation can be accurate to a fraction of a mile where the curves for the two pairs of stations cross steeply, but is poorer where these curves are nearly parallel on crossing. The radio frequency is high enough that the range is limited by the horizon.

Loran operates on the same principle but uses stations in pairs, each pair consisting of a master and a slave station. It also operates on a much lower frequency; hence the range is not limited by the horizon. The use of pairs of stations, rather than a triplet as in gee, makes it possible to place the stations in positions better for getting steeply crossing hyperbolas at long range. The pairs operate on different repetition rates and are identified by the synchronizing-control setting. Because of multiple reflections from the ionosphere, the alternate presentation of stations as in the gee system is not practical. Fixes are made, therefore, by taking a reading on one pair and then resetting the oscilloscope to obtain a reading on a second pair of stations. Map charts are again used to locate the position of the plane or ship. Loran will give a fix to better than 5 miles at a distance of 600 or 700 miles from the stations.

RADAR AIDS TO AIR NAVIGATION AND TRAFFIC CONTROLS

Although airborne radar may be used as a navigational aid, several serious difficulties exist. As was mentioned previously, the ground echoes obscure signals from planes. However, navigation entirely by beacons and the use of airborne beacons would eliminate this difficulty. On the other hand, since it costs about 500 dollars a year to replace a pound of cargo by a pound of equipment in a commercial plane, the installation of both radar and beacon would be quite expensive. Furthermore, this installation will not greatly help the control tower in handling congested traffic at an airport because the controller does not have direct access to the information presented on the airborne set.

An alternate proposal which has many interesting

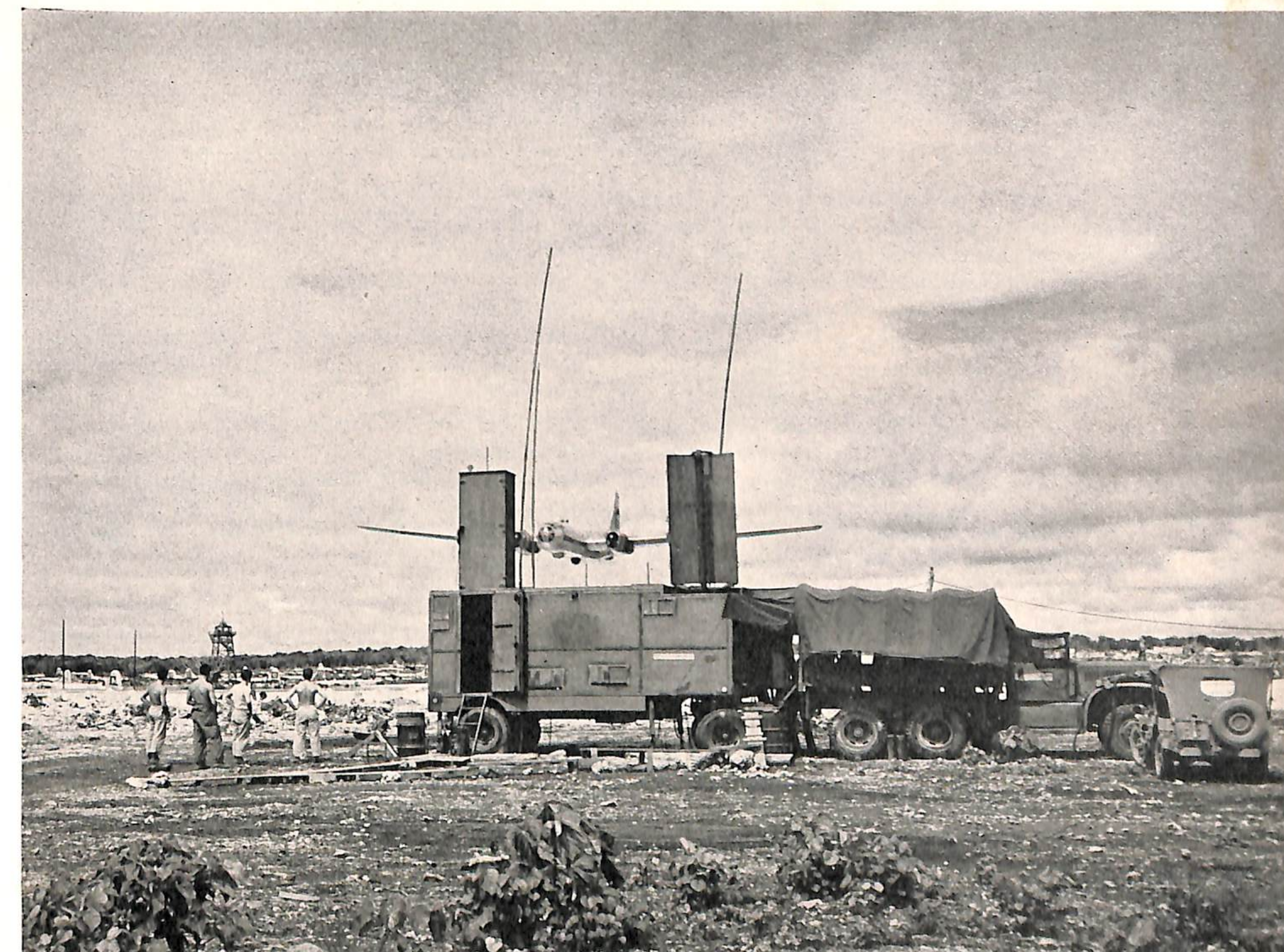


FIGURE 86—*AN/MPN-1 on Guam.*

possibilities is the use of a network of long-range high-resolution ground stations to watch the air traffic. This network provides complete information on aircraft position to the control tower, thereby eliminating the dependence of the controller on the pilot for information as to the location of his plane. The present method of depending on the pilot to supply this information breaks down when most needed; namely, when the pilot is lost. If the signals from these ground radars are mixed with a "video map" on which air routes and fields are marked, the controller can see on his PPI when a plane is off course. Although controllers on the ground could continually direct the pilots in course, altitude, and speed, a much more satisfactory solution would be to use a radio link to relay the radar picture to the plane where the pilot or co-pilot could keep a continual check on the course and on the presence of other aircraft. Such a relay system has been operated on the ground very successfully, but the receiving system needs re-engineering for aircraft use. Only a receiver and PPI are needed in the plane; the weight, therefore, would be considerably less than for an airborne radar, and the radar coverage would be far greater than could be achieved with an airborne set. Where positive identification of a particular plane is required, the plane may be equipped with a beacon.

Since a system of this type would be more useful near an airport than on long flights across open country, the installations might be limited to heavy traffic areas, the present types of navigational systems being used between these areas. A program of comparative tests and further development is needed to work out the proper solution to the airway problems which are already serious when visibility is poor and will increase with the volume of air traffic. At present the problem of navigation is fairly well solved, but the problem of traffic control requires considerable research.

Radar has made a contribution to the instrument-landing problem. Although the AN/MPN-1, shown in figure 86, is by no means a complete solution to this problem, it has already safely landed a number of aircraft which would otherwise have been abandoned by parachute. This set is most suitable for use where there is a low ceiling with fair visibility at low altitude, so that the pilot may make the final touchdown visually. It has, therefore, been nicknamed GCA (ground control of approach). It is a high-resolution search set which is used to locate the plane. The proper approach line and the runway are drawn on a large PPI. There is also a rapid-scan height finder which displays the height of the plane on an RHI. The desired glide path is marked on this tube. A controller verbally tells the pilot how to turn to get on and stay on the proper course, and at the same time gives directions to keep the plane on the desired glide path. When the plane breaks through the overcast, it should be in the proper position for the pilot to take over and land visually. The advantage of this system lies in the fact that no special equipment is needed in the plane. The chief disadvantage is the number of human links in the chain, any one of which may make an error in judgment. A system operating on this principle may become standard airport equipment to take over in the event of failure of a more elaborate system and to handle planes which are not equipped for instrument flying.

Since navigation and aircraft control will be the greatest peacetime uses of radar, a considerable effort will be expended in the next few years in adapting the techniques used on war equipment to the design of suitable sets for these purposes. Military sets were designed for specific purposes and were often rushed into service prematurely; hence, most of them are not immediately adaptable to civilian uses. Suitable radars for ship navigation and collision avoidance are probably more nearly ready for use than those required for the aircraft field where the problem is three-dimensional and speeds are high. Radar for air navigation and traffic control will require considerable development and operational test before commercial use is satisfactory.

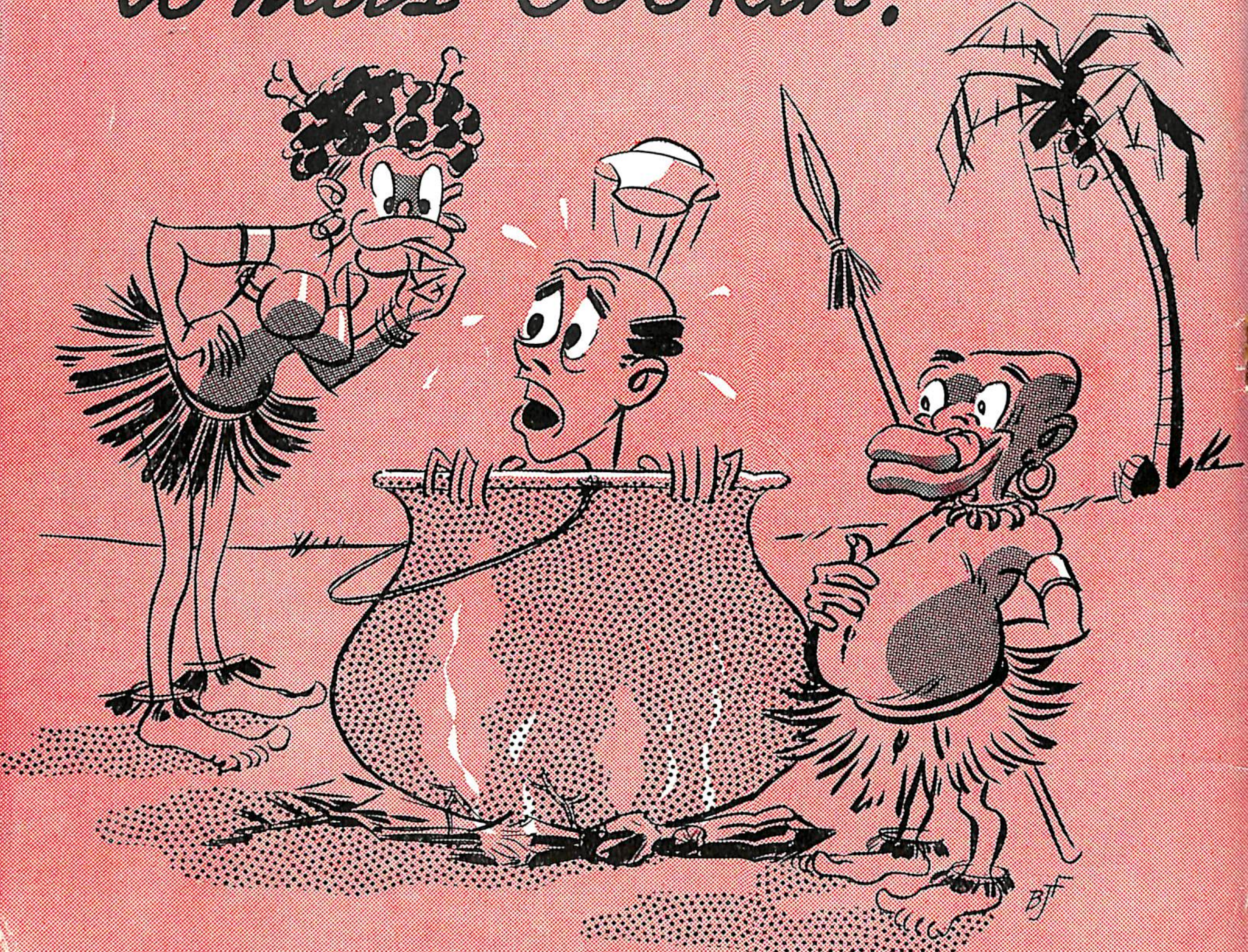
DO IT THE EASY WAY...

Although you may have heard otherwise, the Bureau of Ships desires that you follow this easy way to prepare your Ship's Electronic Equipment Inventory report forms. Doesn't seem logical, does it? But it's the truth: Whenever any electronic equipment is moved, installed, or removed, or when your annual report is due, just take the single machine-printed copy of the inventory and correct it with red ink or red pencil. Draw lines through items removed, and insert the listings of new items on the extra lines provided. Put the date of this revision in the upper-right corner, and mail it to the Bureau. That's all there is to it!

Note that you are NOT to re-type the entire inventory, or any part of it; merely return your copy of the I.B.M. printed form after making the corrections as described. The Bureau will print the corrected list by machine, including any extra copies that may be required, and send you a copy.

In case your carbon copy of the machine-printed I.B.M. list is not available, however, you may follow instructions contained in Enclosure B of BuShips letters (Ser. U-980-324 and 325) of 23 August 1946. Blank copies of the I.B.M. forms (NavShips-4110) should not be requested, as they are for use only in the I.B.M. machines at the Bureau.

Whats Cookin?



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