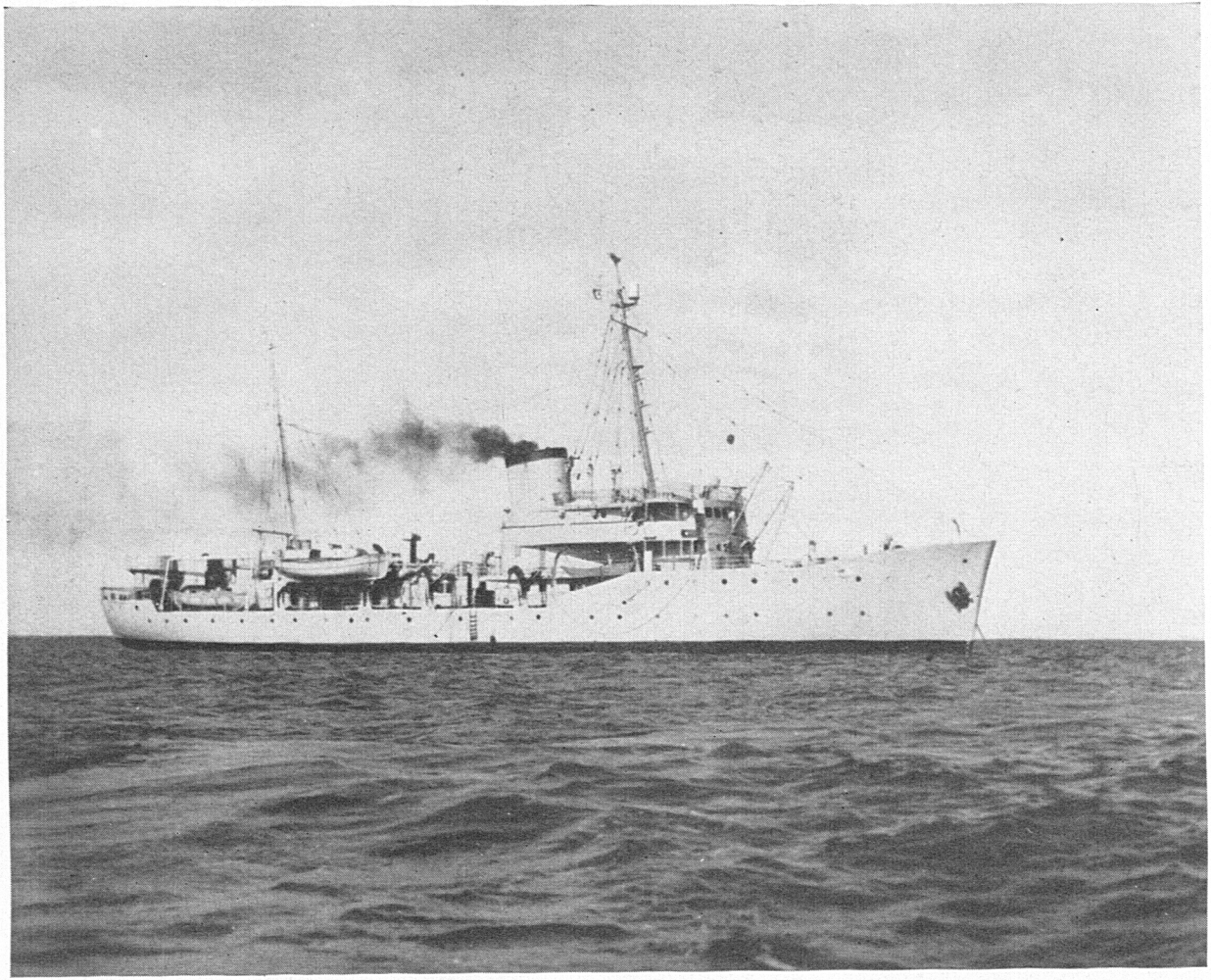

U. S. Coast and Geodetic Survey Ship Pathfinder

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COAST AND GEODETIC SURVEY
ROBERT F. A. STUDDS, *Director*

Special Publication No. 265

EPI

(ELECTRONIC POSITION INDICATOR)

MANUAL

By the

Radiosonic Laboratory Staff

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WARNING

Because of the delicate construction of the 304TH transmitter tubes, it is imperative that great care be taken in the boxing, and handling of these tubes.

When boxing these tubes, the packing around the tube on each side should be equal to the diameter of the tube, or rubber-band suspended in a free space equal to twice the diameter of the tube. Whenever possible, the tubes should be kept in the original cartons which have the correct type of suspension or packing.

Never leave the tubes in the transmitters when the equipment is being transported. When the tubes are carried ashore to a station, they should be carried by a responsible person.

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PREFACE

This manual contains information for the user of the Electronic Position Indicator in the control of hydrographic surveys, for the persons concerned with the installation of ground stations, and for the radio technical personnel who will be required to maintain and operate the equipment from the technical standpoint.

The information appearing here has been gathered over a number of years and represents the experience of a large number of people who have actually worked with this system of control. If proper and efficient use is made of this manual, many of the mistakes made in the early days can be avoided. An attempt has been made to include all the functions that are necessary in using the EPI system for control of hydrographic surveys.

All personnel who will have a part in any of the phases of operation, from planning the whole work, the installation of equipment, the operation and maintenance of the equipment, and so on, should read those sections which apply to their particular phases. If all personnel are thoroughly acquainted with the details of their jobs, all phases can be most efficiently coordinated. The following tabulation gives a breakdown of the portions of the manual for study:

All officers: Sections 1, 2, and 3.

Executive Officers: Sections 1, 2, 3, 4, 5, and 15.

Communications Officers and Chief Radio Technicians: All sections.

Ship Radio Technicians: Sections 1, 3, 4, 7, 9, 11, and 16.

Ground-Station Radio Technicians: Sections 1, 3, 5, 8, 10, and 16.

EPI Ship and Ground-Station Operators: Section 3.

Boatswain: Section 15.

The material appearing in this manual was prepared under the direction of Commander Clarence A. Burmister, Chief of the Radio-Sonic Laboratory, Division of Coastal Surveys. Much valuable information and assistance have been received from officers and men, both in the field and in the office. Especial credits are due: Mr. Thomas J. Hickley, Senior Electronic Scientist, for the general supervision of preparation of the material for the manual; Mr. Richard R. Ross, Electronic Scientist, for supervision of the preparation of the illustrations and diagrams; Mr. Angelo A. Ferrara, Laboratory Scientist, for preparation of the components lists; Commanders Joseph P. Lushene and Robert A. Earle, and Lieutenant Commanders Fair J. Bryant, Howard S. Cole, and David M. Whipp, for information on the installation of the ground stations and the special techniques developed for the use of the system in the control of surveys; Mrs. Ruth C. Culp and Miss Ruth H. Shepard, for assistance in the preparation of the manuscript; Mr. Robert F. Dorka, Division of Charts, for assistance in the preparation of the illustrations and drawings; and Mr. Frank S. Farquhar, Division of Charts, for assistance in editing the manuscript.

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Commander Clarence A. Burmister
U. S. Coast and Geodetic Survey
Washington, D. C.

I

GENERAL

1.100 INTRODUCTION

The Electronic Position Indicator (EPI) was developed shortly after the close of World War II. It was designed primarily for those hydrographic surveys which extend beyond the range of other electronic surveying instruments.

The offshore system—Radio Acoustic Ranging—had shortcomings too numerous to enumerate. The war-developed electronic systems failed to meet all requirements for long-range surveys. Among the objections to these systems were: lack of sufficient range, lack of accuracy, ambiguous positions, loss of position caused by interruptions to the system, and the need to know the starting position to initially adjust the instrument. Postwar development has eliminated some of these objections. The EPI contains fewer of these limitations to offshore surveys than other navigational systems presently in existence.

1.200 GENERAL DESCRIPTION

The EPI establishes the position of the survey vessel by measuring the round-trip time for a radio pulse, initiated on the ship, to travel to two ground stations and return to the ship. Since the positions of the two ground stations are known and the velocity of the radio signal is also known, then the distance of the ship from the two ground stations is measured. Although it is possible to get the position of the ship at any time, a definite time interval is decided upon for the ship's position fix.

1.300 GENERAL DISCUSSION

Long-distance measurements are possible with EPI because of the frequency of the radio wave employed with this system. For frequencies lower than 5 megacycles, the ground wave is propagated for considerable distances. Higher frequency ground waves are attenuated because of the imperfect conduction and other electro-magnetic characteristics of the soil or water over which these waves travel. The lower end of the frequency spectrum was not used because of certain accuracy considerations. The EPI uses a frequency of 1850 kilocycles, which gives desirable range characteristics. This frequency is shared with Loran without interference between these two systems.

Ground waves follow the contour of the earth but extend to great heights above the earth. These waves induce fields into the earth for a short depth. The earth-induced waves in turn re-induce a field above the earth. These waves supplement each other as they travel outward.

At the low frequencies employed by EPI, it is difficult to start electric circuits rapidly because of the electrical inertia of the circuits. Also, the amount of space occupied in the spectrum must be limited to prevent interference with other radio signals. Since the rapidity at which the pulse starts determines, in part, the accuracy

of the system, the two above-mentioned factors place restrictions on the system. At higher frequencies, where the pulse wavefront rises rapidly, the pulse at the receiver-output can be made to trigger the ground-station transmitter without much loss in accuracy. Shoran is such a system. This method is not employed in the EPI system, since the pulse at the receiver-output takes about 12 microseconds to rise and large errors would result when the pulse was noise-modulated or the receiver gain changed.

Instead, a synchronizing method is used at the EPI ground stations which precisely sets the time that the ground-station signal is transmitted in relation to the time the ship-station signal is received. The rate at which the ground-station pulses are transmitted is controlled by a quartz crystal oscillator at the ground station. The rate of this crystal is held the same as that of the ship-station crystal oscillator by the pulse from the ship. The ship and the ground-station signals appear on the ground-station cathode-ray oscilloscope. Their wavefronts are equalized and the leading edges matched. Now the pulse rate and the phase relation between the ship and ground station are correct, which means that the ground-station pulse is being transmitted at the proper time after the ship signal has been received. The automatic synchronizer maintains this relation for long periods with only slight manual adjustment.

The velocity at which the system is calibrated is 299,792 kilometers per second. A velocity correction has not been found necessary. The recurrence rate of the ship and ground-station transmitters is 41.66 pulses per second, the pulse length being about 60 microseconds. Radiated power from the antenna is about 10 kilowatts. The receiver-system band width is about 85 kilocycles.

1.400 ACCURACY

Extensive studies have been made, both in the laboratory and in the field, to determine sources of error for the purpose of improving the accuracy of the system. During the laboratory tests, all factors that could contribute to instrumental error were studied. Field conditions were simulated in the laboratory, but closed circuits were used which made the tests nearly noise-free. Results of these tests appear in the table below. The data is presented as the percentage of observations that comes within plus or minus the fraction of a microsecond, as shown in the left column of the table. Field tests were made at a test buoy anchored in a known position from which the precise distances to the two ground stations were known. The path between the buoy and the ground stations was almost completely over water, the distance to one station being 45 nautical miles and to the other, 90 nautical miles. During a period extending over seven months, 267 observations were made at this buoy. The figures in the table are the means for both stations. During this period, the stations had to be removed three times because of hurricanes; also, instrumental changes and adjustments were made. This data is as read—no modifications or weighting of the data were made.

Microseconds, plus or minus	Field Tests, 267 observations	Laboratory Tests, 21 observations
	Percent	*Percent*
0.1	35	26
.2	53	53
.3	72	71
.4	83	82

Other field tests were made which show that there is little change of correction with range or signal strength.

The system remains stable over a considerable length of time. Static can produce a considerable error in any individual reading; even so, if unreasonable fixes are rejected, a creditable survey can be made.

1.500 RANGE

The minimum range that has been measured with the EPI is 14 nautical miles. With slight modification to the equipment, it is probable that shorter ranges could be measured. Under low static conditions, dependable measurements can be made to distances of 500 nautical miles, and to distances up to 250 nautical miles when the static is abnormal. Since the static is always worse at night, barring local storms, it is customary to plan night operations closer to the ground stations.

1.600 SHIP-STATION EQUIPMENT AND MATERIAL FURNSIHED

1 Controller-indicator, with cables
1 EPI transmitter
1 Modulator, with cables
1 Transmitter antenna-coupler—ship type
1 Receiver antenna-coupler—ship type
1 Voltage regulator, 2.5 kva, 115 volts, 60-cycle
1 EPI manual, special publication No. 265
1 Voltage regulator manual
1 Plotting protractor for scale of survey
1 Plotting abstract, Shoran or EPI (Coastal Surveys M–2527–1)
1 Wavemeter for EPI

1.601 Ship Equipment—Weight, Size, and Other Data

All these measurements are clearance sizes and are to be used for the placement of the instruments and not for design purposes:

CONTROLLER-INDICATOR (See Figure 1)

Width—21⅝ inches
Depth—19⅛ inches
Height—48⅞ inches
Controller projects 10 inches beyond, making effective depth 29⅛ inches
Weight—254 pounds
Power consumed at 118 volts, 60 cycles, 625 watts

TRANSMITTER (See Figure 2)

Width—31 inches
Depth—21 inches
Height—23 inches
Weight—199 pounds
Power consumed at 118 volts, 60 cycles, 500 watts

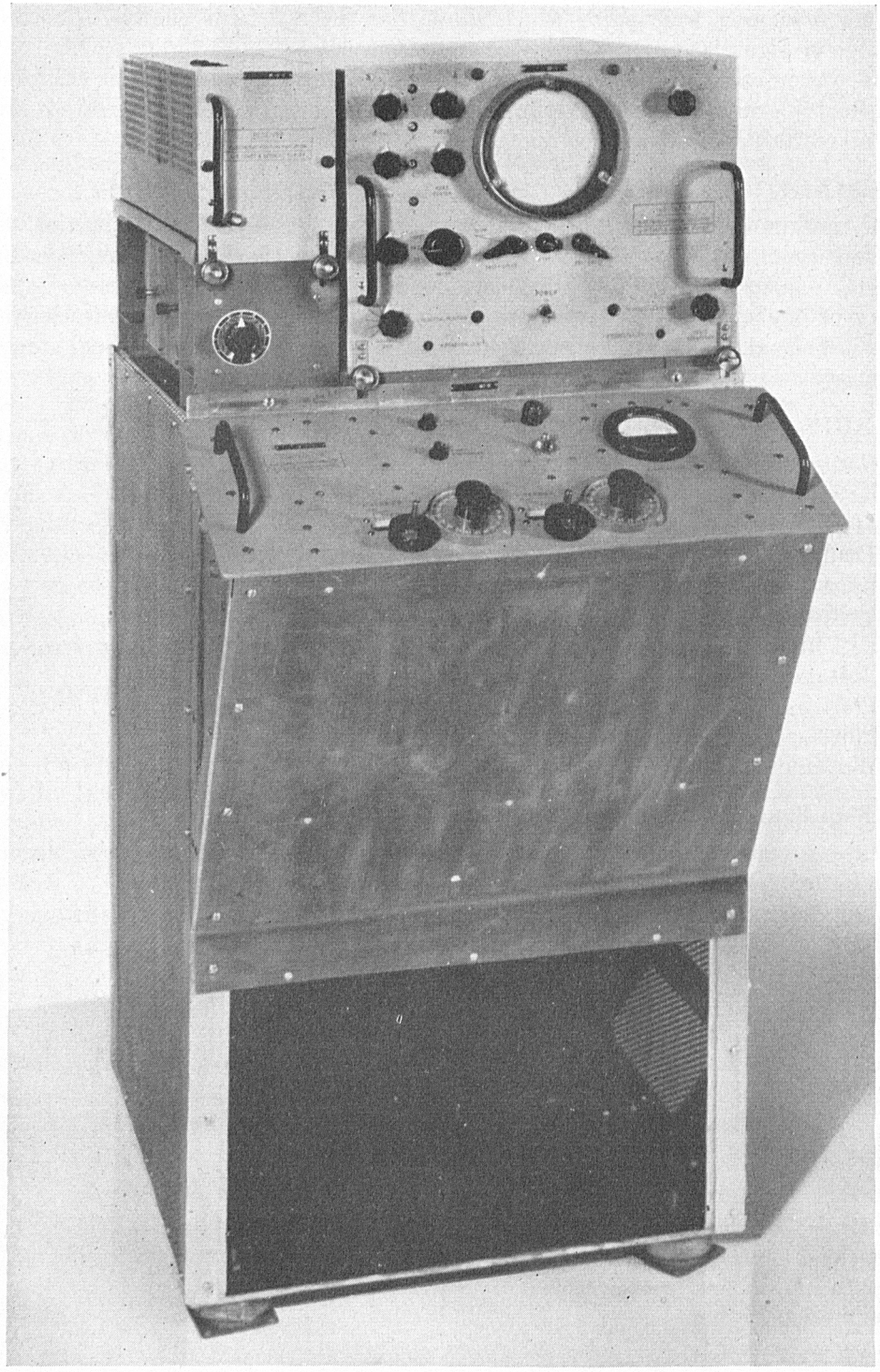

FIGURE 1.—Ship Controller and Indicator.

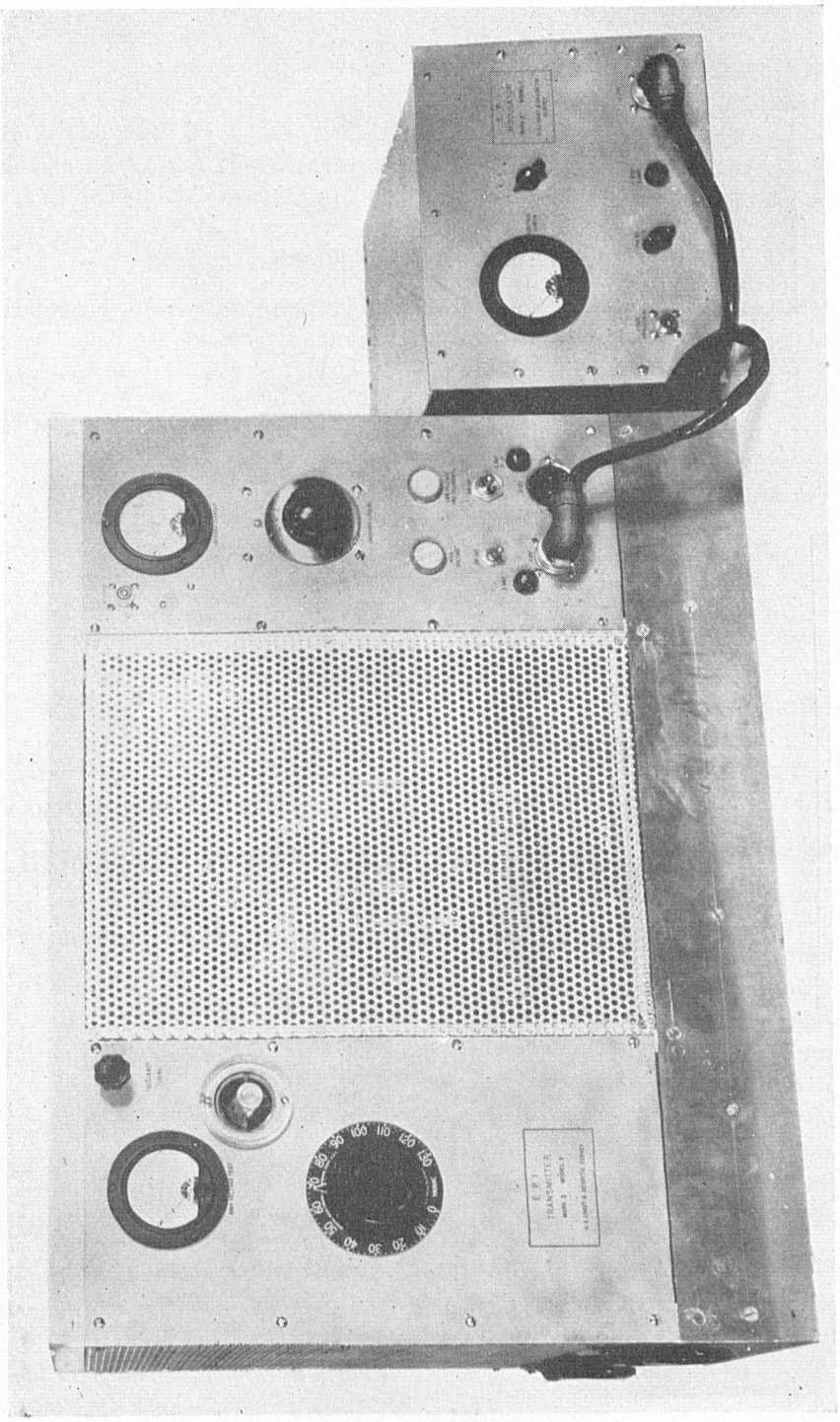

FIGURE 2.—Transmitter and Modulator.

MODULATOR

(for Transmitter)

Width—13 inches
Depth—19 inches
Height—10 inches
Weight—53 pounds
Power consumed at 118 volts, 60 cycles, 115 watts

VOLTAGE REGULATOR

Size, weight, and power consumed will depend on type of regulator used; figures listed here are ample for any type that may be used:
Width—22 inches
Depth—15 inches
Height—14 inches
Weight—225 pounds
Power consumed at 118 volts, 60 cycles, 400 watts

TRANSMITTER-COUPLER

Width—20 inches
Depth—12 inches
Height—22 inches

RECEIVER-COUPLER

Width—10 inches
Depth—12 inches
Height—6 inches
TOTAL POWER REQUIRED TO OPERATE SHIP SYSTEM—1640 WATTS

1.700 GROUND-STATION EQUIPMENT AND MATERIAL FURNISHED

1 Controller-indicator, with cables
1 EPI transmitter
1 Modulator, with cables
1 Transmitter antenna-coupler—ground station type
1 Receiver antenna-coupler—ground station type
1 Voltage regulator, 2.5 kva, 115 volts, 60-cycle
1 Variac and voltmeter panel
1 Line filter for controller-indicator
1 EPI manual, special publication No. 265
1 Voltage regulator manual
1 EPI tower, 100-foot, aluminum or steel, with guys, gin pole, and fittings.

1.701 Ground-Station Equipment—Weight, Size, and Other Data

All these measurements are clearance sizes and are to be used for the placement of the instruments and not for design purposes:

CONTROLLER-INDICATOR (See Figure 3)

Width—33 inches
Depth—24 inches
Height—18 inches
Weight—181 pounds
Power consumed at 118 volts, 60 cycles, 410 watts

For *Transmitter, Modulator,* and *Voltage Regulator,* see **1.601** SHIP EQUIPMENT.

MAST AND GROUND WIRES (See Figure 4)

With gin pole, base insulator, and guy wire—385 pounds, depending on make used

Ground wire (5,500 feet) and cables—250 pounds

1.800 COMMUNICATION EQUIPMENT

TRANSMITTER

(E. F. Johnson Co., Viking No. 1)

Width—21 inches
Depth—15 inches
Height—11⅜ inches
Weight—62 pounds
Power consumed at 118 volts, 60 cycles, 410 watts

RECEIVER

(Hallicrafter SX–71)

Width—19 inches
Depth—13 inches
Height—9 inches
Weight—42 pounds
Power consumed at 118 volts, 60 cycles, 90 watts

SPEAKER

(for Hallicrafter SX–71)

Width—15 inches
Depth—11 inches
Height—11½ inches
Weight—14 pounds

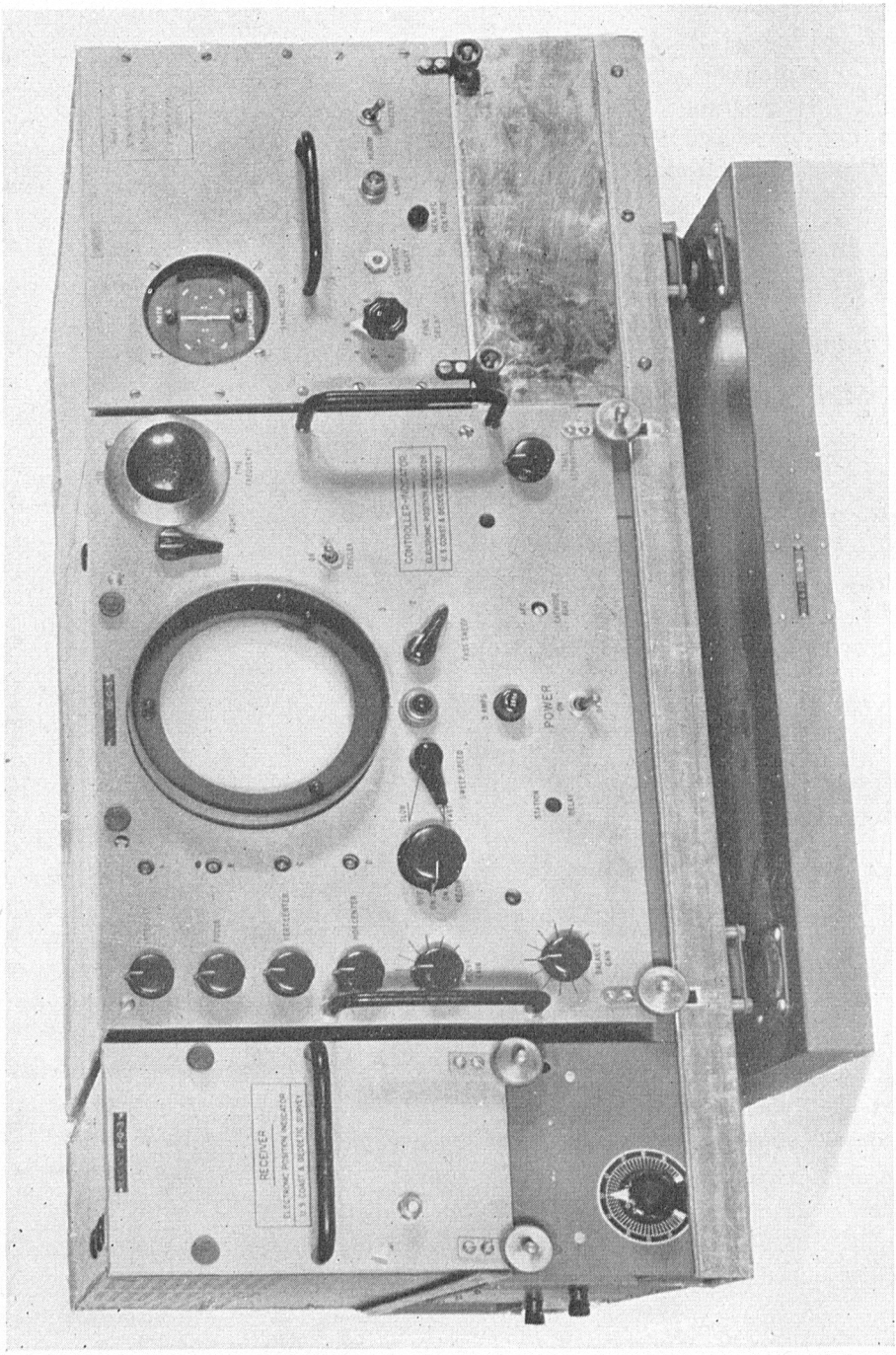

FIGURE 3.—Ground-station Controller-Indicator.

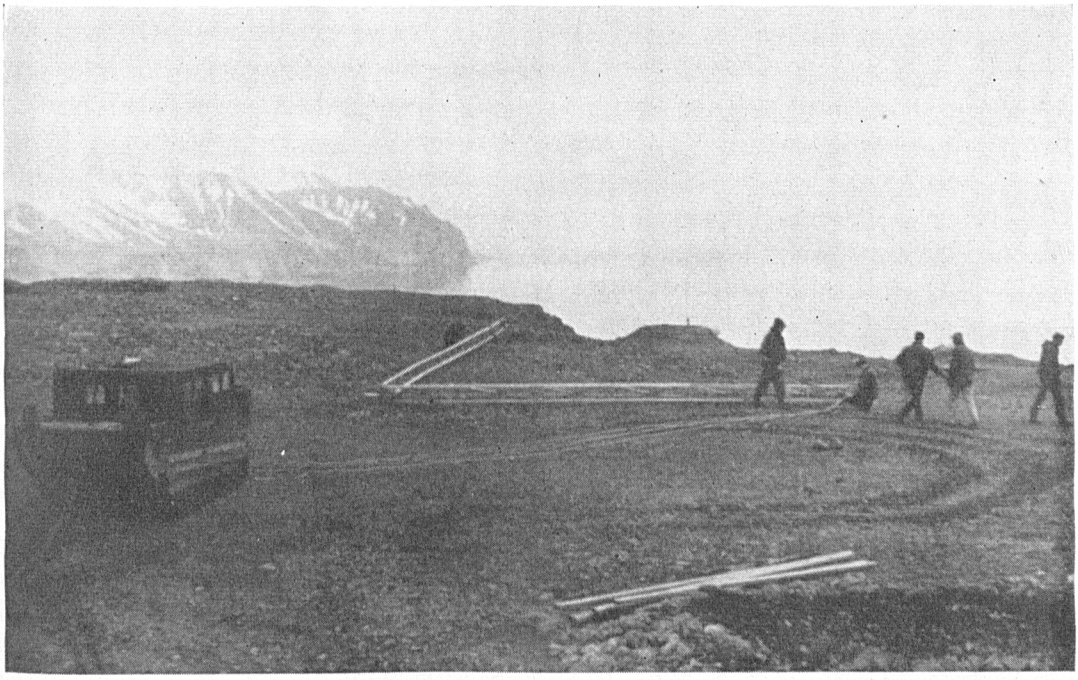

FIGURE 4.—Antenna tower in assembly stage.

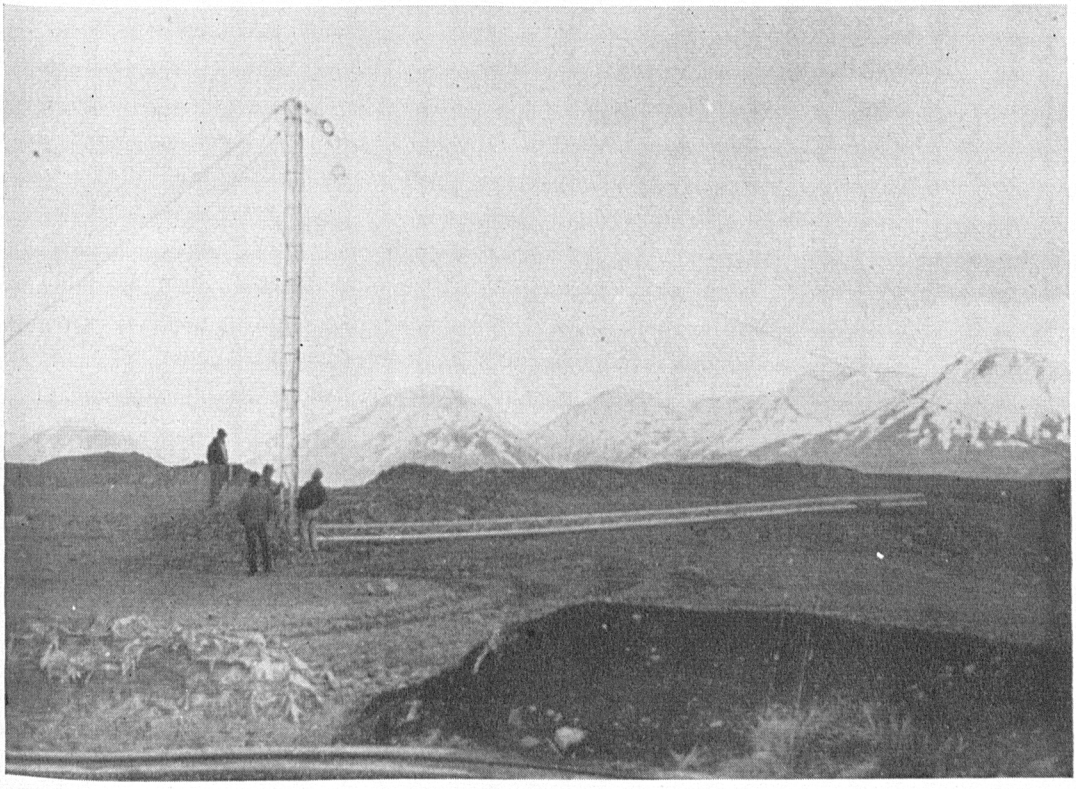

FIGURE 5.—Elevation of gin pole.

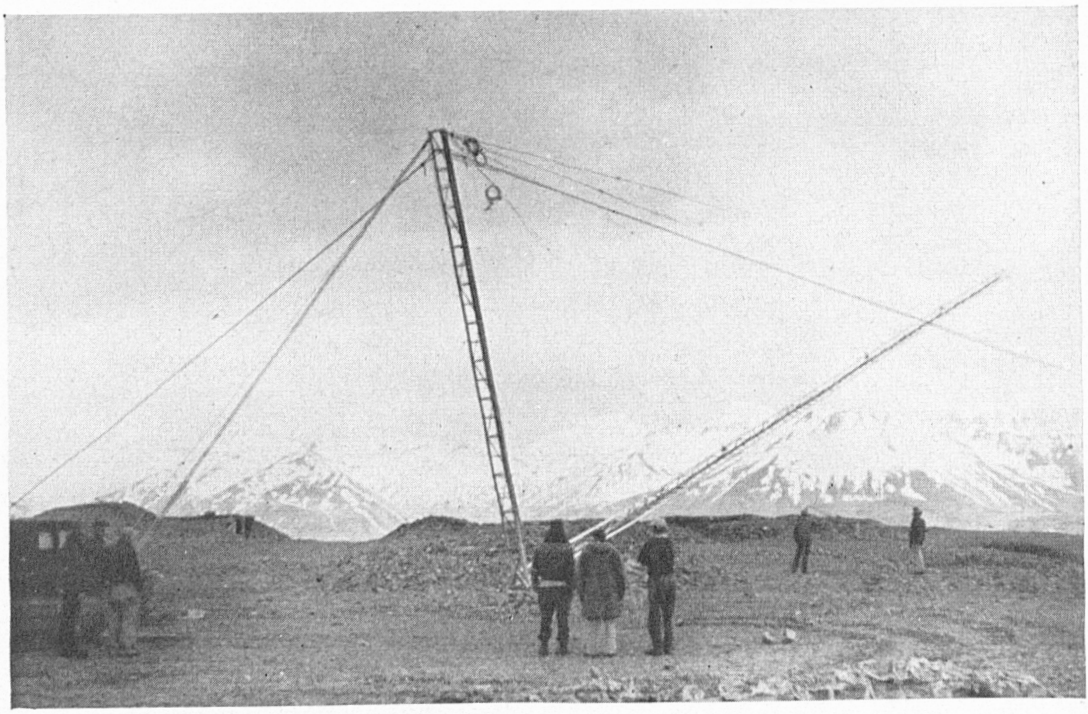

FIGURE 6.—Erecting antenna tower

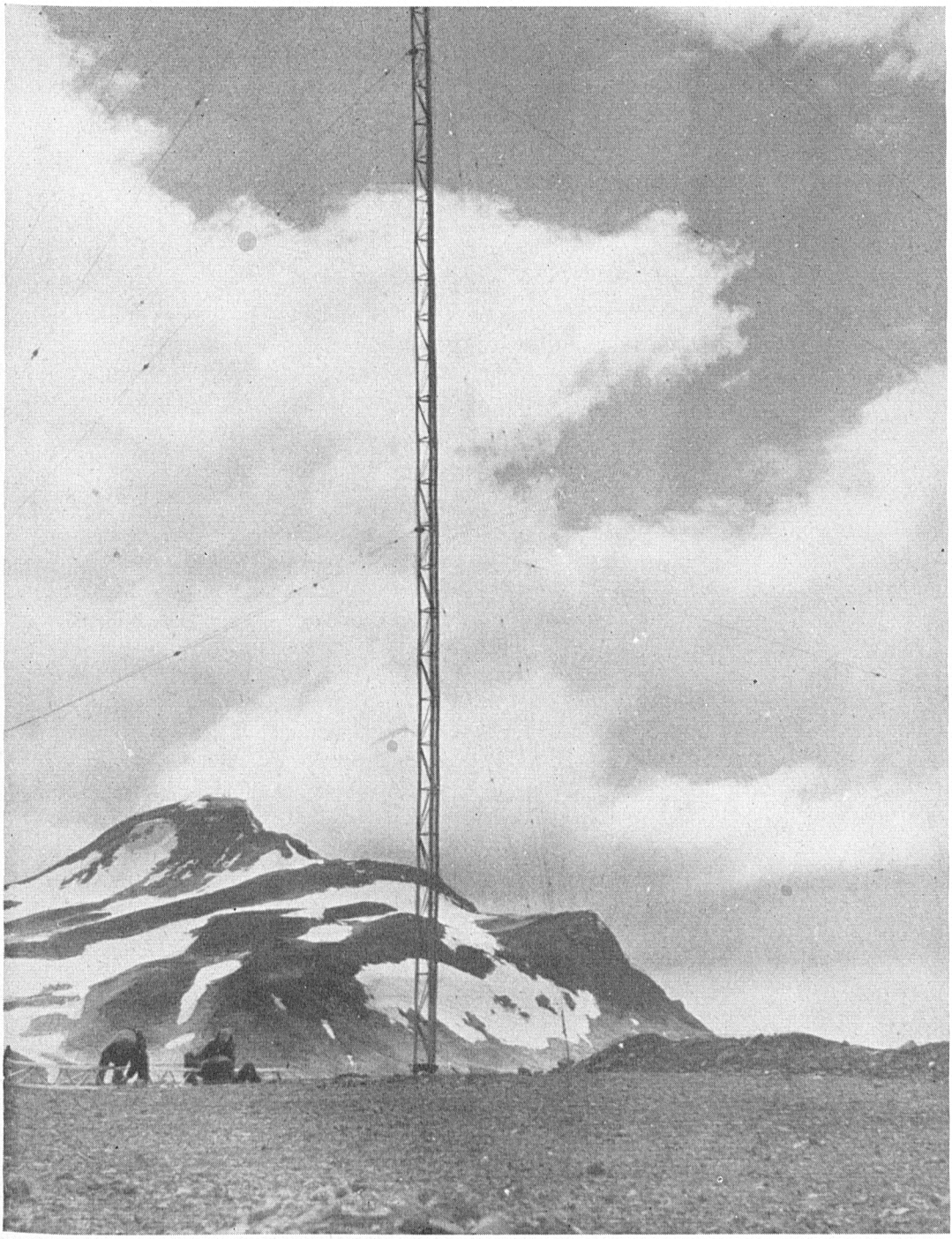

FIGURE 7.—Erection completed and removal of the gin pole.

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SURVEY PROCEDURE

Certain procedures, tests, and computations are necessary when working with EPI equipment so that the most logical location of positions and sounding lines will be obtained. The frequency of these tests is dependent upon the stability of the equipment. The system is not self-calibrating; therefore, you must rely on direct range comparisons to ascertain the system correction. Three methods can be employed to determine this correction for each combination of EPI equipment, namely:

1. EPI–Shoran Calibration method
2. EPI–Buoy Calibration method
3. EPI–Three-Point-Fix Calibration method

Selection of the method will depend on the area to be surveyed and the availability of necessary equipment.

In areas such as the north Pacific Ocean, the EPI–Shoran method of calibration is more adaptable. This method may be used in all localities. In addition, however, to the requirement of Shoran equipment, it is also required that the survey ship run to the vicinity of each station for calibration observations.

However, since the ship must visit the ground station about every two weeks for the purpose of resupply, calibration may be done at this time.

When a buoy can be anchored and its position established by a three-point fix, the buoy calibration method may be used. Areas such as the Atlantic Coast and Gulf of Mexico are favorable for the buoy calibration method.

The third method is usable anywhere a three-point fix can be obtained. It is a variation of the buoy method without the use of a buoy to mark the calibration site.

The advantage of the buoy method is in reducing the distance computations when a great number of observations are to be made in an area over an extended period. Also the buoy method can be used when the shore signals are not visible to take the three-point fix.

For each project a calibration program should be devised using one or more of the methods given. Such program would include calibration observations at the beginning and end of each trip, after each shutdown of the equipment, and more often if convenient. A record should be kept on the ship and at the ground station of all repairs, changes in equipment, or accidents which might affect the calibration.

2.100 EPI–SHORAN CALIBRATION METHOD

The ship EPI set can be calibrated by Shoran if certain conditions are met. Shoran equipment must be available at the EPI ground station and aboard the ship. The geodetic relationship between the EPI ground-station antenna and the Shoran antenna and the calibration values for the Shoran, must be known.

Due to present technical requirements and limitations, it is not considered feasible to mount the EPI and Shoran antenna together. A simple way to utilize Shoran for calibration is to lay down, on the chart, the positions of the EPI and Shoran antennas, and the perpendicular bisector of the line between the antennas. The ship is then placed on the perpendicular bisector of the line between the EPI and Shoran antennas, which insures equal Shoran and EPI distances, provided the ship is on, or very close to, the perpendicular bisector.

To place the ship on the bisector, EPI or Shoran, and in some cases a combination of these controls, is used. The use of EPI for control is usually the best method because no additional equipment is required.

Another method is to place the ship on the line extended between the two antennas and correct the measurement for the distance between them.

In selecting a site for the Shoran antenna at the EPI station, the distance at which calibration is desired must be taken into consideration. Usually the Shoran antenna elevation is chosen so that the signal will carry 25 to 30 statute miles. Since EPI is desired for use at much greater distances than 25 to 30 statute miles, a shorter calibration distance is not considered desirable. The Shoran antenna location, where a 50-foot mast is required, should be at least 400 feet away from the EPI tower.

The actual calibration consists of a series of simultaneous EPI and Shoran readings. With the EPI station on continuous synchronism (sync), 20 readings are obtained at about ½-minute intervals with the ship underway at slow speed, heading along the perpendicular bisector either away from or toward the stations. These values are plotted against each other on graph paper for the purpose of rejection of *wild* readings.

The EPI distance is read directly in microseconds, but the Shoran distance has to be converted from statute miles to microseconds. For this conversion, the value of 10.7401 microseconds per statute mile is used. After correction of the Shoran readings for the ZERO CHECK (see paragraph 7.700), the difference between the mean corrected Shoran value and the EPI mean reading is the EPI calibration correction. Enter under REMARKS identification data on the sets used and whether the EPI ground station being calibrated is an *A* or *B* station. If there is a possibility that the EPI station being calibrated may be used as an *A* or *B* station, it should be calibrated on both *A* and *B* delays.

Calibration should not be made until all equipments are warmed up for a period of not less than 45 minutes. It is also advisable to make and record an EPI zero check and make a routine check of the divider circuits at the time of calibration.

A sample calibration is shown:

EPI CALIBRATION: EPIE vs. SHORAN 31 August 1951

Ship set No. 2
EPIE controller-indicator No. 2
EPIE transmitter No. 3
EPIE Shoran Set No. 3
EPIE on *A* side
Ship Shoran Set No. A

Time	EPIE	SHORAN	Zero check
h m			
16 58	307. 1	28. 115	99. 804
	306. 3	28. 065	
	305. 8	28. 016	
	305. 3	27. 966	
17 00	304. 8	27. 925	
	304. 2	27. 888	
	303. 7	27. 844	
	303. 2	27. 804	
	302. 8	27. 770	
	302. 6	27. 732	
	302. 3	27. 697	
	301. 9	27. 660	
	301. 3	27. 622	
	301. 1	27. 584	
17 05	300. 8	27. 545	
	300. 4	27. 508	
	299. 8	27. 467	
	299. 0	27. 425	
	298. 9	27. 387	
	298. 5	27. 347	99. 801
Total	6049. 8	554. 367	
Mean	302. 49	27. 718	99. 802
		−0. 027	
		27. 691	

99. 802	Mean zero check
99. 775	Zero set
−0. 027	Shoran correction
27. 691	Shoran distance in statute miles
10. 7401	Conversion factor to microseconds
297. 40	Shoran distance in microseconds
302. 49	EPIE distance in microseconds
297. 40	Shoran distance
−5. 09	EPIE correction as *A* station in microseconds

2.200 EPI–BUOY CALIBRATION METHOD

To use this method for EPI calibration, a buoy is planted in a position easily accessible to the ship as it goes to and from the working grounds. A good 3-point fix is necessary at the buoy location and the depth of water must be favorable for buoy planting. Description of construction and methods of locating the hydrographic buoy will be found in chapter two of the U. S. Coast and Geodetic Survey Hydrographic Manual, Special Publication No. 143.

Thus with the buoy accurately located, the EPI system can be checked quickly most any time the ship is in the vicinity of the buoy. The buoy is planted at a position not closer than 30 miles or greater than 300 miles from the stations. More than one test buoy can be used if desired.

2.201 Circle Tests at Calibration Buoy

These tests are made by circling the buoy at reduced speed, keeping the ship approximately 100 meters from the buoy and taking observations at 30-second intervals. Ship's head, pelorus readings, and distances by range finder to the buoy are taken at each observation, and all EPI readings are reduced to the buoy center. The circle test takes about 5 to 7 minutes per circle. At all fixed buoys, the circle test consists of 3 circles, with a different EPI reader for each circle so as to reduce personal equations. The equipment during the test is in continuous sync and the EPI reader constantly maintains a match. Two recorders are used, one who records the range readings at the designated intervals while the second records the other data in a separate book. At the end of the test, the EPI readings are added to the record book and the results computed. A sample record is shown in Table I. If a good circle is made, the corrections cancel each other and the direct mean of the observed readings is the desired result. To reduce the burden of reduction to buoy center, good circles are necessary.

Date: 8 December 1950 Buoy No. 2 Wind: NNE–4 Sea: 2

Position	Time			Ship's head	Buoy bear	Distance	EPID	EPIE
	h	m	s	Degrees	Degrees	Meters	Microseconds	Microseconds
1	06	06	00	196	114	106	1306. 6	2415. 7
2			30	154	076	106	6. 0	5. 0
3		07	00	121	034	106	5. 9	4. 6
4			30	078	357	106	5. 4	4. 0
5		08	00	040	314	107	5. 0	3. 9
6			30	353	268	107	4. 7	4. 0
7		09	00	309	214	107	5. 0	4. 4
8			30	261	160	107	5. 7	5. 3
						Mean------	1305. 5	2414. 6

2.300 EPI–THREE POINT FIX METHOD OF CALIBRATION

The ship is located visually from shore signals by three-point fix while taking a series of EPI readings. The fixes may be plotted on a large-scale aluminum-mounted sheet, which has equal-distance circles from the ground station plotted on it for quick determination of the true distance.

2.400 EPI REDUCERS

In cases where the various observations at the calibration point do not vary much, it may be assumed that the equipment is stable, and the mean of the corrections obtained may be used without further computation. If the observations at the various calibration points indicate a jump or drift in the correction, an effort should be made to determine the reason for the change, and the exact time of the change.

It is recommended that the calibration corrections be obtained from trip to trip rather than using a mean for an entire season. Daily calibration is not required but calibration should be done whenever possible, and certainly at the beginning and end of each 2-weeks trip.

2.500 DUAL-SHIP METHOD FOR HYDROGRAPHY

In the event that two ships are available for hydrographic surveying and only one has EPI equipment, by use of the precision VF radar repeater or a radar of equal accuracy, supplemented by gyro bearing using telescopic-alidade, two hydrographic lines can be run simultaneously.

For this type of work, the VF radar repeater should be calibrated and adjusted to the nearest 20 yards by means of the special delay line inserted in the VF trigger circuit.

This method should only be used in areas where the accuracy of such procedure will not be detrimental to the quality of the survey. In other words, in flat areas where a wide spacing of the hydrographic line is all that is required.

EPI fixes are taken aboard the ship having ERI control at selected intervals (about 15 to 20 minutes) and the other ship takes a VF radar distance and bearing, plus visual bearing, if possible, at the same time. This information is then exchanged via radio telephone between the ships so that both can make a continuous plot of the courses run.

The success of this method depends on careful planning as to the arrangement of sounding lines and the procedure at the ends and beginnings of the lines. The control ship should keep the following ship informed when it intends to make important changes of course or other maneuvers.

2.600 DISTANCE MEASUREMENTS BETWEEN FIXED POINTS BY USE OF EPI

Positioning of off-lying islands and other measurements of distances, or independent datum, may be made by EPI length measurements. Three methods of making these measurements have been used, as follows:

1. The line-crossing method between two EPI ground stations
2. Line-crossing method between an EPI ground station and a Shoran ground station
3. A direct EPI measurement from one ground station and the measurement reduced to a position on shore by means of a visual fix

The line-crossing method is a means of measuring the distance between two EPI ground stations accomplished by having the ship cross the line between the stations while making EPI distance measurements to each ground station. The sum of the minimum distances measured to the ground stations is the distance between these stations, after the instrument corrections have been applied. Range readings are taken at intervals of either thirty seconds or one minute for a period of ten minutes before the minimum and continuing ten minutes after. The figure *eight* crossing is considered best. A series of four crossings is made at the center and is repeated at the quarter-distance points from each ground station.

While the line crossing is going on, it is necessary that the ground station remain in sync with the ship signals for the period the fixes are being made.

A straight continuous sync is quite tiresome to the ground station operator and it is believed that this weariness is responsible for many of the erractic values obtained while using such a system.

It was found that a reading every minute on the minute using CW radio signals from the ship, or the EPI blink for transmitting intelligence to the shore station was

more satisfactory. The radio signals are subject to interference and may be missed, but the use of the EPI blink is positive.

On the minute, the shipboard EPI operator takes his readings and then turns on his blink which notifies the shore operators of a period of relaxation. This relaxes all operators. At 30 seconds before the minute, the ship EPI operator turns off his blink which notifies the ground station operator to resync and re-align his pips in preparation for the next minute reading.

This procedure can be continued for an hour or more which at times is required for line crossings, when the exact position of the line between the stations is doubtful.

As a variation, a 10-second standby warning can be given via radio or blink from the ship but this is not entirely necessary. The ground stations will normally hold sync automatically for the short period of 15 to 20 seconds between the time of the adjustment and the measurements by the ship operator.

When making line measurements by the combination of EPI and Shoran, the line-crossing method is used with some modifications. Because of the limited range of Shoran, the measurements must all be made at the end of the line nearest the Shoran station. This may be a distance of 15 to 30 miles from the Shoran station.

When distances are to be measured by using Shoran equipment at one of the stations, the EPI procedure is the same, but two ship operators are required. At the ship, the Shoran is read simultaneously with the EPI reading. Shoran values can be obtained at any time, thus no prearranged schedule is necessary for the Shoran part of the measurement.

The distance between two stations, or between one station and a point on shore can also be measured with the ship at anchor near one end of the line to be measured; in this case, the distance from the nearby station is obtained by visual fix. An approximate knowledge of the azimuth of the line to be measured must be available. The correction to be applied to the EPI distance measured is then scaled. It is recommended that the control for the visual fix be plotted on an aluminum-mounted sheet to reduce the scaling error to a minimum. The reduction from the anchored position to the adjacent EPI station may be computed if the geodetic positions of the control are available. This anchor method eliminates the use of the EPI calibration correction for the adjacent EPI station.

If the control is not available at the adjacent EPI station, reduction may be accomplished from the anchored ship position by Shoran distance and gyro bearing to the station.

2.700 PLOTTING METHODS AND PREPARATION OF BOAT SHEETS

EPI fixes are readily plotted on a boat sheet constructed on a polyconic projection. Reference is made to the U. S. C. & G. S. Hydrographic Manual, paragraph 7341, distance arc for RAR, where a similar problem is solved. To construct distance arcs on boat sheets, plastic templates can be used in addition to methods described in reference above.

Reference is made to the U. S. C. & G. S. Hydrographic Manual, paragraph 4537 where the Odessey RAR protractor is described. This protractor is well suited for plotting fixes on circle systems. Information concerning the best method for working up line-crossing observations is found in an article by Commander C. A. Burmister, U. S. C. & G. S. published in the Journal of the Coast and Geodetic Survey, Volume 4, December 1951.

THE EPI FIX

The operational characteristics of the system require that certain adjustments be perfected at the time of each fix. The main consideration is that each ground station be properly synchronized with the ship in order to obtain as nearly correct data as possible for the fix. This requires that fixes be obtained at certain predetermined times, at equal time intervals. The fix interval will, in part, be governed by the scale of the survey. The following are the suggested fix intervals for use on boat sheets at scales indicated:

Survey scale	Time between fixes (minutes)
1:100,000	10 or 15
1:200,000	15 or 30
1:400,000 (or smaller)	30 (or longer)

3.100 DUTIES OF SHIP EPI OPERATOR

Before performing duty as an EPI operator, the person assigned to this duty should be instructed by the radio technician in the following particulars:

How to recognize a sky wave

How to check the timing circuits on his indicator but not how to adjust them. (See paragraph **7.200.**)

How to take a zero check. (See paragraph **7.700.**)

The uses of the various knobs, dials, and meters on the indicator

How to recognize a saturated signal

How to adjust the instrument (as described in paragraph **3.102**), match his wavefronts, and take a reading

When first coming on watch, he should inquire from the man whom he is relieving as to the approximate readings to be expected, the approximate settings of the gain controls, whether or not sky waves or static interference is to be expected. He should make a check for sky waves, if indicated, by turning the gain up and searching for other signals 50 to 100 microseconds away from the signal being used. The signal giving the smallest reading is the ground wave regardless of the size of the signal. If static conditions exist, he must be alert to keep track of his signals between fixes so that he does not lose them in static.

He must check the voltage to his equipment before each fix, and should take a zero check at least once a watch.

When it becomes necessary to more closely develop bottom features, the fix-time interval is made less so that better control of the ship's course is possible.

3.101 Procedure On Ship

Assuming that the fix interval has been set at 15 minutes and that the fixes occur on the hour and at each 15-minute interval thereafter, the proper procedure in obtaining the data for the fix is as follows:

EXAMPLE: Fix to be at 10:00:00

09:59:00 The recorder calls out *One minute to go.* If blinking is being used by the ship, it should be stopped by turning the trigger switch to center position. The EPI operator makes such preliminary adjustments to the settings of the indicator as necessary.

09:59:30 The recorder calls out *Thirty seconds*, or makes three warning buzzes on the buzzer. The EPI operator aligns station pips on the indicator scope, and makes such adjustments as necessary.

09:59:45 The recorder calls out *Fifteen seconds*, or makes two buzzes on the buzzer. The EPI operator aligns the station pips on the indicator scope and keeps them aligned, making such other adjustments as necessary until:

10:00:00 The recorder calls *Mark*, or makes one buzz on the buzzer. The EPI operator has the pips aligned, takes both hands off the vernier cranks, and calls out the data as follows: *EPIA one zero six seven point two* (recorded as 1067.2); *EPIB nine eight six point one* (recorded as 986.1). Blinking is now turned back on and the EPI transmitter high voltage turned off. (See paragraph 9.310 for description of the blinking circuit.)

The navigator writes these values down on his Shoran-EPI abstract sheet. The recorder records the data in his record book, then repeats what he has recorded back to the EPI operator, who checks them against the vernier readings still held on the controller. The verniers are NOT changed until the fix has been plotted and verified. The fix will generally be plotted within a period of one to one and one-half minutes. The requirement that verniers be not changed during this time gives the navigator time to plot the data and thus check it. This safeguards against the possibility of incorrect readings of the verniers, which sometimes appear as transpositions in the data as read.

To minimize interference to the ship's communication system, the EPI transmitter high voltage is turned off between fixes. The EPI operator should turn on the high voltage of the transmitter between 5 and 10 minutes before fix time.

3.102 Instrument Adjustment for Range Measurements on Ship

Assume that the position of the ship is not known (such as when the ship first enters the working grounds). With the ship's equipment properly warmed up and the ground stations synchronized, set the controls on the instrument as follows:

SWEEP SPEED on SLOW
RECVR on ON 2
TRIGGER ON
RECVR GAIN about 6 or 7

Set both *A* and *B* 1000-microsecond range dials on zero. (It is not necessary to set the vernier dial to zero.) It should be noted that there are two groups of four timing pips on the right vertical trace. The upper group is the *A* sweep pips and the lower proup is the *B* sweep pips. The *A* ground-station signal should appear somewhere in the group of *A* sweep pips, while the *B* ground-station-signal should appear in the group of *B* sweep pips. If the ground-station delays are set for normal range operation (ship within 3000 microseconds of the ground stations), the approximate range of the ship from a ground station is found as follows: Starting at the top of the group of sweep pips, count the number of pips before reaching the ground-station signal. The distance to the ground station within 1000 microseconds is one less than the number of pips times 1000. As an example, if there are three pips from the start of the group and the ground-station signal, the approximate range will be three less one or two times 1000, or 2000 microseconds. The exact range will be read later fron the vernier and the 2000 microseconds will be added to this reading to give the total exact range. Proceed to the next step by setting the controls as indicated.

SWEEP SPEED on FAST
FAST SWEEP ON 2
RECVR on ON 2
TRIGGER ON
BALANCE GAIN centered
RECVR GAIN about 6

Pull out the knob of the *A* 1000-microsecond range dial and rotate it so that it snaps back into place for each 100-microsecond change. At one or two of these 100-microsecond positions, the *A* ground-station signal should appear on the left side of the scope. When it does, leave the dial set at the point where the knob snaps back into place and crank the *A* range knob until the *A* ground-station signal is adjacent to the local signal on the *A* side. Repeat this operation for the *B* side. For matching the signals, follows the step in Figure No. 8.

3.103 Range Measurements Beyond 3000 Microseconds

The normal range of the EPI from any one ground station is 3000 microseconds; however, ranges of 6000 microseconds or more are possible if the ground station is instructed to introduce the proper delay. Normally, the ground-station operator does not know if extra delay should be put into his instrument; thus, it is the duty of the hydrographer to instruct him. Also, as the ship moves from ranges greater than 3000 microseconds to distances closer to the ground station, the ground station should be informed to remove delay. However, if the ship fails to inform the ground station to remove the delay, it will not affect EPI fixes until distances less than the additional delay added are approached. It should be kept in mind that it is necessary to instruct only the ground station whose ranges will exceed 3000 microseconds. The other ground station may continue to use normal range delay. When it is possible, it is best to inform the ground stations well in advance when they should put in extra delay. It might even be possible to let the ground station know at what time they should make the delay change. When the ship is steaming away from the ground station, they should tell the ground station to put in 1000 microseconds' delay before they are 2800 microseconds from the station. If the ship intends to go to ranges between 4000

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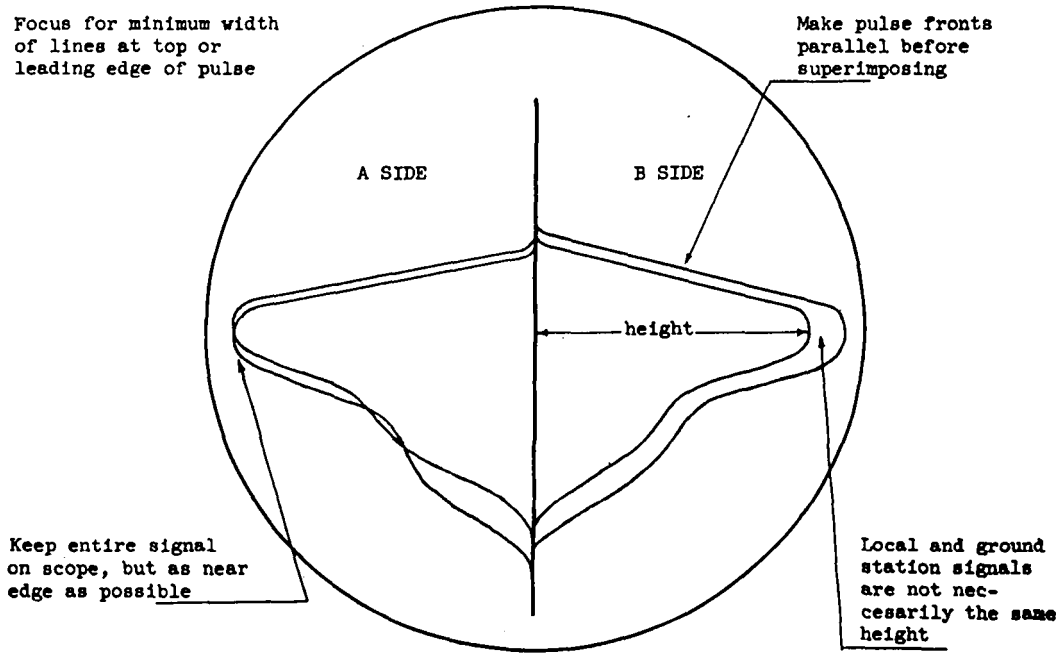

1st. Using receiver gain control, bring weaker shore station to proper amplitude, which is as large as possible and still have entire signal on scope.

2nd. Using local gain control, adjust local signal until wave front of local signal matches wave front of weaker shore station (should be parallel for 0.8 leading edge).

3rd. Using balance gain control, adjust stronger shore station signal to match local signal as in 2nd.

4th. Bring wave fronts into coincidence with goniometers at standby, holding conincidence until mark, then read.

FIGURE 8.—Appearance of signals on the ship's scope just before signals are superimposed.

and 5000 microseconds, they can instruct the ground station to put in 2000 instead of 1000 microseconds.

The instrument adjustment made by the ground-station operator is given in paragraph **3.202.**

3.200 PROCEDURE AT THE GROUND STATION AT FIX TIME

Assuming that the necessary adjustments have been made to the instrument, as described in paragraph **3.101,** then:

At the one-minute-before-fix alarm, the ship operator will cut his blinking circuit. When the ground-station operator notes that the ship signal has stopped blinking, he will make the adjustments preparatory to the fix. First, the SYNC METER is centered by the FINE FREQ control on the controller-indicator. Then the pulse wavefronts are lined up by the FINE DELAY control on the synchronizer. It may be necessary to make small adjustments to the GAIN, BALANCE GAIN, and LOCAL

SIGNAL GAIN controls to make the local- and ship-signal wavefronts parallel. Then comes the final FINE DELAY adjustment to match these wavefronts. Most of these adjustments should be made well before the end of the minute-before-fix time so that at the time of fix there will be no change. The synchronizer, in the absence of noise, will hold the system for a considerable time without adjustment. At the end of the fix, the operator makes the following entries in his log: TIME, FINE FREQ, FINE DELAY, BAL. GAIN, GAIN, QRN, MATCH, LOCAL SIGNAL GAIN, and REMARKS. Once each hour the transmitter's transmission line current is recorded. The MATCH and QRN indexes appear in the following table. Selection of the proper index number is a matter of personal judgment, which will become more accurate as the operator gains experience in operating the equipment.

MATCH Index		NOISE Index (QRN)
0	No signal, or out of sync	Excessive
1	Unsatisfactory	Moderate
2	Satisfactory	Little
3	Excellent	None

3.201 Synchronizing Procedure

After all the equipment has warmed up at least 30 minutes, all timing checks have been made, and the station delay control set properly, the unit is ready for surveying fix matches.

Set controls as follow:

SWEEP SPEED switch on SLOW
FAST SWEEP switch on 3
RECVR switch on ON 1
RECVR GAIN turned up
Use some trace separation
TRIGGER ON

If the ground-station transmitter is working properly, a local-signal pulse should be seen on the lower trace at the leading or left edge of the lower pedestal.

With the electronic attenuator unblanking switch off and the amplitude balance control centered in its range, the ship-station and other ground-station signal pulses should be seen on either top or bottom trace. These signals can be moved to the left or right by pressing the left-right switch correspondingly. The ship signal can be easily identified as it will shift along the trace while in the process of *Blinking*.

Move the ship's pulse by means of the left-right switch to the top of the pedestal on the upper trace. The fast-sweep switch should then be set to 2 and the sweep-speed switch set on fast. If the ship-signal pulse is drifting fast to the left or right (with the left-right switch normally centered), an adjustment should be made with the fine-frequency control. If this drift cannot be stopped by the fine-frequency control, this control should be centered in its range and a coarse-frequency adjustment made until the drift is stopped. The coarse-frequency control is a screwdriver adjustment and is reached through an opening on top of the controller-indicator unit.

Using the left-right switch, the signal should be shifted to the left edge of the sweep or near the local-signal pulse.

Set the sweep-speed switch to 1 and the receiver switch to ON 2. The electronic attenuator unblanking switch is switched to ON.

The balance gain, receiver gain, and local-signal gain controls are adjusted to give a just-below-saturation of signals. This condition is found by noting where the tops of signals just begin to flatten, and the receiver gain is backed off just a little from this point.

Adjust the fine-frequency control so that the synchronizer meter needles are centered.

Adjust the fine delay (also adjust the coarse delay when the fine delay is out of range) on the synchronizer until the leading or left pulse fronts are nearly together.

Using the local-signal gain, receiver gain, and amplitude balance controls, the leading edges of the pulses are adjusted so that they are parallel along their entire front; then these parallel pulse fronts are brought into exact coincidence, using the fine delay control on the synchronizer. See figure No. 9. This adjustment is held for a full minute during fix time (30 seconds before and 30 seconds after), or until the ship signal reblinks.

Care should be taken that these pulses do not go into saturation during adjustment. The balance gain is adjusted in steps of one division of the dial at a time, the settings usually being in the range of 7, 8, 9, or 10.

After making adjustments, operation is a simple matter of trimming the local-signal gain, balance gain, and receiver gain. In case the ship signal goes off, it is a matter of bringing the signal back into synchronism by going back to slow sweeps and repeating the above procedure.

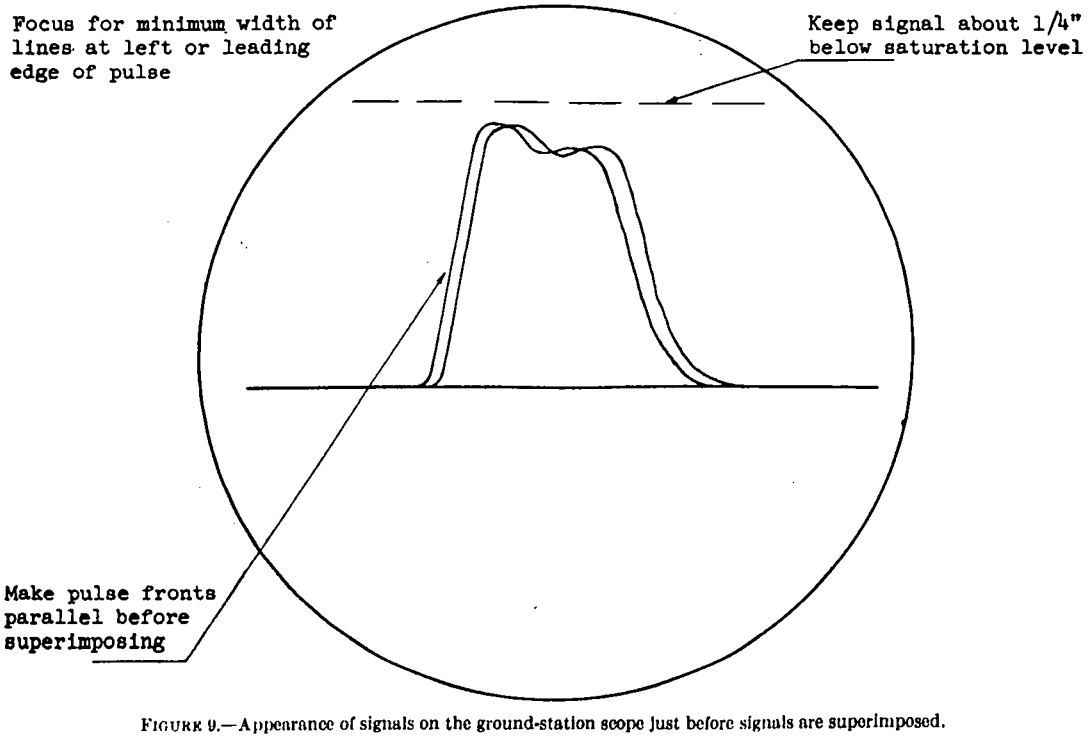

FIGURE 9.—Appearance of signals on the ground-station scope just before signals are superimposed.

Synchronizers Nos. 1 to 9 have an alarm circuit which consists of a 6SN7 tube as a push-pull cathode follower stage. The grids are connected to the output of the differential amplifiers and a sensitive relay is connected across the cathodes. When the ground station is in synchronism, no current flows through the relay coil; but when the ground station is out of synchronism, even to a relatively small degree, the out-of-balance current will close the relay and turn on the alarm light. A buzzer is connected across the alarm light with a switch. If the operator is some distance away where he cannot see the alarm light, he can switch on the buzzer so that he will know when the ground station is out of synchronism.

3.202 Ground-Station Adjustment for Ranges Beyond 3000 Microseconds

The delays are changed at the ground station by means of the control marked STATION DELAY on the front panel and the control marked R on the left side of the controller. Delays are established by the position of the pedestals on the upper and lower slow-sweep traces. When the ground-station operator is told by the ship to put in or remove delay by a certain amount, he should adjust his instrument, using the delay tables shown below. Set the instrument as follows:

SWEEP SPEED on SLOW
FAST SWEEP on 3
RECVR on OFF

For *A* Station

DELAY (Microseconds)	*Top sweep pedestal on (Use *R* control)	*Bottom sweep pedestal on (Use DELAY)
Normal	2nd pip	4th pip
1000	2nd pip	2nd pip
2000	4th pip	2nd pip
3000	6th pip	2nd pip

*Count pips from the left end of the sweep to the left edge of the pedestal.

For *B* Station

DELAY (Microseconds)	*Top sweep pedestal on (Use *R* control)	*Bottom sweep pedestal on (Use DELAY)
Normal	2nd pip	14th pip
1000	2nd pip	12th pip
2000	2nd pip	10th pip
3000	2nd pip	8th pip

*Count pips from the left end of the sweep to the left edge of the pedestal.

3.203 Alternate Method for *A* Ground-Station Adjustment for Ranges Beyond 3000 Microseconds

If the left edge of the pedestal on the *top* sweep is set at the 6th pip, the ranges can be adjusted solely by use of the STATION DELAY control on the front panel. In this case, for normal operation, the left edge of the pedestal on the *bottom* sweep will be set at the 8th pip. Moving the bottom pedestal to the 6th pip will extend the range by 1000 microseconds; to the 4th pip, 2000 microseconds; to the 2nd pip, 3000 microseconds.

IV

INSTALLATION OF SHIP EQUIPMENT

4.100 LOCATION OF INSTRUMENTS

4.101 Controller-Indicator

From electrical considerations, the location of the controller-indicator is not critical. However, it is desirable, but not necessary, to have it in a different compartment than the EPI transmitter. The choice of position for the controller-indicator is most often controlled by the space that is available in the vicinity of the plotting table. When the controller-indicator is located near the plotting table, the hydrographer can supervise its operation. It also simplifies communication between the various points of operation. When the controller-indicator is remotely located, a communication system between this unit and the plotting room will be needed.

There should be two to three feet of space all around the controller-indicator for operation and maintenance of this instrument.

4.102 Transmitter, Modulator, Voltage Regulator, and Wavemeter

While the location of the transmitter is not critical, it is preferable to select a location which will shorten the distance between the transmitter and the antenna. As a secondary consideration, the controller-indicator and transmitter separation should be kept small. Since there is no forced ventilation, the space should be moderately well ventilated. There should be 3 or more feet of space in front of the transmitter and 2 feet on each end. For convenience in adjustment, it should be mounted about 30 inches off deck. The modulator can be mounted in any convenient space within the 5-foot cable length of the transmitter. If there is room, the voltage regulator should be in the same compartment as the transmitter and modulator. Mount the wavemeter sufficiently near the transmitter that a large meter deflection is possible. There should be no large metal surface within 12 inches of the back or bottom of the wavemeter. A satisfactory arrangement is to mount the wavemeter on brackets which attach to a bulkhead in back of or over the transmitter. By looping the RF coaxial cable from transmitter close to the wavemeter, large deflections of the wavemeter are possible (see Figure 11). (Note: All transmitters have been modified by adding a dual type blower to keep the 304th tubes at a lower operating temperature.)

4.200 INSTRUMENT AND CABLE INSTALLATION

4.201 Controller-Indicator

The controller-indicator should be arranged so that the scope faces either forward or aft as this eases operation during rough weather. It may be necessary to place the instrument on a stand which is secured to the deck. The base should be elevated

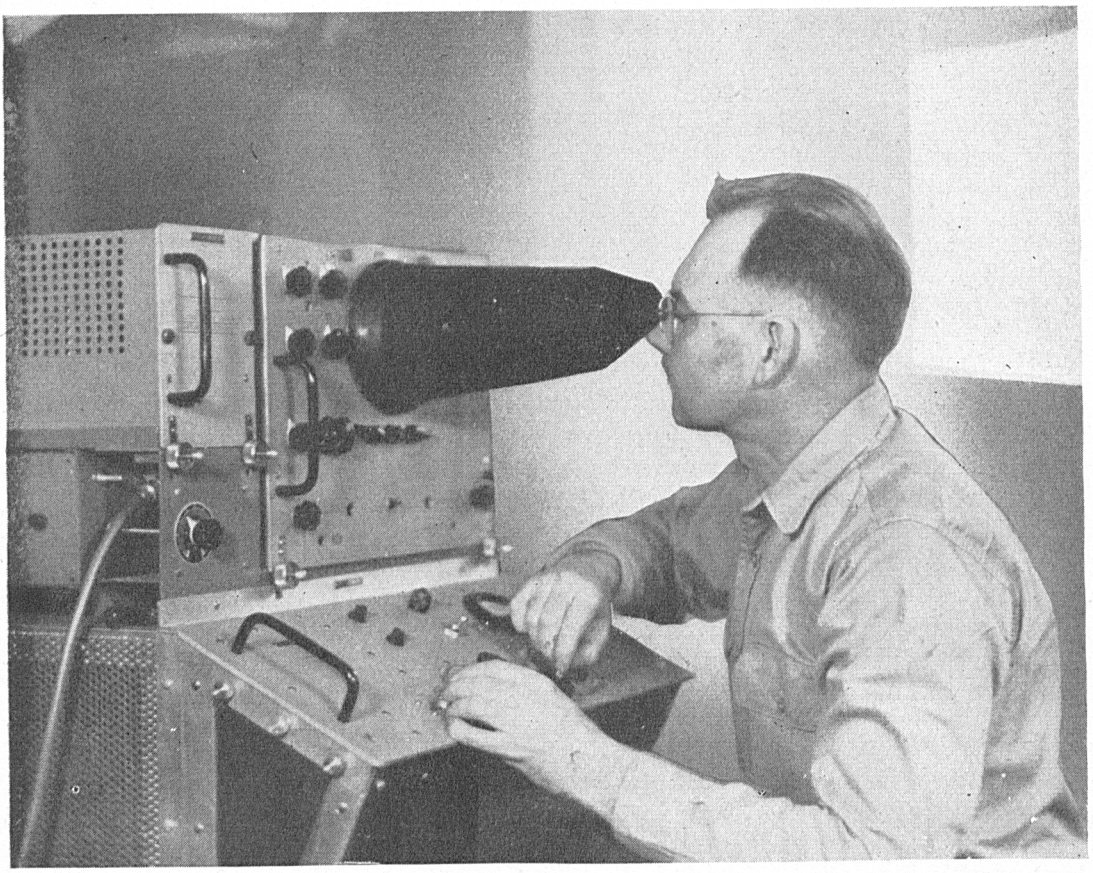

FIGURE 10.—Ship Indicator installed on ship's bridge.

above the deck on a wooden pad so that the center of the cathode-ray tube is about 47 inches from the deck. This will be a convenient height for a seated operator. The stand should be built to fit the slope of the deck so as to level the controller-indicator.

Where practicable, the cables from the controller-indicator should pass through kickpipes between compartments. To keep the cables off the deck, the kickpipe should be located as close to the back of the unit as possible. When this type of cabling is not advisable, the cables may pass through the deck above or be secured to the beams above the instrument.

4.202 Transmitter, Modulator, and Regulator

The transmitter may be on a table-like stand to elevate the base of this instrument about 30 inches above the deck. This makes for convenience in operation and maintenance. Space may be provided for mounting the modulator under the transmitter, although the position of this unit is unimportant provided it is within cable length of

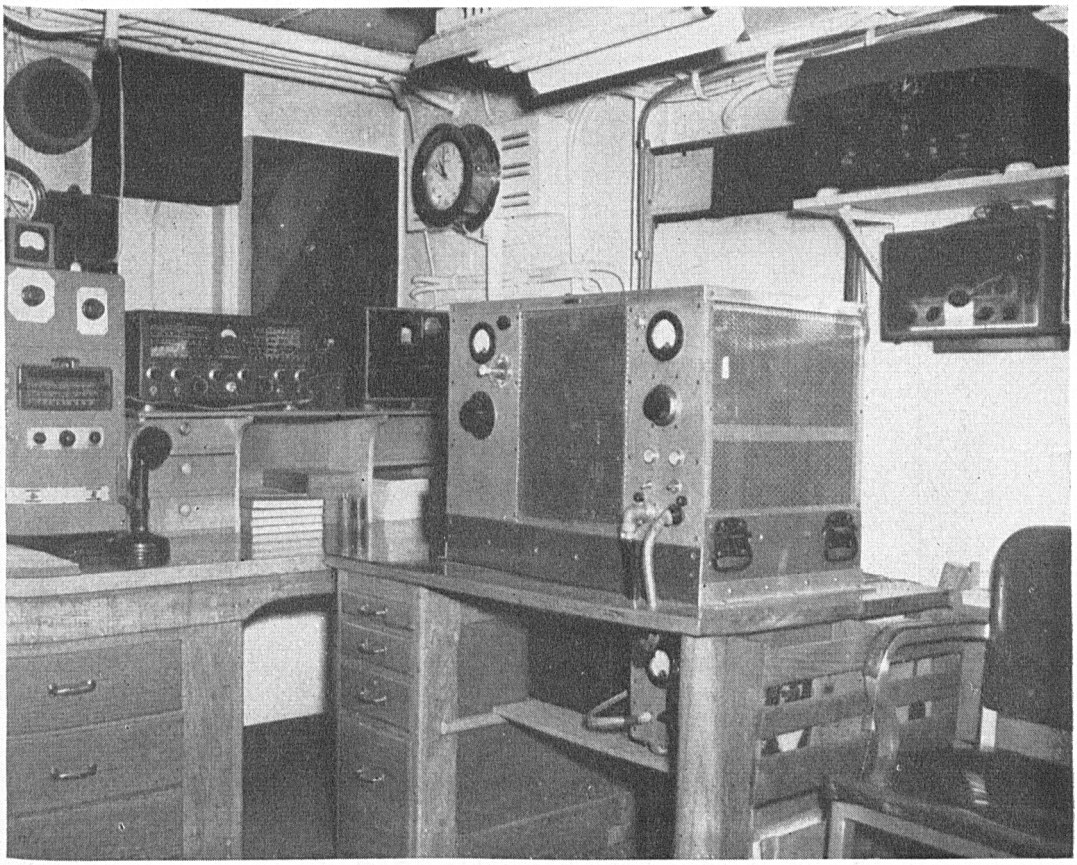

FIGURE 11.—Ship Transmitter installed on ship's radio room.

the transmitter. Another satisfactory expedient is to mount these units on a shelf which is hung from a bulkhead. Enough space (about 6 inches) must be left behind the transmitter to make the antenna and ground connections.

Since the regulator is heavy and needs little attention, it may be located on the deck in some out-of-way place. This space should not be enclosed since a moderate amount of ventilation is needed for this unit. The same applies for all other units.

4.203 Transmitter and Receiver Antenna-Couplers

The transmitter and receiver antenna-couplers should be located together near the base of the vertical EPI antenna. It is desirable to mount these two units in a watertight compartment on the boat deck, or in a compartment below the boat deck. A large bowl insulator should be used where the antenna passes through the bulkhead or deck. The couplers should be grounded to the steel bulkhead or deck, which forms a structural part of the steel hull of the ship. Grounding between the transmitter-

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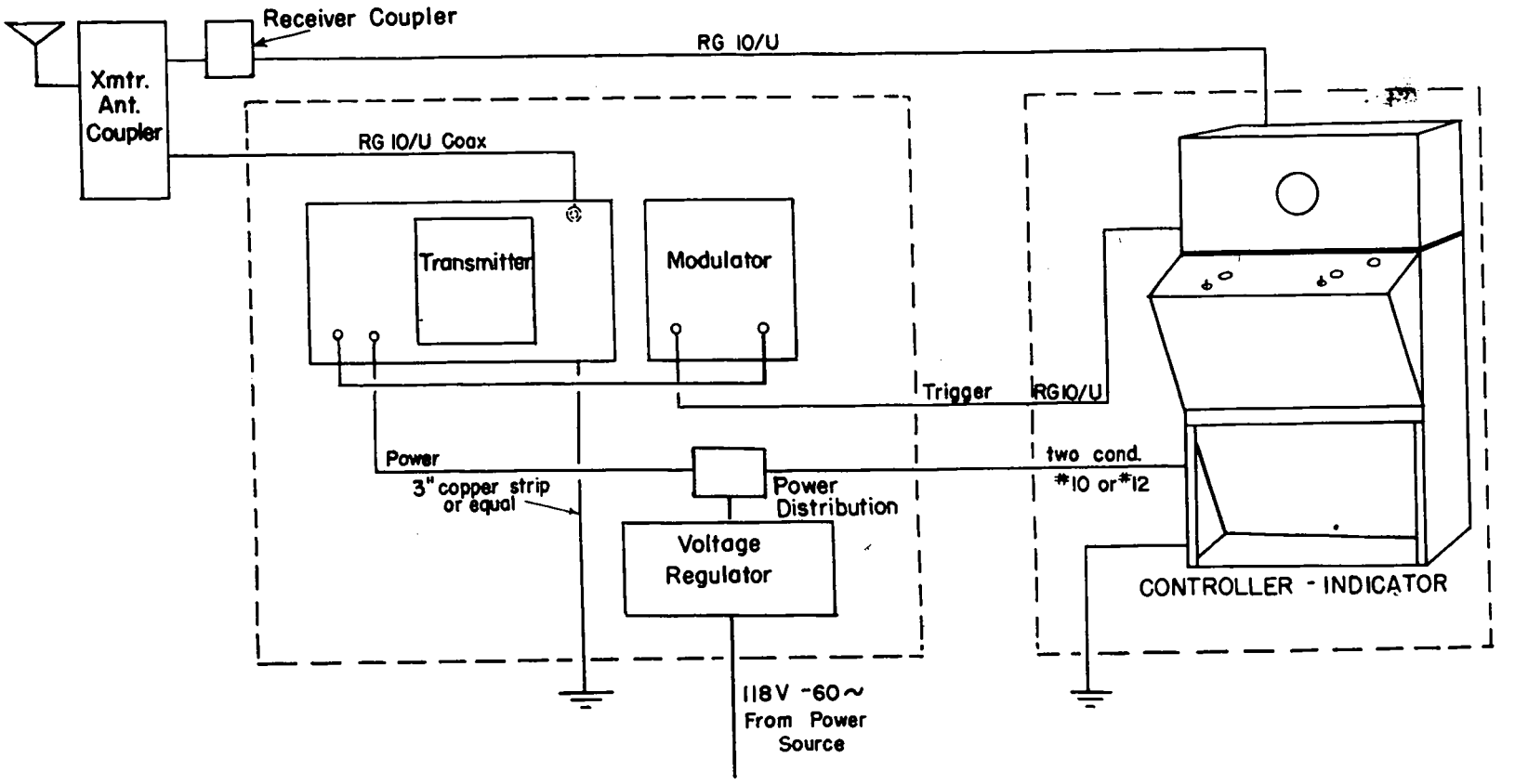


FIGURE 12.—Ship station instrument arrangement and interconnecting cables.

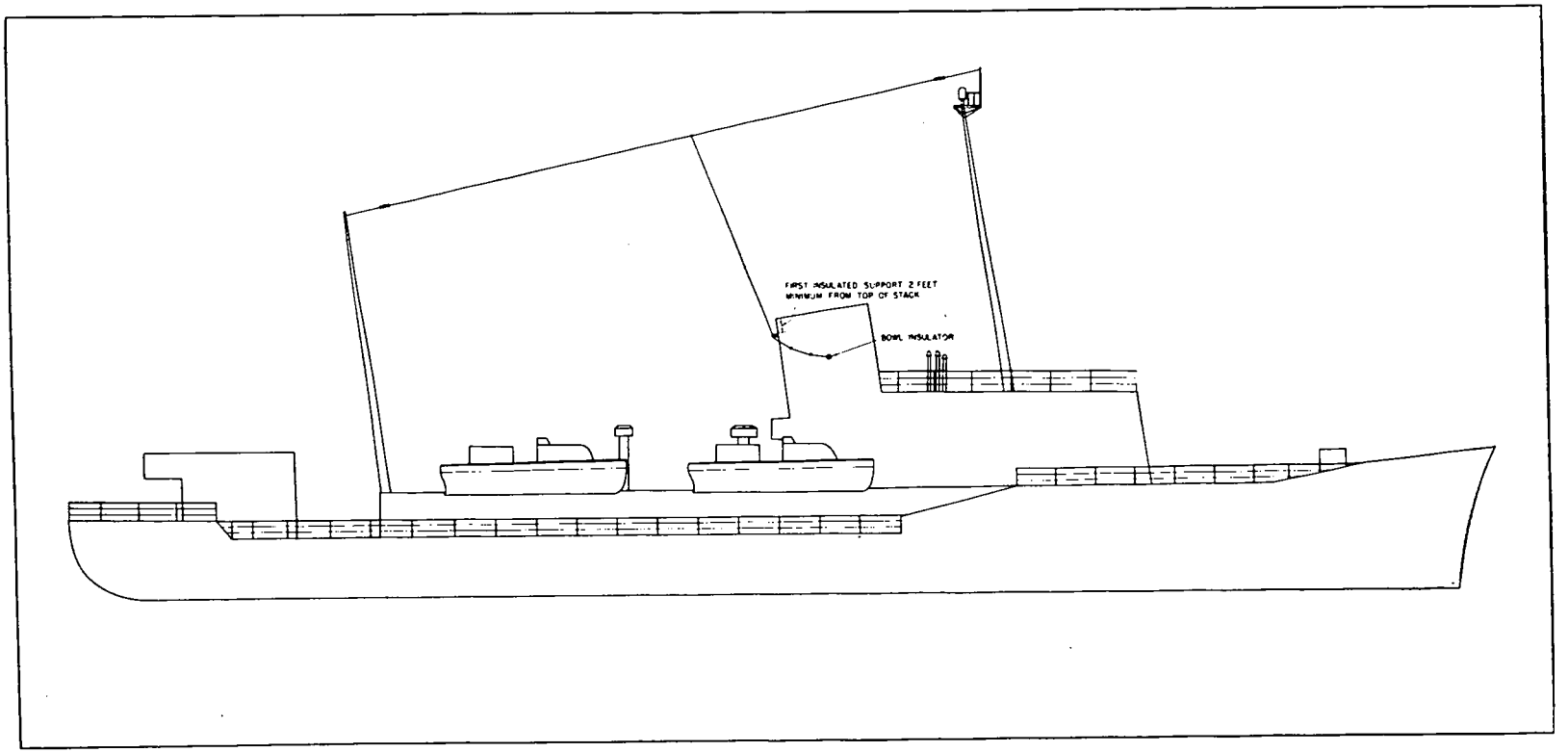


FIGURE 13.—Ship antenna system.

coupler and the ground point should be with a wide copper strip or braid. The receiver-coupler is to be grounded at the same point, but a smaller ground lead may be used. RG–10/U cable is used to connect these units to the transmitter and receiver. Figure 13 illustrates a typical ship antenna installation. Refer to paragraph **9.600** for data on ship antenna.

4.204 Cables and Grounds

For permanent installations where coaxial cable is needed, RG–10/U should be used. For temporary installations, 52-ohm RG–8/U coaxial cable is recommended. The power cable should be 2-wire, No. 10 or 12, leaded and armored—the conventional shipboard type. Grounding strips should be of thin copper shim, 3 or 4 inches wide. The ground point should be as near the transmitter as possible. This may be a bulkhead that is well connected to the hull of the ship. The coaxial cables to the receiver- and transmitter-couplers may be run parallel but should be separated by 6 inches.

V

INSTALLATION OF GROUND STATION

5.100 SELECTION OF GROUND-STATION LOCATION AND OTHER CONSIDERATIONS

Assume that the general location which will give the best control of the area to be surveyed has been decided upon. The exact location should be selected to meet the following requirements:

a. It is desirable that the ground be fairly level and clear for a distance of about 200 feet from the center of the system.

b. While the location may be on high ground, there is no advantage in having the station elevated except when Shoran is used for calibration. In fact, other considerations make it more desirable to have the station on low ground near the water's edge.

c. Have the station so located that the signals will not have to pass over more than a quarter of a mile of land from any direction to the working grounds.

d. Where the ground wire is close to the water's edge, the wire should never be under water at any stage of the tide.

In selecting a site in remote areas, the camp water supply will be a serious problem. When possible, select a site which is close to fresh water or where the transportation of water is not difficult.

It should be kept in mind when undertaking the construction of an EPI ground station that the extensive area served will make it a semipermanent installation, requiring sturdy weather-tight structures for shelter of instruments, equipment and personnel. When the station is to be used to serve a special purpose requiring only a brief period of operation, tents or temporary shelters may be used. In any case, the lightly constructed EPI towers must be carefully erected on a solid foundation and securely guyed, the instrument shelter must be weather-tight to protect the electronic equipment and well lighted. If any assurance of satisfactory operation is to be had, the electronic and electric installations must be done meticulously. In general, time and effort spent on sturdy construction and careful installation is well repaid when stations are to be used for long periods in remote localities. Satisfactory operation is almost as much a personnel problem as a technical one since long periods of conscientious effort must be obtained from the operators. Provision of a moderate degree of comfort in living and working conditions and periodic inspections are of great assistance in obtaining the full cooperation of the operating personnel.

5.200 PRELIMINARY

Figures 14, 15 and 16 show the typical layout of a station when a calibration buoy is used. The physical characteristics of the site are not critical except from the standpoint of ease of construction. When Shoran is used for calibration, the site must be

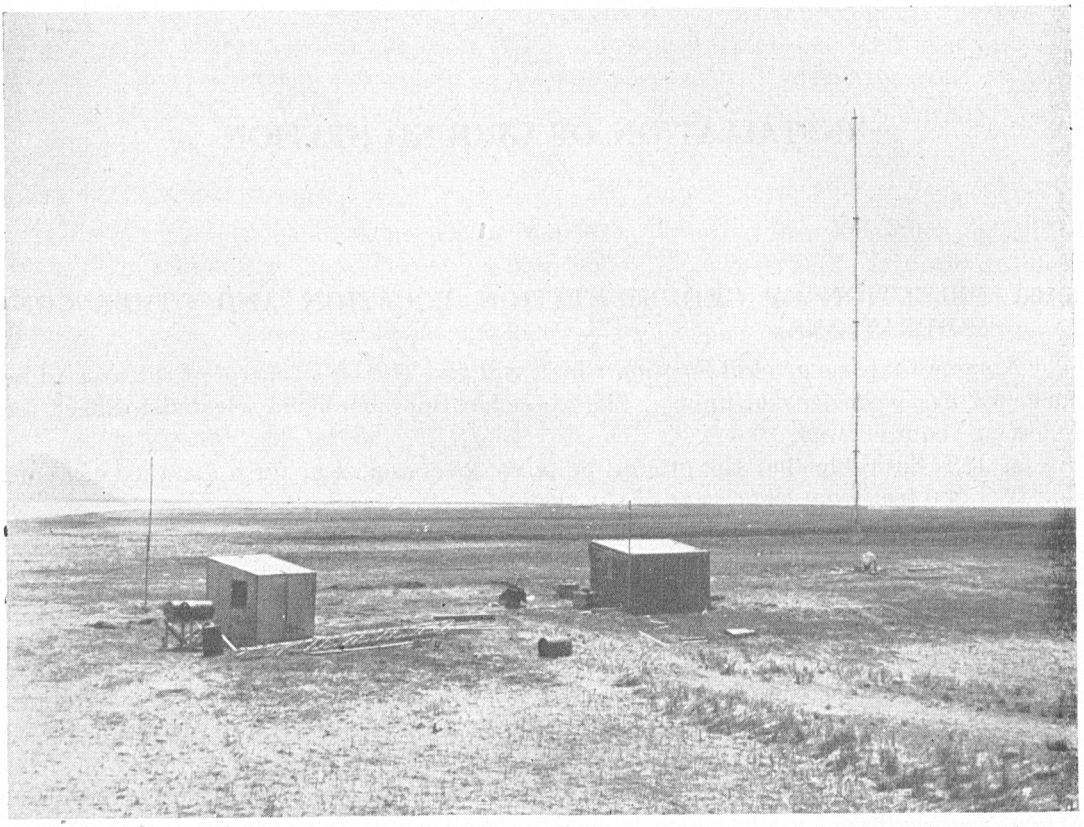


FIGURE 14.—Ground station arrangement showing power shelter at left, instrument shelter in center, and tower with antenna coupler, at base.

selected on higher ground. Operationally, a minimum elevation of 100 feet for the Shoran antenna is essential and 150 feet is desirable. If the elevation of the station site is greater than these limits, the Shoran antenna may be attached to the operating shelter and the need for a separate Shoran shelter eliminated.

The position of the EPI tower must first be selected and the ground plane laid out. The stakes for fastening the wires of the ground system may well be driven at this time, but laying of the wire should be deferred until the major part of the construction is finished to eliminate damage to the system and interference with the work. If the stakes are driven, bright-colored cloth is a help in recovery in grass or tundra. Wooden stakes, 2″ x 2″ x 2′, are satisfactory in firm soil, but where the ground is rocky or frozen, metal stakes must be provided. A ⅜- to ½-inch metal bar, 2 feet long, is suitable. Ideally, it should be pointed at one end and have a boss at the other. The layout of the ground system may be accomplished by improvised means, but a small theodolite with tripod and a 300-foot tape will speed up the work.

Once the ground plane system is staked out, the positions of the structures will be indicated by the terrain. The minimum dispersal is dictated by operational efficiency and technical considerations. If the dispersal of the EPI structures is appreciably increased, longer cable lengths are required and considerable power losses may develop. When an elevated Shoran antenna is used, the Shoran installation should not be less

than 400 feet from the EPI tower. If additional elevation is required, it may be placed as much as a quarter of a mile away. At greater distances, operational problems will multiply.

The following factors should be considered: (1) The station should be accessible from roads, beach, or other entrances; and (2) the power lines that service the station should be in a direction away from the EPI antenna; where possible, these lines should be in a direction away from the ship's working grounds—in no case should elevated power lines be between the ship and the antenna.

The order in which the station is erected is not of importance, so the items needed for construction need not be in the order of the description given here (see Figure 14).

5.201 Camp Construction

The reconnaissance party should determine the available facilities, material such as driftwood suitable for dead men, foundations, and antenna poles. Materials may then be reduced accordingly. They should note the type of soil that must be dug to place the dead men and latrines. The actual shore construction party is then organized according to the work that has to be done at the particular location.

The layout party, consisting of one officer and a man, should stake out the center of the tower, the location of the four dead men or anchors for the tower guys, the 32 terminals of the ground system, and the position of the operating shelter.

Tower assembly party. Depending upon the type of the tower, this should consist of a junior officer and two men. A tool box with the following tools should be brought ashore:

Speed socket, and open-end wrenches to fit all tower bolts, U-clips, shackles, turnbuckles, and foundation bolts

Lineman's pliers

Gas pliers

Hammers and drift pins for aligning tower holes

Also, some light and heavy wire should be taken ashore. The former is for tying cable and chain ends out of the way, and the latter for fastening the tackle to the top of the boom. A small quantity of trichlorethylene for cleaning the guy insulators should be on hand. Normally, 8 hours will be required to assemble the tower, lay out the guy wires, and install the tower base. This time can be varied a little according to how much preparatory work can be done on the ship; but, in general, sufficient men familiar with the work are not available to permit them to work without close supervision, and two men are about all one officer can supervise. The final lengths of the guys and design of the base foundation depend on conditions at the site, and generally cannot be done ahead of time.

Labor party. Men must be provided to carry about 6 tons of equipment from the beach to the site of the camp. The number of men required will depend on the local terrain. A large quantity of the equipment must be kept dry, and tarpaulins must be provided as temporary covers until the shelter is finished.

Shelter-building party. This should consist of one petty officer and two seamen familiar with carpenter tools. The construction of the shelters will take about two days. If possible, the generator shelter and the operating end of the main shelter should be built first so that the engineer and electronic technicians can proceed with

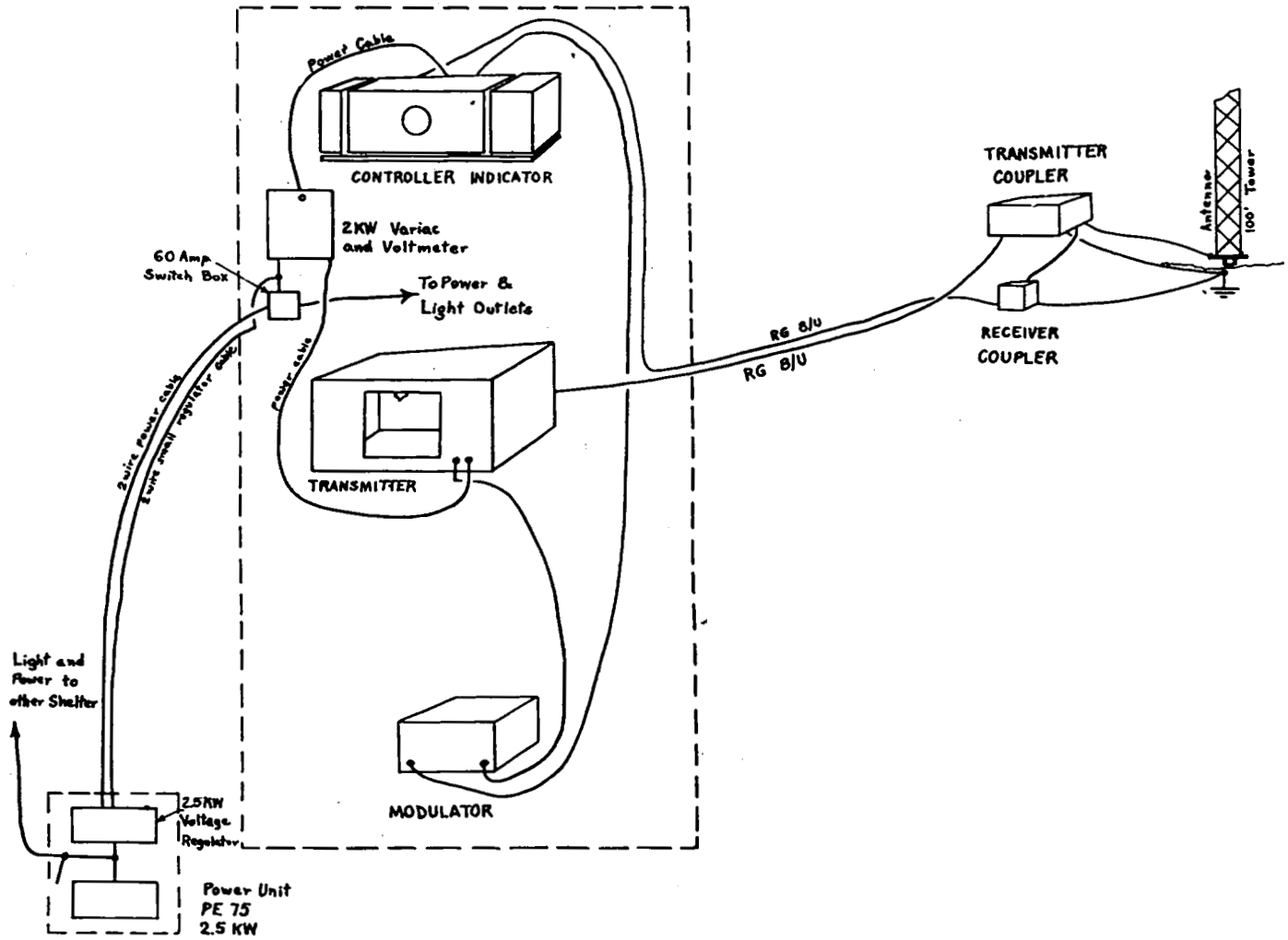


FIGURE 15.—Ground station instrument layout shown for operation without stand by equipment.

their work. If men are available, a slightly larger crew may be assigned to this work. They should be equipped with the tools listed in paragraph **15.600.**

Digging party. The number of men assigned to this party will depend on the soil. A minimum of two men are required in easy digging. They need to dig eight holes for dead men for the towers (EPI and Shoran) and one hole for the latrine.

Tower raising party. Raising the tower is simple if well organized. Five men can raise the tower if power is available to pull the blocks. The best power likely to be available is a weasel winch. If it is necessary to pull the tower up by hand, additional men must be provided for pulling on the block and tackle. This operation takes about 2 hours, and usually the party is formed from the various other groups working at the camp site.

Electronics party. In general, there is no work for this party to perform until the shelter is finished. It should consist of the radio technician and two seamen assigned to the camp, plus one radio technician from the ship. They have to install all wiring in the shelter and ground system, set up and test all electronic gear assigned to the camp, unpack all boxes and place spare parts and tools on shelves, and arrange storage of the empty boxes. The two seamen on the party should set up the sleeping quarters, living quarters, and stow the food supplies on the shelves in the living quarters. In general, they should go ashore with the initial party and assist with the other work until such time as they can start on their own jobs.

Mechanics party. The EPI generators and Shoran generators assigned to the camp should be set up and tested by the engineering department on the ship. Two men should be sufficient if the labor party assists them in moving the heavy equipment.

It may prove practicable to set up a temporary camp site to permit the working parties to live ashore until the station is finished, especially when transportation to and from the ship is difficult.

5.300 SUPPLY AND TRANSPORTATION FOR THE GROUND STATION

The problems of supply and transportation for ground stations may be divided into two classes: supply from the ship to the ground station, and ground stations which attend to their own supply.

In remote areas, all the station supplies and transportation are handled by the ship. In most cases, the supplies and equipment are moved between the ship and shore by means of small power boats. The ground stations depend entirely on the ship for resupply.

When the ground stations are in more developed areas, they may operate more nearly independent of the ship in regards to supplies. Rented quarters are used by the station personnel. The men purchase their own food supplies out of a mess allowance. A truck is normally furnished to be used for personnel transportation and other station business.

5.301 Landing and Transportation

Since no more than moderate elevation is required for an EPI ground station, it may normally be expected that the site will be comparatively easy of access even in remote localities. Ease of access is, in fact, a prime requisite in choosing the site since there is an irreducible minimum of heavy and bulky equipment to be taken ashore

and moved to the location selected. A suitable beach for landing from the sea is essential.

The use of landing craft is required for beach landings unless considerable time is to be lost in coping with even moderate sea conditions. Some form of transportation ashore is also necessary and will permit the selection of more suitable landings at some distance from the desirable site. The task of moving even the bare minimum equipment by manpower for any distance is a considerable one. Suitable vehicles for most localities are weasels or small tractors. Since neither of these vehicles has any considerable carrying capacity, a trailer is a desirable addition. A two-wheel trailer of standard design is capable of traversing moderately rough ground but under the more difficult conditions, a tracked trailer would be required. Where a wheeled trailer is to be used over rough ground, a link must be inserted between the tractor pintle and trailer draw bar to prevent damage to one or both. All tools and material should be packaged in convenient sizes before landing. The electronic equipment should not be landed until a shelter is available for temporary storage.

5.302 Supplying the Camp

In general, camp supplies can be divided into two distinct classifications, namely, camp equipment of a nonexpendable nature which is to remain in camp during the entire season and expendable supplies which include fuel and food which are delivered to the camp at specified intervals. These two classifications are treated separately in the following paragraphs.

5.303 Camp Equipment

Cooking and mess gear. As an EPI camp is generally manned by four men, much time will be saved in the field if boxes containing all necessary cooking and mess gear for four men are prepared when the ship is in port. Increasing the number of men in a camp for any reason simply requires dishes and silverware to supplement the fixed gear box.

Heating units. Due to the explosive qualities of gasoline, heating units which utilize stove oil, kersoene, or Diesel oil should be used in all camps. Experience has shown that the Coleman heating stove, in which stove oil is burned, gives excellent service. In addition to the basic units, about four sections of 6-inch pipe, a T-damper draftometer in the chimney pipe, asbestos wall plates, and a metal roofjack plate will be needed for the installation of each stove in a shelter.

Cooking units. In temporary camps, it will probably be most practical to use the Coleman two-burner stove with detached heating oven. Two of these units and one oven should be furnished for each 4 to 6 men camp. In camps of a more permanent nature, the Coleman flame stove with an enclosed oven is recommended. While this stove is more difficult to move, it is far more adequate for a permanent camp. Considerable success is obtained with converted wood and coal stoves with ovens. A carburetor and burner are fitted on this type of stove to permit the use of diesel or fuel oil. This allows the use of a safer fuel, and also obviates the need of a separate heating stove.

Furniture. Standard cots are recommended for use in temporary camps. In permanent camps, particularly where space is limited, it is recommended that two-tier frames be built along the walls to hold canvas or spring bunk-bottoms. Enough lumber should be furnished the camp so that in addition to shelving, a standard Army-type

mess table and bench can be built in each camp. Several card tables and camp chairs should be furnished or built.

Bedding. Mattresses should be furnished for all cots or bunks. The amount of linen and number of blankets or sleeping bags required will depend on the climate. Four blankets were supplied each man in the Alaska camps.

Tools and miscellaneous equipment. A chest containing a complete set of carpenter tools, nails, and screws should be provided. Fuel cans, water cans, buckets, spigots for drums, shovels, mop, broom, and dustpan are essential for each camp.

Fire extinguishers. At least two 15-pound CO–2 fire extinguishers should be provided, and several pyrene extinguishers should be placed in all buildings and on all vehicles in the camp area.

Lighting equipment. In general, sufficient current is available from the generators to furnish lights to the several buildings in the EPI camp area. At least three Coleman lanterns and a few candles should be supplied for an emergency.

Medical supplies. A complete First-Aid kit which includes bandages and medicants is a necessity.

Water drums. Water drums should be of noncorrosive material; even drums of corrosive material that have been tested are not completely satisfactory. Aluminum kegs, such as beer kegs, are recommended. When water must be transported great distances, the drums should be no larger than 30 gallons.

5.304 Expendable Supplies

Fuel. The amount of fuel used in an EPI camp will depend on the climate and the type of equipment used. If a gas stove is used for cooking, experience has shown that two 91-pound tanks of Flamo gas will be sufficient for an entire season of 4 months.

The amount of stove or Diesel oil used for heating a camp will depend on the climate, size of buildings, etc. In general, five drums of fuel oil a month were used in heating the buildings in each camp in the Alaska area. Blazo, a purified type of white gasoline, is preferable to white gasoline in Coleman lanterns and stoves. A drum of Blazo will supply a camp for a month when gasoline stoves are used. Leaded gasoline was used to run the generators which supplied power for the EPI, Shoran, and for lighting the camp in the Alaska area. In general, 10 drums of this fuel were used in each camp per month.

It should be noted that white gasoline rather than leaded was preferred for use in the Onan generators for the Shoran. The type of lubricating oil to be used in the generators is specified by the manufacturers. About 20 gallons of oil each month were used in each camp.

Cleaning equipment. The supply of soap, soap powder, and toilet paper needed in a camp will depend upon the number of men. A box of lime for use in outdoor toilets and Aerosol bombs for insects is recommended.

Food. Stewards and cooks aboard the ships will generally prepare the list of food supplies which are required for a specified period. In an extensive project area, such as the Bering Sea, it is frequently difficult to supply camps at regular intervals because of landing conditions. It should be standard practice to provide enough additional food for 10 days beyond the anticipated re-provisioning. In isolated areas, supplying the camps is done on an average of 3 weeks to a month.

It is emphasized that in unfavorable climatic areas, the morale of the personnel can be maintained by building comfortable, adequate quarters, providing the camps with reasonable comforts, and making every effort to give them good and adequate supplies of food.

Mail should be dropped off at every opportunity where serious interference to the field work is not involved.

5.400 GROUND SYSTEM

The ground arrangement is illustrated in Figure 12. The ring of stakes 100 feet from the center may be located in one of several ways. Where the ground is free of brush, tall grass, and trees, and reasonably level, attach a 100-foot radial wire to a stake at the center point; then drive a stake at the 100-foot point and to this stake attach a 39-foot wire to be used to space the stakes around the 100-foot circle. There will be 16 stakes around the 100-foot circle. Where this method cannot be used, angles of 22.5 degrees can be turned off from the center of the system and the 100-foot distance chained or measured by stadia method.

The center piece of the ground system is also the foundation base of the antenna and is illustrated in Figure 17. It should be secured before the wire-laying operation is commenced. When the wire is on a reel, an axle may be provided and the reel carried manually or in a truck while the wire unreels, allowing the wire to pay out. Starting at one stake, bring the wire to the center and then back to the stake adjacent to the starting stake, across to the next adjacent stake and back to the center once again. Continue thus around the loop. Join the stakes that have no wire between them and solder at these points. The 200-foot radials are 22.5 degrees apart. Where they cross the 100-foot circle, they should be soldered. At the center piece, all radials are joined by a wide copper strap which bonds all these wires together.

A complete list of materials for the ground station appears in paragraph **15.400.** For convenience, the major parts needed for the ground system are listed below:

Wire, 5,500 feet, 12- to 16-gauge, copper or copper-clad, solid or stranded
Stakes, 32, 24-inch wood (iron preferred); bridge nails desirable
Radial center (see Figure 13)
Solder and paste, 5 pounds

5.500 ANTENNA SYSTEM

A single tower is used both for transmitting and receiving. The antenna is an insulated 100-foot aluminum tower. This tower stands on an insulated base and is held vertical by four sets of guys (four guys to a set) which are sectionalized every 20 feet by insulators. The tower is erected on the base illustrated in Figure 17.

The tower is erected at the center of the ground system by means of a 30-foot gin pole. The details of assembly and erection of the tower appear in a manual furnished by the tower manufacturer. This description concerns the elevation of a tower with an uninsulated base, which differs in some details from that of an insulated tower. The first steps in elevating the tower are the same as those in the manual; however, the base insulators are put into place after the tower has been erected, as the insulators will not stand the strains which accompany the elevation of the tower. If the insulators are in place during the erection, means must be taken to relieve the strain until the tower is erected.

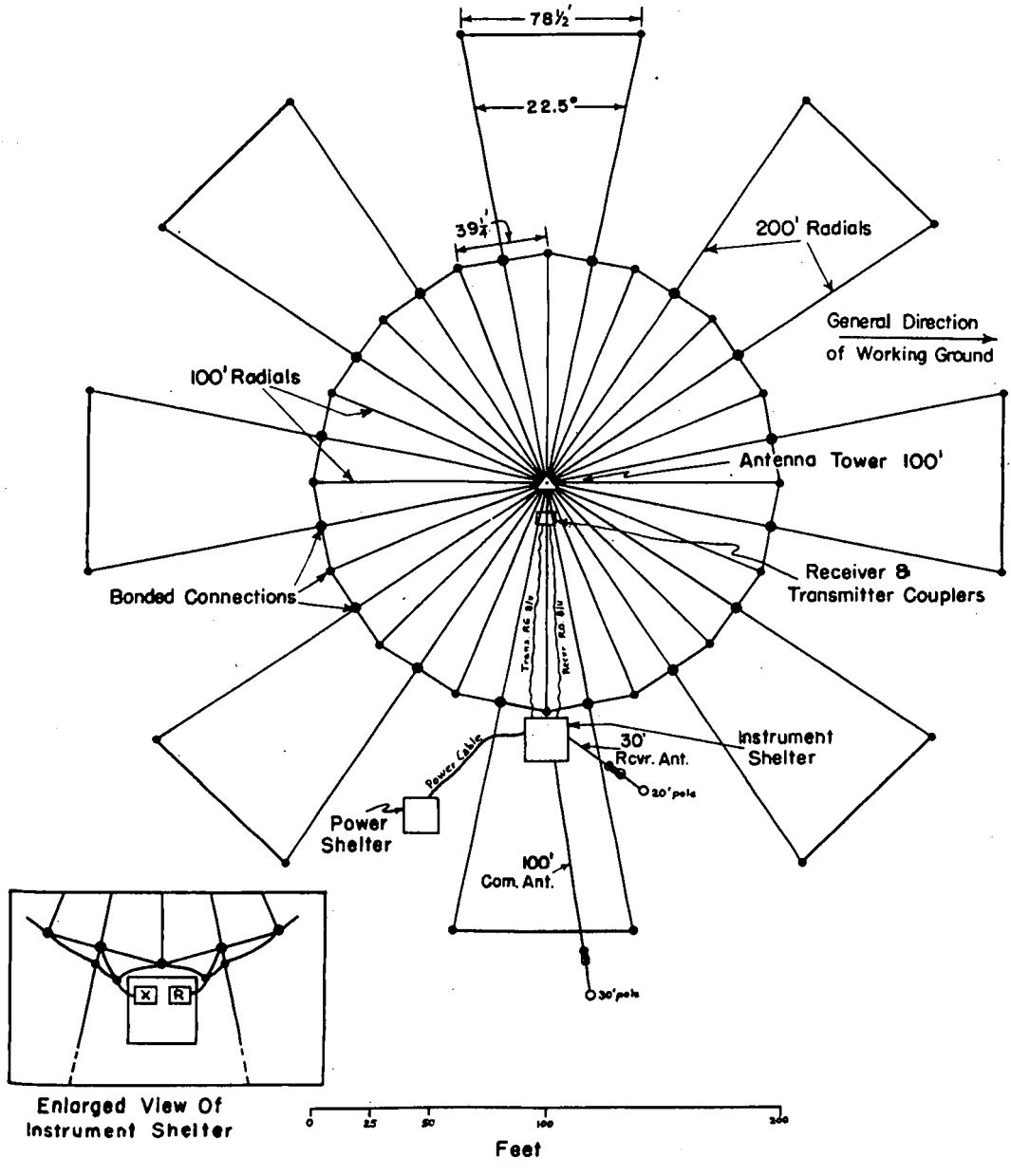


FIGURE 16.—Ground system and station layout.

5.501 Obstruction Marking of the EPI Antenna Tower

When the EPI ground station is to be located so close to an airport that the antenna tower imposes an obstruction, all the Civil Aeronautics Administration marking requirements must be observed. In the following paragraphs the obstruction marking requirements are for the 100-foot EPI antenna tower.

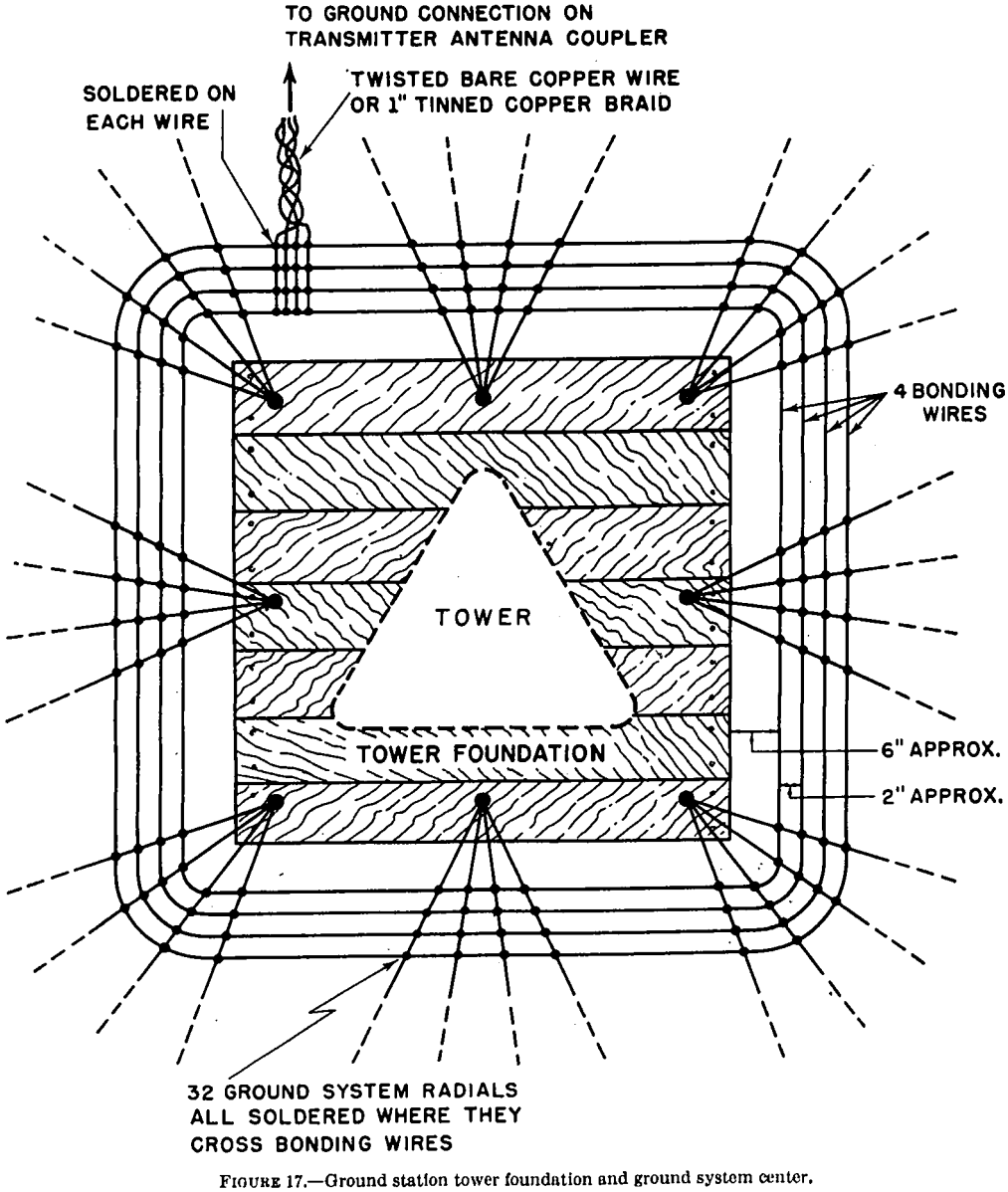


FIGURE 17.—Ground station tower foundation and ground system center.

5.502 Painting the Tower

When the tower is within 2 miles of a landing area, the tower must be painted. Even though the tower may be outside the obstruction area, painting is recommended to preserve the structure.

Paint the top 20 feet of the tower orange; the next 10 feet, white; the next 20 feet, orange; and so on for the entire length of the tower. The bottom 10 feet of the tower will be orange. Care should be taken not to paint surfaces where the 10-foot sections of the tower join, as this will damage the electrical connection between these sections. Paint the inside of the structure as well as the outside.

Several types of orange and white metal protective paints are available. Paints used by the Civil Aeronautics Administration are:

Aviation surface orange paint (Federal Specification TT–P–59, Type B);
Aviation surface orange enamel (Federal Specification TT–E–489); and
White paint (Federal Specification TT–P–40, Type I or II).

5.503 Lighting the Tower

When the EPI tower is within two miles of the landing area of an airport, the tower must be provided with lights. These lights must be kept burning at all times when the sun is more than 6 degrees below the horizon. There shall be a double-obstruction light fitting with aviation-red prismatic or Fresnel globes at the top of the tower; each globe to contain a 100-watt, type A–1, clear lamp.

To prevent the loss of radio-frequency power from the tower, radio-frequency chokes must be used to introduce the lighting power to the tower. Secure the tower-lighting cable to an inside leg of the tower and lash it to the ⅜-inch copper tubing which connects the tower and transmitter-coupler. Place the chokes close to the coupler terminal and run a direct connection of the lighting cable to the chokes. The chokes should be in a weatherproof enclosure. When possible, install them in the same box that houses the coupler (in the newer type couplers, these chokes are included in the coupler box). Use 2-wire rubber-covered cable, such as SJO cable, for the lighting cable which runs from the instrument shelter to the tower and, thence, up the tower. J. W. Miller type 7870, tower-lighting chokes, are satisfactory. One of these chokes is to be inserted in each line of the lighting cable. No bypass condensers are necessary.

5.504 Erection of the Antenna Tower

Several types of tower structures have been used. All are assembled from light aluminum alloy angles, initially in 10 foot sections. A triangular cross section is preferable. Assembly is completed on the ground at the station site and the tower raised by means of an additional section provided as a boom.

Provision of a solid, level foundation for the tower base is essential. This is supplied by two layers of at least 2″ x 12″ timbers placed at right angles and should be about 3 feet square. Since the adoption of the insulated base, the towers now in service do not have any means of hinging the base plate to the foundation during raising. This deficiency is easily supplied by two or more heavy strap hinges. It appears risky to trust to friction to hold the base plate in position. Some means should also be provided to take the lateral strain from the base insulators during the raising process. See figures 4 through 7.

During assembly of the tower on the ground, every effort should be made to keep the members properly aligned and it should be plumbed as well as possible after erection. The structural weakness of a tower having serious kinks is obvious, and the strain on the anchors is increased if not truly vertical.

After erection, no great strain is placed on the tower even in high winds if it is properly guyed. Four sets of guys attached to four equally spaced anchors have been found satisfactory. Four guys comprise a set and are attached to the tower at symmetrical vertical spacing; the construction of the tower will usually dictate the points of attachment. The lengths of the guys are critical and these will depend on the points of attachment and the relative elevations of the tower base and the various anchors.

These differences in elevation should be determined beforehand and the lengths of the guys computed. Since the insulated guys cannot be set up taut without serious risk of structural failure of the tower, an allowance of about 1.5% must be made for catenary. Some leeway is provided in the take-up of the turnbuckles which should be about half extended on erection.

The guys are best attached to the anchors by means of equalizer plates. If not furnished with the structure, these are easily fabricated and are very effective in avoiding serious strain on individual guys.

Anchors of various types may be used, depending on local conditions. In some types of soil, auger-type anchors are satisfactory, but these must be used with caution. Although it is unlikely that the strain would ever be great enough to pull a firmly seated anchor of this type, the continual vibration in the guys tends to loosen the auger and, once started, it will easily pull, especially in light or sandy soils. A small deadman of timber about 4″ x 6″ x 36″, set 3 feet in the ground, is entirely satisfactory. When this method is used, it is recommended that 4 pieces 2″ x 4″ x 14″ be nailed to the deadmen at right angles to provide more bearing surface. In rocky areas, firmly seated cribs may be used or expansion bolts set in bedrock or boulders.

After erection, the guys must be adjusted by means of the turnbuckles to plumb the tower and equalize the strain. As previously mentioned, the guys cannot be set up taut without risk of structural failure, and adjustment to proper tension is a matter of judgment. As a rule of thumb, the longest guys should vibrate through a distance of approximately 2 feet at its center when vigorously shaken, and the shorter guys proportionately less.

5.505 Antenna-couplers

There are two antenna-couplers: one to couple the transmitter coaxial transmission line to the antenna, and the other to couple the antenna to the transmission line that connects to the receiver. The transmitter-coupler is the larger.

These couplers should be mounted near the base of the antenna at a distance of between 3 and 5 feet. Grass and brush should be cleared for a distance of about 8 feet around the base of the antenna before installation is started. Mount the couplers as illustrated in Figure 18. Connect 120 feet of RG-8/U coaxial cable to each coupler. Make the electrical connections inside and insure that the fittings are watertight. Place the coupler assembly near the base of the mast and connect the ground lead from the coupler to the radial ground center. Run the two coaxial cables back to the control shelter.

Run a heavy copper tubing, such as ⅜-inch copper, between the coupler and the base of the antenna just above the insulators. Clean the point on the tower where this connection is made before bolting to the tower. Run a connection, such as ¼-inch copper tubing, between the antenna connection on the transmitter-coupler and the antenna connection of the receiver-coupler. If the coaxial cables are not to be run into the control shelter at once, tape the free ends for protection.

Numerous types of shelters have been used at ground stations. One type, the Jamesway, a 16′ x 16′ shelter, has been used very successfully as an instrument shelter. It is a well insulated shelter, suitable for use in arctic climates. Also, because it can be well ventilated, it is ideal for tropical areas. More often, especially in remote areas, shelters are constructed by parties from the ships. An effort should be made to make

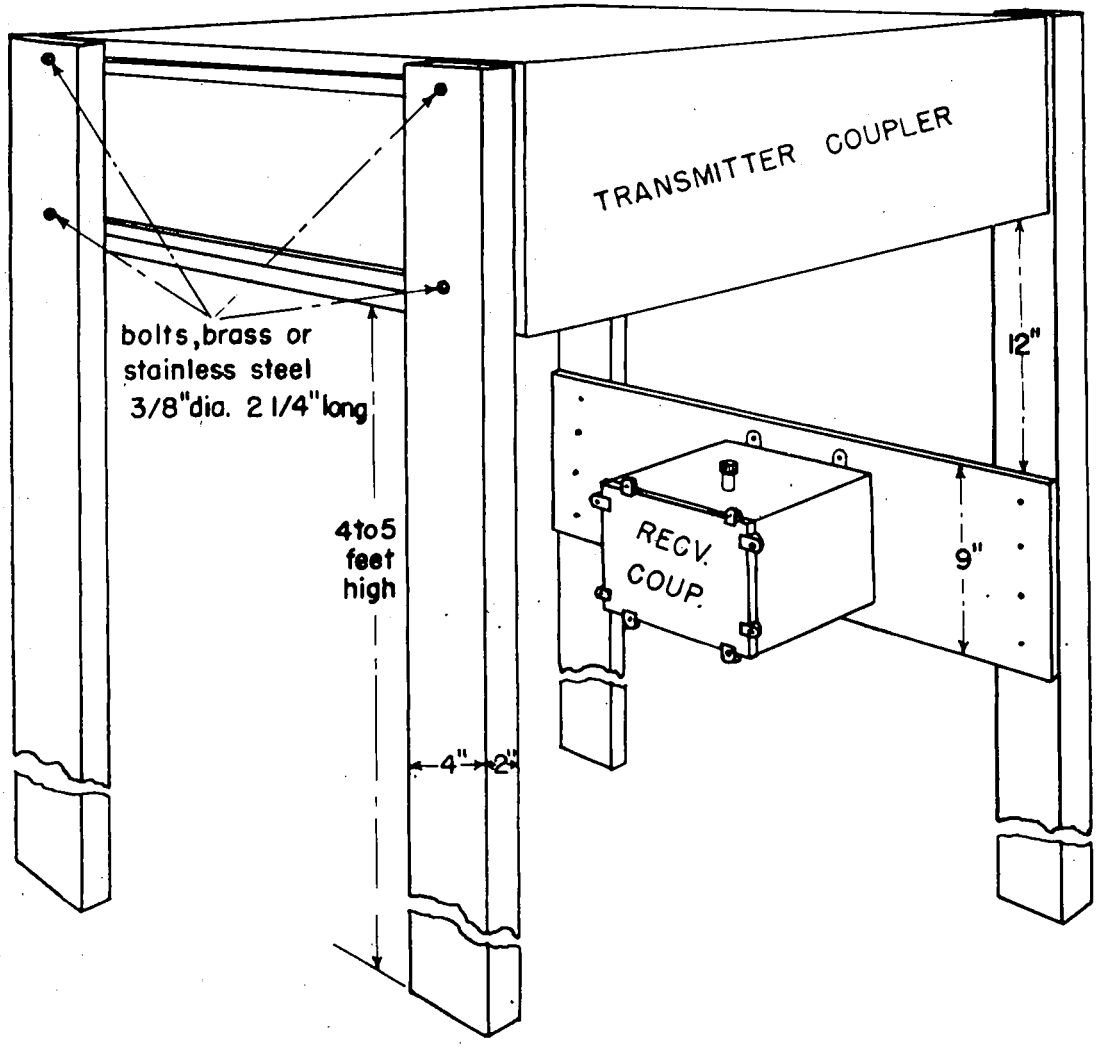


FIGURE 18.—Ground station transmitter and receiver antenna coupler.

these shelters adequate for their intended use, but they need not be elaborate or permanent. Quite often the shelters are left standing after they are no longer needed because of the loss of valuable time to the ship in removing them.

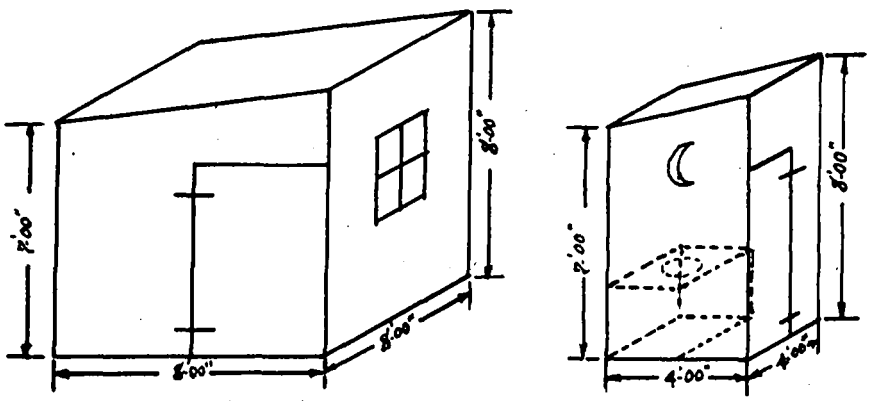
The instrument shelter should have a minimum floor space of 96 square feet; the living shelter for four men should have a minimum of 190 square feet; and the power shelter should have a minimum of 64 square feet. These areas are taken from shelters that have been built in the Alaska regions.

5.600 INSTRUMENT, LIVING, AND POWER SHELTERS

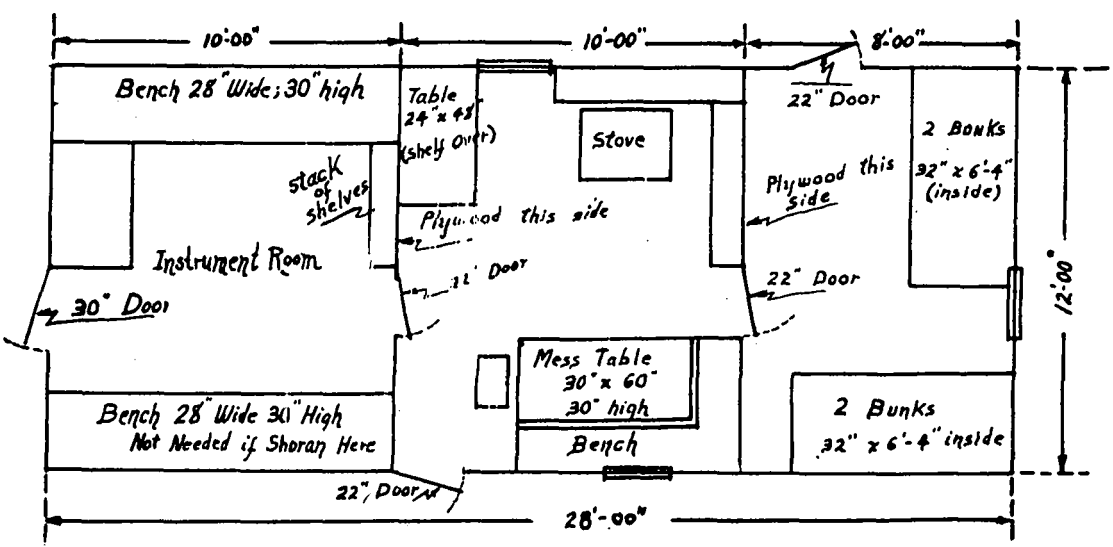
The number and types of shelters needed at a ground station will depend on the location and whether the ground-station personnel live at the station. When the station is in a developed area, probably the only structure needed is the instrument shelter. This is the case where commercial power and living quarters are available.

Some ground stations have been set up in developed areas where it was possible to rent a house suitably located to house both the equipment and the operating personnel. In populated areas, an effort is made to keep up the appearance of the station and to keep it orderly at all times.

There are some advantages in having separate instrument and living shelters. Since most of EPI operation is on a 24-hour basis, at least one of the ground-station crew will be asleep at all times. The normal sounds of communication and other functions in the instrument room proves disturbing to those attempting to sleep. Also the presence of the men off watch tends to disturb the man on duty. The advantage of having a combined instrument and living shelter are simpler and less expensive construction,



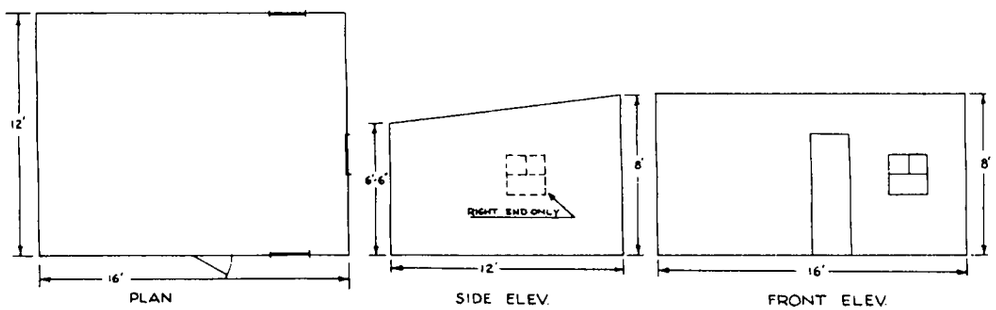
Generator Shelter



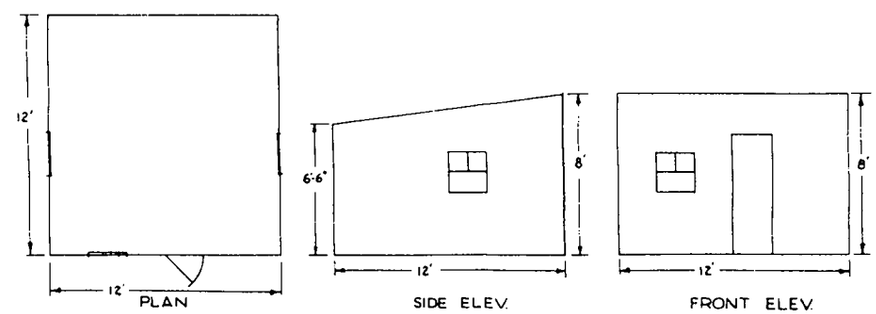
Where more room is desired the length can be increased to 32 feet without altering the basic design. The Galley may then be made 12 x 14' or a division of this extra length may be made between the Galley and Bunk room.

FIGURE 19.—EPI ground-station shelters.

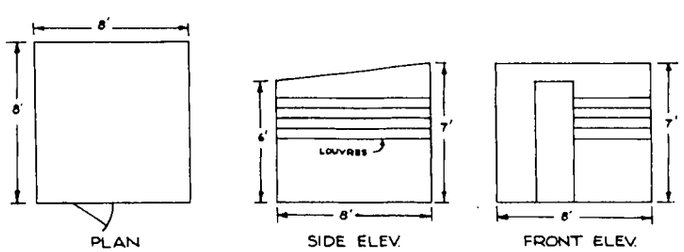
12′ X 16′ LIVING SHELTER



12′ X 12′ INSTRUMENT SHELTER



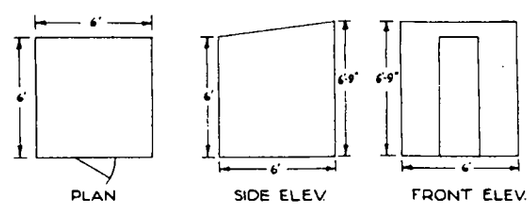
8′ X 8′ GENERATOR SHELTER



BILL OF MATERIALS

10 pcs.	2″x4″x 12′
28 pcs.	2″x4″x 8′
30 pcs.	1″x4″x 8′
5 sheets	4′x 8′x 3/8″ plywood
26 pcs	1″x 8″x 8′ shiplap
1 pc	2″x12″x 8′
1	3′x 6′x 3/4″ plywood door
1 pr.	door hinges
1 roll	roofing paper

6′ X 6′ SHORAN SHELTER



BILL OF MATERIALS

12 pcs	2″x4″x 12′
9 pcs	2″x4″x 6′
20 pcs.	1″x 8″x 12′ shiplap
1	2″x 6′x 3/4″ plywood door
5 sheets	4′x 8′x 3/8″ plywood
1/2 roll	roofing paper
1 pr	9″ strap hinges
8 pcs.	1″x 4″x 12′ batten

4′x4′ SHORAN GENERATOR SHELTER

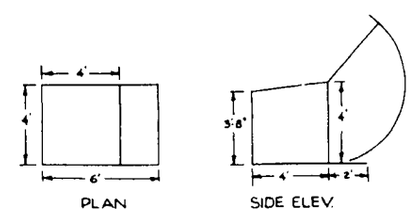


FIGURE 20.—EPI and Shoran ground-station shelters.

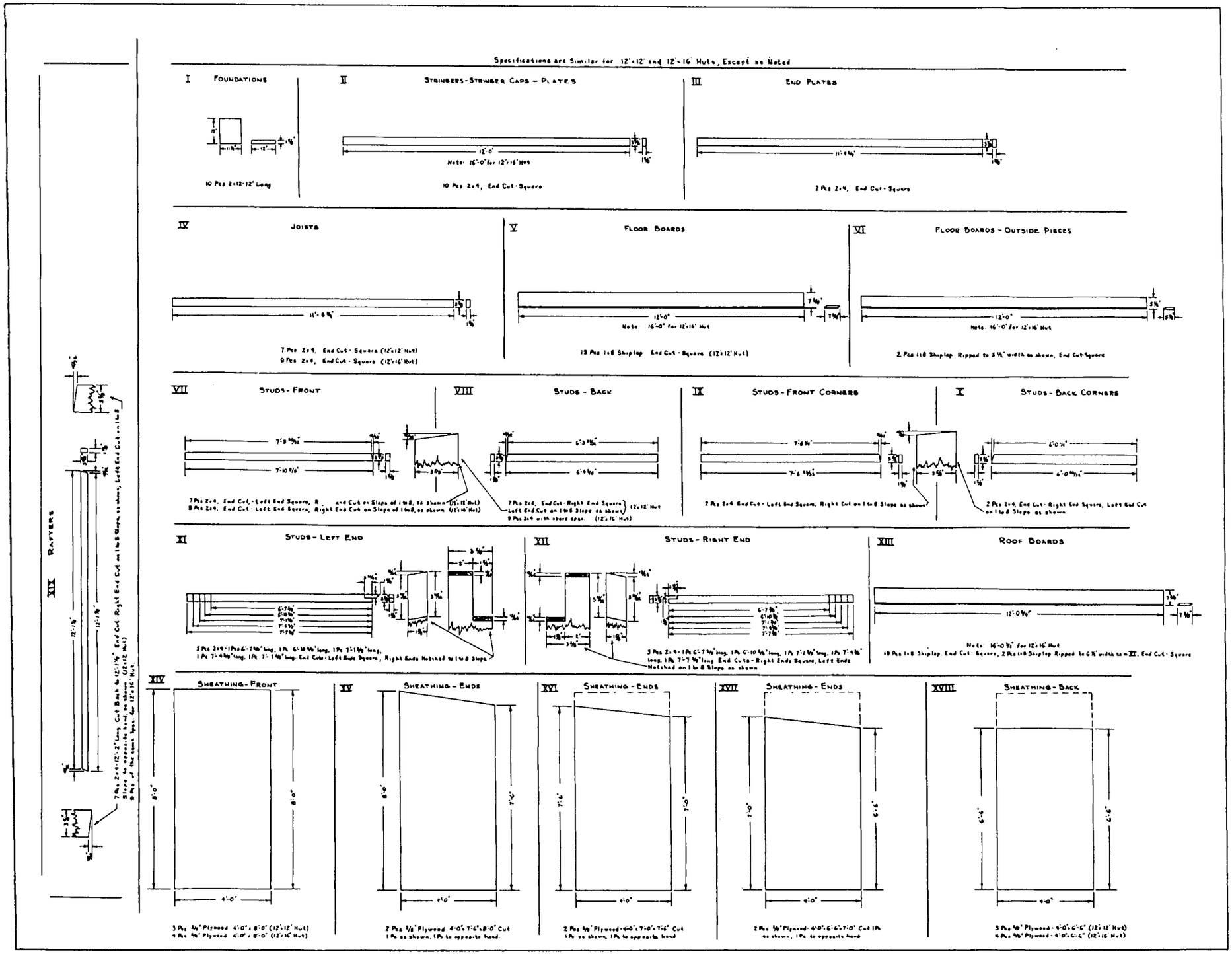


FIGURE 21.—EPI shelter construction details.

and an easier heating problem. Figure 19 illustrates a combined shelter which is shown because it contains the essential interior arrangement for both shelters.

Details for the construction of separate instrument, living, and power shelters appear in Figures 20 and 21.

5.601 Bill of Materials for Combined Instrument-and-Living Shelter and Power Shelter

EPI SHORE CAMP (with 3 rooms; 12′ x 28′ shelter)

Timbers:

4″ x 6″ 3 pieces 28′ long, for main shelter foundation
2 pieces 8′ long, for power shelter foundation
8 pieces 4′ long, for power shelter foundation and outhouse
2 pieces 3′ long, for tower foundarion
3 pieces 2′ long, for tower foundation
8 pieces 4′ long, for deadmen

2″ x 4″ 9 pieces 16′ long, for antenna poles
40 pieces 14′ long, for rafters and plate
64 pieces 12′ long, for floor, plates, tables, bunks, oil racks, coupler racks, antenna base, tower foundation, etc.
66 pieces 8′ long, for studding and for power shelter floor

1″ x 3″ 4 pieces 12′ long, for door and window jambs

1″ x 4″ 4 pieces 12′ long, for door and window jambs

Plywood:

3/16″ 4′ x 7′—10 sheets
3/16″ 4′ x 8′—28 sheets
3/4″ 4′ x 6′—4½ sheets, for doors

Tarpaper:

To cover sides and roof—7 double rolls
To cover roof only—3 double rolls

Laths for over tarpaper—2 bundles

Roofing tar—1 gallon

Flyscreen for windows—1 roll 24″ wide

Windows:

4-glass, 8″ x 12″, outside dimensions 22″ x 28″—5 ea.

Nails:

16d—12 pounds
8d—8 pounds
6d—25 pounds
4d—2 pounds
Roofing nails—2 pounds

House wiring supplies:

8 ceiling-light fixtures with switches and boxes
6 duplex convenience outlets with boxes
1 fuse box, residence-type, 3-wire, 2- or 4-circuit
1 double-pole entrance switch
125-ft, 2-conductor, No. 12 interior wire (Romex, Lumex, or BX)
(These supplies are also listed in Section **XV**)

Hardware:

7 sets door hinges, 6″ strap
5 sets window hinges, 2½″ butt
5 sets door latches
1 collar to bring stove pipe through roof (store jack)
1 gross wood screws (hinges, wiring boxes, etc.), No. 8
15 sheets aluminum roofing, 2′ x 12′
2 sheets aluminum roofing, 2′ x 14′

5.602 Location of Shelters

The instrument shelter should be just outside the 100-foot ground wire system, as illustrated in Figure 16. When the location permits, this building should be so situated that the tower will be between it and the general direction of the working grounds.

Locate the power shelter 50 to 75 feet from the instrument shelter in a direction away from the tower. In placing the living-quarters shelter, many factors are to be considered. Among these are protection from the prevailing winds, accessibility for supplies from the beach or road, and nearness of water supply. It is an advantage to have this shelter sufficiently near the power shelter to get electric power.

5.603 Arrangement of Equipment in Instrument Shelter

The equipment should be placed on a table or stand. When one controller is used, the table may be about 5 feet long and 30 inches wide, with a height of 31 inches. When two control units are used, the table length should be about 8 feet. Arrange this table along one wall of the shelter and, where space allows, leave sufficient room behind this table so that the equipment may be serviced from the rear. The controllers may be placed on the table, with a space between them for the distribution panel.

Locate the transmitter on the opposite side of the shelter with the controller and transmitter facing each other, or in such a way that the controller scope may be viewed while adjusting the transmitter. Leave sufficient space between the transmitter and controller for passage and for the operator. The table for a transmitter should be about 30 inches long, 20 inches wide, and 28 inches high. When two transmitters are used, the table should be 72 inches long. There should be a shelf under this table with a clearance of about 14 inches for the modulators.

Location of the communication equipment will depend upon the remaining space in the shelter. An area having the dimensions of 44 inches long by 20 inches deep should be delegated for this equipment. Where possible, this equipment should be within easy reach of the operator when he is at the controller-indicator. The clock should be clearly visible from this position.

The power and fuse box may be mounted some place near to where the power line enters the shelter.

The voltage regulator may be placed on the floor of the power shelter, and should be so located that it will be accessible for service.

5.604 Power Unit Installation

When the EPI is used in remote areas where power is not obtainable, a power plant must be built for the station. At present, the type of power unit used is a gasoline-engine belt driving a generator. This has the military designation of PE-75. Two

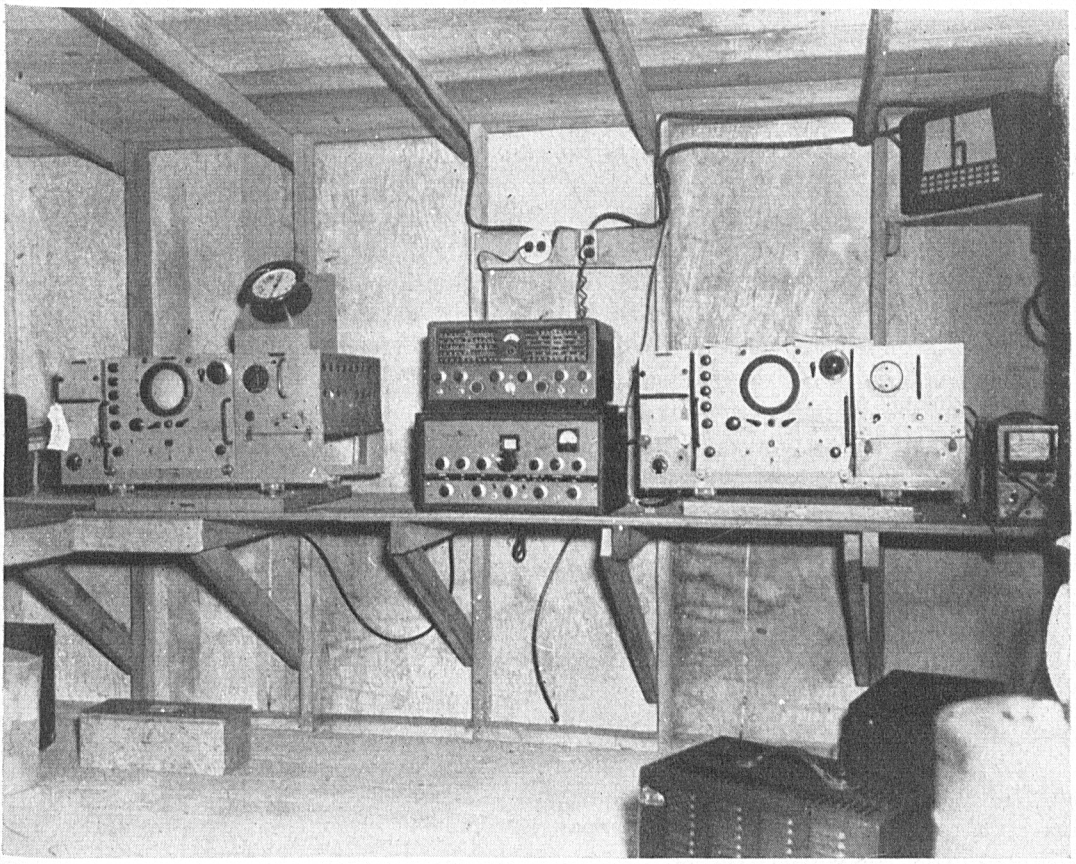


FIGURE 22.—Interior of instrument shelter, showing two Controller-Indicators and communication equipment.

of these units are needed at a station. They should be housed in a shelter of floor space no smaller than 8 by 8 feet, with 7 to 8 feet of head room. Construction of the shelter is discussed in paragraph **5.600.**

As these units are to be used for continuous operation, certain modifications should be made to them. Remove the following parts from the engine and generator: gas tank, tool box, muffler, belt guard, and generator outlet-filter box. Unless this is done, these parts will be shaken off even though the unit is properly balanced and mounted.

The units should not be mounted on the floor of the shelter. The shelter should be only half decked, with the units mounted in the undecked area. If the ground is solid, they may rest on the ground or on a heavy timber embedded in the ground. In addition to reducing vibration, mounting on the earth permits draining the crankcase oil directly into the earth. Face the units so as to make cranking easy. Allow enough room around them for what servicing may be required.

Run the exhaust pipes out through the side of the shelter. They should have a slight downward slope. Insulate the exhaust pipes where they pass through the shelter wall to prevent burning. When possible, face the exhaust-pipe outlets away from the operating and living shelters to reduce noise.

Each engine should have its own 55-gallon gas drum. These drums should be mounted horizontally on cradles outside the shelter. The bottom of the drum should be higher than the top of the engine. There should be a ramp so that each drum may be rolled up on its cradle. The gas line from the drums to the engine should have a short section of rubber-coupling hose at the engine to keep the vibration from damaging the fittings.

Mount the outlet and filter box on the wall of the shelter. Splice out the wires about 7 feet at the generator and run them through a length of Greenfield or other flexible tubing to the outlet box. The proper fittings should be put on the ends of this tubing. Make cable connections from each outlet box to the double-pole double-throw generator selector switch. A 0–150-volt AC voltmeter should be mounted near this switch and attached to the load side of the switch. The load side of this switch also goes to the voltage regulator. From the regulator a line runs to the operating shelter for instrument power. Ground the generator to reduce electrical interference. Suppressors should be used on the spark plug; or, better, a plug with built-in suppressor, such as Auto-Lite L–5, might be used.

If care is taken not to overload the regulator, lights may be used from this circuit; this will save running two cables from the generator shelter. Provisions should be made to bridge out the circuit in case this instrument fails.

5.605 Winterizing Ground-Station Shelters

Since EPI ground stations are of a semi-permanent nature, precautions should be taken to preserve the camp for the following year.

To do this, sufficient tarpaper and laths should be provided at the shore camp to cover all doors, windows, and stove-pipe jacks. The buildings should be banked with dirt up above the lower edge of the tarpaper to prevent snow from blowing under the shelters during the winter storms.

As an added precaution, it is advisable to place 2″ x 4″ timbers under the center of all large, unsupported roof spans to help support the winter snow load. These supports should be placed in both the operating and the living quarters.

5.700 GROUND-STATION PERSONNEL

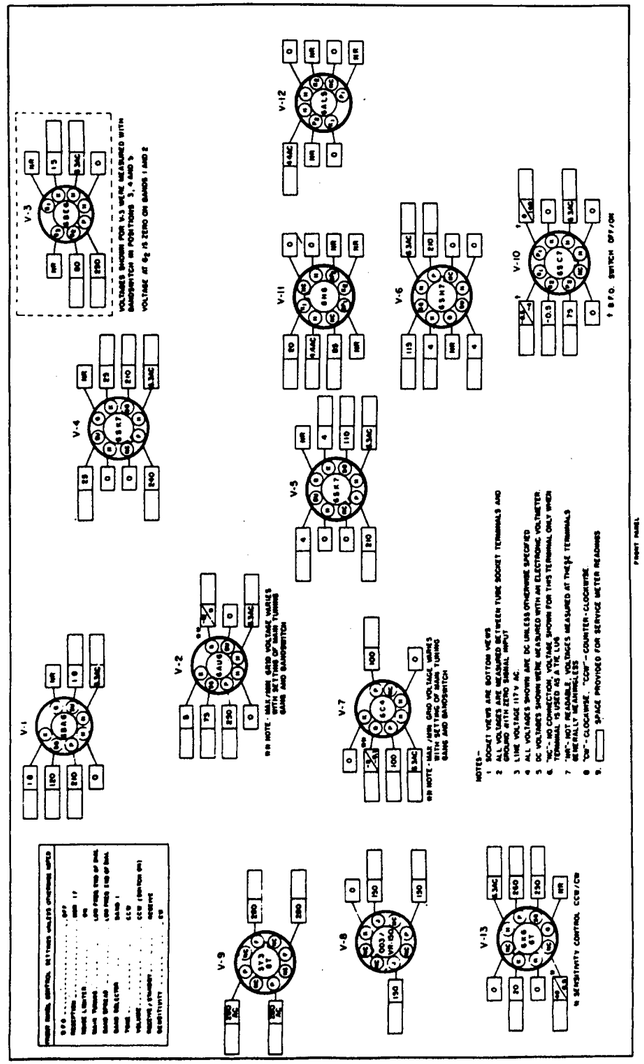
The basic minimum staff of a ground station is one radio technician and two EPI operators. In cases where the living needs of the men are tended to, as is done in many parts of the United States, this minimum is all that is required to staff the station. The technician stands an equal watch with the operators.

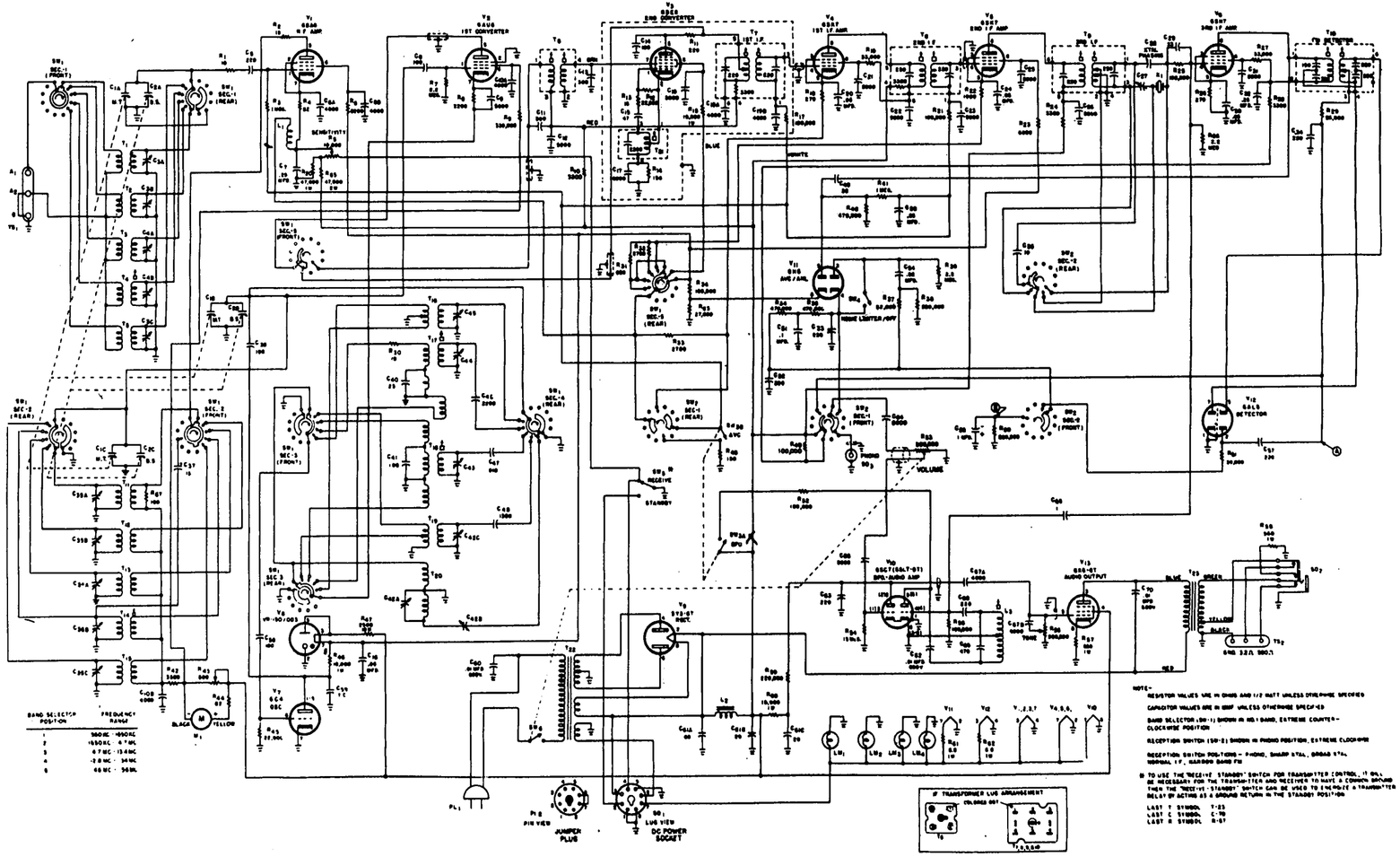
When the EPI station is in a remote area where living quarters are on the station site, it is necessary to increase the number of men to staff the station. There should be the addition of a cook to prepare meals for the camp and perform other duties necessary to the comfort of the operating personnel. A mechanic should be supplied for remote stations when the dependability of the source of power is doubtful or when the power plant is complicated.

It is cautioned about over-staffing remotely located stations. Living space is seldom more than adequate, and additional personnel might make it uncomfortable for all. Also, the larger the number of persons at a station, the greater will be the cooking and supply problems.

Selection of ground-station personnel should be from among the very best members of the crew. These men are to be given responsibility far in excess of their duties aboard ship.

In most cases, it is not practical to assign a cook from the steward department. When a seaman is to act as cook, it is suggested he be given a short course in cooking by working in the galley where he can be taught the rudiments of cooking. Each camp should also be supplied with a simple cookbook.





VALUES AND TOLERANCES SHOWN ARE NOMINAL AND VARIATIONS MAY BE FOUND. IT IS RECOMMENDED THAT THE VALUE OF ANY REPLACEMENT CORRESPOND TO THE NOMINAL VALUE OF THE PART BEING REPLACED.

FIGURE 23.—Hallicrafter SX-71 receiver circuit diagram.

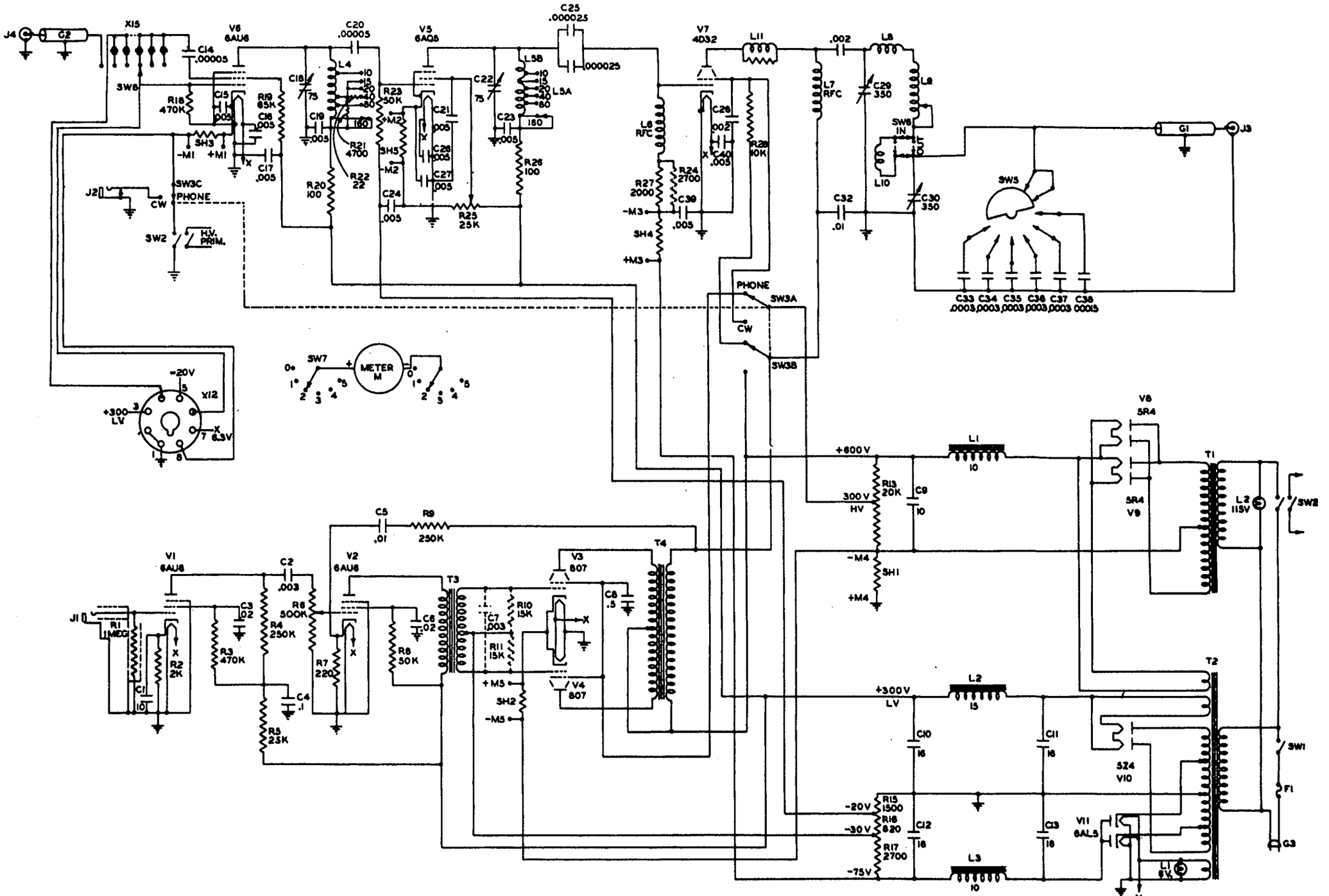


FIGURE 24.—Viking transmitter circuit diagram.

VI

GROUND-STATION COMMUNICATIONS

The communication equipment should be capable of transmitting phone or cw signals for distances up to about 300 miles. A 100-watt transmitter will give very reliable transmission over these distances. Frequencies of 4160 and 8320 kilocycles are most often used for this communication. Types TCS and TDE transmitters have been used for EPI communication, but the TCS do not have sufficient power for the greater distances and the TDE are large for the power delivered. A Johnson Viking No. 1 transmitter, which is capable of delivering a 100-watt output on phone and 115-watts cw, is satisfactory for communication. Hallicrafter Type SX–71 receiver is adequate for reception. See Figures 23 and 24 for circuit diagrams. Communications equipment, while essential to efficient operation, is not furnished as part of the EPI ground station equipment.

Careful consideration should be given the erection of the communication antennas. It is important that these antennas be kept as far from the EPI antenna as practicable. A satisfactory transmitting antenna would be one about 100 feet long and running from the control shelter in a direction away from the EPI antenna. The far support may be a 30-foot pole; the near end can be a short pole secured to the control shelter. The receiving antenna should be about 30 feet long, supported by a 20-foot pole at the far end and to the same pole as the transmitting antenna at the shelter end. Keep this antenna away from the power shelter so as to reduce ignition noise. It should also be directed away from the EPI mast.

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OPERATION AND ADJUSTMENT OF SHIP EQUIPMENT

7.100 INITIAL ADJUSTMENT

This procedure is for that equipment which needs complete readjustment. Some of these adjustments will need repeating at times to keep the equipment in proper working order. These will be considered under the item on routine checking.

7.200 INDICATOR

Perform the following:

a. Turn the power switch S-107 on the face of the indicator to ON.

b. Turn the power switch S-1 on the face of the controller to ON.

c. Set the controls on the indicator as follows:
   SWEEP SPEED switch to FAST
   FAST SWEEP to 1
   INTENSITY, full clockwise
   RECVR to OFF

d. Adjust the HORZ. CENTER and the VERT. CENTER controls until the vertical line is about one-third way up the cathode-ray tube, and equidistant from each side of this tube. Adjust INTENSITY and FOCUS controls until a sharp, clear trace is seen. The pattern seen on the scope should be that seen in Figure 25A. If four small pips do not appear between the larger pips, adjust the screwdriver control *A* on the indicator. Center this control in the proper range.

e. Leaving other controls as in d, set FAST SWEEP on 2. The scope pattern should appear as in Figure 25B. If this is not the case, set adjustment *B* so that the large pip is on the tenth smaller pip.

f. Set controls as follows:
   SWEEP SPEED switch on SLOW
   RECVR to ON 1
   Trace separation, full clockwise
   FAST SWEEP to No. 2
   The pattern should appear as in Figure 25C. If this is not so, adjust *C* so that every fourth smaller pip is as short as possible. These pips can be seen more clearly on the left trace. There should be six groups of pulses composed of three long pips between the short pips. If there are not six such groups, make them by adjustment *D*.

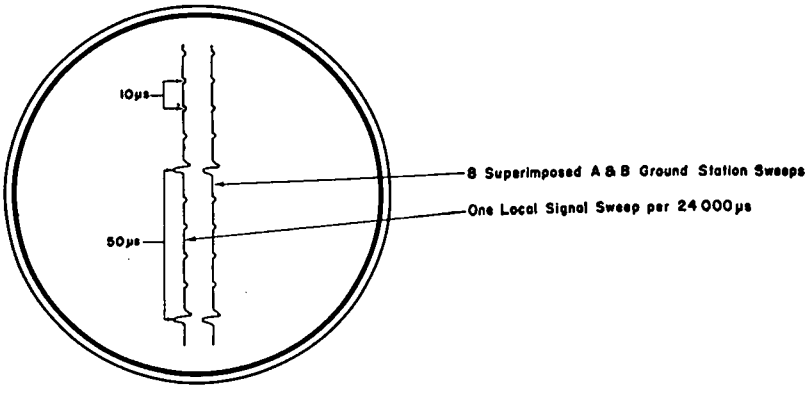
After going through steps a to f, all the divider stages will be in proper adjustment. The next step will be for setting the proper delays.

g. With the same settings as in step f;
   1. Set the range dials on the controller to read zero.

FAST SWEEP INDICATION OF TIMING

FAST SWEEP ON 1

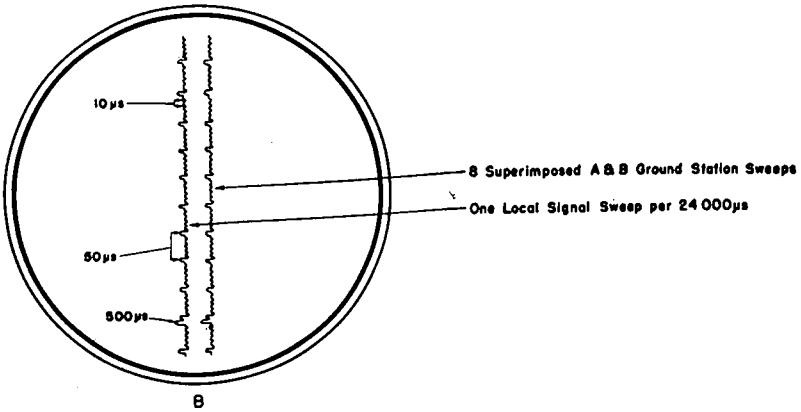
RECVR. ON POS. OFF



A

FAST SWEEP ON 2

RECVR. ON POS. OFF



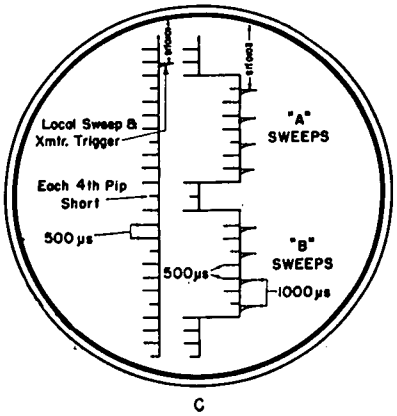
B

SLOW SWEEP INDICATION OF TIMING

FAST SWEEP ON 2

TRACE SEPARATION FULL RIGHT

RECEIVER ON 1



C

FIGURE 25.—Ship divider and delay adjustments.

2. Adjust *A* PEDESTAL POSITION on the indicator so that the top edge of the upper pedestal on the right trace is just at the third 500-microsecond pip from the top, as shown in Figure 25C.
3. Adjust the *A* PEDESTAL LENGTH control until the eleventh 500-microsecond pip just slides down the lower edge of the top pedestal. There should be four 1000-microsecond pips, as shown in 25C on top of this pedestal.
4. Adjust *B* PEDESTAL POSITION on the indicator so that the top edge of the second, or lower, pedestal is just to the thirteenth 500-microsecond pip, as shown in 25C.
5. Adjust the *B* PEDESTAL LENGTH control until the twenty-first 500-microsecond pip just slides off the lower edge of the second pedestal. There should be four 1000-microsecond pips, as shown in Figure 25C on top of this pedestal.

These adjustments are for the proper sweep delays for the *A* and *B* ground-station signals.

h. On the left trace of Figure 25C, the position of the local sweep and transmitter trigger should be just below the second pip. The position of this pip should be made correct by means of the screwdriver control *R* on the right side of the indicator.

7.300 CONTROLLER

Ordinarily, there are no field adjustments necessary to this instrument. The sine-wave divider in this unit is adjusted in the initial line-up. Should adjustments be necessary, see Section **XI**.

7.400 TRANSMITTER AND COUPLER TUNING

Paragraphs 7.401 through 7.403 are for Mark 3, Model 2 transmitters. The design on a new model was started but is not advanced sufficiently to be included in this manual. Data for the new models will be sent out with the new transmitters.

7.401 How to Start and Stop the Mark 3, Model 2 Transmitter

To start the equipment, first throw the main-line switch to ON and allow the line voltage regulator to warm up a minute; then, turn on the power switch S–101 on the face of the transmitter. Allow about ten minutes for the 304TH tubes to warm up. With the variac on the transmitter turned full counterclockwise, turn on the high-voltage line switch S–102. Bring up the variac until the plate voltage indicator reads the value shown alongside the meter. To measure this voltage, push the voltmeter button, which is near the variac knob. Check the frequency as outlined under Ship Transmitter Tuning (paragraph **7.403**). To stop the transmitter, turn off S–102 and –101 in that order; also bring the variac to its full counterclockwise position.

7.402 Adjustment and Operation

Before starting the transmitter, ascertain that the transmitter antenna-coupler has been tuned to somewhere near the proper value. For the ship station, this will be with the antenna tap on 3 of L–403, and for the ground station coupler, on tap D of L–401. Coil taps for the transmitter when set as described will be very close to the final setting. It will not be necessary to make any adjustments to the grid coil

L-102. It may be necessary to change the plate taps on L-101 to get the correct frequency.

Plate taps (L-101)—8 turns from center tap.

Grid coil (L-102)—Feedback tap, 21 turns from center tap; grid tap, 9 turns from center tap.

Impedance transformer (T-101)—Each tap 5 turns from end of coil.

Start the transmitter in accordance with paragraph **7-401**, except bring the high-voltage meter up to 10. This is to prevent arc overs due to mistuning.

7.403 Ship Transmitter Tuning

Put the transmitter on the correct frequency by using a wavemeter. The signals from this transmitter are used to set the tuning of the ship receiver and the ground-station receivers and transmitters. Tune the transmitter to 1850 kilocycles by means of FREQUENCY TUNING on the front of the transmitter. If the frequency is out of range of this control, move the plate coil taps until the transmitter is within the range. If the FREQUENCY TUNING is still close to the extreme range, it may be more nearly centered by moving a tap one or two turns on T-101.

Adjust the LOAD TUNING control for maximum antenna current reading; readjust the frequency to 1850 kilocycles. It should be noted here that the meter on the transmitter front reads transmission line current but is marked ANTENNA CURRENT. Bring the plate voltage up to normal voltage (about a meter reading of 25), and make final frequency adjustment.

Move the tap on the antenna-coupler coil one turn at a time. Cut off high voltage when making these changes. Correct loading and frequency for each tap change. Select the tap that gives the maximum radio frequency current. The antenna current will always be higher than the transmission line current; it may be more than twice as high, depending on the ship antenna. The transmission line current should be between 0.7 and 0.8 ampere.

7.500 RECEIVER TUNING

Before the receiver is tuned, the transmitter must be tuned to the correct frequency by the method described in paragraph **7.403.** The controller-indicator should be warmed up at least 1 hour before tuning is started.

Set controls as follows:

Center the BALANCE GAIN

Turn up RECVR GAIN and LOCAL SIGNAL GAIN until the ship signal appears on the scope

SWEEP SPEED on FAST

FAST SWEEP on 1

The tuning controls are on top of the receiver and are the ANT, MIXER, and OSC controls, in that order, from front to back. Tune the OSC control first for maximum signal amplitude, reducing the RECVR GAIN and LOCAL SIGNAL GAIN to keep the signal from saturating. Next, tune the MIXER and ANT controls, in that order, for maximum signal, reducing gain as necessary. Retune the OSC tuning for maximum signal overshoot, or so that the signal rises to a peak, drops off slightly, and flattens before the final drop-off.

At a time when both ground stations may be viewed along with the local signal, check the OSC tuning by noting if the ground-station signals rise and fall together with the local signal as the OSC is adjusted. If one or both of the ground-station signals do not rise and fall with the local signal, the ground stations should be asked to check and correct their frequency.

7.501 Receiver-coupler Tuning

The receiver-coupler is tuned by viewing the ship or ground station on the indicator scope and adjusting the coupler for maximum signal amplitude. Because the coupler and indicator are usually some distance apart, a communication system should be set up between these points. Sound power phones are quite satisfactory for this. When possible, it is best to have both the ship and ground-station signal on the scope.

There are two adjustments on the coupler: one for large changes in turns and the other for smaller changes. The wire that is attached to the terminal going to the high side of the tuning condenser and damping resistor is for large changes in turns—10-turn steps. The wire attached to the ground terminal is for small turn adjustments—2 or 3 turns. Start with taps set to give 22 turns. While one man observes the scope, a second will make small changes in turns until the maximum signal appears on the scope. The RECVR GAIN should be kept reduced at all times to prevent the signals saturating, which prevents accurate adjustment.

7.600 ROUTINE CHECKS OF EQUIPMENT

By keeping the instrument in its best adjustment, many delays and breaks of sounding lines may be avoided. By having the operator make the following checks shortly after he comes on watch, the checks become systematic and will catch any change in equipment promptly.

a. Delays.—Check the *A* and *B* and local-signal delays by the method outlined in paragraph **7.200 g and h.** The correct pattern should appear as that in Figure 25C.

b. Initial Sweep-timing.—When the system was initially adjusted, the range dials and range verniers were set near zero, or a value which would give a small correction. For this setting, the 10- and 50-microsecond pips, for the *A*, *B*, and local-signal sweeps, should all match exactly. This should appear as in Figure 25A. The proper instrument setting is given with this figure. The *A* and *B* range dial settings, which will match all the pips, should be recorded and should remain this value. See paragraph **7.700.** However, it is possible that by a misadjustment of the *A* and *B* divider circuits, a 10- or 50-microsecond error might occur, which can be corrected by readjusting these controls. Make certain that in this adjustment, the dividers are still dividing properly. Should the proper adjustment prove critical, the radio technician should study the first divider and oscillator-stage operation. Defective tubes or components may account for this.

Record the following on the transmitter: Transmission line, or antenna current, and high-voltage meter reading. Check frequency, using the wavemeter. Correct the transmitter frequency if a change of plus-or-minus 3 kilocycles has occurred.

7.700 ZERO CHECK

The purpose of a zero check is to check all the timing circuits. If any trouble occurs in the time-locking, pulse-selecting, or mixing circuits, it will show up in a zero check. This check should be made once each watch.

When making a zero check, the following steps should be followed:

STEP 1

Be sure all dividers and delays are properly adjusted.

STEP 2

Set both *A* and *B* phase shifters at zero
Set SWEEP SPEED switch to SLOW
Set FAST SWEEP switch to position 2
Set RECVR switch to ON 1

Wave forms as shown on time diagram 25C should be seen. If outward pulses on each pedestal are as shown, the 500-microsecond lock is functioning properly. See paragraph **11.103**

STEP 3

Set SWEEP SPEED switch to FAST
Set RECVR switch to OFF

Wave forms here should be as shown in Figure 25B which indicates the 50-microsecond lock is functioning properly. See paragraph **11.103.**

STEP 4

Set FAST SWEEP switch to position 1.

Wave forms here should be as shown in Figure 25A. The trace separation control can be turned until the two vertical traces come together for precise alignment of pips. When pips from *A* and *B* sweeps are perfectly aligned with the local-signal sweep, the phase-shifter counters should read near zero, the exact value being determined when the original corrections are set up in the equipment.

OPERATION AND ADJUSTMENT OF GROUND-STATION EQUIPMENT

8.100 CONTROLS

The controls on the controller-indicator are listed in tabular form for the purpose of familiarizing operating personnel with these controls and their operation.

8.101 Controller-Indicator

The controller-indicator has been converted from a Loran DAS–4 indicator unit. (NOTE: Tube socket X–112 and associated circuits for Loran operation have been left intact but not used.)

Controls	Function
Focus	Sharpens the electron stream to a point where it contacts the screen.
Intensity	Varies the brightness of the pattern on the screen.
Horizontal center	Adjusts the horizontal location of the pattern on the screen.
Vertical center	Adjusts the vertical location of the pattern on the screen.
Trace separation	Varies vertical separation of the two traces. This control operates only when the receiver switch is on ON 1.
Receiver switch (3 positions)	In the ON 1 position, signal pulses from the receiver-output are fed to the synchronizer and indicator scope. The time markers are shown and variable trace separation is provided. In the ON 2 position, the received signals are still fed to the synchronizer and indicator scope, but the time markers are removed and the two traces are superimposed. This is the position for normal operation. At the OFF position, the signal pulses are cut off from the synchronizer and indicator scope. The time markers are shown and there is a fixed trace separation controllable by adjustment *M* on the right side of the instrument.
Sweep-speed switch (2 positions)	When this switch is set at SLOW the entire recurrence period is shown. This includes the time taken by the retrace. At the FAST position, the pedestal trace is expanded to the width of the screen.

Fast-sweep switch (3 positions)	This switch provides three different widths of the pedestal trace, thus giving the choice of three sweep speeds on the fast sweep.
Left-right switch	This switch may be thrown from its normal center position to left or right to shift the position of the ship signal pulses on the screen in corresponding directions. This is used in the synchronizing process.
Fine frequency	Adjusts the local 100-kilocycle timing crystal to precisely the same frequency as the ship's master crystal. This condition is indicated by zero centering of meter needles on the synchronizer.
Trigger switch	Used to turn on or off the trigger pulse that operates the transmitter. (This switch should never be left off any length of time unless the high voltage is turned off the transmitter.)
Receiver gain	The amplitude of the received signal pulses on the scope screen is adjusted by this control.
Balance gain	Equalizes the amplitude of the local and ship signal pulses. This control is varied in steps of one full dial division and the fine adjustment made by the LOCAL SIGNAL GAIN control.
Station delay	This is a front-panel screwdriver adjustment and moves the pedestal on the lower trace on steps of 500 microseconds over a large range. Another screwdriver control is located just to the left of and slightly above this control. This is R–174 and works in conjunction with the station delay. Once this control is set by a technician, it need not be touched again. The setting of the station delay is dependent upon whether or not the ground station is designated an *A* or *B* station.
AFC cathode bias	This control is a front-panel screwdriver adjustment and controls the cathode bias voltage for the correct point of operation.

8.102 Synchronizer

Controls	Function
Fine delay	Used to match the ship and local signal pulses by moving the ship pulse along the sweep with respect to the local pulse.
Coarse delay	Screwdriver adjustment. Functions the same as the fine delay but is only used to center this control in its usable range. After this, it need not be adjusted.
Buzzer	Turns on alarm, which warns operator when system is out of synchronism. Only on Sets No. 1 to 9.

8.103 Electronic Attenuator

Controls	Function
Local signal gain	Gain-controls the strength of the local signal.

8.104 Technician's Alignment Check

Many of these checks need be made only before the unit is placed in operation at a new station. After a 30-minute warm-up period, set the controls as follows:

RECVR switch to ON 1
SWEEP SPEED on SLOW
FAST SWEEP on 3
Trace separation so that there is about an inch of separation between top and bottom traces
RECVR GAIN all the way counterclockwise

a. Intensity and Focus Control.—Turn the intensity control clockwise and adjust along with the focus control until a sharp and clear pattern of the desired brilliancy is obtained.

b. *C* Control.—The marker pips extending downward are 500-microsecond timing pips. Every fourth one should be shorter than the others. This pattern is adjusted by control *C* on the front panel.

c. *D* Control.—There should be six groups of four short pips. This pattern is adjusted by control *D* on the front panel.

d. *A* Control.—Set the RECVR switch to OFF and the FAST SWEEP switch to 1. There should be four small upward pips in between the larger downward pips. These upward pips are 10-microsecond markers and the larger downward pips are 50-microsecond markers. This pattern is adjusted by control *A* on the front panel.

e. *B* Control.—Set the FAST SWEEP switch to 3. On this pattern there should be a series of small and large downward pips, the small pips being 50-microsecond markers and the large pips being 500-microsecond markers. There should be nine short 50-microsecond pips in between successive large 500-microsecond pips. This pattern is adjusted by control *B* on the front panel.

f. *Q* Control.—With the sweep speed switch set to slow position, center the adjustment of control *Q* (right side). When properly adjusted, there are two separate traces, the spacing being adjustable by the trace separation control on the front panel.

g. *R* Control.—Control *R* (right side) adjusts the time setting of the remote-signal sweep and pedestal on the upper trace in the slow-sweep speed position. For normal operation, this adjustment——the left-hand edge of pedestal—is locked on the second 500-microsecond pip on the upper trace.

h. Station Delay Control.—The station delay is a front-panel control and adjusts the time setting of the local-signal sweep and pedestal on the bottom trace. For normal operation as an *A* ground station, the station delay control is centered in its adjustment when locking the left-hand edge of pedestal on the fourth pip on the bottom trace. For a *B* ground station, lock the pedestal on the fourteenth pip.

i. AFC Cathode Bias.—This is a front-panel screwdriver adjustment and controls the cathode bias voltage on V–136 for the correct point of operation. The cathode D. C. voltage value is usually in the vicinity of plus 10 volts. An exact adjustment is made when synchronizing to the ship signal; or, the signal from another ground station may be used. The signal is first brought into synchronism and the meter needles on the synchronizer brought to center position, using the FINE FREQ control. Now the left-right switch is used (this is done on fast-sweep No. 1 or 2 position) to throw the remote signal first to the left and then to the right of the local transmitted signal. If the remote signal drifts toward the local signal at the same rate from either direction, the AFC cathode bias adjustment is set correctly. If not, a slight adjustment should be made until this condition results.

j. AFC Pull-in Speed.—Once the AFC bias is set correctly, as in *i* adjustment, and the pull-in of synchronized signal is made equal for either side, the speed at which the signal pulls in can be controlled by adjustable condenser C–222. This condenser is located inside the chassis on the underside of top shelf on the right side near the front (near L–101 base).

The rate of pull-in can be checked by putting the receiver switch on ON 1, with other controls set to normal surveying position. This provides 50-microsecond markers on which a time check can be made. The correct pull-in speed should be about 13 to 15 seconds per 50 microseconds. C–222 is a critical adjustment, and should be moved only in small increments to obtain the correct pull-in speed.

k. *P* Control.—Control adjustment is used to control the regulated B-plus power supply and should be adjusted to furnish about 265 volts.

l. *K* Control.—This control adjusts the sweep length of the fast sweeps. It is usually adjusted so that there is a sweep length of about 150 microseconds on the fast-sweep No. 1 position.

m. *J* Control.—This control adjusts the sweep length of the slow-sweep sawtooth generator, thus controlling the length of slow sweep on scope tube.

n. *M* Control.—This control gives a fixed trace separation when the receiver switch is on position OFF. This is used mainly to check for alignment of pips on the fast sweeps. The pips should always line up one above the other on the top and bottom traces of the fast sweeps.

o. *N* Control.—This is an anastigmatic control and is used with the controls on the fastest sweep to make the pulses presented on the scope face focus sharply over the entire length of sweep. This control is always adjusted in conjunction with the intensity and focus controls.

8.200 GROUND-STATION RECEIVER TUNING

When there is a wavemeter at the ground station, the same procedure as outlined for the ship transmitter tuning may be followed. The final adjustment of the ground-station receiver, however, should be as outlined below:

a. Have the ship turn on its EPI equipment so that its signal may be used to tune the ground-station receiver and transmitter.

b. Set the controller-indicator as follows:

SWEEP SPEED on SLOW

RECVR on ON 1
RECVR GAIN to about 6
BALANCE GAIN centered
Electronic attenuator blanking switch OFF (under receiver)

c. If the receiver is almost in tune, the ship-station pip should appear on the scope. Tune the receiver by the screwdriver adjustments through the holes on the top of the receiver. Make the pulse maximum amplitude by first tuning the oscillator, the back control, and the second control; then, the front control. Back the RECVR GAIN off for each adjustment so that the signal does not saturate.

d. Synchronize the ground-station controller-indicator by the method outlined in paragraph **3.201**. The ship signal will now be on the fast sweep. Repeat step *c* above for final receiver tuning. When tuning the oscillator (back control), tune for the maximum overshoot; that is, when the pulse rises to a maximum, drops off a little, and flattens before the final drop-off. The equipment should be on at least one hour before final adjustment. The receiver is now tuned and the next step is to tune the transmitter.

8.300 MARK 3, MODEL 2, TRANSMITTER TUNING

a. Start the transmitter in accordance with paragraph **7.401**. If the transmitter-coupler has not been tuned, set the antenna tap on *D* of L–401 for the first approximation. Set the voltage indicator at about 10 microamperes and make sure the electronic attenuator blanking switch is ON.

b. Adjust the RECVR GAIN, BALANCE GAIN, and LOCAL SIGNAL GAIN controls until the local transmitter signal is seen along with the unsaturated ship signal. Adjust the transmitter FREQUENCY TUNING for the maximum local signal, readjusting the receiver controls to keep the same size ship signal and to keep the local signal from saturating. It may be necessary to change the plate taps to get the transmitter on frequency. Bring the plate voltage up to the value indicated alongside the meter. (The meter reading for the proper plate voltage is written in pencil on the metal near the meter.) Adjust the LOAD TUNING for maximum ANTENNA CURRENT (transmission line current). Correct for frequency as this is done. Proper tuning will be indicated by maximum overshoot and the local signal having the appearance of the ship signal. Find the best adjustment of the antenna-coupler, correcting for frequency and load-tuning as this is done. The transmitter is now adjusted and ready for use.

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IX

THEORY OF OPERATION OF SHIP EQUIPMENT

9.100 GENERAL DESCRIPTION

There are three principal functions of the ship-station instrument: (1) to transmit radio-frequency pulses to the ground stations; (2) to receive similar pulses from the ground stations, along with the attenuated pulse transmitted by the ship instrument; and (3) to present the two ground-station pulses and the ship pulse on the screen of a cathode-ray tube in such a way that when the leading edges of a ground-station and ship pulse are aligned, the distance from the ship to each ground station may be read from range dials.

To accomplish the above three functions, four pieces of equipment are required: (1) the Controller; (2) the Receiver; (3) the Indicator; and (4) the Transmitter. Their combined functions are briefly described.

Figures 26 and 27 will assist in analyzing the theory of operation. Figure 26 illustrates the sequence of events and functions, while Figure 27 will demonstrate how the various circuits are connected, and affected by each other.

The timing of the entire system is controlled by a precision 100-kilocycle crystal oscillator located in the controller. Signals from this crystal oscillator pass into a chain of step-charger divider circuits located in the indicator. The output of this chain produces pulses which are used to start gating circuits needed to give the proper delays and to produce the transmitter trigger. The same 100-kilocycle signal that entered the divider-circuit chain also enters a sine-wave divider chain which has outputs of 10 and 1.0 kilocycles. These signals, along with the 100-kilocycle signal, enter a phase-shifting network. There are two phase shifters attached to the network which operate independently: one to measure the range to the *A* ground station, and the other, to the *B* ground station. Each phase shifter may be independently changed in phase by 360 degrees, giving a range of 1000 microseconds. Each phase shifter has a dial and verniers which indicate the distances to the ground station.

The pulses from the phase shifters go to the indicator where they are combined in a mixer with a delayed gate which was started by the output of the chain of dividers. A selected group of pulses from the mixer circuit starts the sweep circuit which will be used to display the ground-station pulses on the cathode-ray tube. It can be seen that the time position of the sweeps is moved by the phase shifters until the sweep occurs simultaneous with the ground-station signal and, thus, the ground-station signal will appear on the scope. The trigger signal that starts the transmitter also starts a sweep so that the transmitted signal is displayed on a stationary sweep. The movable ground-station sweep is then adjusted by the range dial so that the ground-station and ship pulses can be matched on a scope. The range dial and counters give the range to this ground station.

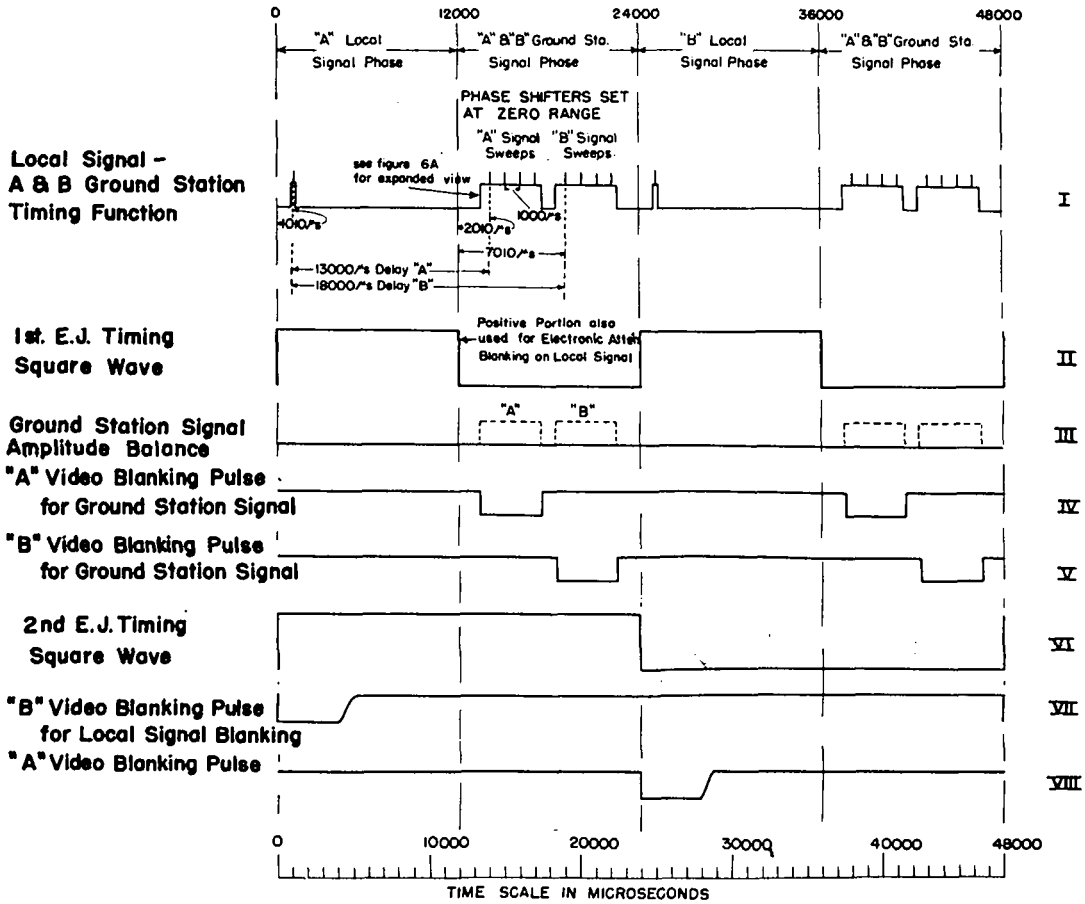

FIGURE 26.—Ship time diagram.

A single antenna serves for both transmission and reception signals. Both the ship and ground-station signals enter the electronic attenuator, which attenuates during the time the ship signal is being received and amplifies during the period the ground-station signals are being received. This instrument helps to equalize in intensity the ship and ground-station signals at the input of the receiver. The gating signal that operates the electronic attenuator at the proper times comes from circuits in the indicator. The electronic attenuator's amplifier is blanked by a gating signal during the time the ship signal is transmitted so as to attenuate the local signal. The amount of local signal entering the receiver is determined by resistance-type local signal attenuator of the electronic attenuator.

The receiver amplifies the signals from a few microvolts at its input to over 100 volts at the output terminals. Seldom are the two ground-station and ship signals equal, so the receiver gain must be changed during the time each ground-station signal is received. The circuits that produce this gain-switching are in the controller and are adjusted by the balance gain control. The receiver gain remains at a fixed level while the ship signal is received. The video signal from the receiver passes into the controller, where it goes through a blanking amplifier. The blanking amplifier has two channels. The output of each goes to opposite horizontal plates of the cathode-

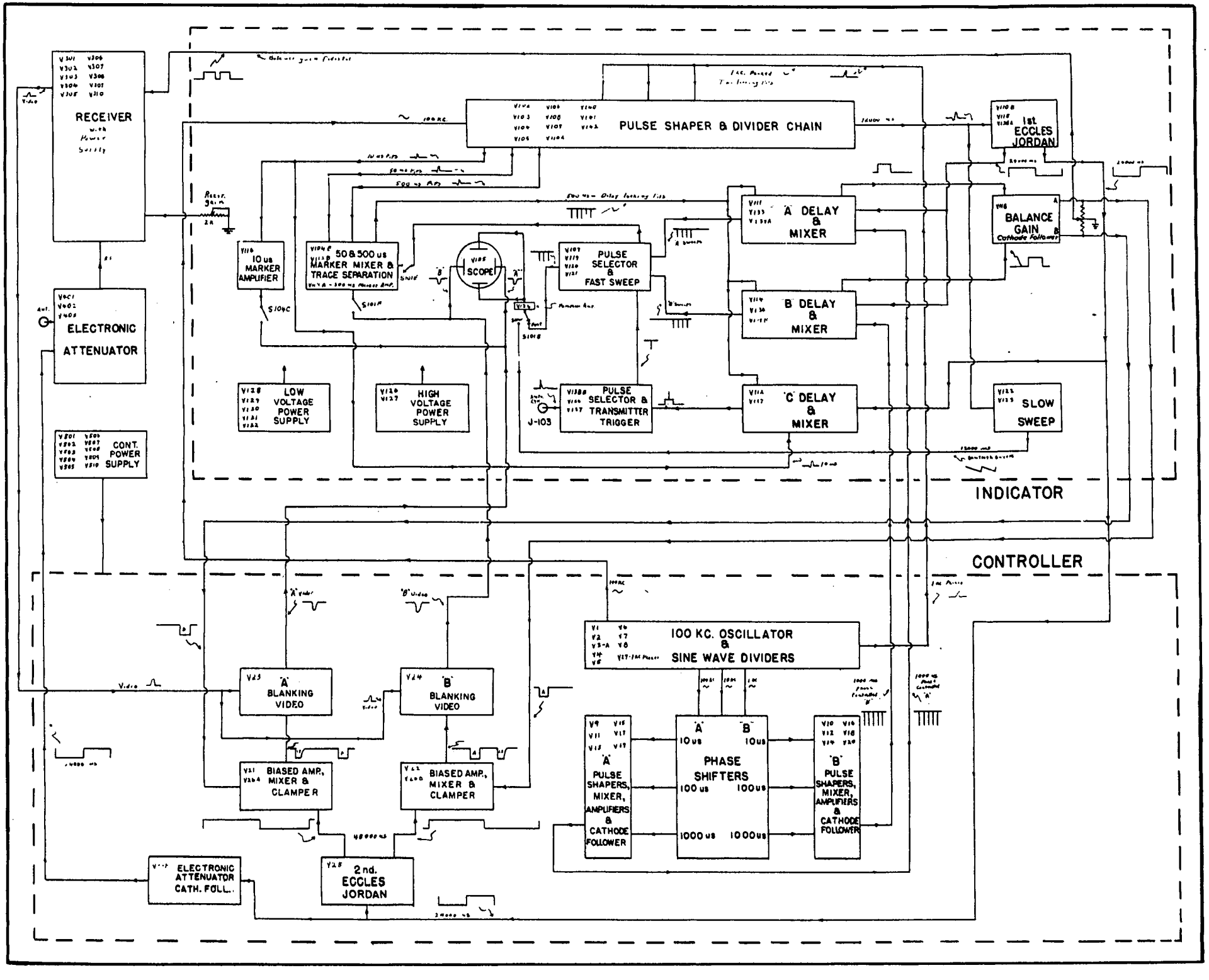

FIGURE 27.—Ship block diagram.

ray tube. Each channel is alternately blanked so that the opposite channel furnishes a signal to the cathode-ray tube. Thus, the local signal appears alternately on each side of the vertical sweep of the cathode-ray tube. Similarly, the ground-station signals are alternately blanked and unblanked in the video blanking circuit so that the *A* station will always appear on the left side of the scope and the *B* ground station on the right side. Since the sweep is vertical, the video pulses will be horizontal. The ship signal will stand out from each side of the vertical trace and will be symmetrical about this line. The ground-station signals on their respective sides of the vertical line will differ slightly in appearance, but their wavefronts (top edges) will be essentially the same as the ship signal.

9.200 CONTROLLER

9.201 100-kilocycle Oscillator and Sine-wave Dividers

This crystal oscillator is known as a bridge-stabilized oscillator. It depends upon a Western Electric GT cut quartz crystal for its accurate control of frequency to better than 1 part in 10 million. To aid in maintaining the precise timing, the crystal is housed in a temperature-controlled oven and used in a circuit that will permit it to oscillate in the most stable state. The crystal is in one arm of a bridge circuit which is connected between the input and output of a two-stage amplifier (V–1 and V–2). The bridge, together with the crystal, forms the coupling between the input and output of this amplifier and has the correct phase to cause feedback through the amplifier, resulting in oscillations of 100 kilocycles. Lamp A–1 in one arm of the bridge has the proper voltage-resistance characteristics to rebalance the bridge when any change occurs in the circuits external to the bridge, thus acting as an AVC circuit for the amplifier. This type of circuit allows the crystal to oscillate in such a way as to be largely independent of tube and circuit characteristics and voltage changes.

The 100-kilocycle sine waves from the oscillator circuit go to a cathode follower V–3A used to isolate the oscillator from the load. V–4 is a 100-kilocycle amplifier. The primary of T–301 is tuned to 100 kilocycles by means of C–304. Tubes V–5 and V–6 and the associated components form the ten-to-one sine-wave divider which takes the 100 kilocycles at its input and delivers 10 kilocycles at the output terminals. The 100 kilocycles from the 3–4 winding of T–301 pass through the secondary winding of T–302 with little attenuation and are impressed on the grid pin 5 of V–6. The plate circuit of this tube is tuned to 10 kilocycles principally by winding 1–2 of T–303 and C–311. T–304 and C–312 are involved to a small extent in the tuning of the plate circuit; however, their main function is to filter the 10 kilocycles to produce a smoother wave form. The 10 kilocycles at the plate of V–6 is coupled to the grid pin 4 of V–5. Since this is an overdriven amplifier, the 10 kilocycles are distorted and, hence, rich in harmonics. The ninth harmonic of 10 kilocycles, or 90 kilocycles, is filtered out in the plate circuit of V–5 by the filter formed by the primary of T–302 and C–308. Thus, there are a 100-kilocycle and a 90-kilocycle current in the secondary of T–302. Because of the nonlinear characteristics of V–6, the sum, or 190 kilocycles, is filtered out by the plate filter of this tube, while the difference, or 10 kilocycles, is passed by this 10-kilocycle filter.

Following this sine-wave divider is a second divider which divides the 10 kilocycles by 10 to produce 1.0 kilocycle. Here the operation is the same as the circuits just

described, except that the plate circuit of V-8 is tuned to 1.0 kilocycle and the plate circuit of V-7 is tuned to 9.0 kilocycles.

9.202 Quadrature Networks and Phase Shifters

The 100-kilocycle signal from the oscillator amplifier V-4 is impressed on a quadrature network. The accuracy of the phase-shifter system depends upon this being a pure 100-kilocycle sine wave. Z-301 is a low-pass filter which cuts off above 100 kilocycles, thus removing high-frequency distortion and giving a nearly pure 100-kilocycle signal. While this 100 kilocycles must be shielded, it is still important that the voltages be balanced with respect to the quadrature network. This is accomplished by connecting the output of T-301 to the center and shield of a shielded cable, the braid of which is also insulated from ground. The capacity of the outside shield to ground is eliminated by forming a parallel-tuned circuit of this capacity with L-343 so that at 100 kilocycles this appears as a pure resistance, of high value, between the shield and ground.

The two stator coils in each phase shifter must be supplied with voltages that are 90 degrees apart in phase. (Refer to the controller circuit diagram, Figure 68, and note the 100-kilocycle quadrature network.) Coils L-316 and L-317 are the stator coils for the *A* 100-kilocycle phase shifter and are 90 electrical degrees apart in phase. Coils L-318 and L-319 are the same for the *B* phase shifter. It will be noted that these stator coils form a square with 90 degrees phase shift between adjacent sides of the square. The phase shift on each side of the square is produced by the resistance-capacitance combination that bridges each coil. The reactance of the 0.002 mf condenser just equals 795 ohms and is the same in magnitude as the associated resistance but 90 degrees different in phase.

In principle, the 10- and 1.0-kilocycle networks are the same as the one just described. In each network, the capacitors are of such a value as to make the reactance equal to 795 ohms at their operating frequency. In the 1.0-kilocycle network, negative-temperature-compensated resistors are used in series with the phase-shifter coils to make up for large changes in resistance of the coils due to temperature.

The phase shifters are of the induction type. All three associated with a channel are similar in construction except that the lower-frequency units have more turns of wire on the coil. The primary coils (L-316 and L-317) of the *A* channel 100-kilocycle phase shifter are wound on a core which is so slotted as to make these two coils at right angles. The secondary coil, L-320, which is the moving coil, is on a form that fits over the primary and is wound in such a way that it has a uniform field through the region of the primary windings. The primary windings are physically and electrically 90 degrees apart. The primary produces a rotating field that cuts the secondary coil. Since the secondary coil may be rotated with respect to the primary, the phase of the induced secondary voltage may be adjusted through 360 electrical degrees by means of a 360-mechanical degree rotation.

All three phase shifters of a single channel are geared together so that the 100-kilocycle (10 microseconds) phase shifter turns ten times to one of that of the 10-kilocycle (100 microseconds), and the 10-kilocycle phase shifter turns ten times to one of that of the 1.0-kilocycle (1000 microseconds) phase shifter. The frequency relation between adjacent phase shifters is also in a ten-to-one ratio. When the 10-microsecond phase shifter turns through 100 mechanical degrees, the gear system turns the 100-

microsecond phase shifter through 10 degrees and the 1000-microsecond dial through 1.0 degree. But the frequency relation between these three units is such that one mechanical degree on the 1000-microsecond phase shifter is the same as 10 and 100 on the 100- and 10-microsecond phase shifters, respectively. Thus, all three phase shifters track exactly in time over the entire range of rotation.

9.203 Phase-shifter Pulse-forming Circuits and Mixer

The output of each phase shifter is connected to a pulse-shaping circuit, the general operation of which is to take the sine wave and convert it to the proper form before it enters the mixer. Circuits for the *A* and *B* phase shifters for each of the three quadrature networks are the same. Pulse-shaping tubes for the *A* side are V–9A, V–11, and V–13; the mixer is V–15. Pulse-shaping tubes for the *B* side are V–10A, V–12, and V–14; the mixer is V–16. Because both *A* and *B* circuits are the same, only the *A* circuits will be described; the corresponding *B* circuits will be evident from the circuit diagram. During this discussion a clearer understanding of circuit operation may be had by referring to the wave forms for these circuits. Tube V–9A is a cathode follower used to isolate the 100-kilocycle phase shifter from the load. V–11 is in the pulse-shaping circuit for the 10-kilocycle signals. The first half of the tube has no fixed bias. During the positive portion of the signal, the grid is prevented from going positive by the 150K resistor in the grid circuit. The negative portion of the wave drives the grid down beyond cut-off, producing a square positive wave in the plate circuit. The 500-mmf condenser and 15K resistor differentiate this square pulse to give a positive and negative pip.

The second half of V–11 is arranged as a diode clamper which clips the positive pip and forms a grid bias for the mixer tube (V–13, pin 8). V–13 is the pulse-shaping tube for the 1.0-kilocycle signals. The first half of V–13 is self-biased in the grid circuit so that only the positive peaks of the 1.0-kilocycle signal causes the tube to conduct, thus producing negative pulses about 100 microseconds in length in the plate circuit. The second half of V–13 inverts this pulse and flattens the peak.

Tube V–15 is the *A* mixer tube that receives the three signals (100, 10, and 1.0 kilocycles) just described, and combines them. The relative phase of these three signals has been adjusted so that they occur in coincidence in such a way that one pulse occurs every 1000 microseconds (from the 1.0-kilocycle signal), that this will be the proper selected pulse of the 100-kilocycle signal. The three phase shifters associated with the channel are mechanically coupled at the proper ratio to make the same 10-microsecond, 100-microsecond, and 1000-microsecond pip track for all settings of the phase shifter. Each of the grids of V–15 are biased so that the peak of all three signals must be coincident before the tube conducts.

Tubes V–17 and V–19 are amplifiers and inverters (the corresponding tubes on the *B* side are V–18 and V–20). Cathode follower V–9B is used so that the 1000-microsecond pulses may be transmitted through a transmission line to the indicator without serious loss of shape or amplitude.

9.204 Blanking Video Amplifiers and Second Eccles-Jordan Multivibrator

There are two main functions for the blanking video circuits: (1) to separate the video signals from the receiver so that the *A* signal will appear to the left of the vertical sweep line and the *B* signal will appear to the right of this line; (2) to blank out undesired

signals while the desired one is being presented, or commutating between the *A* and *B* signals and the ship signal. The *A* blanking video tubes are V–21, V–23, and V–26A; while the *B* tubes are V–22, V-24, and V–26B. Describing the *A* channel, the first half of V–23 is a cathode follower used to isolate the two blanking circuits from each other. The second half of V-23 is biased just beyond cut-off, but will pass the positive video pulse for normal (unblanked) operation.

The negative video signal in the plate circuit of this tube goes to the right horizontal plate of the cathode-ray tube located in the indicator. Because this is a negative signal, the presentation will be on the left side of the sweep line. Blanking signals are introduced into the grid circuit of the second half of V-23, pin 4. This blanking signal is a strong negative pulse, of such a value that the largest video signal will not bring the tube up to conduction. V–21, biased amplifier mixer, amplifies and inverts the blanking signals which come from two sources in the indicator. The signal on grid pin 1 of V–21 blanks every alternate ship signal and the blanking signal on the grid pin 4 blanks at the time the *B* video signal is being received. V–26A clamps the grid pin 4 of V-23 to prevent this element from going positive. See Figure 16.

Tube V-25 is the Eccles-Jordan square-wave multivibrator, whose only purpose is to furnish proper blanking to the blanking video circuits and thus commutate the ship's video to each side of the cathode-ray tube. A more detailed description of the function of the Eccles-Jordan circuit is given in paragraph **9.302**. This circuit is operated every 12,000 microseconds by a pulse from a signal that originates in the first EJ circuit (V–115).

9.205 Controller Power Supply

This is a unit separate from the controller. It is mounted near the bottom of the rack, back and below the controller. Three sources of voltage are furnished: 250 volts at 200 ma. for plate voltage; 105 volts for the crystal oscillator; and minus 50 volts for bias.

The 250-volt supply is regulated electronically by tubes V-502 through V-507. All the load current flows through the four 6B4 tubes, the load being between cathode and ground of these tubes. Across the load are the regulator tubes V–506 and V-507. Any change in load voltage, whether by reason of load- or line-voltage change, causes a change of bias on V-506. This produces a change in plate current of this tube. Since the plate-load resistor of V–506 is between the cathode and grid of the regulator tubes, V–502 through V–505, the bias on these tubes also changes and regulates the current flow in such a direction as to correct the load-voltage change.

The plus-105 volts are taken from the drop across the gas regulator tube V-510. Voltage for the operation of this circuit is from the 250-volt regulated supply.

The minus-50 volts are from the half-wave rectifier V-508, which receives its voltage from tap on the power transformer T–501. The minus-50 volts are from a potential divider across the gas regulator tube V-509.

9.300 INDICATOR

9.301 Squaring Amplifier and Step Charger Divider Circuits

The 100-kilocycle signal from the oscillator circuit in the controller is impressed on the grid (pin 4) of the squaring amplifier, V–102. Since this is an overdriven tube,

rectangular waves appear in the plate circuit. L-102 is used to give these waves sharper rise time. The output of this circuit is fed to the input of the divider chain.

The purpose of the step charger divider circuits is to take the 10-microsecond signals from the squaring amplifier and divide them, in time, so that at the output of the fourth divider, the pulses are spaced 12,000 microseconds. This time division establishes the slow repetition frequency necessary for long-range measurements. Since a description of these circuits appears in paragraph **10.203** of the ground-station controller, it will not be repeated here except in respect to certain aspects where they differ.

It will be noted that diodes V-140, V-141, and V-142 introduce 1000-microsecond pulses into the first, second, and third dividers. This 1000-microsecond pulse, called the locking pulse, starts the division of these three stages at the same time by the addition of an extra charge to the charging condensers in each stage, which will start the divider circuits off in step. It is important that the divider chain be thus locked so that keying circuits and phase-shifter circuits will be locked in phase and not have a random relation. The 1000-microsecond locking pulses come from a blocking-grid circuit (V-27) in the controller, which is driven by the 1.0-kilocycle (1000-microsecond) sine-wave divider.

9.302 First Eccles-Jordan Multivibrator—Square-wave Generator

The purpose of this circuit is to divide the operating period into two equal parts so as to separate, in timing, the sequence of events that occur in each cycle. Signals from the fourth divider circuit start this square-wave generator, V-115, through the clipper circuit V-110B. This square-wave generator is called a bi-stable circuit since one of its tubes will remain cut off and the other conducting until a signal is applied to the grid circuits to reverse the state of these two tubes. This condition will remain until switched back by another trigger. For a brief description of the operation of this circuit, assume that V-115A is strongly conducting while V-115B is cut off. Tube V-115A is strongly conducting because V-115B is cut off and the plate of this tube is near to B-plus (270 volts); the potential divider formed by R-179 and R-188 holds the grid of V-115A close to zero volts with respect to the cathode, while the potential divider from plate V-115A holds the grid of V-115B to just below cut-off. When a negative trigger is applied to the grids of these tubes, V-115B having its grid at cut-off can do nothing more than go more negative, but V-115A grid will be carried down through cut-off; thus, the potential dividers connected to the plates of each will hold the grids in this new stable state. The cathodes are held at a fixed potential.

9.303 Delay Multivibrators

There are three delay multivibrators: one to delay the local-, or ship-, transmitted signal (V-112) called *C* delay; one to delay the sweep signals for the *A* ground-station sweeps (V-111); and one to delay the *B* ground station sweeps (V-114). The transmitter-delay multivibrator, *C* delay, is started from the positive-going edge of the square wave from the plate of V-115A, while both the *A* and *B* delay multivibrators are started from the positive-going edge of the signal from the plate of V-115B—or the two sets of delays are started 12,000 microseconds apart. Since all three delay multivibrators are similar in their operating principle, only the *A* delay multivibrator will be described.

In the nonoperating state, the first half of V–111 is strongly conducting while the second half is cut off. This is because the grid return of pin 1 goes to B-plus, while the grid return of pin 4 of the second half goes to some lesser positive value. Because of the lower grid voltage and the high cathode voltage, the second half of V–111 is cut off. When the positive part of the square wave, which is differentiated by C–135 and R–131, arrives at the grid (pin 4), it drives this tube up into conduction and the plate voltage drops to a low value. The other grid (pin 1) is carried to a negative value through C–136, and the first half is cut off. C–136 discharges through the plate circuit of the second half and R–133 in such a direction that it will finally bring the grid (pin 1) back to cut-off and going toward zero, causing plate conduction. It is the positive rectangular pulse on the plate (pin 2) that is used for the delay.

The length of the delay is controlled by R–172, which controls the current through the second tube during the ON period and thus establishes the cathode voltage, which is also the bias on the first tube and determines how soon the grid (pin 1) returns to cut-off. Along with the square wave used to start the multivibrator are 500-microsecond negative pulses. These pulses are intended to stop the multivibrator at some definite 500-microsecond interval after it has once been started (after 1500 microseconds, or the third 500-microsecond pulse for the *A* delay). The negative 500-microsecond signal when applied to grid (pin 4) during the ON time, is amplified by this tube and the positive pulse on the plate circuit is passed to grid (pin 1) through C–136. During this time, grid (pin 1) is cut off but coming up toward cut-off by the action already described. The 500-microsecond pulses drive the grid up toward cut-off, but nothing changes until the first 500-microsecond pulse that drives the grid through cut-off voltage, at which time the tube is switched back to its normal rest state and the delay of the multivibrator is over. The *B* delay is 6500 microseconds, while the *C* delay is 500 microseconds. Note that all these delays are with respect to the square-wave signal that starts the multivibrator. See Figure 26.

9.304 Mixer and Pulse-Selector Circuits

Because the three mixers associated with each of the three delay multivibrators are the same in function, only the *A* sweep mixer (V–133) will be described. By referring to the indicator-circuit diagram, it will be noted that the plates of V–133 are connected and supplied through a common plate load resistor. Also, both tubes are strongly conducting during the no-signal time. The grid (pin 1) receives short 1000-microsecond pulses from the *A* channel phase-shifter circuit in the controller. During these pulses, this grid (pin 1) of V–133 is cut off and positive pulses appear in the plate circuit. The signal from the *A* delay multivibrator is a positive pulse, the length of which is the intended delay (1500 microseconds for *A* delay). Since the grid (pin 4) of V–133 is strongly conducting, the positive edge and the flat top of the pulse do not change the state of this tube, but the negative edge carries this grid (pin 4) down through cut-off. The time this tube remains cut off depends on the size of the signal and the time-constant of the circuit composed of the .005mf condenser and the 1.0-megohm resistor, as well as the setting of the 100,000 ohms *A* pedestal-length control (R–171). When grid (pin 4) is driven negative, the voltage on this grid starts to come back toward cut-off and, while the grid is cut-off, the plate voltage rises up to a higher value and remains so until the grid returns to the original value, thus forming a positive pedestal in the plate circuit.

For normal operation, the pedestal is made 4000 microseconds long. Any 1000-microsecond pulses that occur at the time of the pedestal will cut off the other half of the tube so that these pulses (four in number) will stand on the pedestal. The position of these pulses on the pedestal is controlled by the phase shifter and can be moved with respect to the pedestal. It will be noted that the delay and mixer circuits are used to select the desired group of 1000-microsecond pulses in the timing sequence. Four sweep pulses are selected so that the instrument range may be made 4000 microseconds. The B mixer, V–134, is the same in all details. The C mixer differs in that the pedestal is much shorter—about 20 microseconds and only one 10-microsecond pulse on the pedestal. It may be that the pedestal is longer so that two 10-microsecond pulses appear but the first pulse has all the control.

The purpose of the pulse selector is to select the pulses that stand on the pedestal and exclude the pedestal and all other pulses. All three pulse selectors are the same. The first half of V–107 is the *A* pulse selector. Cathode bias used on this tube has a value that exceeds cut-off by an amount a little in excess of the pedestal voltage. In this way, only the pulses on the pedestal will drive the grid up through cut-off and produce negative pulses in the plate circuit. Signals from the three pulse-selector circuits operate the fast-sweep circuit, a description of which follows.

9.305 Pedestal Generator, Fast-sweep Generator, and Paraphase Amplifier

Tube V–119 is used as a multivibrator which operates the fast-sweep generator. It produces an intensifying pulse for the cathode-ray tube and a pedestal which appears on the slow sweep and aids in the synchronizing process. This circuit is known as the pedestal generator. Because this is a conventional multivibrator, it will not be discussed.

The positive pulse from plate pin 2 of V–119 through V–120B and the intensity limiter V–135 intensifies the cathode-ray tube during the fast sweep. The negative pulse from plate (pin 5) of V–119 is used to start the fast-sweep generator. Tubes V–120A and V–121 form the fast-sweep generator. During the OFF period, V–120A is conducting and the condenser selected by S–102B is charged. When the multivibrator operates during the ON period, V–120A is cut off and the condenser starts to discharge through V–121. Since V–121 is a pentode, the current is uniform and a linear discharge results, producing a linear sawtooth sweep voltage. S–102 also selects circuits which change the time-constant of the multivibrator to control the length of the sweep and, at the same time, change the size of the charging condenser in the sweep circuit so that the sweep will be linear over most of its length. Control K, R–202, controls the discharge current through V–121 and, in part, controls the sweep speed.

The negative sawtooth signal from the sweep generator goes to the paraphase amplifier V–124, which is used to amplify and phase-split both slow and fast sweeps. The paraphase amplifier has two outputs. The signals from each are the same in shape but opposite in sign (increasing and decreasing sawtooth waves). This is produced by having equal resistors in the plate and cathode of V–124. The output of this amplifier is applied to the vertical plates of the cathode-ray tube and sweeps from top to bottom of this tube.

9.306 Slow-sweep Circuit

The pulse from the output of the last blocking grid divider circuit is used to start the slow-sweep circuit. This means that a new sweep is started once every 12,000 microseconds and continues for that time with only the short retrace time between new sweeps.

When the gas tube V–122 is triggered by the starting pulse, C–211 is discharged. This condenser then starts to recharge through R–264. It is the recharging of this condenser that produces the sawtooth wave which is amplified and inverted by V–123.

9.307 Transmitter Trigger Generator

The output of the pulse-selector tube V–138B, in addition to starting the sweep used to view the ship-transmitted signal, also starts the circuits which trigger the ship transmitter. The negative pulse from the C pulse-selector tube V–138B, goes to the inverted amplifier and cathode follower V–136. Since these circuits are conventional, they need not be described. A gas tube (thyratron V–137), when triggered by the signal on its grid, discharges the 0.005-mf condenser in the plate circuit through the primary winding of T–107. Because of the rapid discharge of the condenser, a very fast-rising voltage is developed across the transformer primary. This is coupled to the secondary winding with the proper polarity to give a positive pulse to the coaxial line which starts the transmitter operation. During the OFF period, the 0.005-mf condenser recharges through the 1-megohm plate resistor.

9.308 10-, 50-, and 500-microsecond Marker Circuits and Trace Separator

These circuits were described in the section on the ground-station controller-indicator, paragraphs **10.214**, **10.215**, and **10.216**. Because the function is the same, it will not be repeated here.

9.309 Oscilloscope Circuits and Power Supply

These circuits are described in paragraphs **10.217** and **10.219** of the ground-station controller-indicator (paragraph **10.200**).

9.310 Blinking Circuit

By blinking the EPI equipment, the ship passes information to the EPI ground stations. By means of blinking, the ground station can identify one ship signal from another ship signal or from another ground station. However, the most important use of blinking is to notify the ground stations of the fix interval as described in the beginning of Section III.

Blinking is accomplished by shifting the delay of the ship-transmitted signal at a rate of between one and four seconds per blink. At a ground station, the blinking viewed on the slow sweep will show the ship signal moving rapidly from the top pedestal a few thousand microseconds and back on the pedestal again at the same rate between the limits mentioned. On the fast sweep the ship signal will appear to blink at this rate. Each ship in an area will have a different blink-rate by which the ground-station operator can identify each ship.

The blinking circuit operates on the C delay multivibrator V–112, which is described in paragraph **9.303.** A simple relaxation oscillator, composed of a neon tube NE–51, a 1-mf condenser C–1003, and a resistor of a value between 10 and 40 megohms, gen-

erates a sawtooth signal. The blink-rate is established by the value of this resistor selected. The negative-going part of the sawtooth is coupled to the grid (pin 4) of V–112 through C–1004, the diode IN–34, and C–142. The diode permits only the negative signal to pass. This negative signal cuts off the right side of V–112; the recovery time depends upon the size of this signal and the time constant of the circuits connected to the grid (pin 4). While the tube is cut off, a positive pedestal appears at the plate (pin 5) of V–112, which is similar to but longer than the regular delay pedestal. During the short time the blinking signal is on, the ship signal is swept out of synchronism at the ground stations and then back in again. The time of blinking is so short that the synchronizer does not lose control.

9.400 RECEIVER

This unit is a broadbanded double-detection (superheterodyne) type receiver. It employs one radio-frequency stage, mixer, three intermediate-frequency amplifiers, detectors, and a video amplifier. There is a conventional gain control and a special commutated gain control. It contains its own power supply.

Signals from the electronic attenuator are transformer-coupled to the grid (pin 4) of the radio-frequency tube V–301. The secondaries of the input transformer are tuned to 1850 kilocycles by means of adjustable iron cores. The plate circuit is RC-coupled to the mixer grid, which is tuned to the signal frequency by the parallel-tuned circuit. Three sets of filters to reject any signal at the intermediate frequency of 1050 kilocycles, are employed in this circuit. The gain of this stage is connected to the balance-gain circuit, which changes the potential of the cathode of V–301 between the time when the A and B ground-station signals are received.

The mixer stage is a combined oscillator and converter. The oscillator operates at a frequency of 2900 kilocycles to convert the signal frequency of 1850 kilocycles to the intermediate frequency of 1050 kilocycles.

The three 1050-kilocycle intermediate-frequency amplifiers are stagger-tuned for the purpose of broadbanding. Most of the broadbanding is accomplished by stagger-tuning the primary and secondary of the IF transformers. Additional broadbanding is obtained from loading the secondaries of these transformers with rather low-value resistors. A gain control, located in the indicator, is in the cathode of the mixer and IF stages.

A simple diode is used for the second detector V–306. There is a filter between the detector and the input of the video stage to remove the IF signal from the envelope. The second half of V–306 is used to prevent the grid of the video amplifier from going positive. The video amplifier V–306 is made broadbanded by use of a low plate load resistor. The gain of the receiver is such that a 5-microvolt signal will produce about 200 volts out of the video amplifier. The over-all band width is about 85 kilocycles—6 db down from the center frequency.

9.401 Receiver-coupler

For the theory of operation of this unit, refer to paragraph **10.600,** which is the description of the ground-station receiver-coupler. In the ship unit, the coupling condenser from the antenna is only 15 mmf as contrasted with 100 mmf in the ground-station coupler. It was found necessary to use smaller coupling on the ship as the ship antenna is considerably shorter than a quarter wave and therefore very reactive. This

means high impedance at the antenna base, hence higher impedance coupling to the receiver circuit. Because of the smaller coupling, there is some loss in low-frequency response and, therefore, some rounding of the signal where there should be a flat top. However, there is little loss in high-frequency response, so that the sharpness of the wavefront does not suffer and, hence, no loss in matching accuracy.

9.500 ELECTRONIC ATTENUATOR

The function of the electronic attenuator was described in the general description, paragraph **9.100,** but a brief review will be given here before taking up the more detailed function of this component. This unit serves three principal functions, as follows: (1) to amplify the weak ground-station signals; (2) to offer high attenuation to the strong local ground-station signal; and (3) to permit the local signal to pass through an adjustable resistance network so that the local signal may be made equal to ship signal at the input of the receiver. To produce these functions, it is necessary for the amplifier portion of the unit to be normal during the reception of the ground-station signal and to be turned off during the time the local signal is transmitted. This latter process is called blanking.

During the description of this unit, refer to the circuit diagram Figure 71. Tubes V–401 and V–402 are the amplifier portion of the unit. In most respects, it is similar to the conventional resistance-capacity coupled video amplifier. It is important that this amplifier pass the 1850-kilocycle pulse without distortion, either phase or amplitude. This has been accomplished by making the amplifier broadbanded. The gain of the amplifier is 20 db at 1850 kilocycles and is 3 db down at 3000 kilocycles. Broadbanding is made possible by reason of the low values of plate-load resistance of V–401 and V–402. Resistor R–17, which is between the input and ground, loads the antenna-coupling unit and tends to increase the system band width. Except for this and the blanking feature, the amplifier is conventional.

It can be noted from the diagram that the grid return resistors R–5 and R–6 of V–401 and V–402 are connected to a common point where the large negative blanking voltage is introduced. Resistor R–4 and condenser C–13 form a decoupling network to prevent degeneration between these two tubes due to a common impedance. Tube V–403 constitutes the blanking amplifier and clamper. The blanking signal is a square wave which is generated by the Eccles-Jordan circuit in the indicator. The positive half of this cycle does the blanking of the electronic attenuator; the transmitter operates during this half cycle. The triode part of V–403 is biased so that nearly full-plate voltage appears at its plate. When its grid is driven positive by the positive part of the square wave, the plate voltage drops to a low value and remains so for 12,000 microseconds, which is the duration of the Eccles-Jordan half cycle. This negative pulse is coupled through C–3 to the video-amplifier grid-return resistors, which pull the grids of these tubes well down below cut-off. These grids are held well below the value of the transmitter signal so that the amplifier is inoperative. The clamper part of V–403 prevents the blanking signal from driving the amplifier grid positive during the unblanked portion of the cycle, so that the video amplifiers will have a normal grid bias during this period.

In a well-designed electronic attenuator the attenuation between the input and output terminals should be high, the only signal at the output terminal being that through the resistance network. To accomplish this, careful electrical and mechanical

design is required. Input and output terminals are isolated and shielded from each other. Any closed circuits in the input and output are made small to reduce magnetic coupling. A ground bar runs through the center of the unit to which all grounded components are attached so that there will be a minimum of coupling because of the impedance between ground points. The limit of the attenuation through the amplifier network is set by the network formed by the grid-to-plate capacity and the plate-load resistor. All attenuators used with the EPI system are tested and must have an attenuation of at least 120 db between input and output terminals, with the resistance attenuator disconnected.

The attenuator which bridges the amplifier controls the amount of the local transmitter signal that reaches the input of the receiver. This attenuator, which is a part of the electronic attenuator, is known as the LOCAL SIGNAL GAIN. The range of this attenuator should be such that the local transmitter signal can be made almost equal to the remote signal at the input to the receiver. This should make the ship and ground-station signals equal for all distances separating the ship and ground stations. The attenuation range of the local signal attenuator is from 40 db to over 100 db, but the useful maximum attenuation is about 80 db. Where the signal differences are more than 40 db and less than 80 db, the balance-gain circuit in the receiver can be made to extend the range. The reason that the upper range of the attenuator cannot be used is that the signal due to stray coupling begins to become as large, in amplitude, as that through the local signal attenuator. Since the phase of the spurious signal may differ from the attenuator signal pulse, distortion will take place.

9.600 SHIP ANTENNA CHARACTERISTICS

Ideally, the ship antenna should be about a quarter-wave, be broadbanded, and nearly free of large metal objects which disturb the antenna field pattern. Also, a single antenna, which is used for both transmitting and receiving, is desirable, since the phasing between two antennas can cause a directive effect, which, in turn, causes the measured distance to change with ship's heading.

In practice it is hard to realize anything approaching the ideal system on most ships because of the multitudinous rigging and also because the long wave lengths used by EPI require a vertical antenna more than 100 feet long.

The antenna is a T-type with the vertical part as nearly a quarter wave as the ship structure will permit. In general, it will be supported between the foremast and the aftmast, and as free of stays and other antennas as possible. The flat-top horizontal wire is used to give toploading, which helps to make the current distribution in the vertical portion of the antenna more uniform and thus a more efficient radiator The lead-in insulators are of the high-voltage type. Because of the short antenna and its high base impedance, the voltages become quite high near the base.

Figure 12 illustrates the antenna system used on a 220-foot vessel. This antenna is a quarter wave at a frequency of about 2200 kilocycles, which is somewhat higher than the operating frequency of 1850 kilocycles. Listed in the table below are the impedance characteristics of antenna illustrated in Figure 12. It will be noted that the resistive component is quite constant over a wide band of frequencies; its low value means that the antenna current will be quite large. The reactive component is capacitive and changes 30 ohms over a 100-kilocycle band, considering 1850 kilocycles as the center frequency. This means that the Q of the antenna is increased and that this

reactance must be tuned out in the transmitter before satisfactory load characteristics are presented to the transmitter.

9.601 Table of Antenna Characteristics

Frequency Kc	Resistance ohms	Reactance ohms
1750	12.0	−j170
1800	13.5	−j135
1850	15.0	−j116
1900	17.0	−j105
1950	19.0	−j98

9.700 TRANSMITTER AND TRANSMITTER-COUPLER

9.701 General Description of Mark 3, Model 2 Transmitter and Modulator

The Mark 3, Model 2, transmitter is constructed in two parts: (1) a small cabinet containing the pulse-shaping multivibrator and amplifiers (called the modulator), and (2) a larger cabinet containing the radio-frequency part of the transmitter (called the transmitter). In the transmitter part are a push-pull oscillator (1850 kilocycles), a key tube, and a high-voltage power supply for the RF oscillator. The modulator has a pulse-shaping multivibrator and two stages of pulse amplifiers. The output of the modulator works into the key tube, which starts the oscillator. The oscillator continues to oscillate for a time determined by the pulse shaping multivibrator.

9.702 The Modulator

The trigger signal from the controller unit is a short positive pulse. It is necessary to amplify and invert this signal, which is done by V–201A. Tube V–202 is the pulse-shaping multivibrator. Since there is no bias on the *A* half of this tube, there is a strong conduction, while the *B* half is cut off by reason of the bias voltage on the cathode.

The negative signal from V–201A drives the grid of V–202A down through cut-off and the plate stops conducting; hence, the voltage rises to B-plus value, where it remains during this portion of the pulse. The plate of V–202A is coupled to the grid of V–202B so that this grid is swung in a positive direction and this tube becomes strongly conducting. After the trigger starts V–202 operating, it remains in the new state for a period governed by the 330-mmf condenser between pins 1 and 5—the 100–K resistor connected to pin 1, the bias on the low end of this resistor, and the circuits associated with V–202B. Before the trigger signal starts the multivibrator operating, the 330-mmf condenser has been charged to a high value. During the operating period, this condenser discharges through the plate circuit of V–202B up through the pulse length-control circuit and the 100–K resistor. The grid of V–202A remains cut off until the drop across the pulse length-control circuit and the 100–K grid resistor is less than the cut-off (about 13 volts). At this point, the circuits start back to reach the stable condition they had before the circuits were triggered into operation. The length of the pulse is adjustable by the potentiometer in the grid circuit of V–202A (about 40 to 100 microseconds). Tube V–203 is biased very near to cut-off by reason of the large value of cathode resistance. The strong positive signal from the multivibrator on the grid of this tube then produces a large negative signal on the plate.

V–204 is a power amplifier whose purpose is to produce a large positive pulse to operate the key tube, which is located in the transmitter, Power supplies in this unit are conventional and need no description. A test voltmeter may be switched into the various power supply outputs. Correct voltages are indicated when meter reads half scale (0.4 to 0.6 ma.).

9.703 The Transmitter

The push-pull oscillator is conventional in most respects. It differs mostly in the way it is modulated. Because of the high cathode resistor, the oscillator will not operate during periods of no signal. Between signals, the key tube is biased beyond cut-off, but when the large positive signal arrives from the modulator, the key tube conducts strongly. This is the same as reducing the bias on the oscillator cathode and the transmitter starts to oscillate, continuing as long as the key tube is conducting. The condenser connected between the plate coil center tap and the cathodes of the oscillator is charged from the power supply during the time the oscillator is not in operation. These condensers furnish most of the energy for the oscillator during the time of the pulse from the modulator. The discharge path is through the oscillator tubes; very little returns through the oscillator cathode ground path and power supply.

During the time the oscillator is operating, the 4-mf condenser in the cathode circuit of the oscillator is discharging through the key tube. However, the time constant of this circuit is long as compared with the length of the signal pulse; thus, the charge across the condenser is not greatly reduced. At the beginning of the pulse, the key tube draws current through L–105, thus causing a voltage drop across L–105 and reducing the bias on the oscillator to operating value. At the end of the pulse, when the key tube is again cut off, the current suddenly stops flowing through L–105 and, for this reason, a large positive voltage is developed across this coil. As it is the same as a large bias on the oscillator circuit, this causes a positive quenching of the oscillator. The 20K resistor across L–101 damps out the oscillations that develop across this inductance. The condensers across the plate coil of the oscillator serve to tune this circuit and act as an impedance divider to aid in matching the low impedance antenna circuit to the higher impedance of the transmitter tubes. Additional impedance transformation is made possible by transformer T–101.

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THEORY OF OPERATION OF GROUND-STATION EQUIPMENT

10.100 GENERAL DESCRIPTION

There are two principal functions of the ground-station instrument: (1) to receive a radio-frequency pulse from a ship station; and (2) to transmit the signal back to the ship at a definite time delay after reception of the ship signal.

To accomplish the above two functions, four pieces of equipment are required: (1) the controller-indicator; (2) the receiver; (3) the synchronizer; and (4) the transmitter and antenna. Their combined functions are briefly described.

The timing of the ground-station system is controlled by a 100-kilocycle crystal oscillator located in the controller-indicator. Signals from this crystal oscillator pass into a chain of step-charger divider circuits. The output of this chain produces pulses which are used to start gating circuits needed to give the proper delays and to produce the transmitter trigger, sweep triggers, and synchronizer trigger.

Pulses from the step-charger divider chain, which key the *A* delay multivibrator, are 180 degrees out of phase from the pulses keying the *B* delay multivibrator and are 12,000 microseconds apart in time. A complete time cycle in the ground station is 24,000 microseconds, which represents a repetition rate of 41.66 cycles per second.

Pulses from the *A* delay multivibrator are mixed with the 50-microsecond pulses coming from the output of the first divider circuit. These mixed pulses go to a pulse-selector circuit, which selects one pulse of the 50-microsecond group every 24,000 microseconds. This pulse is precise in its timing and is used (1) to key the circuit of the fast-sweep for the cathode-ray tube, on which will be presented the video signals from the ship station and is called the remote-signal sweep; and (2) to start the chain of events in the synchronizer, which produces a movable time delay that allows the operator to match the leading edges of the remote-signal pulse to the local-signal pulse on the cathode-ray tube.

From the synchronizer also comes a DC error voltage that actuates an automatic frequency-control tube which keeps the 100-kilocycle basic-timing crystal in exact synchronism with the ship-station crystal.

The pulses from *B* delay multivibrator go to mixing and pulse-selecting circuits in the same manner as the *A* delay multivibrator. Pulses from *B* pulse selector are used to key two channels: (1) the fast-sweep circuits of the cathode-ray tube, on which will be presented the video signals from the ground station's own transmitter; and (2) the transmitter trigger circuit, whose output keys the pulse-shaping circuits in the transmitter modulator.

The video signals on the ground-station scope will stand vertical, the sweep being horizontal. Since the ground station, or local signal, is much stronger than the ship signal, it is highly attenuated in the electronic attenuator before going on to the re-

ceiver. The ship-station signal will differ slightly in appearance, but the leading (left-hand) edges will be essentially the same as the ground-station signal.

10.200 CONTROLLER-INDICATOR

A complete block diagram, Figure 29, shows the electrical location of the controller-indicator, receiver, synchronizer, and electronic attenuator of the various circuits, and how they are interconnected. Note that the tubes used in the different circuits are also indicated within the blocks. The time relation between the different circuits is shown in Figure 28.

Refer to schematic diagram, Figure 80, for ease in understanding the operation of various circuits.

10.201 100-kilocycle Oscillator (V–101) and Automatic Frequency Control (V–136)

An accurately ground V-cut quartz crystal, Y–101, oscillating at 100,000 cycles per second is used to control the frequency. A pentode tube, connected as a triode, is in a tuned-plate circuit. While this circuit will operate without the crystal as a tuned-grid, tuned-plate, oscillator, the Q of the grid circuit is low; thus, the frequency control is assumed by the crystal when it is inserted into the circuit.

Plate current is supplied to tube V–101 through R–102. The condenser C–110C acts as the decoupling between the B-plus supply and the plate oscillator circuit.

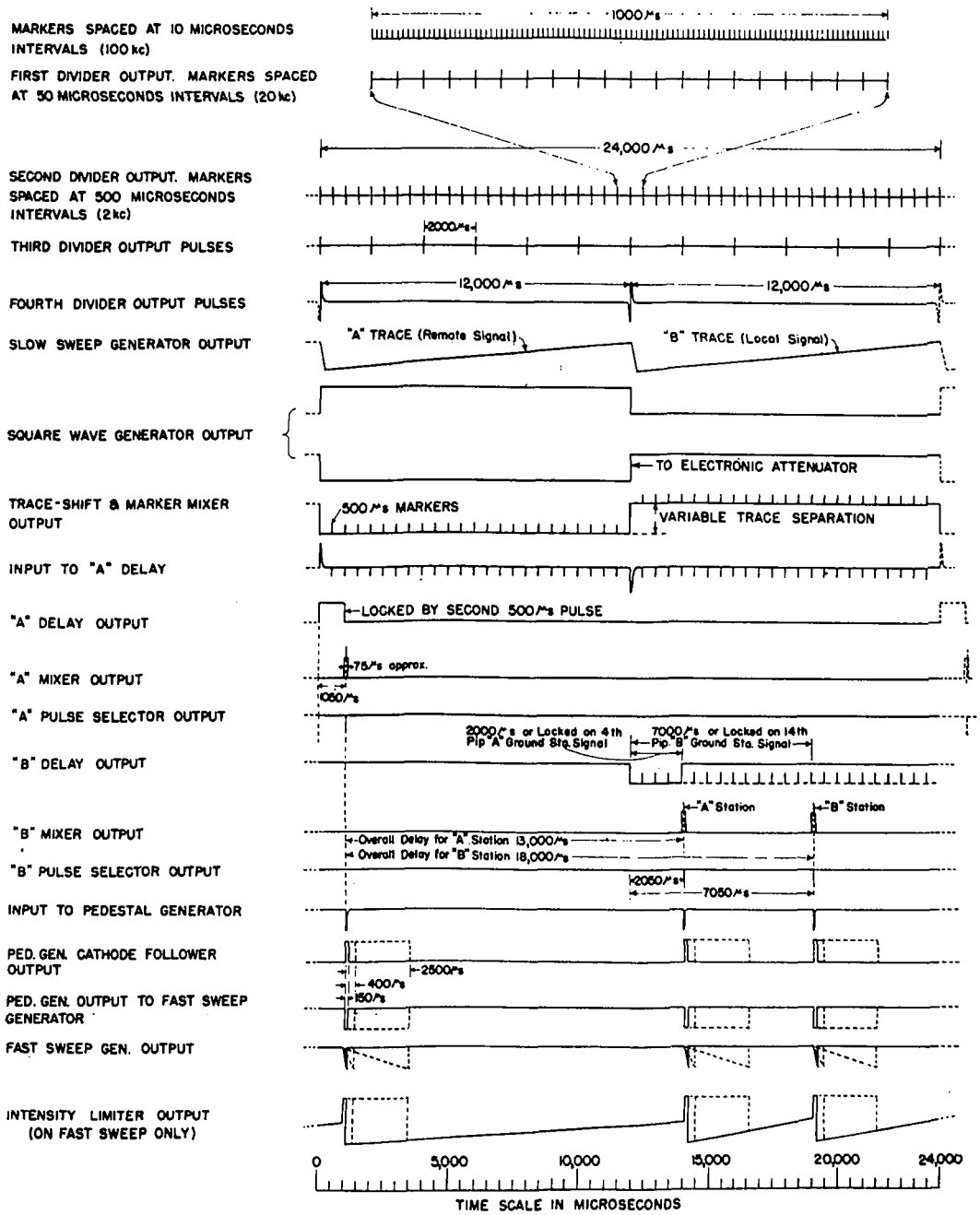
If the primary of the transformer T–101 is wrongly tuned so that the resonant frequency of the plate circuit is close to 100 kilocycles, the oscillator circuit will oscillate close to the standard frequency even through the crystal is in the circuit.

The fine-frequency control C–104 will shift the 100 kilocycles-per-second oscillations over a very small range. L–101 is a slug-tuned inductance and will vary the frequency over a large range in comparison with the precise standard crystal in the ship unit. The ease in holding this frequency precisely in synchronism with the ship-station crystal is greatly aided by the use of an automatic synchronizer.

The automatic frequency control tube (V–136) is located near the 100-kilocycle oscillator and is operated from the synchronizer error signal. A negative *in-sync* voltage of about 4.5 volts is fed into the grid of V–136 from the synchronizer, with the cathode bias set correctly by front-panel-control AFC cathode bias (R–138). A small amount of current will flow in the tube, producing a certain resistance in series with the capacitor C–222. This series combination is connected in parallel with the crystal resonant circuit. If the negative grid bias from the synchronizer becomes more negative in value, the plate current of V–136 becomes less, the plate resistance becomes more, thus shifting the phase angle by reason of the impedance formed by C–222 and V–136 plate resistance. This action changes, in effect, the basic frequency by a slight amount. The AFC error voltage will always be in such a direction as to correct the oscillator frequency to that of the ship station. The way this error voltage is produced is described in the section on the synchronizer.

10.202 Squaring Amplifier (V–102)

A 100-kilocycle sine wave is fed from V–101 to the grid of the high-gain pentode V–102. Because of the wide range of grid-voltage swing (approximately 125 volts), the operating point of the amplifier tube shifts abruptly between saturation and cut-off at each half-cycle of the oscillator, thus producing a square wave in the plate circuit. The inductance L–102 helps to steepen the wavefront of the output wave.



WAVE FORMS OF INDICATOR CIRCUITS, SHOWING TIME RELATIONSHIP. WAVE FORMS ARE FOR BASIC PULSE REPITION RATE OF 41 2/3 CYCLES PER SECOND. THE COLUMNS WHICH INDICATE BOTH "A" & "B" GROUND STATIONS ARE FOR OPERATION OF THE EQUIPMENT AS EITHER "A" OR "B" BUT NOT BOTH AT THE SAME TIME.

FIGURE 28.—Ground station time diagram.

10.203 Step Charger Divider Circuits

DIVIDER NO. 1

This divider is essentially a combined blocking oscillator and voltage-storage tripping circuit. Tube V–104A is held cut-off by bias developed by the cathode-to-ground potential taken off potentiometer R–109. This potentiometer is part of a voltage divider circuit made up of resistors R–108 and R–110 and the cathode bypass capacitor C–114A. The grid-to-cathode DC bias voltage is the difference between the voltage across the capacitor C–112 in the grid circuit and the voltage across C–114A connected between the cathode and ground. When there is no charge on C–112, the grid bias is set by the cathode potential and the plate current in the tube will be cut off.

Negative and positive pulses pass through C–111 from the squaring amplifier. The negative pulses are grounded through the diode V–103, but the positive pulses are passed by diode V–103 and stored in C–112. As the positive pulses cannot discharge through the diode, the potential of C–112 and the grid of V–104A are raised one step for each positive pulse. The amount of this voltage is dependent on the values of C–111 and C–112 and the value of input voltage. Counting from a time when there was no charge on the capacitor C–112, the fifth pulse will decrease the grid bias to a point where plate current begins to flow in the triode section of V–104A.

This rise in plate current induces a voltage across the grid winding of transformer T–102. The transformer windings are very closely coupled and are connected in such a way that a rise in plate current drives the grid more positive, producing a further rise in plate current; thus, the tube is saturated in a very short time. This action is accompanied by a surge of grid current which discharges storage capacitor C–112. At this point, the plate current ceases to increase and the voltage across the grid winding of T–102 drops sharply. As the grid voltage drops, the plate current falls off.

The voltage induced across the grid winding of the coupling transformer is reversed from the former condition of rising plate current, and the grid bias is carried sharply negative past cut-off. The negative charge placed on C–112 is quickly reduced to zero by the conductivity of diode V–103 and the counting cycle begins again.

C–111 is discharged between each charging of C–112 through the pins 3 and 4 portion of V–103, so there will be no net charge left on C–111 between cycles.

When plate current starts flowing in tube V–104A, a large signal is induced at the plate by reason of the plate winding of T–102. This is a condition similar to ringing and R–107 produces slightly less than critical damping, resulting in only one cycle.

The output pulses from triode V–104A drive divider No. 2 circuit and also provide the 50-microsecond markers seen on the oscilloscope screen. They also go into mixer circuits, a description of which is given in another section.

The varying of the setting of potentiometer R–109 (screwdriver adjustment *A*) adjusts the bias on triode section V–104A and thus fixes the critical point at which the voltage on the storage capacitor C–112 overcomes the bias fixed by the potentiometer; this allows plate current to flow. In this way, the division of the divider is controlled and is set at a division of 5.

DIVIDER NO. 2

The operation is essentially the same as for divider No. 1. Potentiometer R–113 (screwdriver adjustment *B*) is adjusted until a division of 10 to 1 is seen on the oscilloscope. The output from V–106A is fed to divider No. 3 through C–123 and also goes

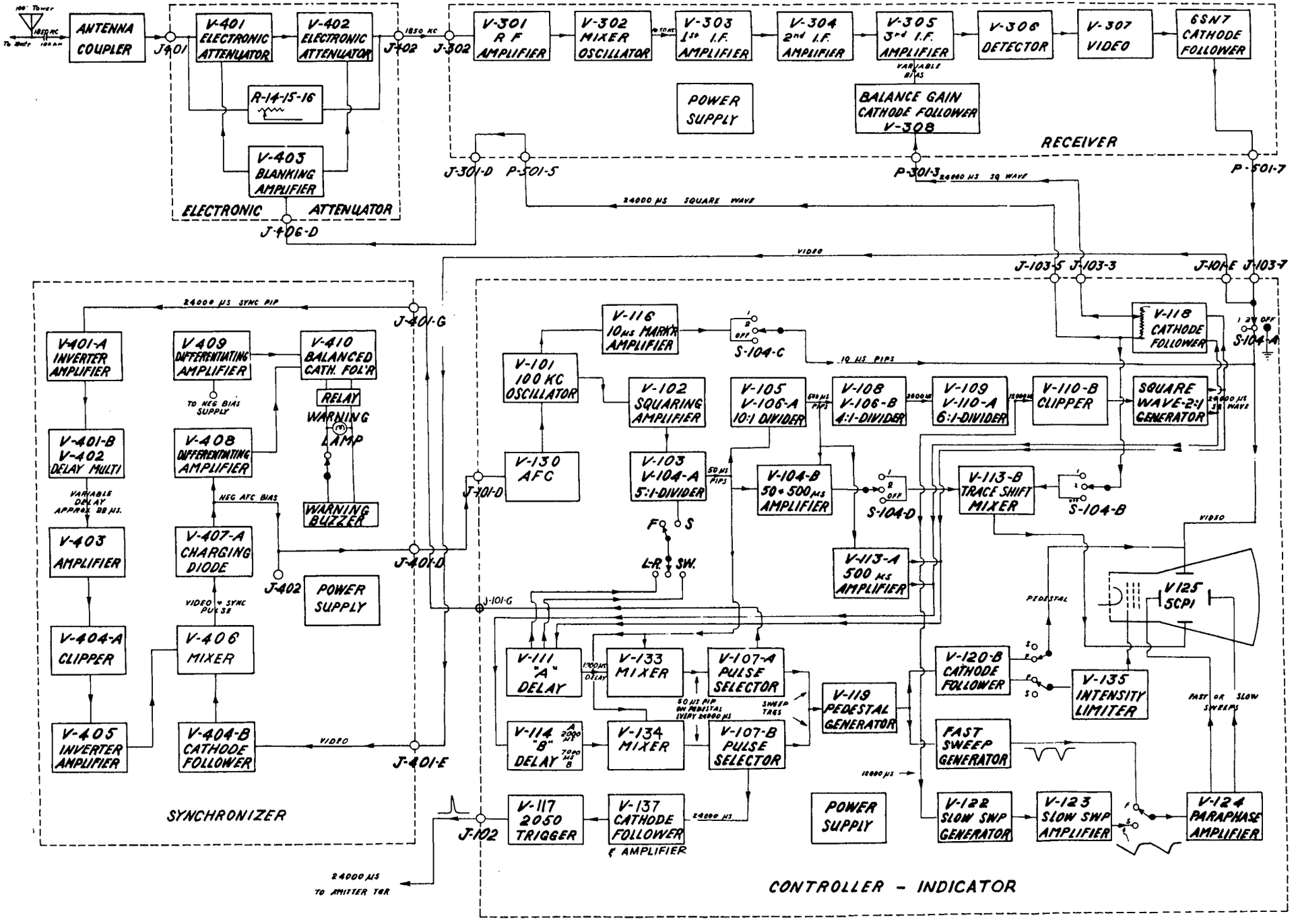


FIGURE 29.—Ground station block diagram.

to a 500-microsecond amplifier V–113A for *A* and *B* delay locking. It also feeds V–104 marker mixer amplifier for monitoring this circuit on the oscilloscope and indicates the proper delay settings.

DIVIDER NO. 3

The operation is essentially the same as for divider No. 1. This output feeds divider No. 4 through C–128. The division is controlled by R–119 (screw-driver adjustment *C*), and is set at a division of 4 to 1. This is adjusted by making every fortieth 500-microsecond pulse as short as possible as viewed on the oscilloscope test pattern.

DIVIDER NO. 4

This circuit is essentially the same as that of the other dividers. Division count is controlled by adjustment of R–122 (screw-driver adjustment *D*) and is set at a division of 6 to 1. This is adjusted by making a total of six short 500-microsecond pulses as viewed on the oscilloscope test pattern. The pulses from this circuit feed a clipper tube V–110B that controls the operation of a square-wave generator. Pulses also go to a slow-sweep generator V–122, which produces sweep voltages on the oscilloscope for viewing the entire time sequence.

10.204 Slow-sweep Generator and Amplifier (V–122 and V–123)

V–122 is a conventional gas triode (thyratron) sweep generator. The grid is driven positive by pulses from divider No. 4 and the tube rapidly discharges C–211. This condenser slowly charges in a sawtooth manner through R–264. Amplifier V–123 is a conventional biased amplifier, used to amplify a positive sawtooth voltage.

10.205 Square-wave Generator (V–110B, V–115A, and V–115B)

Only negative pulses are passed by V–110B, which is connected as a diode. The Eccles-Jordan multivibrator (V–115A and V–115B) uses direct coupling between the grids and plates of the two triodes V–115A and V–115B. Circuit equilibrium exists at two points, which may be either tube section conducting heavily while the other is near cut-off. Either a positive or a negative pulse applied to the grids of the tubes may be used to switch conduction from one tube section to the other. Due to the absence of capacity to ground from either plate circuit, the output from either plate is a square wave.

The output of the square-wave generator is applied to triode sections V–118A and V–118B, which are applied to the vertical plates of the oscilloscope to appear on the screen as two horizontal traces one above the other. Both triode sections of V–118 are used for amplitude balance control.

The output of the square-wave generator also trips the *A* and *B* delay circuits. These circuits require sharp tripping pulses and, to obtain this result, the square wave is differentiated.

10.206 Amplitude Balance Circuit (V–118)

This circuit is used to provide different amounts of receiver gain during *A* and *B* traces so that the two signals from a remote station (A) and from the ground station's own transmitter (B) can be made the same size on the screen for correct leading edge match. A square-wave signal is fed from pin 3 of V–118 through pin 5 of J–103 to the electronic attenuator for local-signal blanking.

10.207 *A* and *B* Delay Circuits (V–111 and V–114)

These circuits are essentially the same in operation except for their delay time adjustment. The *A* delay is adjusted for a 1000-microsecond delay. The *B* delay is set at a 2000-microsecond delay for an *A* ground station and at a 7000-microsecond delay for a *B* ground station.

These circuits are monostable multivibrators and are turned *on* by a positive differentiated pulse from the square-wave generator. The two halves of the square-wave generator are 180 degrees out of phase with respect to each other. Since the *A* and *B* delay multivibrators are turned *on* by opposite sides of the square-wave generator, they too are started half the square-wave cycle apart, or 12,000 microseconds apart.

Negative pulses 500 microseconds apart are fed into the same grid circuits. These pulses turn *off* the multivibrator, which was started by the square-wave generator, at a precise time and always precisely at a 500-microsecond interval. The desired 500 microseconds are selected by bias control R–129 (screw-driver adjustment *R*) in the case of *A* delay; and R–172 (screw-driver adjustment STATION DELAY on front panel) in the case of *B* delay. The *A* delay is sometimes called the remote-signal delay and the *B* delay, the local-signal delay.

10.208 *A* Delay Mixer (V–133) and *A* Pulse Selector (V–107, 1st Section)

In its steady state, the double triode V–133 has both sections conducting current heavily through a common plate-load resistor. On the grid (pin 1) of the first section, 50-microsecond negative pulses are impressed. These pulses drive the grid down through cut-off for the duration of the pulse and, therefore, produce similar positive pulses on its plate. Since the second half of the tube is strongly conducting, the plate voltage does not rise to a very high value. On the second triode grid, a negative differentiated pulse from the *A* delay multivibrator appears and cuts off the plate current. This makes a positive pedestal appear on the plate and should be about 75 microseconds in duration. The length of this pulse is established by the 0.001 mf. condenser and the 200–K resistor connected to the grid circuit (pin 4), and the amplitude of the signal as applied to this circuit.

When both halves of the triode are cut off, 50-microsecond pulses occur in the plate circuit at the same time that the pedestal is generated, and the 50-microsecond pip appears in the plate circuit on top of the pedestal. The pulses go to a pulse-selector grid (V–107, 1st section) which is biased in the cathode to a value slightly exceeding the sum of the tube cut-off and the pedestal amplitude. Therefore, the only pulse that exceeds this value is the 50-microsecond pulse on top of the *A* delay pedestal, and the tube starts to conduct, producing a negative pulse in its plate circuit. As long as the 50-microsecond pulse remains on the pedestal, all timing in circuits controlled by this pulse will have the high precision of this pulse. Changes in divider chains or delay circuits will not alter timing. This pulse is used to key a fast-sweep sawtooth voltage on which will be seen the ship or remote-station signal.

10.209 *B* Delay Mixer (V–134) and *B* Pulse Selector (V–107, 2d Section)

These circuits work precisely the same as the *A* delay mixer and pulse selector. Their output is used to key a fast-sweep circuit on which is viewed the local transmitted video signal. This output is also used to key the radio-frequency transmitter through the circuits of V–137 and V–117.

10.210 Transmitter Trigger Generator (V–137 and V–117)

Negative pulses from pulse selector V–107 plate (pin 5) are amplified by the first section of V–137, and the positive output pulses go through the cathode follower in the second section of V–137. These positive pulses actuate the grid of V–117 (thyratron) to overcome the fixed negative bias voltage making the tube draw plate current. This tube draws a very heavy plate current and gets most of its current from the 0.005 mf. coupling condenser connecting to terminal 1 of the transformer T-107. This makes a heavy current flow in the primary winding of the trigger transformer. The secondary is phased so a positive pulse is supplied to the transmitter modulator where pulse-forming circuits key the transmitted radio-frequency pulse.

10.211 Pedestal Generator and Fast-sweep Circuits (V–119, V–120, and V–121)

The pedestal generator is a monostable multivibrator and is started by pulses from the pulse selectors. It produces a square-topped wave for each *A* and *B* pulse. These pulses are impressed upon the vertical deflecting plates of the cathode-ray tube and are seen as two pedestals, one on each slow trace. Three values of pedestal length may be had by setting the fast-sweep switch.

The output of the pedestal generator gates the fast-sweep generator. This circuit generates a sawtooth voltage wave whose amplitude varies almost linearly with the length of the pedestal. The output of the fast-sweep generator is applied to the horizontal deflecting plates of the oscilloscope through the paraphase amplifier, to sweep only during the time controlled by the setting of the pedestal generator.

10.212 Paraphase Amplifier (V–124)

The paraphase amplifier is a phase-splitting device that converts the sawtooth waves from either the fast- or slow-sweep circuits into symmetrical push-pull sawtooth waves, which are then applied to the horizontal plates of the oscilloscope. The use of a push-pull phase-splitting amplifier of this sort obviates the use of high voltage supplying the plate voltage of an amplifier.

10.213 Left-Right Circuit

The left–right switch is used to shift the received pulses to the desired position on the traces. This switch has three positions, with spring return to the center neutral position.

The left-right circuit has two portions. When the sweep-speed switch is at the fast position, only that portion of the circuit which is connected to the standard frequency generator through switch S–105A is used. On the slow sweep, an additional connection is made between the *A* delay circuit and divider No. 1 through switches S–105B and S–101F. In this manner, a small frequency change is provided on the fast sweeps and a greater frequency change is provided on the slow sweeps so that the pulses may be moved at a convenient speed during either slow or fast sweeps.

10.214 10-microsecond Marker Circuit (V–116A and V–116B)

The purpose of this circuit is to place markers at intervals of every 10 microseconds on the oscilloscope traces. The markers are clearly seen on the two faster sweeps only, since the time base is compressed on the slower sweeps.

10.215 Marker Mixer and Trace-shift Mixer Circuits (V–104B and V–113B)

The purpose of the marker mixer (V–104B) is to mix the pulses from dividers Nos. 2 and 3 at intervals of 50 and 500 microseconds, and to supply them to a vertical deflection plate of the oscilloscope.

Triode section V–113B is a cathode follower which passes a square wave from the square-wave generator supplied by pin 3 of V–118.

These pulses are combined in the cathode circuits and are fed to a vertical deflection plate of the oscilloscope.

10.216 500-microsecond Amplifier (V–113A)

The 500-microsecond amplifier circuit is used to amplify pulses from divider No. 2, clipping the positive portion of the wave form and using the negative portion of the wave form to lock the *A* and *B* delay multivibrators.

10.217 Oscilloscope (V–125)

The 5-inch cathode-ray oscilloscope tube (V–125) is a type 5CP1, with a green fluorescent screen of medium intensity. The cathode grid and anodes Nos. 1 and 2 constitute the *electron gun.* This gun section controls a beam of electrons, which, after passing between the vertical and horizontal deflection plates and the accelerator ring, strike the screen.

The pattern viewed on the oscilloscope screen is the result of the movement of the electron beam. The intensity and focusing of the electron stream are dependent on the voltages impressed upon the grid (pin 3), upon the anodes Nos. 1 and 2 (pins 5 and 9), and upon the average voltage on the deflecting plates. All the voltages are in reference to the cathode (pin 2). The vertical position of the electron beam on the screen depends on the voltage between the vertical deflecting plates (pins 10 and 11). The horizontal position of the beam is dependent upon the voltage between the horizontal deflecting plates (pins 7 and 8).

10.218 Intensity-limiting Diode (V–135)

When the fast sweeps are used, this circuit supplies a blanking pulse to the grid of the oscilloscope so that the beam is cut off except when the forward sweep is actually taking place. Because of the relatively long inter-pedestal period between horizontal sweeps, an intensely brilliant spot would appear at the left-hand end of each trace upon the screen unless the intensity of the beam is diminished during the retrace and the stationary periods between horizontal sweeps.

10.219 Power Supply

One transformer supplies all the AC voltages necessary for operation of the controller-indicator. The voltage (rms) and current ratings of the several windings follow:

1100—at 5 milliamperes for the high-voltage rectifiers
750—at 100 milliamperes (center-tapped) for the low-voltage rectifiers
2. 5—at 2 amperes for tube V–126 filament
2. 5—at 2 amperes for tube V–127 filament
5. 0—at 3 amperes for tube V–128 filament
2. 5—at 5 amperes for the voltage regulator tubes V–129 and V–130

6. 3—at .8 ampere for the oscilloscope tube (V–125) and the intensity limiter (V–135) heaters

6. 3—at 6 amperes for half the controller-indicator tube heaters

6. 3—at 6 amperes to the other half of controller-indicator tube heaters

The high-voltage rectifiers operate from the 1100-volt winding of the power transformer. Positive half-cycles from the windings are rectified by tube V–126 and filtered by resistor R–217 and capacitor C–175. The protective-bleeder resistors R–218A, B, C, and D discharge capacitor C–175 when the indicator is turned off. The positive high voltage is applied only to the intensifier anode of the oscilloscope. Since the current is low, the DC voltage is about 1500 volts—nearly equal to the peak voltage of the AC input to the rectifier.

Negative half-waves from the same 1100-volt winding used for supplying the positive half-waves, are rectified by tube V–127 and filtered by resistors R–219 and R–220 and by capacitors C–176 and C–177.

A two-stage filter is used because of the greater current drain in this circuit. This is the main high-voltage supply for the oscilloscope. Resistors R–233, R–234, and R–235 are used as a voltage divider and as bleeder resistors. The DC-output voltage is about 1280-volts.

The low-voltage plate supply winding of T106 furnishes an AC voltage to the full-wave rectifier tube V–128, resulting in a DC voltage to ground of about 480 volts (at normal load) at the filament of this tube. The circuit is filtered through the choke coil L–103 and capacitors C–178 and C–179. Bleeder resistor R–221 is connected between the supply and ground.

A stabilized and regulated B-plus voltage is applied to the various circuits in the controller-indicator, except to the plates of tubes V–122 and V–124, where an unregulated and somewhat higher B-plus voltage is supplied. The two triodes V–129 and V–130 (connected in parallel) are in series with the regulated B-plus load. This is taken off the center tap of resistor R–280. Tube V–131 acts as the grid voltage control for the triodes V–129 and V–130, which are in effect a variable resistor in series with the B-plus load. The combined plate-to-cathode drop in these tubes is about 140 volts at normal current flow so that a voltage of 265 volts is available on the regulated B-plus. This is the voltage across resistor R–230 and the potentiometer R–231. The arm of the potentiometer is set so that about 105 volts appear on the grid (pin 4) of tube V–131. The screen and cathode voltages of V–131 are established by the voltage divider made up of resistors R–229 and R–227 and the glow discharge regulator tube V–132.

The voltage across the terminals of the tube V–132 will maintain a constant drop of about 105 volts provided the current through the tube is between 5 and 30 milliamperes. Since about 10 milliamperes are provided, the tube is within its operating limits. The plate (pin 8) of tube V–131 is connected to the grids of tubes V–129 and V–130 through the balancing resistors R–225 and R–226. The unregulated B-plus voltage is also connected to the plate of tube V–131 through the decoupling and plate resistors R–222, R–224, R–223, and the condenser C–180A. The setting of potentiometer R–231 (screwdriver adjustment P) controls the bias upon the grid (pin 4) of the tube V–131 and is so set that 265 volts is obtained on the regulated B-plus on an AC supply of 105 to 130 volts.

10.300 SYNCHRONIZER

The purpose of the synchronizer is to keep the ground-station crystal oscillator at the same frequency as the ship oscillator. To accomplish this, a pulse gate controlled from the ground-station crystal is mixed with the leading edge of the wavefront of the ship-station pulse (at the output of the receiver). The resulting combined pulse at the output of a mixer is rectified and the resulting DC voltage stored in a condenser. This voltage is the control-error voltage of automatic-frequency-control (AFC) circuit which corrects the crystal-oscillator frequency. Should a frequency or phase change occur between the ship and ground-station crystals, the gate moves with respect to the ship pulse, so that the mixing takes place on a different portion of the wavefront. This produces a change in the output of the mixer, which means a different value of error voltage. The direction of this voltage change is such as to make the AFC correct the ground-station oscillator frequency. Since the error voltage can be either plus or minus with respect to the normal, or no-error voltage, the AFC can correct for a plus or minus change in relative frequency of the two oscillators.

The first six tubes in the synchronizer are used to give the proper delay and to produce the proper shape of the gate pulse, which is mixed with the ship video pulse. The trigger that starts this operation also starts the sweep on which will appear the ship signal. This trigger starts at the moment that the ship signal arrives at the input of the receiver, but there is a lag through the receiver of 20 to 30 microseconds. If the gate pulse, which is started by the sweep trigger, is to mix with the ship pulse, it too must be delayed by an amount equal to the ship pulse delay through the receiver.

To detail the operation, the negative sweep-trigger pulse from plate (pin 2) of V–107 in the indicator is amplified and inverted by V–401A in the synchronizer. Tubes V–401B and V–402A form the delay multivibrator, the length of the delay being controlled by the setting of the coarse and fine delay controls on the front panel. V–402B is a clamping tube used to stabilize the operation of the multivibrator. A positive pulse appears at the plate (pin 2) of V–402A. The length of this pulse is the delay of the gate pulse. C–402 and R–413 form a peaking circuit, which gives a short negative pulse corresponding to the lagging negative edge of the delay pulse.

The reason that only the negative pulse is seen at the grid pin 5 of V–403 is that the grid of this tube is conducting and acts as a clipper for any signals which tend to go positive. When the negative signal drives V–403 beyond cut-off, the grid potential is a large negative value which starts back towards zero because of the charging of C–402 through R–413. This combination sets the gate width and may be adjusted by means of C–402. It is usually set, and remains, at 15 to 20 microseconds. Since this tube is cut off during the negative excursion of the grid, a positive pulse appears in the plate circuit. Tube V–404B is the video cathode follower (positive ship video signal). Tube V–405 is an inverter amplifier. Tube V–406 is the mixer tube. The negative gate is supplied to the cathode and the positive video signal to the grid. The actual bias between grid and cathode depends upon the sum of the two signals. When one is absent, there is very little signal on the plate of V–406. The correct error-voltage output is when the gate pulse is between the start of the video rising edge and half to three quarters up the leading edge of this pulse. The output of V–406 charges C–414 through V–407A. The DC voltage (error voltage) on C–414 is used for two purposes: (1) for operation of the automatic frequency control; and (2) to actuate the sync-meter circuit and the sync-alarm circuit.

Tubes V–408 and V–409 operate as a differential amplifier. The grid of V–409 is held at a small fixed negative bias, while the negative voltage on C–414 is applied to the grid of V–408. When the ground station is in sync, equal voltages appear at the grids of the differential amplifier tubes; hence, the plate potentials are equal and the sync meter which is connected between the two plates is at the center of the scale (zero center meter). When change in error voltage occurs, V–408 draws more or less current; and since V–408 and V–409 are connected through their cathodes, the current through V–409 changes in an opposite sense. There will now be a large potential difference between the plates of these tubes, and the sync meter will deflect to show an out-of-sync condition. This same potential difference is direct-coupled to the grids of the two cathode followers, in the cathode of which is the alarm-circuit relay. This too is a differential system and when V–408 and V–409 are out of balance, V–410 will also be out of balance. The relay will close and set off the alarm light, or buzzer, thus showing that the system is out of synchronism. On synchronizers beginning with serial No. 10, the alarm light and buzzer circuit have been eliminated.

10.400 Receiver

The ground-station receiver is the same as the ship receiver in all but two details. For the theory of operation of this unit, refer to paragraph **9.400.** The ground-station receiver employs a video cathode follower, whereas the ship station does not. Because of the large size of the local signal on the ship, it was found that a larger range of gain could be had by introducing the balance-gain signal on the radio-frequency tube (V–301). Since the local signal is less at the ground station, the original design of balance gain on the last IF stage (V–305) is used.

10.500 ELECTRONIC ATTENUATOR

Since the ground- and ship-station electronic attenuators are the same in all details, it will not be described here. See paragraph **9.500** for theory of operation of this unit.

10.600 TRANSMITTER AND RECEIVER ANTENNA-COUPLERS

The purpose of the transmitter coupler is to match the 50-ohm coaxial transmission line to the 30-ohm antenna (100-foot tower). An L-type coupler circuit is employed, using capacitive shunt reactance and inductive series reactance, the inductance being on the load side of the capacitance. For the sake of a fast-rising transmitted pulse, the smallest condenser that would still meet coupling requirements was used. Looking into the coaxial transmission line from the transmitter, the reactance remains zero for 50 kilocycles each side of 1850 kilocycles, while the resistance changes from 36 to 58 ohms over this range. A 0-to-1.5-ampere radio-frequency meter indicates antenna current. The coupler circuit is housed in a waterproof aluminum housing which is located, along with the receiver-coupler, at the base of the antenna. See Figure 18 for mounting of these units.

The receiver-coupler connections to the antenna are at the same point as the transmitter-coupler. While this coupler should be as efficient as possible in transferring the signal from the antenna to the receiver transmission line, it should not absorb excessive power from the antenna during the transmission period. In order to keep this coupler simple, a compromise design was arrived at which suitably met the above requirements. The circuit consists of a parallel-tuned circuit, heavily damped for

broadbanding by a 5K resistor. Coaxial transmission is coupled to this circuit by a three-turn link on the ground end of the parallel-tuned circuit. A 100-mmf condenser couples the parallel-tuned circuit to the antenna. There is about 8 db of ship signal lost by the compromise coupling.

10.700 ANTENNA AND GROUND SYSTEM

The ground-station antenna is a vertical nearly quarter-wave (100 feet) radiating tower. It is base-insulated and braced by four sets of insulated guys (four guys per set). This tower antenna is elevated or lowered by means of a 30-foot gin pole, the tower base being first attached to a hinged portion before being elevated or lowered. The antenna is erected at the center of a radial ground system that extends 200 feet from the tower. Since the current distribution in the ground is greatest near the base of the antenna, the radial type ground system is well suited to reduce the ground-system losses.

An insulated 100-foot telescoping hydraulic-operated tower is under consideration for use as the radiator. A special instruction book will be supplied if this tower proves suitable.

In any pulse system where the accuracy depends, in part, on the steepness of the pulse wavefront, special attention must be paid to reduce storage factor in all reactive elements. In other words, the Q of circuits must be kept small; this is in an effort to produce the desired band width which is necessary to fast-rising pulse fronts. The same is true of the antenna system, since it is a reactive system. The Q of the antenna system can be reduced by using an antenna of large diameter. The triangular aluminum tower—12 inches on each face of the triangle and of uniform cross section for its entire length—gives quite suitable band-width characteristics. Since the antenna is almost a quarter-wave long, there is little reactance at the base of the antenna (where the transmitter connects). From the table listed below, it can be seen that antenna resistance of 30 ohms is nearly constant for a band width of 100 kilocycles, the operating frequency being 1850 kilocycles. The reactance variation can also be seen to be small. It is to be noted that the quarter-wave point is not at the design frequency but a little lower; this, however, does not detract from the usefulness of this antenna since the important characteristic is that the reactance remains nearly constant over the band of about 100 kilocycles.

Ground-station Antenna Impedance Characteristics
Measured at the base of the Antenna
100-foot Triangular Tower

(Transmitter disconnected: measured with a General Radio 916–A, R. F. bridge)

Frequency Kc	Resistance ohms	Reactance ohms
1750	27	—j100
1800	29	—j50
1850	31	0
1900	35	+j4
2000	42	+j50

Because of the low base impedance, the voltage at the base of the antenna is quite low even at 10 kilowatts radiated. This means that small insulators may be used at the base of the tower.

The ground system and station layout can be seen by referring to Figure 16. The principal reason for the ground system is to reduce the radiating-system losses caused by the large currents flowing in the earth near the base of the antenna. Another purpose of this system is to keep the radiation at a low angle, which is desirable as the EPI system uses only the ground wave. Sky-wave radiation would be wasted energy in this system. By using a radial system, the resistance is less near the antenna base where the current density is greatest. While there is current flowing in the earth a considerable distance from the base of the antenna, there is little gained in making radial lengths over one-half wave. Since the currents in the vicinity of the antenna penetrate to a considerable depth, the station site should be selected in a place where the earth has good conductivity. In the design of the ground system for the EPI, attempts were made to keep the construction as simple as possible. To double the radials of the present system would result in only a ten percent improvement in field strength. Doubling the lengths of the radials would result in even less improvement in field strength.

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TROUBLE-SHOOTING AND PREOPERATIONAL MAINTENANCE OF SHIP EQUIPMENT

11.100 TROUBLE-SHOOTING

It is not the purpose of this section to give a complete outline of trouble-shooting. It is intended only to suggest how to correct trouble which can be detected on the EPI scope. Many of the difficulties will entail nothing more than the adjustment of the instrument. The apparent reasons will not be discussed as the experienced technician will consider these before referring to the Manual.

Some probable faults and the methods of correcting them follow:

a. Ship's position appears to be off by 10, 50, or 500 microseconds:
   1. Go through all steps of the zero check (paragraph **11.102**).
   2. Correct by one of the methods outlined in paragraph **11.103.**

b. Ground-station signals disappear or jump in time for certain settings of the range dial. (It is most common to have this occur for one ground station.)
   1. Phase shifters may be out of alignment check, as in **11.104.**

c. Ground-station signals on the scope but no local signals:
   1. Second Eccles-Jordan may need adjustment (see paragraph **11.107**).

d. One of the local signals may be advanced on the scope more than the other:
   1. See paragraph **11.105.**

e. No fast sweeps:
   1. Adjust first Eccles-Jordan (see paragraph **11.108**). There will be no pedestals; they should appear on the slow sweep.

f. Both ground-station signals jump from the fast sweep; or, neither ground station comes into sync:
   1. See paragraph **7.200.**

g. Both ground-station ranges appear to be off by 500 microseconds:
   1. Check to see if local transmitter trigger is on second pip, as in Figure 25C, and, if not, correct by adjusting *R* control.

h. One of the ground-station signals begins losing shape, starting at the peak of the signal:
   1. The distance to the ground station is exceeding the range of the instrument. Inform the ground station to insert more or less delay as required.

11.101 Instruments needed for Servicing

For trouble-shooting the ship equipment, the following instruments are needed:

DuMont 248, or equivalent, with synchroscope features having driven sweep ranges of 5, 25, 100, and 1000 microseconds.

RCA Voltohmyst VTVM, or equivalent, with input impedance of 10 megohms or more.

20,000 ohms-per-volt Volt-Ohm-Milliammeter, such as a Triplett Model 630 or Simpson Model 260.

11.102 Zero Check

The purpose of a zero check is to inspect all the timing circuits. If any trouble occurs in the time-locking, pulse-selecting, or mixing circuits, it will show up in a zero check. This check should always be made before surveying.

In making a zero check, the following steps should be followed:

STEP 1

Be sure all dividers and delays are properly adjusted.

STEP 2

Set both *A* and *B* phase shifters at zero.
Set SWEEP SPEED switch to SLOW.
Set FAST SWEEP switch to position 2.
Set RECVR switch to ON 1.

Wave forms as shown on time diagram Figure 25C should be seen. If outward pulses on each pedestal are as shown, the 500-microsecond lock is functioning properly.

STEP 3

Set SWEEP SPEED switch to FAST.
RECVR switch to OFF.

Wave forms here should be as shown in Figure 25B, which indicates that the 50-microsecond lock is functioning properly.

STEP 4

Set FAST SWEEP switch to position 1.

Wave forms here should be as shown in Figure 25A. The trace separation control can be turned until the two vertical traces come together for precise alignment of pips. When pips from *A* and *B* sweeps are perfectly aligned with the local-signal sweep, the phase-shifter counters should read near zero, the exact value being determined when the original corrections are set up in the equipment.

11.103 Correcting the 10-, 50-, or 500-microsecond Discrepancy

The methods outlined below are for correcting the range discrepancies as discovered by direct-range measurement or by the zero check (paragraph **11.102**). None of these tests need be made in expectation of such trouble, as a systematic zero check will disclose any tendency of this type of time jump.

Tube or circuit components may change enough to cause locking to occur at other points, resulting in an error or 10, 50, or 500 microseconds. Locking an adjacent 10-microsecond pip in divider No. 1 would give a 10-microsecond error and would probably be caused by an increase in rise time of the 1-kilocycle locking pulse from 7 to 10 microseconds or higher.

If it is impossible to change tubes V–27, V–140, V–141, and V–142 or components to make the time-locking fall in, as in the original adjustment, changes can be made in the phase-shifter adjustment (see Correction Method No. 2 below) to cause a zeroing at the proper setting of the phase-shifter counters.

The zero setting of the phase-shifter counters referred to is not always at exactly zero but usually a little lower; 998.2 microseconds is a typical example of one instru-

ment. This is the value always used for returning the counters for alignment of all pips, as shown in the time diagram given for setting the timing adjustments properly.

Special attention should be given the first and second divider adjustments *A* and *B* to insure that they are centered in their range.

CORRECTION METHOD NO. 1

If the instrument is locking 10 microseconds out, thus giving a 10-microsecond error, and cannot be made to zero properly, tube V–27 in the controller should first be changed. Tubes V–140, V–141, V–103, V–104, V–105, and V–102 in that order, should also be changed. All voltages and components associated with these circuits should be checked.

If this fails to correct the 10-microsecond error, either one of the two following correction methods will correct the discrepancy.

CORRECTION METHOD NO. 2

Both *A* and *B* phase shifters will need identical adjustments. For adjusting *A* phase shifter, use the special wrench attached to the top left side of the controller.

Set indicator controls as follows:

SWEEP SPEED switch on FAST
FAST SWEEP switch on position 1
RECVR switch on position ON 1

Loosen the clamp screw slightly on the 100-microsecond (center unit) phase shifter. Using the special phase-shifter wrench, advance or retard the stator section about one-tenth turn. This will change the zeroing for *A* phase-shifter counter in discreet steps of 10 microseconds. The adjustment should be left so that the zero check is the original value, and should be centered before locking.

The adjustment of *B* phase shifter is the same.

CORRECTION METHOD NO. 3

If the time locking is in error by 10 microseconds, the phase-shifter counters can be mechanically changed by that amount. The main phase-shifter dial screws can be loosened and the main dial twisted somewhat to make the zero line-up when the counters are at zero.

If at any time the unit persists in locking 50 microseconds out from zero and the reason cannot be determined, the time sequence can be shifted by 50 microseconds by reversing the slip-ring brush connections on both *A* and *B* 100-microsecond (center unit) phase shifters.

The time sequence can also be shifted by 500 microseconds by reversing the slip-ring brush connections on both *A* and *B* 1000-microsecond (forward unit) phase shifters.

11.104 Alignment of Phase Shifters

The phase-shifter alignment is a laboratory adjustment and should not require realignment. However, if for some reason alignment is necessary, the outlined procedure should be followed. If the phase shifters are out of alignment, it will be evidenced by the shifting or disappearance of the fast sweep signals at different points on the range dials. Observe the 1000-microsecond pips on the slow sweep and note if

they vanish for any range dial setting. Adjustment is made only on the 100- and 1000-microsecond phase shifters.

When aligning the *A* phase shifters, connect the test-scope *Y* probe to pin 8 of V–17 and sync to the negative pips coming from pin 6 of V–10B. Use the 100-microsecond-driven sweep on test scope and turn *B* phase shifters until the positive pip from *A* phase shifters are about in the middle of sweep. Turn *A* and *B* phase-shifter vernier cranks in the same direction, by the same amount, and the positive pip will remain in the middle of the sweep. Turn both phase shifters through a range of 100 microseconds. If the 100-microsecond *A* phase shifter is not tracking properly, at some point within the 100-microsecond range another pip will begin to show to the left or right of the pip being viewed and will be displaced by 10 microseconds. Very slight adjustment should be made to the *A* 100-microsecond stator until the adjacent pip does not appear when phase shifters are cranked through a 100-microsecond range.

A check of *B* 100-microsecond phase shifter can be made in the same manner. The test-scope *Y* probe is connected to pin 8 of V–18 and negative sync to pin 6 of V–9B.

The *A* and *B* 1000-microsecond phase shifters can be checked in the same manner. Test-scope driven sweep speed of 1000 microseconds is used. The main phase-shifter dials are rotated in 100-microsecond steps throughout their entire range. If 1000-microsecond phase shifters are not tracking properly, another pip will begin to show to the left or right of the pip being viewed and will be 1000 microseconds away. Adjustment is made in the same manner as with the 100-microsecond phase shifters.

11.105 *A* and *B* Blanking Video Bias Adjustments

These adjustments are infrequent. The adjustments should be made when there are noticeable differences in the starting points of the local signals on each side of the vertical sweep line.

These controls are screwdriver adjustments R–55 and R–62, and are reached by removing the bottom panel on the controller. They are located at the left rear.

All the controls should be set to a normal surveying position, with the local signal appearing on both *A* and *B* sides of the vertical sweeps. To adjust the *A* blanking video bias, turn screwdriver adjustment R–55 counterclockwise, reducing the bias on pin 6 of V–23 until the center-line sweeps begin to separate. Now turn this control clockwise until the vertical sweeps come together; then, turn the control a very small amount beyond this point. Use the same procedure on the *B* side, adjusting screwdriver control R–62. The *B* control R–62 can be adjusted so that the start of the local-signal pulse at the top on *B* side will be exactly opposite the *A* local-signal pulse.

11.106 Divider-chain Failure in Indicator

Other than tubes, the most common failure in these circuits is in the insulation breakdown of transformers T–102, T–103, T–104, and T–105. If these transformers develop a very small leakage on the grid windings to ground, or to the plate windings, the voltage on the charging condensers C–112, C–118, C–125, or C–129 will be changed, giving erratic operation of a step-charger divider.

When checking the resistance of the grid windings to ground, be sure to pull out the 6H6 and 6SN7 tubes associated with the transformer being checked.

11.107 First Eccles-Jordan Failure

If the first Eccles-Jordan multivibrator fails to operate, the fast sweeps will disappear entirely. This circuit is adjusted by screw-driver adjustment Q (R–184) on the right side of the indicator. Set the SWEEP SPEED switch to SLOW and turn the trace separation control clockwise. When operating properly, two separate traces will be seen on the indicator scope.

11.108 Indication for Second Eccles-Jordan Multivibrator Adjustment

This tube, V–25, is used only for alternately presenting the local-signal pulse on first the *A* and then the *B* side of the indicator scope.

This circuit can be adjusted by control E (R–39) on the front left side of the controller without taking off the side cover. The control is reached by using a long-shafted screw driver and inserting it in the hole just under the left end of the sloping control panel. It can easily be adjusted by viewing the local signals on the indicator scope. If the local signals are standing out from both sides of the center-line sweeps, the circuit is functioning properly. If the circuit is not in proper adjustment, the local signals will become only a blurred line about the center-line sweeps and possibly separate from the center line on one side only by about a quarter of an inch. No difference will be seen in the appearance of the remote-received signals.

11.200 PREOPERATIONAL MAINTENANCE

Before the start of each field season, take the following steps to assure that the ship instrument is in good operating condition and will give the minimum of trouble during the season:

a. Test the tubes (see paragraph **11.201**).
b. Check the power supply and filament voltage.
c. Clean the instrument thoroughly.
d. Check the *C* pulse-selector bias (see paragraph **11.202**).
e. Check the *A* and *B* pulse-selector bias (see paragraph **11.203**).

In making tests, use should be made of the zero check (see paragraph **11.101**) and the pulse test oscillator tests. (See paragraph **12.300**.)

11.201 Tube Tests

When an instrument has had considerable use during a field season, it is well to check all the tubes before putting the instrument back in service the following season. Before starting tube tests, check the B+ and adjust to correct value if necessary. A good tube checker should be on hand for these tests. Remove one tube at a time from the instrument, check it, and replace with a new tube if it shows signs of being subnormal. Check all new tubes before putting them in the instrument. When a tube is replaced, make certain that the new tube is functioning as it should. In doing this, consider the circuit in which the tube operates and what presentation you should have on the scope for normal operation of this circuit. It should be kept in mind that a new tube may require readjustment of controls associated with the circuit in which it operates.

Most of the gas-type tubes, such as 884, 2050, VR–105, and VR–150, cannot be tested with most tube checkers, so they should be replaced without checking.

The test pulse oscillator may be used while making these tests since it is a rapid method of making certain the equipment is working properly.

11.202 Checking the *C* Pulse-selector Bias on Pin 6 of V–138B in Indicator

A DuMont 248, or equivalent, scope is needed. Connect the test-scope *Y* probe to pin 5 of V–138B. Connect negative sync to pin 6 of V-9B in controller. Use 100-microsecond-driven sweep. Turn the *A* phase shifter until the negative pip coming from plate of V–138B will be on the sweep. If the bias is too low on the cathode of this tube, the pedestal coming from V-117 will begin to show. The resistor values in the cathode to ground, and cathode to B+ should be changed until the pedestal just disappears.

11.203 Checking the *A* and *B* Pulse-selector Bias on Pins 3 and 6 of V–107 in Indicator

Connect test-scope *Y* probe first to pin 2, then to pin 5 of V-107. Sync scope to pin 2 or 5 of V–115. Use continuous sweep on test scope. Set both *A* and *B* phase shifters to zero. Be sure the timing delays are set up properly in the indicator.

On pin 2 of V–107 should be seen only four 1000-microsecond *A* sweep pips. On pin 5 of V–107 should be seen only four 1000-microsecond *B* sweep pips. If the cathode bias on V–107 is not properly adjusted, the pedestals coming from *A* or *B* sweep mixers will show on its plate, pins 2 or 5. This bias should be adjusted so that the pedestals from the mixer circuits just disappear.

11.204 WWV Check

At the beginning of a season or when an instrument is first put in operation, it is desirable to check the frequency of the ship's master 100-kilocycle crystal oscillator against a primary standard such as WWV. This can easily be done by lightly coupling a lead to pin 8 of V–102 in the indicator, using a 5-mmf condenser or merely a twisted pair of insulated wires to obtain the proper coupling. This lead then connects to the antenna post of a communications receiver, along with its regular antenna. Harmonics of 100 kilocycles will be heard up to 15 megacycles.

When checking the crystal at, say, 10 megacycles and a 5-cycle beat is heard, the crystal is off frequency by 0.05 times the basic frequency of 100 kilocycles, or one part in two million.

11.300 RECEIVER ALIGNMENT

NOTE: This procedure applies equally to ship- and ground-station receiver alignment.

The receiver circuits are carefully aligned at the laboratory. Normally, the intermediate frequency circuits will require no adjustment. On account of the bandwidth of the I. F. circuit, alignment is difficult and should not be attempted without good reason. Only the radio frequency circuits may require a very slight touching up on actual signals from the EPI transmitters, when the equipment is installed or checked.

As a check on receiver performance, before the start of each field season, the overall sensitivity and bandwidth should be measured.

The receiver unit should be removed from its dust cover, placed on a table near the indicator and the interconnecting cable reconnected. Allow the receiver to warm up for about fifteen minutes before proceeding with alignment.

11.301 Test Equipment

A signal generator with a calibrated output attenuator is required. Navy model LM, General Radio and Federal type 605, or General Radio 1001-A is suitable. Modulation is not used on the signal generator when a RCA Voltohmyst or equivalent VTVM is used for indication.

A dummy antenna resistor will generally be required to make the signal generator output impedance to 50 ohms. Many signal generators have an output impedance of about 10 ohms, and if this is the case, a carbon resistor of 40 ohms should be inserted between the generator and the antenna jack of the receiver.

In addition, small fixed capacitors with values of 500-mmf., 0.01-mf., and 0.05-mf. will be required.

In using the voltmeter, it is advisable to use the 10-volt scale. Noise voltages should be added to all output readings. This is done in order that accurate readings may be obtained when sensitivity measurements are being made. The usual method is as follows: Move the BALANCE GAIN control to its central position. Connect the VTVM to the electrical junction of R-318 and C-328. This point in the circuit is called the detector load. After the signal generator is connected to the various circuits, the attenuator control is advanced until five volts putput is read on the meter. Then the signal generator attenuator is set at zero output. The remaining reading on the output meter is the noise-level voltage. Then the attenuator input is increased to five volts plus this noise-level voltage for the output voltage readings.

11.302 Checking the Overall Sensitivity

Connect a VTVM across the detector load. Connect the signal generator through the dummy antenna resistor to the antenna jack. The signal generator frequency should be set to 1850 kilocycles. A 5-microvolt signal from the generator should result in an output of five volts at the meter. This is the frequency assigned at the present time. If other frequencies come into use at a later date, the new frequencies should be used when making receiver alignment.

11.303 Checking the Overall Bandwidth

Connect a VTVM across the detector load. Connect the signal generator to the antenna jack and adjust its output to produce five volts, plus the noise voltage at the output meter. The signal generator frequency is set at 1850 kilocycles. Then increase the signal generator voltage two times and note the generator frequency above and below the channel frequency which gives the same output (5 volts) at the meter. The difference between the two frequencies gives the bandwidth at two times the input (6 db). The correct bandwidth is about 85 kilocycles.

11.304 Checking the Overall I. F. Sensitivity and Bandwidth

Connect a VTVM across the detector load. Connect the signal generator to the grid (pin 8) of V–302 through a 0.01-mf condenser. Short out the oscillator voltage during the I. F. alignment to prevent interference from the oscillator by connecting a 0.05-mf condenser between the grid (pin 5) of V–302 and ground. The generator frequency is set at 1050 kilocycles, unmodulated. Increase the generator output until five volts, plus noise level is obtained at the output meter. Then the attenuator

reading will give the I. F. sensitivity. The minimum sensitivity should be about 400 microvolts.

Increase the generator output to two times the sensitivity reading as indicated above. Adjust the generator frequency both above and below the I. F. frequency (1050 kilocycles) until the indicated output is 5 volts on the meter. Note the two frequencies corresponding to a 5-volt output. Then subtracting the lower frequency from the higher will give the bandwidth at twice the input. The correct bandwidth should be about 120 kilocycles.

CAUTION.—Do not disturb the I. F. alignment unless it is certain that there is trouble in these circuits and they are out of adjustment. First check the overall bandwidth and sensitivity of the receiver or the overall I. F. bandwidth and sensitivity by the method given above. Because of the wide bandwidth, I. F. adjustment is difficult.

11.305 Adjustment of Fourth I. F. Stage

The oscillator should be shorted out as previously mentioned. Connect the signal generator through a 0.01-mf condenser to the grid (pin 4) of V–305. The ground or common lead from the signal generator is connected as usual to the receiver chassis. Connect a 500-mmf condenser between the plate (pin 3) of V–306 and ground. Set the signal generator frequency at 1060 kilocycles. Note that this frequency is 10 kilocycles above the I. F. frequency of 1050 kilocycles.

Turn on the signal generator and adjust its output so that a suitable indication is obtained on the VTVM.

Turn the bottom (primary) screw of T–304 until maximum output is indicated on the output meter. Decrease the signal generator output and disconnect the 500-mmf condenser temporarily connected to the plate of V–306.

Turn the top (secondary) screw of T–304 until a comparatively level peak is obtained in the output when the signal generator is varied between 1010 and 1090 kilocycles.

Always decrease the output of the signal generator between adjustment in order to avoid damaging the output meter.

11.306 Adjustment of Third I. F. Stage

Connect a 500-mmf condenser between the grid (pin 4) of V–305 and ground. Set the signal generator to 1060 kilocycles as before, and connect it to the grid (pin 4) of V–304 through a 0.01-mf condenser. Turn the bottom (primary) screw of T–303 until maximum output is shown on the output meter.

Disconnect the 500-mmf condenser from the grid of V–305. Turn the top (secondary) screw of T–303 until two peaks of equal amplitude are obtained in the output, one at about 1015 kilocycles and the other at about 1085 kilocycles. If the amplitude of the two peaks differ, readjust the top screw on T–303 until the two peaks have equal amplitude.

11.307 Adjustment of Second I. F. Stage

Connect a 500-mmf condenser between the grid (pin 4) of V–304 and ground. Set the generator frequency at 1050 kilocycles (the actual I. F. frequency). Connect the signal generator through a 0.01-mf condenser to the grid (pin 4) of V–303.

Turn the bottom (primary) screw on T–302 until maximum output is obtained. Remove the 500-mmf condenser from the grid of V–304.

Turn the top (secondary) screw of T–302 until double peaks are produced in the output, one at about 1020 kilocycles and the other at about 1080 kilocycles. The two peaks should be of equal amplitude.

11.308 Adjustment of First I. F. Stage

Connect a 500-mmf condenser between the grid (pin 4) of V–303 and ground. Connect the signal generator through a 0.01-mf condenser to the grid (pin 8) of V–302. The signal generator should be tuned to 1050 kilocycles.

Turn the bottom (primary) screw of T–301 until maximum output is indicated. Remove the 500-mmf condenser from the grid of V–303. Turn the top screw of T–301 until two peaks of equal amplitude are obtained in the output. These peaks should occur at about 1025 and 1075 kilocycles.

11.309 Adjustment of Wave Traps

Detune the oscillator by connecting a 0.05-mf condenser between the grid (pin 5) of V–302 and ground. Temporarily detune the wave trap inductances L–306 and L–315 by turning the screws on these coils a few turns. Connect the signal generator (set at the I. F. frequency—1050 kilocycles) through a dummy antenna resistor to the antenna jack. Turn the screw on coil L–305 until minimum output is obtained. As minimum indication is reached, the output of the signal generator should be increased. Readjust the screw on coil L–305 for minimum output with higher generator voltage.

Then connect the signal generator through a 0.01-mf condenser to the grid (pin 4) of V–301. Turn screw on L–315 until a minimum response to the 1050-kilocycle signal is obtained. Short-circuit the parallel trap L–305 by a wire across its terminals. Connect the signal generator, still set at 1050 kilocycles, to the antenna jack through a dummy antenna resistor. Turn the screw on L–306, part of a series trap, until minimum response is obtained on the output indicator. Then remove the short-circuit on L–305. Retune all the traps (L–305, L–306, and L–315) for minimum response at the output.

11.310 Alignment of Oscillator, Mixer, and Antenna Circuits

For a description of the alignment of these circuits, refer to paragraph **7.500**.

11.311 Gain Test of Video Amplifier Tube

A 1-volt (peak to peak), 60 cycle signal may be fed into the grid of V–307. An AC output meter connected between the output side of C–334 and ground should show at least 15 volts (R. M. S.).

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TROUBLE-SHOOTING AND PREOPERATIONAL MAINTENANCE OF GROUND-STATION EQUIPMENT

12.100 TROUBLE-SHOOTING

Indications of trouble and proposed corrections:

a. Unable to match leading edges of ship pulse with ground-station pulse, using either coarse or fine delay controls on synchronizer:
   1. Make checks as outlined in paragraph **12.101**.

b. On fast sweep, marker pips on upper sweep do not line up vertically with corresponding pips on lower sweep:
   1. Make checks as outlined in paragraph **12.102**.

c. Ship pulse not pulling into sync from either right or left:
   1. Make adjustment on AFC bias control as outlined in paragraph **8.104j**.

d. Complaint by ship that ground station is 500 microseconds off in range:
   1. Check *R* control as outlined in paragraph **8.104g**, and STATION DELAY control as outlined in paragraph **8.104h**.

e. Local signal normal but no remote signals:
   1. Electronic-attenuator amplifier not functioning. This can be checked quickly by switching the electronic-attenuator unblanking switch. If the local signal does not saturate or change greatly in amplitude, the electronic-attenuator amplifier is not functioning.

f. Erratic operation of electronic-attenuator amplifier can cause erratic appearance of local-transmitted-signal pulse shape, especially in the lagging edge of pulse:
   1. Have another station look at your signal pulse to determine if transmitted signal is actually erratic.

g. When synchronizing ship signal, signal jumps in time when sweep speed switch is turned from slow to fast:
   1. All step-charger adjustments should be centered in their range. Special care should be taken in centering Eccles-Jordan control *Q*.

h. No fast sweep:
   1. Eccles-Jordan may need adjusting (control *Q* on left side of indicator).

i. Ship signal cannot be stopped on fast sweep with fine frequency control:
   1. This is normal during warm-up period. Adjust COARSE FREQUENCY control through top of controller-indicator cabinet.

12.101 Checking the Synchronizer Delay Multivibrator and Sync Gate

STEP 1

Connect open end of the special test probe (type 281 test probe in Figure 83, to be constructed by the user) to junction of R–318 and C–328 in receiver, insuring that the coaxial shield is connected to a good ground.

STEP 2

In the controller-indicator, connect pin 2 of V–111 to pin 1 of V–119 through a 150-mmf condenser.

STEP 3

Set the controller-indicator controls as follows:

SWEEP SPEED control at FAST
FAST SWEEP at 1
GAIN at 0
RECVR switch at ON 1
Delay and *R* adjustments normal

STEP 4

TEST 1. Check for Proper Amplitude of Negative Pip from Controller-Indicator to Synchronizer Delay Chain:

In synchronizer, connect probe to pin G of J–401 (one side of C–401). Use some trace separation. At the first 50 microsecond (us) pip on the top trace, an upward deflection of about ¼-inch and about 5-us long, should be viewed. This is an upward deflection because the video amplifier in the receiver inverts the signals.

TEST 2. Check for Proper Operation of Delay Multivibrator:

Connect probe to pin 5 of V–401. On the upper trace, starting at the first 50-us pip, an upward deflection of about ⅜-inch should be viewed. The length of this pulse should vary from near zero to about 25-us, depending on the setting of the COARSE DELAY (R–405) and FINE DELAY (R–406).

TEST 3: Check on Sync Gate Width:

Connect probe to pin 3 of V–405. On the upper trace there should be an upward deflection of about 1½ inches. Its position on the sweep depends on the setting of the COARSE and FINE DELAYS. The width of this pulse should be about 18-us, measuring from the start of pulse at base line to the right edge at top of pulse. The width is controlled by adjustment of C–402.

Pulse-length measurements can be made by using the vertical center control for positioning pulses and switching the receiver switch from ON 1 to OFF to view 10-us markers for comparison.

12.102 Checking V–133 and V–134 Mixers and V–107 Pulse-Selector Wave Forms on the Controller-Indicator, Using the Controller-Indicator Itself for Viewing

TEST 1. Check for Proper Pedestal Width on the Output of Mixer V–133:

STEP 1

Set the controller-indicator controls as follows:

SWEEP SPEED at SLOW
FAST SWEEP at 1
RECVR switch at ON 1
GAIN at 0
Use trace separation

STEP 2

Back up *R* control until pedestal on top trace locks on first 500-us pip.

STEP 3

From pins 2 and 5 on V–133, connect a 0.01-mf condenser and run a lead from the other terminal of the condenser to pins 1 and 4 of V–310 cathode follower in receiver.

STEP 4

Connect to pin 1 of V–119 a 150-mmf condenser, and from opposite terminal on condenser run a lead to pin 3 of V–118.

STEP 5

Set the controller-indicator controls as follows:

SWEEP SPEED at FAST
FAST SWEEP at 2
RECVR switch at ON 1
GAIN at 0
Use trace separation

A pedestal of about 75-us in width should appear on the top trace. One pip of a group recurring at a rate of 50-us should stand on top of the pedestal. If the pedestal is too wide, a second pip, or more, will appear on the top. The width of this pedestal is controlled by the 0.001-mf and 200,000 ohms resistor on pin 4 of V–133. If more than one pip appears on the pedestal, it is best to first try other 5692 to correct this before changing the RC circuit.

TEST 2. Check for Proper Pedestal Width on Output of Mixer Tube, V–134:

STEP 1

Set the controller-indicator controls the same as in Step 1 of test 1 (V–133).

STEP 2

Back up STATION DELAY adjustment until pedestal on bottom trace is locked on the first 500-us pip.

STEP 3

Same as Step 3, Test 1, except connections to pins 2 and 5 of V–134.

STEP 4

Same as Step 4, Test 1 (for V–134, however), with the exception that the 0.01-mf condenser goes to pin 6 of V–118 instead of to pin 3.

STEP 5

Set controller-indicator controls the same as in Step 5, Test 1. A pedestal of about 75-us in width should appear on the bottom trace. One pip of a group recurring at a rate of 50-us should stand on top of the pedestal. If the pedestal is too wide, a second pip, or more, will appear on top. The width of this pedestal is controlled by the 0.001-mf and 250–K resistor values on the grid (pin 4) of V–134.

TEST 3. Check for Proper Bias on V–107 Cathode for Selection of Pulses from V–133 and V–134:

STEP 1

Same as Step 1, Test 1, in V–133 mixer tests.

STEP 2

Same as Step 2, Test 1.

STEP 3

Use special test probe. Connect open end of probe to receiver video input, as described in Step 4, paragraph **12.101**, of synchronizer tests. Connect probe end to pin 2 of V–107.

STEP 4

Set the controller-indicator controls the same as in Step 5 (V–133 mixer tests). On the upper trace a positive pip should be viewed. (Keep in mind that the receiver video amplifier inverts these signals.) A test can be made for proper bias setting by connecting a 100–K, or so, pot from cathodes to ground on V–107 and adjusting pot so that there is less bias. With a smaller value of bias, the leading (left-hand) edge of the V–133 putput pedestal will start appearing and will key the fast sweep on the upper trace in normal operation, thus giving an error. On the other hand, the bias could be too great in normal operation and the proper pip would not be strong enough to key the fast sweep. The cathode bias should be adjusted so that the pedestal edge does not appear on the plate of V–107.

STEP 5

Same as Step 1, Test 2, in V–134 mixer tests.

STEP 6

Same as Step 2, Test 2, in V–134 mixer tests.

STEP 7

Same as Step 3 in this group except that probe end should be connected to pin 5 of V–107 instead of to pin 2.

STEP 8

Same as Step 4 in this group except that the positive pip will appear on the bottom trace. Make same observations as in Step 4.

12.200 PREOPERATIONAL MAINTENANCE

Before the start of the field season, take the following steps to assure that the ground-station equipment will give satisfactory operation during the season:

a. Test the tubes (see paragraph **11.201**)
b. Check the power supply and filament voltages
c. Clean the equipment thoroughly
d. Use the test pulse oscillator for tests (see paragraph **12.300**)

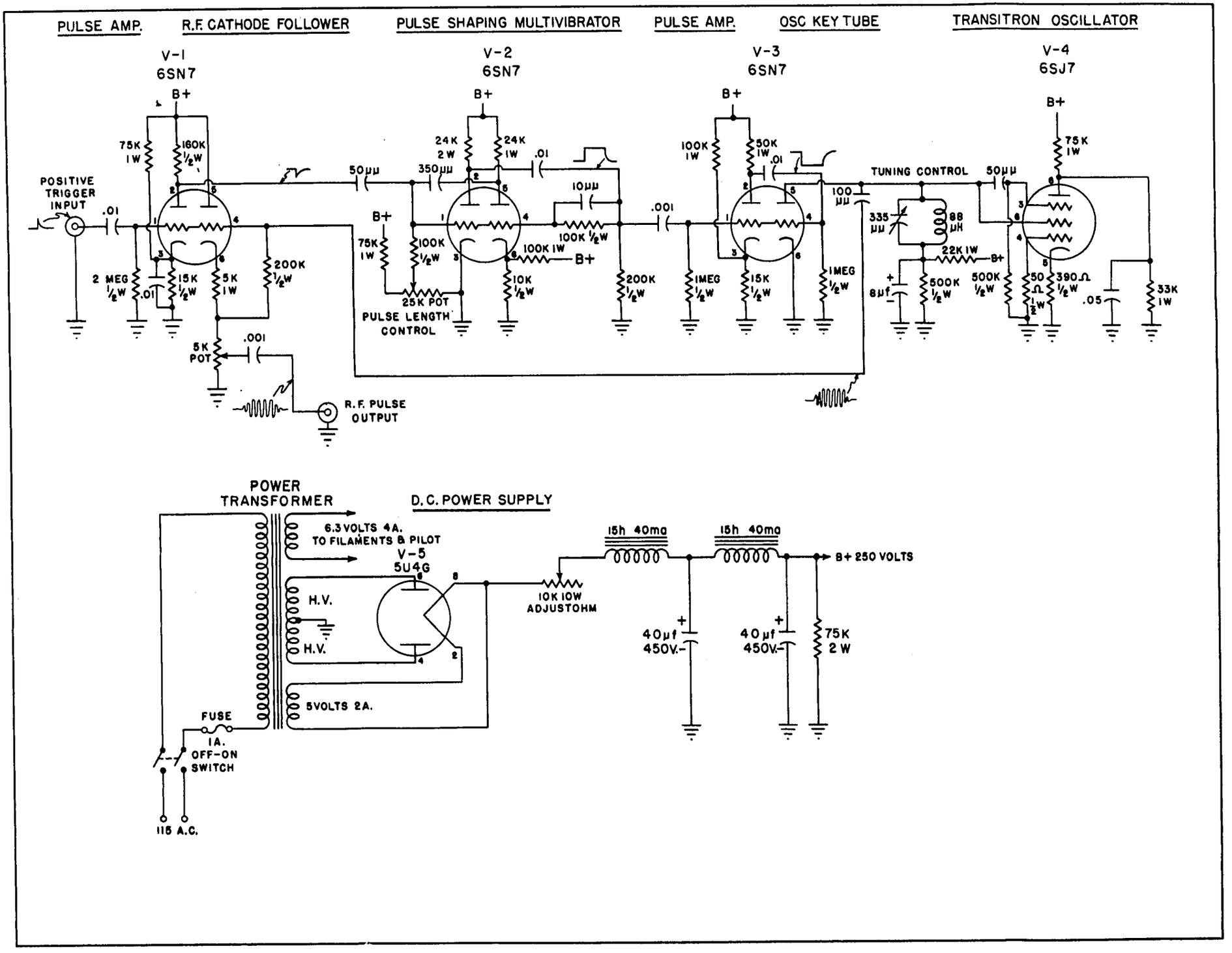

FIGURE 30.—Test Pulse Generator circuit diagram.

12.300 MAINTENANCE, TESTING, AND ADJUSTING WITH THE TEST PULSE OSCILLATOR

By use of the test pulse oscillator it is possible to make bench tests which closely simulate field conditions. Nearly all tests can be made except those to the transmitter and antenna systems, and to the local-signal part of the electronic attenuator.

It is recommended that the test-pulse-oscillator tests be made before the start of a field season as a final operation check after all routine checks and adjustments have been completed. This method of testing may also be used after a major field repair job.

A test-pulse-oscillator can be constructed in accordance with Figure 30.

12.301 Circuit Connection

A closed coaxial (RG–8/U) circuit is needed to connect the RF pulse output from the test oscillators to EPI electronic-attenuator-receiver antenna inputs. A ship unit and one ground-station unit are usually tested at one time. However, it is possible to test two ground-station units against each other, using one unit to supply the trigger for a test pulse oscillator instead of the ship unit. A coaxial trigger cable is run from a ground-station trigger output to a second test oscillator. The R. F. pulse output from both test oscillators are paralleled by means of a T coaxial connector (Amphenol 83–1T) and run to the paralleled electronic-attenuator-receiver antenna inputs of ship and ground-station units. This simulates a field setup, using only one ground station with the absence of atmospheric noise. Since a ground station can be made either an *A* or *B* station, it is not necessary to set up two ground stations. The electronic-attenuator blanking switch must be turned to OFF so that the weak R. F. signals from the test pulse oscillators will be amplified during the local-signal transmitting time of each instrument.

12.302 Ship-station Tests

The following are some tests that can be made using the test pulse oscillator. Be sure all equipment has been warmed at least 30 minutes.

a. Tuning of EPI receiver:

See paragraph **12.303a.**

b. Basic timing check:

Assuming the ground-station timing has been set up properly, a quick check of the ship's basic timing can be made by matching the ship signal on the ground-station scope set to slow sweeps. If it is steady, the dividers are set up properly.

Since there is zero distance between ship and ground station, the ship range counters will read near zero when the ground station is properly synchronized. This is a check of the ship-unit time-locking circuits, sine-wave dividers, and phase-shifting goniometers.

12.303 Ground-station Tests

a. Tuning of EPI receiver:

With the test oscillator tuned to the correct center frequency of EPI assigned frequency, the receiver antenna-and-mixer adjustment can be peaked for maximum amplitude of received pulse. The receiver local-oscillator adjustment can be made for maximum rise time of received pulse.

b. Basic timing check:

With the ship's basic timing set up properly, a quick check can be made of the ground station's basic timing. If the crystal oscillator is off frequency or any of the step-chargers out of adjustment, the ship's transmitted signal will run erratically across the scope traces on slow sweeps.

c. Synchronizer AFC pull-in time:

For this adjustment, refer to paragraphs **8.104i** and **8.104j**.

d. Synchronizer fine delay control operation:

Move the fine delay control full counterclockwise. Synchronize and close-match the ship and ground-station leading edges of signals, using the coarse delay screwdriver adjustment for matching. On the *A* or *B* ship range counter, depending on how the ground station is set up, match the signals and read the ship-unit range counter. Move the fine delay control full clockwise. Rematch the signals on the ship unit and read the range counters. The difference in ship range-counter readings is the amount of delay change caused by the ground-station fine delay control and should be about 10 microseconds for the entire range.

e. Time check on stability of instrument:

A check can be made on the stability of a ground-station instrument over a period of several hours by having an operator close-sync the signals at a ground station and another operator match the signals on the ship unit. Since the range between the ship and ground-station unit does not change, this gives a good plot of synchronizer fine delay stability and 100-kilocycle oscillator stability.

f. Check of video blanking circuits:

A check of the video blanking circuits can be made by using the ground station in sync with the ship station. First, set the ground station for an *A* station: the top pedestal on No. 2 pip and bottom pedestal on No. 4 pip. Then, close-sync the ground station equipment to the ship signal and measure the distance on the ship unit. Change the ground-station STATION DELAY until the bottom pedestal is on the 6th, then the 8th, and then the 10th pip. There should be no difference in the ranges read on the ship-unit counters for any of these settings.

The same procedure can be used with the ground-station set as for a *B* station. Measurements are made with the ground-station STATION DELAY pedestal set on the 14th, 16th, 18th, and 20th pips.

TABLES OF TYPICAL VOLTAGES TO GROUND AT TUBE SOCKET TERMINALS

13.100 SHIP CONTROLLER POWER SUPPLY

The regulated B plus voltage set at 250 volts by screwdriver control R–150. Measurements taken with RCA Voltohmyst.

Symbol	Type	Function	Pin No.	Element	Voltage to ground
V–501	5U4	Rectifier	4 or 6 8	P H	530 AC 550
V–502 through V–505.	6B4	Voltage regulator	3 5 7	P G H	530 190 250
V–506	6SJ7	Voltage-control pentode	3 or 5 4 6 8	SP or K G SG P	105 100 135 190
V–507	VR–105	Glow discharge voltage regulator	5	Anode	105
V–508	6X5	Bias rectifier	3 or 5 8	P K	−490 360 AC
V–509	VR–105	Glow discharge voltage regulator	2	K	−105
V–510	VR–105	Glow discharge voltage regulator	5	Anode	105

13.200 SHIP CONTROLLER

The regulated B plus voltage set at 250 volts. Measurements taken with RCA Voltohmyst.

Symbol	Type	Function	Pin No.	Element	Voltage to ground
V-1	6AC7	100-KC oscillator	4	G	0
			5	K	2.8
			6	SG	84
			8	P	83
V-2	6AC7	100-KC oscillator	4	G	−4.5
			5	K	3.5
			6	SG	100
			8	P	100
V-3	6SN7	Cathode follower	1	G	44
			2	P	187
			3	K	55
			4	G	150
			5	P	250
			6	K	158
V-4	6AG7	Amplifier	4	G	−22
			5	K	2.8
			6	SG	160
			8	P	230
V-5	6AC7	Sine-wave divider	4	G	−92
			6	SG	80
			8	P	245
V-6	6V6	Sine-wave divider	3	P	245
			4	SG	240
			5	G	−66
			8	K	11
V-7	6AC7	Sine-wave divider	4	G	−96
			6	SG	70
			8	P	245
V-8	6V6	Sine-wave divider	3	P	240
			4	SG	240
			5	G	−10
			8	K	19
V-9 and V-10	6SN7	Cathode follower	1	G	30
			2	P	245
			3	K	40
			4	G	−2.2
			5	P	250
			6	K	0.4
V-11 and V-12	6SN7	Amplifier and clamper	1	G	−5
			2	P	110
			4 & 5	G & P	−15
V-13 and V-14	6SN7	Amplifier	1	G	−7.5
			2	P	10
			4	G	−0.8
			5	P	46

Symbol	Type	Function	Pin No.	Element	Voltage to ground
V-15 and V-16	6SA7	*A* and *B* mixer	3	P	250
			4	SG	−1.9
			5	G	−14
			8	SG	−15
V-17 and V-18	6AC7	Amplifier	4	G	0
			5	K	1.1
			6	SG	85
			8	P	13
V-19 and V-20	6AG7	Amplifier	4	G	−0.3
			5	K	13
			6	SG	250
			8	P	220
V-21 and V-22	6SN7	Biased amplifier and cathode follower.	1	G	−62
			2 & 5	P	180
			4	G	−45
V-23 and V-24	6SN7	Blanking video cathode follower and amplifier.	1	G	0
			2	P	250
			3	K	12
			4	G	−35
			5	P	250
			6	K	24
V-25	6SN7	2nd E. J. multivibrator	1	G	20
			2	P	135
			3 & 6	K	27
			4	G	20
			5	P	135
V-26	6SN7	Clamper	1 & 2	G & P	−39
			4 & 5	G & P	−39
V-27	5692	1-KC peaker and cathode follower	1	G	−135
			2	P	240
			4	G	−1
			5	P	250
			6	K	16

13.300 SHIP INDICATOR

B plus set at 265 volts with control P. RCA Voltohmyst used except where indicated by an asterisk. These latter are measured with a 20,000 ohms-per-volt meter.

Symbol	Type	Function	Pin No.	Element	Voltage to ground
V-102	6AC7	Squaring amplifier	4	G	−27
			6	SG	105
			8	P	200
V-103	6H6	Divider diode	4 & 5	K & P	26
			8	K	30
V-104	6SN7	Marker mixer and divider	1	G	0
			2	P	270
			3	K	15
			4	G	29
			5	P	270
			6	K	67
V-105	6H6	Divider diode	4 & 5	K & P	9
			8	K	36
V-106	6SN7	Divider	1	G	34
			2	P	270
			3	K	71
			4	G	17
			5	P	270
			6	K	30
V-107	5692	Pulse selector	1	G	−3.3
			2	P	270
			3 & 6	K	37
			4	G	−3.9
			5	P	270
V-108	6H6	Divider diode	4 & 5	K & P	1.2
			8	K	17
V-109	6H6	Divider diode	4 & 5	K & P	0.6
			8	K	17
V-110	6SN7	Divider and clipper	1	G	18
			2	P	270
			3	K	54
			4 & 5	G & P	−0.5
			6	K	0.2
V-111	6SN7	*A* delay multivibrator	1	G	65
			2	P	140
			3 & 6	K	68
			4	G	29
			5	P	270
V-112	6SN7	*C* delay multivibrator	1	G	25
			2	P	270
			3 & 6	K	72
			4	G	70
			5	P	140
V-113	6SN7	Trace shift mixer and marker amplifier.	1	G	87
			2	P	270
			3	K	155
			5	P	240
			6	K	14

Symbol	Type	Function	Pin No.	Element	Voltage to ground
V-114	6SN7	*B* delay multivibrator	1	G	52
			2	P	160
			3 & 6	K	64
			4	G	26
			5	P	250
V-115	6SN7	1st E. J. multivibrator	1	G	20
			2	P	150
			3 & 6	K	28
			4	G	21
			5	P	150
V-116	6SL7	10-microsecond marker amplifier	1	G	−35
			2	P	98
			4	G	0
			5	P	270
			6	K	74
V-117	5692	Mixer	1	G	−19
			2 & 5	P	17
			4	G	3
V-118	6SL7	Amplitude balance	1	G	−88
			2 & 5	P	270
			3	K	15
			4	G	−84
			6	K	15
V-119	6SN7	Pedestal generator	1	G	16
			2	P	105
			3 & 6	K	26
			4	G	−16
			5	P	210
V-120	6SN7	Fast-sweep generator and cathode follower.	1	G	220
			2 & 5	P	270
			3	K	250
			4	G	−16
			6	K	23
V-121	6SJ7	Fast-sweep generator	3 & 5	SP & K	4.3
			6	SG	90
			8	P	250
V-122	884	Slow-sweep generator	3	P	50
			5	G	0
			8	K	14
V-123	6SJ7	Slow-sweep amplifier	4	G	0
			5	K	12
			6	SG	220
			8	P	130
V-124	6SL7	Paraphase amplifier	1 & 4	G	58
			2 & 5	P	240
			3 & 6	K	67
V-125	5CP1	Oscilloscope tube	1, 2, 14	H & K	−1200*
			3	G.	−1230*
			5	A1	−855*
			7	HDP	120*
			8	HDP	115*
			9	A2	140*
			10	VDP	135*
			11	VDP	120*

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Symbol	Type	Function	Pin No.	Element	Voltage to ground
V-126	2X2	Positive high voltage rectifier	1 4 Cap	H H P	1500* 1500* 1050 AC*
V-127	2X2	Negative high voltage rectifier	Cap	P	−1300*
V-128	5T4	Rectifier	2 4 6	H P P	420 380 AC 380 AC
V-129 and V-130.	2A3	Voltage regulator	1 2 3 4	H P G H	270 360 265 270
V-131	6SJ7	Voltage-control pentode	4 3 & 5 6 8	G SP & K SG P	102 105 130 260
V-132	VR-105	Glow discharge voltage regulator	5	Anode	105
V-133	5692	*A* sweep mixer	1 2 & 5 4	G P G	0.7 25 −9.1
V-134	5692	*B* sweep mixer	1 2 & 5 4	G P G	0.8 28 −9.8
V-135	6SL7	Intensity limiter	1, 2, 4, 5 3 & 6	GP K	1300* 1250*
V-136	6SN7	Amplifier and cathode follower	1 2 4 5 6	G P G P K	0.6 79 0 270 15
V-137	2050	Trigger generator	3 5	P G	190 −49
V-138	5692	Cathode follower and pulse selector	1 2 3 4 5 6	G P K G P K	135 265 140 −0.3 265 68
V-139	6SN7	Amplifier	1 2 4 5	G P G P	−9 86 −9 82

*Measured with a 20,000 ohms-per-volt meter.

13.400 SHIP AND GROUND-STATION RECEIVERS

Gain control set at minimum. Measurements taken with 20,000 ohms-per-volt meter.

Symbol	Type	Function	Pin No.	Element	Voltage to ground
V-301	6SK7	R. F. amplifier (ground station)	5 6 8	K SG P	39.5 275 290
V-301	6SK7	R. F. amplifier (ship station)	5 6 8	K SG P	19.5 275 290
V-302	6SA7	Converter	3 4 5 6	P SG G K	325 135 38 37
V-303	6SK7	First I. F. amplifier	5 6 8	K SG P	38 235 320
V-304	6SK7	Second I. F. amplifier	5 6 8	K SG P	39 237 320
V-305	6SK7	Third I. F. amplifier	5 6 8	K SG P	39.5 230 302
V-306	6H6	Second detector	5	K	19.5
V-307	6AC7	Video amplifier	5 6 8	K SG P	0.9 172 117
V-308	6SN7	Amplitude balance cathode follower	2 & 5 3 & 6	P K	320 19.5
V-309	5Y3	Rectifier	2 & 8 4 & 6	H P	360 300 AC
V-310	6SN7	Cathode follower (ground station only).	1 & 4 2 & 5 3 & 6	G P K	0 320 14.5

13.500 SHIP AND GROUND-STATION ELECTRONIC ATTENUATOR

Measured with RCA Voltohmyst. These voltages may vary as much as 20 percent, depending on whether the unit is located in a ship or ground station.

Symbol	Type	Function	Pin No.	Element	Voltage to ground
V-401	6AC7	Amplifier	4	G	−30
			5	K	1
			6	SG	200
			8	P	235
V-402	6AC7	Amplifier	4	G	−28
			5	K	1
			6	SG	200
			8	P	240
V-403	6SL7	Amplifier and clamper	1	G	0
			2	P	200
			3	K	4
			4 & 5	G & P	−30

13.600 GROUND-STATION CONTROLLER-INDICATOR

B plus set at 265 volts with control P. Values taken with RCA Voltohmyst except where otherwise indicated by an asterisk. These latter are measured with a 20,000 ohms-per-volt meter.

Symbol	Type	Function	Pin No.	Element	Voltage to ground
V-101	6SJ7	Standard frequency generator	4	G	−39
			6 & 8	SG & P	195
V-102	6AC7	Squaring amplifier	4	G	−17
			6	SG	80
			8	P	170
V-103	6H6	Divider diode	4 & 5	K & P	29
			8	K	37
V-104	6SN7	Marker mixer and divider	1	G	0
			2	P	265
			3	K	16
			4	G	29
			5	P	255
			6	K	64
V-105	6H6	Divider diode	4 & 5	K & P	6.2
			8	K	24
V-106	6SN7	Divider	1	G	24
			2	P	255
			3	K	54
			4	G	16
			5	P	260
			6	K	48
V-107	5692	Pulse selector	1	G	−0.2
			2	P	255
			3 & 6	K	49
			4	G	−0.2
			5	P	255

Symbol	Type	Function	Pin No.	Element	Voltage to ground
V-108	6H6	Divider diode	4 & 5	K & P	1.2
			8	K	16
V-109	6H6	Divider diode	4 & 5	K & P	2.2
			8	K	13
V-110	6SN7	Divider and clipper	1	G	13
			2	P	255
			3	K	43
			4 & 5	G & P	−0.4
			6	K	0
V-111	6SN7	*A* delay multivibrator	1	G	63
			2	P	125
			3 & 6	K	65
			4	G	32
			5	P	250
V-112		Socket X-112 and its associated components are left in unit but not used.			
V-113	6SN7	Trace shift mixer and marker amplifier.	1	G	61
			2	P	265
			3	K	120
			5	P	225
			6	K	13
V-114	6SN7	B delay multivibrator	1	G	63
			2	P	135
			3 & 6	K	65
			4	G	23
			5	P	255
V-115	6SN7	Square-wave generator	1	G	24
			2	P	150
			3 & 6	K	32
			4	G	25
			5	P	150
V-116	6SN7	Marker amplifier	1	G	−1
			2	P	90
			4	G	0
			5	P	265
			6	K	20
V-117	2050	Trigger shaper	3	P	175
			5	G	−44
V-118	6SL7	Amplitude balance	1	G	140
			2 & 5	P	265
			3	K	140
			4	G	140
			6	K	140
V-119	6SN7	Pedestal generator	1	G	12
			2	P	100
			3 & 6	K	25
			4	G	−15
			5	P	200
V-120	6SN7	Fast-sweep generator	1	G	200
			2 & 5	P	265
			3	K	220
			4	G	−15
			6	K	20

Symbol	Type	Function	Pin No.	Element	Voltage to Ground
V-121	6SJ7	Fast-sweep generator	3 & 5	SP & K	4.5
			6	SG	88
			8	P	220
V-122	884	Slow-sweep generator	3	P	52
			5	G	0.3
			8	K	13
V-123	6SJ7	Slow-sweep amplifier	4	G	0
			5	K	11
			6	SG	205
			8	P	110
V-124	6SL7	Paraphase amplifier	1 & 4	G	52
			2 & 5	P	300
			3 & 6	K	62
V-125	5CP1	Oscilloscope tube	1, 14, 2	H & K	−1200*
			3	G	−1230*
			5	A1	−855*
			7	HDP	120*
			8	HDP	115*
			9	A2	140*
			10	VDP	135*
			11	VDP	120*
V-126	2X2	HV rectifier	1	H	1425*
V-127	2X2	HV rectifier	Cap	P	−1260*
V-128	5T4	LV rectifier	2	H	455
			4	P	400 AC
			6	P	400 AC
V-129 and V-130.	2A3	Voltage regulator	1	H	265
			2	P	410
			3	G	240
V-131	6SJ7	Voltage regulator pentode	3 & 5	SP & K	100
			4	G	100
			6	SG	130
			8	P	225
V-132	VR-105	Glow discharge voltage regulator	5	Anode	105
V-133	5692	*A* mixer	1	G	−2.6
			2 & 5	P	6.3
			4	G	3.1
V-134	5692	*B* mixer	1	G	−2.6
			2 & 5	P	6.8
			4	G	3.2
V-135	6SL7	Intensity limiter	1, 2, 4, & 5.	G & P	−1220*
			3 & 6	K	−1220*
V-136	6SN7	AFC (out of sync)	1 & 4	G	−0.7
			2 & 5	P	265
			3 & 6	K	12
V-137	6SN7	Amplifier	1	G	0.4
			2	P	98
			4	G	0
			5	P	265
			6	K	14

13.700 GROUND-STATION SYNCHRONIZER

The regulated B plus voltage set at 250 volts by screwdriver adjustment R-443.

Symbol	Type	Function	Pin No.	Element	Voltage to Ground
V-401	6SN7	Amplifier and delay multivibrator	1	G	−0.8
			2	P	69
			4	G	10
			5	P	250
			6	K	29
V-402	6SN7	Multivibrator and clamper	1	G	28
			2	P	140
			3	K	29
			4 & 5	G & P	28
			6	K	28
V-403	6V6	Amplifier	3	P	27
			4	SG	50
			5	G	0.5
V-404	6SN7	Biased clipper and video amplifier	1 & 2	G & P	−105
			4	G	58
			5	P	250
			6	K	72
V-405	6V6	Inverter	3	P	250
			4	SG	250
			5	G	−105
V-406	6SJ7	Mixer (out of sync)	3 & 5	SP & K	250
			4	G	0.1
			6	SG	250
			8	P	250
V-407	6SN7	Charging diode	1 & 2	G & P	−0.7
			3	K	0.5
V-408	6V6	Differential amplifier	3	P	50
			4	SG	100
			5	G	−1
			8	K	4
V-409	6V6	Differential amplifier	3	P	71
			4	SG	100
			5	G	−4.7
			8	K	4
V-410	6SN7	Cathode follower (This tube not used in models starting with No. 10).	1	G	80
			2	P	250
			3	K	85
			4	G	72
			5	P	250
			6	K	84
V-411	5Y3	Rectifier	2	H	480
			4	P	440 AC
V-412	5Y3	Bias rectifier	2	H	440 AC
			4 & 6	P	−560
V-413	2A3	Voltage regulator	1	H	250
			2	P	475
			3	G	220
V-414	6SJ7	Voltage regulator pentode	3 & 5	SP & K	105
			4	G	100
			6	SG	130
			8	P	220
V-415	VR-105	Glow discharge voltage regulator	5	Anode	105
V-416	VR-105	Glow discharge voltage regulator	2	K	−105

13.800 MODULATOR

Values measured with a RCA Voltohmyst. Trigger OFF.

Symbol	Type	Function	Pin No.	Element	Voltage to ground
V-201	6SN7	Amplifier and clamper	1	G	0
			2	P	210
			3	K	10
			4 & 5	G & P	0
			6	K	0.75
V-202	6SN7	Pulse length	1	G	0.75
			2	P	80
			3	K	0
			4	G	0
			5	P	265
			6	K	24
V-203	6V6	Amplifier	3	P	239
			4	SG	230
			5	G	0.75
			8	K	25
V-204	807	Driver	2	SG	82
			3	G	0.75
			4	K	0
			Cap	P	39
V-205	6X5	Bias rectifier	3 & 5	P	−280
			8	K	370 AC
V-206	VR-150	Glow discharge voltage regulator	2	K	−150
V-207	5U4	Regulated voltage rectifier	4	P	370 AC
			6	P	370 AC
			2 & 8	H	300
V-208	5U4	Unregulated voltage rectifier	2 & 8	H	560
			4 & 6	P	560 AC
V-209	VR-150	Glow discharge voltage regulator	5	Anode	255
V-210	VR-105	Glow discharge voltage regulator	5	Anode	105

XIV

WAVEFORMS OF EPI SHIP AND GROUND-STATION EQUIPMENT

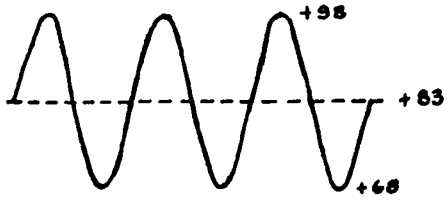
Reference voltage measurements are to ground, using RCA Voltohmyst. Waveform voltages, using a DuMont oscilloscope type 248, are above or below the reference voltage.

OSCILLOSCOPE SETTINGS

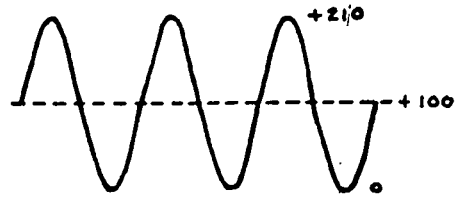
Intensity	62
Focus	28
Sync Selector	Ext. 20:1
Sync Gain	+82
Accelerating Potential	High
Trigger Rate	Off
Y-Attenuation	1:1
X-Signal Selector	12K
Y-Gain	75
Z-Signal Selector	Ext. Input
Z-Gain	0
X-Gain	26

Use oscilloscope settings listed above unless different settings are indicated at the scope pattern for the point of measurement.

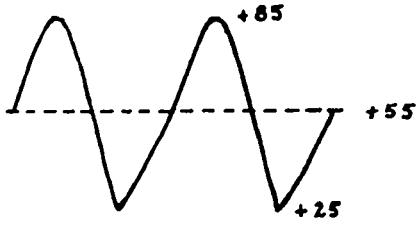
SHIP CONTROLLER



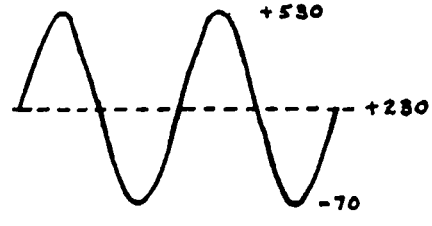
V-1 6AC7
Pin 8 Plate
100KC Sine wave
Sync obtained from pin 8 of V-1



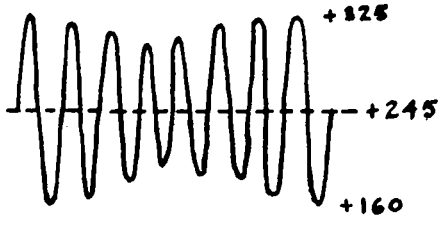
V-2 6AC7
Pin 8 Plate
100KC Sine wave
Y-Attenuation 10:1
Y-Gain 63



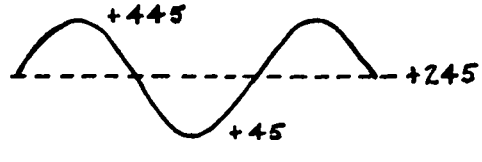
V-3 6SN7
Pin 3 Cathode
100KC Sine wave



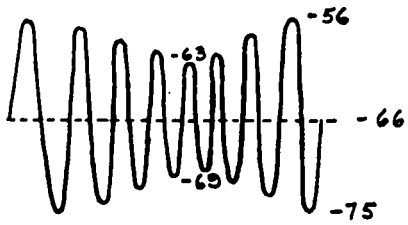
V-4 6AC7
Pin 8 Plate
100KC Sine wave
Y-Attenuation 100:1
Sync obtained from Pin 4 of V-4



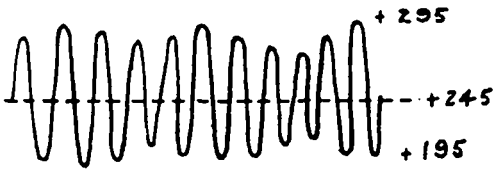
V-5 6AC7
Pin 8 Plate
Y-Attenuation 10:1
X-Signal selector 500



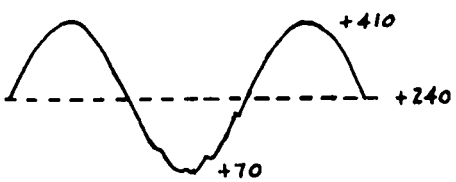
V-6 6V6
Pin 3 Plate



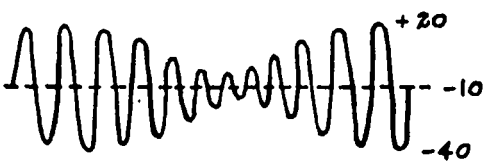
V-6 6V6
Pin 5 Grid
X-Signal selector 2K



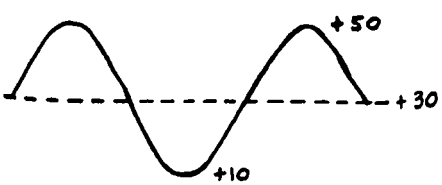
V-7 6AC7
Pin 8 Plate
X-Signal selector 500
Sync obtained from Pin 6 of V-27



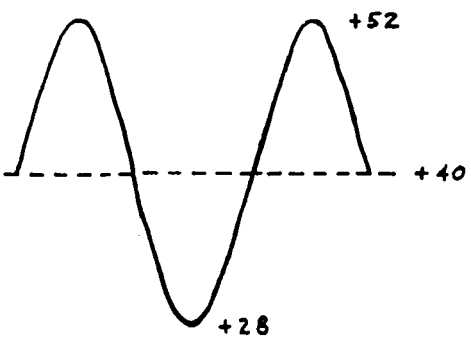
V-8 6V6
Pin 3 Plate



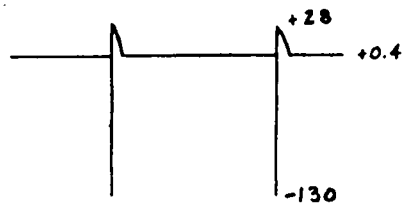
V-8 6V6
Pin 5 Grid



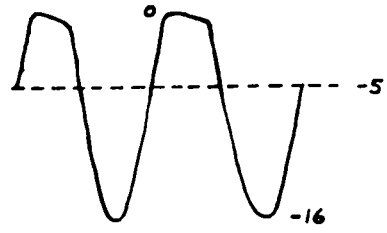
V-9 and V-10 6SN7
Pin 1 Grid
X-Signal selector 12K
Sync obtained from Pin 4 of V-4



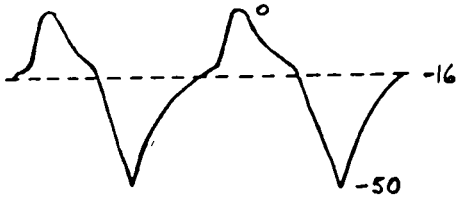
V-9 and V-10 6SN7
Pin 3 Cathode
Y-Attenuation 1:1



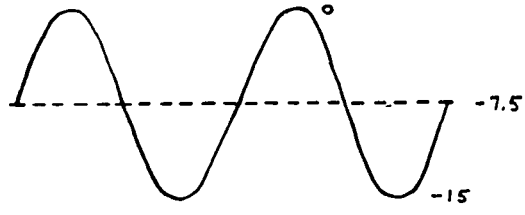
V-9 and V-10 6SN7
Pin 6 Cathode
Y-Attenuation 10:1
X-Signal selector 500
Sync obtained from Pin 8 of V-19



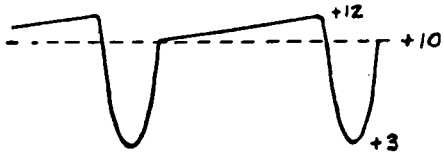
V-11 and V-12 6SN7
Pin 1 Grid
Y-Attenuation 1:1
X-Signal selector 2K
Sync obtained from Pin 6 of V-27



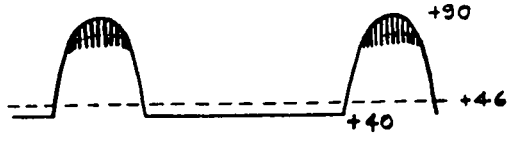
V-11 and V12 . 6SN7
Pins 4 and 5 Grid and Plate
Y-Attenuation 10:1



V-13 and V14 6SN7
Pin 1 Grid
Y-Attenuation 1:1
X-Signal selector 125

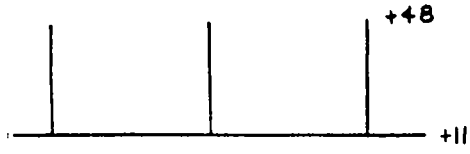


V-13 and V-14 6SN7
Pin 2 Plate

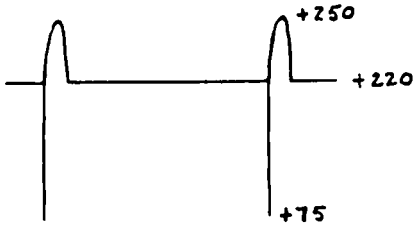


V-13 and V-14
Pin 5 Plate
Y-Attenuation 10:1

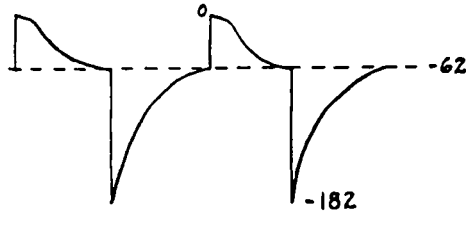
V-15 and V-16 6SA7
Pin 3 Plate
Y- Attenuation 1:1



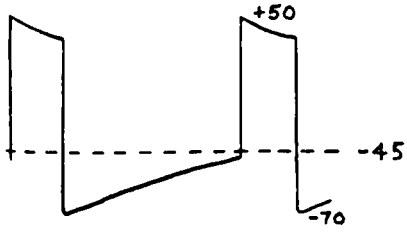
V-17 and V-18 6AC7
Pin 8 Plate
Y-Attenuation 10:1



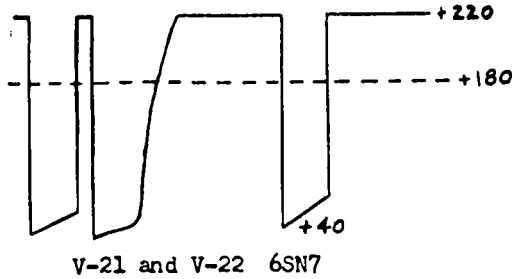
V-19 and V-20 6AG7
Pin 8 Plate



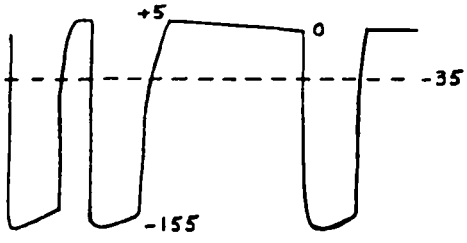
V-21 and V-22 6SN7
Pin 1 Grid
X-Signal selector 15



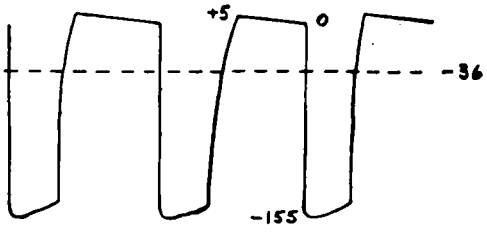
V-21 and V-22 6SN7
Pin 4 Grid
Recvr. switch on ON-2 position



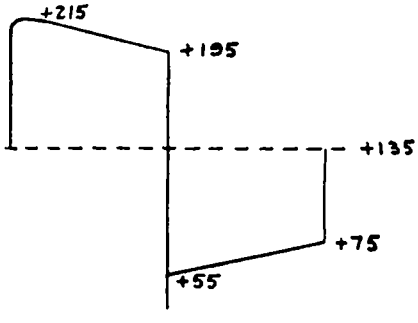
V-21 and V-22 6SN7
Pins 2 and 5 Plate



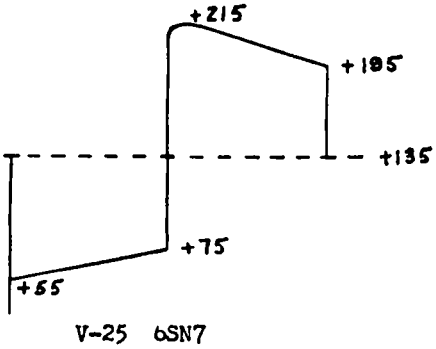
V-23 6SN7
Pin 4 Grid
Without video signal



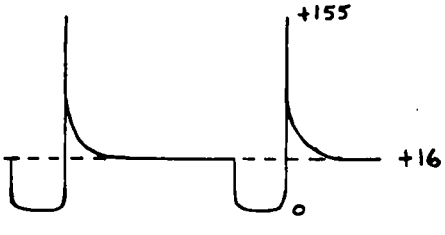
V-24 6SN7
Pin 4 Grid
Without video signal



V-25 6SN7
Pin 2 Plate



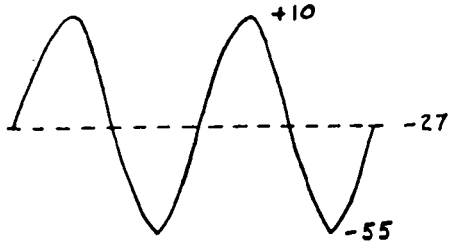
V-25 6SN7
Pin 5 Plate



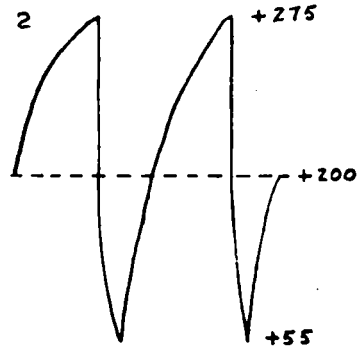
V-27 5692
Pin 6 Cathode
Rise time - 7.7 us

SHIP INDICATOR

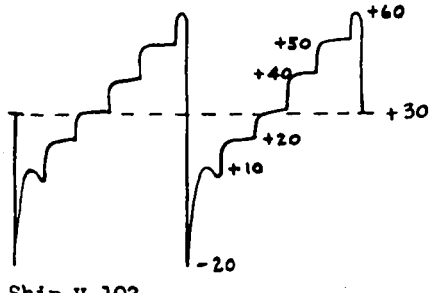
SWEEP SPEED - SLOW, FAST SWEEP - 2



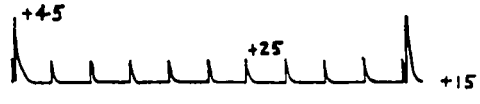
Ship V-102
Tube Type 6AC7 Pin 4 Grid
X-Signal selector driven sweep
Driven sweep duration - 100 us
Sync obtained from Pin 5 of V-115
B+ 280 volts



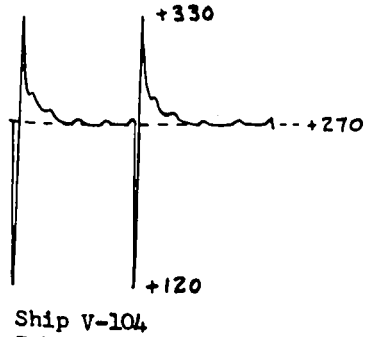
Ship V-102
Tube Type 6AC7 Pin 8 Plate



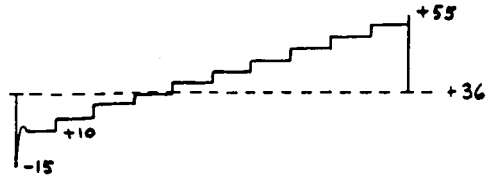
Ship V-103
Tube Type 6H6 Pin 8 Cathode
Driven sweep duration - 1000 us



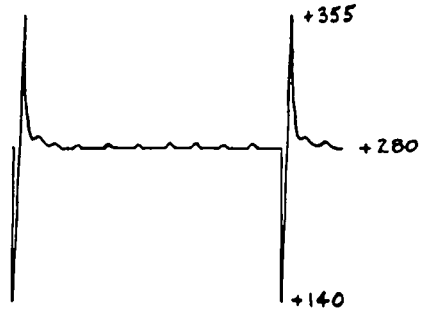
Ship V-104
Tube Type 6SN7 Pin 3 Cathode



Ship V-104
Tube Type 6SN7 Pin 5 Plate



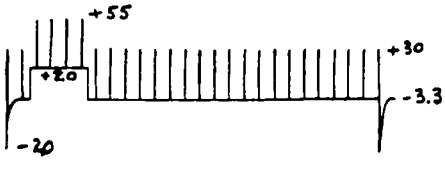
Ship V-105
Tube Type 6H6 Pin 8 Plate



Ship V-106
Tube Type 6SN7 Pin 2 Plate

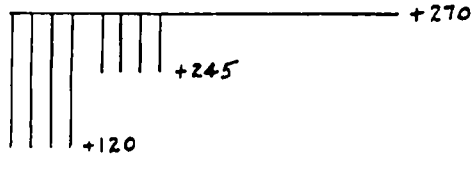
Ship V-106
Tube Type 6SN7 Pin 5 Plate
X-Signal selector 125

ON PIN 4 PIPS NO. 7,8,9,& 10
APPEAR ON PEDESTAL

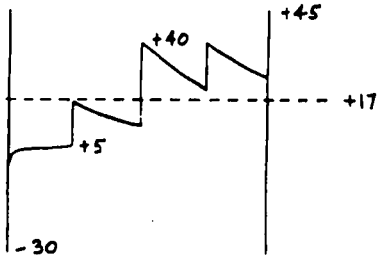


Ship V-107
Tube Type 5692 Pins 1 and 4 Grid
X-Signal selector 15

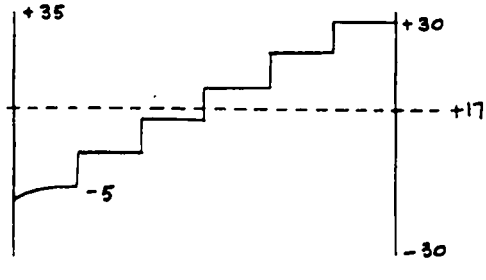
ON PIN 5 FIRST FOUR PIPS ARE
SHORT AND LAST FOUR ARE LONG



Ship V-107
Tube Type 5692 Pins 2 and 5 Plates

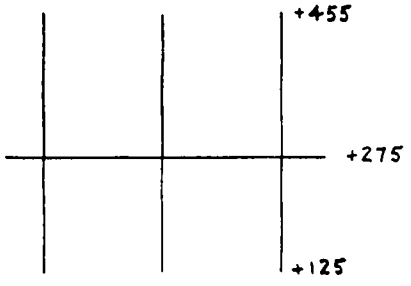


Ship V-108
Tube Type 6H6 Pin 8 Cathode
X-Signal selector 125

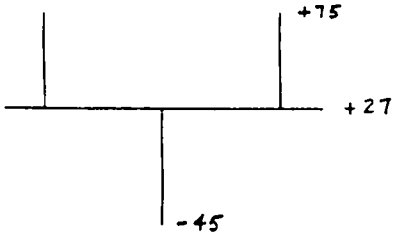


Ship V-109
Tube Type 6H6 Pin 8 Cathode
X-Signal selector 15

2

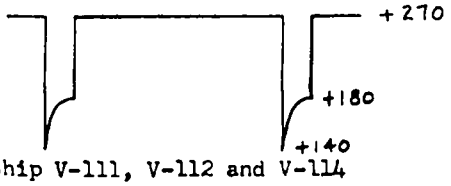


Ship V-110
Tube Type 6SN7 Pin 2 Plate



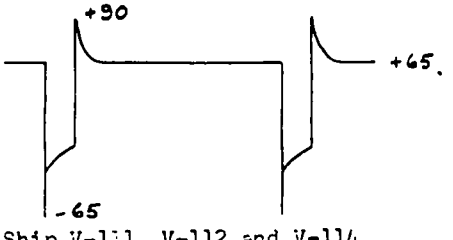
Ship V-111, V-112 and V-114

Tube Type 6SN7
Pin 4 (V-111 and V-114) Pin 1 (V-112)
Grid

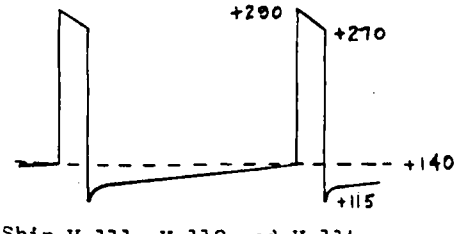


Ship V-111, V-112 and V-114

Tube Type 6SN7
Pin 5 (V-111 and V-114) Pin 2 (V-112)
Plate

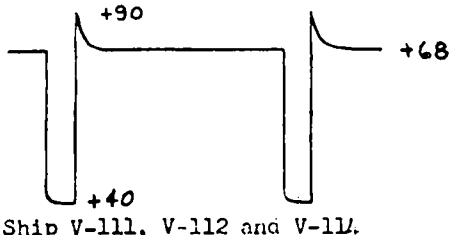


Ship V-111, V-112 and V-114
Tube Type 6SN7
Pin 1 (V-111 and V-114) Pin 4 (V-112)
Grid



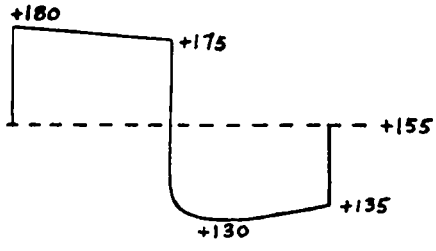
Ship V-111, V-112 and V-114

Tube Type 6SN7
Pin 2 (V-111 and V-114) Pin 5 (V-112)
Plate

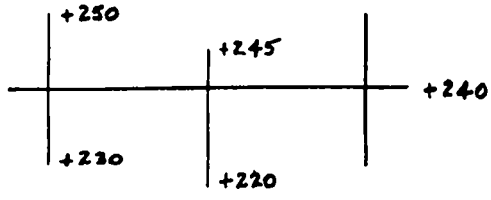


Ship V-111, V-112 and V-114
Tube Type 6SN7
Pins 3 and 6 Cathode

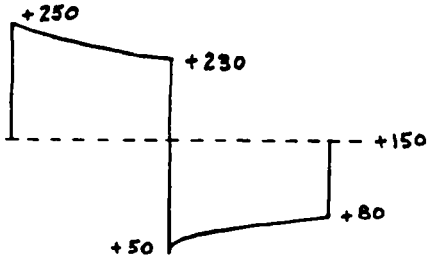
3



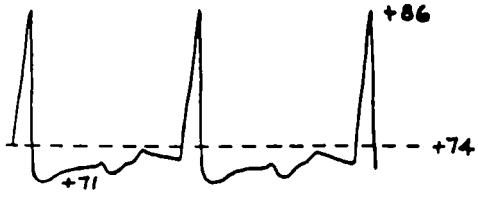
Ship V-113
Tube Type 6SN7 Pin 3 Cathode



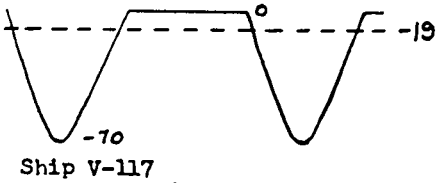
Ship V-113
Tube Type 6SN7 Pin 5 Plate



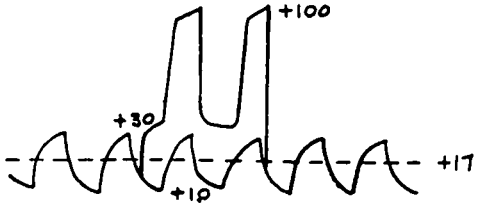
Ship V-115
Tube Type 6SN7 Pin 2 Plate



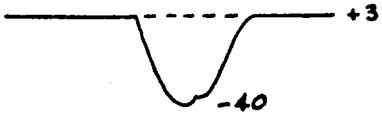
Ship V-116
Tube Type 6SL7 Pin 6 Cathode
X-Signal selector driven sweep
Driven sweep duration - 25 us
Y-Attenuation 1:1



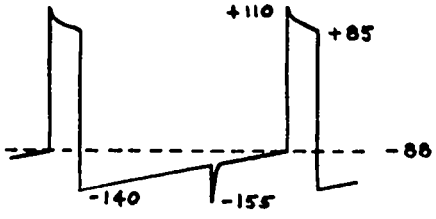
Ship V-117
Tube Type 5692 Pin 1 Grid
Y-Attenuation 10:1



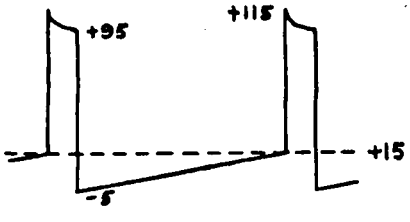
Ship V-117
Tube Type 5692 Pins 2 and 5 Plate
Driven sweep duration - 100 us



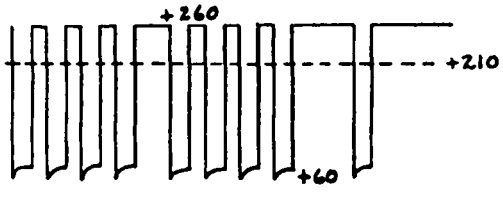
Ship V-117
Tube Type 5692 Pin 4 Grid



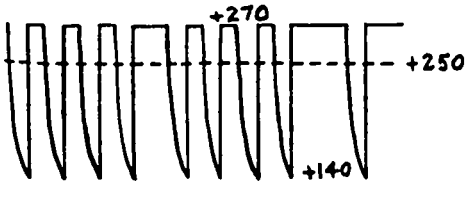
Ship V-118
Tube Type 6SL7 Pin 1 and 4 Grid
X-Signal selector 15



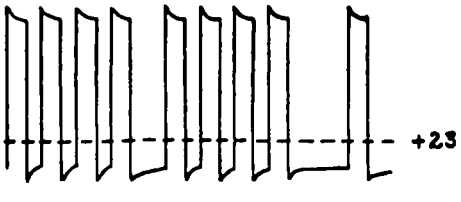
Ship V-118
Tube Type 6SL7 Pin 3 and 6 Cathode



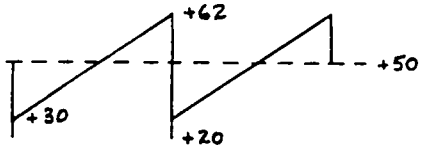
Ship V-119
Tube Type 6SN7 Pin 5 Plate



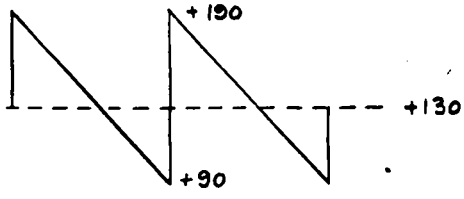
Ship V-120
Tube Type 6SN7 Pin 3 Cathode



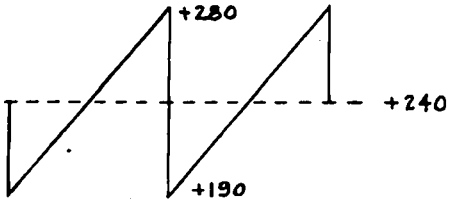
Ship V-120
Tube Type 6SN7 Pin 6 Cathode



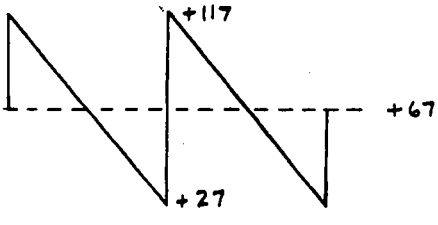
Ship V-122
Tube Type 884 Pin 3 Plate



Ship V-123
Tube Type 6SJ7 Pin 8 Plate

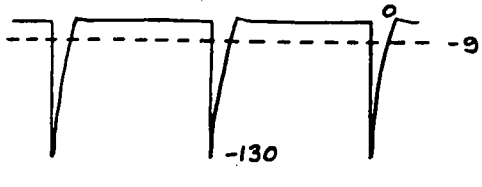


Ship V-124
Tube Type 6SL7 Pin 2 & 5 Plate



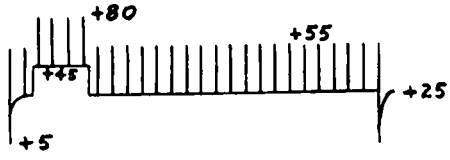
Ship V-124
Tube Type 6SL7 Pins 3 & 6 Cathode

Ship V-133 and V-134
Tube Type 5692 Pin 1 Grid



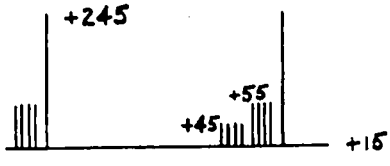
Ship V-133 and V-134
Tube Type 5692 Pin 4 Grid

6

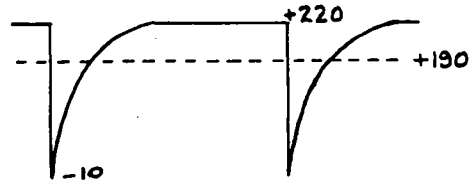


Ship V-133 and V-134
Tube Type 5692 Pin 2 & 5 Plate

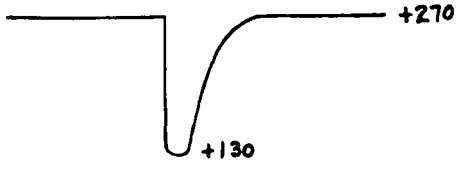
Ship V-136
Tube Type 6SN7 Pin 2 Plate



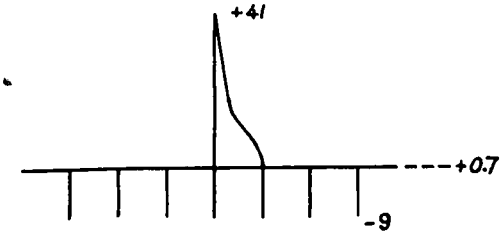
Ship V-136
Tube Type 6SN7 Pin 6 Cathode



Ship V-137
Tube Type 2050 Pin 3 Plate

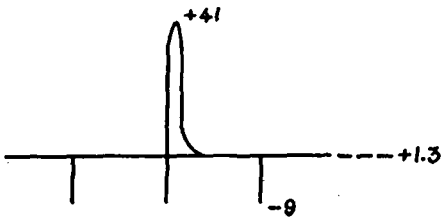


Ship V-138
Tube Type 5692 Pin 5 Plate
X-Signal selector driven sweep
Driven sweep duration - 100 us

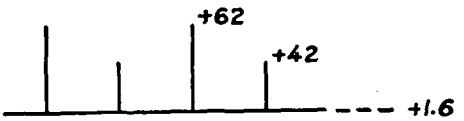


Ship V-140
Tube Type 6J6 Pins 3&8 Plate & Cathode
X Signal selector 2K
Sync to Y amplifier input

7

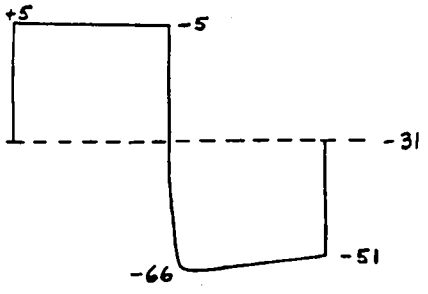


Ship V-141
Tube Type 6H6 Pins 3&8 Plate & Cathode
X Signal selector 2K
Sync to Y amplifier input

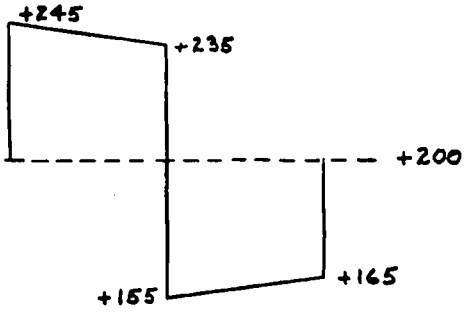


Ship V-142
Tube Type 6H6 Pins 3&8 Plate & Cathode
X Signal Selector 2K
Sync to Y amplifier input

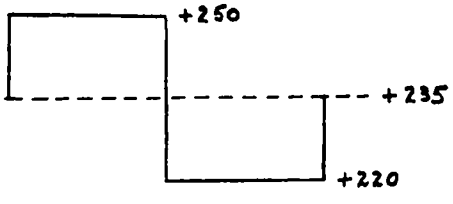
ELECTRONIC ATTENUATOR
SHIP & GROUND STATION



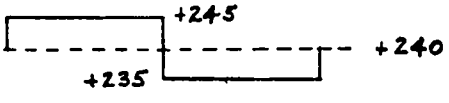
V-401 Tube Type 6AC7
Pin 4 Grid



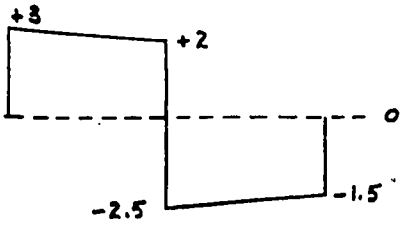
V-401 Tube Type 6AC7
Pin 6 Screen Grid



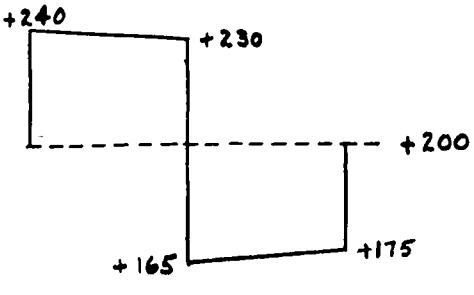
V-401 Tube Type 6AC7
Pin 8 Plate



V-402 Tube Type 6AC7
Pin 8 Plate



V-403 Tube Type 6SL7
Pin 1 Grid

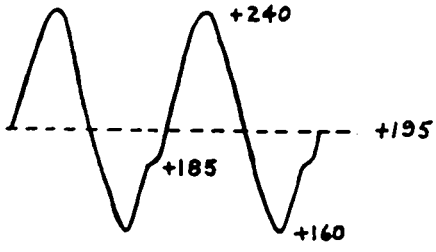


V-403 Tube Type 6AC7
Pin 2 Plate

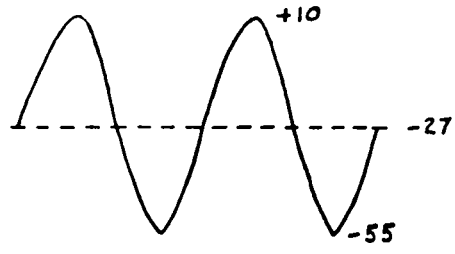
14

GROUND STATION CONTROLLER-INDICATOR

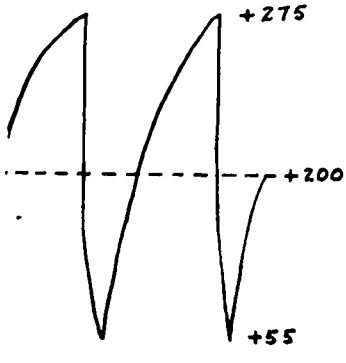
SWEEP SPEED - SLOW, FAST SWEEP - 2



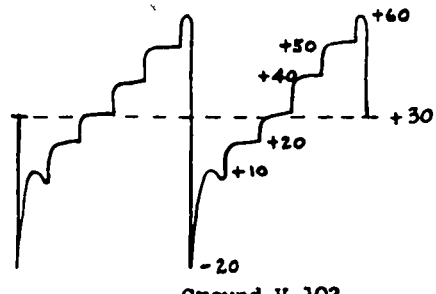
Ground V-101
Tube Type 6SJ7 Pin 8 Plate
Recvr. switch - OFF
Sweep speed - SLOW
Fast sweep - 3



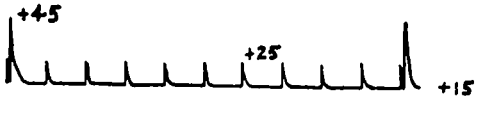
Ground V-102
Tube Type 6AC7 Pin 4 Grid
X-Signal selector driven sweep
Driven sweep duration - 100 us
Sync obtained from Pin 5 of V-115
B+ 280 volts



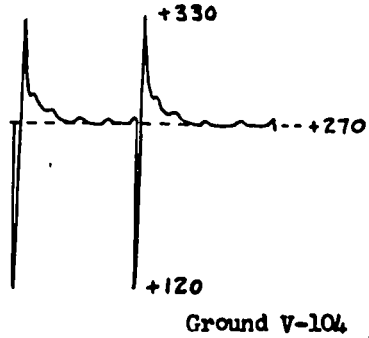
Ground V-102
Tube Type 6AC7 Pin 8 Plate



Ground V-103
Tube Type 6H6 Pin 8 Cathode
Driven sweep duration - 1000 us

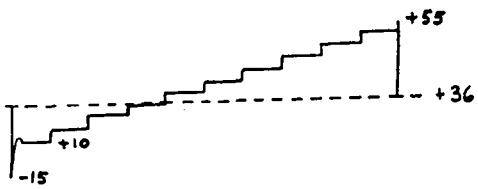


Ground V-104
Tube Type 6SN7 Pin 3 Cathode

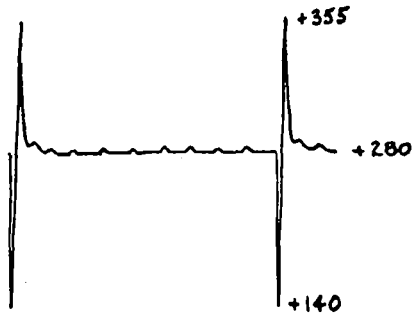


Ground V-104
Tube Type 6SN7 Pin 5 Plate

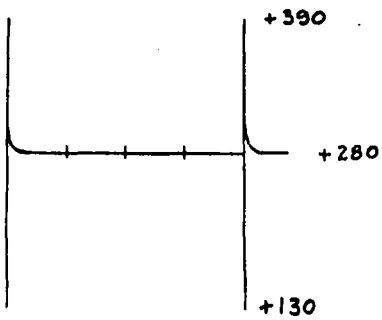
17



Ground V-105
Tube Type 6H6 Pin 8 Plate

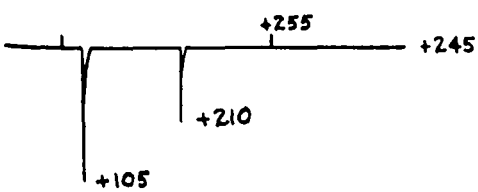


Ground V-106
Tube Type 6SN7 Pin 2 Plate

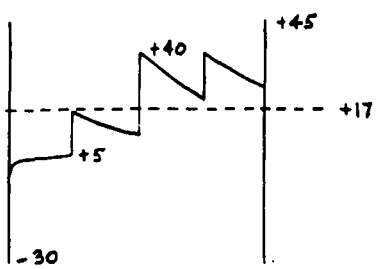


Ground V-106
Tube Type 6SN7 Pin 5 Plate
X-Signal selector 125

Ground V-107
Tube Type 5692 Pin 1 & 4 Grid
X-Signal selector 125

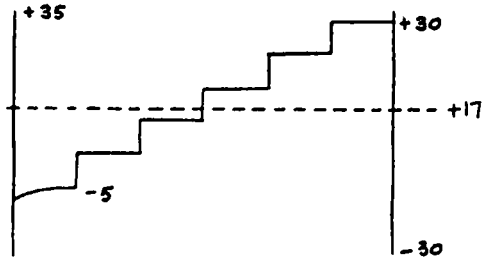


Ground V-107
Tube Type 5692 Pin 2 & 5 Plate

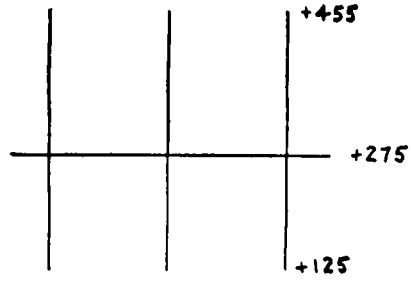


Ground V-108
Tube Type 6H6 Pin 8 Cathode
X-Signal selector 125

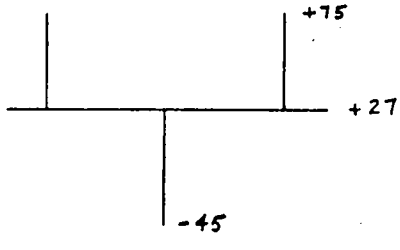
18



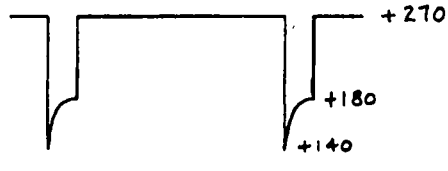
Ground V-109
Tube Type 6H6 Pin 8 Cathode
X-Signal selector 15



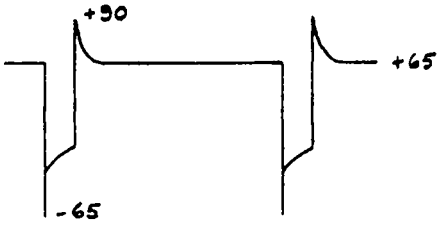
Ground V-110
Tube Type 6SN7 Pin 2 Plate



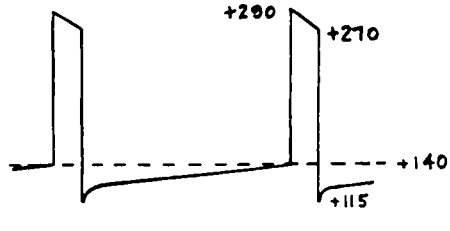
Ground V-111, V-114
Tube Type 6SN7
Pin 4 (V-111 and V-114)



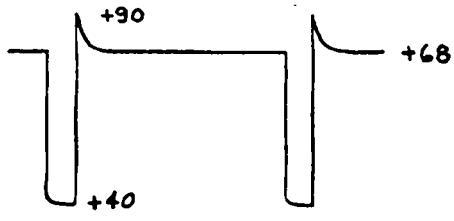
Ground V-111, V-114
Tube Type 6SN7
Pin 5 (V-111 and V-114)



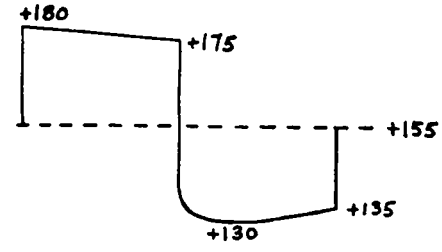
Ground V-111, V-114 Tube Type 6SN7
Pin 1 (V-111 and V-114)



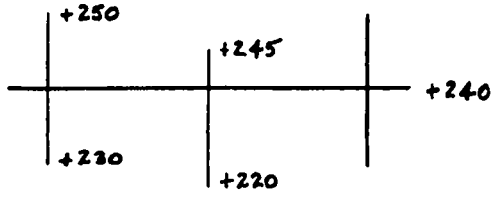
Ground V-111, V-114
Tube Type 6SN7
Pin 2 (V-111 and V-114)



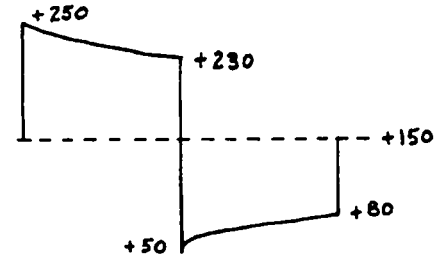
Ground V-111, V-114 Tube Type 6SN7
Pins 3 and 6 Cathode



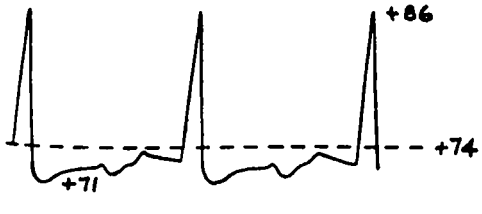
Ground V-113
Tube Type 6SN7 Pin 3 Cathode



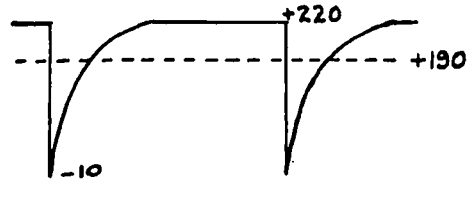
Ground V-113
Tube Type 6SN7 Pin 5 Plate



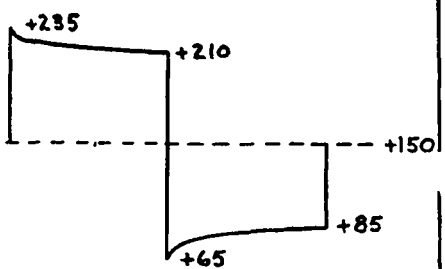
Ground V-115
Tube Type 6SN7 Pin 2 Plate



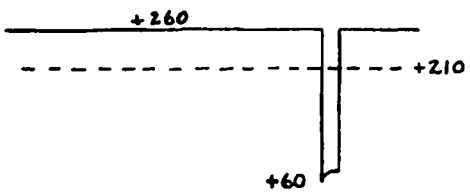
Ground V-116
Tube Type 6SL7 Pin 6 Cathode
X-Signal selector driven sweep
Driven sweep duration - 25 us
Y-Attenuation 1:1



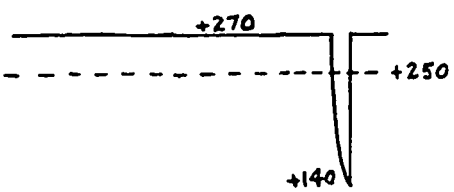
Ground V-117
Tube Type 2050 Pin 3 Plate



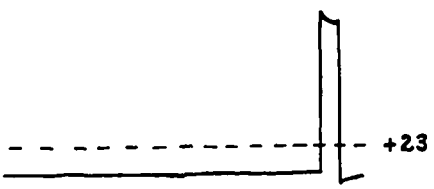
Ground V-118
Tube Type 6SL7 Pin 3 Cathode
X-Signal selector 15



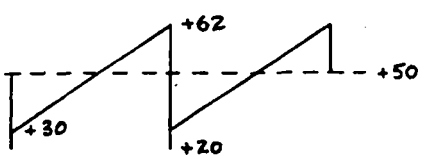
Ground V-119
Tube Type 6SN7 Pin 5 Plate



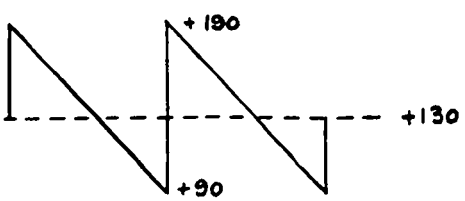
Ground V-120
Tube Type 6SN7 Pin 3 Cathode



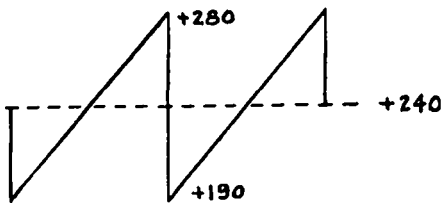
Ground V-120
Tube Type 6SN7 Pin 6 Cathode



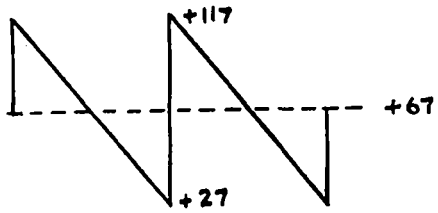
Ground V-122
Tube Type 884 Pin 3 Plate



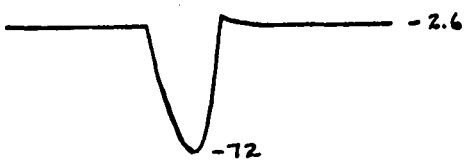
Ground V-123
Tube Type 6SJ7 Pin 8 Plate



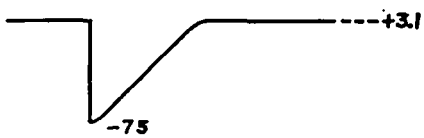
Ground V-124
Tube Type 6SL7 Pin 2 & 5 Plate



Ground V-124
Tube Type 6SL7 Pins 3 & 6 Cathode

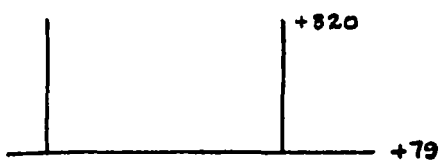


Ground V-133 and V-134
Tube Type 5692 Pin 1 & 4 Grid
X-Signal selector driven sweep
Driven sweep duration - 100 us



Ground V-133 & V-134
Pim 1 Grid
+ Signal selector 15-125

Ground V-137
Tube Type 6SN7 Pin 6 Cathode



Ground V-137
Tube Type 6SN7 Pin 2 Plate

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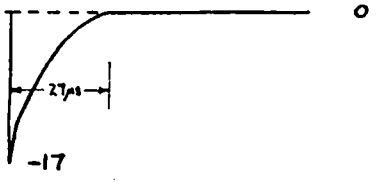
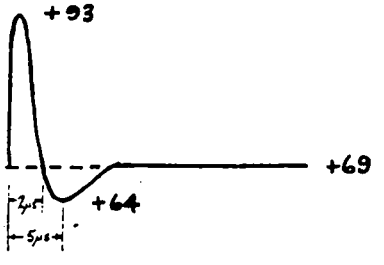
SYNCHRONIZER

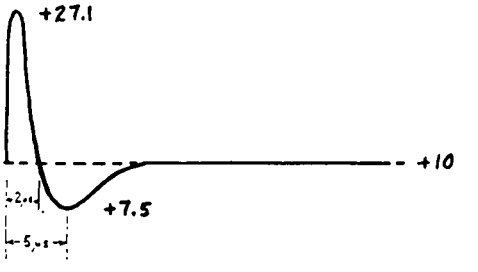


Input to C-401
Y-Attenuation 1:1
Z-Signal selector 10 us mark
Sync obtained from input to C-401

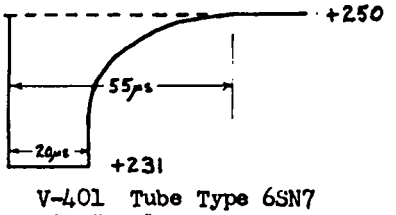
V-401
Tube Type 6SN7
Pin 1 Grid
Driven sweep duration - 5 us
Z-Signal selector 1 us mark



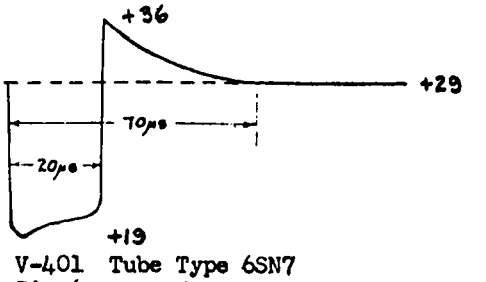
V-401
Tube Type 6SN7
Pin 2 Plate
Driven sweep duration - 25us
Sync gain -20



V-401
Tube Type 6SN7
Pin 4 Grid

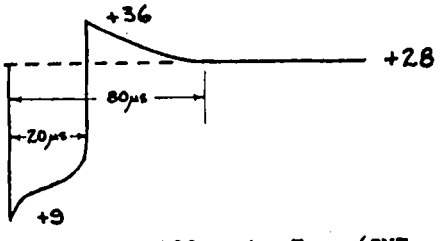


V-401 Tube Type 6SN7
Pin 5 Plate
Driven sweep duration - 100 us
Z-Signal selector 10 us Mark
R-405 adjusted for 20 us delay

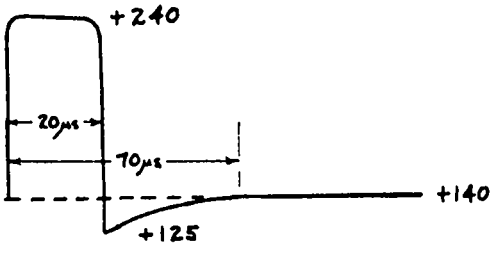


V-401 Tube Type 6SN7
Pin 6 Cathode

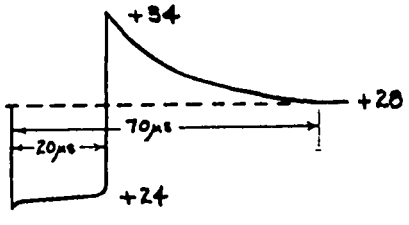
23



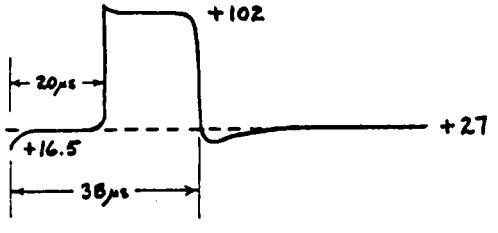
V-402 Tube Type 6SN7
Pin 1 Grid



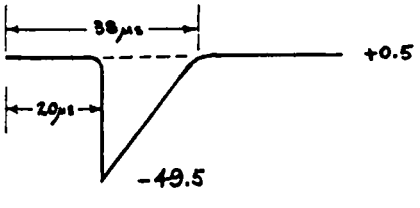
V-402 Tube Type 6SN7
Pin 2 Plate
Y-Attenuation 10:1
Y-Gain 60



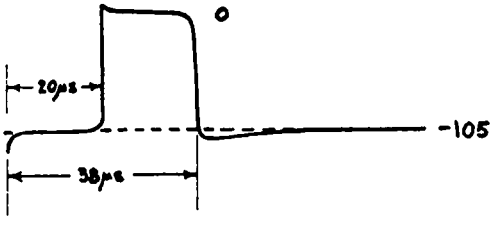
V-402 Tube Type 6SN7
Pin 6 Cathode
Y-Attenuation 1:1



V-403 Tube Type 6V6
Pin 3 Plate
Y-Attenuation 10:1
38 us adjusted by C-402

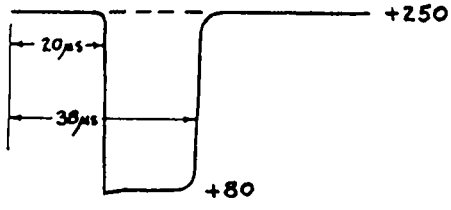


V-403 Tube Type 6V6
Pin 5 Grid



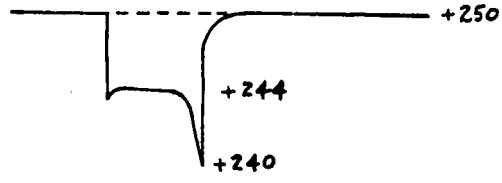
V-404 Tube Type 6SN7
Pins 1 & 2 Plate & Grid

24

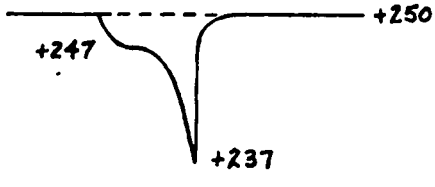


V-405 Tube Type 6V6
Pin 3 Plate

TAKEN WHILE "IN SYNC"

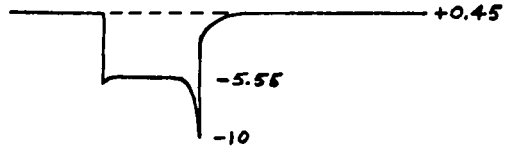


V-406 Tube Type 6SJ7
Pin 8 Plate
Y-Attenuation 1:1
Slow speed on Indicator



V-406 Tube Type 6SJ7
Pin 8 Plate
Fast speed on Indicator

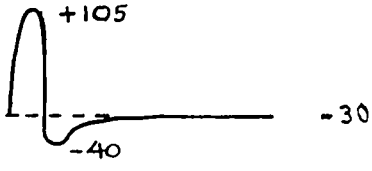
TAKEN WHILE "IN SYNC"



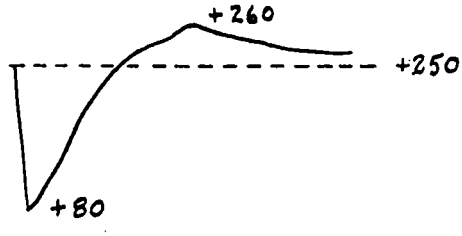
V-407 Tube Type 6SN7
Pin 3 Cathode
Slow speed on Indicator

26

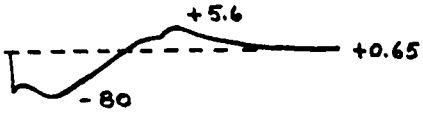
MODULATOR
SHIP & GROUND STATION



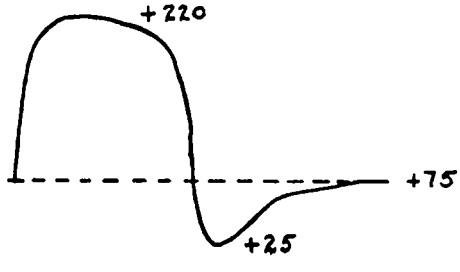
V-201 Tube Type 6SN7
Pin 1 Grid
X-Signal selector driven sweep
Driven sweep duration - 100 us



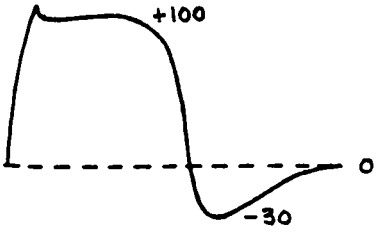
V-201 Tube Type 6SN7
Pin 2 Plate



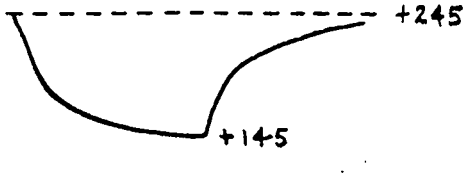
V-202 Tube Type 6SN7
Pin 1 Grid



V-202 Tube Type 6SN7
Pin 2 Plate



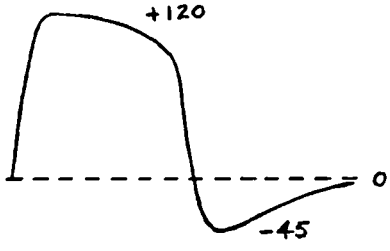
V-202 Tube Type 6SN7
Pin 4 Grid



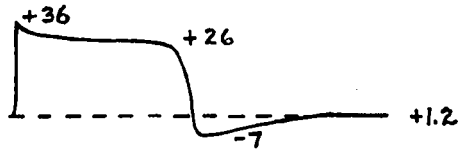
V-202 Tube Type 6SN7
Pin 5 Plate

15

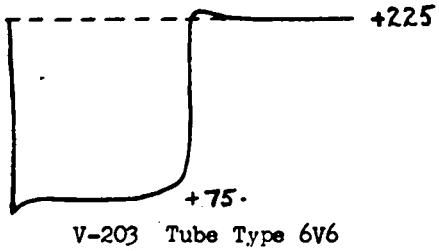
983449—52——11



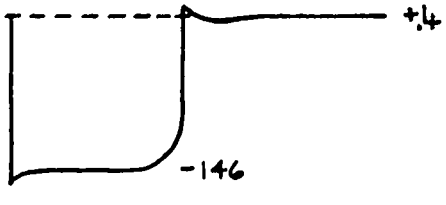
Between C-221 and R-214, C-208



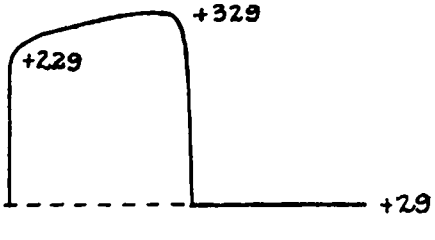
V-203 Tube Type 6V6
Pin 5 Grid



V-203 Tube Type 6V6
Pin 3 Plate



V-204 Tube Type 807
Pin 3 Grid



V-204 Tube Type 807
Cap Plate

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XV

LIST OF EPI EQUIPMENT AND MATERIALS NEEDED FOR SHIP AND GROUND STATIONS, TO BE SUPPLIED BY THE USER

15.100 SHIP-STATION MATERIAL

200 feet of coaxial cable, type RG–10/U
300 feet of antenna wire, bronze, stranded, No. 10
200 feet of power cable, armored, 2-wire, No. 8, copper
4 antenna insulators, 12-inch
2 boxes of spare parts
1 lead-in insulator, bowl type, about 4-inch
The EPI and other items required for the ship station are found in paragraph **1.600.**

15.200 SHIP-STATION TEST INSTRUMENTS

1 Vacuum tube voltmeter, such as RCA Voltohmyst, Jr.
1 Test set, volt-ohm-milliammeter, Simpson 260 or Triplett 630
1 Oscilloscope, DuMont type 248, with manual

15.300 SHIP-STATION TOOLS

On most ships there are sufficient tools in the radio department to service the EPI. If this is not so, the tools listed in **15.600** will give the minimum needed.

15.400 GROUND-STATION INSTRUMENTS AND MATERIAL

1 Communication receiver (Hallicrafter SX-71) with manual
1 Communication transmitter (Johnson Viking 1) with manual
1 Clock, wind type, with second hand (like sounding clock)
1 Clock, alarm
1 Fuse box, 60-ampere, with four 15-ampere branch circuits
1 Switch box, DPDT, 30 to 60 amperes, for selecting generators
1 Voltmeter, 0–150-volt, AC, mounted, for use in power shelter
2 Generators, PE–75 or equivalent, gasoline-driven, with spare parts, manual, tools, flaring tool for copper lines, funnels, flexible coupling for gasoline line, and fittings
50 feet of ¼″ copper tubing for generators and stoves
8 Receptacles, duplex, with box and fittings
8 Light outlets, with box and fittings
1 box of 100-watt light bulbs
1 box of 60-watt light bulbs
1 box of 35-ampere cartridge fuses
1 box of 15-ampere plug fuses

1 Electric lantern
3 Flashlights and batteries
100 feet of power cable, 2-wire, number 8 stranded, copper, Simplex Tyrex, or equal
150 feet of Romex cable for power and light wiring
250 feet of portable 110-volt cable, type SJO, for tower lighting
300 feet iron wire, number 10 or 12
250 feet coaxial cable, type RG–8/U
5,500 feet ground wire, copper, number 12 to 16, solid or stranded
100 feet hook-up wire
200 feet antenna wire, copper, number 12, stranded, for communications
2 Bowl insulators, 1- or 2-inch, for communication antenna lead-ins
4 Antenna insulators, 4-inch, for communication antennas
2 25- to 30-foot poles to support the receiver and transmitter communication antennas
2 Pulleys, for communication antennas
100 feet of small line for hoisting communication antennas
100 feet of ⅜″ boat chain for dead-men
4 1- by 30-inch iron pins for tower base
10 feet of ⅜-inch copper tubing for antenna to coupler connections
4 large solder lugs to fit ⅜-inch tubing
24 Solder lugs, 50-ampere size
2 Tower lighting chokes, J. W. Miller Co. type 7870, 1.1-mH, 5-ampere, .56 ohm resistance
3 Fire extinguishers
1 lot of assorted sandpaper
1 14-inch Stillson wrench
1 Hacksaw
2 rolls of friction tape
2 rolls of rubber tape
5 pounds of solid solder, with paste, for soldering the ground system
1 pound of rosin-core solder
32 Stakes, iron or wood, 24 inches long, to hold the ends of ground system wire

15.500 GROUND-STATION TEST INSTRUMENTS

1 Test set, volt-ohm-milliammeter, Triplett 630 or Simpson 260, with high-voltage probe (optional)
1 Tachometer to check speed of PE–75. This instrument is convenient when first adjusting the engine, but needed little after that.
1 Frequency meter for power circuits (optional)

15.600 GROUND-STATION TOOLS

1 box of tools to service the electronic equipment here listed:
- 1 pair diagonal cutting pliers
- 1 pair long-nose needle-point pliers
- 1 pair gas pliers, thin-nose combination
- 1 pair electrician pliers
- 6 Assorted screwdrivers

1 Tuning stick
1 set Spintite wrenches
1 250-watt Weller soldering gun or 100-watt soldering iron
1 Phillips screwdriver
1 set Allen wrenches
1 Hone for generator commutator

1 box of tools for camp use:
1 Shovel
1 Claw hammer
1 Sledge hammer
1 Cross-cut saw
1 Pinch bar
1 Ax
1 set Crescent wrenches, 6 to 12 inches
1 Blow torch
1 bag assorted nails
1 box assorted screws

1 lot of tools needed during construction of camp but not needed at camp:
1 Post-hole digger
1 Mattock
1 assorted set of end, box, and Crescent wrenches for assembling the EPI antenna tower

15.700 FUEL FOR GROUND STATION

Normal practice is to have a 55-gallon drum of gasoline supplying each engine.

10 drums 80-octane gasoline, sufficient for a month of continuous operation

20 gallons lubricating oil, SAE No. 30

1 drum white gas (Blazo) for cookstoves, lanterns, and blowtorch (when not used for cooking, this may be reduced)

5 drums stove oil for heating and cooking for a 1-month period

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SPARE PARTS—SHIP AND GROUND STATION

It is seldom practical to keep each ground station completely supplied with spare parts. To furnish complete spare-parts protection would entail an expense many times the amount that would furnish ninety percent protection. The list of ground-station spares, listed in paragraph **16.200**, should cover most expected emergencies.

However, the ship should carry a spare-parts kit for the ground station, which will include those parts which were not in the ground-station spares. One of these kits should suffice for two or three ground stations, as most of these parts are duplicated in the ship-station spares. The ground-station spares kept on the ship will be known as ship-ground-station spares and are listed in **16.300**.

A careful record should be kept of spares; a note should be made when parts are removed. After removing, these parts should be replaced as soon as practical. Unless there is good storage space at hand, it is better to keep spare parts in their boxes; however, the boxes should be kept near the equipment. Fuses should be kept handy to the instrument where they are used.

16.100 SHIP-STATION SPARE PARTS AND TUBES

Only that information essential to identify the parts is given here. When further information is needed, such as for ordering parts, this additional data should be taken from parts in the instrument.

Ship spares can be stowed in two containers of 4,000 cubic inches each. The division of stowage should be made in accordance with the following lists:

16.101 Spare Components

1 High-voltage transformer, T–103, for transmitter
1 Filament transformer, T–102, for transmitter
1 Filament transformer for modulator T–202, S–54
1 Plate transformer for receiver T–305, 12638
1 Plate transformer for controller power supply T–201, PSR–300
1 Plate transformer for indicator T–106
1 Filter choke for modulator L–203, RC–8105
1 Filter choke for indicator L–103
1 Filter choke for controller power supply L–501, RC–8300
1 Filament transformer for controllers T–4 and T–5, F–610
1 Trigger transformer for controller T–103
1 100-kc transformer for controllers T–1 and T–2, D–99917
1 Coupling transformer for controllers T–11 and T–12, ST–311
1 40-mh choke for transmitter L–105
1 2-mf 7500-volt condenser for transmitter
1 1.5-amp rf meter

16.102 Spare Tubes

2—2A3	2—6BN6*	2—6X5
2—2AC15*	4—6H6	2—VR105
2—2X2	2—6L6	2—VR150
3—5U4G	2—6SA7	2—807
3—5Y3	3—6SJ7	1—884
1—5CP1	3—6SK7	2—1236
4—6AC7	3—6SL7	1—2050*
2—6AG7	8—6SN7	2—5692
2—6B4G	2—6V6	

*When Sorensen regulator is used, 2AC15 is required; when Superior regulator is used, 1236 and 6BN6 are required.

1 100-mmf 20,000-volt vacuum condenser
1 box, each, of 3-, 5-, and 7½-amp Littlefuse AGC or 3AG
1 40-mf electrolytic condenser
2 20-20-50-mf condensers
2 4-mf 600-volt condensers
2 1-mf 600-volt bathtub condensers
2 0.25-mf 600-volt bathtub condensers
1 0.25-mf 2,000-volt condenser
2 0.25-mf 5,000-volt condensers
2 0.1-mf 600-volt bathtub condensers
1 0.5-mf 600-volt bathtub condenser
1 8-mf 600-volt condenser, oil
1 0.002-mf 6,000-volt condenser
1 15-mmf 20,000-volt vacuum condenser
1 0.003-mf 12,500-volt mica condenser
1 0.0015-mf 12,500-volt mica condenser
1 4-mf 2,000-volt condenser
1 box of assorted condensers (see list under paragraph **16.104**)
1 box of assorted resistors (see list under paragraph **16.103**)
1 40K 10-watt resistor
1 60K 40-watt resistor
1 10K 20-watt resistor
1 10K 10-watt resistor
1 2K 10-watt resistor
1 5-ohm 100-watt resistor
1 1-meg potentiometer
1 500K potentiometer
1 100K potentiometer
1 25K potentiometer
1 10K potentiometer
1 15K potentiometer
1 5K potentiometer
1 Step-charger transformer 12524
1 2.5-mh choke

16.103 Resistors (in ohms) contained in Box of Assorted Resistors—Ship Station

ONE-HALF-WATT

1—39
1—51
1—68
1—100
1—150
2—180
2—220
1—330
1—470
1—680
1—1K
1—1.5K
1—2.2K
1—3.3K
1—4.7K
1—6.8K
1—8.2K
1—10K
1—15K
1—22K
2—33K
1—47K
1—68K
2—100K
2—150K
1—220K
1—330K
1—470K
1—680K
2—1M
1—2M
2—3.3M
1—10M
1—20M

ONE-WATT

1—51
1—68
1—100
1—150
1—220
1—330
1—470
1—680
2—1K
1—1.5K
2—2.2K
1—3.3K
2—4.7K
1—6.8K
2—10K
1—15K
1—22K
1—33K
1—47K
1—68K
1—75K
1—82K
2—100K
2—220K
1—330K
1—470K
1—680K
2—1M
1—3.3M
1—6.8M
1—10M

TWO-WATT

1—2.2K
2—5K
2—10K
1—20K
1—50K
1—100K

16.104 Condensers contained in Box of Assorted Condensers—Ship Station

MICA CONDENSERS

1—5-mmf 600-volt.
2—10-mmf 600-volt.
4—25-mmf 600-volt.
4—50-mmf 600-volt.
1—75-mmf 600-volt.
1—100-mmf 600-volt.
1—150-mmf 600-volt.
1—200-mmf 600-volt.
1—240-mmf 600-volt.
1—330-mmf 600-volt.
2—500-mmf 600-volt.
1—800-mmf 600-volt.
2—0.001-mf 600-volt.
1—0.0015-mf 600-volt.
2—0.002-mf 600-volt.
2—0.005-mf 600-volt.
6—0.01-mf 600-volt.
1—0.01-mf 1,000-volt.

PAPER CONDENSERS

6—0.01-mf 600-volt.
1—0.02-mf 600-volt.
1—0.05-mf 600 volt.

16.200 GROUND-STATION SPARE PARTS AND TUBES

Ground-station spares can be stowed in a container of about 4000 cubic inches. The list under paragraph **16.201** contains spare tubes for all units except the transmitter tubes, which require special packing.

983449—52——12

16.201 List of Spares

1 box, each, of 3-, 5-, and 7½-amp Littlefuse AGC or 3AG
1 box of assorted resistors (see list in **16.202**)
1 box of assorted condensers (see list in **16.203**)
3 15K 10-watt resistors
1 10K 20-watt resistor
2 2K 10-watt resistors
1 5-ohm 100-watt resistor
1 1-meg potentiometer
1 500K potentiometer
1 100K potentiometer
1 25K potentiometer
1 15K potentiometer
1 10K potentiometer
1 5K potentiometer
1 40-mf electrolytic condenser for receiver
2 20–20–50-mf electrolytic condensers
1 4-mf 2,000-volt condenser
2 4-mf 600-volt condensers
1 1-mf 600-volt condenser
2 0.25-mf bathtub-type condensers
1 0.25-mf 2,000-volt condenser
2 0.25-mf 5,000-volt condensers for transmitter
2 0.1-mf bathtub-type condensers
1 0.003-mf 12,500-volt mica condenser
1 0.0015-mf 12,500-volt mica condenser
1 0.002-mf 6,000-volt mica condenser
1 100-mmf vacuum condenser
1 100-mmf 2,500-volt mica condenser
1 2.5-mf rf choke
1 Step-charger transformer 12524

2—2AC15*	1—6AQ5	2—6SJ7
2—2A3	4—6AU6	5—6SK7
2—2X2	1—6BA6	2—6SL7
3—3B24	1—6BE6	8—6SN7
2—3E29	2—6BN6*	2—6V6
1—4D32	2—5692	2—6X5
1—5CP1	1—6C4	2—VR105
1—5R4	4—6H6	2—VR150
2—5U4	1—6K6	3—807
5—5Y3	4—6L6	1—884
1—5Z4	2—6SA7	2—1236*
2—6AC7	1—6SC7	1—2050
2—6AL5		

*When Sorensen regulator is used, 2AC15 is required; when Superior regulator is used, 1236 and 6BN6 are required.

16.202 Resistors (in Ohms) Contained in Box of Assorted Resistors—Ground Station

ONE-HALF-WATT

1—50
1—100
1—150
1—330
1—680
1—1.5K
1—3.3K
2—10K
2—15K
1—22K
2—100K
1—220K
1—500K
2—1M
1—2.2M

ONE-WATT

1—200
1—500
1—1K
1—5K
1—10K
2—25K
2—50K
1—80K
2—100K
1—500K
2—1M

TWO-WATT

1—2.2K
2—5K
2—10K
2—25K
2—50K
2—100K

16.203 Condensers Contained in Box of Assorted Condensers—Ground Station

MICA CONDENSERS

1—5-mmf 600-volt.
2—10-mmf 600-volt.
1—30-mmf 600-volt.
2—50-mmf 600-volt.
2—75-mmf 600-volt.
1—100-mmf 600-volt.
1—150-mmf 600-volt.
1—240-mmf 600-volt.
1—330-mmf 600-volt.
1—510-mmf 600-volt.
1—800-mmf 600-volt.
1—0.001-mf 600-volt.
1—0.002-mf 600-volt.
1—0.005-mf 600-volt.
2—0.01-mf 600-volt.
1—0.01-mf 1,000-volt.

PAPER CONDENSER

2—0.01-mf 600-volt.

16.300 GROUND-STATION SPARES CARRIED ON SHIP

These are the spares that will seldom be needed for repairing ground-station equipment. One set of these spares should suffice for two or three ground stations. These spares can be contained in a box of about 4000 cubic inches.

1 C103, 2-mf 7,500-volt condenser for transmitter
1 L101, Oscillator coil for controller
1 L103, Filter choke for controller
1 L105, 40-mh choke for transmitter
1 L203, Filter choke for modulator RC–8105
1 M102, 1.5-amp rf meter
1 T101, Oscillator transformer for controller
1 T102, Filament transformer for transmitter
1 T103, High-voltage transformer for transmitter
1 T106, Plate transformer for controller
1 T107, Trigger transformer for controller
1 T201, Plate transformer for modulator PSR–300
1 T202, Filament transformer for modulator S–54
1 T305, Plate transformer for receiver No. 12638
1 T401, Plate transformer for synchronizer PSR–105
1 T402, Filament transformer for synchronizer S–65

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XVII

PHOTOGRAPHS OF INSTRUMENTS

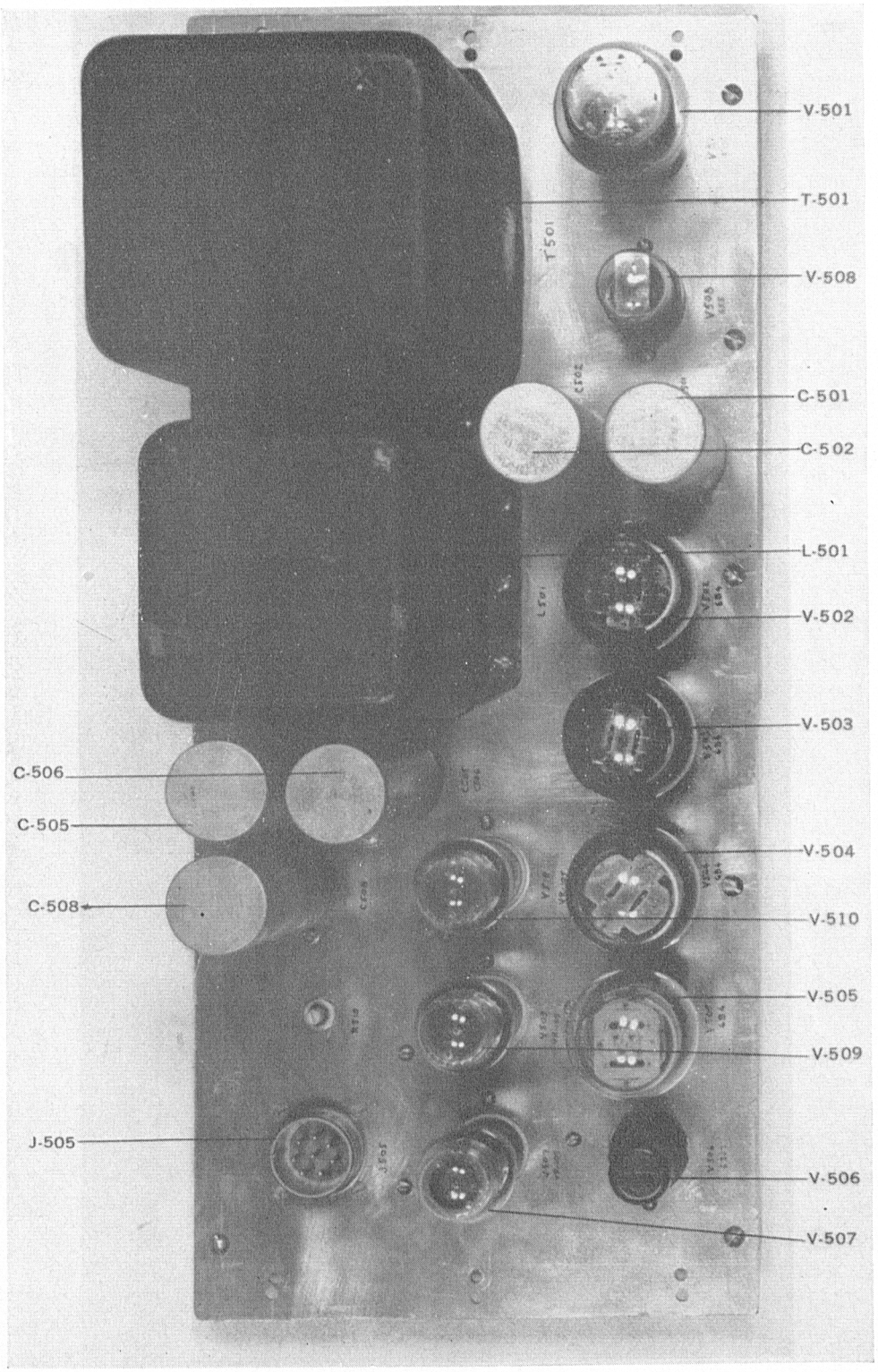

FIGURE 31.—Ship Controller Power Supply (top view).

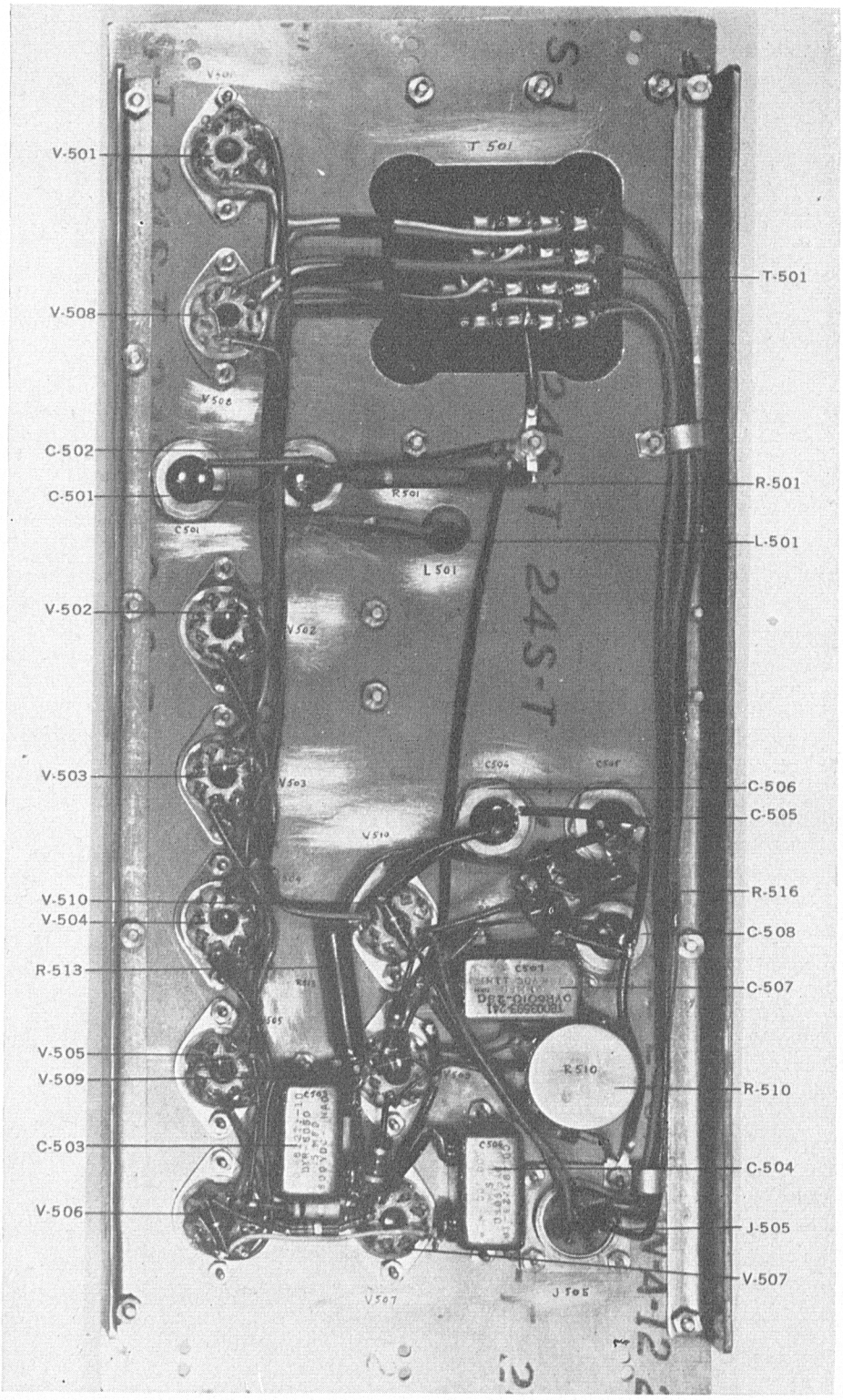

FIGURE 32.—Ship Controller Power Supply (bottom view).

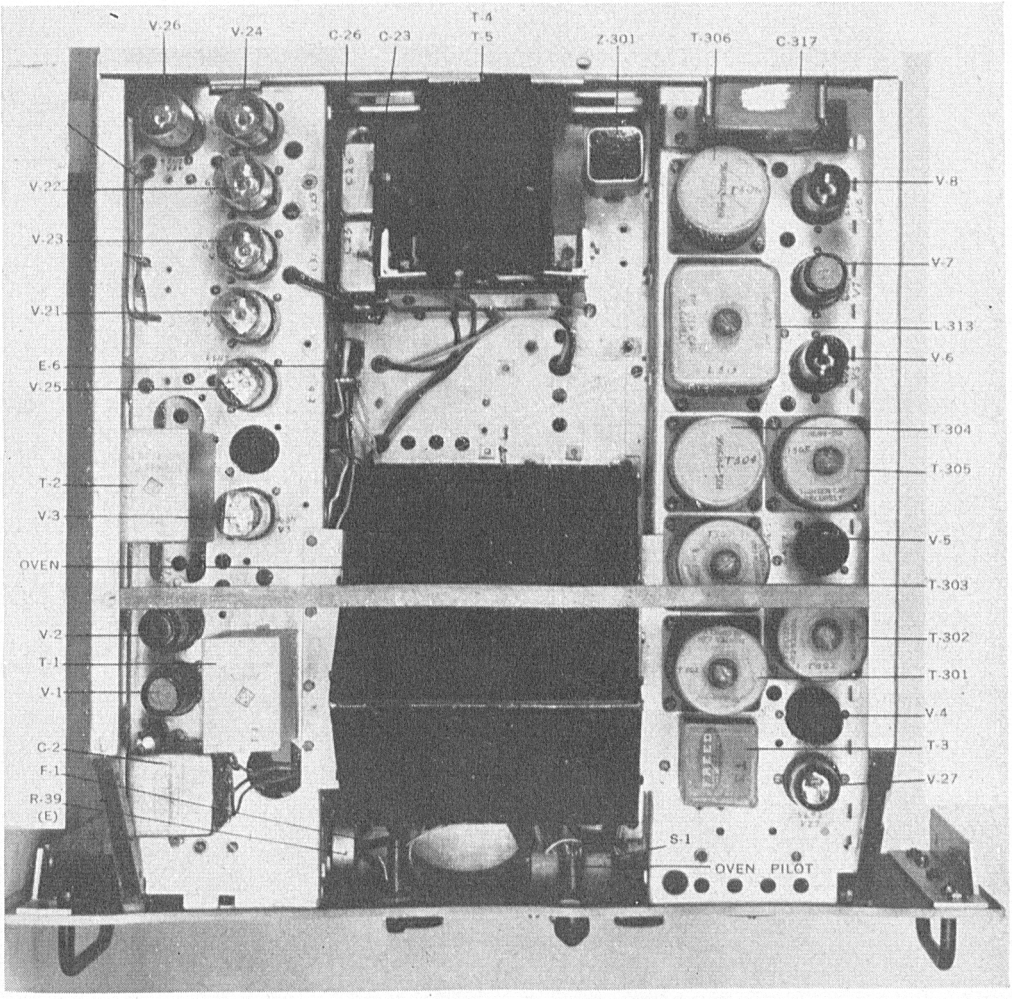

FIGURE 33.—Ship Controller (top view).

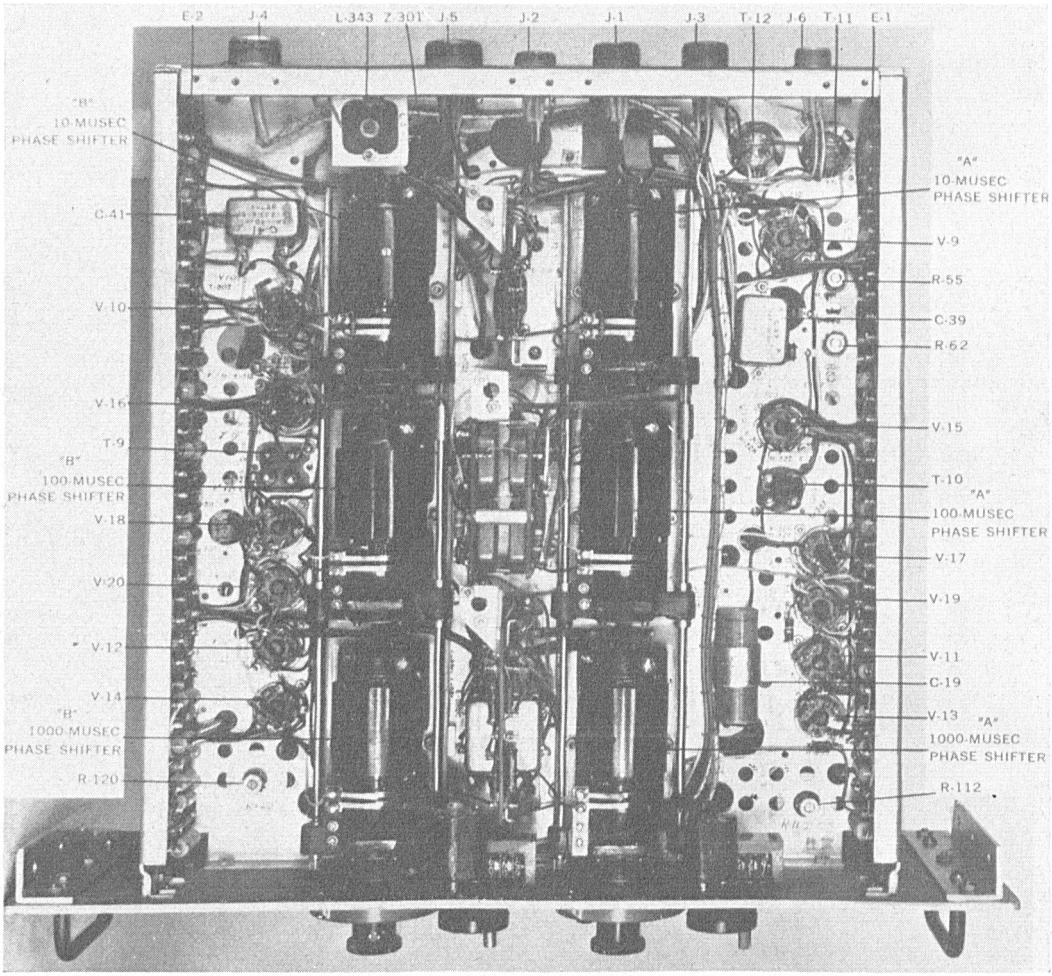

FIGURE 34.—Ship Controller (bottom view).

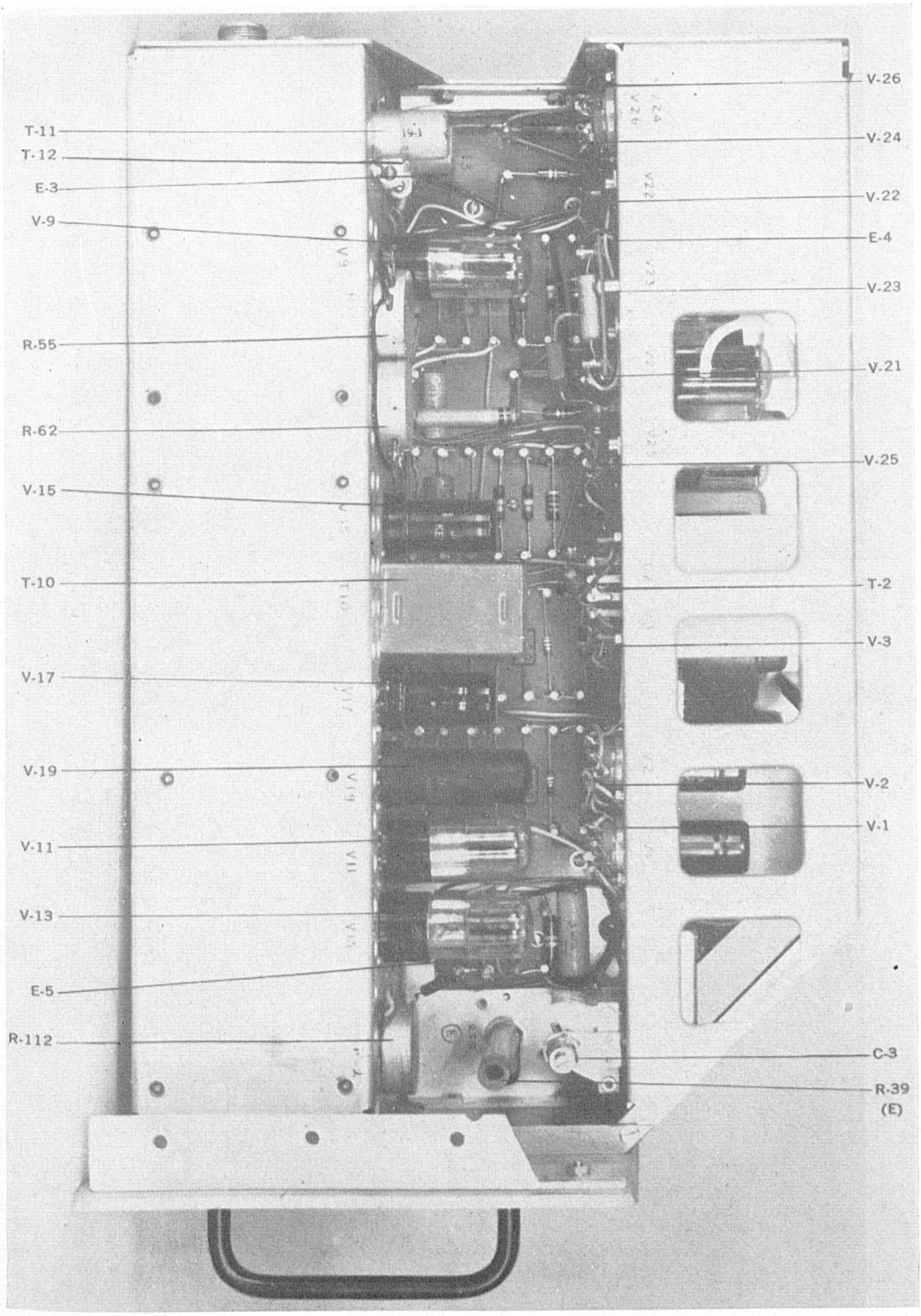

FIGURE 35.—Ship Controller (left side).

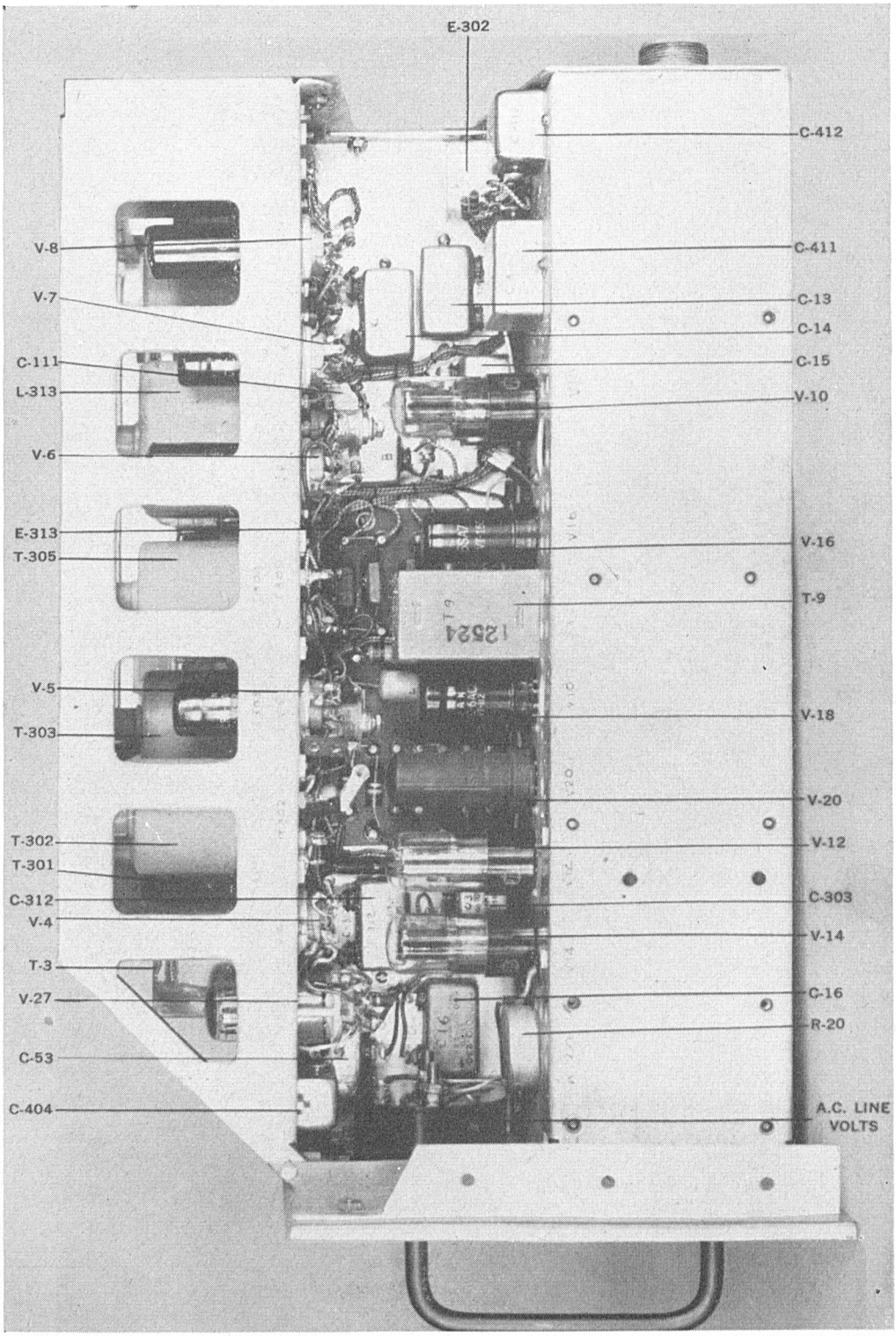

FIGURE 36.—Ship Controller (right side).

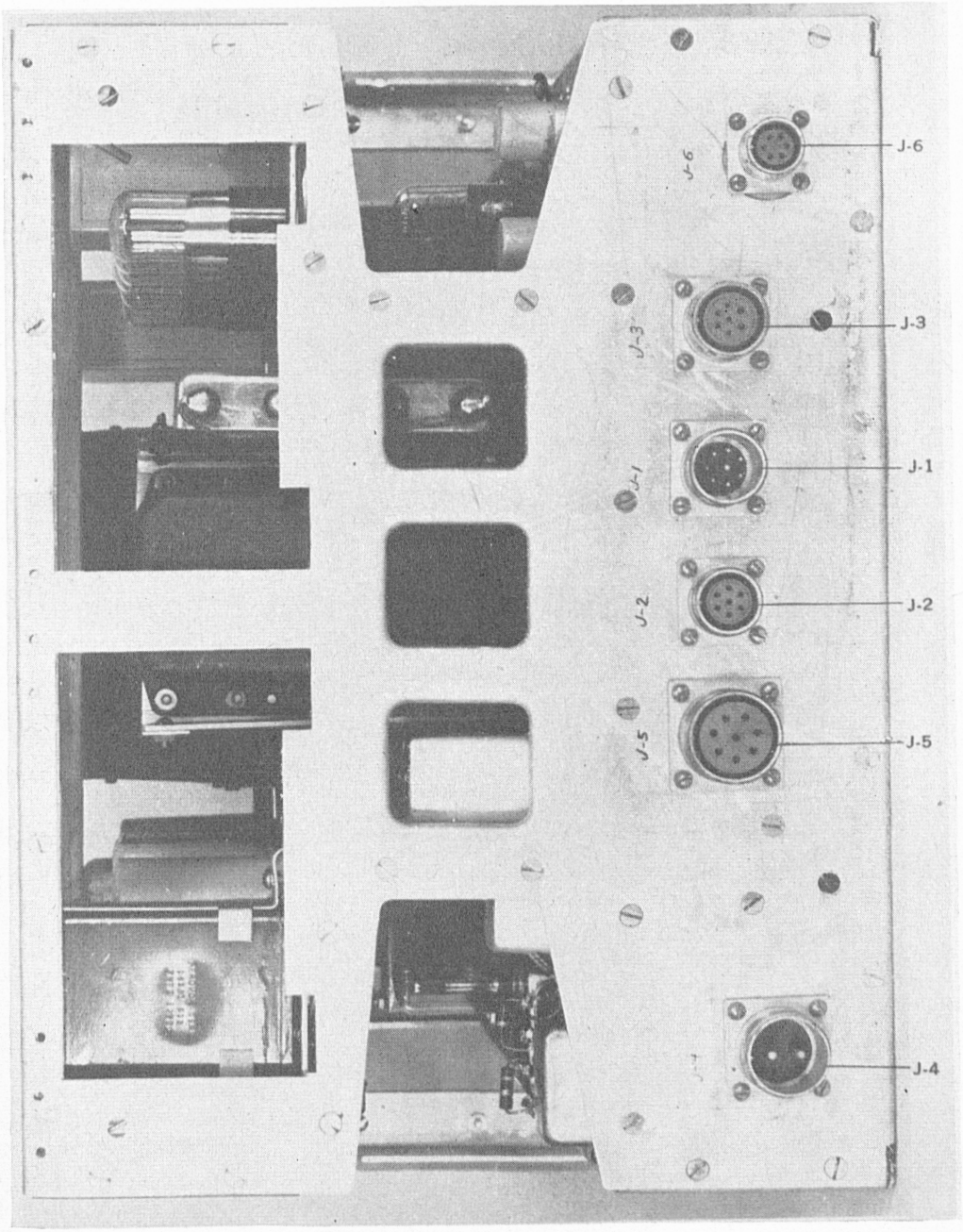

FIGURE 37.—Ship Controller (back view).

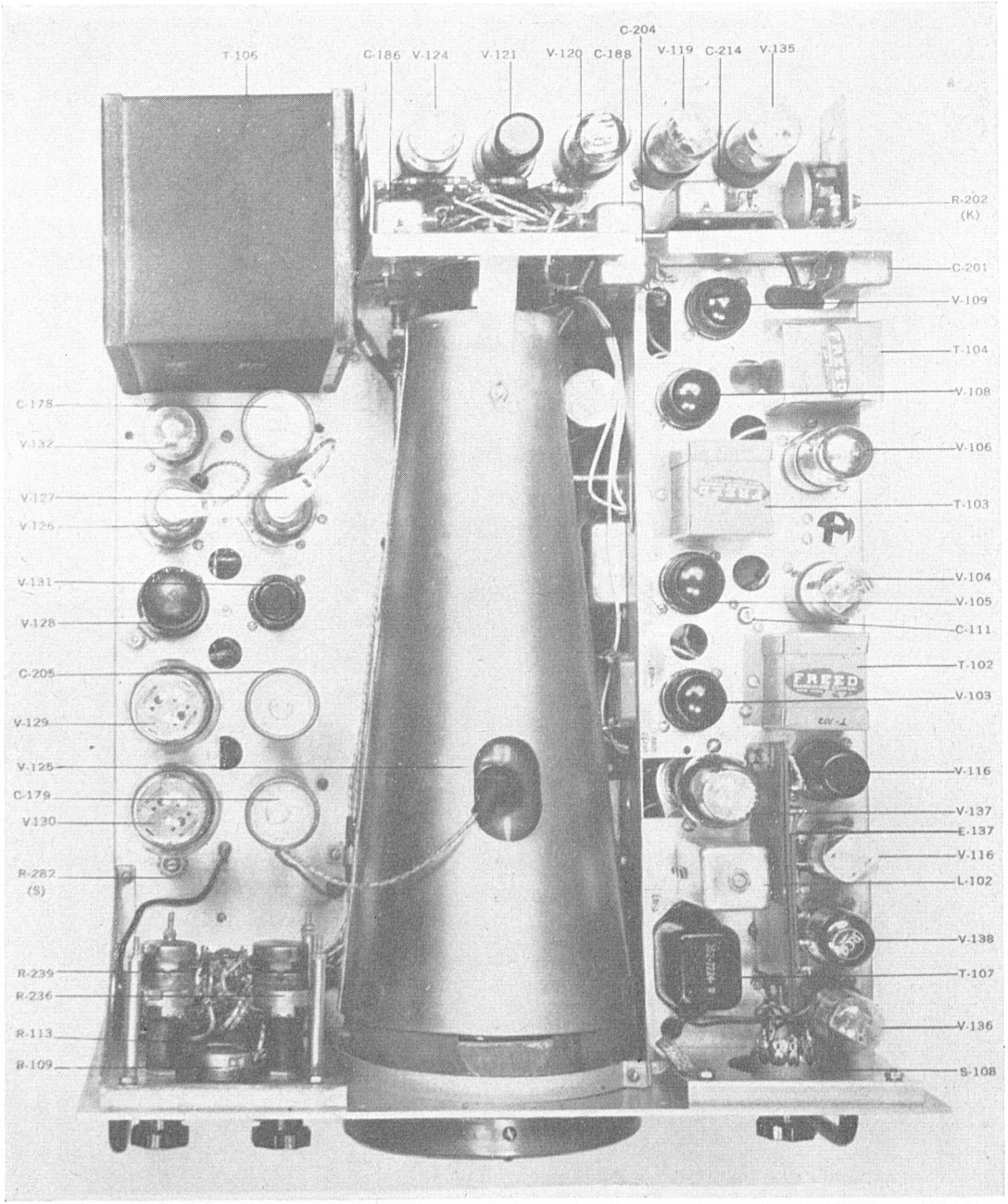

FIGURE 38.—Ship Indicator (top view).

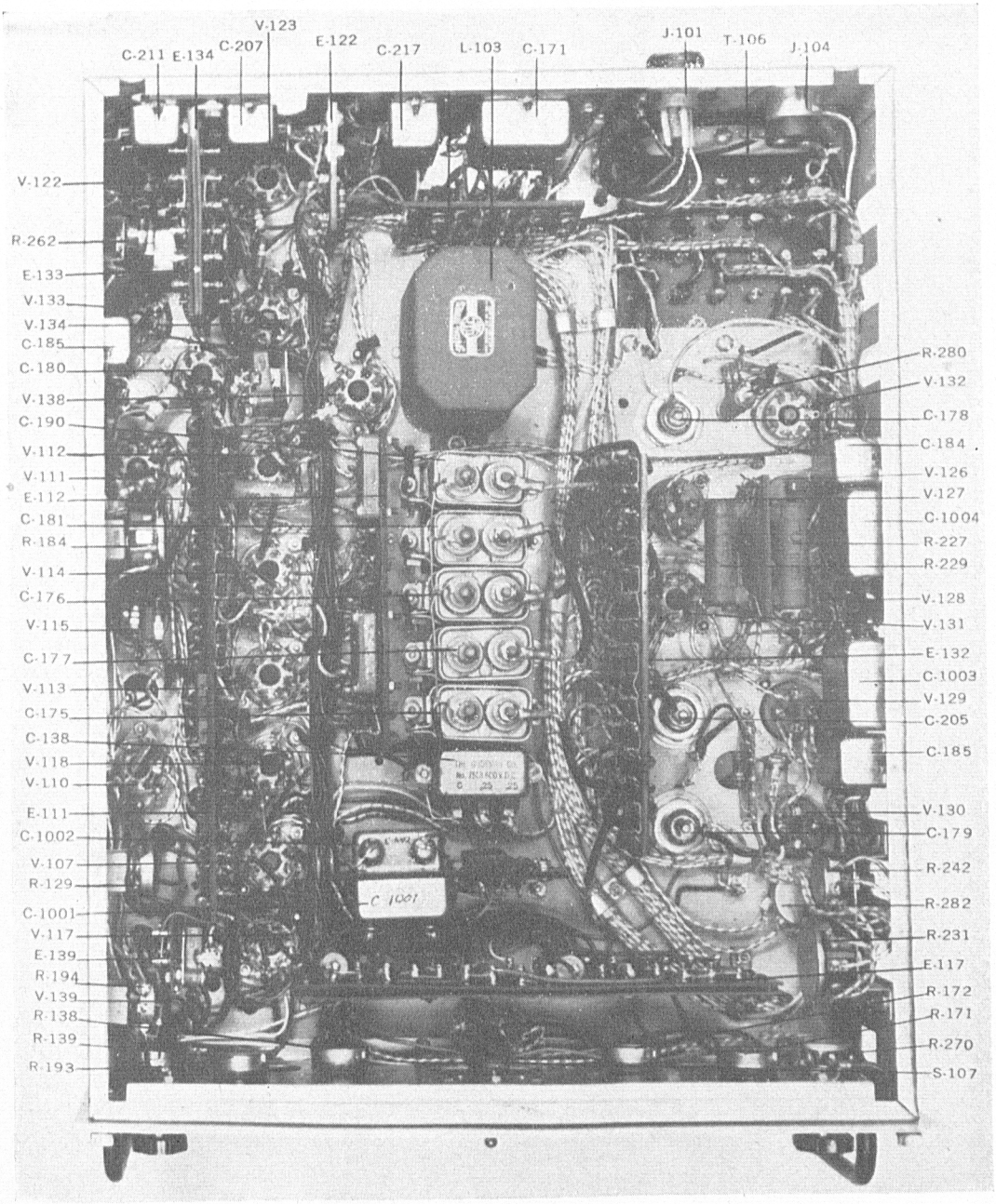

FIGURE 39.—Ship Indicator (bottom view).

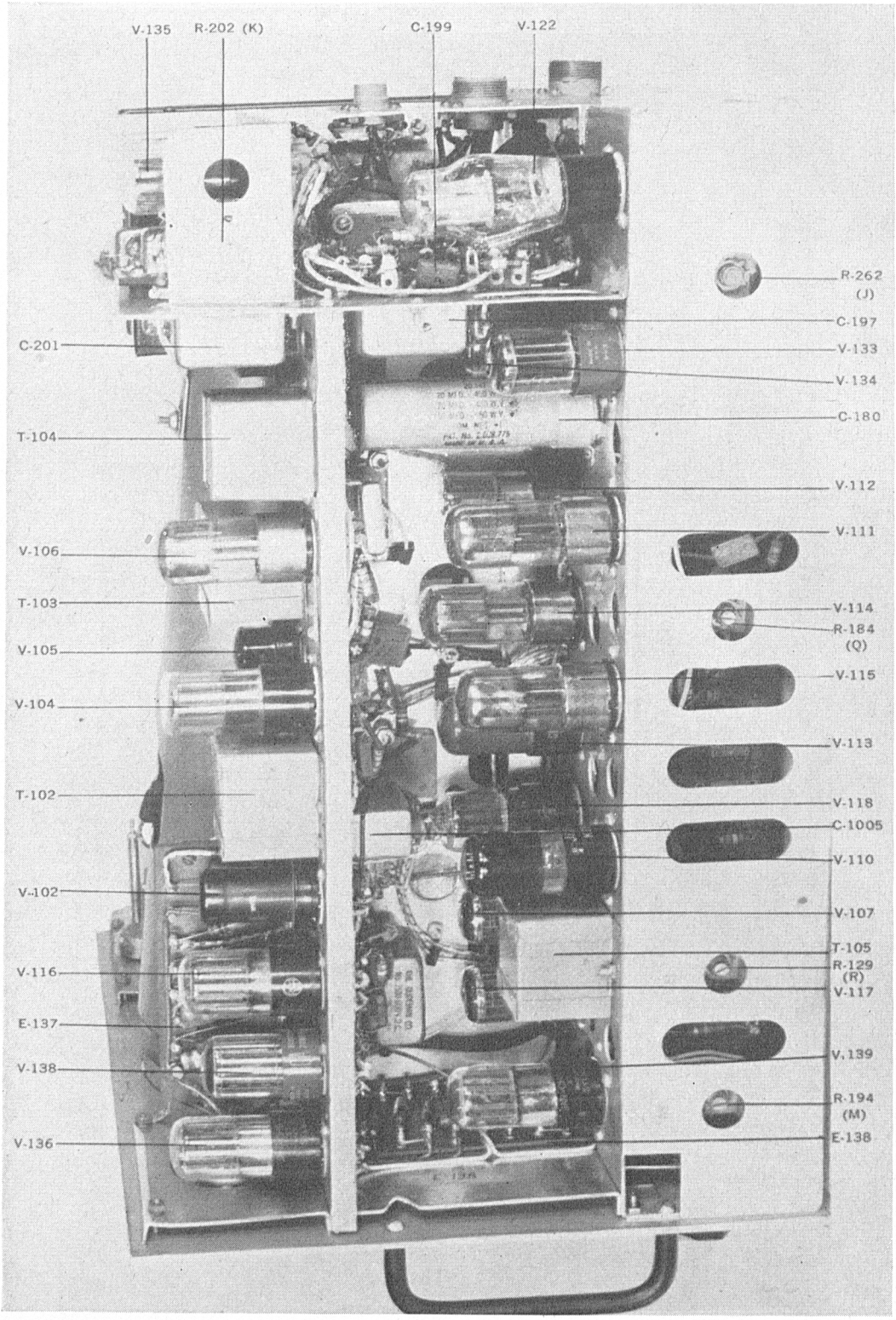

FIGURE 40.—Ship Indicator (right side)

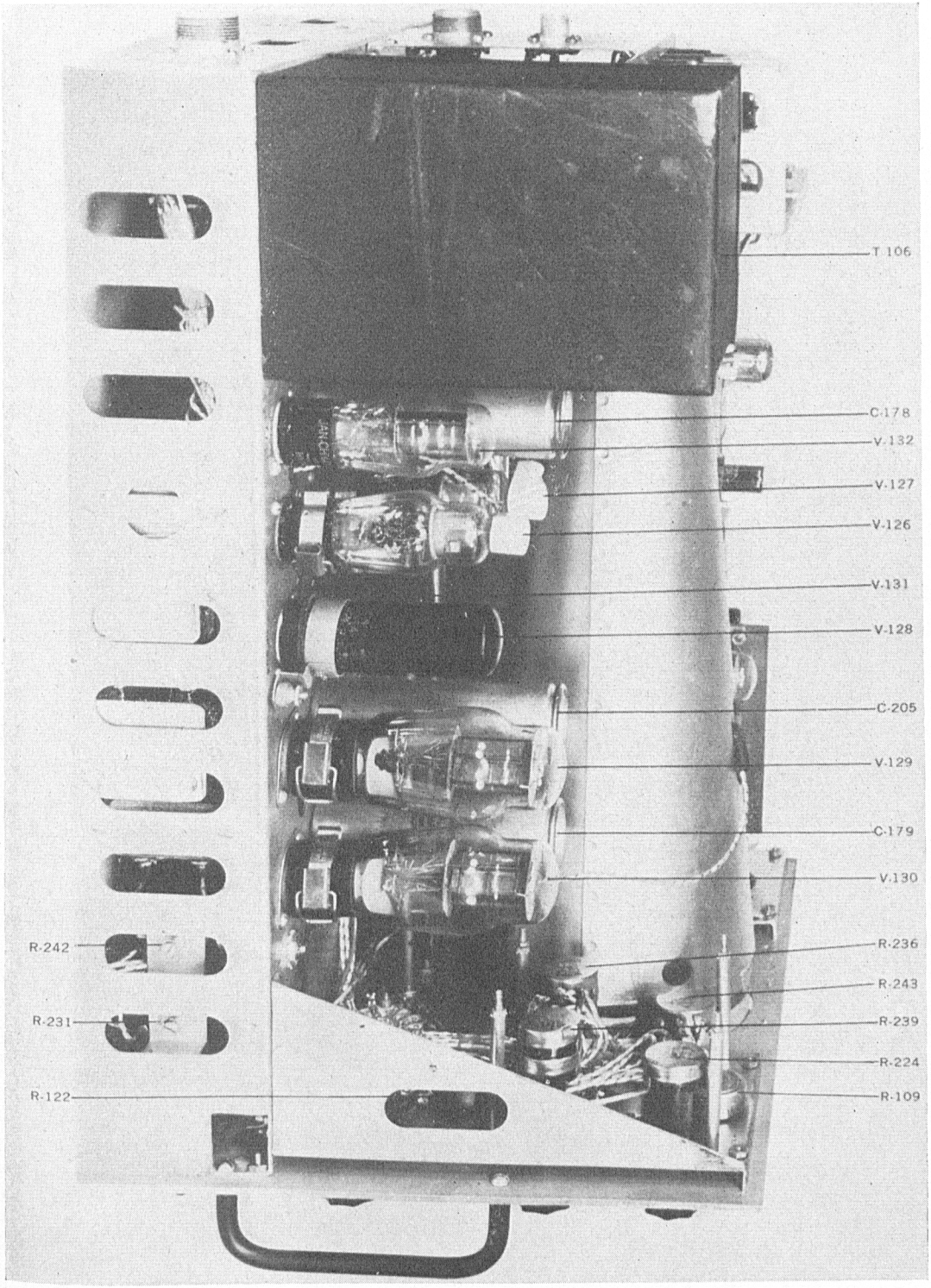

FIGURE 41.—Ship Indicator (left side).

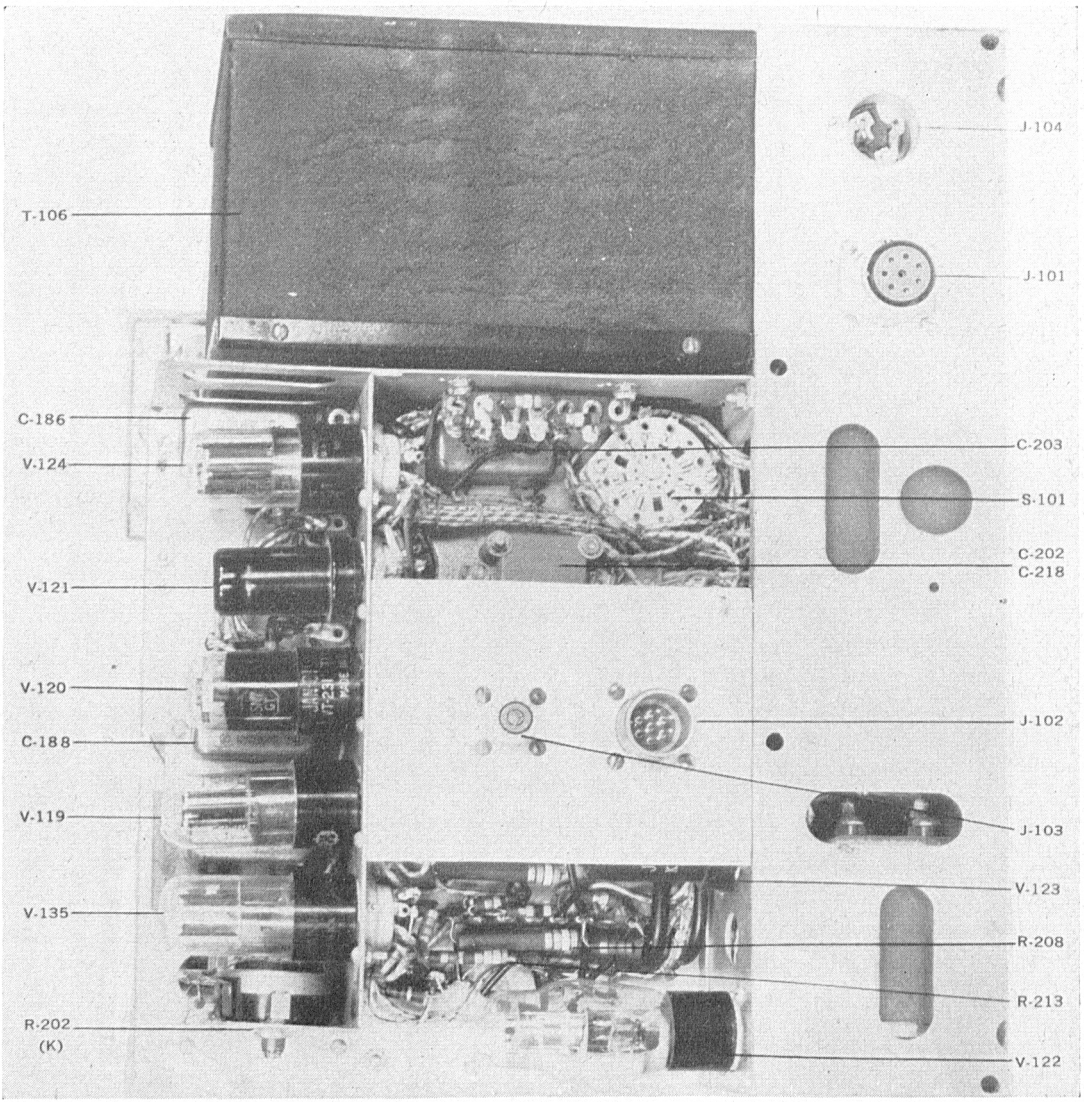

FIGURE 42.—Ship Indicator (back view).

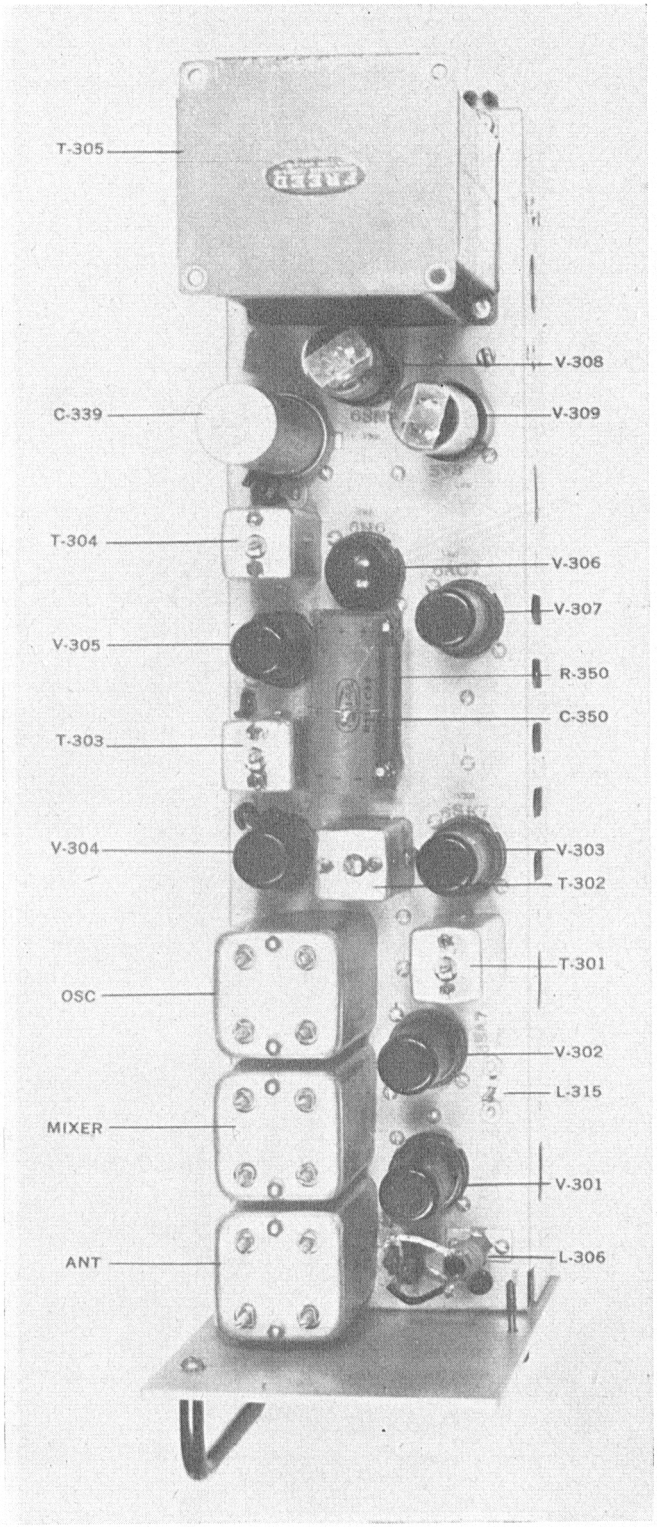

FIGURE 43.—Ship Receiver (top view).

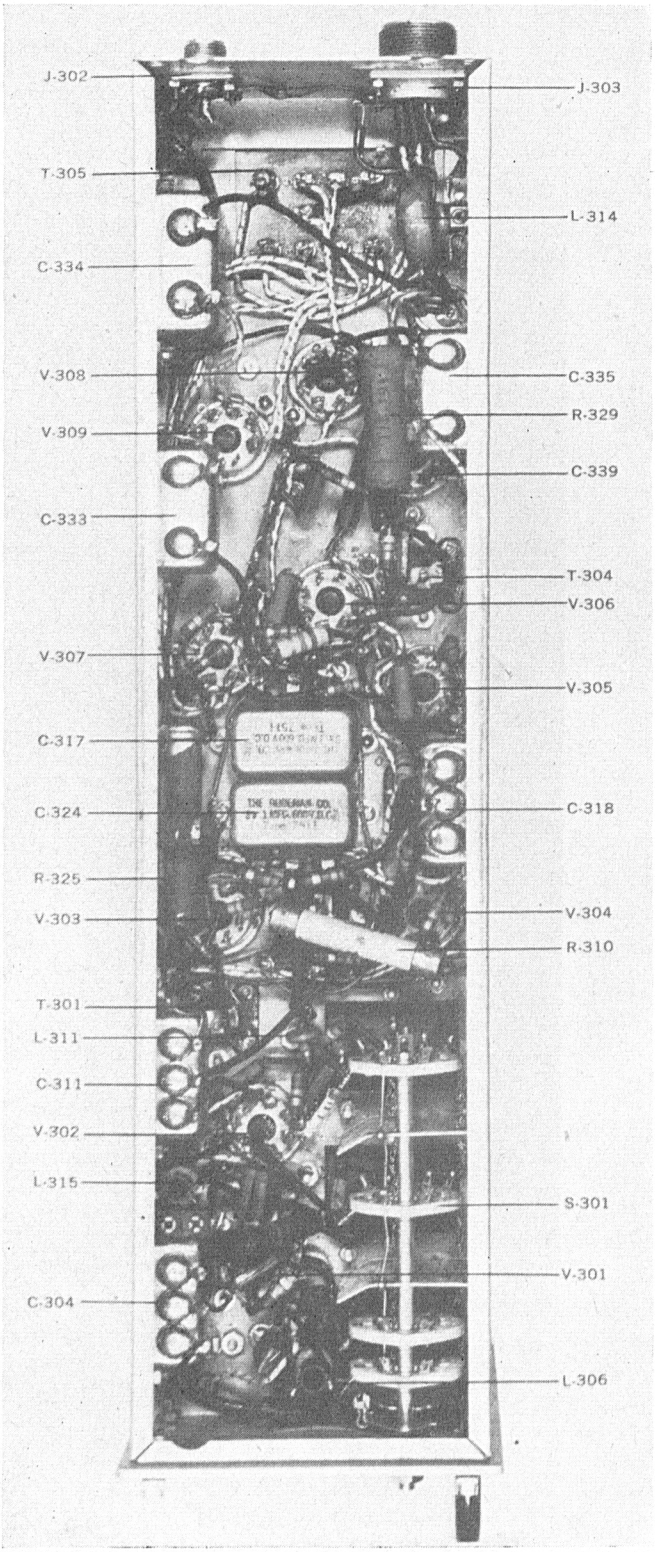

FIGURE 44.—Ship Receiver (bottom view).

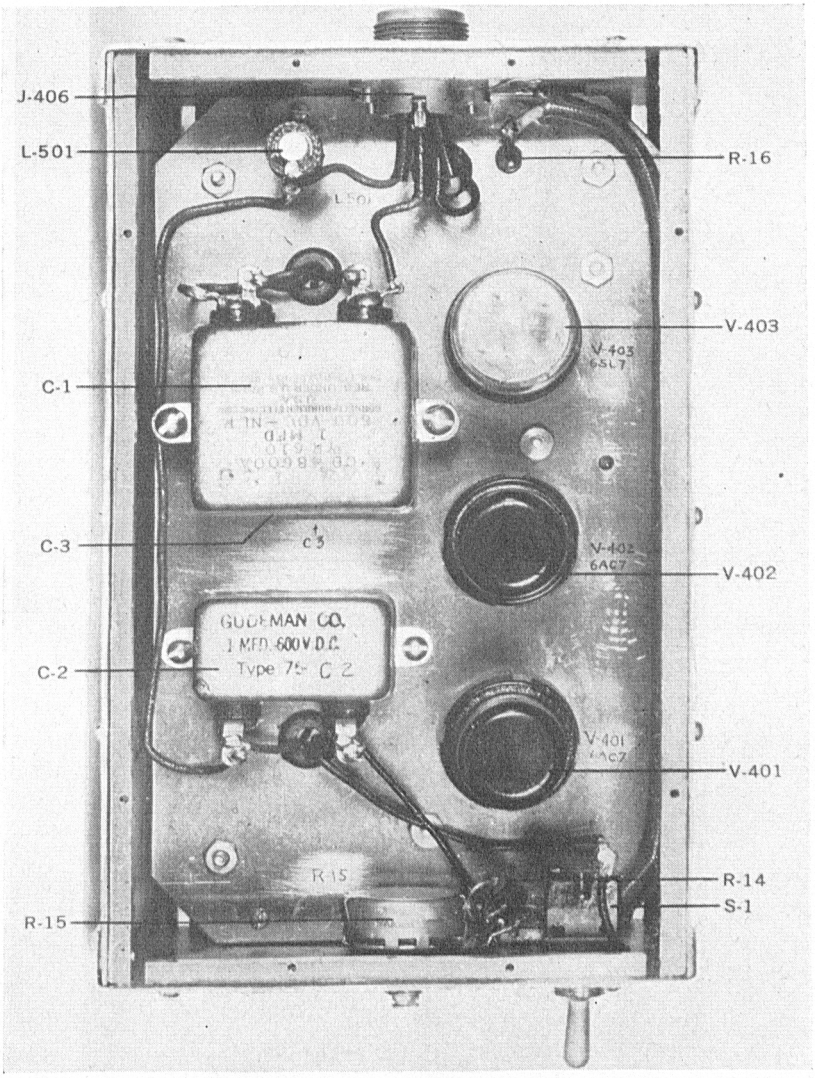

FIGURE 45.—Electronic Attenuator, ship or ground station (left, or tube side).

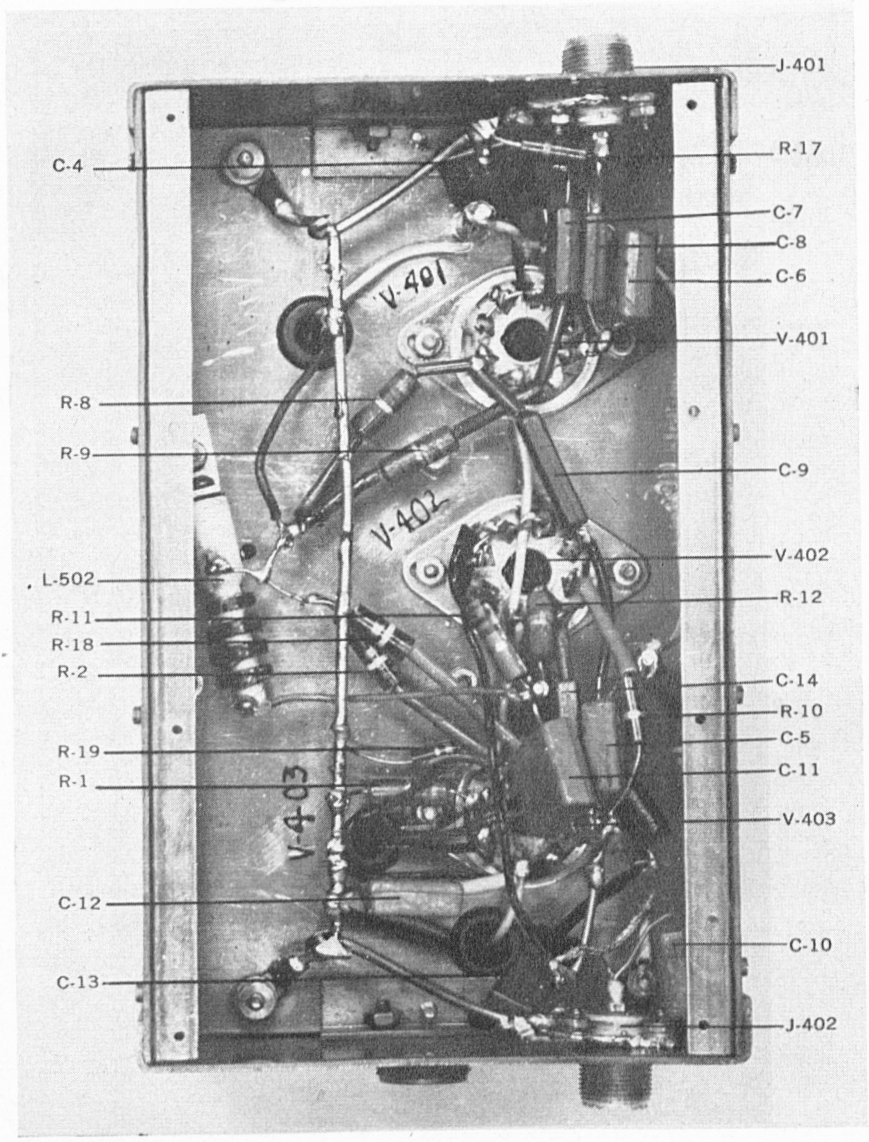

FIGURE 46.—Electronic Attenuator, ship or ground station (right, or component side).

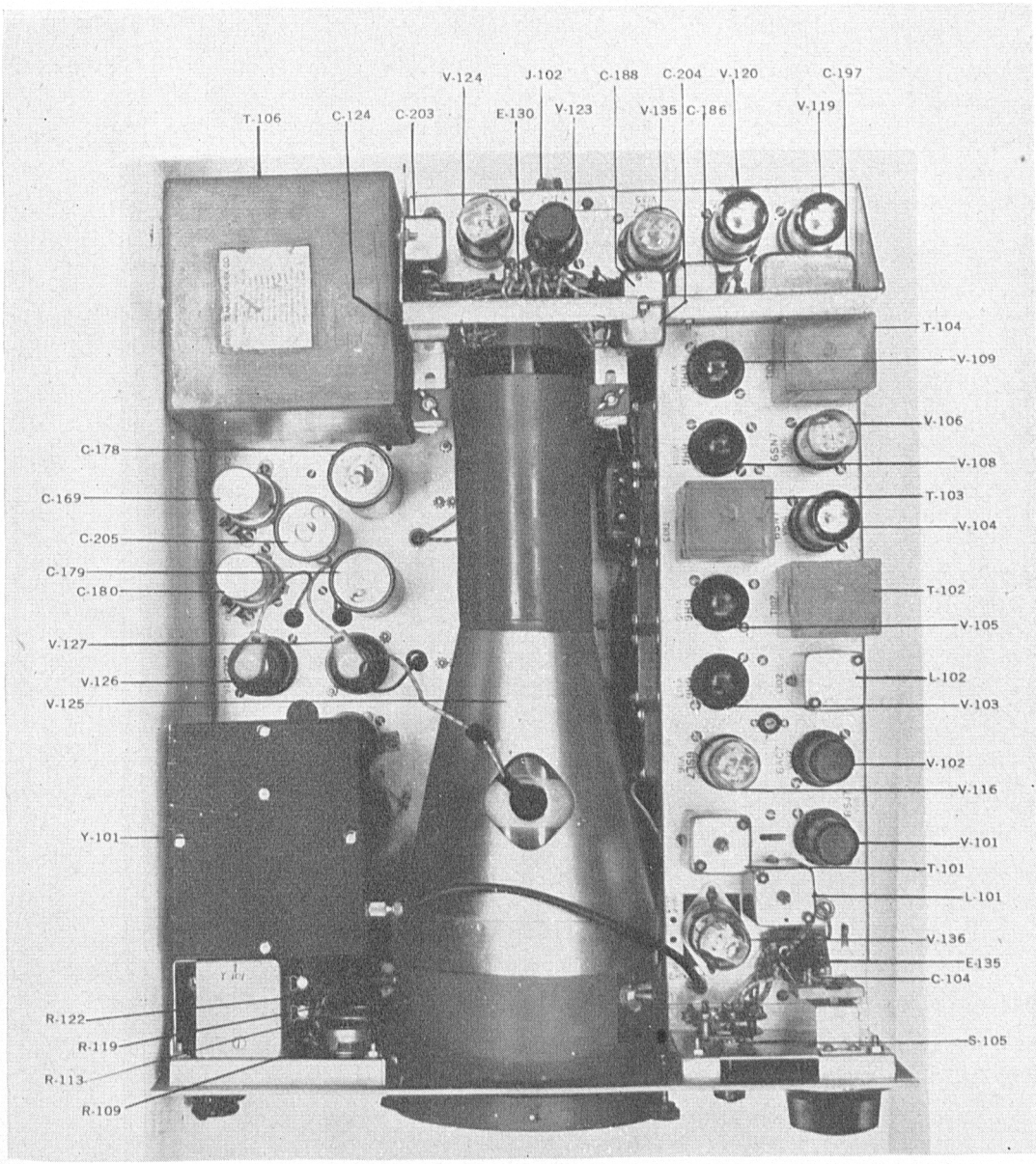

FIGURE 47.—Ground-station Controller -Indicator (top view).

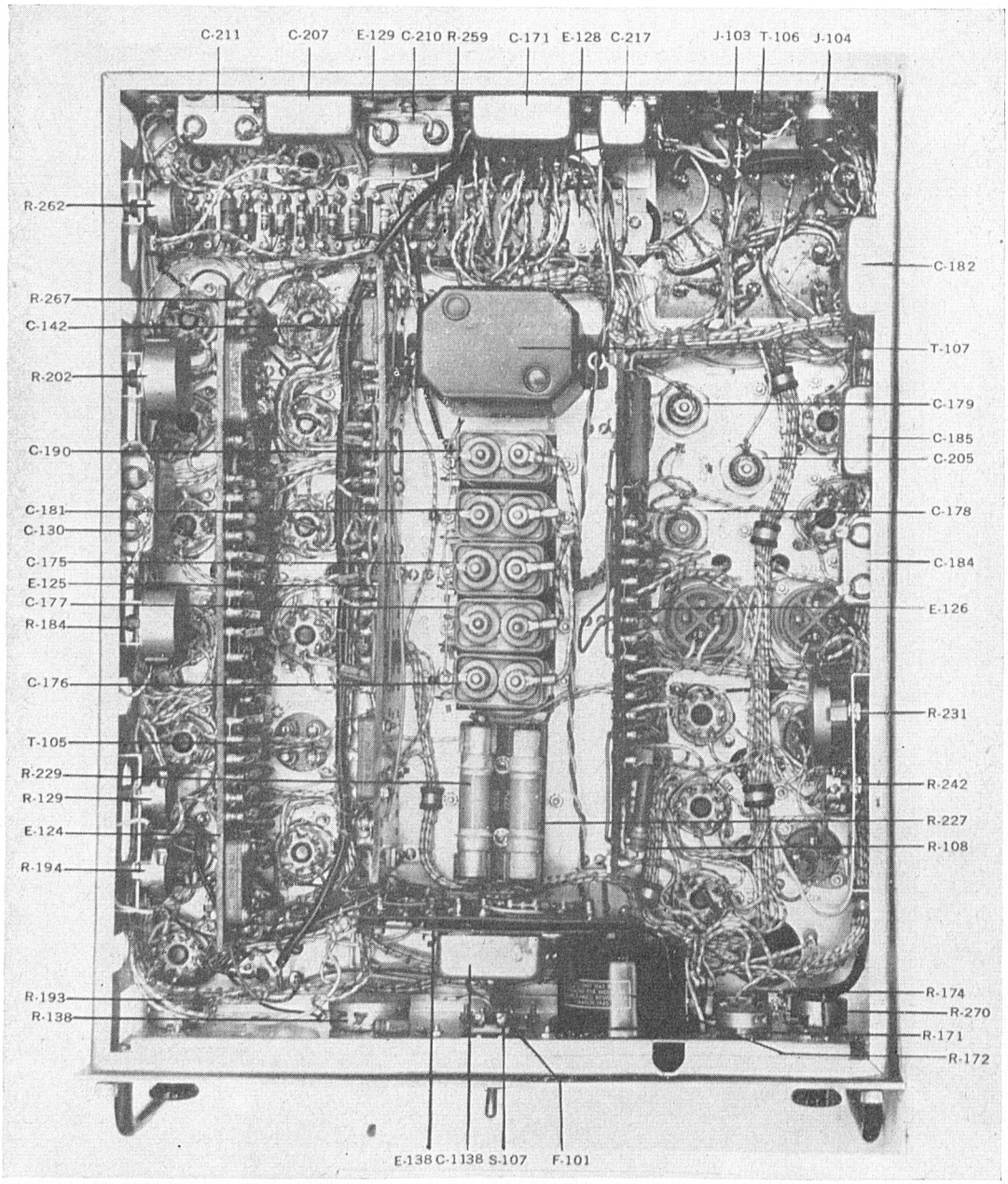

FIGURE 48.—Ground-station Controller-Indicator (bottom view).

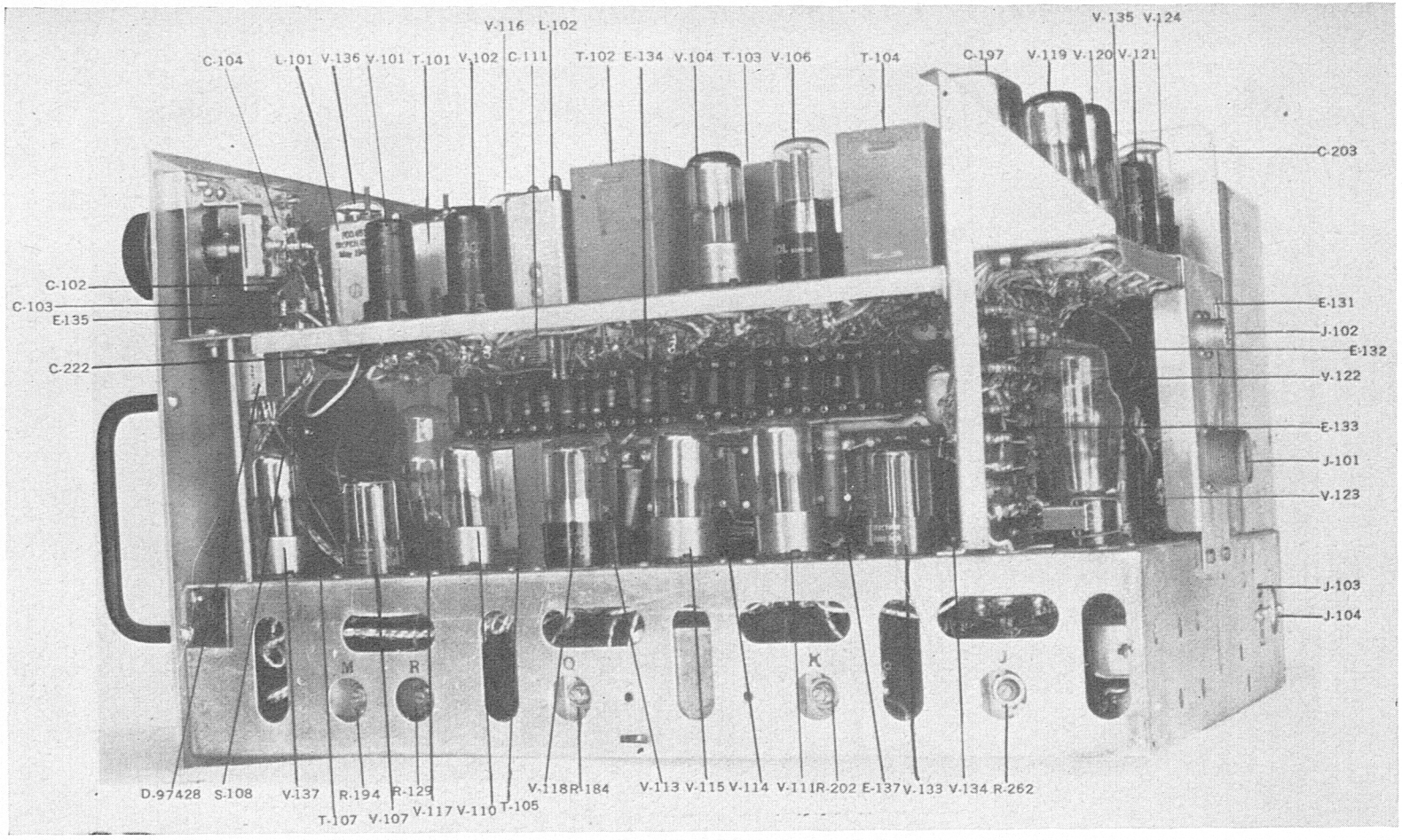

FIGURE 49.—Ground-station Controller-Indicator (right side).

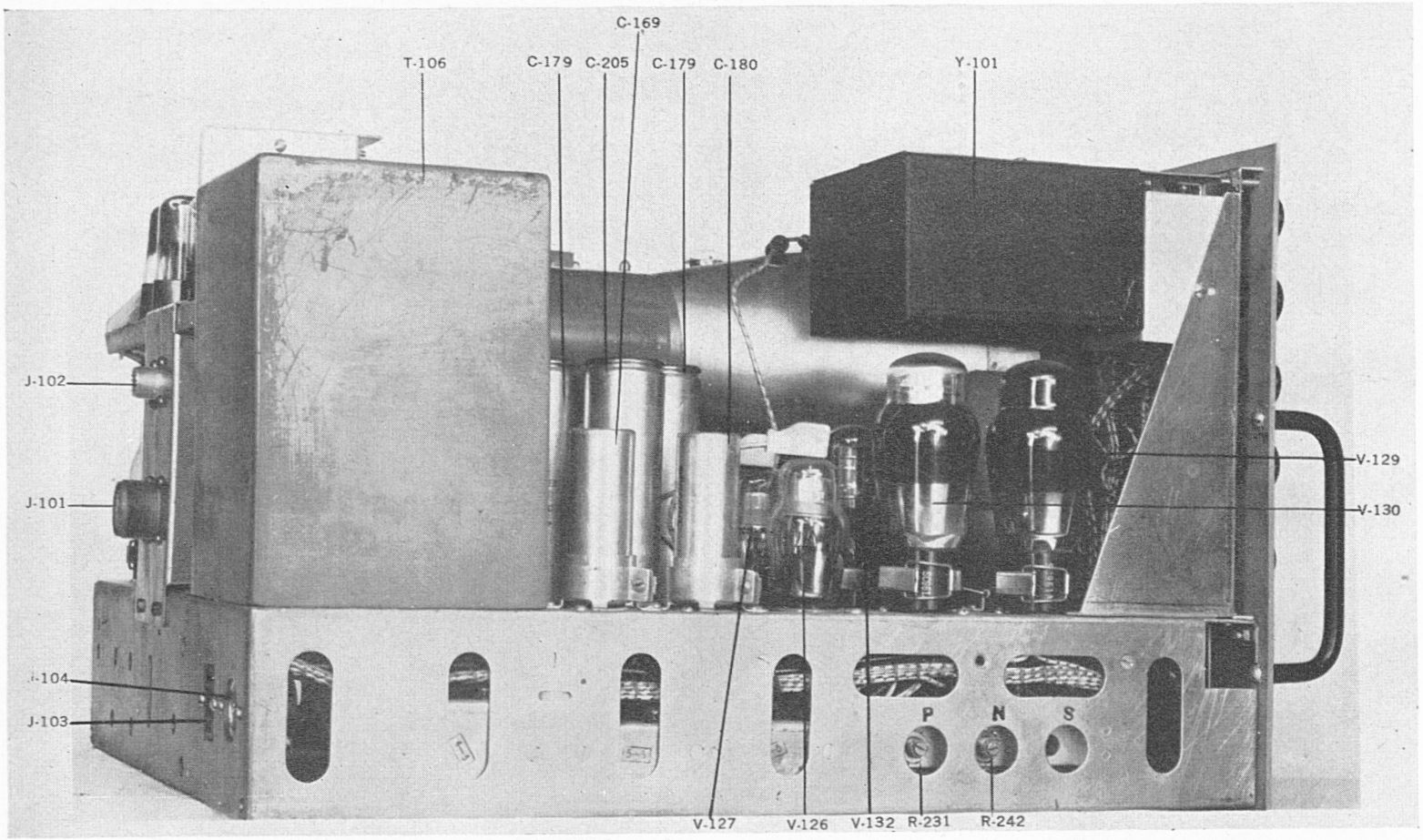

FIGURE 50.—Ground-station Controller-Indicator (left side).

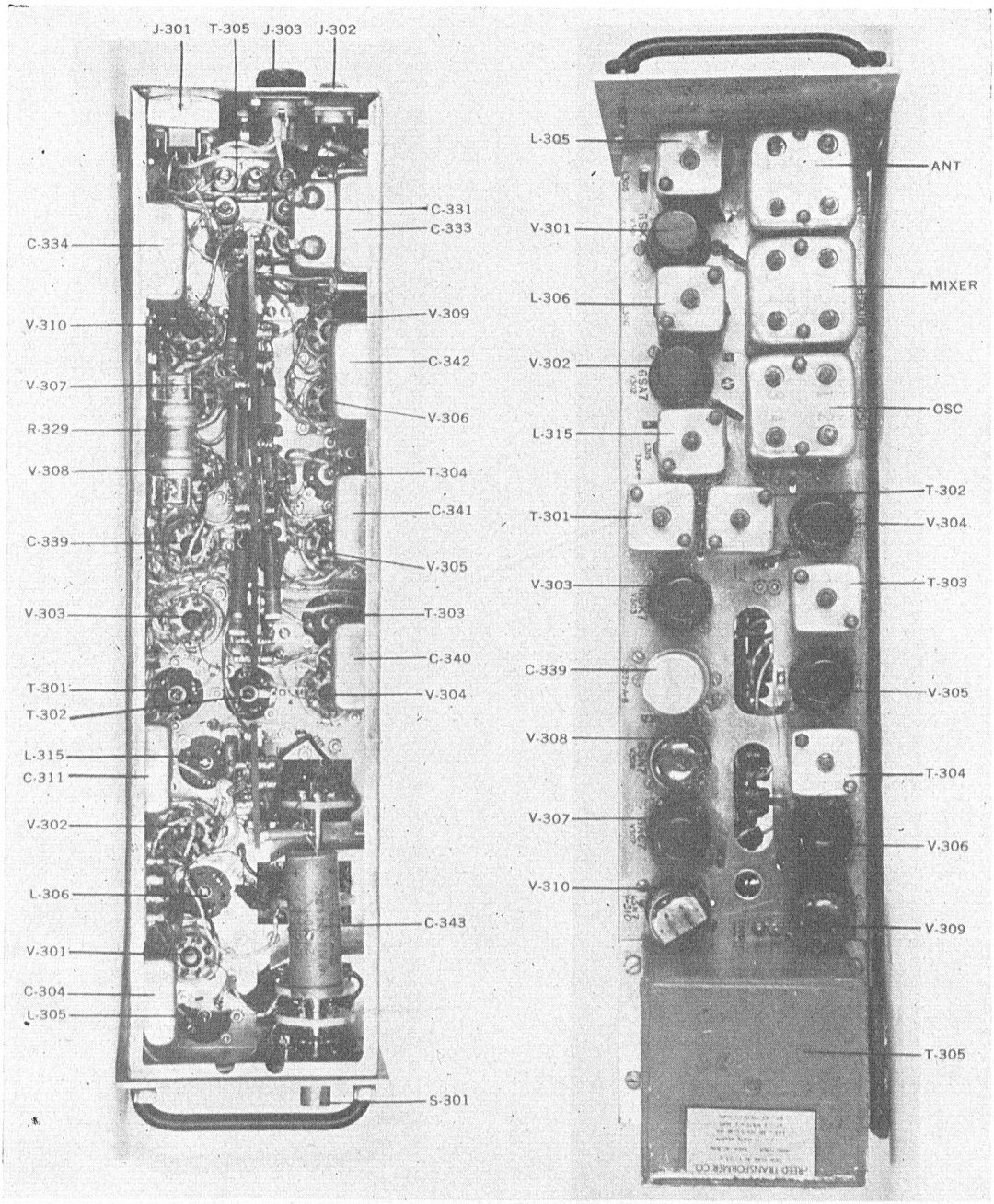

FIGURE 51.—Ground-station Receiver (top and bottom view).

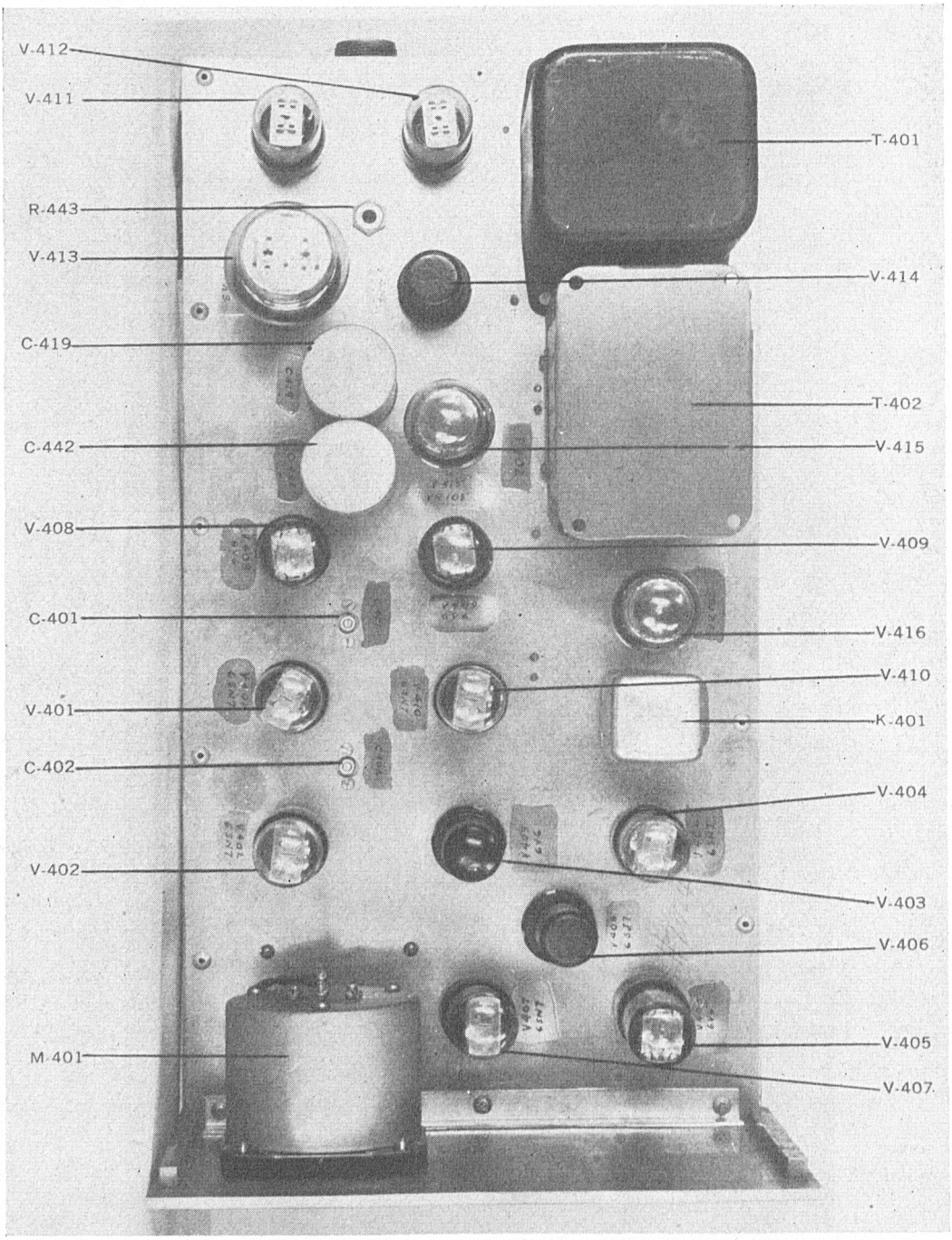

FIGURE 52.—Ground-station Synchronizer (top view).

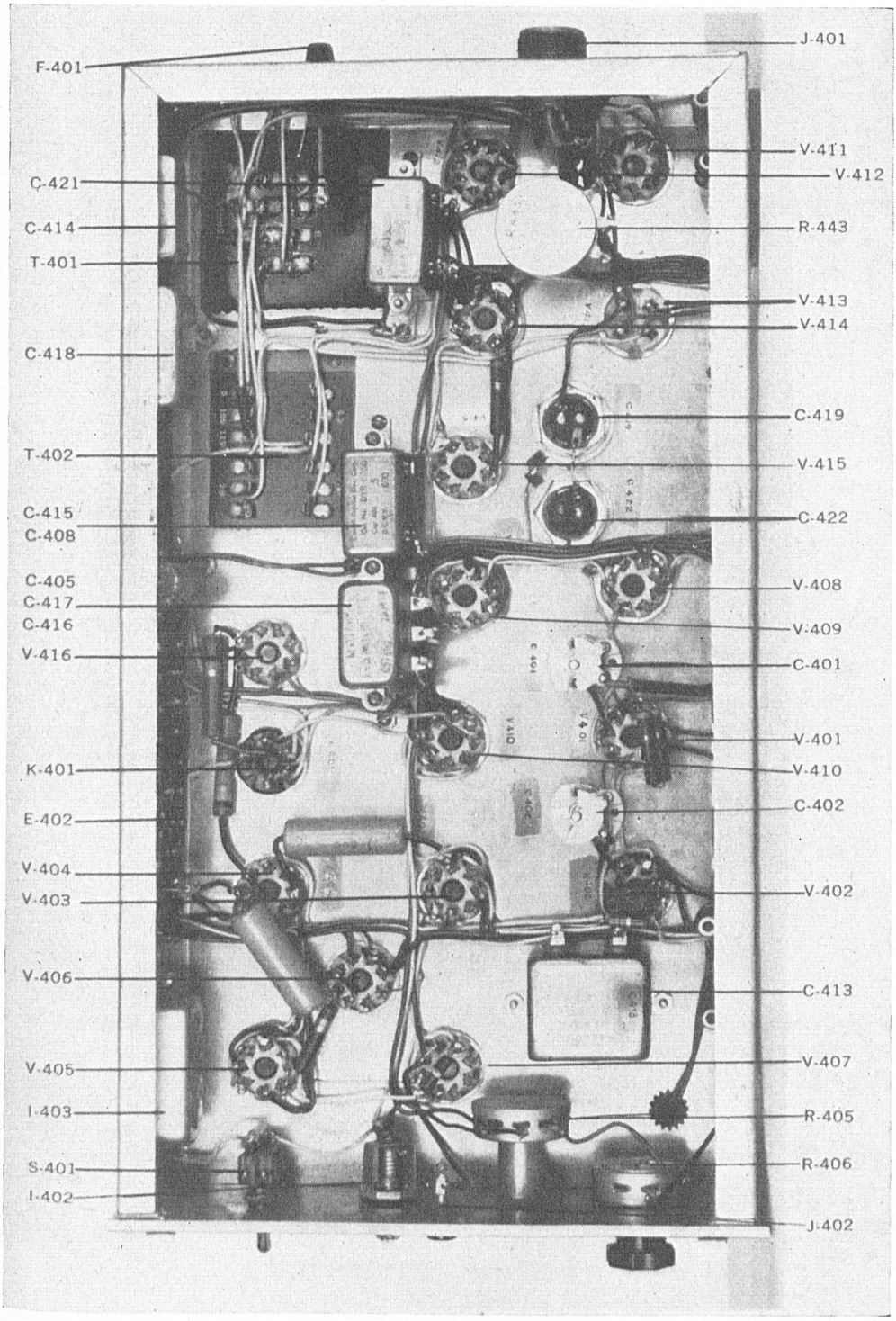

FIGURE 53.—Ground-station Synchronizer (bottom view).

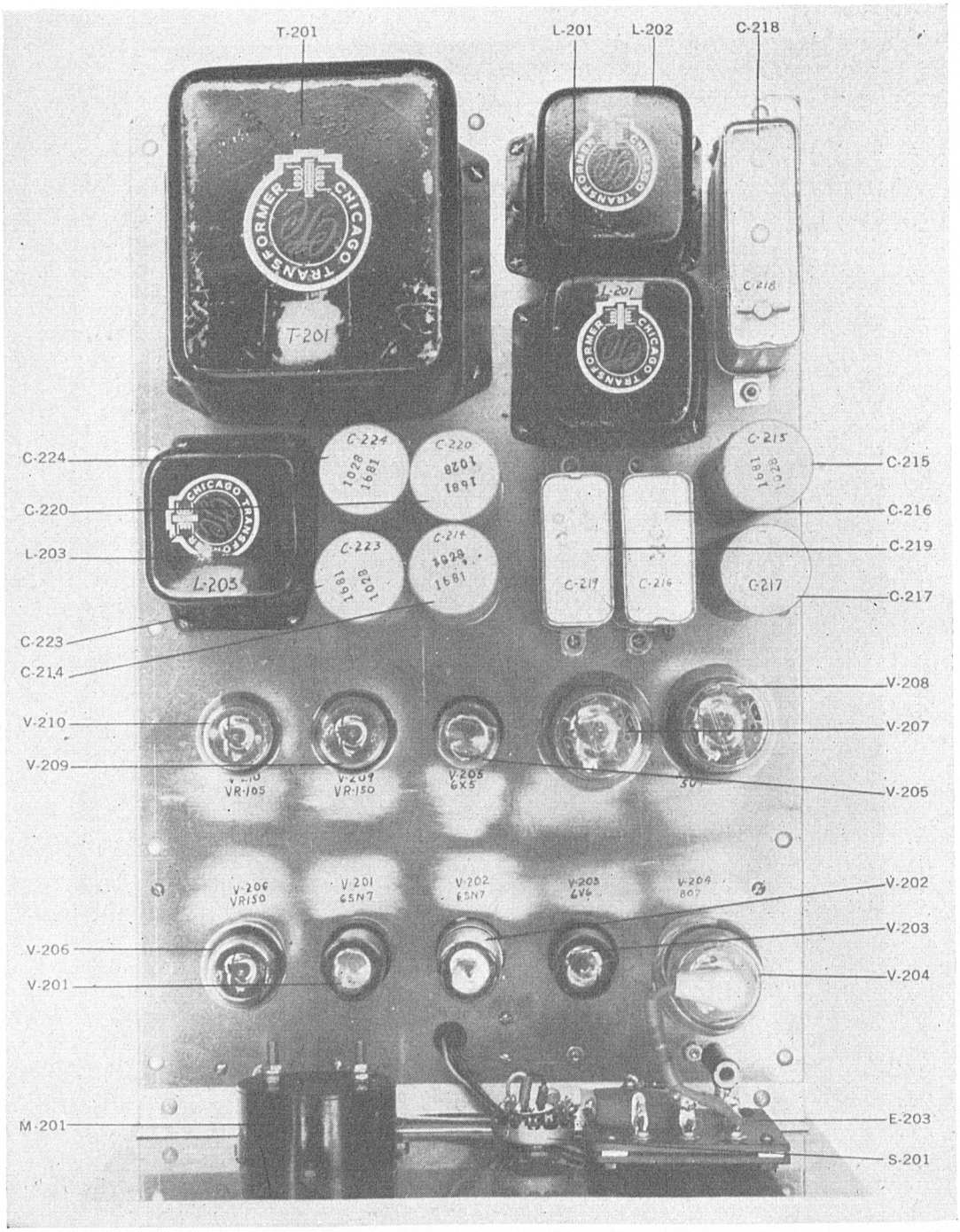

FIGURE 54.—Modulator, ship or ground station (top view).

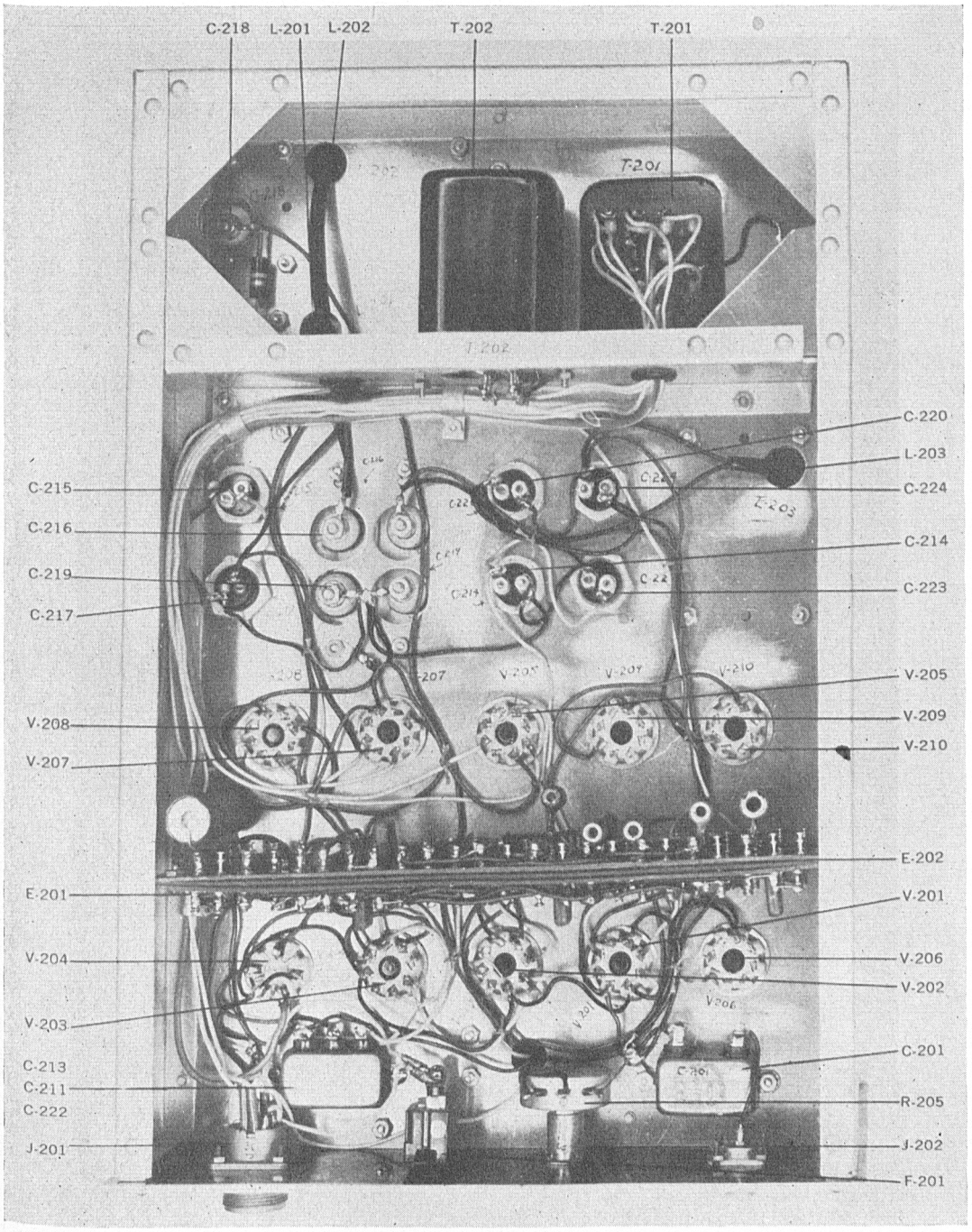

FIGURE 55.—Modulator, ship or ground station (bottom view).

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MISCELLANEOUS DATA

SHIP STATION

Jack No.	Location	Connecting plug	Cable No.	Goes to plug No.	Then to jack No.	Located in—
J-1	Controller	P-1	1	P-101	J-101	Indicator.
J-2	do	P-2	2	P-102	J-102	Do.
J-3	do	P-3	3	P-303	J-303	Receiver.
J-4	do	P-4	4	115/60/1		
J-5	do	P-5	5	P-505	J-505	Power supply.
J-6	do	P-6	6	P-406	J-406	Electronic attenuator.
J-103	Indicator	P-103	Trigger	P-202	J-202	Modulator.
J-302	Receiver	P-302	7	P-402	J-402	Electronic attenuator.
J-401	Electronic attenuator.	P-401	Coaxial	Receiver antenna coupler.		

SHIP STATION

Jack No.	Army-Navy No.	Plug No.	Army-Navy No.
J-1	3102-28-8P.	P-1	3106-18-8S.
J-2	3102-16S-1S.	P-2	3106-16S-1P.
J-3	3102-18-9S.	P-3	3106-18-9P.
J-4	3102-20-23P.	P-4	3106-20-23S.
J-5	3102-22-23S.	P-5	3106-22-23P.
J-6	3102-14S-6S.	P-6	3106-14S-6P.
J-101	3102-18-8S.	P-101	3106-18-8P.
J-102	3102-16S-1P.	P-102	3106-16S-1S.
J-103	SO-239.	P-103	PL-259.
J-202	SO-239.	P-202	PL-259.
J-302	SO-239.	P-302	PL-259.
J-303	3102-18-9P.	P-303	3106-18-9S.
J-401	SO-239.	P-401	PL-259.
J-406	3102-14S-6P.	P-406	3108-14S-6S.
J-505	3102-22-23P.	P-505	3106-22-23S.

Cable No.	Shielded wire (letters)	Cable length (inches)
1	A, B, C, F, and G	50
2	A	50
3	A, C, D, E, and F	60
5		30
6		50
7	Coaxial RG-8/U	30

GROUND STATION

Jack No.	Location	Connecting plug	Cable No.	Goes to plug No.	Then to jack No.	Located in—
J-101	Controller indicator.	P-101	1	P-401	J-401	Synchronizer.
J-102	do	P-102	Trigger	P-202	J-202	Modulator.
J-103	do	P-103	2	P-301	J-301	Receiver.
J-104	do	P-104	5	115/60/1		
J-303	Receiver	P-303	3	P-406	J-406	Electronic attenuator.
J-401	Electronic attenuator.	P-401	Coaxial	Receiver antenna coupler.		
J-402	do	P-402	4	P-302	J-302	Receiver.

GROUND STATION

Jack No.	Army-Navy No.	Plug No.	Army-Navy No.
J-101	3102-18-8S.	P-101	3106-18-8P.
J-102	SO-239.	P-102	PL-259.
J-103	Jones S-308-AB.	P-103	Jones P-308-CCT.
J-104	GE-3164.	P-104	GE-3159.
J-202	SO-239.	P-202	PL-259.
J-301	Jones P-308-AB.	P-301	Jones S-308-CCT.
J-302	SO-239.	P-302	PL-259.
J-303	3102-16S-1S.	P-303	3106-16S-1P.
J-401 (E. A.)	SO-239.	P-401 (E. A.)	PL-259.
J-401 (Sync)	3102-18-8P.	P-401 (Sync)	3106-18-8S.
J-402	SO-239.	P-402	PL-259.
J-406	3102-14S-6P.	P-406	3108-14S-6S.

Cable No.	Shielded wire, numbers or letters	Cable length (inches)
1	A, B, E, and G	40
2	1, 2, 5, and 7	40
3		30
4	Coaxial RG-8/U	30
5	2-wire shielded power cable	72

TRANSMITTER AND MODULATOR

Jack No.	Location	Connecting plug	Cable	Goes to plug No.	Then to jack No.	Located in—
J-101	Transmitter	P-101	Modulator	P-201	J-201	Modulator.
J-102	do	P-102	Power	115/60/1		
J-103	do	P-103	Monitor	For oscillator monitoring.*		
J-104	do	P-104	Coaxial	Transmitter antenna coupler.		
J-202	Modulator	P-202	Trigger	P-103	J-103	Ship indicator.
J-202	do	P-202	do	P-102	J-102	Ground-station controller-indicator.

* Installed only in Transmitters No. 1 through 9.

TRANSMITTER AND MODULATOR

Jack No.	Army-Navy No.	Plug No.	Army-Navy No.
J-101	3102-18-8S.	P-101	3106-18-8P.
J-102	Amphenol 61-M10.	P-102	Amphenol 61-F11.
J-103	SO-239.	P-103	PL-259.
J-104	UG-61A/U.	P-104	UG-59A/U.
J-201	3102-18-8P.	P-201	e106-18-8S.
J-202	SO-239.	P-202	PL-259.

Transmitter to Modulator cable length: 66 inches.

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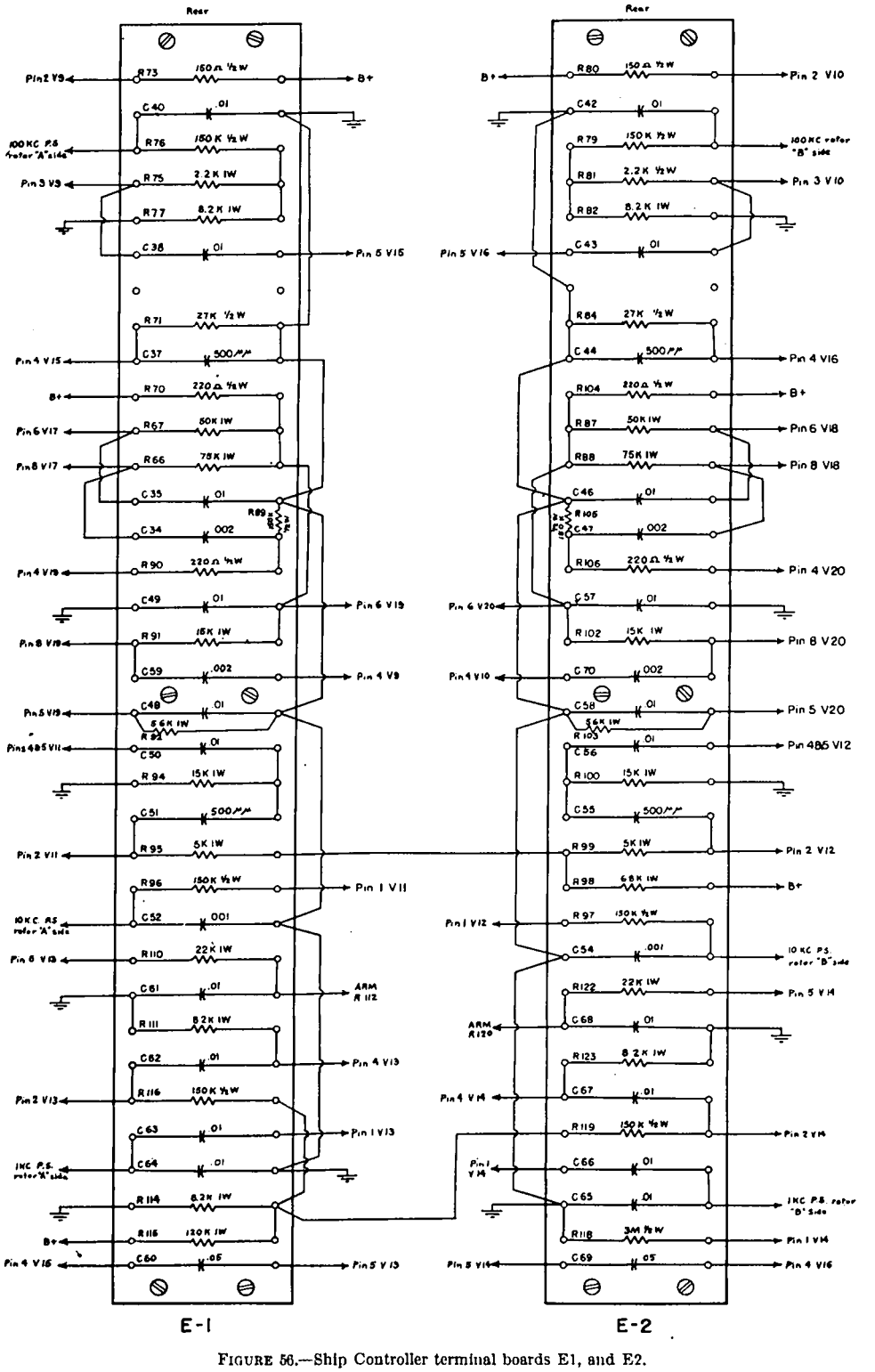


FIGURE 56.—Ship Controller terminal boards E1, and E2.

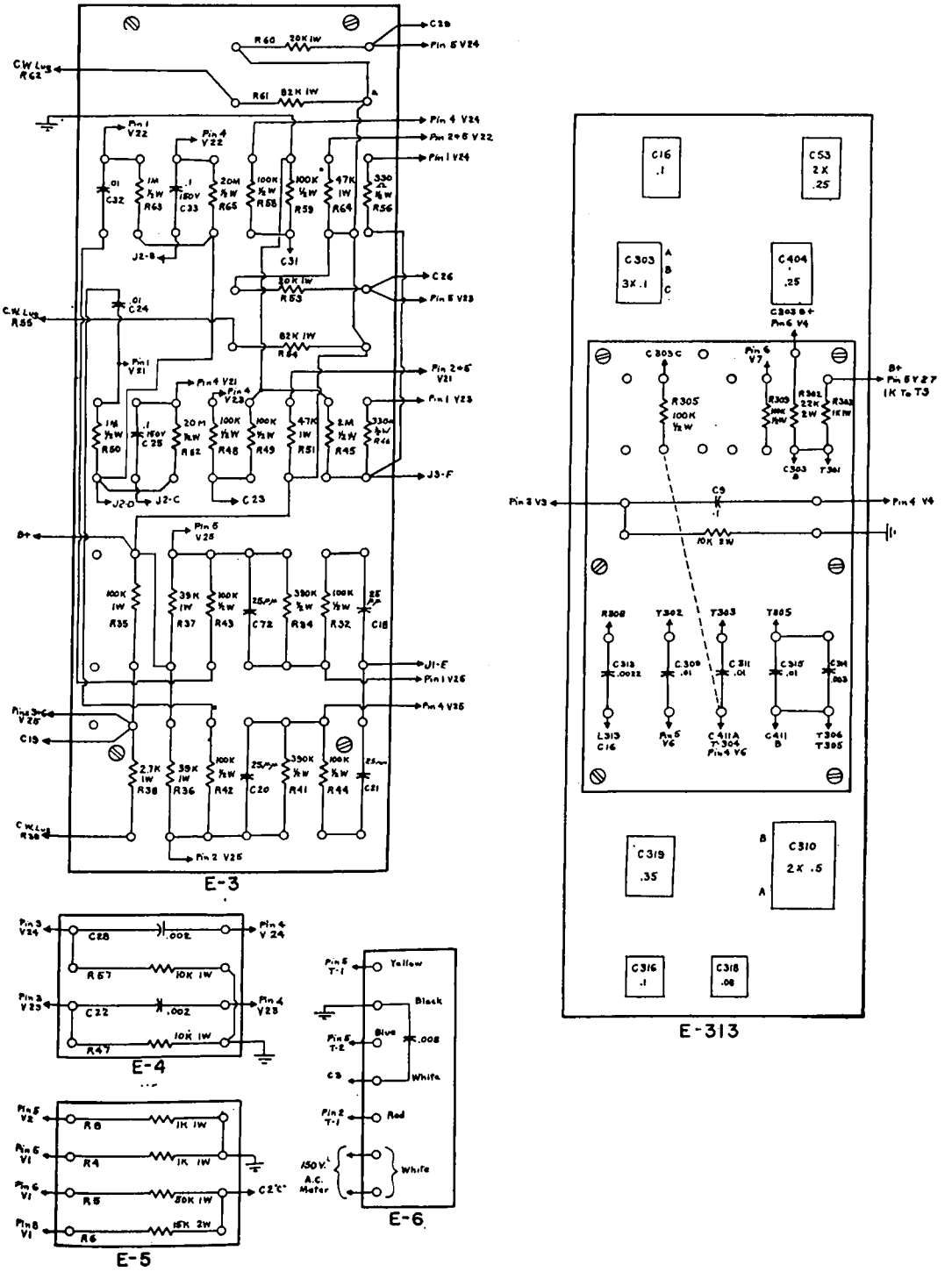


FIGURE 57.—Ship Controller terminal boards E3, E4, E5, E6, and E313.

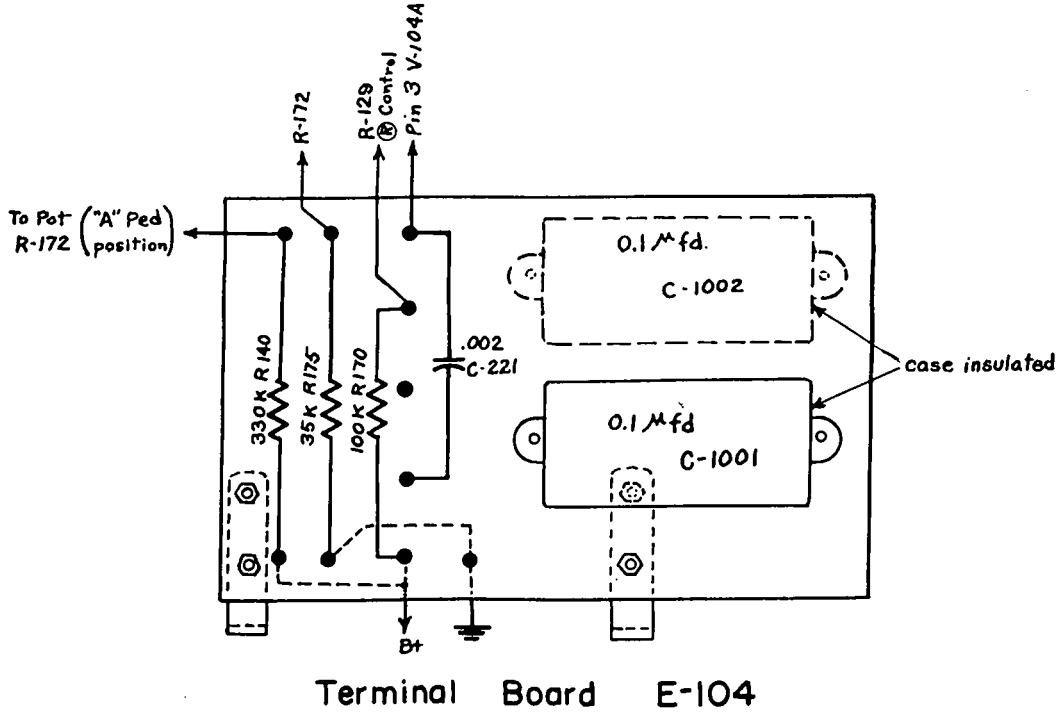


FIGURE 58.—Ship Indicator terminal board E104.

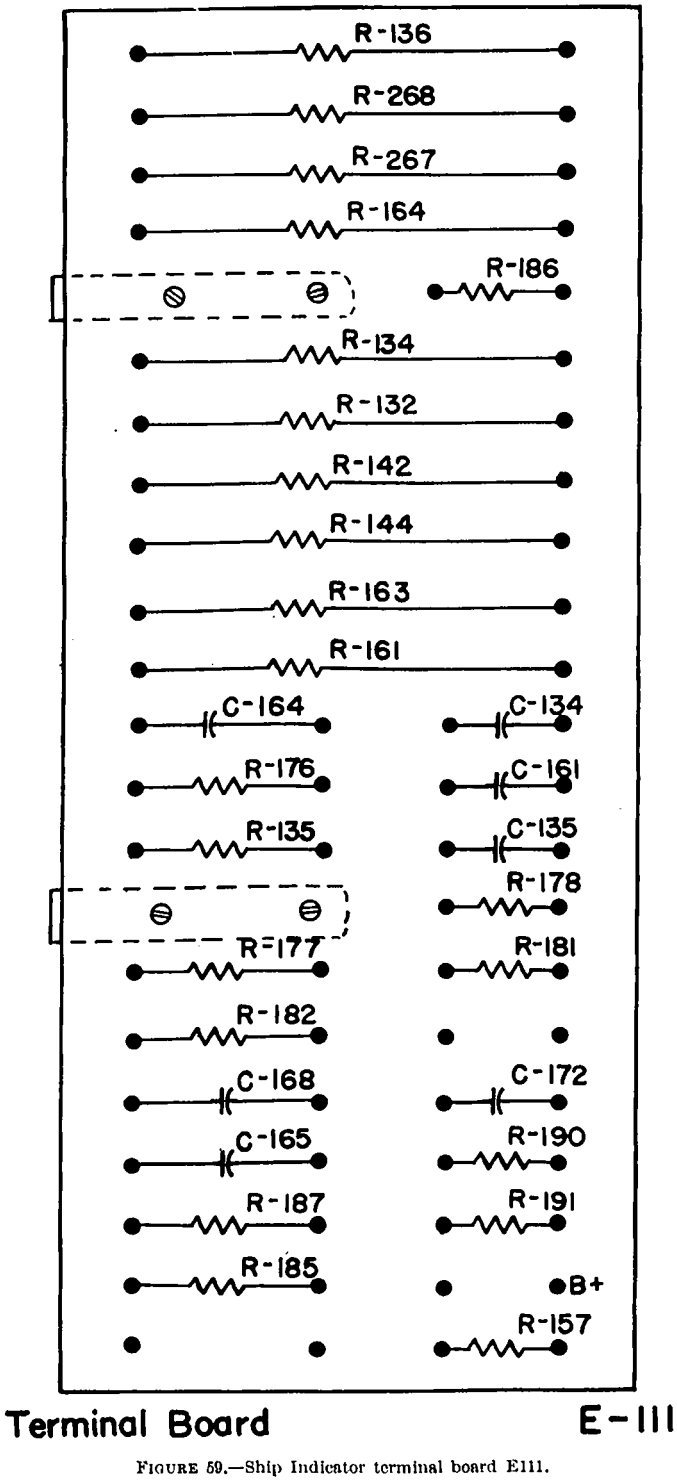
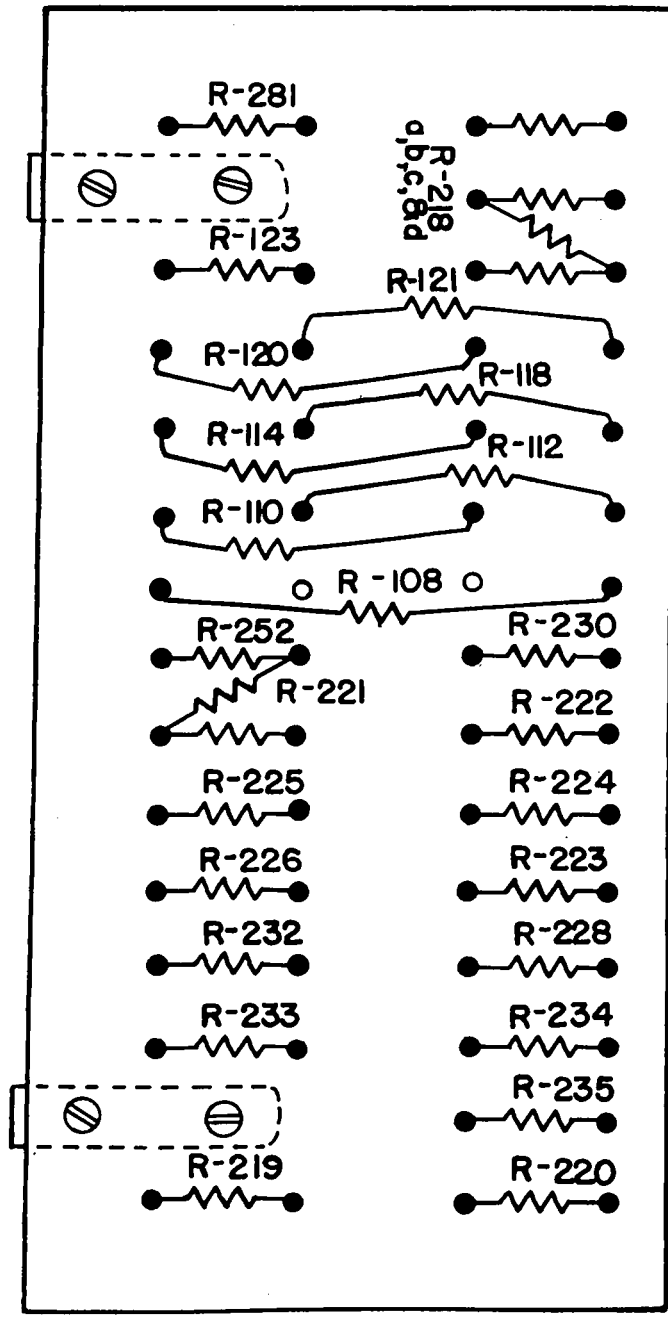
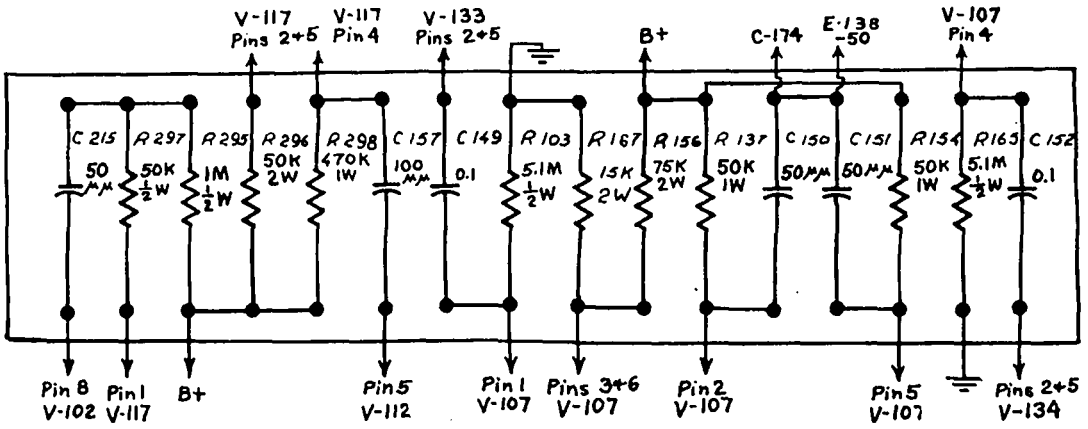


FIGURE 59.—Ship Indicator terminal board E111.

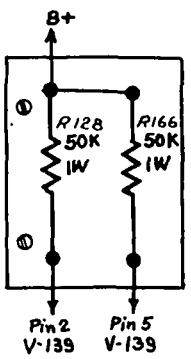


Terminal Board E-132

FIGURE 60.—Ship Indicator terminal board E132.

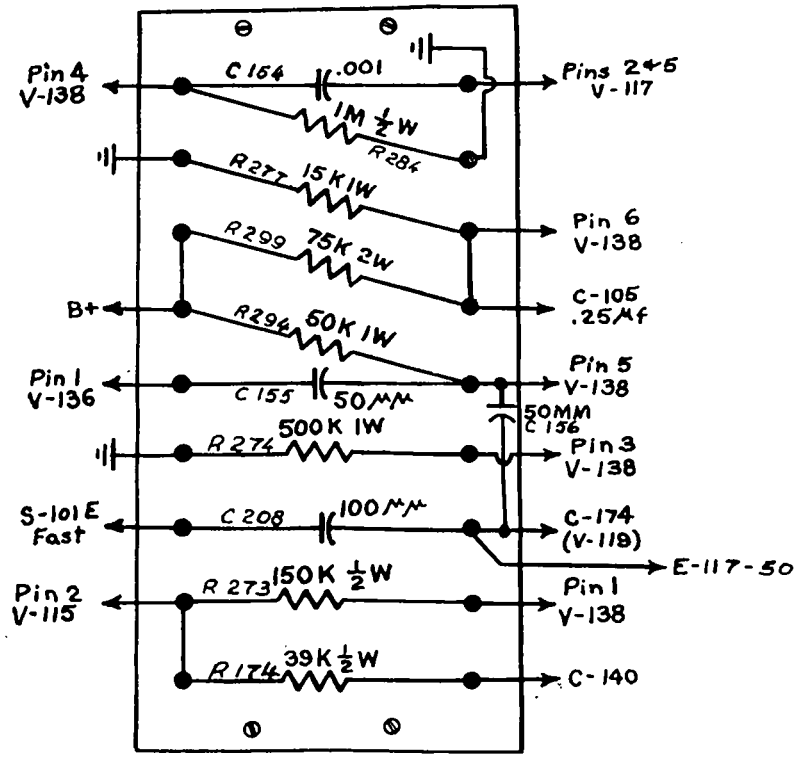


Terminal Board E-117

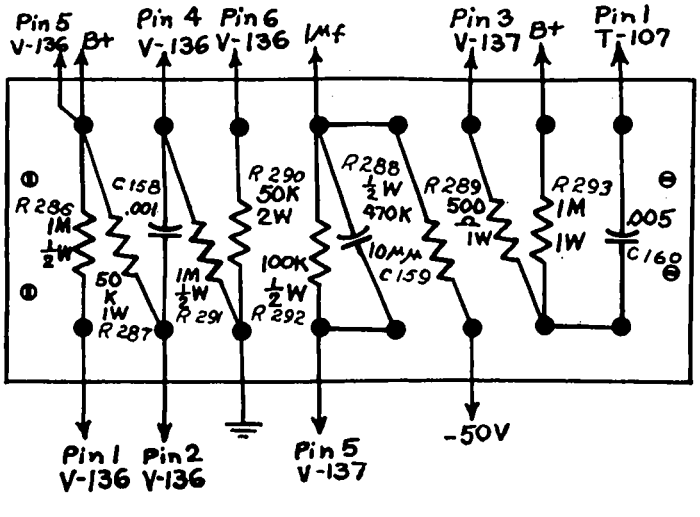


Terminal Board E-139

FIGURE 61.—Ship Indicator terminal boards E117, and E139.



Terminal Board E-138



Terminal Board E-137

FIGURE 62.—Ship Indicator terminal boards E137, and E138.

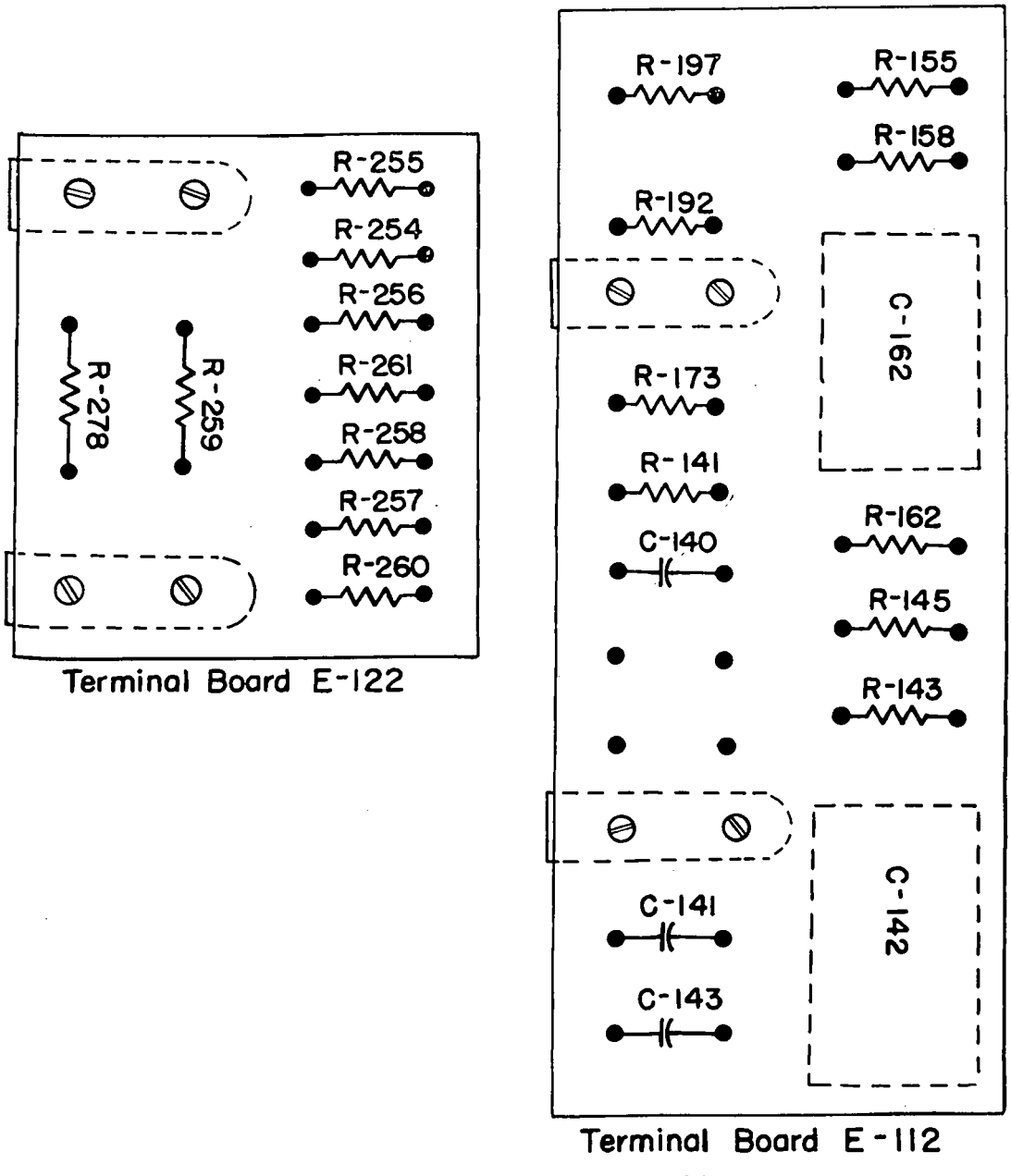
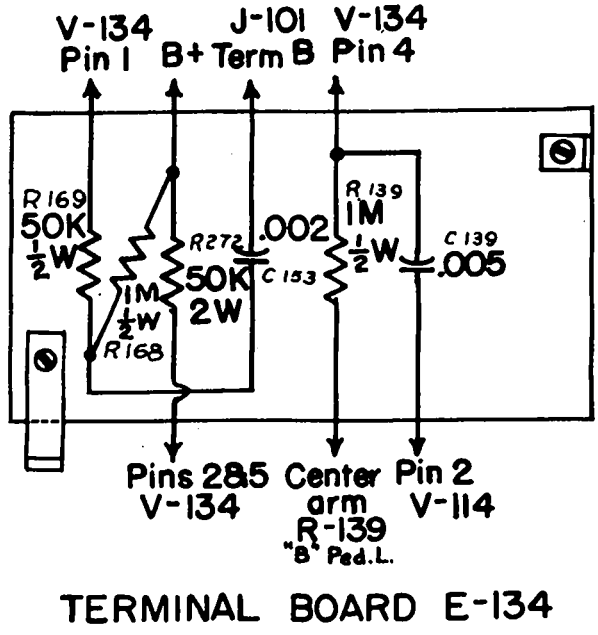
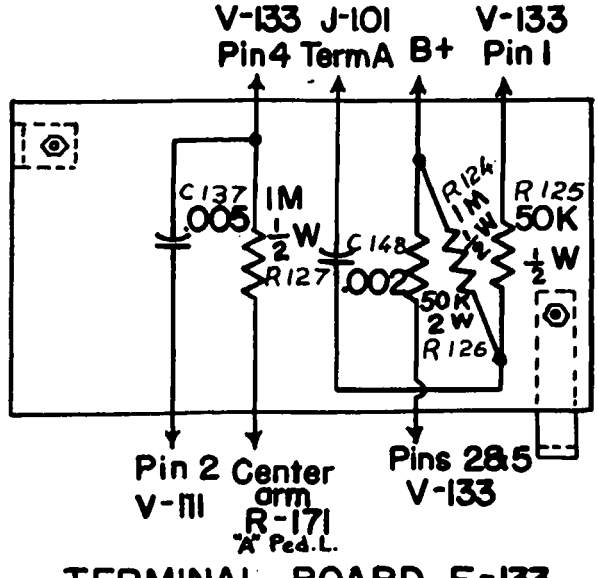


FIGURE 63.—Ship Indicator terminal boards E112, and E122.

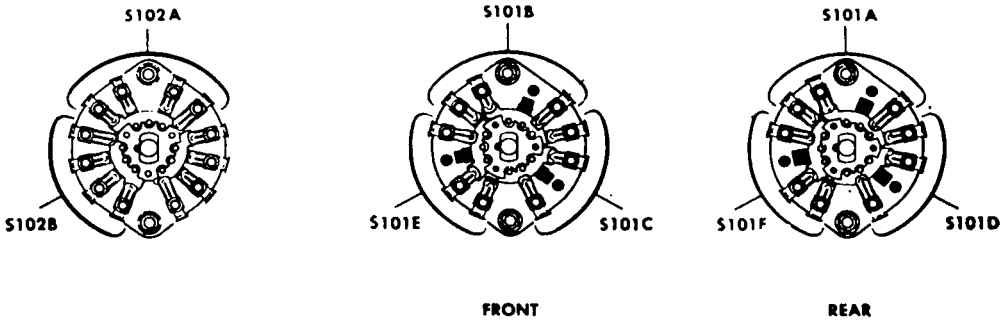


TERMINAL BOARD E-134



TERMINAL BOARD E-133

FIGURE 64.—Ship Indicator terminal boards E133, and E134.



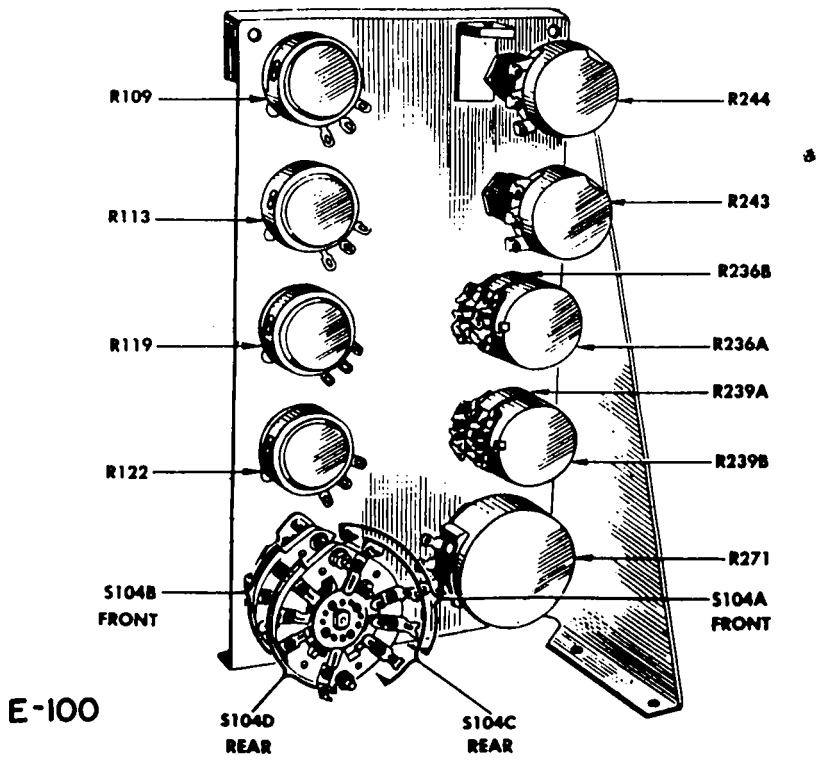


FIGURE 65.—Ground-station Controller-Indicator subpanel E100.

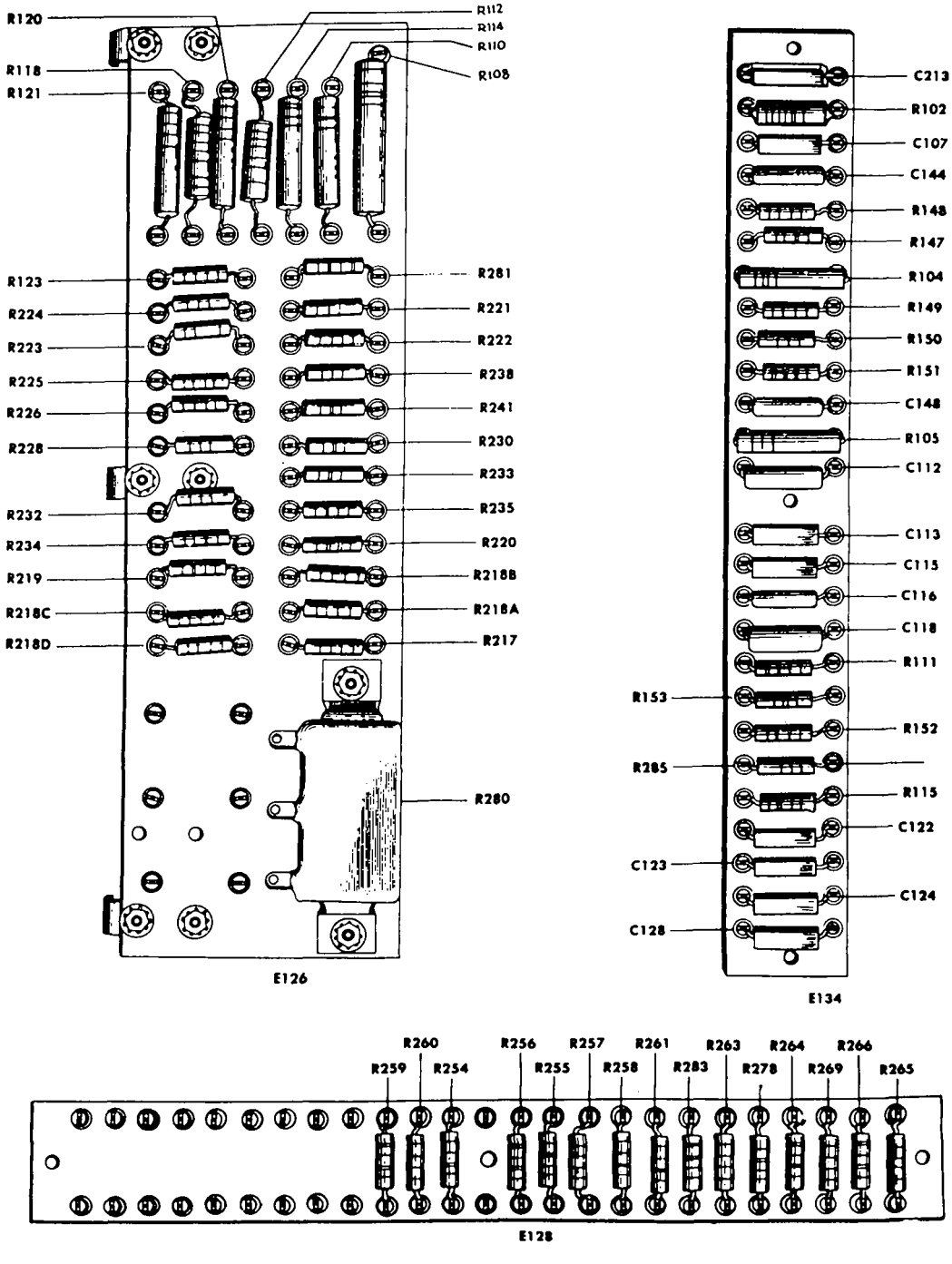


FIGURE 66.—Ground-station Controller-Indicator terminal boards E126, E128, and E134.

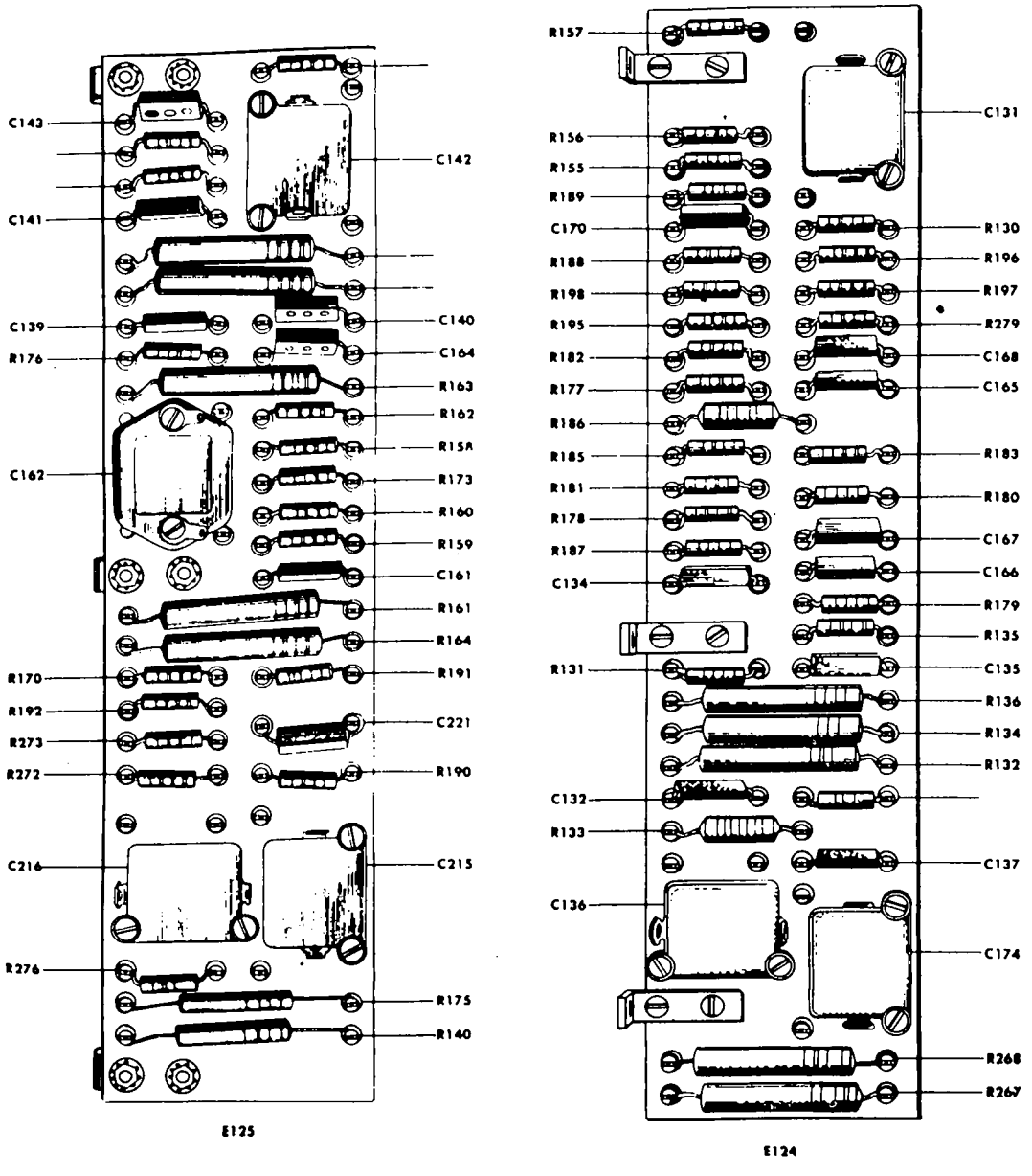


FIGURE 67.—Ground-station Controller-Indicator terminal boards E124, and E125.

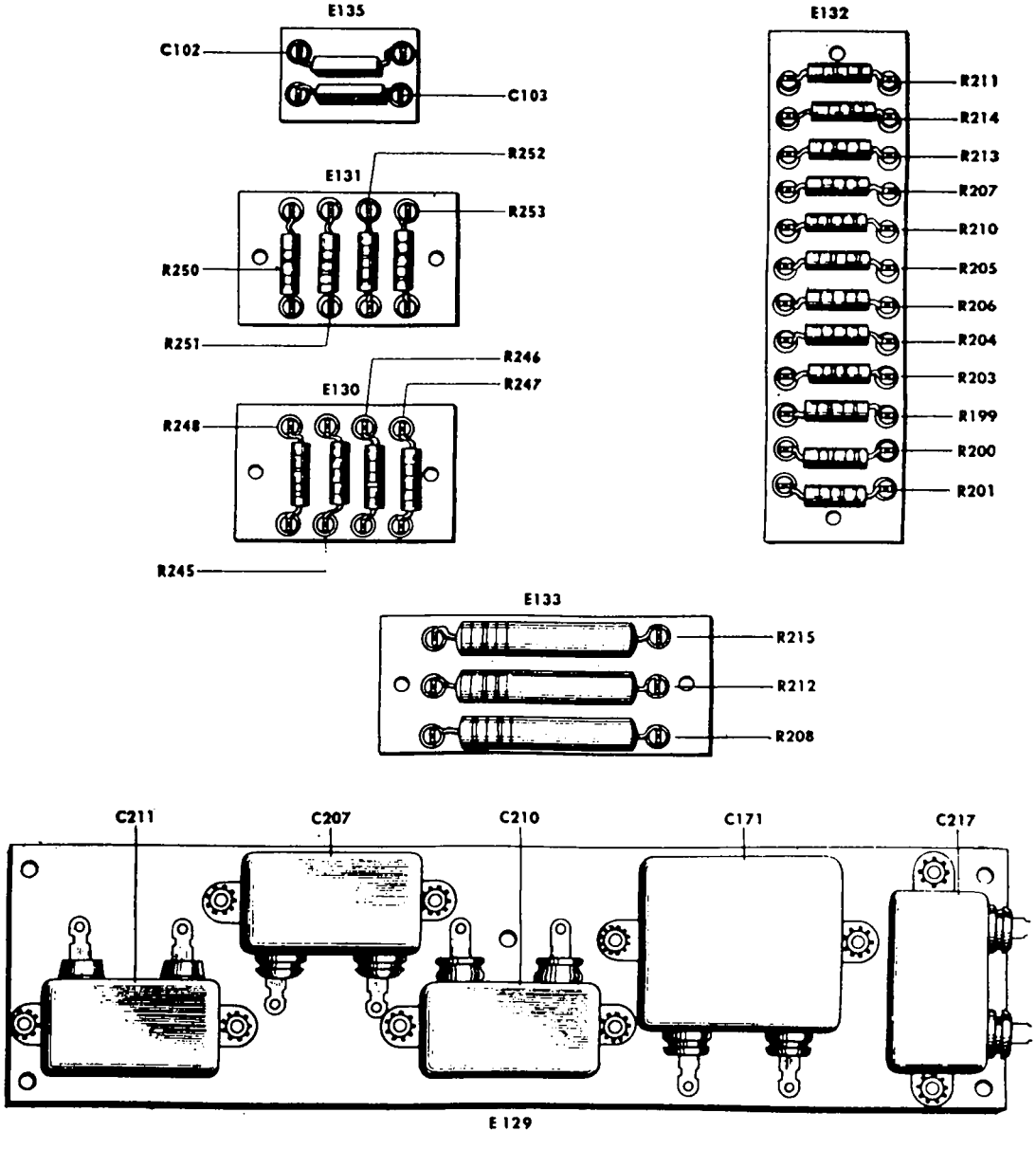


FIGURE 68.—Ground-station Controller-Indicator terminal boards E129, E130, E131, E132, E133, and E135.

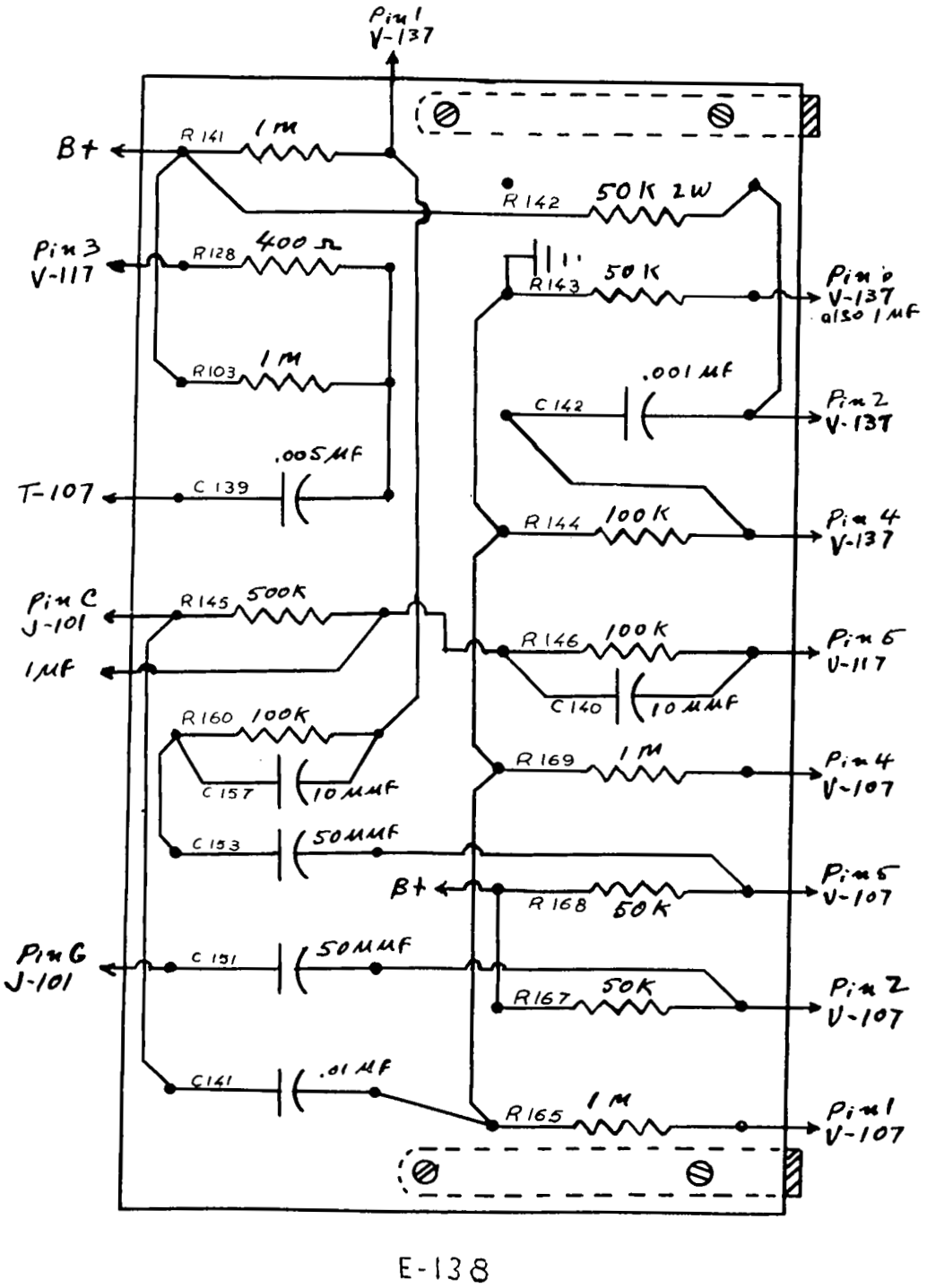
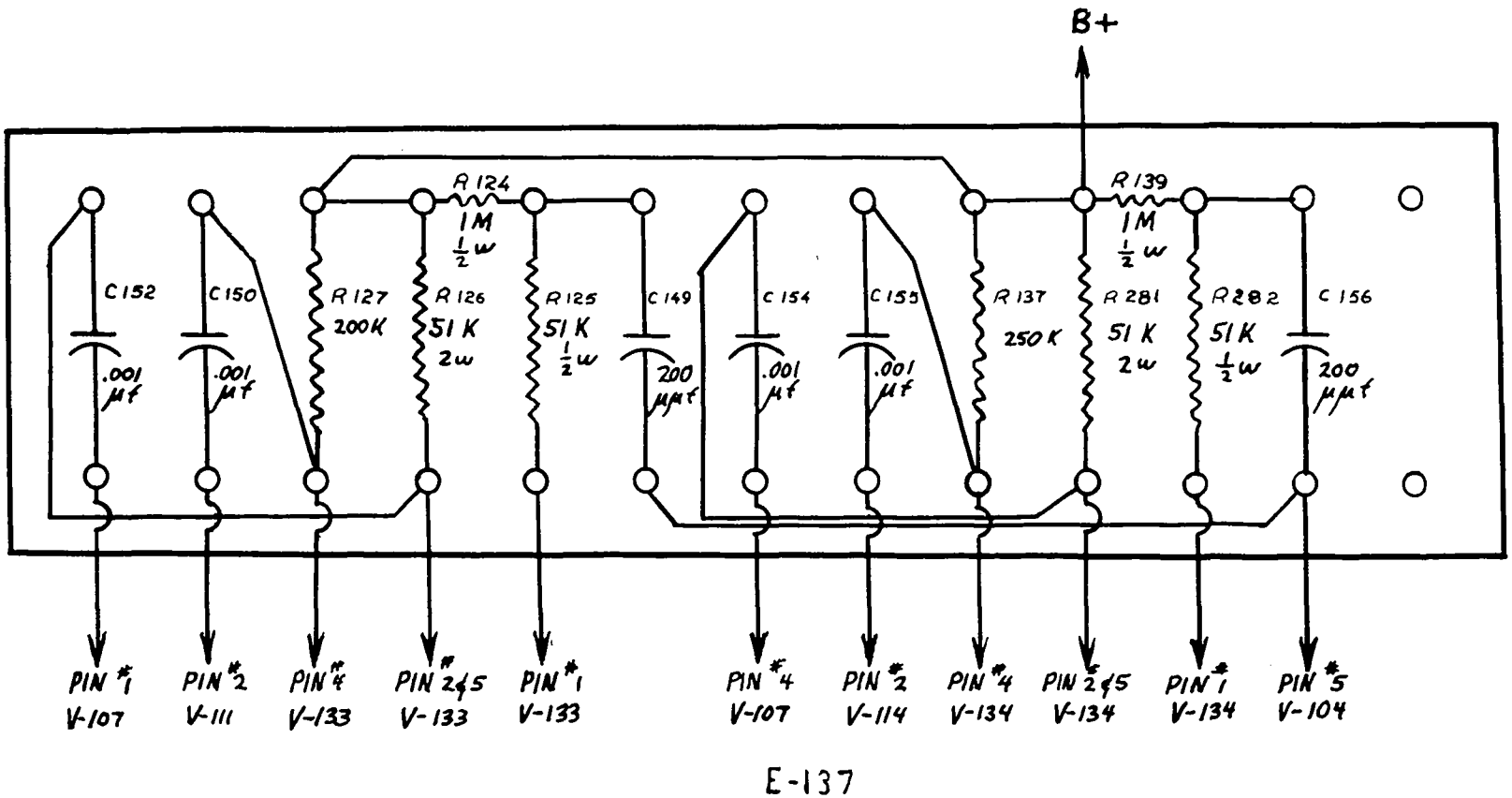
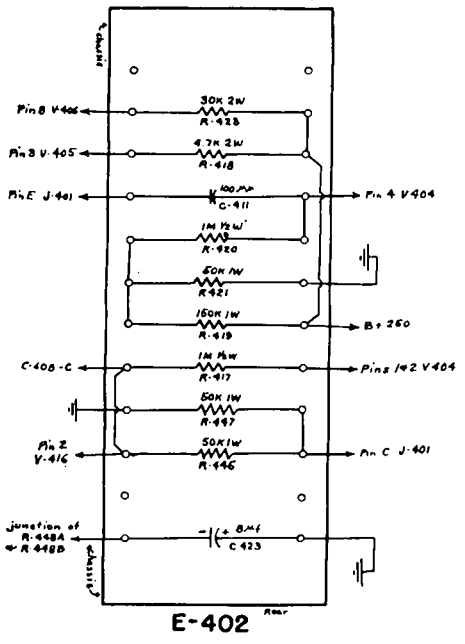


FIGURE 69.—Ground-station Controller-Indicator terminal board E138.

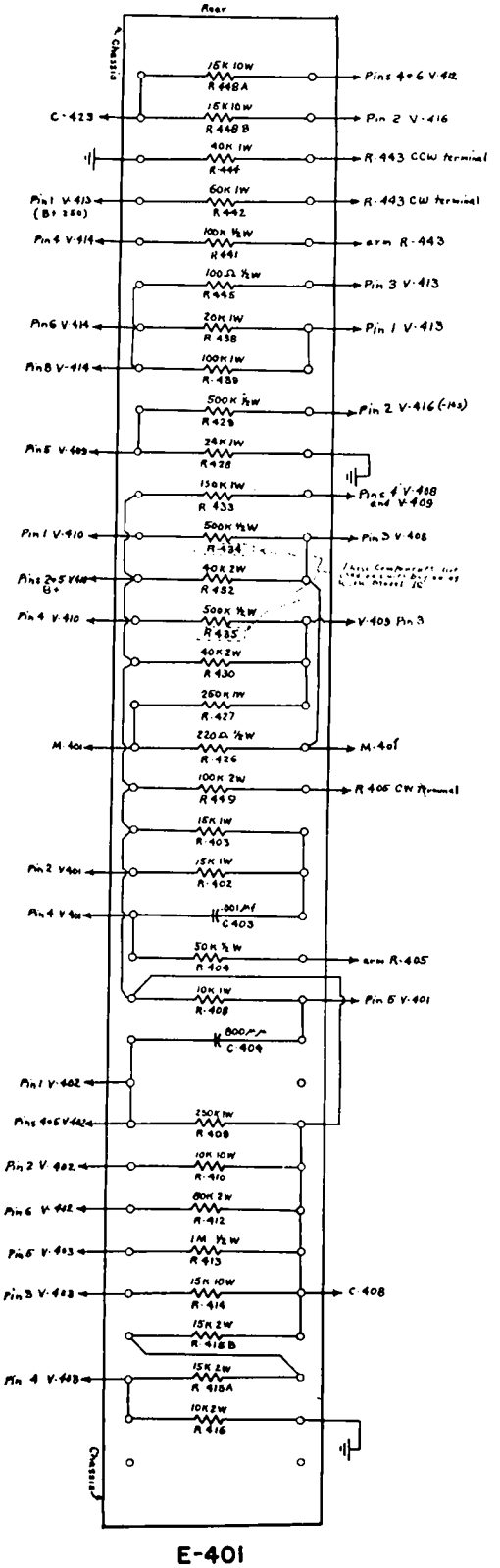


E-137

FIGURE 70.—Ground-station Controller-Indicator terminal board E137.



E-402



E-401

FIGURE 71.—Ground-station Synchronizer terminal boards E401, and E402.

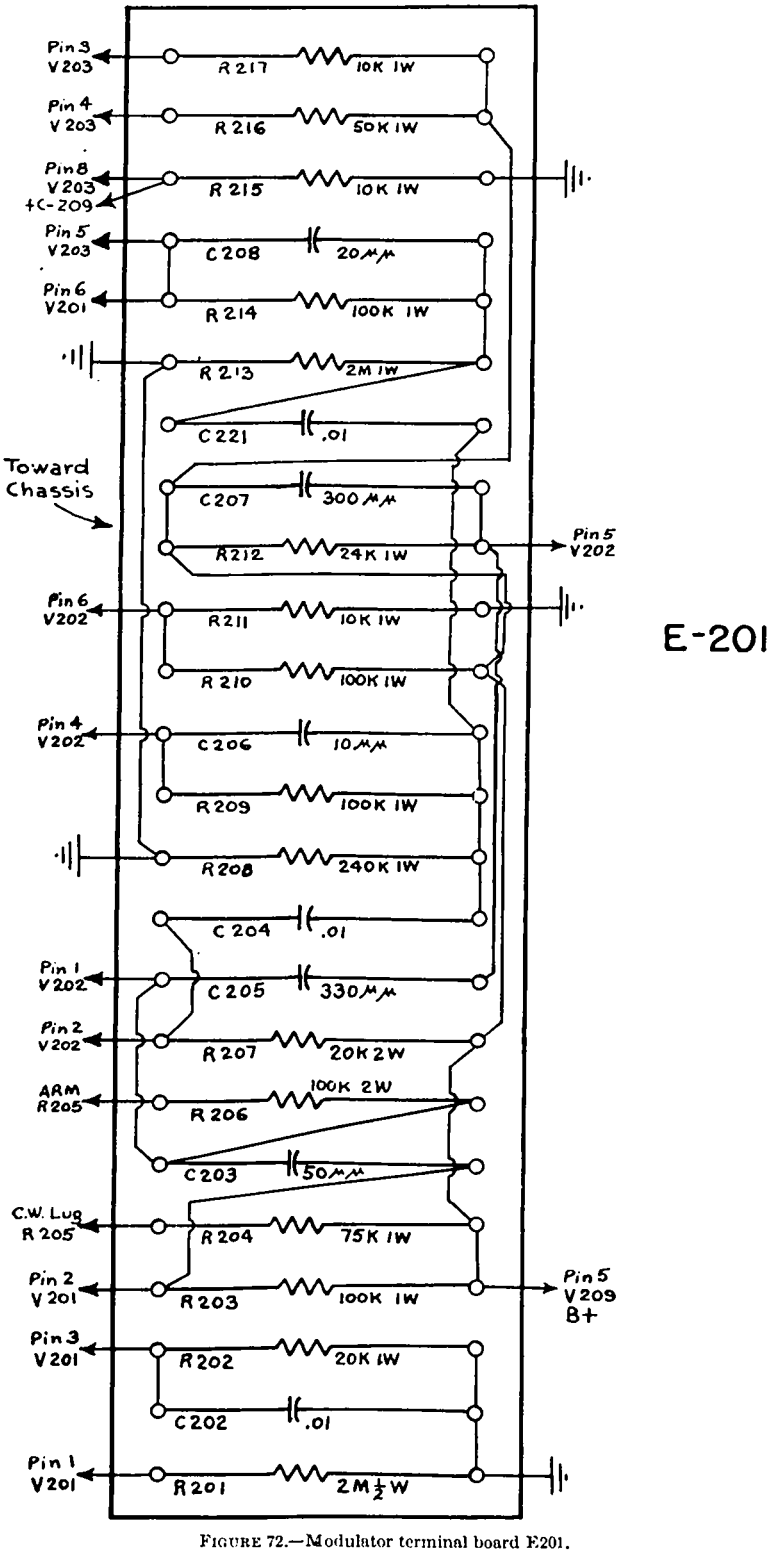


FIGURE 72.—Modulator terminal board E201.

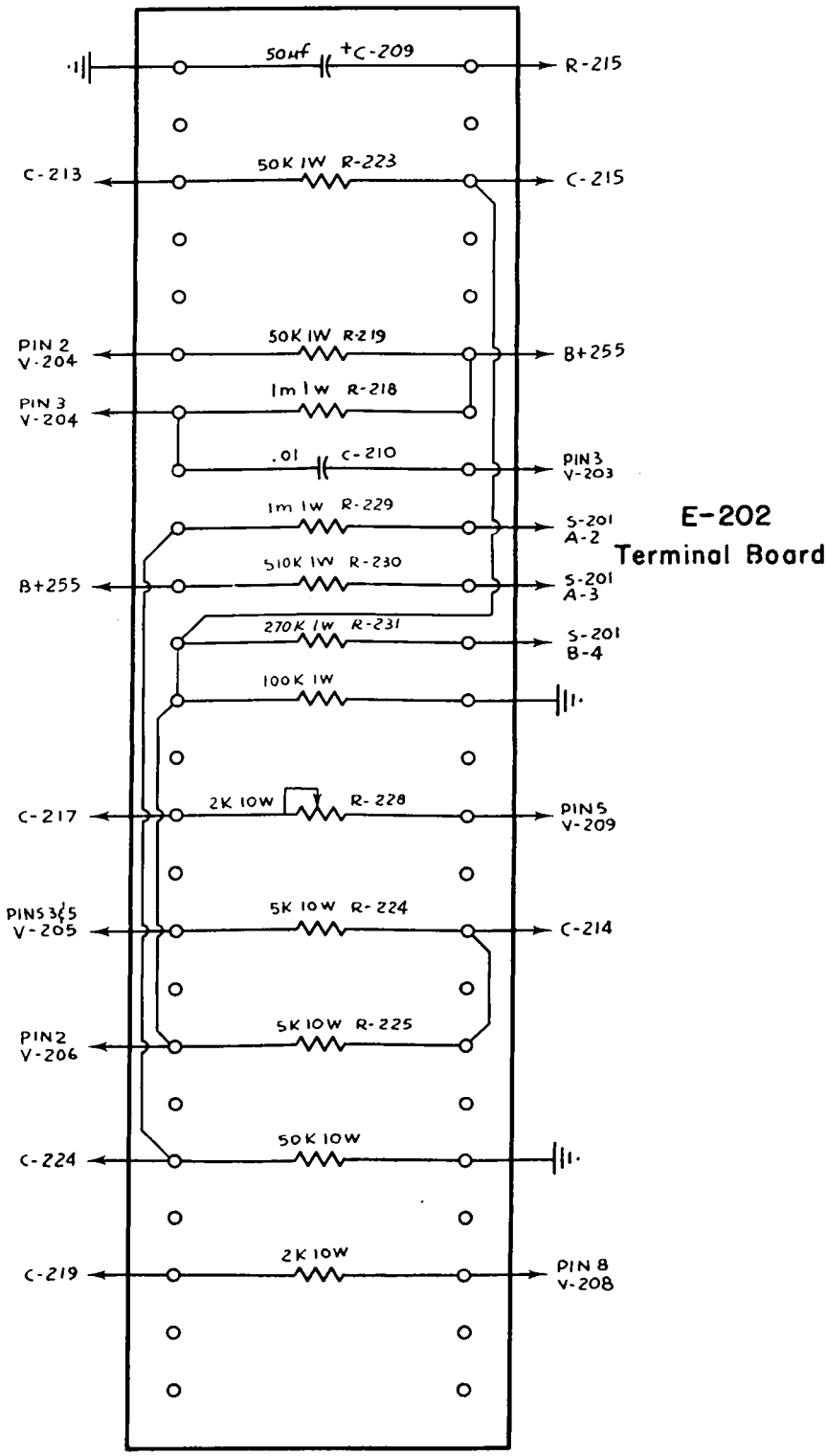
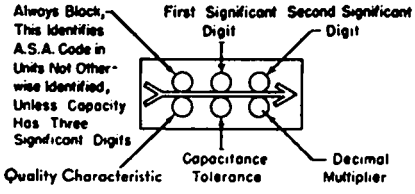


FIGURE 73.—Modulator terminal board E202.

A S A COLOR CODE FOR CAPACITORS



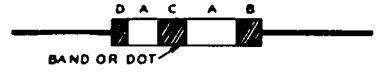
Color	Significant figure	Decimal multiplier	Tolerance	Characteristic
Black	0	1	20 percent(M)	A
Brown	1	10		B
Red	2	100	2 percent(G)	C
Orange	3	1,000		D
Yellow	4			E
Green	5			F
Blue	6			G
Violet	7			
Gray	8			
White	9			
Gold	—	0.1	5 percent(J)	
Silver	—	.01	10 percent(K)	

See JAN C-5 for definition and explanation of Quality Characteristics.

RMA COLOR CODE FOR RESISTORS (OHMS)

COLOR	A 1st DIGIT	B 2nd DIGIT	C MULTIPLIER
SILVER			0.01
GOLD			0.1
BLACK		0	1.0
BROWN	1	1	10
RED	2	2	100
ORANGE	3	3	1,000
YELLOW	4	4	10,000
GREEN	5	5	100,000
BLUE	6	6	1,000,000
PURPLE	7	7	10,000,000
GRAY	8	8	100,000,000
WHITE	9	9	

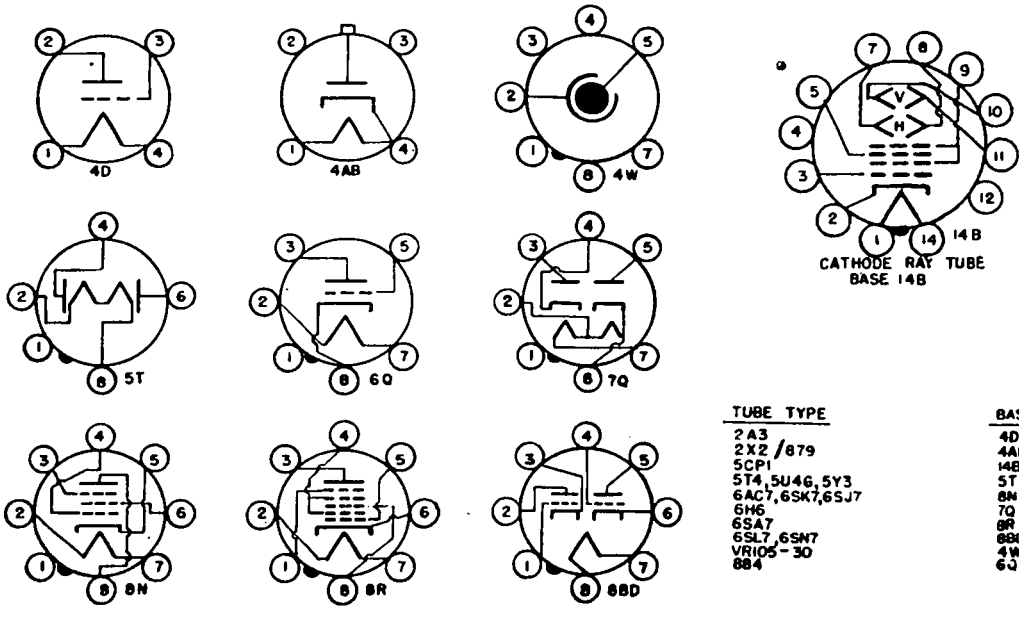
D — TOLERANCE CODE.
GOLD = 5% SILVER = 10% NO COLOR = 20%



OLD COLOR ARRANGEMENT

NEW COLOR ARRANGEMENT

BODY COLOR (NEW COLOR ARRANGEMENT ONLY) INDICATES TYPE OF RESISTOR, AS FOLLOWS —
BLACK — COMPOSITION, NON-INSULATED
TAN, OLIVE OR WHITE — COMPOSITION, INSULATED
DARK BROWN — WIRE-WOUND, INSULATED



TUBE TYPE	BASE
2A3	4D
2X2/879	4AB
5CP1	14B
5T4, 5U4G, 5Y3	5T
6AC7, 6SK7, 6SJ7	8N
6H6	7Q
6SA7	8R
6SL7, 6SN7	8BD
VR105-30	4W
884	6Q

FIGURE 74.—Color code, and tube base diagrams.

PARTS LIST

SHIP CONTROLLER POWER SUPPLY

Symbol	Function	Description
C501	B plus input filter	4-mf, oil, can, 600V.
C502	B plus filter	4-mf, oil, can, 600V.
C503	V506 plate filter	0.5-mf, bathtub, 600V.
C504	V506 cathode bypass	0.5-mf, bathtub, 600V.
C505	V506 plate filter	4-mf, oil, can, 600V.
C506	−50V filter	4-mf, oil, can, 600V.
C507	V509 bypass	0.1-mf, bathtub, 600V.
C508	−50V filter	4-mf, oil, can, 600V.
L501	Filter choke	Chicago Trans. Co. RC–8300.
R501	B plus bleeder	1 meg. 1 watt.
R502	V502 grid equalizer	100 ohms, 1 watt.
R503	V503 grid equalizer	100 ohms, 1 watt.
R504	V504 grid equalizer	100 ohms, 1 watt.
R505	V505 grid equalizer	100 ohms, 1 watt.
R506	V506 plate load	100,000 ohms, 1 watt.
R507	V506 screen dropping	20,000 ohms, 20 watts.
R508	V506 screen dropping	5,000 ohms, 1 watt.
R509	V506 grid return	500,000 ohms, 1 watt.
R510	V506 grid bias	50,000 ohms potentiometer, 4 watts, linear taper.
R511	V506 grid bias	4,700 ohms, 1 watt.
R512	V506 grid bias	30,000 ohms, 1 watt.
R513	V509 regulator	40,000 ohms, 10 watts.
R514	−50V voltage divider	51,000 ohms, 2 watts.
R515	−50V voltage divider	51,000 ohms, 2 watts.
R516	V510 regulator	10,000 ohms, 10 watts adjustable.
T501	Power transformer	Chicago Trans. Co. PSR–300.

SHIP CONTROLLER

Symbol	Function	Description
	A Goniometer assembly	U. S. A. F. stock No. 2Z9629–45.*
	B Goniometer assembly	U. S. A. F. stock No. 2Z9629–45.*
C1	Crystal tuning	800-mmf, mica, 500V.
C2A	Oscillator plate filter	0.5-mf, triple, bathtub, 600V.
C2B	V3A plate bypass	
C2C	Oscillator plate filter	
C3	Crystal tuning	320-mmf, variable, air.
C4	V1 grid tuning	500-mmf, mica, 500V.
C5	V1 screen bypass	0.1-mf, bathtub, 600V.
C6	V1, V2 coupling	0.01-mf, tubular, 600V.
C7	V2 plate bypass	150-mmf, mica, 500V.
C8	V3A grid coupling	50-mmf, mica, 500V.
C9	V3A, V4 coupling	0.1-mf, tubular, 600V.
C10	V6, V5 coupling	220-mmf, mica, 600V.
C11A	V6 cathode bypass	0.5-mf, dual, bathtub, 600V.
C11B	V7 screen bypass	
C13	T305, V8 coupling	0.1-mf, bathtub, 600V.
C14	V8 plate tuning	0.08-mf, bathtub, 600V.
C15	T306 tuning	0.35-mf, bathtub, 600V.
C16	V8, T3 coupling	0.1-mf, bathtub, 600V.
C17	V27B grid coupling	0.001-mf, tubular, 600V.
C18	V25A grid coupling	25-mmf, mica, 500V.
C19	V25 cathode bypass	40-mf, electrolytic, 450V.
C20	V25B timing	25-mmf, mica, 500V.
C21	V25B grid coupling	25-mmf, mica, 500V.
C22	V23A, V23B coupling	0.002-mf, tubular, 600V.
C23	V21, V23B coupling	1-mf, bathtub, 600V.
C24	V21A grid coupling	0.01-mf, tubular, 600V.
C25	V21B grid coupling	0.1-mf, tubular, 150V.
C26	V23B output	1-mf, bathtub, 600V.
C27	V23B cathode bypass	0.005-mf, tubular, 600V
C28	V24A, V24B coupling	0.002-mf, tubular, 600V.
C29	V24B output	1-mf, bathtub, 600V.
C30	V24B cathode bypass	0.005-mf, tubular, 600V.
C31	V22, V24B coupling	1-mf, bathtub, 600V.
C32	V22A grid coupling	0.01-mf, tubular, 600V.
C33	V22B grid coupling	0.1-mf, tubular, 150V.
C34	V17, V19 coupling	0.002-mf, tubular, 600V.
C35	V17 screen bypass	0.01-mf, tubular, 600V.
C36	V15 plate bypass	0.0004-mf, tubular, 600V.
C37	V15 screen bypass	500-mmf, mica, 500V.
C38	V9A, V15 coupling	0.01-mf, mica, 500V.
C39A	V11A plate bypass	0.25-mf, dual, bathtub, 600V.
C39B	V9 plate bypass	
C40	V9A cathode filter	0.01-mf, mica, 500V.
C41	V10A plate bypass	0.25-mf, bathtub, 600V.
C42	V10A cathode bypass	0.01-mf, mica, 500V.
C43	V10A, V16 coupling	0.01-mf, mica, 500V.
C44	V16 screen bypass	500-mmf, mica, 500V.
C45	V16 plate bypass	0.004-mf, tubular, 600V.
C46	V18 screen bypass	0.01-mf, tubular, 600V.

* Further description on these components will be found in the APN-3 SHORAN manual.

SHIP CONTROLLER—Continued

Symbol	Function	Description
C47	V18, V20 coupling	0.002-mf, tubular, 600V.
C48	V19 cathode bypass	0.01-mf, mica, 500V.
C49	V19 screen bypass	0.01-mf, mica, 500V.
C50	V11A, V11B coupling	0.01-mf, mica, 500V.
C51	V11A plate filter	500-mmf, mica, 500V.
C52	V11A grid tuning	0.001-mf, mica, 500V.
C53A	V12A plate bypass	0.25-mf, dual, bathtub, 600V.
C53B	V14A plate bypass	
C54	V12A grid tuning	0.001-mf, mica, 500V.
C55	V12A, V12B filter	500-mmf, mica, 500V.
C56	V12A, V12B coupling	0.01-mf, mica, 500V.
C57	V20 screen bypass	0.01-mf, mica, 500V.
C58	V20 cathode bypass	0.01-mf, mica, 500V.
C59	V9B grid coupling	0.002-mf, mica, 500V.
C60	V13B output	0.05-mf, tubular, 600V.
C61	V13B plate filter	0.01-mf, mica, 500V.
C62	V13A, V13B coupling	0.01-mf, mica, 500V.
C63	V13A grid coupling	0.01-mf, mica, 500V.
C64	V13A grid tuning	0.01-mf, mica, 500V.
C65	V14A grid tuning	0.01-mf, mica, 500V.
C66	V14A grid coupling	0.01-mf, mica, 500V.
C67	V14A, V14B coupling	0.01-mf, mica, 500V.
C68	V14B plate filter	0.01-mf, mica, 500V.
C69	V14B output	0.05-mf, tubular, 600V.
C70	V10B grid coupling	0.002-mf, mica, 500V.
C71	Thermostat bypass	0.01-mf, mica, 500V.
C72	V25A timing	25-mmf, mica, 500V.
L343	Tune 1 KC output cable	Coil, 20 microhenries, RCA part No. M-429894-502*
R1	Crystal balance	510 ohms, 1 watt.
R2	Crystal balance	250 ohms, 1 watt.
R3	Oven heater	800 ohms, 40 watts.
R4	VI cathode bias	1,000 ohms, 1 watt.
R5	VI screen dropping	50,000 ohms, 1 watt.
R6	VI plate load	15,000 ohms, 2 watts.
R7	V2 grid return	1 meg. ½ watt.
R8	V2 cathode bias	1,000 ohms, 1 watt.
R9	V3A grid return	1 meg. ½ watt.
R10	V3A plate load	10, 000 ohms, 2 watt.
R11	V3A cathode bias	10,000 ohms, 2 watt.
R12	V4 grid return	500,000 ohms, ½ watt.
R13	V4 cathode bias	200 ohms, ½ watt.
R20	T304 decoupling	180 ohms, ½ watt.
R26	T306 decoupling	39 ohms, ½ watt.
R27	Pulse limiter	50,000, ½ watt.
R28	V27 grid return	1 meg. ½ watt.
R29	V27 plate filter	1,000 ohms, 1 watt.
R30	V27 cathode bias	10,000 ohms, 1 watt.
R31	V27 grid return	1 meg., ½ watt.
R32	V25 pulse limiter	10,000 ohms, ½ watt.
R33	V25 grid return	10,000 ohms, ½ watt.
R34	V25 timing	390,000 ohms, ½ watt.

SHIP CONTROLLER—Continued

Symbol	Function	Description
R35	V25 cathode bias	100,000 ohms, 1 watt.
R36	V25 plate load	39,000 ohms, 1 watt.
R37	V25 plate load	39,000 ohms, 1 watt.
R38	V25 cathode bias	2,700 ohms, 1 watt.
R39	V25 2nd E. J. Adj	5,000 ohms potentiometer 3 watt, linear taper.
R40	V25 grid return	100,000 ohms, ½ watt.
R41	V25 timing	390,000 ohms, ½ watt.
R42	V21A pulse limiter	100,000 ohms, ½ watt.
R43	V22A pulse limiter	100,000 ohms, ½ watt.
R44	V25B pulse limiter	100,000 ohms, ½ watt.
R45	V23A grid return	2 meg. ½ watt.
R46	V23A grid suppressor	330 ohms, ½ watt.
R47	V23A cathode bias	10,000 ohms, 1 watt.
R48	V23B pulse limiter	100,000 ohms, ½ watt.
R49	V23B grid return	100,000 ohms, ½ watt.
R50	V21 grid return	1 meg. ½ watt.
R51	V21 plate load	47,000 ohms, 1 watt.
R52	V21 grid return	20 meg. ½ watt.
R53	V23B plate load	20,000 ohms, 1 watt.
R54	V23B cathode bias	82,000 ohms, 1 watt.
R55	V23B cathode bias	10,000 ohms potentiometer, 3 watts, linear taper.
R56	V24A grid suppressor	330 ohms, ½ watt.
R57	V24A cathode bias	10,000 ohms, 1 watt.
R58	V24B pulse limiter	100,000 ohms, ½ watt.
R59	V24B grid return	100,000 ohms, ½ watt.
R60	V24B plate load	20,000 ohms, 1 watt.
R61	Voltage dropping for R62	82, 000 ohms, 1 watt.
R62	V24 blanking video bias adj	10,000 ohms potentiometer 3 watts, linear taper.
R63	V22 grid return	1 meg. ½ watt.
R64	V22 plate load	47,000 ohms, 1 watt.
R65	V22 grid return	20 meg. ½ watt.
R66	V17 plate load	75,000 ohms, 1 watt.
R67	V17 screen dropping	50,000 ohms, 1 watt.
R68	V17 cathode bias	180 ohms, ½ watt.
R69	V17 grid return	3,900 ohms, ½ watt.
R70	V17 plate filter	220 ohms, ½ watt.
R71	V15 screen return	27,000 ohms, ½ watt.
R72	V15 grid return	3.3 meg. ½ watt.
R73	V9A plate load	150 ohms, ½ watt.
R74	V9A grid return	33,000 ohms, ½ watt.
R75	V9A cathode bias	2,200 ohms, ½ watt.
R76	V9A grid return	150,000 ohms, ½ watt.
R77	V9A cathode bias	8,200 ohms, 1 watt.
R78	V10A grid return	33,000 ohms, ½ watt.
R79	V10A grid return	150,000 ohms, ½ watt.
R80	V10A plate load	150 ohms, ½ watt.
R81	V10A cathode bias	2,200 ohms, ½ watt.
R82	V10A cathode bias	8,200 ohms, 1 watt.
R83	V16 grid return	3.3 meg. ½ watt.

SHIP CONTROLLER—Continued

Symbol	Function	Description
R84	V16 screen return	27,000 ohms, ½ watt.
R85	V18 grid return	3,900 ohms, ½ watt.
R86	V18 cathode bias	180 ohms, ½ watt.
R87	V18 screen dropping	50,000 ohms, 1 watt.
R88	V18 plate load	75,000 ohms, 1 watt.
R89	V19 grid return	150,000 ohms, ½ watt.
R90	V19 grid suppressor	220 ohms, ½ watt.
R91	V19 plate load	15, 000 ohms, 1 watt.
R92	V19 cathode bias	5,600 ohms, 1 watt.
R93	V11B diode load	150,000 ohms, ½ watt.
R94	V11A filter	15,000 ohms, ½ watt.
R95	V11A plate load	5,000 ohms, 1 watt.
R96	V11A grid suppressor	150,000 ohms, ½ watt.
R97	V12A grid suppressor	150,000 ohms, ½ watt.
R98	V12A plate filter	6,800 ohms, 1 watt.
R99	V12A plate load	5,000 ohms, 1 watt.
R100	V12A filter	15,000 ohms, ½ watt.
R101	V12B diode load	150,000 ohms, ½ watt.
R102	V20 plate load	15,000 ohms, 1 watt.
R103	V20 cathode bias	5,600 ohms, ½ watt.
R104	V20 plate filter	220 ohms, ½ watt.
R105	V20 grid return	150,000 ohms, ½ watt.
R106	V20 grid suppressor	220 ohms, ½ watt.
R107	V3B cathode bias	470,000 ohms, ½ watt.
R108	V9B grid return	100,000 ohms, ½ watt.
R110	V13 plate load	22,000 ohms, 1 watt.
R111	V13 cathode bias	82,000 ohms, ½ watt.
R112	1 KC amplitude mixing, *A*	50,000 ohms potentiometer 2 watts, linear taper.
R113	Voltage dropping for R112	50,000 ohms, 1 watt.
R114	V13A plate voltage divider	8,200 ohms, 1 watt.
R115	Part of voltage divider with R114	120,000 ohms, 1 watt.
R116	V13A plate load	150,000 ohms, 1 watt.
R117	V13A grid return	3 meg. ½ watt.
R118	V14A grid return	3 meg. ½ watt.
R119	V14A plate load	150,000 ohms, 1 watt.
R120	1 KC amplitude mixing, *B*	50,000 ohms potentiometer, 2 watts, linear taper.
R121	Voltage dropping for R120	50,000 ohms, 1 watt.
R122	V14B plate load	22,000 ohms, 1 watt.
R123	V14B grid return	82,000 ohms, ½ watt.
R124	V10B grid return	100,000 ohms, ½ watt.
S1	A-C power switch	DPDT, toggle, 10 amps. at 125V.
T1	100 KC transformer	W. E. No. D99917.
T2	100 KC transformer	Same as T1.
T3	V27 peaker	Freed No. 12524.
T4	Filament transformer	Chicago Trans. Co. No. F610.
T5	Filament transformer	Same as T4.
T9	V16, V18 coupling	Freed No. 12524.
T10	V15, V17 coupling	Same as T9.

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SHIP CONTROLLER—Continued

Symbol	Function	Description
T11	V9B output	RCA No. K-885119-1.*
T12	V10B output	Same as T11.
T301	100 KC coupling and output	RCA No. K-901688-501.*
T302	90 KC coupling	Same as T301.
T303	10 KC coupling	RCA No. K-901689-501.*
T304	10 KC output	RCA No. K-901684-501.*
T305	10 KC coupling	Same as T303.
T306	1 KC output	RCA No. K-901683-501.*
Z301	93 KC filter	Filter assembly, RCA part No. M-422282-501.*
Z302	93 KC filter	Filter assembly, RCA part No. M-430123-501.*

* Further description on these components will be found in the APN-3 SHORAN manual.

SHIP INDICATOR

Symbol	Function	Description
C105	V138B cathode bypass	0.25-mf, bathtub, 600V.
C108	V137 grid filter	0.01-mf, mica, 500V.
C110A	V102 screen bypass	0.25-mf, dual, bathtub, 600V.
C110B	V116B cathode bypass	
C111	V102, V103 coupling	4-50-mmf, variable, air.
C112	V103 storage	620-mmf, mica, 500V.
C113	V104, V105 coupling	240-mmf, mica, 500V.
C114A	V104 cathode bypass	0.25-mf, dual, bathtub, 600V.
C114B	V106 cathode bypass	
C115	V104A, V104B coupling	10-mmf, mica, 500V.
C116	V104A, V104B coupling	5-mmf, mica, 500V.
C117	V140 coupling	150-mmf, mica, 500V.
C118	V105 storage	750-mmf, mica, 500V.
C119	V141 coupling	39-mmf, mica, 500V.
C120	V142 coupling	200-mmf. mica, 500V.
C121	V106A plate bypass	200-mmf, mica, 500V.
C122	V106A, V104A coupling	24-mmf, mica, 500V.
C123	V106A, V108 coupling	75-mmf, mica, 500V.
C124	V106A, V113B coupling	10-mmf, mica, 500V.
C125	V108 storage	1500-mmf, mica, 500V.
C127A	V106B cathode bypass	0.25-mf, dual, 600V bathtub.
C127B	V107 cathode bypass	
C128	V106B, V109 coupling	240-mmf, mica, 500V.
C129	V109 storage	0.01-mf, mica, 600V.
C130	V110A cathode bypass	0.25-mf, bathtub 600V.
C131	V110A, V122 coupling	0.01-mf, mica, 500V.
C132	V111 plate bypass	51-mmf, mica, 500V.
C133	V111 grid filter bypass	0.25-mf, bathtub 600V.
C134	V111, V113B coupling	240-mmf, mica, 500V.
C135	V111B grid coupling	240-mmf, mica, 500V.
C136	V111 *A* pedestal timing	0.0062-mf, mica, 300V.
C137	V111A, V133 coupling	0.005-mf, mica, 500V.

SHIP INDICATOR—Continued

Symbol	Function	Description
C138A	V112A grid filter bypass	0.25-mf, dual, bathtub, 600V.
C138B	V114 *B* pedestal position	
C139	V114, V134 coupling	0.005-mf, mica, 500V.
C140	V115A, V112 coupling	200-mmf, mica, 500V.
C141	V112A plate bypass	100-mmf, mica, 500V.
C142	V112A, V112B coupling	0.0062-mf, mica, 600V.
C143	V112A, V112B coupling	0.02-mf, mica, 600V.
C144	V116 grid coupling	51-mmf, mica, 500V.
C145	V116A, V116B coupling	51-mmf, mica, 500V.
C146	V116B cathode coupling	51-mmf, mica, 500V.
C147	V104A cathode bypass	0.02-mf, mica, 500V.
C148	V133A grid coupling	0.002-mf, mica, 500V.
C149	V133, V107 coupling	0.1-mf, tubular, 600V.
C150	V107 output	51-mmf, mica 500V.
C151	V107 output	51-mmf, mica, 500V.
C152	V134, V107 coupling	0.1-mf, tubular, 600V.
C153	V134A grid coupling	0.002-mf, mica, 500V.
C154	V117, V138B coupling	0.001-mf, mica, 500V.
C155	V138B, V136 coupling	51-mmf, mica, 500V.
C156	V138B, V119 coupling	51-mmf, mica, 500V.
C157	V112B, V117 coupling	100-mmf, mica, 500V.
C158	V136A, V136B coupling	0.001-mf, mica, 500V.
C159	V137 grid coupling	10-mmf, mica, 500V.
C160	V137 putput	0.005-mf, mica, 500V.
C161	V113B, V114 coupling	24-mmf, mica, 500V.
C162	V114A, V114B coupling	0.03-mf, mica, 500V.
C164	V115B, V114 coupling	150-mmf, mica, 500V.
C165	V110B, V115A coupling	24-mmf, mica, 500V.
C166	V115A, V115B coupling	24-mmf, mica, 500V.
C167	V115A, V115B coupling	24-mmf, mica, 500V.
C168	V110B, V115B coupling	24-mmf, mica, 500V.
C169A	V115 cathode bypass	20/20/50-mf, 450/450/50V, electrolytic, octal base.
C169B	V123 screen bypass	
C169C	V123 cathode bypass	
C170	V110A, V110B coupling	100-mmf, mica. 500V.
C171	V113A, V125 coupling	1-mf, bathtub, 600V.
C172	V113B, V112A coupling	200-mmf, mica, 500V.
C173	V113A grid coupling	0.5-mf, bathtub, 600V.
C174	V119 grid coupling	0.0015-mf, mica, 500V.
C175	Filter, high voltage	0.25-mf, oil, 2000V.
C176	Filter, high voltage	0.25-mf, oil, 2000V.
C177	Filter, high voltage	0.25-mf, oil, 2000V.
C178	V128 input filter	4-mf, oil, can, 600V.
C179	Filter, unregulated voltage	4-mf, oil, can, 600V.
C180A	V129, V130 filter	20/20/50-mf, 450/450/50 V, electrolytic. octal base.
C180B	Filter, regulated voltage	
C180C	V122 cathode bypass	
C181	V125 cathode bypass	0.5-mf, oil, 1500V.
C182	Regulated voltage bypass	1-mf, bathtub, 600 V.
C184	V131 screen bypass	0.5-mf, bathtub, 600V.
C185	V131 coupling	0.5-mf, bathtub, 600V.

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SHIP INDICATOR—Continued

Symbol	Function	Description
C186A	V125 hor. plates	0.1-mf, dual, bathtub, 600V.
C186B	V125 hor. plates	
C188A	V125 vert. plates	0.1-mf, dual, bathtub, 600V.
C188B	V125 vert. plates	
C190	V135 cathode bias	0.5-mf, oil, 1500V.
C191	V121 screen bypass	1-mf, bathtub, 600V.
C192	V121 sweep forming	51-mf, mica, 500V.
C193	V102 grid coupling	0.01-mf, mica, 500V.
C194	V121 sweep forming	0.0013-mf, mica, 500V.
C195	V121 sweep forming	0.0051-mf, mica, 500V.
C196	V119 plate bypass	1-mf, bathtub, 600 V.
C197	V119B, V119A coupling	1-mf, bathtub, 600V.
C198	V119 timing	0.0024-mf, mica, 500V.
C199	V119 timing	500-mmf, mica, 500V.
C200	V119 timing	100-mmf, mica, 500V.
C201	V119B grid filter	0.5-mf, bathtub, 600V.
C202	V120B, V125 coupling	0.01-mf, mica, 1200V.
C203	V124, V125 coupling	0.5-mf, bathtub, 600V.
C204	V124, V125 coupling	0.5-mf, bathtub, 600V.
C205	V124 plate filter	4-mf, oil, can, 600V.
C206	V121, V124 coupling	0.5-mf, bathtub, 600V.
C207	V123, V124 coupling	0.1-mf, bathtub, 600V.
C208	V138B, V113A coupling	100-mf, mica, 500V.
C210	V122, V123 coupling	0.5-mf, bathtub, 600V.
C211	V122 sweep forming	0.1-mf, bathtub, 600V.
C214	V125 hor. plate coupling	0.25-mf, bathtub, 600V.
C215	V102, V117 coupling	51-mf, mica, 500V.
C217	V122 plate filter	0.5-mf, bathtub, 600V.
C218	V120B, V125 coupling	See C202.
C221	V104A, V113A coupling	0.002-mf, mica, 600V.
C222	V125 hor. plate coupling	0.25-mf, bathtub, 600V.
C1001	V139A output	0.1-mf, bathtub, 600V.
C1002	V139B output	0.1-mf, bathtub, 600V.
C1003	Neon bulb storage	1-mf, bathtub, 600V.
C1004	Neon bulb coupling	1-mf, bathtub, 600V.
C1005	V136, V137 coupling	1-mf, bathtub, 600V.
L102	V102 plate peaking	Essex Specialty Co. part No. 35.358B.*
L103	B plus filter choke	United Trans. Co. No. S-28.*
R103	V107A grid leak	5 megs, ½ watt.
R104	V102 plate load	22,000 ohms, 1 watt.
R105	V102 screen dropping	56,000 ohms, 1 watt.
R106	V102 grid leak	100,000 ohms, ½ watt.
R107	T102 secondary damper	33,000 ohms, ½ watt.
R108	V104B cathode bias	68,000 ohms, 2 watts.
R109	V104B cathode bias adj. (A)	10,000 ohms potentiometer, ½ watt, linear taper.
R110	V104B cathode bias	6,800 ohms, 1 watt.
R112	V106A cathode bias	82,000 ohms, 1 watt.
R113	V106A cathode bias adj. (B)	25,000 ohms potentiometer, ½ watt, linear taper.

* Further description on these components will be found in the APN-3 SHORAN manual.

SHIP INDICATOR—Continued

Symbol	Function	Description
R114	V106A cathode bias	22,000 ohms, 1 watt.
R115	V104A grid limiter	100,000 ohms, ½ watt.
R116	V108 cathode bias	1 meg. ½ watt.
R117	T104 secondary damper	33,000 ohms, ½ watt.
R118	V106B cathode bias	56,000 ohms, 1 watt.
R119	V106B cathode bias adj. (C)	25,000 ohms, potentiometer, ½ watt, linear taper.
R120	V106B cathode bias	22,000 ohms, 1 watt.
R121	V110A cathode bias	220,000 ohms, 1 watt.
R122	V110A cathode bias	25,000 ohms potentiometer, ½ watt, linear taper.
R123	V110A cathode bias	47,000 ohms, ½ watt.
R124	V133A grid return	1 meg. ½ watt.
R125	V133A grid return	50,000 ohms, ½ watt.
R126	V133 plate load	50,000 ohms, 2 watts.
R127	V133B grid return	1 meg. ½ watt.
R128	V139A plate load	50,000 ohms, 1 watt.
R129	V112A grid bias	10,000 ohms potentiometer, ½ watt, linear taper.
R130	V112A grid bias	2,200 ohms, ½ watt.
R131	V111B grid filter	180,000 ohms, ½ watt.
R132	V111B plate load	22,000 ohms, 2 watts.
R133	V111A grid timing	3.9 megs, 1 watt.
R134	V111A plate load	22,000 ohms, 1 watt.
R135	V111B grid pulse limiter	39,000 ohms, ½ watt.
R136	V111A cathode bias	10,000 ohms, 1 watt.
R137	V107A plate load	50,000 ohms, 1 watt.
R138	V114B *B* pedestal position	10,000 ohms potentiometer, ½ watt, linear taper.
R139	V134B *B* pedestal length	100,000 ohms potentiometer, ½ watt, linear taper.
R140	V111B grid bias	330,000 ohms, ½ watt.
R141	V112A grid differentiator	180,000 ohms, ½ watt.
R142	V112A plate load	22,000 ohms, 2 watts.
R143	V112B grid timer	3.9 megs. ½ watt.
R144	V112B plate load	22,000 ohms, 2 watts.
R145	V112A cathode bias	10,000 ohms, 1 watt.
R146	V134 grid leak	1 meg. ½ watt.
R147	V116A plate load	270,000 ohms, 1 watt.
R148	V116A grid leak	1 meg. ½ watt.
R149	V116B grid leak	1 meg. ½ watt.
R150	V116B cathode bias	5,600 ohms, ½ watt.
R151	V116B cathode bias	270,000 ohms, ½ watt.
R152	V104A cathode bias	1,500 ohms, 1 watt.
R153	V104A grid leak	1 meg. ½ watt.
R154	V107B plate load	50,000 ohms, 1 watt.
R155	V114A cathode bias	150,000 ohms, ½ watt.
R156	V114B grid bias	20,000 ohms, ½ watt.
R157	V107 cathode bias	15,000 ohms, 2 watts.
R158	V113B plate load	100,000 ohms, 1 watt.
R159	V113B cathode bias	220,000 ohms, 1 watt.
R160	V113B cathode bias	10,000 ohms, 1 watt.

SHIP INDICATOR—Continued

Symbol	Function	Description
R161	V114A plate load	22,000 ohms, 1 watt.
R162	V114A grid timing	2.2 megs. ½ watt.
R163	V114B plate load	22,000 ohms, 1 watt.
R164	V114 cathode bias	10,000 ohms, 1 watt.
R165	V107B grid leak	5 megs, ½ watt.
R166	V134B plate load	50,000 ohms, 1 watt.
R167	V107 cathode bias	15,000 ohms, 1 watt.
R168	V134A grid return	1 meg, ½ watt.
R169	V134A grid return	50,000 ohms, ½ watt.
R170	V112A grid bias	100,000 ohms, ½ watt.
R171	V133B A pedestal length adj	100,000 ohms potentiometer ½ watt, linear taper.
R172	V111B A pedestal position adj	10,000 ohms potentiometer, ½ watt, linear taper.
R173	V114B grid return	100,000 ohms, ½ watt.
R174	V115A, V112A differentiator	39,000 ohms, ½ watt.
R175	V111B grid bias	33,000 ohms, 1 watt.
R176	V114B grid limiter	39,000 ohms, ½ watt.
R177	V115A grid limiter	100,000 ohms, ½ watt.
R178	V115A plate load	39,000 ohms, ½ watt.
R179	V115A grid bias	390,000 ohms, ½ watt.
R180	V115A grid bias	390,000 ohms, ½ watt.
R181	V115B plate load	39,000 ohms, ½ watt.
R182	V115B grid limiter	100,000 ohms, ½ watt.
R183	V115 cathode bias	2,700 ohms, ½ watt.
R184	V115 cathode bias	5,000 ohms potentiometer, 3 watts, linear taper.
R185	V115B grid leak	100,000 ohms, ½ watt.
R186	V115 cathode bias	100,000 ohms, 1 watt.
R187	V115A grid leak	100,000 ohms, ½ watt.
R188	V110B plate load	100,000 ohms, ½ watt.
R189	V110B cathode load	100,000 ohms, ½ watt.
R190	V113A cathode bias	100,000 ohms, ½ watt.
R191	V113A cathode bias	4,700 ohms, ½ watt.
R192	V113A grid leak	1 meg. ½ watt.
R193	Trace separation control	50,000 ohms potentiometer, ½ watt, linear taper.
R194	Trace separation adjustment	200,000 ohms potentiometer, ½ watt, linear taper.
R195	V118A grid leak	10 megs. ½ watt.
R196	V118A cathode load	24,000 ohms, 1 watt.
R197	V118B cathode load	24,000 ohms, 1 watt.
R198	V118B grid leak	10 megs, 1 watt.
R199	V121 screen bleeder	100,000 ohms, ½ watt.
R200	V121 screen bleeder	180,000 ohms, ½ watt.
R201	V121 cathode bias	4,700 ohms, ½ watt.
R202	V121 cathode bias	10,000 ohms potentiometer, 3 watts, linear taper.
R203	V120B cathode load	100,000 ohms, ½ watt.
R204	V120B cathode load	30,000 ohms, ½ watt.
R205	V120B limiter, grid	100,000 ohms, ½ watt.

SHIP INDICATOR—Continued

Symbol	Function	Description
R206	V119 plate filter	2,200 ohms, ½ watt.
R207	V119A grid leak	100,000 ohms, ½ watt.
R208	V119A grid leak	39,000 ohms, ½ watt.
R210	V119A grid limiter	56,000 ohms, ½ watt.
R211	V119 cathode bias	2,200 ohms, ½ watt.
R212	V119B plate load	39,000 ohms, ½ watt.
R213	V119B timing	39,000 ohms, ½ watt.
R214	V119 cathode bias	2,700 ohms, ½ watt.
R215	V119 cathode bias	39,000 ohms, ½ watt.
R217	High voltage filter	56,000 ohms, ½ watt.
R218A	High voltage bleeder	5.6 megs. ½ watt.
R218B	High voltage bleeder	5.6 megs. ½ watt.
R218C	High voltage bleeder	5.6 megs. ½ watt.
R218D	High voltage bleeder	5.6 megs. ½ watt.
R219	High voltage filter	27,000 ohms, ½ watt.
R220	High voltage filter	100,000 ohms, ½ watt.
R221	B plus bleeder	820,000 ohms, ½ watt.
R222	V131 plate filter	100,000 ohms, ½ watt.
R223	V131 plate load	2.2 megs. ½ watt.
R224	V131 plate decoupling	1.2 megs. ½ watt.
R225	V129 grid equalizer	100 ohms, ½ watt.
R226	V130 grid equalizer	100 ohms, ½ watt.
R227	V131 screen grid bleeder	5,000 ohms, 20 watts.
R228	V131 grid filter	560,000 ohms, ½ watt.
R229	V131 screen bleeder	20,000 ohms, 20 watts.
R230	V131 grid bias	56,000 ohms, ½ watt.
R231	V131 grid bias	50,000 ohms potentiometer, 3 watts, linear taper.
R232	High voltage bleeder	820,000 ohms, ½ watt.
R233	High voltage bleeder	560,000 ohms, ½ watt.
R234	High voltage bleeder	390,000 ohms, ½ watt.
R235	High voltage bleeder	100,000 ohms, ½ watt.
R236A, R236B	V125 vert. center control	1 meg. potentiometer, ½ watt, linear taper.
R238	V125 hor. deflection	56,000 ohms, ½ watt.
R239A, R239B	V125 hor. center control	1 meg. potentiometer, ½ watt, linear taper.
R241	V125 hor. deflection	560,000 ohms, ½ watt.
R242	V125 focus adj	500,000 ohms potentiometer, ½ watt, linear taper.
R243	V125 focus control	1 meg. potentiometer, ½ watt, linear taper.
R244	V125 intensity control	1 meg. potentiometer, ½ watt, linear taper.
R245	V125 vert. load	1 meg. ½ watt.
R246	V125 vert. load	1 meg. ½ watt.
R247	V125 hor. load	1 meg. ½ watt.
R248	V125 hor. load	1 meg. ½ watt.
R249	V125 grid bias	8.2 megs. ½ watt.
R250	V124 cathode load	100,000 ohms, ½ watt.
R251	V124 plate load	100,000 ohms, ½ watt.
R252	V124 plate filter	68,000 ohms, ½ watt.
R253	V124 grid bias	1 meg. ½ watt.

SHIP INDICATOR—Continued

Symbol	Function	Description
R254	V124 grid bias	150,000 ohms, ½ watt.
R255	V124 grid bias	820,000 ohms, ½ watt.
R256	V124 grid bias	470,000 ohms, ½ watt.
R257	V123 screen bleeder	100,000 ohms, ½ watt.
R258	V123 screen bleeder	22,000 ohms, ½ watt.
R259	V123 cathode bias	3,300 ohms, ½ watt.
R260	V123 cathode bias	1,500 ohms, ½ watt.
R261	V123 plate load	180,000 ohms, ½ watt.
R262	V123 slow sweep adj	200,000 ohms potentiometer, ½ watt, linear taper.
R263	V122, V123 dropping	390,000 ohms, ½ watt.
R264	C211 charging	1 meg. ½ watt.
R265	V122 grid leak	100,000 ohms, ½ watt.
R266	V122 grid limiter	47,000 ohms, ½ watt.
R267	V122 cathode bias	4,700 ohms, 2 watts.
R268	V122 cathode bias	68,000 ohms, 2 watts.
R269	V122 plate limiter	330 ohms, ½ watt.
R270	Amplitude Balance control	500,000 ohms potentiometer, Clarostat T–90.
R271	Gain control	2,000 ohms potentiometer, 2 watts, linear taper.
R272	V134 plate load	51,000 ohms, 2 watts.
R273	V138A grid return	150,000 ohms, ½ watt.
R274	V138A cathode bias	500,000 ohms, 1 watt.
R277	V138B cathode bias	15,000 ohms, 1 watt.
R278	V122 plate filter	100,000 ohms, ½ watt.
R279	V113A grid circuit	100,000 ohms, ½ watt.
R280	V129, V130 center tap	10 ohms, 10 watts.
R281	V110A cathode bias	47,000 ohms, 1 watt.
R282	V110A cathode bias	100,000 ohms potentiometer, ½ watt, linear taper.
R283	V122, V123 dropping	220,000 ohms, ½ watt.
R284	V138B grid leak	1 meg. ½ watt.
R285	V104A cathode bias	22,000 ohms, ½ watt.
R286	V136A grid return	1 meg. ½ watt.
R287	V136A plate load	51,000 ohms, 1 watt.
R288	V137 grid filter	470,000 ohms, ½ watt.
R289	V137 plate limiter	500 ohms, 1 watt.
R290	V136B cathode bias	51,000 ohms, 2 watts.
R291	V136B grid return	1 meg. ½ watt.
R292	V137 grid return	100,000 ohms, ½ watt.
R293	V137 plate load	1 meg. 1 watt.
R294	V138B plate load	51,000 ohms, 1 watt.
R295	V117A grid return	1 meg. ½ watt.
R296	V117 plate load	51,000 ohms, 2 watts.
R297	V117A grid return	51,000 ohms, ½ watt.
R298	V117B grid return	470,000 ohms, ½ watt.
R299	V138B cathode bias	75,000 ohms, 1 watt.

SHIP INDICATOR—Continued

Symbol	Function	Description
S101A	Sweep speed	2 wafers, 2 positions, 6 circuits, Centralab No. 2517.
S101B		
S101C		
S101D		
S101E		
S101F		
S102A	Fast sweep selector	1 wafer, 3 positions, 2 circuits, Centralab No. 2505.
S102B		
S104A	Receiver on-off	2 wafers, 3 positions, 3 circuits, Centralab No. 2507.
S104B		
S104C		
S107	A C power switch	DPST 10-ampere, 125V.
S108A	Trigger	1 wafer, 3 positions, 3 circuits, Mallory No. 3243J.
S108B		
T102	1st divider	Freed No. 11793.*
T103	2d divider	Freed No. 11793.*
T104	3d divider	Freed No. 11793.*
T105	4th divider	Freed No. 11793.*
T106	Power Transformer	Freed No. 11851.*
T107	Trigger output	Philco T352–7224–2.

* Further description on these components will be found in the DAS-3 LORAN manual.

SHIP-STATION RECEIVER

Symbol	Function	Description
C301	L305 padder	30-mmf, mica, 500V.
C302	L306 tuning	15-mmf, mica, 500V.
C304B	V301 screen bypass	0.1-mf, triple, bathtub, 600V.
C304C	V305 cathode bypass	
C305	Secondary tuning, antenna coils	24-mmf, mica, 500V.
C306	V301, V302 coupling	250-mmf, mica, 500V.
C308	L315 tuning	15-mmf, mica, 500V.
C309	V302 grid tuning	24-mmf, mica, 500V.
C310	V302 osc. grid coupling	50-mmf, mica, 500V.
C311A	V302 screen bypass	0.1-mf, dual, bathtub, 600V.
C311B	V302 plate filter	
C312	T301 primary tuning	75-mmf, mica, 500V.
C313	T301 secondary tuning	75-mmf, mica, 500V.
C315	T302 primary tuning	75-mmf, mica, 500V.
C316	T302 secondary tuning	75-mmf, mica, 500V.
C317A	V307 screen bypass	0.1-mf, triple, bathtub, 600V.
C317B	V307 screen bypass	
C317C	V305 plate filter	
C318B	B plus filter	0.1-mf, triple, bathtub, 600V.
C318C	V307 screen bypass	
C319	T303 primary tuning	75-mmf, mica, 500V.
C320	T303 secondary tuning	75-mmf, mica, 500V.
C322	T304 primary tuning	75-mmf, mica, 500V.
C323	T304 secondary tuning	75-mmf, mica, 500V.

SHIP-STATION RECEIVER—Continued

Symbol	Function	Description
C324A	V303 cathode bypass	0.1-mmf, triple, bathtub, 600V.
C324B	Cathode bias bus bypass	
C324C	V304 cathode bypass	
C325	V305 screen bypass	0.002-mf, mica, 500V.
C327	V306 load bypass	150-mmf, mica, 500V.
C328	Filter network	75-mmf, mica, 500V.
C330	Filter network	0.01-mf, mica, 500V.
C333	V307 screen bypass	0.5-mf, bathtub, 600V.
C334	V307 output	1-mf, bathtub, 600V.,
C335	V308 grid coupling	0.5-mf, bathtub, 600V.
C336	Oscillator tuning	250-mmf, zero temp. ceramic tubular.
C337	Oscillator tuning	0.001-mf, mica, 500V.
C339A	B plus filter	20/20/50, 400/400/50, electrolytic, octal base.
C350	V307 decoupler	40-mf, electrolytic, 450V.
L301A	Antenna transformer	Coil assembly, consisting of 4 antenna transformers. Essex Specialty Co. part No. 300.280.*
L301B		
L302A		
L302B		
L303A		
L303B		
L304A		
L304B		
L305	Wave trap, parallel	Single winding, 560 microhenries. Essex Specialty Co. type A201.*
L306	Wave trap, series	1125 microhenries inductance made by Essex Specialty Co. part No. 300.447.*
L307	Oscillator inductance	Coil assembly, consisting of 4 coils. Essex Speciality Co. part No. 300.381.*
L308		
L309		
L310		
L314	V307 plate inductance	Single winding, 55 mH. Essex Specialty Co. Type A202.*
L315	Wave trap, series	1125 microhenries inductance. Essex Specialty Co. part No. 300.447.*
L316	V302 input inductance	Coil assembly consisting of 4 coils. Essex Specialty Co. part No. 300.279.*
L317		
L318		
L319		
RL301	V302 cathode loading	3,300 ohms, ½ watt with 235 T of No. 36 SSE wire in single pie winding.
R302	V301 screen dropping	47,000 ohms, 1 watt.
R303	V301 plate load	18,000 ohms, 2 watts.
R304	V301 damping input	5,000 ohms, ½ watt.
R307	V302 grid leak	22,000 ohms, ½ watt.
R308	T301 primary filter	3,300 ohms, ½ watt.
R309	T301 secondary damper	15,000 ohms, ½ watt.
R310	V302 screen resistor	18,000 ohms, 3 watts.
R311	V303 cathode bias	680 ohms, ½ watt.
R312	T302 secondary damper	15,000 ohms, ½ watt.
R313	V303, V304 screen resistor	56,000 ohms, 1 watt.
R314	V304 cathode bias	680 ohms, ½ watt.

* Further description on these components will be found in the DAS-3 LORAN manual.

SHIP-STATION RECEIVER—Continued

Symbol	Function	Description
R315	T303 secondary damper	15,000 ohms, ½ watt.
R316	V305 screen resistor	47,000 ohms, 1 watt.
R317	T304 primary decoupler	3,300 ohms, 1 watt.
R318	Filter network	10,000 ohms, ½ watt.
R319	V306 detector load	27,000 ohms, ½ watt.
R323	V307 grid current limiter	330 ohms, ½ watt.
R324	V307 cathode bias	56 ohms, ½ watt.
R325	V307 plate load	15,000 ohms, 5 watts.
R326	V307 screen resistor	47,000 ohms, 1 watt.
R327	V308 cathode bias	2,200 ohms, 2 watts.
R328	V308 grid leak	470,000 ohms, ½ watt.
R329	B plus filter	1,000 ohms, 15 watts.
R331	Oscillator damping	15,000 ohms, ½ watt.
R332	V307 grid leak	220,000 ohms, ½ watt.
R350	V307 plate filter	5,100 ohms, 2 watts.
S301A S301B S301C S301D S301E S301F S301G S301H	Channel selector	Switch assembly, rotary, 4 circuits and 4 Grounding sectors, 4 positions. Centralab part No. 45.244.* Use wafer GG for replacement.
T301	I. F. transformer	Essex Specialty Co. No. 35.354.*
T302	I. F. transformer	Same as T301.
T303	I. F. transformer	Same as T301.
T304	I. F. transformer	Same as T301.
T305	Power transformer	Freed No. 10929.*

*Further description on these components will be found in the DAS-3 LORAN manual.

ELECTRONIC ATTENUATOR

Symbol	Function	Description
C1	V403A grid coupling	1-mf, bathtub, 600V.
C2	B plus bypass	0.1-mf, bathtub, 600V.
C3	V403A, V403B coupling	1-mf, bathtub, 600V.
C4	V403B grid bypass	0.002 -mf, mica, 500V.
C5	V402 cathode bypass	0.01-mf, mica, 500V.
C6	V401 cathode bypass	0.01-mf, mica, 500V.
C7	V401 screen bypass	100-mmf, mica, 500V.
C8	V401 grid coupling	100-mmf, mica, 500V.
C9	V401, V402 coupling	100-mmf, mica, 500V.
C10	V402 plate output	0.01-mf, mica, 500V.
C11	V402 plate filter	0.01-mf, mica, 500V.
C12	Filament bypass	0.01-mf, mica, 500V
C13	V402 grid filter	100-mmf, mica, 500V.
C14	V402 screen bypass	0.001-mf, mica, 500V.
C15	Receiver-coupler tuning	100-mmf, vacuum.
C16	Receiver-coupler tuning	100-mmf, mica, 2,500V.

ELECTRONIC ATTENUATOR—Continued

Symbol	Function	Description
C17	Transmitter-coupler	20-mmf, vacuum, 17,500V.
C18	Transmitter-coupler tuning	0.002-mf, mica, 6,000V.
R1	V403A grid leak	51,000 ohms, ½ watt.
R2	V403A plate load	100,000 ohms, 1 watt.
R3	V403B grid leak	1 meg. ½ watt.
R4	V403B grid isolation	100,000 ohms, ½ watt.
R5	V401 grid leak	100,000 ohms, ½ watt.
R6	V402 grid isolation	100,000 ohms, ½ watt.
R7	V401 cathode bypass	240 ohms, 1 watt.
R8	V401 plate load	5,100 ohms, 1 watt.
R9	V401 screen dropping	51,000 ohms, 1 watt.
R10	V402 cathode bypass	240 ohms, 1 watt.
R11	V402 plate load	500 ohms, 1 watt.
R12	V402 screen dropping	51,000 ohms, 1 watt.
R13	Signal input divider	200 ohms, 1 watt
R14	Signal input divider	1,000 ohms, 1 watt.
R15	Local Signal Gain	15,000 ohms potentiometer, 4 watts, linear taper.
R16	Attenuator output limiter	20,000 ohms, 1 watt.
R17	Signal input divider	150 ohms, 1 watt.
R18	V403A cathode bias	100,000 ohms, 1 watt.
R19	V403A cathode bias	1,500 ohms, 1 watt.
R20	Receiver-coupler shunt	1,000 ohms, 2 watts each (5 resistors used).
S1	Unblanking switch	SPST toggle, 3A, 250V.

GROUND-STATION CONTROLLER INDICATOR

Symbol	Function	Description
C101	V101 grid circuit	510-mmf, mica, 500V.
C102	100-KC oscillator	10-mmf, mica, 500V.
C103	V101 grid padder	5-mmf, mica, 500V.
C104	Fine frequency control	3-plate, variable, air.
C105	Fine frequency control	10-mmf, mica, 500V.
C106	V101 feedback	10-mmf, mica, 500V.
C107	V116A grid coupling	240-mmf, mica, 500V.
C109	V101, V102 coupling	51-mmf, mica, 500V.
C110A	V102 screen bypass	0.25-mf, triple, bathtub, 600V
C110B	V116B cathode bypass	
C110C	V101 plate filter	
C111	V102, V103 coupling	50-mmf, variable, air.
C112	V103 storage	620-mmf, mica, 500V.
C113	V104A, V105 coupling	24-mmf, mica, 500V.
C114A	V104A cathode bypass	0.25-mf, triple, bathtub, 600V.
C114B	V106A cathode bypass	
C114C	V106B cathode bypass	
C115	V104A, V104B coupling	10-mmf, mica, 500V.
C116	V104A, V104B coupling	5-mmf, mica, 500V.
C118	V105 storage	750-mmf, mica, 500V.
C119	V105 cathode bypass	0.024-mf, mica, 500V.

GROUND-STATION CONTROLLER INDICATOR—Continued

Symbol	Function	Description
C122	V106A, V104B coupling	24-mmf, mica, 500V.
C123	V106A, V108 coupling	75-mmf, mica, 500V.
C124	V106A, V113A coupling	10-mmf, mica, 500V.
C125	V108 storage	0.0015-mf, mica, 2,500V.
C128	V106B, V109 coupling	240-mmf, mica, 500V.
C129	V109 storage	0.01-mf, mica, 500V.
C130A	V110 cathode bypass	0.25-mf, dual, bathtub, 600V.
C130B	V111A grid filter	
C131	V110A, V122 coupling	0.01-mf, mica, 500V.
C132	V111A plate bypass	51-mmf, mica, 500V.
C134	V113A, V111A coupling	240-mmf, mica, 500V.
C135	V111A, V115B coupling	240-mmf, mica, 500V.
C136	V111 timing	0.0062-mf, mica, 500V.
C137	V107A plate output	51-mmf, mica, 500V.
C138A	V112A grid bypass	0.25-mf, triple, bathtub, 600V.
C138B	V114B grid bypass	
C138C	V107 cathode bypass	
C139	V117 plate output	0.005-mf, mica, 500V.
C140	V117 grid coupling	10-mmf, mica, 500V.
C141	V117 grid filter	0.01-mf, mica, 500V.
C142	V137A, V137B coupling	0.001-mf, mica, 500V.
C143	V107B plate output	51-mmf, mica, 500V.
C144	V116A grid coupling	51-mmf, mica, 500V.
C145	V116A, V116B coupling	51-mmf, mica, 500V.
C147	V104B cathode bypass	0.02-mf, mica, 600V.
C148	V116B, V125 coupling	51-mmf, mica, 500V.
C149	V104A, V133A coupling	200-mmf, mica, 500V.
C150	V111B, V133B coupling	0.001-mf, mica, 500V.
C151	V107A plate output	51-mmf, mica, 500V.
C152	V133, V107A coupling	0.001-mf, mica, 500V.
C153	V107B plate output	51-mmf, mica, 500V.
C154	V134B, V107B coupling	0.001-mf, mica, 500V.
C155	V114A, V134B coupling	0.001-mf, mica, 500V.
C156	V104A, V134A coupling	200-mmf, mica, 500V.
C157	V107B, V137 coupling	10-mmf, mica, 500V.
C161	V113A, V114B coupling	24-mmf, mica, 500V.
C162	V114 grid timing	0.03-mf, mica, 600V.
C164	V115A, V114B coupling	150-mmf, mica, 500V.
C165	V110B, V115A coupling	24-mmf, mica, 500V.
C166	V115A, V115B coupling	24-mmf, mica, 500V.
C167	V115A, V115B coupling	24-mmf, mica, 500V.
C168	V110B, V115B coupling	24-mmf, mica, 500V.
C169A	V115 cathode bypass	20/20/50, 400/400/50V, electrolytic, octal base.
C169B	V123 screen bypass	
C169C	V123 cathode bypass	
C170	V110A, V110B coupling	100-mmf, mica, 500V.
C171	V113B, V125 coupling	1-mf, bathtub, 600V.
C173	V113B grid coupling	0.5-mf, bathtub, 600V.
C174	V119A grid coupling	0.0015, mica, 2500V.
C175	Filter, high voltage	0.25-mf, paper, 2000V.
C176	Filter, high voltage	0.25-mf, paper, 2000V.

GROUND-STATION CONTROLLER INDICATOR—Continued

Symbol	Function	Description
C177	Filter, high voltage	0.25-mf, paper, 2000V.
C178	Input filter, V128	4-mf, can, 600V.
C179	Output filter, V128	4-mf, can, 600V.
C180A	V131 filter	20/20/50, 400/400/50V, electrolytic, octal base.
C180B	Regulated voltage filter	
C180C	V122 cathode bypass	
C181	V125 cathode bypass	0.5-mf, paper, 1,500V.
C182	Regulated voltage bypass	1-mf, bathtub, 600V.
C184	V131 screen bypass	0.5-mf, bathtub, 600V.
C185	V131 grid coupling	0.5-mf, bathtub, 600V.
C186A	Vert. center control bypass	0.1-mf, dual, bathtub, 600V.
C186B	Vert. center control bypass	
C188A	Hor. center control bypass	0.1-mf, dual, bathtub, 600V.
C188B	Hor. center control bypass	
C190	V135 cathode bypass	0.5-mf, paper, 1,500V.
C191A	V121 screen bypass	1-mf, dual, bathtub, 600V.
C191B	V119 plate filter	
C192	V121 sweep forming	51-mmf, mica, 500V.
C194	V121 sweep forming	0.0013-mf, mica, 500V.
C195	V121 sweep forming	0.0051-mf, mica, 600V.
C197	V119B, V119A coupling	1-mf, bathtub, 600V.
C198	V119 timing	0.0024-mf, mica, 1,200V.
C199	V119 timing	750-mmf, mica, 500V.
C200	V119 timing	200-mmf, mica, 2,500V.
C201	V119A grid filter	0.5-mf, bathtub, 600V.
C202	V120B, V135	0.01-mf, mica, 1,200V.
C203	V124, V125 coupling	0.5-mf, bathtub, 600V.
C204	V124, V125 coupling	0.5-mf, bathtub, 600V.
C205	V124 plate filter	1-mf, bathtub, 600V.
C206	V121, V124 coupling	0.5-mf, bathtub, 600V.
C207	V123, V124 coupling	0.1-mf, bathtub, 600V.
C210	V122, V123 coupling	0.5-mf, bathtub, 600V.
C211	V122 sweep forming	0.1-mf, bathtub, 600V.
C213	T101 primary tuning	0.0015-mf, mica, 500V.
C214	V125 vert. coupling	0.25-mf, bathtub, 600V.
C215	V111B, V103 coupling	0.01-mf, mica, 500V.
C216	V111A, V103 coupling	0.01-mf, mica, 500V.
C217	V122 plate filter	0.5-mf, mica, 500V.
C218	V120B, V135 coupling	0.01-mf, mica, 500V.
C221	V113B, V104B coupling	0.0015-mf, mica, 500V.
C222	V136 output	45-mmf, variable, mica.
L101	V101 grid coil	Single winding, with adj. iron core, 29 to 44 millihenries, shielded. Essex Specialty Co. type A202.*
L102	V102 plate peaking	Single winding, 10.5 millihenries. Essex Specialty Co. type A250.*
L103	Filter choke	20 Henries at 100 ma. DC. United Trans. Co. type 80259.*
R101	V101 grid leak	1 meg. ½ watt.
R102	V101 plate filter	10,000 ohms, 1 watt.

* Further description on these components will be found in the DAS-4 LORAN manual.

GROUND-STATION CONTROLLER INDICATOR—Continued

Symbol	Function	Description
R103	V117 plate load	1 meg. 1 watt.
R104	V102 plate load	22,000 ohms, 1 watt.
R105	V102 screen dropping	56,000 ohms, 1 watt.
R106	V102 grid leak	100,000 ohms, ½ watt.
R107	T102 secondary damper	33,000 ohms, ½ watt.
R108	V104A cathode bias	68,000 ohms, 2 watts.
R109	V104A cathode bias	10,000 ohms potentiometer ½ watt, linear taper.
R110	V104A cathode bias	6,800 ohms, 1 watt.
R111	V105 cathode circuit	6.8 megs. ½ watt.
R112	V106A cathode bias	82,000 ohms, 1 watt.
R113	V106A cathode bias	25,000 ohms potentiometer ½ watt, linear taper.
R114	V106A cathode bias	22,000 ohms, 1 watt.
R115	V106A plate limiter	100,000 ohms, ½ watt.
R116	V136 cathode bias	500 ohms, ½ watt.
R117	T104 secondary damper	33,000 ohms, ½ watt.
R118	V106B cathode bias	82,000 ohms, 1 watt.
R119	V106B cathode bias	25,000 ohms potentiometer ½ watt, linear taper.
R120	V106B cathode bias	22,000 ohms, 1 watt.
R121	V110A cathode bias	220,000 ohms, 1 watt.
R122	V110A cathode bias	25,000 ohms potentiometer, ½ watt, linear taper.
R123	V110A cathode bias	39,000 ohms, 1 watt.
R124	V133A grid bias	1 meg. ½ watt.
R125	V133A grid bias	51,000 ohms, ½ watt.
R126	V133 plate load	51,000 ohms, 2 watts.
R127	V133B grid bias	200,000 ohms, ½ watt.
R128	V117 plate limiter	400 ohms, 1 watt.
R129	V111A grid bias	100,000 ohms potentiometer, ½ watt, linear taper.
R130	V111A grid bias	270,000 ohms, ½ watt.
R131	V111A grid filter	180,000 ohms, ½ watt.
R132	V111A plate load	22,000 ohms, 2 watts.
R133	V111B timing	3.9 meg. ½ watt.
R134	V111B plate load	22,000 ohms, 2 watts.
R135	V111A grid limiter	39,000 ohms, ½ watt.
R136	V111B cathode bias	10,000 ohms, 2 watts.
R137	V134B grid bias	250,000 ohms, ½ watt.
R138	V136 cathode bias	5,000 ohms potentiometer, ½ watt, linear taper.
R139	V134A grid bias	1 meg. ½ watt.
R140	V136 cathode bias	100,000 ohms, ½ watt.
R141	V137A grid bias	1 meg. ½ watt.
R142	V137A plate load	50,000 ohms, 2 watts.
R143	V137B cathode bias	50,000 ohms, 2 watts.
R144	V137B grid leak	100,000 ohms, ½ watt.
R145	V117 grid filter	500,000 ohms, ½ watt.
R146	V117 grid limiter	100,000 Ohms, ½ watt.
R147	V116A plate load	270,000 ohms, ½ watt.

GROUND-STATION CONTROLLER INDICATOR—Continued

Symbol	Function	Description
R148	V116A grid leak	1 meg. ½ watt.
R149	V116B grid leak	1 meg. ½ watt.
R150	V116B cathode bias	5,600 ohms, ½ watt.
R151	V116B cathode bias	270,000 ohms, ½ watt.
R152	V104B cathode bias	1,500 ohms, ½ watt.
R153	V104B grid leak	100,000 ohms, ½ watt.
R157	V107 cathode bias	75,000 ohms, 2 watts.
R158	V113A plate load	100,000 ohms, ½ watt.
R159	V113A cathode bias	220,000 ohms, ½ watt.
R161	V114A plate load	22,000 ohms, 2 watts.
R162	V114A grid timer	2.2 meg, ½ watt.
R163	V114B plate load	22,000 ohms, 2 watts.
R164	V114 cathode bias	10,000 ohms, 2 watts.
R165	V107A grid leak	1 meg, ½ watt.
R166	V107 cathode bias	15,000 ohms, 2 watts.
R167	V107A plate load	50,000 ohms, 2 watts.
R168	V107B plate load	50,000 ohms, 2 watts.
R169	V107B grid leak	1 meg. ½ watt.
R170	V114B grid bias	6,800 ohms, ½ watt.
R171	V114B grid bias	10,000 ohms potentiometer ½ watt, linear taper.
R172	V114B grid bias	10,000 ohms potentiometer ½ watt, linear taper.
R173	V114B grid limiter	100,000 ohms, ½ watt.
R174	V114B grid bias	50,000 ohms, potentiometer, ½ watt, linear taper.
R175	V114B grid bias	120,000 ohms, 1 watt.
R176	V114B grid limiter	39,000 ohms, ½ watt.
R177	V115A pulse limiter	100,000 ohms, ½ watt.
R178	V115A plate load	39,000 ohms, ½ watt.
R179	V115A grid bias	390,000 ohms, ½ watt.
R180	V115B grid bias	390,000 ohms, ½ watt.
R181	V115B plate load	39,000 ohms, ½ watt.
R182	V110B pulse limiter	100,000 ohms, ½ watt.
R183	V115 cathode bias	2,700 ohms, ½ watt.
R184	V115 cathode bias	5,000 ohms potentiometer, 3 watts, linear taper.
R185	V115B grid leak	100,000 ohms, ½ watt.
R186	V115 cathode bias	100,000 ohms, 1 watt.
R187	V115A grid leak	100,000 ohms, ½ watt.
R188	V110B plate load	100,000 ohms, ½ watt.
R189	V110B cathode load	100,000 ohms, ½ watt.
R190	V113B cathode bias	100,000 ohms, ½ watt.
R191	V113B cathode bias	4,700 ohms, ½ watt.
R192	V113B grid leak	1 meg. ½ watt.
R193	Trace separation control	200,000 ohms potentiometer, ½ watt, linear taper.
R194	Trace separation adjustment	50,000 ohms potentiometer, ½ watt, linear taper.
R195	V118A pulse limiter	150,000 ohms, ½ watt.
R196	V118A cathode load	470,000 ohms, ½ watt.

GROUND-STATION CONTROLLER INDICATOR—Continued

Symbol	Function	Description
R197	V118B cathode load	470,000 ohms, ½ watt.
R198	V118B pulse limiter	150,000 ohms, ½ watt.
R199	V121 screen bleeder	100,000 ohms, ½ watt.
R200	V121 screen bleeder	180,000 ohms, ½ watt.
R201	V121 cathode bias	4,700 ohms, ½ watt.
R202	V121 cathode bias	10,000 ohms potentiometer, 3 watts, linear taper.
R203	V120B cathode load	100,000 ohms, ½ watt.
R204	V120B cathode load	30,000 ohms, ½ watt.
R205	V120B grid limiter	100,000 ohms, ½ watt.
R206	V119A plate filter	2,200 ohms, 2 watts.
R207	V119B grid leak	100,000 ohms, ½ watt.
R208	V119B plate load	39,000 ohms, 2 watts.
R209	V118A pulse limiter to sync	100,000 ohms, ½ watt.
R210	V119B grid limiter	56,000 ohms, ½ watt.
R211	V119 cathode bias	2,200 ohms, ½ watt.
R212	V119A plate load	39,000 ohms, 2 watts.
R213	V119A grid return	390,000 ohms, ½ watt.
R214	V119 cathode bias	2,700 ohms, ½ watt.
R215	V119 cathode bias	39,000 ohms, 2 watts.
R217	High voltage filter	56,000 ohms, ½ watt.
R218A	High voltage bleeder	5.6 megs, ½ watt.
R218B	High voltage bleeder	5.6 megs, ½ watt.
R218C	High voltage bleeder	5.6 megs, ½ watt.
R218D	High voltage bleeder	5.6 megs, ½ watt.
R219	High voltage filter	27,000 ohms, ½ watt.
R220	High voltage filter	100,000 ohms, ½ watt.
R221	B plus bleeder	820,000 ohms, ½ watt.
R222	V131 plate filter	100,000 ohms, ½ watt.
R223	V131 plate load	2.2 megs, ½ watt.
R224	V131 plate filter	1.2 megs, ½ watt.
R225	V129 grid equalizer	100 ohms, ½ watt.
R226	V130 grid equalizer	100 ohms, ½ watt.
R227	V131 screen bleeder	5,000 ohms, 20 watts.
R228	V131 grid filter	560,000 ohms, ½ watt.
R229	V131 screen dropping	20,000 ohms, 20 watts.
R230	V131 grid bias	56,000 ohms, ½ watt.
R231	V131 grid bias	50,000 ohms potentiometer, 3 watts, linear taper.
R232	High voltage bleeder	820,000 ohms, ½ watt.
R233	High voltage dropping	560,000 ohms, ½ watt.
R234	High voltage dropping	330,000 ohms, ½ watt.
R235	High voltage dropping	100,000 ohms, ½ watt.
R236A R236B	Vert. center control for V125	1 meg potentiometer, ½ watt, linear taper, insulated shaft.
R238	V125 sweep adjustment	560,000 ohms, ½ watt.
R239A R239B	V125 hor. center control	1 meg potentiometer, ½ watt, linear taper, insulated shaft.
R241	V125 sweep adjustment	560,000 ohms, ½ watt.
R242	V125 fine focus control	5000,000 ohms potentiometer, ½ watt, linear taper.

GROUND-STATION CONTROLLER INDICATOR—Continued

Symbol	Function	Description
R243	V125 focus control	1 meg. potentiometer, ½ watt, linear taper.
R244	V125 intensity control	1 meg. potentiometer, ½ watt, linear taper.
R245	V125 vertical load	1 meg. ½ watt.
R246	V125 vertical load	1 meg. ½ watt.
R247	V125 horizontal load	1 meg. ½ watt.
R248	V125 horizontal load	1 meg. ½ watt.
R249	V125 grid bias	8.2 megs, ½ watt.
R250	V124 cathode load	100,000 ohms,½ watt.
R251	V124 plate load	100,000 ohms, ½ watt.
R252	V124 plate filter	68,000 ohms, ½ watt.
R253	V124 grid bias	1 meg. ½ watt.
R254	V124 grid bias	250,000 ohms, ½ watt.
R255	V124 grid filter	820,000 ohms, ½ watt.
R256	V124 grid bias	470,000 ohms, ½ watt.
R257	V123 screen bleeder	100,000 ohms, ½ watt.
R258	V123 screen dropping	22,000 ohms, ½ watt.
R259	V123 cathode bias	3,300 ohms, ½ watt.
R260	V123 cathode bias	1,500 ohms, ½ watt.
R261	V123 plate load	180,000 ohms, ½ watt.
R262	V123 slow sweep	200,000 ohms potentiometer, ½ watt, linear taper.
R263	V123 grid limiting	390,000 ohms, ½ watt.
R264	C211 charging resistor	1 meg. 1 watt.
R265	V122 grid leak	100,000 ohms, ½ watt.
R266	V122 grid limiter	47,000 ohms, ½ watt.
R267	V122 cathode bias	3,300 ohms, 2 watts
R268	V122 cathode bias	68,000 ohms, 2 watts.
R269	V122 plate limiter	330 ohms, ½ watt.
R270	Amplitude balance control	500,000 ohms potentiometer Clarostat Type T–90, tapped at 250,000 ohms.
R271	Gain control	2,000 ohms potentiometer, 2 watts, V taper.
R272	V111B pulse limiter, left-right circuit	390,000 ohms, ½ watt.
R273	V111A pulse limiter, left-right circuit	680,000 ohms, ½ watt.
R276	Left-right circuit decoupling	220,000 ohms, ½ watt.
R278	V122 plate filter	100,000 ohms, ½ watt.
R279	V113B grid circuit	100,000 ohms, ½ watt.
R280	V129, V130 center tap	10 ohms, center tapped, 31 watts.
R281	V134 plate load	47,000 ohms, ½ watt.
R282	V134 grid bias	50,000 ohms, ½ watt.
R283	V123 grid limiting	220,000 ohms, ½ watt.
R285	V104B cathode bias	22,000 ohms, ½ watt.
S101A S101B S101C S101D S101E S101F	Sweep speed	2 wafers, 2 positions, 6 circuits, Centralab No. 2517.
S102A S102B	Fast sweep selector	1 wafer, 3 positions, 2 circuits, Centralab No. 2505.

GROUND-STATION CONTROLLER INDICATOR—Continued

Symbol	Function	Description
S104A	Receiver on-off	2 wafers, 3 positions, 4 circuits, Centralab No. 2515.
S104B		
S104C		
S104D		
S105A	Left-right switch	1 wafer, 3 positions, 2 circuits special switch made by Oak Mfg. Co. No 28286–1H.
S105B		
S107	A C power switch	DPST 10-amperes, 125V.
T101	V101 output	100-KC oscillator transformer made by Essex Specialty Co. No. A–249.
T102	1st divider	Blocking grid transformer, Freed No. 12524.*
T103	2d divider	Freed No. 12524.*
T104	3d divider	Freed No. 12524.*
T105	4th divider	Freed No. 12524.*
T106	Power transformer	Freed No. 11851.*

*Further description of these components will be found in the DAS-4 LORAN manual.

GROUND-STATION RECEIVER

Symbol	Function	Description
C301	L305 padder	30-mmf, mica, 500V.
C302	L306 tuning	15-mmf, mica, 500V.
C304A	V301 cathode bypass	0.1-mf, dual, bathtub, 600V.
C304B	V301 screen bypass	
C305	Secondary tuning, antenna coils	24-mmf, mica, 500V.
C306	V301, V302 coupling	240-mmf, mica, 500V.
C308	L315 tuning	15-mmf, mica, 500V.
C309	V302 grid tuning	24-mmf, mica, 500V.
C310	V302 grid coupling	51-mmf, mica, 500V.
C311A	V302 screen bypass	0.1-mf, dual, bathtub, 600V.
C311B	V302 plate filter	
C312	T301 primary tuning	75-mmf, mica, 500V.
C313	T301 secondary tuning	75-mmf, mica, 500V.
C315	T302 primary tuning	75-mmf, mica, 500V.
C316	T302 secondary tuning	75-mmf, mica, 500V.
C319	T303 primary tuning	75-mmf, mica, 500V.
C320	T303 secondary tuning	75-mmf, mica, 500V.
C322	T304 primary tuning	75-mmf, mica, 500V.
C323	T304 secondary tuning	75-mmf, mica, 500V.
C325	V305 screen bypass	0.002-mf, mica, 500V.
C326	V305 cathode bypass	510-mmf, mica, 500V.
C327	V306 load bypass	250-mmf, mica, 500V.
C328	Filter network	75-mmf, mica, 500V.
C330	V307 grid coupling	0.01-mf, mica, 500V.
C331	V310 cathode output	1-mf, bathtub, 600V.
C333	V307 screen bypass	1-mf, bathtub, 600V.
C334	V307 output	1-mf, bathtub, 600V.
C335	V308 grid coupling	0.5-mf, bathtub, 600V.
C336	Osc. tuning	240-mmf, mica, 500V.
C337	Osc. tuning	0.001-mf, mica, 500V.

GROUND-STATION RECEIVER—Continued

Symbol	Function	Description
C339A	B plus filter	20/20/50, at 450/450/50V, electrolytic, octal base.
C339B	B plus filter	
C340A	V303, V304 screen bypass	0.1-mf, triple, bathtub, 600V.
C340B	V304 cathode bypass	
C340C	V303 cathode bypass	
C341A	Cathode bias bus bypass	0.1-mf, triple, bathtub, 600V.
C341B	B plus filter	
C341C	V305 plate filter	
C343	V307 decoupling	40-mf, electrolytic, 450V.
L301A	Antenna transformer	Coil assembly, consisting of 4 antenna transformers. Essex Specialty Co. part No. 300.280.*
L301B		
L302A		
L302B		
L303A		
L303B		
L304A		
L304B		
L305	Wave trap, parallel	Single winding, 560 microhenries, Essex Specialty Co. type A201.*
L306	Wave trap, series	1125 microhenries, made by Essex Specialty Co., part No. 300.447.*
L307	Oscillator inductance	Coil assembly, consisting of 4 coils. Essex Specialty Co. part No. 300.281.*
L308		
L309		
L310		
L316	V302 input inductance	Coil assembly, consisting of 4 coils. Essex Specialty Co. part No. 300.279.*
L317		
L318		
L319		
RL301	V302 cathode loading	3,300 ohms, ½ watt with 235 T of No. 36 SSE wire in single pie winding.
R302	V301 screen dropping	47,000 ohms, 1 watt.
R303	V301 plate load	18,000 ohms, 2 watts.
R304	V301 damping input	5,000 ohms, ½ watt.
R305	V301 cathode bias	390 ohms, ½ watt.
R307	V302 grid leak	22,000 ohms, ½ watt.
R308	T301 filter primary	3,300 ohms, ½ watt.
R309	T301 secondary damper	15,000 ohms, ½ watt.
R310	V302 screen resistor	9,100 ohms, 2 watts.
R311	V303 cathode bias	680 ohms, ½ watt.
R312	T302 secondary damper	15,000 ohms, ½ watt.
R313	V303, V304 screen resistor	56,000 ohms, 1 watt.
R314	V304 cathode bias	680 ohms, ½ watt.
R315	T303 secondary damper	15,000 ohms, ½ watt.
R316	V305 screen resistor	47,000 ohms, 1 watt.
R317	T304 primary decoupler	3,300 ohms, 1 watt.
R318	Filter network	10,000 ohms, ½ watt.
R319	V306 detector load	27,000 ohms, ½ watt.
R320	V310 grid leak	2 meg, ½ watt.
R321	V310 cathode bias	10,000 ohms, ½ watt.
R323	V307 grid current limiter	330 ohms, ½ watt.

* Further description on these components will be found in the DAS-4 LORAN manual.

GROUND-STATION RECEIVER—Continued

Symbol	Function	Description
R324	V307 cathode bias	56 ohms, ½ watt.
R325	V307 plate filter	5,100 ohms, 2 watts.
R326	V307 screen resistor	47,000 ohms, 1 watt.
R327	V308 cathode bias	2,200 ohms, 2 watts.
R328	V308 grid leak	2. 2 meg, ½ watt.
R329	B plus filter	1,000 ohms, 15 watts.
R330	V302 screen resistor	9,100 ohms, 2 watts.
R331	Oscillator damping	15,000 ohms, ½ watt.
R332	V307 plate load	5,100 ohms, 2 watts.
R333	V307 plate load	5,100 ohms, 2 watts.
R334	V307 grid leak	2.2 meg, ½ watt.
R335	V307 plate load	5,100 ohms, 2 watts.
S301A	Channel selector	Switch assembly, rotary, 4 circuits and 4 grounding sectors, 4 positions. Centralab part No. 45.244.* Use wafer GG for replacement.
S301B		
S301C		
S301D		
S301E		
S301F		
S301G		
S301H		
T301	I. F. transformer	Essex Specialty Co. No. A251.*
T302	I. F. transformer	Same as T301.
T303	I. F. transformer	Same as T301.
T304	I. F. transformer	Same as T301.
T305	Power transformer	Freed No. 12580.*

* Further description on these components will be found in the DAS-4 LORAN manual.

GROUND-STATION SYNCHRONIZER

Symbol	Function	Description
C401	V401A grid coupling	100-mmf, variable, air.
C402	V402A output	140-mmf, variable, air.
C403	V401A, V402A coupling	0.001-mf, mica, 500V.
C404	V401B, V402A coupling	800-mmf, mica, 500V.
C405A	R405 bypass	0.1-mf, triple, bathtub, 600V.
C405B	V403 screen bypass	
C405C	V405 grid filter bypass	
C406	V402A grid bypass	100-mmf, mica, 500V.
C408	B plus bypass	0.5-mf, bathtub, 600V.
C409	V403, V404A coupling	0.1-mf, tubular, 600V.
C411	V404B grid coupling	100-mmf, mica, 500V.
C412	V404B, V406 coupling	0.1-mf, tubular, 600V.
C413	V406, V407A coupling	1-mf, bathtub, 600V.
C414	V407A storage	0.25-mf, bathtub, 600V.
C415	V409 grid filter	0.5-mf, bathtub, 600V.
C416	V408 plate filter	0.1-mf, bathtub, 600V.
C417	V409 plate filter	0.1-mf, bathtub, 600V.
C419	V411 filter	4-mf, oil, 600V.
C420	V415 bypass	0.5-mf, bathtub, 600V.
C421	V414 grid filter	0.5-mf, bathtub, 600V.

GROUND-STATION SYNCHRONIZER—Continued

Symbol	Function	Description
C422	V412 input filter	4-mf, oil, 600V.
C423	V416 circuit filter	8-mf, electrolytic, 450V.
R401	V401A grid leak	1,500 ohms, ½ watt.
R402	V401A plate load	15,000 ohms, 1 watt.
R403	V401A plate load	15,000 ohms, 1 watt.
R404	V401B grid return	50,000 ohms, ½ watt.
R405	Coarse delay control	5,000 ohms potentiometer, 2 watts, linear taper.
R406	Fine delay control	500 ohms potentiometer, 2 watts, linear taper.
R407	V401B cathode bias	2,500 ohms, 2 watts.
R408	V401B plate load	10,000 ohms, 1 watt.
R409	V402A grid return	250,000 ohms, 1 watt.
R410	V402A plate load	10,000 ohms, 10 watts.
R411	V402B cathode bias	7,000 ohms, 1 watt.
R412	V402B cathode bias	80,000 ohms, 2 watts.
R413	V403 grid return	1 meg. ½ watt.
R414	V403 plate load	15,000 ohms, 10 watts.
R415	V403 screen resistor	30,000 ohms, 4 watts.
R416	V403 screen resistor	10,000 ohms, 2 watts.
R417	V405 grid return	1 meg. ½ watt.
R418	V405 plate load	4,700 ohms, 2 watts.
R419	V404B grid bias voltage divider	150,000 ohms, 1 watt.
R420	V404B grid return	1 meg. ½ watt.
R421	V404B grid bias voltage divider	50,000 ohms, 1 watt.
R422	V404B cathode bias	25,000 ohms, 1 watt.
R423	V406 plate load	30,000 ohms, 2 watts.
R424	V406 grid return	500,000 ohms, ½ watt.
R425	V407A cathode resistor	100,000 ohms, ½ watt.
R426	Sync Meter shunt	220 ohms, ½ watt.
R427	Sync Meter current limiter	250,000 ohms, 1 watt.
R428	V409 grid return	24,000 ohms, 1 watt.
R429	V409 grid isolation	500,000 ohms, ½ watt.
R430	V409 plate load	40,000 ohms, 2 watts.
R431	V408 cathode bias	400 ohms, 1 watt.
R432	V408 plate load	40,000 ohms, 2 watts.
R433	V408, V409 screen dropping	150,000 ohms, 1 watt.
R438	V414 screen dropping	20,000 ohms, 1 watt.
R439	V414 plate load	100,000 ohms, 1 watt.
R440	V414 screen dropping	5,000 ohms, 1 watt.
R441	V414 grid return	100,000 ohms, ½ watt.
R442	V414 grid bias divider	60,000 ohms, 1 watt.
R443	V414 grid bias divider	10,000 ohms potentiometer, 2 watts, linear taper.
R444	V414 grid bias divider	40,000 ohms, 1 watt.
R445	V413 grid isolation	100 ohms, ½ watt.
R446	V416 bias divider	50,000 ohms, 1 watt.
R447	V416 bias divider	50,000 ohms, 1 watt.
R448	V412 filter network	Two 15,000 ohms, 10 watts resistors in series.
T401	Power transformer	Chicago Trans. Co. PSR-105.
T402	Filament transformer	United Trans. Co. S-65.

MODULATOR

Symbol	Function	Description
C201	V201 grid coupling	0.25-mf, bathtub, 600V.
C202	V201A cathode bias	0.01-mf, mica, 500V.
C203	V201A, V202A coupling	50-mmf, variable, air.
C204	V202A, V202B coupling	0.01-mf, mica, 500V.
C205	V202B, V202A feedback	330-mmf, mica, 500V.
C206	V202B grid coupling	10-mmf, mica, 500V.
C207	V202B plate bypass	300-mmf, mica, 500V.
C208	V203 grid coupling	20-mmf, mica, 500V.
C209	V203 cathode bypass	50-mf, electrolytic, 50V.
C210	V203, V204 coupling	0.01-mf, mica, 500V.
C211	V204 screen bypass	0.1-mf, bathtub, 600V.
C212	V204 output	0.01-mf, mica, 1,000V.
C213	V204 output filter	0.1-mf, bathtub, 600V.
C214	−150V filter	4-mf, oil, can, 600V.
C215	−150V filter	4-mf, oil, can, 600V.
C216	250V filter	4-mf, oil, can, 600V.
C217	250V filter	4-mf, oil, can, 600V.
C218	250V filter	8-mf, oil, 600V.
C219	480V filter	4-mf, oil, can, 600V.
C220	−150V filter	4-mf, oil, can, 600V.
C221	V202B, V203 coupling	0.01-mf, mica, 500V.
C222	V203 screen bypass	0.1-mf, bathtub, 600V.
C223	480V filter	4-mf, oil, can, 600V.
C224	480V filter	4-mf, oil, can, 600V.
L201	250V filter choke	Chicago Trans. Co. RC-8105.
L202	250V filter choke	Chicago Trans. Co. RC-8105.
L203	480V filter choke	Chicago Trans. Co. RC-8105.
R201	V201A grid leak	2 meg. ½ watt.
R202	V201A cathode bias	20,000 ohms, 1 watt.
R203	V201A plate load	100,000 ohms, 1 watt.
R204	V202A grid bias	25,000 ohms, 1 watt.
R205	V202A grid bias	25,000 ohms, potentiometer, 4 watts, linear taper.
R206	V202A grid leak	100,000 ohms, ½ watt.
R207	V202A plate load	20,000 ohms, 2 watts.
R208	V202B grid return	240,000 ohms, ½ watt.
R209	V202B grid return	100,000 ohms, ½ watt.
R210	V202B cathode bias	100,000 ohms, 1 watt.
R211	V202B cathode bias	10,000 ohms, 1 watt.
R212	V202B plate load	24,000 ohms, 1 watt.
R213	V203 grid leak	2 megs. ½ watt.
R214	V203 grid return	100,000 ohms, ½ watt.
R215	V203 cathode bias	10,000 ohms, 1 watt.
R216	V203 screen dropping	50,000 ohms, 1 watt.
R217	V203 plate load	10,000 ohms, 2 watts.
R218	V204 grid leak	1 meg. ½ watt.
R219	V204 screen dropping	50,000 ohms, 1 watt.
R220	V204 plate load	10,000 ohms, 20 watts.
R221	V204 plate limiter	51 ohms, 1 watt.
R222	V204 plate filter	10,000 ohms, 1 watt.
R223	V204 plate filter	50,000 ohms, 1 watt.

GROUND-STATION SYNCHRONIZER—Continued

Symbol	Function	Description
R224	−150V filter	5,000 ohms, 2 watts.
R225	−150V filter	5,000 ohms, 2 watts.
R226	480V current limiter	2,000 ohms, 10 watts.
R227	480V bleeder	50,000 ohms, 10 watts.
R228	V209 regulator	2,000 ohms, 10 watts adjustable.
R229	480V meter dropping	1 meg. 1 watt.
R230	250V meter dropping	510,000 ohms, 1 watt.
R231	−150V meter dropping	270,000 ohms, 1 watt.
R232	−150V bleeder	100,000 watts, 1 watt.
R233	250V bleeder	100,000 watts, 2 watts.
T201	Power Transformer	Chicago Trans. Co. PSR-300.
T202	Filament Transformer	Chicago Trans. Co. F-54.

TRANSMITTER

Symbol	Function	Description
C101	V105 feedback	100-mmf, vacuum, 20,000V.
C102	V104 feedback	Same as C101.
C103	H. V. bypass	0.75-mf, oil, 5,000V.
C104	H. V. bypass	Same as C103.
C105	Plate tuning	0.0015-mf, mica, 12,500V.
C106	Plate tuning	Same as C105.
C107	Plate tuning	Same as C105.
C108	V104, V105 cathode bypass	4-mf, oil, 2,000V.
C110	Antenna tuning	0.003-mf, mica, 12,500V.
C111	H. V. filter	2-mf, oil, 7,500V.
C112	H. V. filter	Same as C111.
L101	V104, V105 plate coil	Johnson Hi-Q coil No. 239-622.
L102	V104, V105 grid coil	Johnson Hi-Q coil No. 239-620.
L103	V104 suppressor	20 turns of No. 26 DCC close wound, ½-inch diameter.
L104	V105 suppressor	Same as L103.
L105	V104, V105 cathode inductance	3 plies, universal wound, of No. 26 DCC, making a total of 40 microhenries inductance.
L106	Antenna loading	Variometer, modified, manufacturer unknown.
R101	V104, V105 grid return	50 ohms, 1 watt.
R102	L103 damping	63 ohms, 1 watt.
R103	V105 grid suppressor	63 ohms, 1 watt.
R104	V104 grid suppressor	63 ohms, 1 watt.
R105	L104 damping	63 ohms, 1 watt.
R106	V103 grid suppressor	63 ohms, 1 watt.
R107	V103 plate suppressor	63 ohms, 1 watt.
R108	L105 damping	20,000 ohms, 2 watts.
R109	V104, V105 cathode bias	60,000 ohms, 40 watts.
R110	Same as R109	Same as R109.

TRANSMITTER—Continued

Symbol	Function	Description
R111	Same as R109	Same as R109.
R112	Static drain for T101	5 meg, 2 watts.
R113	T102 voltage dropping	5 ohms, 100 watts.
R114	C111 bleeder	7–1 meg. 1 watt.
R115	C112 bleeder	7–1 meg. 1 watt.
R116	H. V. probe	H. V. probe for Triplett multimeter No. 630.
R117	H. V. current limiter	10,000 ohms, 10 watts.
R118	C103, C104 static drain	5 meg. 1 watt.
S–101	A-C power switch	DPDT, toggle, 10 amps at 125V.
S–102	High voltage on-off	SPST, toggle, 3 amps at 250V.
T101	Antenna coupling transformer	Constructed from E. F. Johnson Co. *HI–Q* inductors.
T102	Filament transformer	G. E. Cat. No. 7470614, Dwg M–7479614, or Coast Guard No. 303438.
T103	High voltage transformer	G. E. Cat. No. 86–G–34.

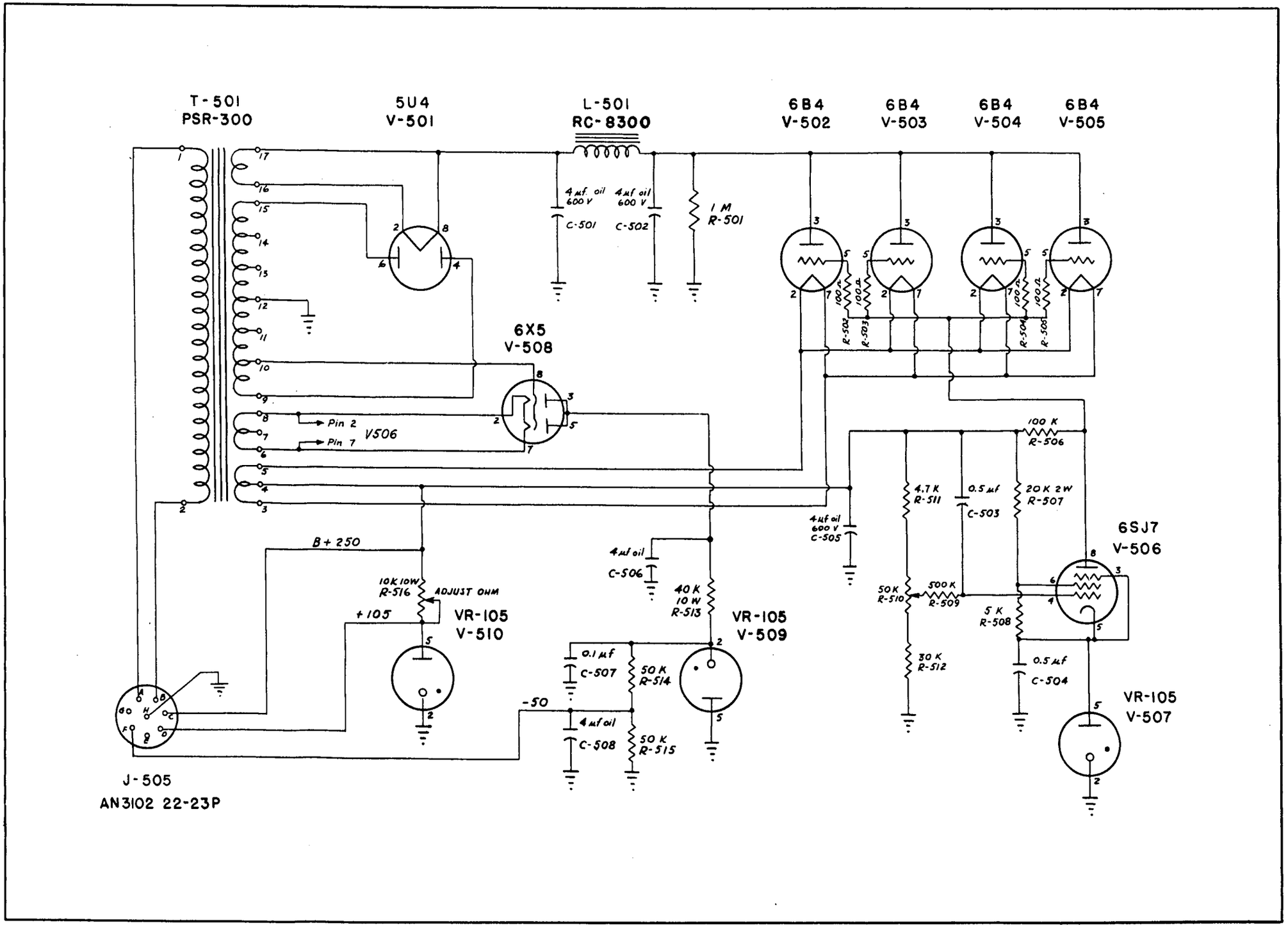


FIGURE 75.—Ship Controller Power Supply circuit diagram.

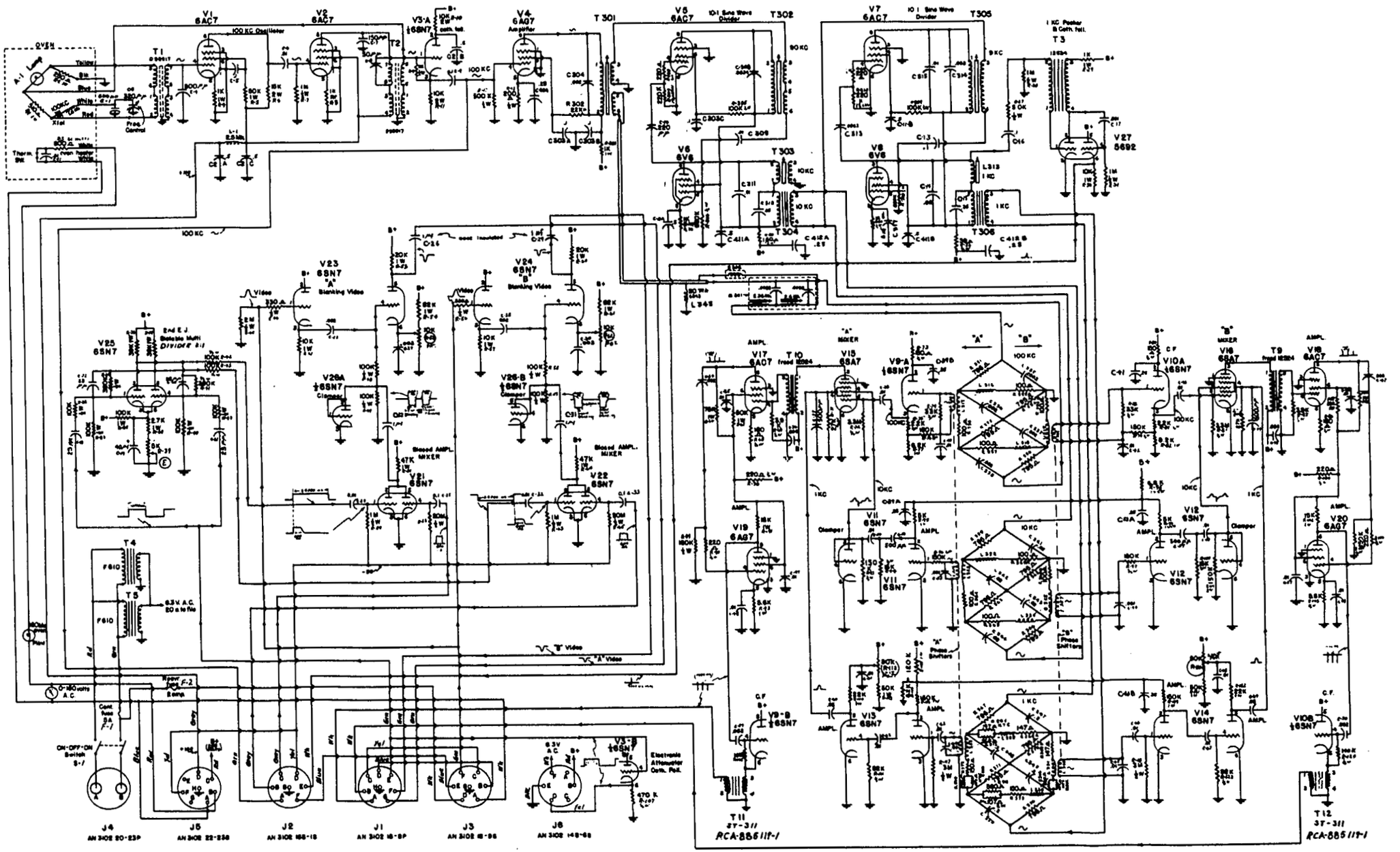


FIGURE 70.—Ship Controller circuit diagram.

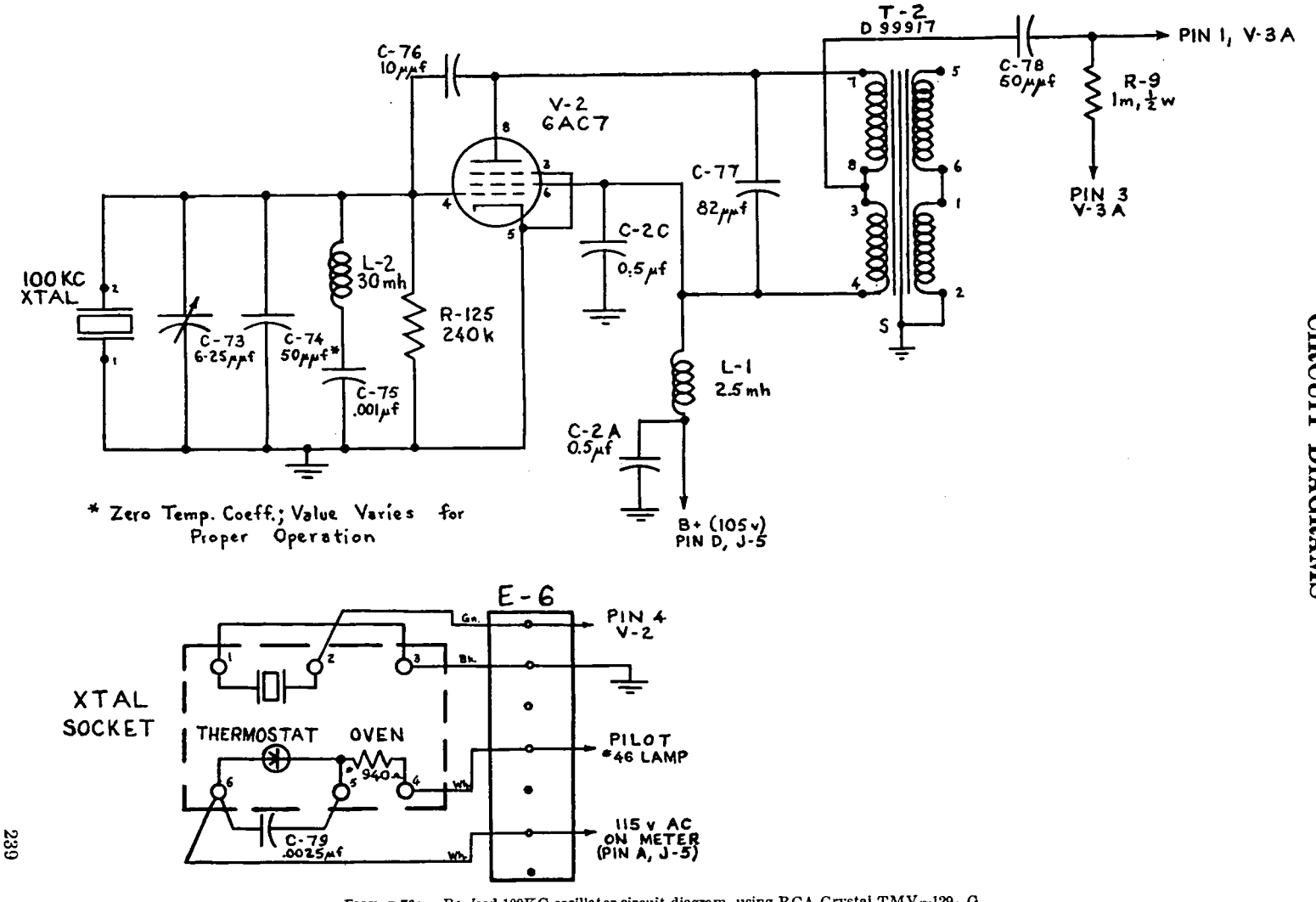
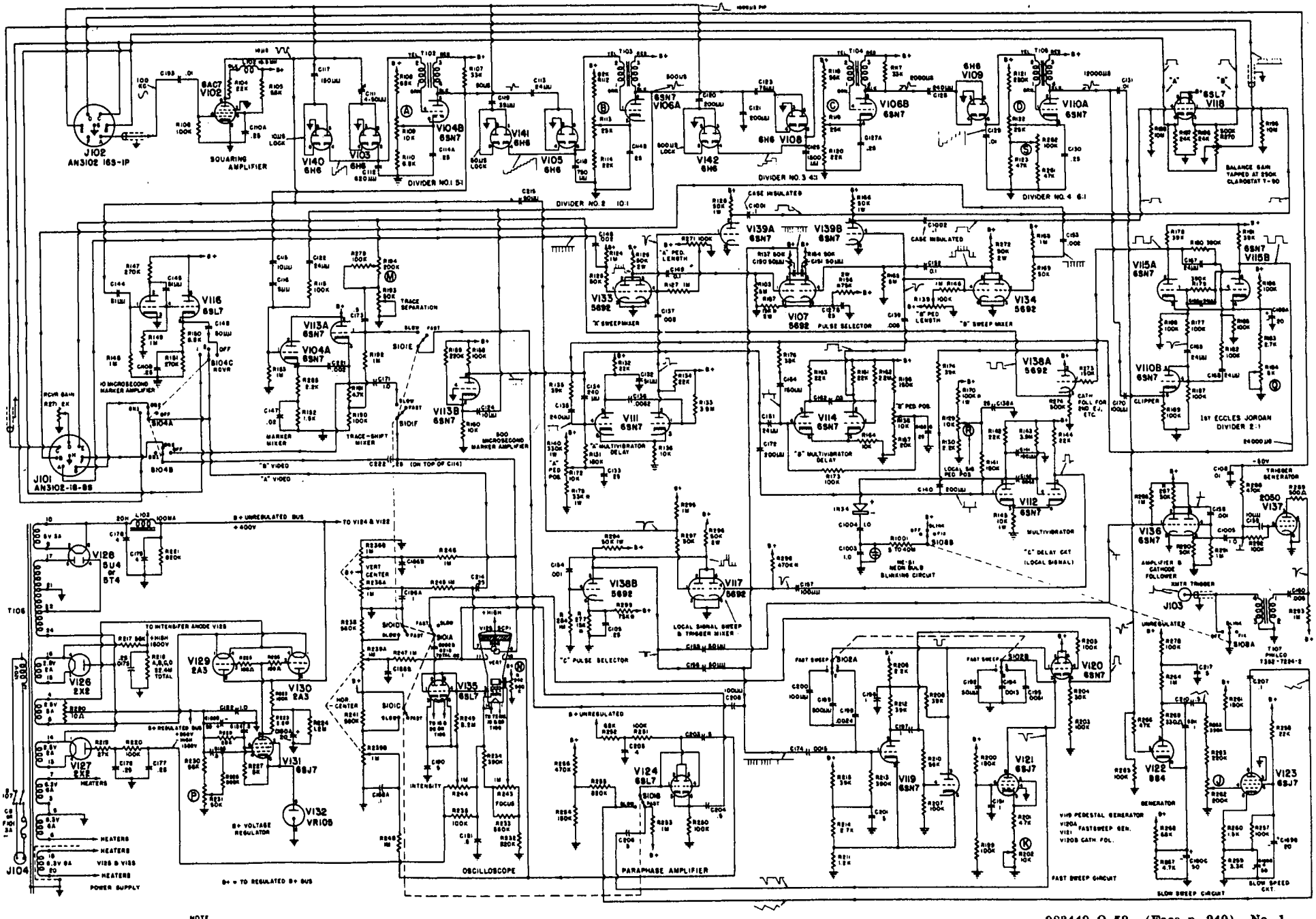


FIGURE 76A.—Revised 100KC oscillator circuit diagram, using RCA Crystal TMV-129-G.



NOTE

1. - ALL CAPACITORS IN MICROFARADS UNLESS OTHERWISE SHOWN.
2. - * APPROXIMATE VALUES - SELECTIONS TO BE MADE FOR EACH INDIVIDUAL INSTRUMENT.

FIGURE 77.—Ship Indicator circuit diagram.

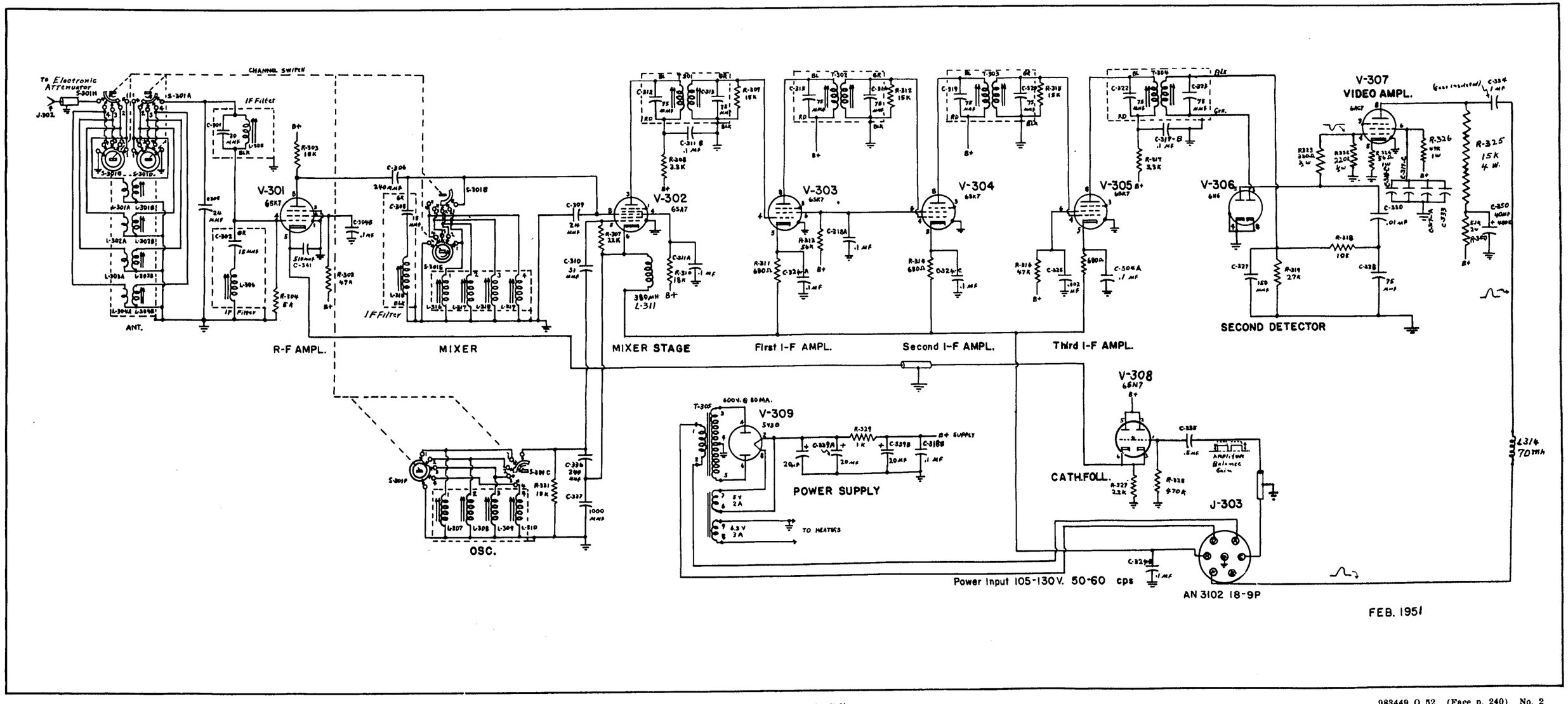


FIGURE 78.—Ship Receiver circuit diagram.

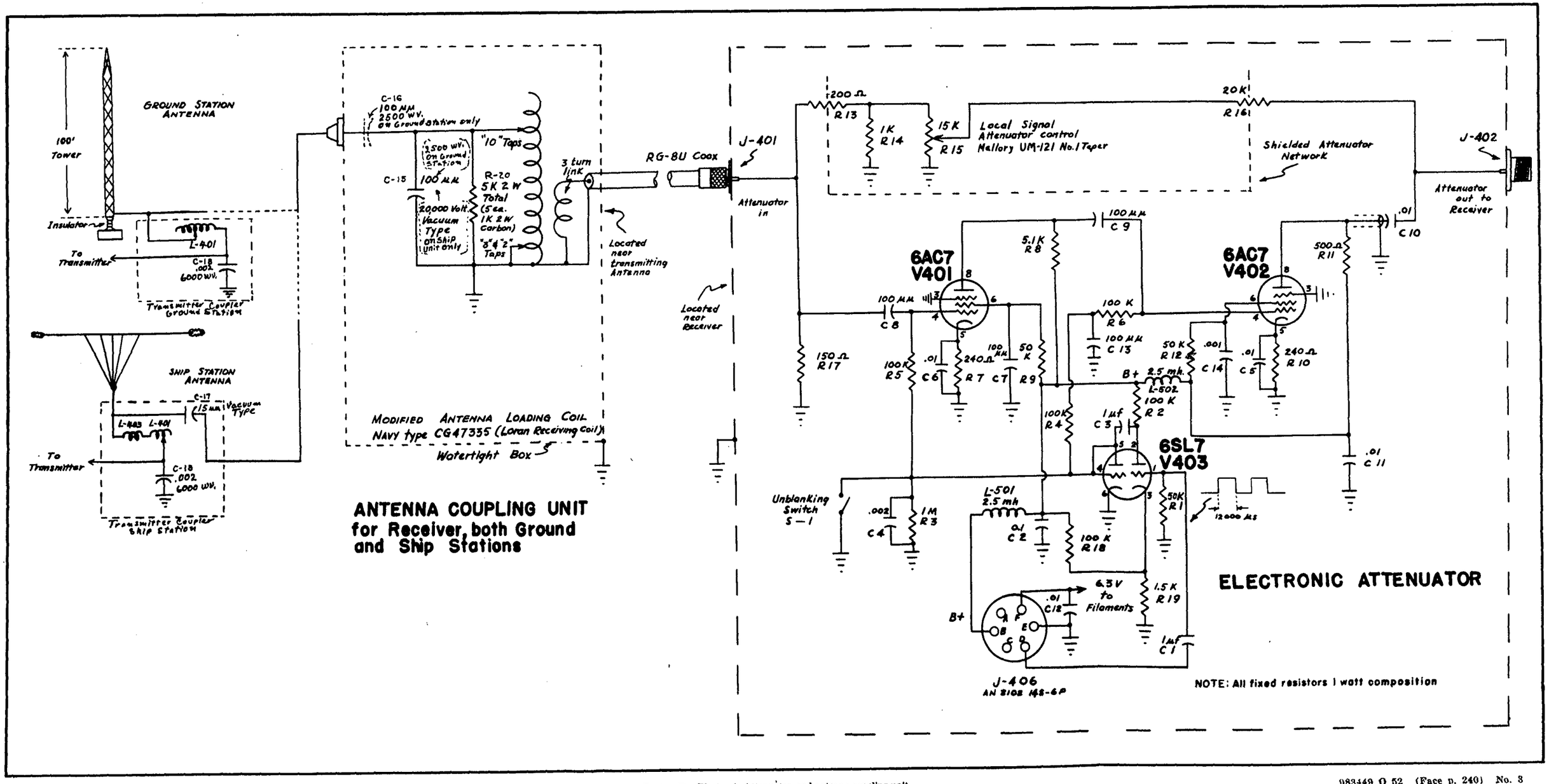


FIGURE 79.—Electronic Attenuator, and antenna coupling unit.

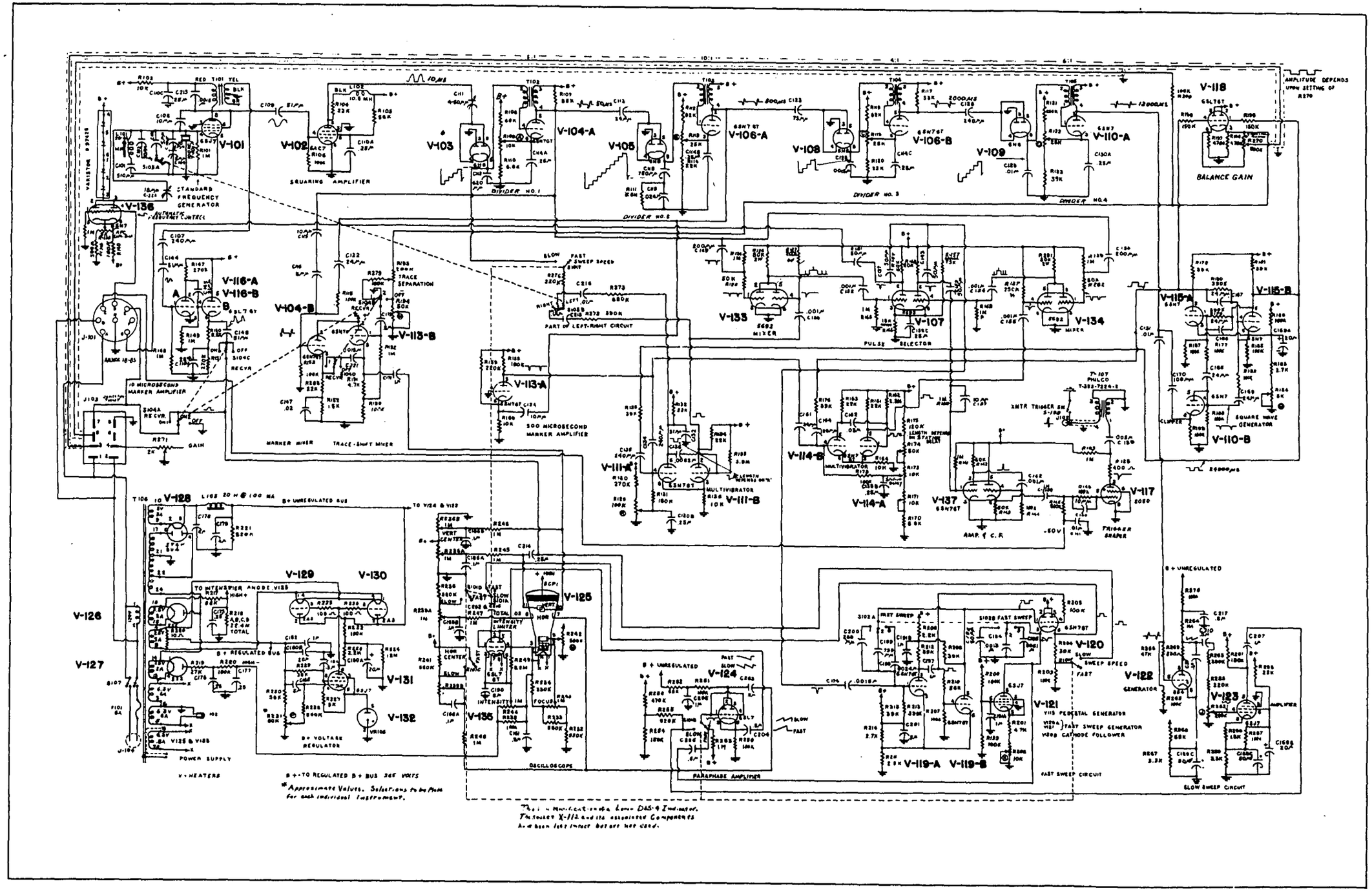


FIGURE 80.—Ground-station Controller-Indicator circuit diagram.

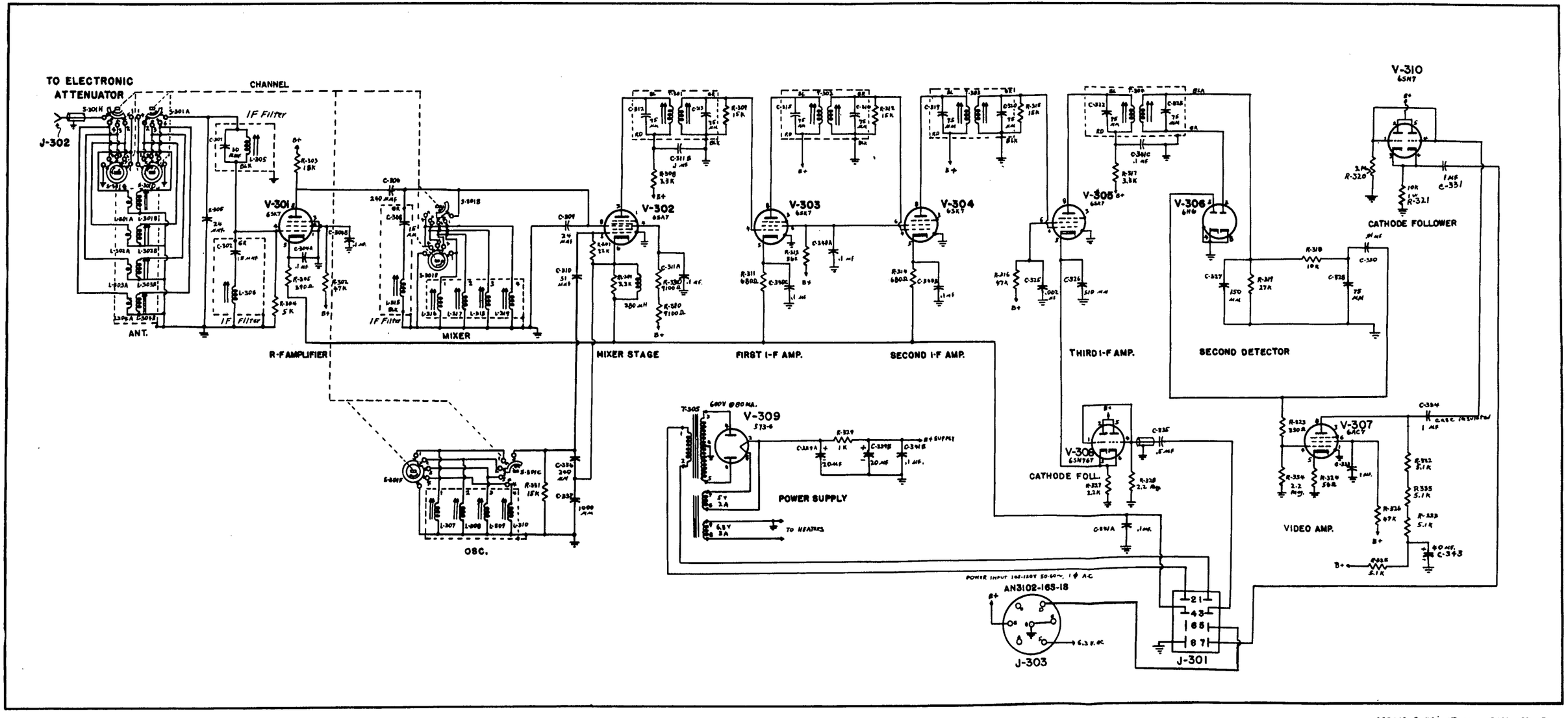


FIGURE 81.—Ground-station Receiver circuit diagram.

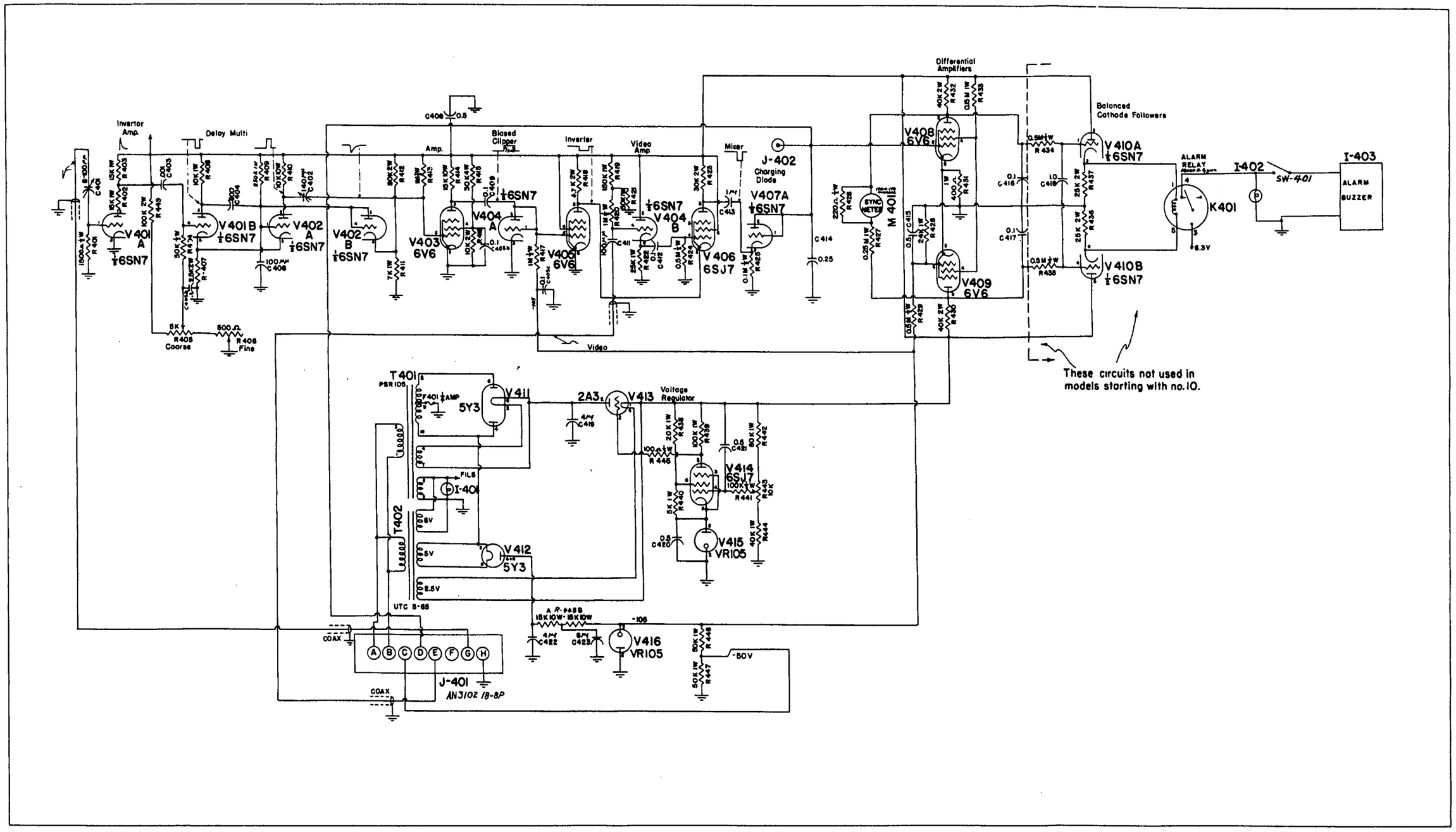


FIGURE 82.—Ground-station Synchronizer circuit diagram.

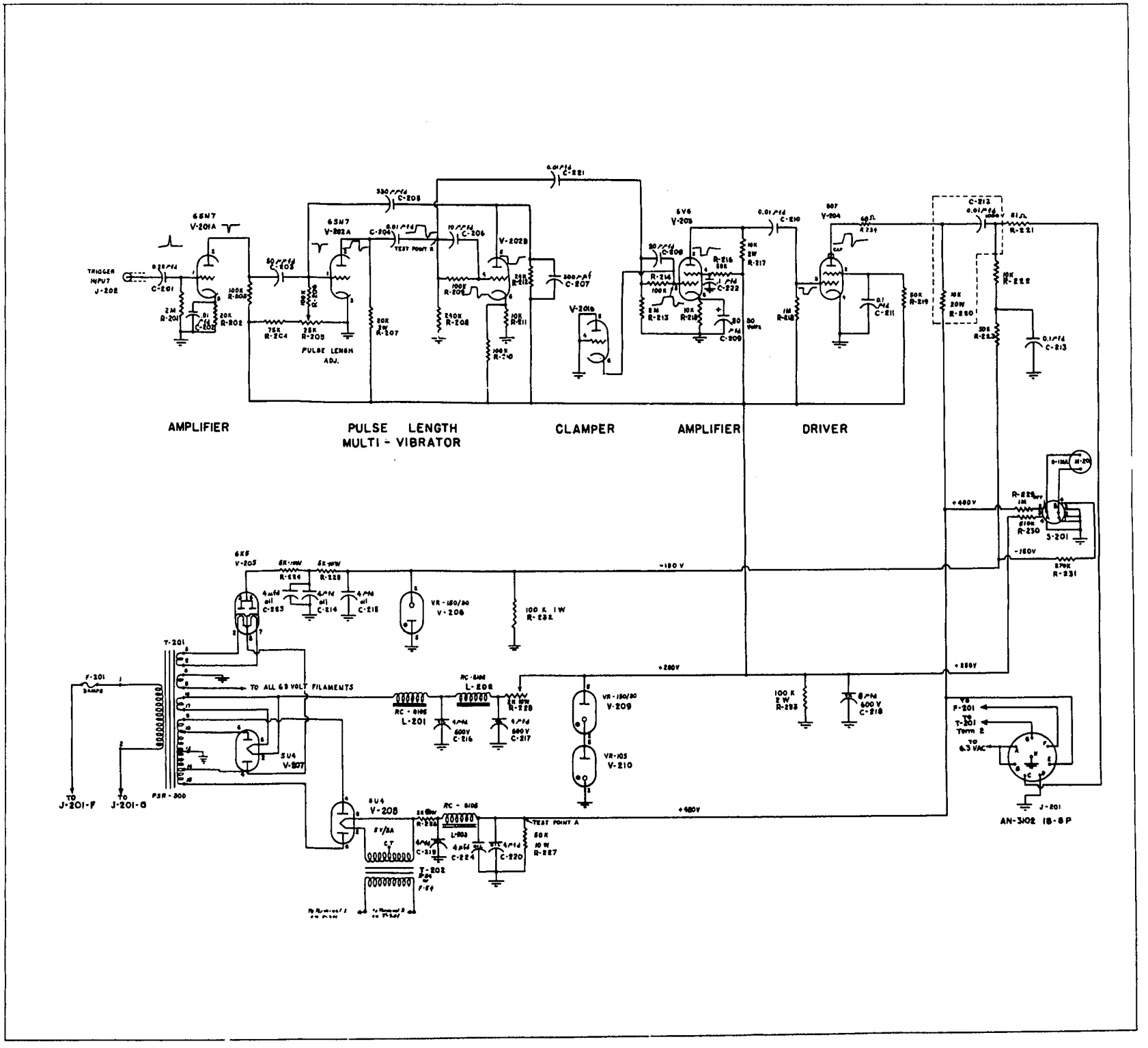


FIGURE 83.—Modulator circuit diagram.

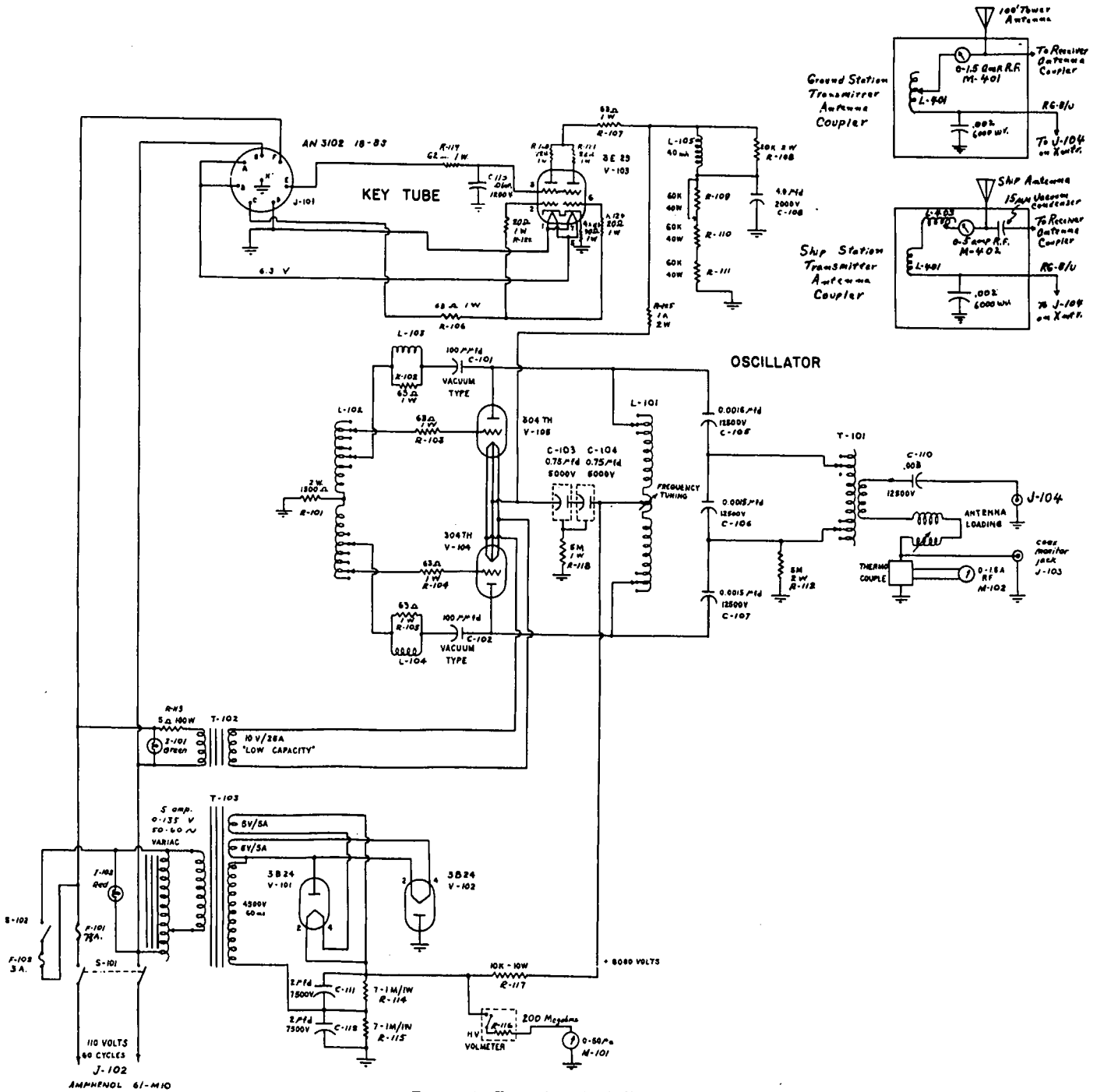


FIGURE 84.—Transmitter circuit diagram.

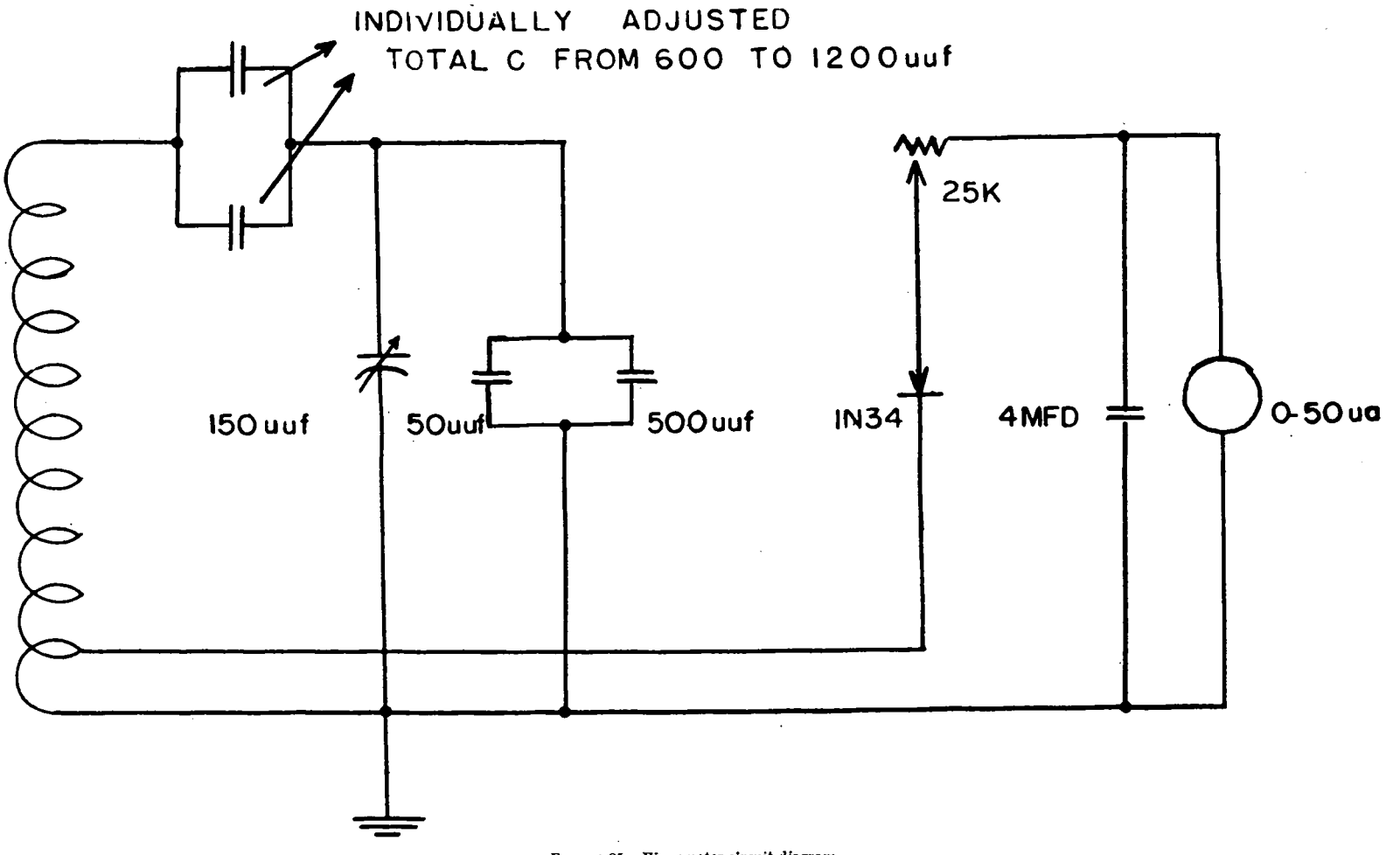
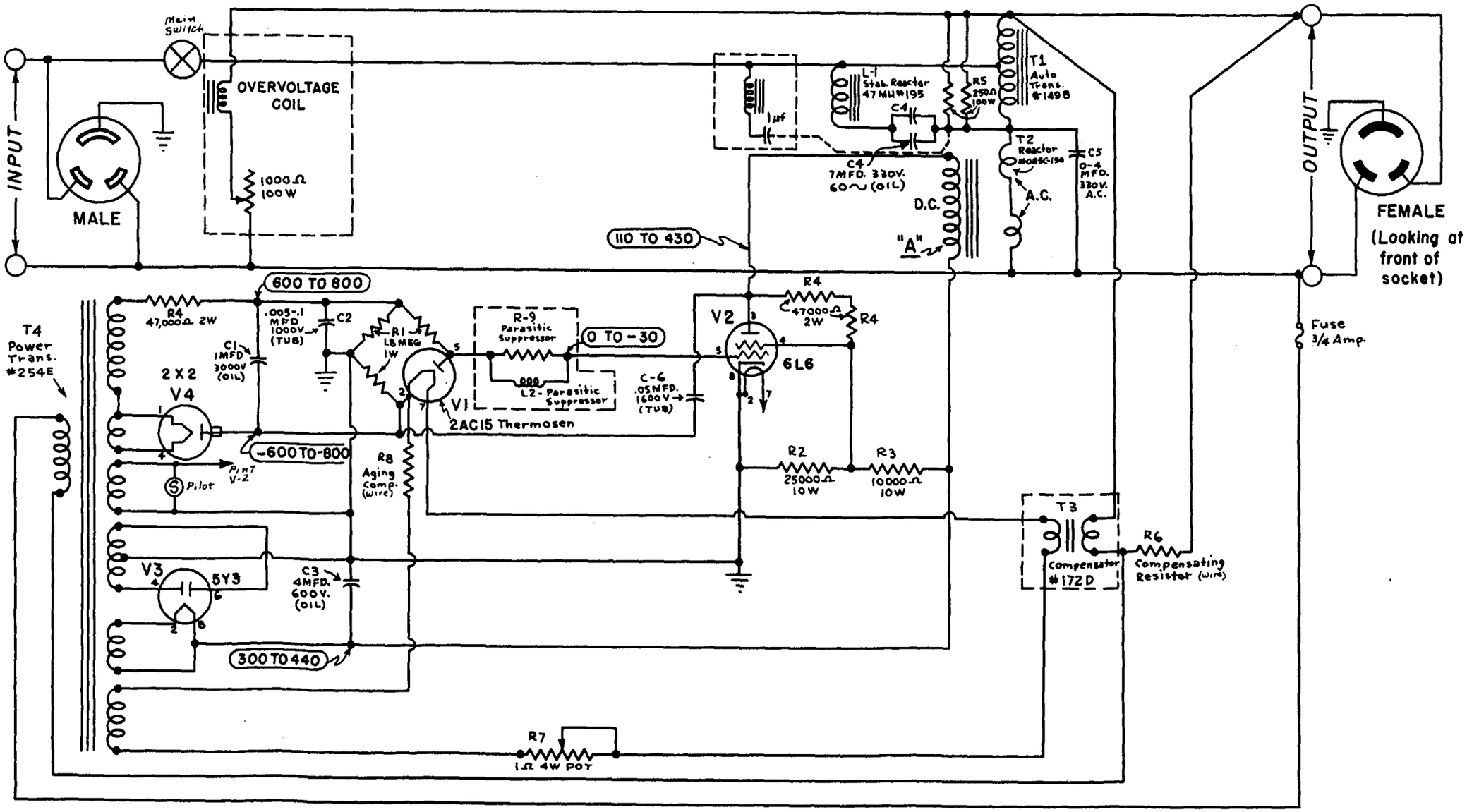


FIGURE 85.—Wavemeter circuit diagram.



SORENSEN VOLTAGE REGULATOR

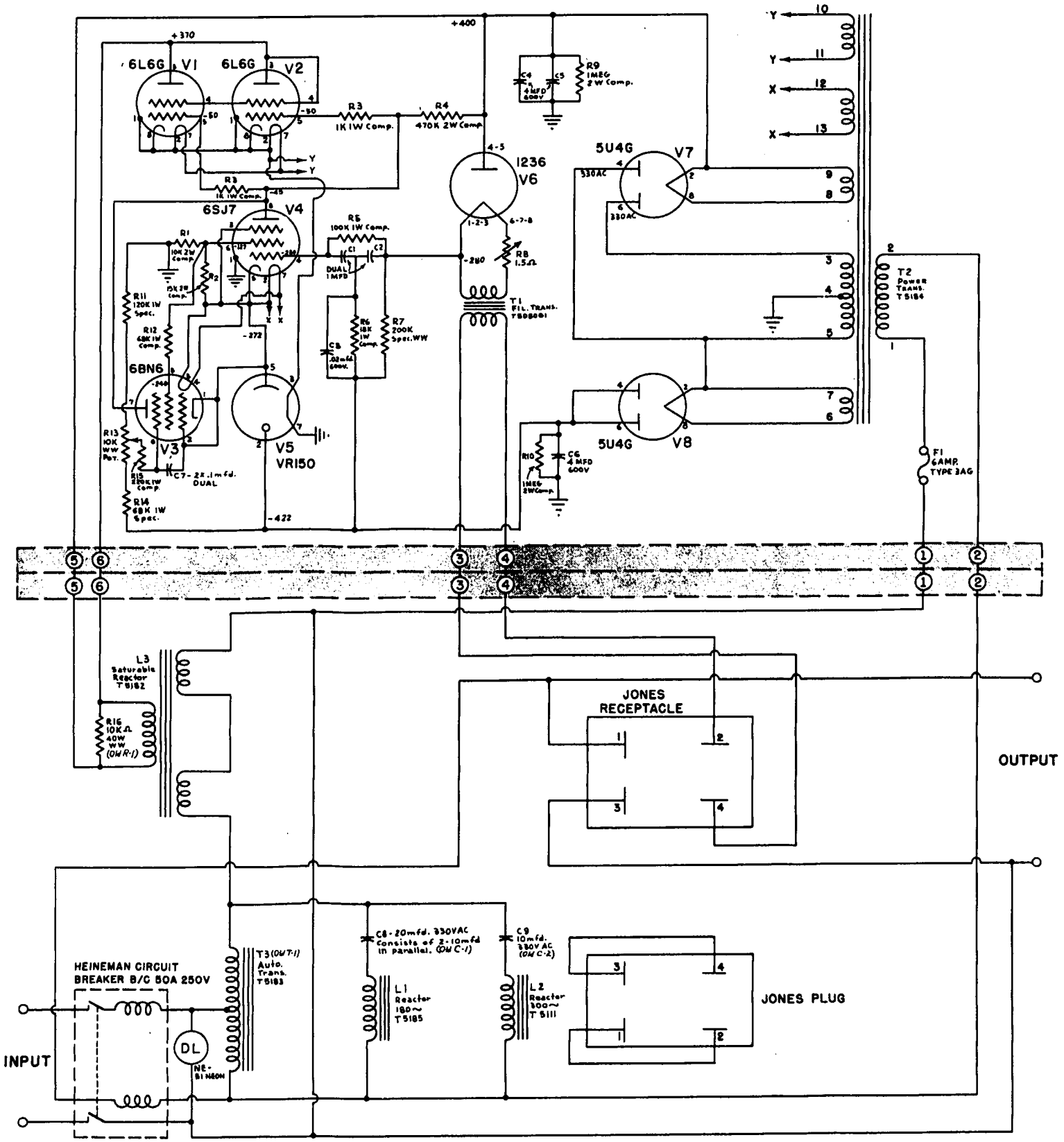
2500 W. - MODEL 1750 - SC200104

NOTE: DASHED ENCLOSED COMPONENTS ARE LEFT OUT OF SOME UNITS.

ENCIRCLED VALUES ARE NORMAL D.C. POTENTIALS WITH RESPECT TO GROUND (CHASSIS).

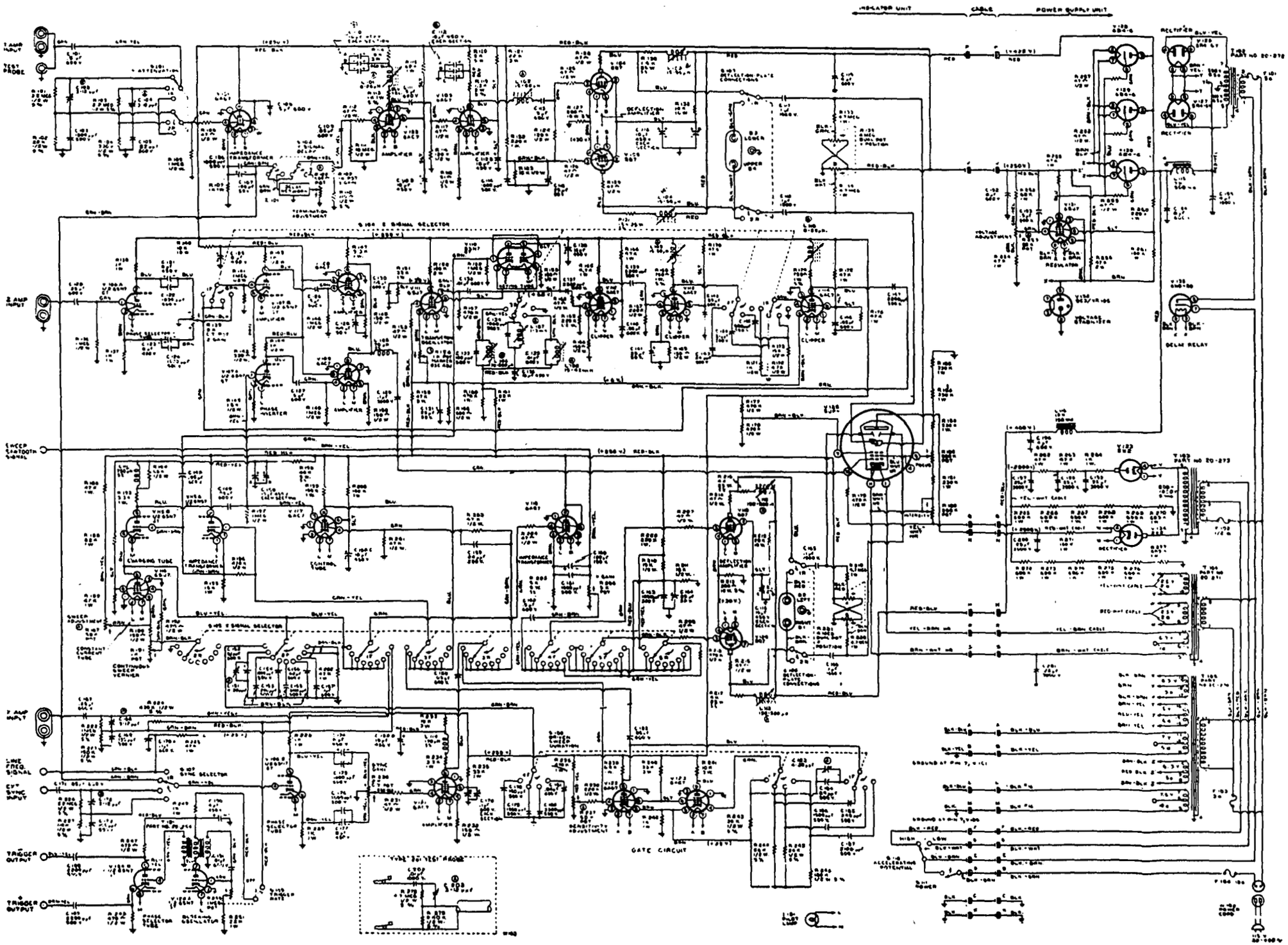
"A" - RESISTANCE OF D.C. WINDING 2200 Ω (APPROX.).

FIGURE 86.—Voltage regulator, Sorensen, circuit diagram.



SUPERIOR VOLTAGE REGULATOR

FIGURE 87.—Voltage regulator, Superior, circuit diagram.



NOTES

1. Abbreviations are as follows:

   Ω = Ohms
   K = 1000 Ohms
   W = Watts
   V = Volts
   mH = Millihenry
   uf = Micro Farad
   uuf = Micromicro Farad
   H = Henry
   uH = Micro Henry

2. Location of switch contacts is indicated by the switch section number, and "F" or "R" for front or rear respectively of this section. Sections are numbered from knob end of switch.

3. Small arrows indicate movement upward or to the right.

4. Typical Operating voltages are given in parentheses as measured with a 20,000-Ohm-per-volt meter.

5. A-C voltages are RMS.

6. (A) Indicates factory adjusted component.

7. Percentages refer to resistance tolerance. Unless otherwise specified this is ±10% for fixed resistors, ±20% for variable resistors.

8. Color coding may be omitted on component lead wires.

9. R-154 in some units may be 180 ohm ½ watt ±5%.

FIGURE 88.—Oscillograph, cathode ray, DuMont type 248, circuit diagram.