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Report on

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SYSTEMS TESTS OF THE SL RADAR

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Reviewer's name(s): P. HANNA

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Section I Submitted by:

John P. Hagen
John P. Hagen, Principal Physicist
Chief, Centimeter Wave Research Section

Section II Submitted by:

R.B. Meyer
R.B. Meyer, Principal Engineer
Chief, Transmitter Section

Section III Submitted by:

Thomas M. Davis
T. Mcl. Davis, Principal Engineer
Chief, Receiver Section

Reviewed by:

A. Hoyt Taylor
A. Hoyt Taylor, Supt. Radio Division

Approved by:

J. L. Reinartz
J. L. Reinartz, Comdr., U.S.N.R.

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CNO (3)

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REPORT OF THE SYSTEMS TEST
OF THE SL RADAR

1-1 INTRODUCTION

1-1-1 From 3 March 1943 to 29 April 1943, the SL radar was given a systems test at the Naval Research Laboratory's Chesapeake Bay Annex. For convenience in discussing the results of these systems tests, the report is divided as follows:

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1-2 DESCRIPTION OF EQUIPMENT

1-2-1 The SL radar equipment is an "S" band search radar designed for use on shipboard primarily for detecting ships, submarines, landmarks and planes flying at low altitudes.

1-2-2 The equipment consists of the following units:

Radar Transmitter-Converter	300 lbs.
Indicator-Modulator Assembly	700 lbs.
Antenna Assembly with Hood	300 lbs.
Wavemeter	15 lbs.

1-2-3 Transmitter: The transmitter tube is a magnetron keyed by a rotary spark gap in a d-c- resonance charging circuit. A 4,000 volt pulse from the modulator is stepped up by means of a pulse transformer to 18,000 volts across the magnetron. The repetition rate is 800 cps, and the pulse length is about 1.5 microseconds.

1-2-4 Receiver: The receiver is a superheterodyne using a reflex klystron as the local oscillator. A crystal converter is followed by eight stages of intermediate frequency amplification at 60 mc. This is followed by the second detector and two stages of video amplification.

1-2-5 Indicator: The indicator is a seven-inch, long persistence, magnetic deflection, PPI tube. Scales with maximum ranges of 5, 25, and 60 miles are available. Range is read with respect to five evenly spaced range circles etched on the amber filter placed over the PPI screen. Bearing is read with respect to 10° bearing lines etched on the filter. Zero on the bearing scale is arranged to correspond, as the operator may desire, either to the ship's course, or to true north. The bearing and range lines may be indirectly illuminated. An azimuth marker may be flashed on the PPI screen, if desired, each time the antenna swings by the bow of the ship or past true north. The PPI is driven by a synchronous motor and is made to correspond to the antenna position by removing the power momentarily from either the PPI motor or the antenna motor until they are in phase.

1-2-6 Antenna: The antenna is a 42 x 20 inch section of a paraboloid. The beam width is about 6° in azimuth and 12° in elevation. Scanning is done at the rate of 18 rpm by a synchronous motor. The antenna is fed by waveguide from the magnetron through a rotary joint in the casting at the base of the antenna. The emitted wave is horizontally polarized. A wooden hood covers the antenna assembly but is open at the bottom.

1-2-7 Wavemeter: A wavemeter is provided for measuring the relative frequencies of RF and the beat oscillator. The receiver and transmitter may be completely tuned with this wavemeter without the presence of echoes.

1-2-8 Power: The SL is designed for operation on the 115 volt 60 cycle ship supply. The equipment draws 1330 watts from this supply of which 900 watts are dissipated in heat in the indicator console. A separate report was submitted covering these measurements.

1-3 INSTALLATION

1-3-1 The SL was installed according to the instruction book. The instruction book seems adequate for all normal installations.

1-4 TUNE-UP

1-4-1 The SL was tuned-up according to the instruction book. The instruction book gives satisfactory information. The addition of an "A" scope would greatly increase the ease of tuning and shorten the time necessary, although it is possible to tune the system completely without an "A" scope by using the wavemeter.

1-5 DESCRIPTION OF TESTS

1-5-1 The following tests were performed on the SL equipment:

1. System Sensitivity
2. Maximum Range on Land Targets
3. Maximum Range of Surface Craft of Various Sizes
4. Minimum Range
5. Range accuracy
6. Azimuth accuracy
7. Effect of varying Line Voltage $\pm 10\%$
8. Effect of Warm-up
9. Power Measurements

1-5-2 Data: The following data were obtained on the system components:

Transmitter Power output	85 kw
Pulse width	1.5 microsecond
Receiver Sensitivity	-17.5 db
Antenna Gain	21 db

1-5-3 System Sensitivity: The data of the last paragraph can be correlated as follows. The overall sensitivity, S, of one system compared to another can be given by the equation:

$$S = (W_1/W_2) \text{ db} + (T_1/T_2) \text{ db} + 2G_1 + 2G_2 - R_1 + R_2$$

Where:

- W_1/W_2 = ratio of output powers expressed in db
- T_1/T_2 = ratio of pulse widths expressed in db
- G_1 = Antenna gain of arbitrary radar expressed in db over a dipole
- G_2 = Antenna gain of test radar expressed in db over a dipole
- R_1 = Receiver sensitivity of arbitrary radar in db
- R_2 = Receiver sensitivity of test radar in db

If we take as standard a fictitious radar having a power output of 30 kilowatts, a pulse length of 1 microsecond, a receiver sensitivity of 20 db, and an antenna gain of 20 db over a dipole, then we can classify any radar under test with respect to this standard radar. On this scale, the SL has an overall sensitivity of 10.8 db. For purposes of comparison, it might be mentioned that the SF has a sensitivity figure of approximately 9.4 db and the modified SG a figure of 9.3 db.

Since the SL has only PPI presentation the signal to noise ratio for standard fixed targets was not determined.

1-5-4 Maximum Range: Maximum range on land targets under normal conditions was 46000 yds. at 90° on an unidentified target. Under conditions of atmospheric inversion echoes were seen out to 120,000 yds. on various unidentified targets.

Maximum range on a 44-ft wooden motor boat was 17000 yds. as compared with 15,000 yds on the SG.

Maximum range on freighters such as pass the Naval Research Laboratory's Bay Station was 42000 yds. under normal conditions.

Planes were seen as far as 34,000 yds. No special tests were made on planes

1-5-5 Minimum Range: Minimum Range is a function of the condition of the sea but was found to be about 500 yds. on an average day the Chesapeake Bay Station.

1-5-6 Range Accuracy: The range accuracy is about as good as the range can be estimated between the range circles: about ± 200 yds. on the 5 mile scale, about ± 1000 yds. on the 25 mile scale, and about ± 2000 yds. on the 60 miles scale.

The range resolution is of about the same order as the range accuracy.

1-5-7 Bearing Accuracy: The bearing accuracy is about $\pm 1^\circ$ at ranges beyond 1 mile. The bearing resolution is about 6° . The accuracy is less at very short ranges because an echo covers a wider angle on the protractor.

1-5-8 Line Voltage Change of $\pm 10\%$: The only noticeable effect of $\pm 10\%$ voltage change was a change in indicated range. The higher the voltage the less the indicated range. With a voltage change of $\pm 10\%$ the total shift in range is about $\frac{1}{2}$ mile for a target at $7\frac{1}{2}$ miles.

1-5-9 Warm-Up: Operation during warm-up is normal except for focusing which becomes stable after about 30 minutes, and local oscillator tuning, which becomes stable after about 80 minutes of warm-up.

1-6 DEFECTS AND RECOMMENDATIONS

1-6-1 In order to protect the crystal, which deteriorated rapidly in the original circuit, the circuit was modified to give a "keep alive" current of 150 microamperes rather than 40 microamperes. This necessitated shorting out R472 and placing 3.9 megohms and 15 megohms both in parallel with R473.

1-6-2 After the equipment is turned on cold the magnetron current creeps up, and if not watched will exceed the recommended maximum. This necessitates watching the magnetron current meter and reducing the high voltage variac when necessary.

1-6-3 The warm up time of 80 minutes during which the local oscillator drifts is considered excessive.

1-6-4 Rubber washers under bolts fastening top cover of indicator became chewed up quickly.

1-6-5 Magnetron coupling sleeves failed. The spring metal contact for the wave guide came unsoldered from the tubing on two of these sleeves.

1-6-6 The converter is constructed in such a way that the fingers making contact with the small end of the crystal are

easily broken off. It is recommended that a more rugged type of holder be made.

1-6-7 The 115-volt a-c input to the solenoid is exposed in such a manner that it is very easy to short the terminals with the end of the wavemeter patch cord.

1-6-8 The lock for the local oscillator tuning control does not keep the control from turning. It is recommended that the lock be changed for a more satisfactory type.

1-6-9 There is serious RF leakage around the expansion joint in the transmitter. A neon bulb can be lit at almost any place near the cover of the transmitter. There is sufficient RF pick up on the cover bolts so that there is arcing between the bolts and their washers when the washers are moved.

1-6-10 It is recommended that an "A" scope be added for ease and rapidity in tuning. Also final tuning (repeller voltage control on indicator) would be possible when there are no targets other than "wave hash".

1-6-11 The method of antenna drive and the method of antenna PPI synchronizing are not considered satisfactory. The antenna and PPI are both driven by synchronous motors and are gotten into step by removing the power momentarily from one or the other of the motors. In this method of operation, the antenna cannot be stopped and trained on a target. Also, if power is removed from the antenna, the operator has no way of knowing the position of the antenna. Furthermore, if the antenna and PPI get out of step, because of shock or some other reason, and if the azimuth marker is not on, the operator has no way of knowing that the bearing is incorrect.

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Section 2

Model SL Radar Transmitting Equipment

Electrical and Mechanical Tests

2-1 INTRODUCTION.

During the period 9 January to 6 February 1943, the mechanical construction and electrical operation of the Model SL Radar Transmitting Equipment were investigated to determine the suitability of the equipment for use in the Naval Service. The following units were involved in these tests:

<u>Unit</u>	<u>Model</u>	<u>Manufacturer's Designation</u>
Transmitter	SL	D-150608
Modulator	SL	D-150611
Antenna	SL	D-150606
Wavemeter	SL	D-150925

The results of these investigations are discussed below.

2-1-1 Contents. For convenient reference the results of the investigations are divided as follows:

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2-1-3 List of Plates. The following plates are appended to Section 2.

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2-2 EFFECTS OF TEMPERATURE.

Tests were made to determine the ability of the equipment to perform satisfactorily when subjected to wide variations in ambient temperature. Three different tests were made, namely, Variation in Ambient Temperature, Starting at a Sub-Freezing Temperature, and Effect of Antenna Icing. As a preliminary to these tests the equipment was installed in a temperature test chamber and suitable measuring instruments were connected externally to permit monitoring of appropriate circuits. The radio frequency power output of the transmitter was conducted by means of a section of a wave-guide to an electro-magnetic horn which was situated outside the test chamber. The electro-magnetic horn presented the correct load for the transmitter. The following apparatus was used to obtain the desired data:

- (a). A bolometer probe inserted in the wave-guide adjacent to the electro-magnetic horn permitted measurement of the relative power output of the transmitter. By comparing the values obtained with this bolometer before and after changes were made in the temperature, it was possible to determine the effect of these changes upon the power output of the transmitter.

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- (b). The internal temperature of the transmitter was measured by means of a resistance thermometer. The thermometer element was located immediately over the magnetron and directly in front of the intake of the blower.
- (c). The wavelength of the r-f power emitted by the transformer was measured by means of the wavemeter furnished with the equipment. No calibration was furnished with this meter. It was therefore necessary to calibrate this wavemeter at the Naval Research Laboratory. The calibration data is listed on Table 1 and presented graphically in Plate 1.

2-2-1. Variation in Ambient Temperature. With the equipment in operation, the ambient temperature was increased to 50° C. This value was maintained for three hours after which the temperature was reduced first to 35° then to 20° and finally to zero degrees Centigrade. Each of these temperatures were maintained for approximately one hour to permit stabilization. At the conclusion of the period of operation at zero degrees Centigrade, the ambient temperature was increased to 45° C over a period of fifteen minutes. The data recorded are listed in Table 2 and are graphically presented in Plate 2. The following items were noted during this test:

- (a). Operation of the transmitting equipment including modulator, transmitter, and antenna was satisfactory throughout the test. At no time did the equipment cease to function.
- (b). A noticeable change occurred in the power output of the transmitter as the temperature was varied. Referring to Plate 2, it may be seen that when the equipment was put into operation at an ambient temperature of 50° C, the power output went through a period of fluctuation but finally stabilized at the end of 2-1/2 hours at a value of 104% as compared with its value of 100% at the start of the test. As the temperature was lowered the power output increased. After the ambient temperature had been held at zero degrees Centigrade long enough to permit stabilization of the internal temperature of the transmitter, the power output had increased to a relative value of 122%. Since the power obtained under stabilized conditions at 50° C had a relative value of 104%, the ratio of overall change in power between the temperature limits of 50 and zero degrees Centigrade is therefore the ratio 1.22/1.04 or 1.17 which represents an increase in power of 17%. Increasing the ambient temperature to 45° C at the end of the test

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caused the power output to decrease abruptly to a relative value of 112% and would probably have resulted in a further decrease had observations been made over a longer period.

- (c). When the ambient temperature was maintained at 50° C for three hours with the equipment operating, the temperature inside the transmitter cabinet increased to 76° C. No tests were made to determine the effect of continual operation in a high ambient temperature for an extended period, but it is considered that the life of the component parts in the transmitter may be shortened under such conditions.

2-2-2 Starting at Sub-Freezing Temperatures. With the equipment in operation, the ambient temperature was reduced from room temperature (25° C) to -23° C over a period of approximately five hours. The equipment, excepting the heaters, was then de-energized and permitted to remain idle while the ambient temperature was further reduced to -28° C. This reduction in temperature required two hours. At the end of this period power was reapplied, and observations were made to determine any malfunctioning of the equipment. The data for this test are listed in Table 3, and presented graphically in Plate 3. The following items were noted during this test:

- (a). The equipment operated satisfactorily during the periods in which the ambient temperature was being reduced to -23° C. The power output of the transmitter increased as the temperature was decreased. The amount of this change was 14%.
- (b). The antenna scanning motor started slowly at -28° C and was noisy. After one revolution the spinner speed became normal at 18 rpm.
- (c). The blower motor in the transmitter was extremely noisy when starting at -28° C. After running about thirty seconds, the noise decreased to its normal level.
- (d). The heater inside the transmitter unit remained energized continuously during the test, but it was noted that during the two-hour period in which the transmitter was idle the internal temperature of the transmitter cabinet decreased to -15° C.

2-2-3 Effect of Antenna Icing. Tests were made to determine the ability of the antenna to rotate when coated with ice. The procedure in this test was as follows. With the spinner at rest and the plywood hood removed, the ambient tem-

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perature was reduced to -15°C and a fine spray of water was directed at the antenna. This spray was continued until a layer of ice approximately one-half inch thick formed between the base of the spinner and the top of the pedestal. A view of the antenna under these conditions is shown in Plate 32. Power was then applied to the antenna drive motor. It was found that the spinner would not rotate since it was locked fast in the ice. The ice was then chipped off around the edge of the skirt on the spinner shaft, and the spinner could then be rotated normally. The ambient temperature was still -15°C . The results of this test indicate that if rotation of the antenna is to be obtained under icing conditions, the design of the spinner must be changed to prevent ice from forming in a manner that will prevent its rotation. It is also suggested that a more powerful motor may aid in this respect but in the absence of tests, this is uncertain. The hood, being open at the bottom, will not prevent the formation of ice. The foregoing discussion refers only to the possibility of obtaining rotation of the spinner under icing conditions and not to the effect of ice on other parts of the antenna, such as the reflector or waveguide aperture.

2-3 EFFECTS OF RELATIVE HUMIDITY.

A number of tests were made to determine whether or not wide variations in relative humidity would have a detrimental effect upon the equipment or upon its performance. For the purpose of these tests the equipment was installed in a humidity test chamber and provided with measuring apparatus in the manner described in paragraph 2-2. The procedures and results are described in the following paragraphs.

2-3-1 Variation in Relative Humidity: Part 1. With the equipment in operation, the ambient temperature was adjusted to 40°C and the relative humidity was adjusted to a low value as shown in Table 4. After these conditions had been maintained for $1\text{-}1/4$ hours the relative humidity was raised to 97% and was maintained at this value for one hour. Finally, the humidity was reduced and maintained at a low value for $3/4$ of an hour. The data recorded during this test are listed in Table 4 and are presented graphically in Plate 4. The results of the test were as follows.

- (a). There were no failures during this test, and the equipment sustained no damage.
- (b). The power output of the transmitter decreased as the humidity was increased but returned approximately to its initial value when the humidity was restored to a low value. The overall change in power output was from a relative value of 100% to a relative value of

64% which indicates that exposure of the equipment to a high relative humidity caused a 36% reduction in power output.

2-3-2 Variation in Relative Humidity: Part 2. Subsequent to the test described in the preceding paragraph an investigation revealed that the only place at which moist air could have entered the transmitter was a very small opening at one of the interconnecting cable entrances. This opening was resealed and a test was made to determine whether or not it had been responsible for the difficulty encountered. The data for this test are listed in Table 5 and are presented graphically in Plate 5. The procedure of the test was as follows:

With the equipment completely sealed the ambient temperature was adjusted to 40° C and the relative humidity to 15%. After a period of operation to permit stabilization, the humidity was increased to 97% and was maintained at that value for one hour. As compared with the result obtained previously when the transmitter had a small leak in its cabinet, the high humidity did not on the present occasion cause a significant reduction in the power output of the transmitter. Following the period of operation at high humidity, the humidity was restored to a low value and a small opening was made at one of the cable entrances. As indicated by point 1 on Plate 5 this opening resulted in no change in the power output as long as the humidity was maintained at a low value. However, when the humidity was subsequently raised to 97% the power output decreased rather abruptly. When the opening was reclosed (at the time corresponding to point 2, Plate 5), the power output continued to decrease. At the time corresponding to point 3, Plate 5, the transmitter cover was opened slightly but this had no appreciable effect since the power output continued to decrease at a constant rate. The effect of opening the transmitter during the present test may be summarized as follows: The power output at the end of the stabilized period at low humidity had a relative value of 102%. When the transmitter was opened in the presence of high humidity the power output decreased to a relative value of 57%. Since this is the ratio of 57/102 or 0.55, the reduction in power resulting from a high humidity amounted to 45%. Following the period of high humidity described above, the cover of the transmitter was left slightly open and the humidity was reduced. The power output thereupon rose abruptly and after 3/4 of an hour regained a relative value of 100% which was close to the value obtained before the transmitter was unsealed.

2-3-3 Variation in Relative Humidity: Part 3. Following the tests described in the previous paragraphs, an effort was made to discover the source of the variation in power output with humidity. A detailed visual inspection of the interior of the transmitter was therefore made to determine whether any circuits or components were likely to be the source. This inspection suggested that if the pulse modulation transformer was exposed to a high humidity there might be sufficient current leakage between its various terminals to reduce the pulse voltage applied to the magnetron and thereby reduce the power output of the transmitter. This transformer was, therefore, removed from the transmitter and tested separately. The transformer was mounted in a temperature-humidity test chamber and was supplied with a pulse voltage from the Modulation Generator. The secondary of the transformer delivered these pulses into a resistance load which simulated insofar as possible the impedance of the magnetron. A voltmeter was provided to measure the peak voltage obtained from the pulse transformer. It was found that the peak voltage obtained remained unchanged when the relative humidity in the test chamber was raised from an initially low value to a value approaching saturation. The results of this test were, therefore, negative, although they indicated that the transformer was not the source of the difficulty.

2-3-4 Variation in Relative Humidity: Part 4. Since the source of the reduction in the power output which resulted from exposure of equipment to high relative humidity was not discovered during the tests described above, it is proposed to conduct further investigations on this subject with the next Model SL Equipment that is made available to the Naval Research Laboratory. However, it is believed that the following precautions ought to be observed when using the equipment.

- (a). Care should be taken to insure that the Transmitter Unit is completely sealed both during operation and during periods of idleness.
- (b). It may be found that the power output of the transmitter is noticeably low following servicing operations which require the removal of the transmitter cover. This will be the result of the entrapment of moist air when the cover was replaced, and to regain normal output under these circumstances it will be necessary to dry the interior of the transmitter.

2-3-5 Starting at High Relative Humidity. At the conclusion of the tests described in paragraph 2-3-1, input power was removed from the equipment (the heaters were free to become energized if the thermostat closed) and the relative humidity was adjusted to 97% at 40° C (Table 4). After these conditions

had been maintained for two hours the equipment was again placed in operation. During the starting period and immediately thereafter the equipment was observed for evidences of abnormal or unsatisfactory operation. The results were as follows:

- (a). When the equipment was started, the power output was lower than normal. That is, as is shown on Table 4, the relative value of power output was 69% as compared with the value of 93% obtained at the conclusion of the tests described in paragraph 2-3-1. The low power output obtained under these conditions is further evidence of the sensitivity of this equipment to high relative humidity.
- (b). A flashover occurred during the first minute of operation. It is not known in which circuit this occurred, but its presence was indicated by momentary increase in magnetron plate current. Although only one flashover occurred, this condition is undesirable and it is recommended the Contractor be required to modify the equipment to prevent flashovers from occurring.

At the conclusion of this test the equipment was allowed to remain idle overnight (16 hours). During this period the ambient temperature decreased to 25° C and the relative humidity to 28%. Upon reapplying power to equipment the next morning the power output was found to have increased to a relative value of 125%.

2-4 EFFECTS OF VIBRATION.

A test was made to determine the ability of the equipment to withstand vibration. The procedure was as follows. The equipment was secured to a Vibration Test Table by means of its normal hold-down fittings and subjected to vibration at frequencies ranging from 600 to 2000 cycles per minute. This test was conducted in two parts. The first part of the test included the Transmitter and Modulator Indicator Unit and the second part the Antenna Unit only. Except for the r-f connection between the Transmitter and the Antenna, all the units were interconnected and operated during these tests. A section of wave-guide was used to radiate the transmitter's r-f power.

2-4-1 Transmitter Unit. The transmitter unit was subjected to vibration for a period of three hours. The following items were noted.

- (a). The wave-guide joint at the top of the transmitter resonated at 1450 cpm and vibrated vertically with an

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amplitude of $3/8$ ". This vibration imposed severe stresses on the entire top of the transmitter unit. The top of the case should be stiffened sufficiently to prevent this resonance effect.

- (b). The type 705-A tube in the transmitter unit resonated at 1250 cpm and also at 950 cpm. At both frequencies the resulting vibration was vertical and had an amplitude of $1/8$ ". Although no immediate damage resulted from this vibration, it is recommended that steps be taken to prevent this resonance effect.

2-4-2 Modulator-Indicator Unit. The modulator-indicator unit was subjected to vibration for a period of three hours. During this time the following items were noted.

- (a). The upper right-hand corner of the modulator unit resonated at 1250 cpm with a resulting amplitude of vibration of $1/16$ ". This unit is not mounted on flexible supports and the other corners did not vibrate. This indicates that the applied vibration was resulting in stresses on the framework of the unit.
- (b). The type 705-A high voltage rectifier tubes in the modulator unit resonated at a vibration frequency of 1250 cpm. This resulted in a vertical motion with an amplitude of $1/8$ of an inch. This vibration caused no obvious damage to the rectifier tubes and had no noticeable effect upon the operation of the equipment. However, it is considered that continuous vibration of this magnitude is likely to result in short tube life.
- (c). In the Model SL Equipment the required synchronism between the rotation of the trace on the screen of the PPI oscilloscope and the rotation of the antenna is obtained by the use of synchronous motors on each of these units. Since a system of this type does not insure that the relative angular position between the trace and the antenna will be automatically adjusted to the proper relationship, an arrangement has been provided to permit the necessary adjustments to be made manually. A switch operated by the rotation of the antenna causes the rotating trace on the PPI screen to brighten each time the antenna points toward the ship's bow. It is possible to obtain the correct relative angular position between the antenna and the PPI oscilloscope trace by manipulation of two switches on Modulator-Indicator units. Operation of one of these switches de-energizes the antenna motor while operation of the other de-energizes the PPI drive motor. Upon one occasion during the

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vibration test of the Modulator-Indicator unit, it was noted that the relative position of the trace on the PPI scope changed 5° with respect to the antenna. This occurred at a vibration frequency of 1250 cpm. It is pointed out that when the ship's gyro is connected to the PPI drive, a change in the relative position of the PPI trace resulting from the above circumstances will not be immediately noticeable and will cause an error in target bearing. For this reason the system should be modified to prevent vibration from interfering with the synchronization.

2-4-3 Antenna Unit. The antenna unit was subjected to vibration for 25 minutes. No damage occurred, but it was noted that at a vibration frequency of 900 cpm the top of the parabolic antenna reflector resonated and vibrated horizontally with an amplitude of 7/16". This is considered excessive and, if continued, likely to result in the destruction of the antenna. It is recommended that remedial action be instituted.

2-5 EFFECTS OF INCLINATION.

The antenna was secured to an inclination test table by means of its normal hold-down fittings and inclined through an arc of 90°, that is 45° from the vertical towards the left and right and at the rate of 5 complete cycles per minute. This process was continued for fifteen minutes. During this entire period the antenna spinner was rotating. During part of the period the antenna was vibrated. With the plane of the reflector in a plane parallel to the slope of the table, the vibration of the reflector was excessive.

2-6 EFFECTS OF SHOCK.

The equipment was subjected to a series of shock simulating conditions encountered aboard Naval vessels. The procedure of this test was as follows. The units were secured to a shock test table by means of their regular hold-down fittings. All the units could not be mounted on the test table simultaneously, and it was therefore necessary to shock-test the antenna unit separately from the remainder of the equipment. Except for the r-f connection between the transmitter and antenna, all of the units were interconnected and operating during these tests. As a substitute for the normal antenna connection, a section of waveguide was used to radiate the transmitter r-f power.

2-6-1 Shock-Testing Apparatus. The shock testing apparatus consists of a table to which a horizontal acceleration may be imparted by means of a pneumatic shock device. The construction of the table permits it to be rotated so that any one of its

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four edges may be presented to the pneumatic device. Thus, by mounting the equipment under test on this table with its sides parallel to those of the table, shocks can be applied toward any of the four sides of the equipment. During each shock of the series described below, momentary peak acceleration of the table top was 250 g.

2-6-2 Transmitter Unit. A total of 61 shocks were applied to the Transmitter Unit. Of these 25 were applied toward the front of the unit and 12 were applied to each of the other 3 sides. The following items were noted.

- (a). The first 12 shocks applied toward the front of the unit caused no difficulty. Previous to the 13th shock the front cover of the unit was removed. Upon the delivery of the 13th shock the magnetron plate current rose to 19.5 ma from its former value of 19.1 ma. Echoes could still be received. However, an r-f arc inside the transmitter was noted. Examination revealed that the top of the wave-guide in the transmitter had moved $3/8$ " and was no longer resting against its rubber supports. These supports are visible on Plate 13 and 14, immediately above the blower. When the cover is in place on the transmitter cabinet, a third similar support located on the cover also presses against the top of the wave-guide. Removal of the cover removed the support and permitted the shock to move the top of the wave-guide. As shown in Plate 16, supports on the bottom of this section of wave-guide permit it to be fastened to the transmitter chassis. As a result of the movement of the top of the wave-guide during shock, these supports were bent. Shock may occur while the transmitter is being serviced with its cover removed. The wave-guide will then be inadequately supported and damage will result. It is therefore considered that the present construction is unsatisfactory.
- (b). Shock had caused the magnetron to move in its mounting by an amount that caused a gap between the flange on the coupling section and the waveguide. The flange is visible in Plate 16.
- (c) After the waveguide had been re-straightened and the equipment had been restored to its original condition, the cover was replaced and 12 additional shocks were applied. These caused no damage.
- (d) The cap plates on the bottom right and left shock mount assemblies on the transmitter unit struck the welded seams on the case when the shocks were applied

toward the sides. These plates should be redesigned to provide sufficient clearance to prevent this striking from occurring. One of these plates is visible on Plate 9.

2-6-3 Modulator-Indicator Unit. Sixty-one shocks were applied to the Modulator-Indicator unit. Of these, 25 were applied toward the left side of the unit, and 12 were applied toward each of the other three sides. The rotating trace on the PPI oscilloscope screen apparently lost synchronization momentarily during certain shocks so that at the conclusion of the shock the bearing of the PPI trace lagged the bearing of the antenna by 6 to 15 degrees. It is probable that this lag was brought about because the shocks caused the PPI drive mechanism to stop rotating momentarily.

2-6-4 Antenna Unit. The antenna was subjected to a total of 20 shocks. These were applied with the antenna rotating and the following items were noted.

- (a). During many of the shocks the azimuth marker, discussed in paragraph 2-4-2, became visible even though the antenna was not pointed in the corresponding direction. As indicated in that paragraph, the antenna when pointed in one particular direction operates a switch which energizes the marker circuits. This switch was evidently actuated by the shocks. It is undesirable to have the azimuth marker appear in this manner since the shocks imposed by the ship's own guns will result in confusion.
- (b). As a result of many of the shocks, the antenna spinner momentarily stopped rotating, and since the PPI motor continued to rotate, a change of the relative angular position of the trace on the PPI scope with respect to the antenna azimuth bearing resulted. This change amounted to as much as 8° with the exact amount depending upon the bearing of the antenna spinner at the instant the shock was applied. As shown by Table 6, the effect was cumulative with successive shocks and unless the antenna and PPI trace bearings are realigned following each shock, a constantly increasing divergence would result. No definite conclusions were drawn as to the mechanics of this momentary stoppage, but it may be possible that the shock caused the worm gear drive or the antenna bearings to lock, or that the load imposed by the moment arm formed by the spinner was too great.

Following the shock tests described above the plywood cover of the antenna was removed and three additional shocks were applied. These caused no mechanical damage.

2-7 PRIMARY POWER CONTROL AND SUPPLY CIRCUITS.

A number of tests and measurements were made of the primary power control and supply circuits. The results of these tests are described below under appropriate headings.

2-7-1 Power Required from Supply Line. The power that the equipment requires from the 115 volts supply line under various conditions of operation is listed in Table 7. A maximum of 1540 watts is required for normal operation. This value includes the requirement for the entire equipment rather than for only the transmitting portion thereof.

2-7-2 Variation in Line Voltage. A test was made to determine whether or not the performance of the equipment would be adversely effected if the supply voltage was varied over wide limits. The data recorded during these tests are listed in Table 8 and are presented graphically in Plate 6. The procedure of this test was as follows. The equipment was put into operation with the line voltage adjusted to 115 volts. The voltage was increased in increments to 128 volts. Following this the line voltage was restored in one step to 115 volts. By a similar procedure the line voltage was reduced to 102 volts. The following items were noted during this test.

- (a). The power output obtained when the line voltage was 102 volts was 86% of that obtained with normal line voltage. The power output obtained when the line voltage was 128 volts was 118% of that obtained with normal line voltage.
- (b). The equipment suffered no obvious damage during this test.

2-7-3 Effect of Line Voltage Surges. A test was made to determine the ability of the equipment to withstand line voltage surges without damage and to return to normal operation promptly upon restoration of rated line voltage. The data for this test are listed in Table 9. The procedure was as follows. The equipment was placed in operation at rated line voltage (115 volts). The voltage was then suddenly increased to 149.5 volts which is 30% above normal. After it had been maintained at that value for approximately 1/2 second, it was restored to 115 volts. Following this the line voltage was reduced in a similar manner to 80 volts which is 30% below normal. The following items were noted during these line voltage variations.

- (a). When the line voltage was increased to 30% above normal the magnetron plate current, which is normally 17 ma, exceeded 25 ma. The exact value was not determined, since the information was obtained from

the reading of the plate current milliammeter whose full scale reading is only 25 ma. The trace on the indicator oscilloscope became defocused and the echoes disappeared. The power output of the transmitter increased 27%. Upon restoration of the line voltage to 115 volts, normal operation was regained in four seconds.

- (b). When the line voltage was decreased to 30% below normal the output of the modulator and of the transmitter became zero. The antenna butterfly-valve relay chattered but the valve did not close. Upon restoration of the line voltage to 115 volts the operation of the equipment immediately became normal.
- (c). The performance of the transmitting equipment was considered satisfactory providing the surges did not occur at frequent intervals.

2-7-4 Variation in High Voltage. A test was made to determine the effect of varying the voltage applied to the primary of the high-voltage supply transformer, T-503, of the modulator unit. This transformer, through its associated rectifier, furnishes high voltage to the modulator, and that unit, in turn, supplies power to the plate circuit of the r-f oscillator tube, V-702, in the transmitter unit. The primary voltage was varied by adjusting the setting of the variac, T-502, in the primary circuit from its minimum to its maximum value. The data recorded during the test are listed in Table 10 and are presented graphically in Plate 7. It was found that the power output of the transformer increased as the modulator voltage was raised. However, saturation commenced at 4 kv and increase in power as the voltage was raised above this value was relatively small.

2-8 CONTROLS.

Table 11 lists the controls of the transmitting portion of the equipment.

2-9 COMPONENT PARTS.

Where circumstances permitted, measurements were made of the component parts in the equipment to determine whether or not they were operating within their ratings. In addition, visual inspection was made of the component parts to determine whether they were of the quality, type of construction, and workmanship which is required of equipment intended for the Naval Service. Results of these measurements and inspections are discussed below.

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2-9-1 Resistors. Table 12 lists the resistors employed in the transmitter equipment and includes the potentials applied to each resistor as well as the actual power which each resistor is required to dissipate. The following items were noted concerning the resistors.

- (a) The resistor, R-501, in the Modulator Unit has a rating of 6 watts but is required to dissipate 10.1 watts. It is, therefore, overloaded and should be replaced by a resistor of an adequate rating.
- (b) The coating on the resistor, R-501, of the Modulator Unit, is chipped in several places so that the underlying porcelain core is exposed. More care should be exercised during construction to prevent this type of damage, or the present resistors should be replaced by a type that is less easily damaged.

2-9-2 Capacitors. Table 13 lists the capacitors employed in the various units of the transmitting equipment and includes the measured d-c or 60 cycle a-c operating potential applied to each capacitor.

2-9-3 Meters. Table 14 lists the meters employed in the equipment. The following items were noted concerning these meters.

- (a) Neither of the meters listed in Table 14 are marked with a Navy type number. Paragraph D-19b of Navy Specifications 17-I-12(INT) requires that all meters used on Navy radio equipment be marked with a Navy type number. It is recommended that the contractor be required to comply with this requirement.
- (b) The magnetron plate current meter, which is a 3-1/2" switchboard type, indicates approximately 3% high. Paragraph E-7a of Navy Specification 17-I-12(INT) requires an initial accuracy of 2% or better for meters of this type. The contractor should be required to comply with this provision.
- (c) It was noted that although the full scale reading of the magnetron plate current meter is marked 25 ma, the meter actually is deflected to full scale by 1 ma. The notation on the meter, namely, FS = 1 ma might serve as a warning but is so inconspicuous that it is probable that in the event of a failure an attempt would be made to replace the meter by a standard 0 - 25 ma meter. Since the use of a 0 - 1 ma movement is necessitated by the use of the same meter to indicate crystal mixer current, it is recommended that the face of the meter be conspicuously marked "USE WITH EXTERNAL SHUNT"

- (d) As indicated on Table 14, meter M452 is used to measure magnetron plate current and crystal mixer current. When it is being used to measure magnetron plate current, it has a 24,000 ohm resistor R-481 in series with it and the 1000 ohm resistor R-702 acts as a current shunt across this combination. It was found that the specified resistance tolerance of this 1000 ohm resistor is 10%. Although the resistor actually provided was found to be very close to its rated value, the replacement of this resistor by another of like tolerance might result in a 10% change in the meter calibration. It is recommended that a resistor having a 1% resistance tolerance be specified for use in this position.

2-9-4 Vacuum Tubes. Table 16 lists the static potentials applied to the vacuum tubes of the transmitting equipment. The instruction book states that the d-c voltage applied to the T-R tube, V-703, (type 721-A) is -1000 volts. However, the measured voltage was only -370 volts when the equipment was operating normally and -410 volts when the high voltage supply to the modulator unit was "off", that is, when the transmitter was not operating. This voltage was measured with an electronic voltmeter whose input resistance was approximately 11 megohms. Inspection of the circuit diagram indicated that the internal impedance of the rectifier which supplies this voltage is approximately 18 megohms. Therefore a voltmeter with 11 megohms internal resistance represents an appreciable load. While the equipment operated satisfactorily with the voltage applied to it, and it is probable that this voltage is close to -1,000 volts, the statement that there is 1,000 volts applied to the tube will be misleading to operators, since they will not be able to obtain such a value with any measuring instruments likely to be available to them. A statement should be included in the instruction book indicating what this voltage will be when measured with the meters available to the Forces Afloat.

2-9-5 Fuses. Table 17 lists the fuses of the equipment and the amount of current which passes through each fuse during normal operation. The following items were noted concerning the fuses.

- (a) Four 250 volt cartridge type fuses are used in the equipment. Two of these are of the refillable type and two are of the non-refillable type.
- (b) There are no fuses provided to protect the heater circuits of the transmitter and modulator-indicator units. Suitable fuses should be provided in the equipment.

2-9-6 Thermostats. Table 15 lists the thermostats used in the equipment. The thermostat in the Transmitter Unit is marked 40° C. However, during the temperature test, paragraph 2-2-1, it was noted that this thermostat cycled in a manner which indicated that it was operating at between 50 and 60° C. Referring to Plate 2, it may be seen that between 0.5 and 1 hours, the thermostat in the transmitter opened and de-energized the heater. The internal temperature of the transmitter at this time was between 50 and 60° C. The thermostat remained open until the ambient temperature was reduced to 20° C, whereupon it began to cycle so that the internal temperature of the transmitter remained at 56° C. When the thermostat was subsequently removed from the Transmitter Unit and tested separately, it was found to open and close at 53.5° C. Care should be taken to insure that the transmitter be provided with a thermostat that will operate at the desired temperature and that this temperature be correctly marked on the thermostat.

2-9-7 Transmitter Blower Motor. The motor, B-701, which drives the blower which circulates the air inside the transmitter cabinet bears a nameplate which contains the following information:

Bodine Electric Company
Chicago
U.S.A.

Type MSI-53
Volts 115AC
Amps 1.4
RPM 1725
No. 730601
Date Mfd --

Phase 1 Cy 60
Winding --
Inter H.P. --
Cont H.P. 1/15

Contract --
Ship No. --
Temp. Rise 30° C
Time --
Duty Cont.

The following items were noted concerning this motor:

- (a) The motor is enclosed in the transmitter cabinet and since the temperature of the air within this cabinet rises under the conditions indicated in paragraph 2-2-1 to 76° C, the motor has an operating temperature of 76° + 30° or 106° C. Although no data are available concerning the material used in the construction of this motor, it is pointed out that paragraph D-10a(1) of Navy Specifications 17M10(INT) indicates that 105° C is the maximum temperature to which Class A insulation may be safely subjected. It is probable that the insulation on this motor is Class A as defined in the above specifications. The contractor should be required to clarify this situation, and if necessary, provide a motor which meets the requirements of the above specifications.

- (b) A film of oil was found on the outside of the case of the transformers mounted in back of the vertical panel inside the transmitter unit. It is believed that this oil came from the bearings of the blower motor and that the leak occurred during a period when the temperature within the transmitter unit was high. The reason for the leak and the circumstances attending it were not discovered, but it is possible that the rotating shaft of the blower motor "threw" the oil against the transformers. Such leakage is undesirable not only because the oil is deposited where it is not wanted, but also because it may result in the bearings being entirely depleted of lubricant.
- (c) Although the blower motor is not a Navy type motor, and is being furnished the Navy as a part of a complete equipment, attention is called to the fact that its rating is 1/15 H.P. This size is not included in the list of standard sizes in which, according to amendment 6 of Navy Specifications 17-M-10(INT), motors are to be furnished to the Navy. It is not suggested that a motor of this size is detrimental to the operation of the equipment.

2-9-8 Coaxial Pulse Cable. The pulse voltage required for the operation of the magnetron in the transmitter unit is generated by the modulator unit and introduced into the transmitter by means of a length of coaxial cable. The inner conductor of this cable consists of a number 14 solid copper wire. This is insulated by a layer of rubber which, in turn, is covered by a layer of copper braid which forms the outer conductor. The outer conductor is enclosed in a layer of rubber insulation and the entire assembly is protected by an outer layer of braided armor. During normal operation this cable is subjected to a peak voltage of 4,000 volts applied between the inner and outer conductor. The duty cycle of this voltage is 0.0012, and the pulse rate is 830 cps. The test described herein was made to determine the stability of the insulation resistance of this cable. As a preliminary to the test a 70 ohm resistor was connected between the inner and outer conductor of the cable selected for test (a 75 inch long section) and arrangements were made to apply to the other end a pulse voltage having a repetition rate of 60 cps, a pulse length of 5 microseconds, and a peak value of 7,000 volts. Calculations showed that the application of such a voltage results in a peak current of 100 amperes through the cable and a power dissipation of 700 kw (peak) or 210 watts (average) in the resistor connected to the end of the cable. After preliminary arrangements had been completed, the ambient temperature of the cable was increased to 50° C, the humidity was adjusted to

a low value and the insulation resistance between the inner and outer conductors was measured. With the ambient temperature and relative humidity remaining unchanged, the pulse voltage described above was then applied for a period of three-quarters of an hour. At the end of this period the pulse voltage was removed for a period of five minutes while the insulation resistance was measured. The pulse voltage was reapplied for an additional period of 1-1/2 hours after which the insulation resistance was again measured. This concluded the test. As shown by the following items the performance of the cable was satisfactory.

- (a) The insulation on this cable withstood the application of a pulse voltage having a 7,000 peak, while being subjected to an ambient temperature of 50° C.
- (b) There was no measurable change in the insulation resistance during the two-hour period of the test. The insulation resistance between the inner and outer conductors exceeded 50,000 megohms at the beginning and end and during the progress of the test.

This 75 inch section of coaxial cable was also subjected to d-c test voltages. The cable withstood the application of 13 kv d-c applied momentarily between its inner and outer conductor and also withstood a voltage of 10 kv d-c applied in a similar manner for 1.5 minutes. The outer conductor and the protective armor were connected together electrically for this test and there was no resistor or other type of load connected between the inner and outer conductor.

2-9-9 Pulse Transformer. The pulse transformer located in the Transmitter-Receiver Unit (Plates 13 and 15) which supplies power to the magnetron is immersed in oil. To permit expansion of this oil, the case of the transformer is similar in construction to a sylphon bellows. The terminal board which is made of micalex, or similar material, forms the top of the case. The joint between the bellows and the terminal board is sealed by a gasket of a rubber-like material. This gasket is provided to prevent the oil from leaking out of the case. However, it was found that the joint is not oil tight, since placing the transformer in a partial vacuum (pressure equivalent to 14 inches of mercury) caused a part of the oil to leak out. The total amount which leaked out was estimated to be 1/4 pint. Judging by the sound emitted by the transformer when shaken a considerable percentage of the oil was removed during this leakage. While the low pressure to which the transformer was subjected does not represent a condition that will be encountered when the equipment is in actual operation, the results of this test indicate two objections to the present construction.

- (a) Paragraph 3-5-(3) of Navy Specifications RE 13A 554D requires that transformers be hermetically sealed in their cases so as to be air tight. The pulse transformer does not meet this requirement.
- (b) Since the transformer leaks oil when exposed to low pressures, spare or replacement transformers cannot be shipped by aircraft.

It is recommended either that the transformer be made oil tight or that the use of oil be eliminated.

2-10. GENERAL PHYSICAL CONSTRUCTION

A number of items of a mechanical nature were noted during the course of the investigation made on the Model SL Equipment. These items are discussed below under appropriate headings.

2-10-1. Mechanical. The following items were noted concerning the construction of the equipment.

- (a) The wings on the thumb screws which hold the transmitter chassis in its case are so large that they strike against the case when the thumb screws are being put into place or removed. Sufficient clearance should be provided for these thumb screws.
- (b) The Modulator Unit is designed in a manner which permits it to be unfastened and removed from the Modulator Indicator Cabinet. A flange around the bottom edge of the modulator is used to secure this unit in the cabinet. The construction can be seen on Plates 22 and 24. The portion of this flange which is at the front of the modulator is secured to the frame of the cabinet by five machine screws, while a part of the flange at the rear of the unit fits under a lip that has been welded to the frame of the cabinet. Difficulty was experienced while replacing the modulator unit in its cabinet. The flange at the rear of the unit drops down so far that it strikes against the rear frame before the unit is fitted "home." Before the unit can be pushed completely "home," it must first be tilted slightly forward. The weight of the unit is estimated to be between 250 and 350 pounds, and since it must be tilted forward and pushed backward at the same time, more than one man is necessary to perform this operation. It is recommended that tapered guide pins somewhat similar to those used in the transmitter unit be provided at the bottom rear of the main frame of the modulator-indicator unit to facilitate the process of

replacing the modulator unit. If these pins are made sufficiently strong, it will no longer be necessary to have a lip on the main frame to hold down the rear of the modulator.

- (c) The machine screws holding the modulator unit in its cabinet and the captive thumb screws holding the back panel on the Modulator-Indicator Unit cannot be fitted into the holes provided for them in the main frame without considerable difficulty. This difficulty is due to the incorrect location of the holes. This same condition exists with respect to the thumb screws holding the indicator unit in the main frame excepting that it is difficult not only to replace these screws but also to remove them. It is also pointed out that holes in the main frame should not be tapped as they cannot be plated. The screw rusts in place and cannot be removed. The difficulty encountered with the two sets of thumb screws could be avoided by eliminating the use of tapped holes in the main frame and substituting floating nuts therefore.
- (d) There are a number of unplated brass parts on the antenna butterfly-valve assembly; these should be plated to protect them from corrosion.
- (e) The connection between the coaxial cable and the pulse transformer in the transmitter unit is made by means of an unplated brass or bronze clip. This clip should be suitably plated to prevent it from corroding and thereby causing a faulty contact.
- (f) To facilitate removal of the magnetron from the transmitter unit, two of the four screws which fasten the magnetron to its base are on swivel joints. It is suggested that all four screws be of the swivel type since this will increase the ease with which the magnetron can be replaced.
- (g) It was noted during the course of the test that the aluminum antenna reflector was very soft and easily bent. While it is not recommended that any change be made in the present construction, attention is called to the fact that if installation is undertaken with the protective cover off, care must be exercised to prevent the reflector from being damaged.

- (h) A considerable amount of oil leaked from the antenna gear case into the compartment which contains the antenna drive motor. This leakage will have two detrimental effects, namely, the antenna drive gearing will be damaged because of lack of lubrication and the insulation of the motor and its associated wiring will deteriorate when exposed to oil. The joint through which the drive shaft passes into the antenna gear case should be made oil-tight. It is also recommended that an entry be made in the instruction book to call attention to the possibility of this leakage and instructing that inspection be made frequently to insure that there is sufficient oil remaining in the antenna gear case oil reservoir.
- (i) It is difficult to remove and even more difficult to replace the plywood antenna cover. The supporting brackets spread when the cover is lowered so that the cover locks part way down and cannot be lowered further without a considerable amount of manipulation. The antenna-cover supporting-brackets should be redesigned to give satisfactory performance.
- (j) The paint on the antenna hood chips off very easily; better paint or an improved method of application is required.
- (k) The cement holding the rubber gasket around the front edge of the transmitter cabinet is not satisfactory since during the temperature and humidity tests the gasket came loose from the case. This gasket fits into a groove around the front of the transmitter in a manner visible on Plates 12 and 13. An improved method of securing the gaskets should be provided. In addition, consideration should be given to the application of an anti-adhesive compound to the portion of the transmitter cover upon which the gasket impinges. The application of such a compound prior to closing the cover would prevent the gasket from adhering to the cover and would therefore tend to prevent the cover from pulling the gasket out of its groove.
- (l) Although the Modulator-Indicator Unit weighs 713 pounds, no convenient means have been provided for applying slings to it for hoisting or lowering during installation. It is recommended that four

eye bolts or some other suitable type of device be provided which will permit the easy attachment of slings of an adequate size.

- (m) The center bolts of the shock mount assembly at the lower right front end and left front of the transmitter are made of steel. It was found that these bolts had rusted. The present bolts should be replaced by bolts that will be corrosion and rust resistant.
- (n) The micrometer handle of the wavemeter was found to have rusted. The micrometer should be modified either by suitable plating to prevent rust or by constructing it of a rust and corrosion resistant material.

2-10-2. Accessibility. The following items were noted concerning the accessibility of the component parts for replacement or servicing.

- (a) It is extremely difficult to lubricate the blower motor, B-701, in the Transmitter Unit. Extensive dis-assembly is required, and it is estimated that under favorable conditions at least four hours would be required for the entire process including disassembly of the transmitter, removal of the motor, disassembly of the motor, lubrication of the bearings and complete reassembly of all these items. The time required is considered to be much too long, and it is recommended that the motor be made more easily accessible for lubrication.
- (b) When the protective cover is in place on the antenna, the lack of accessibility makes it difficult to remove or replace the screws which hold the cover on the antenna drive motor compartment. It is probable that the difficulty would be greatly increased if either of these processes were undertaken with the antenna atop a mast.
- (c) Provision should be made on the antenna unit to permit the convenient attachment of slings for lowering or hoisting it during installation. There are no sling eyes on the unit and no instructions are given for applying slings. It would be particularly difficult to apply slings to the unit with the protective cover in place.

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2-10-3 Wiring. An inspection of the wiring of the equipment revealed the following items.

- (a) Table 18 lists the interconnecting cable used with the equipment.
- (b) A portion of the wiring in the equipment is secured to its supports by means of string. It is recommended that the use of string for this purpose be abandoned and that clamps be provided to fasten the wires.
- (c) The antenna unit should be provided with a safety switch which should be designed in a manner that it will be possible to de-energize the drive motor at the antenna assembly.

2-10-4 Weights and Dimensions. Table 19 lists the weights and dimensions of the various units of the equipment.

2-10-5 Watertightness. A test was made to determine whether or not the Transmitter-Receiver Unit is watertight. The cover was placed on the unit and the cover securing bolts were carefully tightened. The waveguide opening was sealed. The interconnecting cables were removed from the terminal tubes and the openings of these tubes were sealed in a manner which rendered them watertight. A stream of water from a hose connected to the city's mains was then sprayed on the unit. The spray was directed successively toward each side of the unit for a total period of ten minutes. Inspection of the interior of the transmitter following application of the spray revealed that water had leaked in around the fiber gasket of one of the terminal tubes. It was concluded that this had occurred because the nut holding the inner end of the terminal tube had not been tightened sufficiently during manufacture. If steps are taken to preclude leakage around the terminal tubes, the Transmitter-Receiver Unit will be adequately watertight. The remainder of the equipment is not intended to be exposed to the weather and was, therefore, not subjected to spray.

2-11. MARKING.

An examination was made to determine whether or not all of the units were provided with suitable nameplates by which they could be identified and to determine whether or not the component parts were labeled in a manner that would facilitate servicing of the equipment and the procurement of the replacement parts. The results of this examination are discussed below.

2-11-1 Nameplates. None of the units of the equipment had nameplates. It is recommended that nameplates be provided in

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accordance with the provisions of paragraph 4-5 of Navy Specification RE 13A 554D.

2-11-2. Component Part Labels. A number of component parts are not labeled; and others are labeled in an incomplete manner. The following items were noted.

- (a) There is no label on the wave-guide butterfly-valve relay in the Transmitter Unit. A nameplate bearing all data required for reordering the relay should be attached to the relay.
- (b) Paragraph 2-7-(1) of Navy Specification RE 13A 554D requires that all essential parts must be permanently and legibly marked for identification with the manufacturer's type number, current carrying capacity, working voltage and other appropriate information. Most of this information has been omitted from the transformers, capacitors, and inductors of the equipment. This omission will hinder servicing and also the procurement of replacements. It is recommended that the contractor be required to comply with the provisions of the specification referred to above.
- (c) The thermostats S-501 in the Transmitter Unit and S-701 in the modulator are not marked with the manufacturer's name and Navy type number. This information should be provided.

2-11-3 Symbol Designations. A number of instances were noted in which the markings required by paragraph 4-5-1(d) of Navy Specification RE 13A 554D and established by section 2 of Navy Specification XA 8810A had either been omitted or incorrectly accomplished. The following items were noted.

- (a) The symbol designations for the components in the Transmitter Unit are completely omitted therefrom.
- (b) The instruction book lacks a Parts List. However, the spare parts list includes the heater resistor for the transmitter and according to this list, no "symbol designation" has been assigned to this resistor. It is recommended that a symbol be assigned.
- (c) The symbol designation, for most of the capacitors in the modulator Unit have not been marked on the

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chassis. It is recommended that such marking be provided in the interest of rapid servicing.

- (d) The fuse mounts are not marked with their symbol designation or the current and voltage ratings of the fuses to be used therein. These omissions will render servicing difficult and it is therefore recommended that such markings be provided.
- (e) Since the terminal boards on the Transmitter Unit are not labeled, the identification with their representation on the schematic diagram is difficult. In addition, the individual terminals on each board are not numbered so that servicing and installation will be retarded. It is recommended that suitable labels and numbers be provided.

2-12 INSTRUCTION BOOK.

Use of the instruction book revealed a number of items that require correction. These were as follows.

- (a) The use on the schematic diagrams of the Greek letter "small omega" to indicate ohms and of "capital omega" to indicate megohms is confusing, since there is a tendency to mistake one letter for the other. It is recommended that the use of these symbols be entirely abandoned.
- (b) The instruction book does not give a schematic diagram for Z-501, the artificial line in the Modulator Unit. This omission precludes the use of a continuity test to check the condition of the unit. The instruction book should include information to show what components are included in this artificial line, the electrical constants of each component, and the manner in which the components are interconnected.
- (c) It was found difficult to trace the wiring from one schematic diagram to the next. It is recommended that notations be placed at appropriate places on each schematic diagram to show the number of the schematic diagram upon which the continuation of the wiring is to be found.

2-13 IFF VOLTAGE.

The equipment provides the voltage for "triggering" IFF equipment. The adequacy of this voltage for its intended purpose was investigated in the following manner. The voltage obtained in the synchronizing pulse Jack of the Model SL Equipment was introduced into a Model BL-4 Equipment, the necessary

interconnection being provided by means of 15 feet of the 70 ohm flexible coaxial cable. The Model BL-4 Equipment was adjusted to pulse at 400 cps and the output of its modulator circuits was monitored by means of an oscilloscope. The following items were noted.

- (a) The synchronizing voltage provided by the Model SL Equipment operated the model BL-4 Equipment satisfactorily.
- (b) The voltage which the Model SL Equipment provided at the Model BL-4 synchronizing input terminals was measured and found to be 52.4 volts (peak). The attention of the Bureau is directed to the fact that specifications for interconnection of Radar and IFF Equipment require that this synchronizing voltage be not over 40 volts into a 70 ohm line.
- (c) The IFF control switch on the Model SL Equipment is a two position momentarily closed, toggle switch, that is, when operated it returns to the open position unless held closed. The specifications quoted above require a three position switch with "lock-off-momentary on" positions.

2-14 SUMMARY OF DEFECTS AND RECOMMENDATIONS.

The defects encountered during the tests of the Model SL Radar Transmitting Equipment are summarized below. The numerals in parenthesis refer to the paragraph of this report in which the item is discussed at greater length. The relative order of listing is not indicative of the relative importance attached to the items.

2-14-1 (2-2-1, 2-2-2). The power output of the transmitter unit varied a noticeable amount as the ambient temperature was changed. However, it is considered that the amount of this variation is not so great as to interfere seriously with the operation of the equipment.

2-14-2 (2-2-1). The internal temperature of the Transmitter-Receiver Unit was found to be excessively high when the ambient temperature was 50°C. It is probable that this high temperature will shorten the life of the components in the transmitter unit.

2-14-3 (2-2-2) The antenna scanning motor started very sluggishly at low temperatures and was very noisy. The starting characteristics under these circumstances while not entirely satisfactory are considered adequate. It is recommended that the noise be reduced for reasons of security.

2-14-4 (2-2-2) The blower motor in the Transmitter-Receiver Unit was extremely noisy when starting at low temperatures.

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Since the transmitter will be mounted outdoors, it is recommended that the amount of noise emitted by this motor be reduced.

2-14-5 (2-2-2). The heater resistors inside the Transmitter-Receiver Unit do not provide sufficient heat to maintain the interior of the transmitter at 53°C, which is the operating temperature of the thermostat provided, when the ambient temperature is -28°C. It is recommended that heaters of more adequate rating be provided.

2-14-6 (2-2-3). It was found that if ice forms on certain parts of the antenna the spinner will be locked, and the antenna drive motor will be unable to rotate it. A change in the design of the antenna will be necessary if it is desired to insure that the spinner can be rotated under icing conditions.

2-14-7 (2-3). Tests indicated that the power output of the transmitter unit is decreased when the equipment is exposed to high relative humidity. However, the source of this difficulty could not be found so that no definite recommendations for improvement are possible at this time.

2-14-8 (2-4-1a). The top of the Transmitter-Receiver Unit case vibrates excessively. It is recommended that construction of the cabinet be modified to reduce the amount of vibration noted.

2-14-9 (2-4-1b). The Type 705A tube in the transmitter unit vibrated noticeably at certain frequencies. It is recommended that steps be taken to reduce the amount of vibration.

2-14-10 (2-4-2a). The upper right hand corner of the modulator unit vibrates in a manner which imposes a strain on the framework of the modulator unit.

2-14-11 (2-4-2b). The Type 705A high voltage rectifier tubes in the modulator unit resonate when subjected to a frequency of 1250 cycles per minute. It is considered that the vibration noted is likely to damage the tubes in a short time. It is recommended that adequate protection against vibration be provided for these tubes.

2-14-12 (2-4-2c). Vibration caused the trace on the PPI oscilloscope to change its relative position with respect to the antenna bearing. The source of this difficulty was not discovered, but since such a change will cause an error in target bearing, it is recommended that the system be modified

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an adequate rating. The coating on this resistor was found to be chipped. More care should be exercised during construction to prevent this type of damage.

2-14-21 (2-9-3a). The meters in the equipment lack Navy type numbers. In order to provide interchangeability it is recommended that the contractor be required to provide the equipment with Navy type meters.

2-14-22 (2-9-3b). The error in the indications of the magnetron plate current meter M452 is greater than is permitted by Navy specifications.

2-14-23 (2-9-3c). In order to direct attention to the fact that the magnetron plate current meter has a 1 ma. movement although the meter scale is marked 25 ma. full scale, the face of the meter should be marked "Use with External Shunt." The resistor R702 which acts as a current shunt for this meter has a specified tolerance of 10%. It is recommended that a resistor having a 1% resistance tolerance be specified.

2-14-24 (2-9-4). The Instruction Book should state what the magnitude of the d-c voltage applied to the T-R tube V703 will be when the voltage is measured with instruments available to the Forces Afloat.

2-14-25 (2-9-5a). Two of the 250 volt cartridge type fuses used in the equipment are refillable and two are non-refillable. It is recommended that the Contractor be required to supply fuses of a single type. The type used should be in accordance with instructions from the Bureau of Ships.

2-14-26 (2-9-5b). Fuses have not been provided for the heater resistors in the equipment. It is recommended that suitable fuses be included in the equipment.

2-14-27 (2-9-6) The thermostat in the Transmitter-Receiver Unit is marked 40°C but operates at approximately 53°C. This discrepancy should be eliminated.

2-14-28 (2-9-7) Under certain conditions the blower motor in the Transmitter-Receiver Unit is required to operate in an ambient temperature of 76°C. The information available on this motor does not indicate that it is designed to withstand an ambient temperature of this value. The Contractor should be required to clarify this situation and, if necessary, provide a motor which will withstand operation under the stated conditions.

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conditions.

2-14-29 (2-9-7). Oil is leaking from the bearings of the blower motor in the Transmitter-Receiver Unit. Such leakage is undesirable and it is recommended that steps be taken to prevent it.

2-14-30 (2-9-9). The pulse transformer which supplies power to the plate circuit of the magnetron was found to leak oil when exposed to an atmosphere at a low pressure. It is recommended that this transformer be provided with a hermetically sealed case, or that the use of oil be abandoned.

2-14-31 (2-10-1a). The clearance around the thumb screws in the Transmitter-Receiver Unit should be increased sufficiently to prevent the wings on these thumb screws from striking the cabinet.

2-14-32 (2-10-1b). The Modulator Unit is difficult to replace in the modulator-indicator cabinet and modifications in the construction are required to reduce this difficulty.

2-14-33 (2-10-1c). The workmanship used in locating a number of tapped holes in the Modulator-Indicator Unit frame was poor. It is, therefore, difficult to replace a number of panels on this unit. The difficulty could be eliminated by providing floating nuts to accommodate the screws by which the panels are secured.

2-14-34 (2-10-1d,e). There are a number of unplated brass or copper parts in the Transmitter Unit. These should be suitably plated to prevent them from corroding.

2-14-35 (2-10-1f). It is suggested that all of the four screws which hold the magnetron be made to swivel on their mountings. This will increase the ease with which the magnetron can be removed.

2-14-36 (2-10-1g). Attention is called to the ease with which the antenna reflector can be bent. Care should be taken during installation to prevent this from occurring.

2-14-37 (2-10-1h). It was found that oil was leaking out of the antenna gear case into the compartment which holds the antenna drive motor. It is recommended that the joint between these compartments be made oil tight.

2-14-38 (2-10-1i). It is difficult to remove and even more difficult to replace the plywood antenna cover. It is understood that it has been decided not to use this cover, but in the event that it is to be used, the supporting brackets should be redesigned to permit the cover to be replaced more easily.

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2-14-39 (2-10-1j). The paint on the antenna hood chips very easily. Better paint or improved method of application is necessary.

2-14-40 (2-10-1k). Steps should be taken to prevent the Transmitter-Receiver Unit cover gasket from being dislodged.

2-14-41 (2-10-1l). It is recommended that suitable eye bolts or other type of device be provided on the Modulator-Indicator Unit to permit the use of slings for hoisting or lowering during installation.

2-14-42 (2-10-1m). The center bolts on certain of the Transmitter-Receiver Unit shock mounts were found to be rusted. It is recommended that these bolts be replaced by bolts that will be rust and corrosion resistant.

2-14-43 (2-10-1n). The micrometer handle on the wavemeter was found to be rusted. The micrometer should be modified to make it rust and corrosion resistant.

2-14-44 (2-10-2a). It is recommended that the accessibility of the blower motor in the Transmitter-Receiver Unit be improved so that its bearings can be more readily lubricated.

2-14-45 (2-10-2b). Lack of accessibility makes it difficult to remove or replace the screws which hold the cover on the antenna drive motor compartment. This lack of accessibility exists only when the plywood cover is in place, and if this cover is not to be used, no corrective action is necessary.

2-14-46 (2-10-2c). Provision should be made on the Antenna Unit to permit the convenient attachment of slings for lowering or hoisting it during installation.

2-14-47 (2-10-3b). A portion of the wiring in the equipment is secured to supports by means of string. It is recommended that clamps be provided in lieu of the string.

2-14-48 (2-10-3c). The Antenna Unit should be provided with a safety switch for use during servicing.

2-14-49 (2-10-5). Care should be exercised during manufacture to insure watertightness of the terminal tubes.

2-14-50 (2-11-1). The unit is not provided with "Model" nameplates. It is recommended that such nameplates be provided and that they be in accordance with the provisions of Navy Specifications.

2-14-51 (2-11-2). A number of the components in the equipment are not labeled in a satisfactory manner and it will therefore be difficult to replace these parts or to effect repairs. It is recommended that these parts be provided with suitable labels.

2-14-52 (2-11-3). A number of symbol designations required by Navy Specification RE 13A 554D have been omitted. These omissions will render servicing difficult. It is recommended that such markings be provided.

2-14-53 (2-12a). The use on the schematic diagrams of the Greek letter, omega, to indicate resistance is confusing. It is recommended that the use of this symbol be abandoned.

2-14-54 (2-11b). The Instruction Book does not give a schematic diagram for the artificial line (Z501) in the Modulator Unit. It is recommended that such a diagram be included in the Instruction Book.

2-14-55 (2-12c). It is recommended that notations be placed at appropriate places on each schematic diagram in the Instruction Book to show the number of the schematic diagram upon which the continuation of the wiring is to be found.

2-14-56 (2-13). Attention is called to the fact that the voltage provided by the equipment for IFF "triggering" is higher than specified. Attention is called to the use of a non-standard IFF control switch.

2-15. CONCLUSIONS.

The investigations conducted on the Model SL Radar Transmitting Equipment lead to the following conclusions.

2-15-1. No difficulty or failure occurred as a result of operating the equipment at high ambient temperatures. However, such operation resulted in an internal temperature of the transmitter unit which is considered sufficiently high to result in rapid deterioration of the component parts contained in the transmitter.

2-15-2. There is evidence that the power output of the Transmitter Unit will be reduced when the equipment is exposed to high humidity. Lack of availability of the equipment precluded the further investigation of the source of this effect.

2-15-3. The equipment sustained no damage during the vibration tests to which it was subjected. However, a large number of difficulties were noted which indicate that the equipment is

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not adequately protected against vibration. Satisfactory and trouble-free operation over a long period of time cannot be expected until these difficulties have been corrected.

2-15-4. The equipment is not adequately protected against shock.

2-15-5. A number of component parts are required to operate under conditions which will cause them to fail after operating a relatively short time.

2-15-6. A number of defects were noted which are attributable to poor workmanship or improper design. A number of modifications are needed to improve maintenance, servicing and operation.

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Table 1

Section 2

MODEL SL RADAR EQUIPMENT

Calibration of Wavemeter

<u>Wavemeter Setting</u>	<u>Wave Length (cms)</u>	<u>Frequency (Mc)</u>
918	8.65	3470
882	8.80	3413
819	9.05	3318
768	9.27	3240
683	9.62	3120
640	9.81	3057
585	10.01	2999
500*	10.36*	2895*

* This point was extrapolated from remainder of data.

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Table 2

Section 2

MODEL SL RADAR EQUIPMENT

Variation in Ambient Temperature

Time (Hours)	Amb. Temp. (°C)	Rel. Hum. (%)	Relative Power Output	Mag. Plate Current (Ma)	Freq. (Mc/s)	Input Power (Watts)	Input Current (Amps)	Transm. Internal Temp. (°C)
0800	49	13	1.00	17.5	2931.5	1490	14.6	27.1
0815	50	10	1.00	17.7	2930.5	1480	14.5	38.1
0830	"	"	1.00	17.9	2931.0	1480	14.5	52.9
0845	"	"	1.00	18.1	2931.5	1360	13.7	59.5
0900	"	"	1.00	18.1	2930.5	1240	13.0	63.4
0915	"	"	1.08	18.2	2929.0	1240	13.0	66.1
0930	"	"	1.12	18.4	2929.0	1250	13.0	69.6
0945	"	"	1.12	18.5	2929.0	1250	13.0	71.6
1000	"	"	1.08	18.5	2929.0	1235	12.9	73.2
1015	"	"	1.08	18.6	2929.0	1230	12.8	74.3
1030	"	"	1.04	18.3	2929.0	1250	13.0	75.1
1045	"	"	1.04	18.4	2929.0	1240	13.0	75.9
1100	"	"	1.04	18.5	2929.0	1240	13.0	76.3
1115	35	"	1.08	18.5	2929	1240	13.0	75.1
1130	"	"	1.08	18.4	2928.5	1240	13.0	72.4
1145	"	"	1.12	18.5	2928.5	1240	13.0	70.0
1200	"	"	1.12	18.5	2928.5	1240	13.0	68.5
1215	"	"	1.12	18.4	2928.5	1240	13.0	67.3
1230	"	"	1.08	18.3	2928.5	1240	13.0	66.5
1245	"	"	1.12	18.2	2928.5	1240	13.0	65.4
1300	20	31	1.12	18.2	2929.0	1240	13.0	62.2
1315	"	28	1.12	18.0	2928.5	1240	13.0	57.6
1330	"	23	1.15	18.0	2928.5	1370	14.0	56.4
1345	"	20	1.15	18.2	2928.5	1250	13.1	56.4
1400	"	20	1.12	18.1	2928.0	1370	13.9	56.0
1415	"	20	1.15	18.2	2928.0	1370	13.9	56.0
1430	3	--	1.15	18.0	2928.0	1370	13.9	54.0
1445	0	--	1.15	18.0	2928.5	1490	14.8	48.6
1500	0	--	1.15	18.1	2928.5	1480	14.6	43.9
1515	0	--	1.19	18.0	2929.0	1490	14.8	41.2
1530	0	--	1.19	17.9	2929.0	1480	14.8	38.8
1545	0	--	1.22	18.0	2929.0	1490	14.8	37.3
1600	0	--	1.22	18.0	2929.0	1480	14.8	36.5
1615	45	5	1.12	18.0	2929.0	1480	14.7	43.9

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Table 2 (Cont'd)

Line Volts = 115 volts; Repetition Rate 830 cps

Notes No.	Time	
1	0845	Thermostat opened and de-energized heater.
2	0900	Another thermostat opened and de-energized remaining heater.
3	1330	Thermostat closed and energized heater.
4	1345	Thermostat opening and closing intermittently.
5	1445	Thermostats in both Transmitter and Modulator- Indicator Units are both closed so that both heaters are energized.

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Table 3

Section 2

MODEL SL RADAR EQUIPMENT

Starting at a Sub-Freezing Temperature

<u>Time (Hours)</u>	<u>Amb. Temp. (°C)</u>	<u>Relative Power Output</u>	<u>Mag. Plate Current (Ma)</u>	<u>Freq. (Mc/s)</u>	<u>Input Power (Watts)</u>	<u>Input Current (Amps)</u>	<u>Transm. Internal Temp. (°C)</u>
0815	25	Equipment put into operation at 0815 hours.					
0845	25	1.00	17.5	2929	1480	14.7	42
0900	8	1.04			1480	14.7	46.6
0915	-2	1.04	17.5		1480	14.8	43.1
0930	-6	1.07			1480	14.7	38.4
0945	-11	1.08	17.5	2929	1480	14.7	33.4
1000	-14	1.08			1480	14.8	28.3
1015	-14	1.10	17.5		1490	14.9	25.6
1030	-15	1.08			1480	14.8	23.6
1045	-15	1.08	17.5	2929	1480	14.8	21.3
1100	-15	1.07			1490	14.9	19.7
1115	-15	1.07	17.5		1490	14.9	18.9
1130	-15	1.07			1480	14.8	17.8
1145	-15	1.07	17.5	2929	1480	14.8	17.8
1200	-15	1.17	17.5	2929	1490	14.9	17.8
1215	-18	1.14			1480	14.8	16.6
1230	-20	1.12			1480	14.8	15.4
1245	-21	1.14			1480	14.8	13.9
1300	-22	1.14			1490	14.9	13.1
1315	-23	1.14			1490	14.9	11.9
1330	-23	1.14	17.5	2929	1490	14.9	10.8

Power (except to heaters) was removed at 1330 hours.

1345	-24				240	2.1	6.5
1400	-24				240	2.1	2.6
1415	-25				240	2.1	-1.3
1430	-25				240	2.1	-5.2
1445	-25				240	2.1	-8.0
1500	-26				240	2.1	-9.6
1515	-27				240	2.1	-11.9
1530	-28				240	2.1	-14.2

Power was reapplied at 1545 hours.

1545	-28	0.98	16.5	2933	1500	15.5	-15.0
1600	-28	1.04	17.2	2929	1480	15.2	-8.0
1615	-5	1.00	17.2	2929	1490	14.9	-1.7

Line Voltage = 115 Volts; Repetition Rate 830 cps.

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Table 4

Section 2

MODEL SL RADAR EQUIPMENT

Variation in Relative Humidity
Starting at High Humidity

Time (Hours)	Amb. Temp. (°C)	Rel. Hum. (%)	Relative Power Output	Mag. Plate Current (Ma)	Freq. (Mc)	Input Power (Watts)	Input Current (Amps)	Transm. Internal Temp. (°C)
1000	39	38	0.70	17.5	2960	1480	14.8	50.5
1015	40	38	0.97	18.0	2960	1380	14.3	57.6
1030	40	34	1.00	17.8	2960	1380	14.3	60.7
1045	39	17	1.00	18.1	2960	1250	13.2	63.4
1100	39	17	0.97	18.2	2960	1240	13.1	64.6
1115	39	20	0.93	18.2	2960	1240	13.2	66.1
1130	41	93	0.91	18.2		1240	13.2	67.7
1145	41	97	0.89	18.3		1260	13.3	68.9
1200	40	97	0.89	18.2		1260	13.2	68.9
1215	40	97	0.85	18.2		1260	13.3	68.9
1230	41	97	0.73	18.3	2960	1240	13.2	69.3
1245	39	57	0.69	18.5		1260	13.3	69.3
1300	39	31	0.64	18.2		1260	13.3	69.7
1315	40	23	0.69	18.2		1260	13.3	70.0
1330	40	20	0.93	18.2	2960	1260	13.3	70.0

Power was switched off at 1330 hours.

1345	40	93		0		0	0	66.1
1400	40	97				0	0	63.0
1415	40	97				0	0	60.3
1430	40	97				0	0	57.2
1445	40	97				0	0	54.8
1500	40	97				0	0	53.3
1515	40	97				0	0	52.1
1530	40	97				0	0	51.3

Power was reapplied at 1545 hours.

1545	40	97	0.60	17.5	2962	1360	14.2	50.5
1600	40	97	0.69	18.0	2960	1260	13.2	57.2
1615	40	97	0.69	17.6	2960	1240	13.2	60.3

Power was switched off at 1615 and humidity and temperature were reduced. Power was reapplied at 0855 hours the following day.

0855	25	20	1.25	17.4	2967.5	1480	14.8	26.4
0900	25	20.	1.25	17.4	2961.0	1480	14.8	32.2
0915	25	20	1.25	17.4	2960.0	1460	14.6	40.8

Line Voltage = 115 Volts; Repetition Rate = 830 cps.

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Table 5

Section 2

MODEL SL RADAR EQUIPMENT

Effect of High Humidity

Time (Hours)	Amb. Temp. (°C)	Rel. Hum. (%)	Relative Power Output	Mag. Plate Current (Ma)	Freq. (Mc/s)	Input Power (Watts)	Input Current (Amps)	Transm. Internal Temp. (°C)
1000	25	20	1.00	17.5	2966	1460	14.7	32.2
1015	25	20	1.00	17.5	2961	1460	14.7	41.2
1030	40	16	1.00	17.6	2960	1460	14.7	50.1
1045	40	15	1.06	17.8	2960	1450	14.6	57.2
1100	40	15	1.04	17.8	2960	1340	14.2	60.3
1115	40	15	1.04	17.8	2960	1220	12.8	62.6
1130	40	15	1.02	17.8	2960	1220	12.8	63.0
1145	40	15	1.02	18.2	2960	1220	12.8	63.8
1200	40	74	1.02	----	----	1220	12.8	65.4
1215	40	97	1.01	----	----	1220	12.8	66.5
1230	40	97	1.01	18.2	2960	1220	12.8	66.9
1245	40	97	1.01	----	----	1220	12.8	66.9
1300	40	97	1.01	----	----	1220	12.8	66.9
1315	40	97	1.01	18.2	2960	1220	12.8	67.3
1330	40	41	1.01	----	----	1220	12.8	67.7
1345	40	26	1.01	18.1	2960	1220	12.8	68.1

Following 1345 hours a small opening was made at a cable entrance so that the outside air could enter the transmitter cabinet.

1400	40	26	1.01	18.1	2960	1220	12.8	68.5
1415	40	97	0.86	18.0	----	1220	12.8	68.1

Following 1415 the transmitter was resealed.

1430	40	97	0.75	----	----	1220	12.8	68.1
------	----	----	------	------	------	------	------	------

Following 1430 the transmitter door was opened partly.

1445	40	97	0.75	----	----	1220	12.8	68.1
1500	40	97	0.57	----	----	1220	12.8	66.1
1515	40	31	0.66	18.0	2960	1220	12.8	61.5
1530	40	23	0.89	18.0	2960	1220	12.8	61.1
1545	40	20	1.00	18.0	2960	1220	12.8	62.6

Following 1545 hours the transmitter was reclosed.

1600	40	18	1.00	18.0	2960	1220	12.8	64.2
------	----	----	------	------	------	------	------	------

Line Voltage = 115 Volts; Repetition Rate = 830 cps.

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Table 6

Section 2

MODEL SL RADAR ANTENNA

Effect of Shock

<u>Shock No.</u>	<u>Azimuth Degrees</u>	<u>Marker True or False</u>	<u>Azimuth Error (Degrees)</u>
Start	0	True	0
1	0	True	0
2	002	False	2
3	008	False	6
4	009	False	1
5	012	False	3
6	012	False	0
7	016	False	4
8	017	False	1
9	017	False	0
10	021	False	4
11	022	False	1
12	029	False	7
13	031	False	2
14	032	None	1
15	035	None	3
16	042	False	7
17	044	False	2
18	050	False	6
19	050	False	0
20	058	False	8
			<u>58</u>

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Table 7

Section 2

MODEL SL RADAR EQUIPMENT

Power Required from the Supply Line

<u>Unit(s)</u>	<u>Line Volts</u>	<u>Line Amps. Normal</u>	<u>Line Amps. Surge</u>	<u>Watts Input</u>
"Power" switch "ON"				
Modulator-Indicator energized	115	4.8	29	290
"Drive Motor" switch "ON"	115	8.1	11.5	700
High voltage switch "ON"	115	13.3	25	1280
"Power" and "Drive Motor" switches "ON"	115	8.1	36.5	700
Drive Motor only	115	2.9	5.2	
Transmitter Unit only, less high voltage	115	.65	.9	
Transmitter Unit only, with high voltage	115	1.46	9.5	
Heaters only	115	2.3	2.3	260
Power required from supply lines	1540 watts			
Note Magnetron I _p = 17.5 ma.				

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Table 8

Section 2

MODEL SL RADAR EQUIPMENT

Variation in Line Voltage

<u>Line</u>	<u>Load</u>	<u>Freq.</u>	<u>Power</u>	<u>Repetition</u>	<u>Mag</u>	<u>Mod.</u>	<u>Line</u>	<u>Watts</u>
<u>Volts</u>	<u>Volts</u>	<u>Mc/s</u>	<u>Output</u>	<u>Rate</u>	<u>I_p</u>	<u>E_p</u>	<u>Curr.</u>	<u>Input</u>
			<u>(%)</u>		<u>(ma)</u>	<u>KV</u>	<u>Amps</u>	
115	115	2937	100	825	17.5	4.0	10.2	1030
120	120	2937	109	830	18.2	4.2	10.5	1100
125	125	2936	118	830	19.8	4.4	11.0	1180
128	128	2936	118	835	20.5	4.6	11.3	1240
115	115	2937	100	825	17.4	4.0	10.1	1030
110	110	2937	93	825	16.0	3.9	9.7	960
105	105	2937	91	820	14.6	3.6	9.3	880
102	102	2937	82	815	13.7	3.3	9.0	840
115	115	2937	100	825	17.4	4.0	10.1	1040

Note: Antenna and PPI motor not energized.

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Table 9

Section 2

MODEL SL RADAR EQUIPMENT

Effect of +30% Line Voltage Surges

<u>Line Volts</u>	<u>Load Volts</u>	<u>Line Watts</u>	<u>Rel. Po</u>	<u>Mag. Ip Ma</u>
-----------------------	-----------------------	-----------------------	--------------------	-----------------------

NORMAL

115	115	1540	1.00	17.5
-----	-----	------	------	------

+30% Surge (Appr. 0.5 sec)

149.5	145	1800	1.27	Above 25
-------	-----	------	------	-------------

OPERATION: C.R. Tube out of focus. Required 3-4 seconds to recover. Magnetron current exceeded the 25 ma calibration of the current meter.

-30% Surge (Appr. 0.5 sec)

80	80	1200	0	0
----	----	------	---	---

OPERATION: Modulator output zero. C.R. Tube intensity decreased greatly. Antenna "butterfly" relay chattered but did not drop out. Operation normal when correct line voltage was restored.

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Table 10

Section 2

MODEL SL RADAR EQUIPMENT

Power Output Vs Modulator Voltage

<u>Mod. Pot. (KV)</u>	<u>Mag. Actual (Ma)</u>	<u>I_p Meter (Ma)</u>	<u>Relative Power Input (%)</u>	<u>Power Output (%)</u>
*				
3.6	13.5	13.8	67	77
3.75	14.5	15	75	84
3.9	15.5	16	84	90
4.0	16.4	17	91	97
4.2	17.2	18	100	100 Normal
4.4	18.3	19	111	100

* Obtained by variation of "Mag. current adjustment" variac through pre-set range.

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Table 11

Section 2

MODEL SL RADAR EQUIPMENT

List of Controls

<u>Cir.</u> <u>Symb.</u>	<u>Control Marking</u>	<u>Circuit</u> <u>Controlled</u>	<u>Type of Control</u>
S451	Power OFF-ON	Main line switch	DPST toggle switch
S453	Drive motor OFF-ON	Antenna drive motor	DPST toggle switch
S455	Retard antenna	Antenna drive motor	Momentary open push switch
S457	Ammeter Mag.-Conv.	Mag. or Conv. selector	DPDT toggle switch
S458	High voltage OFF-ON	Input to H.V. supply and mag. filament	SPST toggle switch
T501	Load voltage adjustment	Supply line "Variac"	Rotatable knob
T502	Mag. current adjustment	H.V. supply "Variac"	Rotatable knob
R462	Azimuth mark increase	Intensity of azimuth mark	Rotatable knob
S454	Retard indicator	Oscilloscope drive motor	Series push-to-open single circuit switch

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Table 12

Section 2

MODEL SL RADAR EQUIPMENT

List of Resistors

Cir. Symb.	Type No.	Resistance (Ohms)		Size (In.) ^a		Watts		IR Volts
		Rated	Measured	Dia.	Leng.	Rated	Meas.	
R481	None	24000	24000			0.5	.016	18
R501	CAD 63338E	250	254	9/16	1 3/8	6	10.16*	51
R502	None	500	539			0.5	0.37	307
R503	CIR 10	6000	5710	7/8	3 1/2	10	3.12	4000
R504	None	100	99.4			500	133	115
R505	None	1 Meg.	1 Meg.	7/8	3 1/2	10	1.7	1650
R506	None	1 Meg.	1 Meg.	7/8	3 1/2	10	1.7	1680
R702	None	1000	1000			2	0.32	18
None	None**	None	101			500	131	115

R501-503-505-506 Ferrule Type.

Note: *Exceeds dissipation ratings.

**Labeled "Chromaloy 607, 230V, 500W".

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Table 13

Section 2

MODEL SL RADAR EQUIPMENT

List of Capacitors

Cir. Symb.	CAP MFD	Voltage		Where Used
		Rated	Applied	
C501A	0.1	Note 1	150 AC	Mod
C501B	0.1	"	150 AC	
C502A	0.1	"	150 AC	
C502B	0.1	"	150 AC	
C503A	0.1	"	150 AC	
C503B	0.1	"	150 AC	
C504A	0.1	"	150 AC	
C504B	0.1	"	150 AC	
C505A	0.25	600	150 AC	
C505B	0.25	600	150 AC	
C506A	0.25	600	150 AC	
C506B	0.25	600	150 AC	
C507A	0.25	600	150 AC	
C507B	0.25	600	150 AC	
C508A	0.25	600	150 AC	
C508B	0.25	600	150 AC	
C509	2.0	None	2000 DC	
C510	2.0	None	2000 DC	
C511	2.0	None	4000 DC	
C512	2.0	None	4000 DC	
C701A	0.1	600		Trans.
C701B	0.1	600		
C703	0.1	600	6 AC	
C705	0.1	600	18 DC	
None	7.5	None	150 AC	Ant.
None	7.5	None	150 AC	

Note 1 - Method of installation precluded viewing markings. C501-C508 are part of supply line "Noise" filters.

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Table 14

Section 2

MODEL SL RADAR EQUIPMENT

List of Meters

<u>Circ. Sym.</u>	<u>Meter Range</u>	<u>Meter Indicates</u>	<u>Meter Dial Marking</u>
M451	0-150 Volt AC	Load Voltage	Volts AC 0-150 Weston Electrical Instrument Corp., Newark, N.J. Model 476 No. 284848.
M452	0-25 Ma	Magnetron or crystal mixer current.	Milliamperes 0-25 Weston Electrical Instrument Corp., Newark, N.J. Model 301 F.S=1 Ma No. 1736801.

Table 15

Section 2

MODEL SL RADAR EQUIPMENT

List of Thermostats

<u>Circ. Sym</u>	<u>Where Used</u>	<u>Type No.</u>	<u>Contacts Normally</u>	<u>Temp. Rating</u>	<u>Voltage Rating</u>	<u>Size (In.)</u>	
						<u>Dia.</u>	<u>Length</u>
S501	Modulator	12997	Closed	40°C	115	19/32	3 1/8
S701	Transmitter	12997	Closed	40°C	115	19/32	3 1/8

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Table 16

Section 2

MODEL SL RADAR EQUIPMENT

List of Vacuum Tube Potentials

<u>Tube Circ. Sym.</u>	<u>Type Tube</u>	<u>E_p V</u>	<u>I_p Ma</u>	<u>E_f V</u>	<u>Where Used</u>	<u>Note No.</u>
V501	705A		85	5.05	H.V. Rectifier	1
V502	705A		85	5.00	H.V. Rectifier	1
V701	705A	Pulse			Pulse "swamping"	
V702	706Y	Pulse			Mag. oscillator	
V703	721A	-340			T.R. Box	3

Load Voltage = 115 AC

- Note 1 - Magnetron current set at 17.5 ma.
 2 - When H.V. switch is "On" the magnetron filament voltage is automatically reduced to 2.55 volts.
 3 - With H.V. supply "Off" E_p = -410 volts.
 Voltage specified in Instruction Book is 1000 volts.

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Table 17

Section 2

MODEL SL RADAR EQUIPMENT

Cir. Symb. #	Fuse Mount Marking			Size Inch		Rating on Fuse		Operating Conditions			Fuse Circuit
	Cir Symb.	Amps	Volt	Dia.	Leng.	Amp.	Volt	Volt	Amps Surge	Nor.	
F451	N	None	None	9/16	2	30	250	115	36.5	13.3	Main line
F452	N	"	"	9/16	2	30	250	115	36.5	13.3	Main line
None	R	"	"	9/16	2	10	250	115	5.2	2.9	Antenna motor
None	R	"	"	9/16	2	10	250	115	5.2	2.9	Antenna motor
F455	N	"	"	1/4	1	3/8	250	110	0.035	0.035	Output V406
F456	N	"	"	1/4	1	3/8	250	450	0.19	0.20	Indicator

Note 1: F455 is on input to I.F. amplifier panel.

2: F456 is in Indicator Circuit.

#: N in this column indicates non-refillable type fuse.
R indicates refillable type fuse.

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Table 18

Section 2

MODEL SL RADAR EQUIPMENT

List of Cables

Cable No.	Navy Type	Comm. Type	No Cond.	Active Cond.	From Unit	To Unit	Use
1	DHFA3		3	2	Ind.	Ant.	Power
2	DHFA3		3	2	Ind.	Ant.	Az. marker
3		D163015	1	1	Mod.	Trans.	H.V. pulse
4		KS8525	1	1	Trans.	Ind.	Cryst. mixer current.
5		KS8525	1	1	Trans.	Ind.	I.F. Sig.
6	MHFA7		7	5	Ind.	Trans.	Power
7	MHFA7		7	6	Ind.	Trans.	Converter
8							
9							
10	DHFA3		3	2	Line	Trans. Htr.	Heater pow.
11	MHFA7		7	5	Comp. Rptr.	Ind.	True Bearing
12	DHFA4		4	2	Line	Ind.	Main pow.
13	DHFA3		3	2	Line	Mod. Htr.	Heater pow.
14	DHFA3		3	2	Ind.		Warning circuit
15	DHFA3		3	2	Ind.	I.F.F. Trans.	I.F.F. control
16		KS8525	1	1	Ind.	I.F.F. Trans.	I.F.F. sync.
17	THFA3		3	3	Ind.	I.F.F. Revr.	I.F.F. Revr. gain
18		KS8525	1	1	I.F.F. Revr.	Ind.	I.F.F. video

Table 19

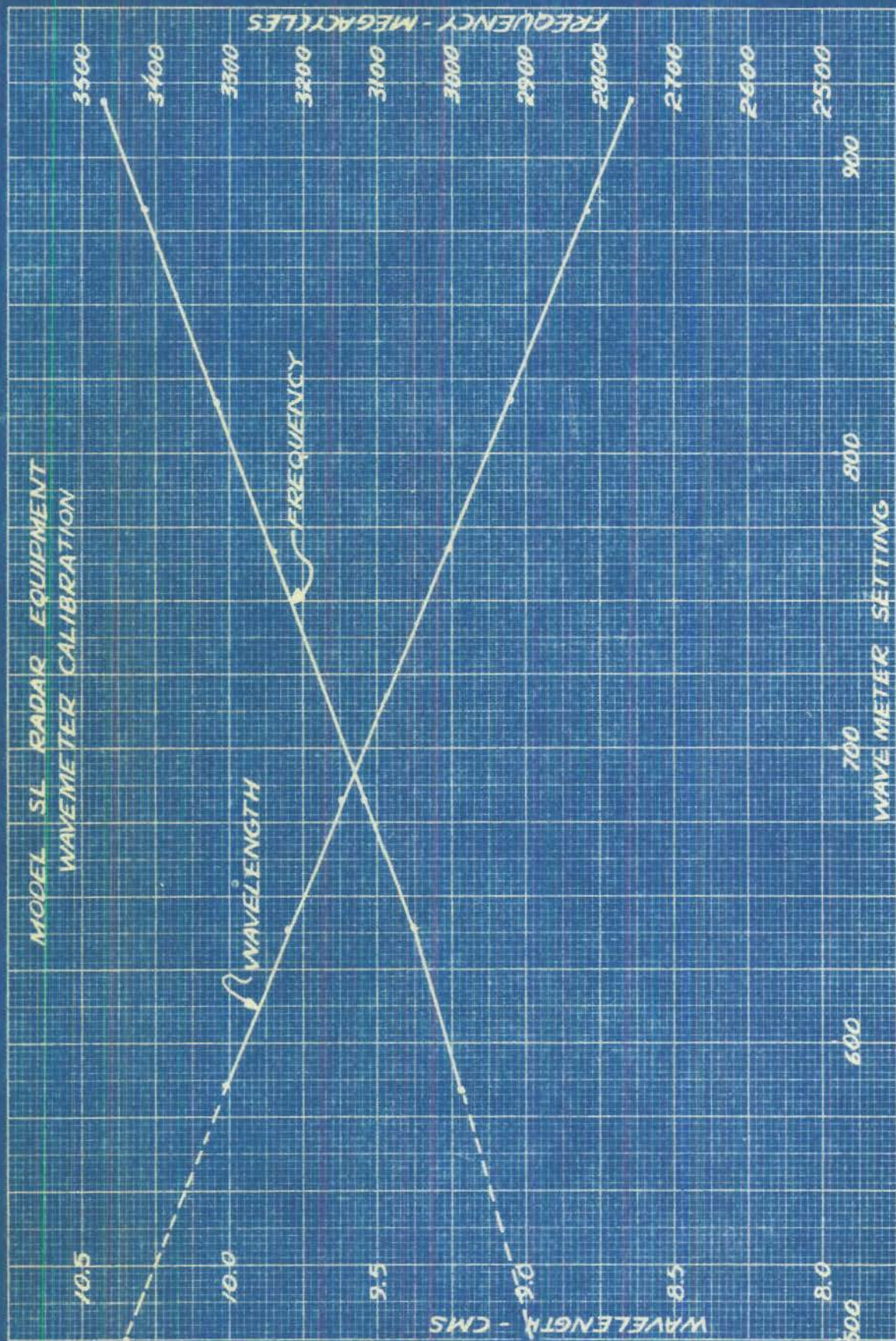
Section 2

MODEL SL RADAR EQUIPMENT

List of Weights and Dimensions

Unit	Dimensions in Inches			Weight Pounds
	Height	Width	Depth	
Modulator-Indicator	53 3/4	34 1/2	18 1/4	713
Transmitter	23 1/2	23	24 1/4	300
Antenna with Hood	48 3/4	50	50	376

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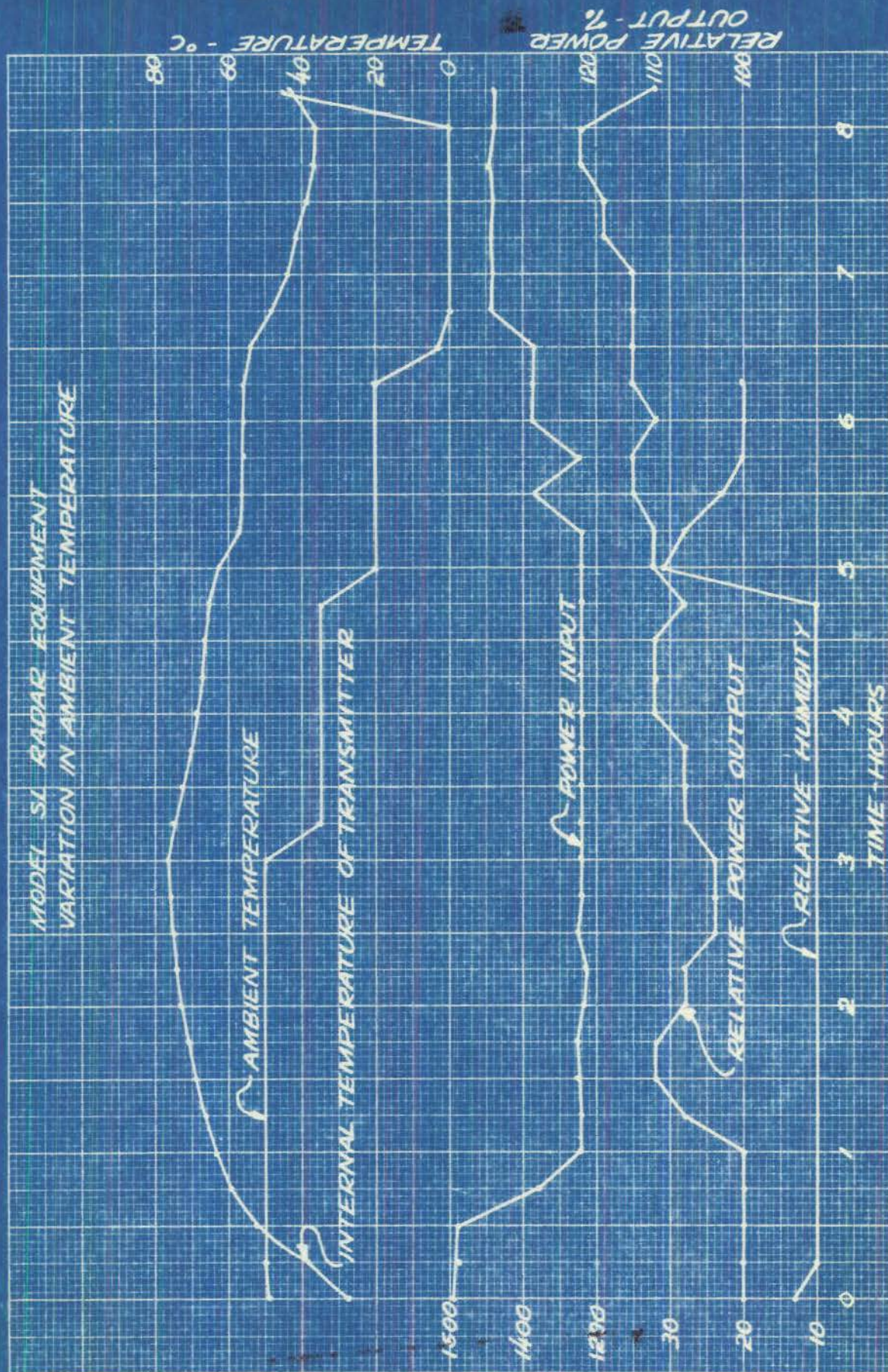


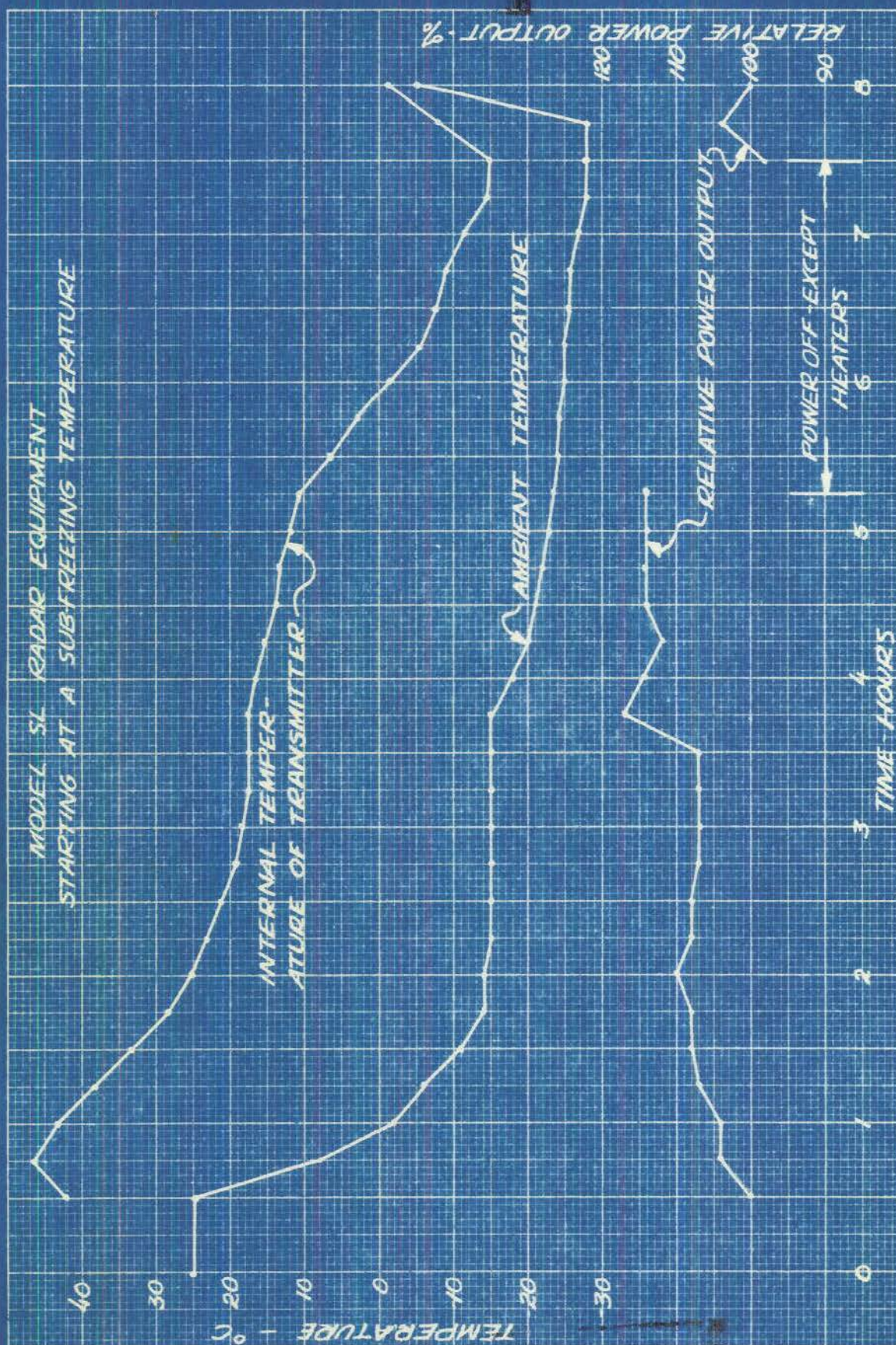
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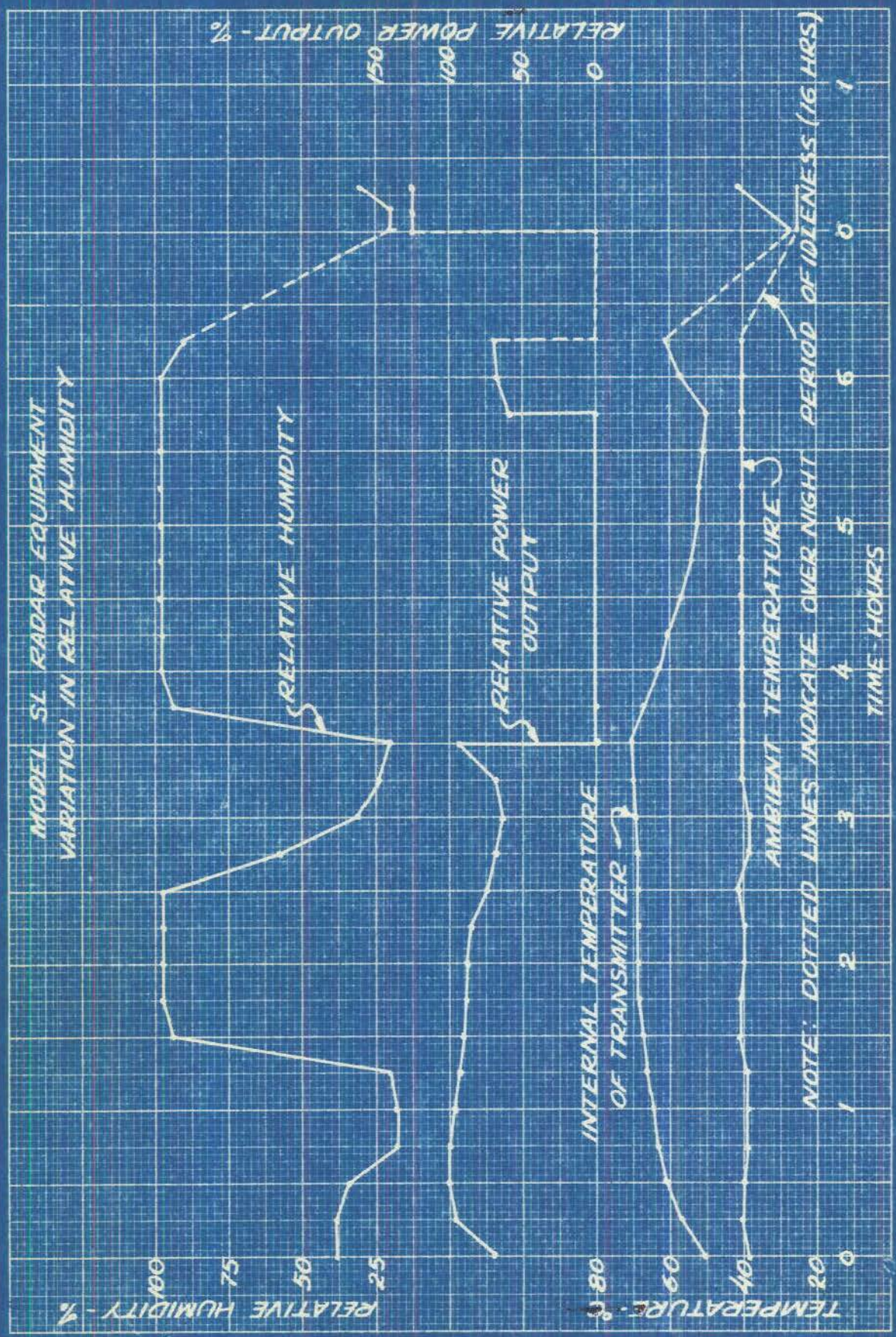


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2. SES 2. PLATE
POWER INPUT
REL. HUM. %

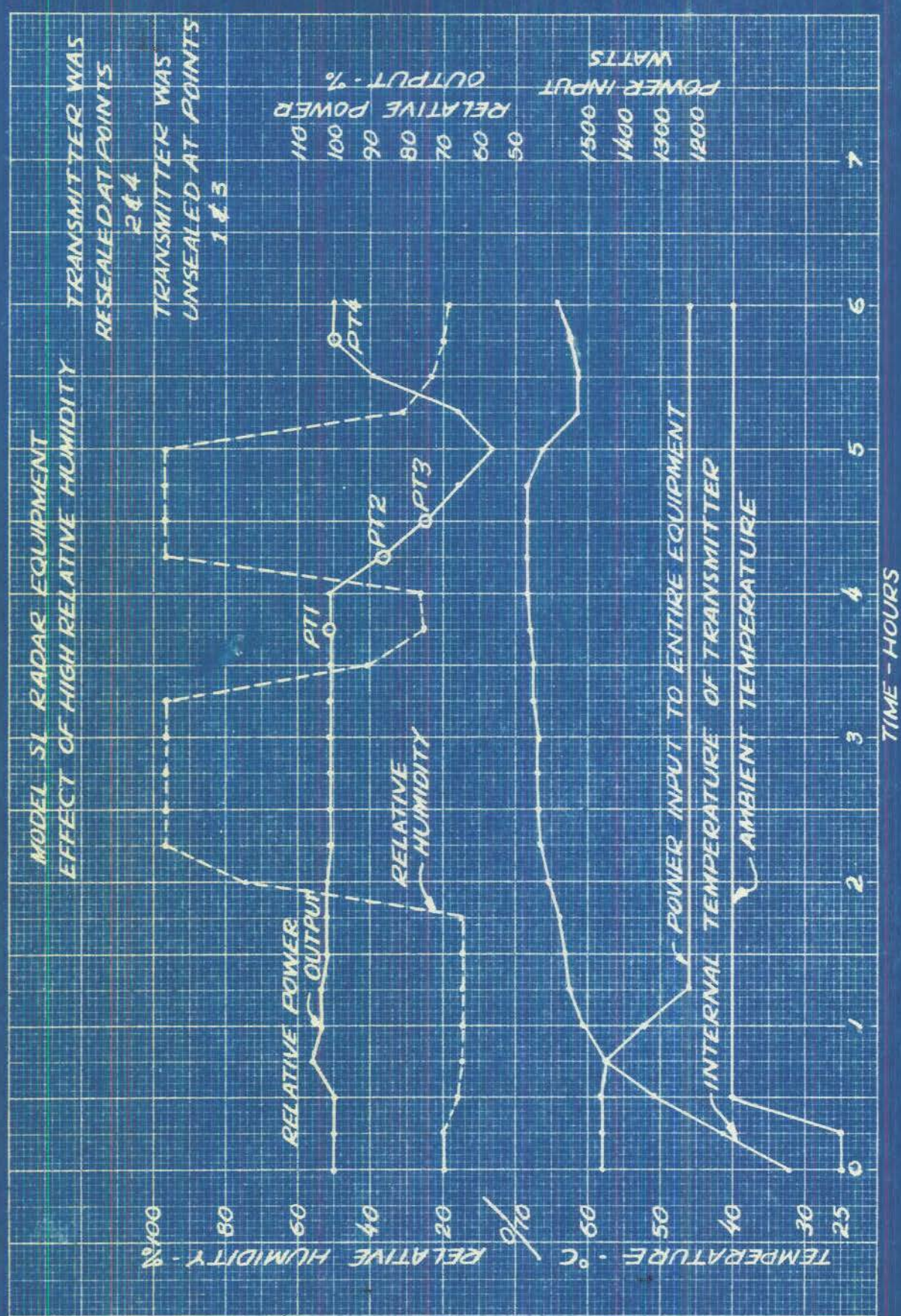






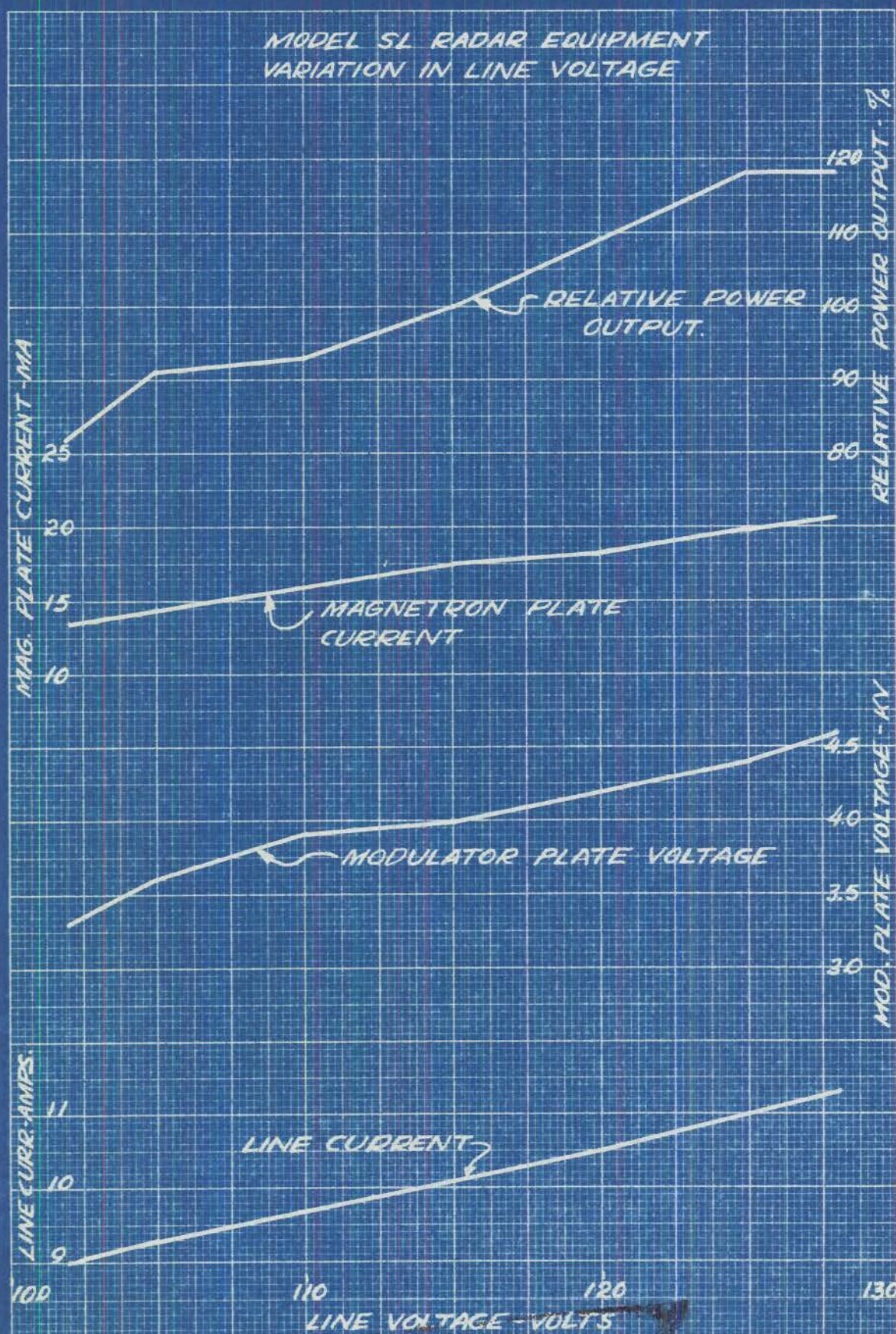
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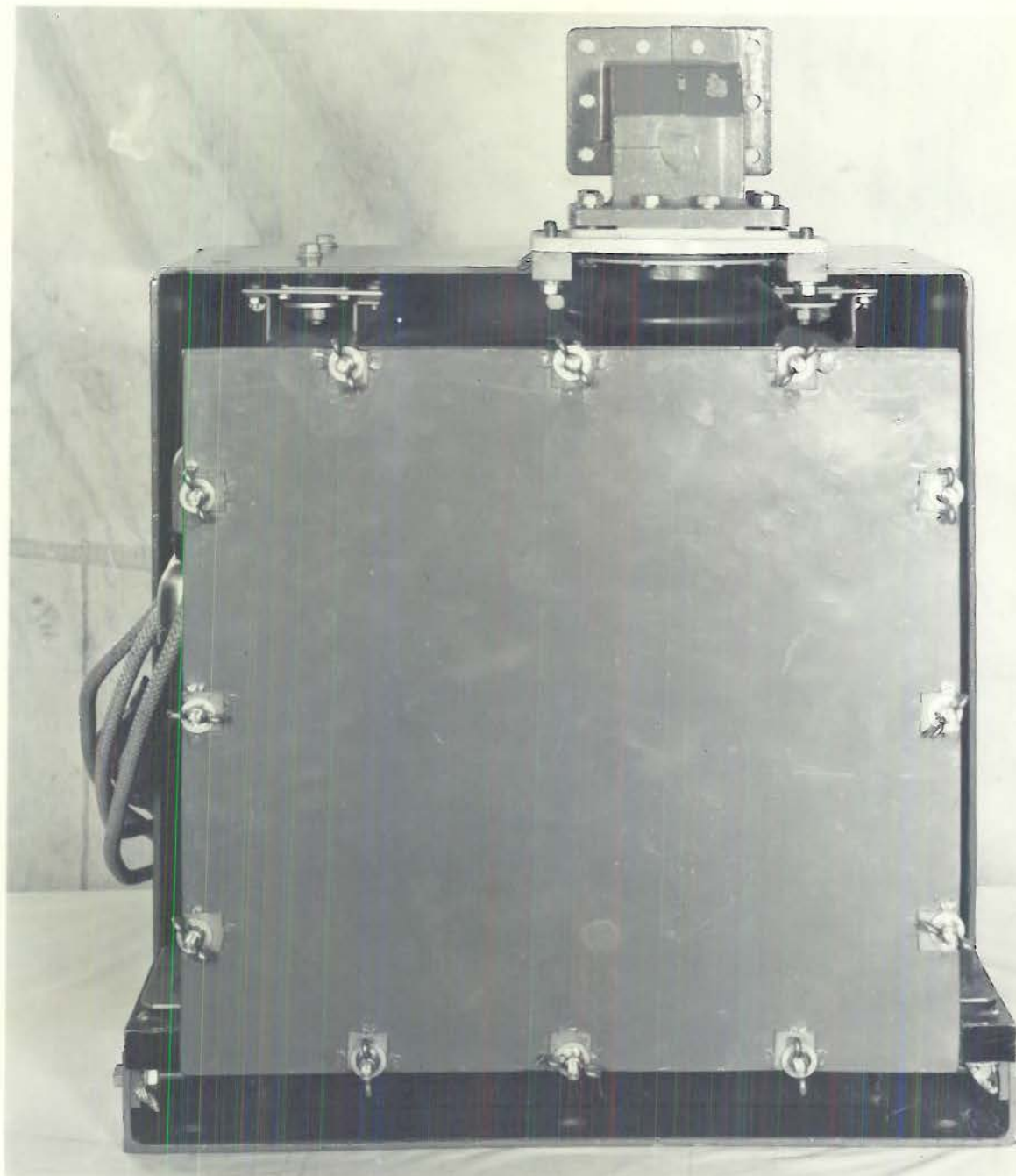
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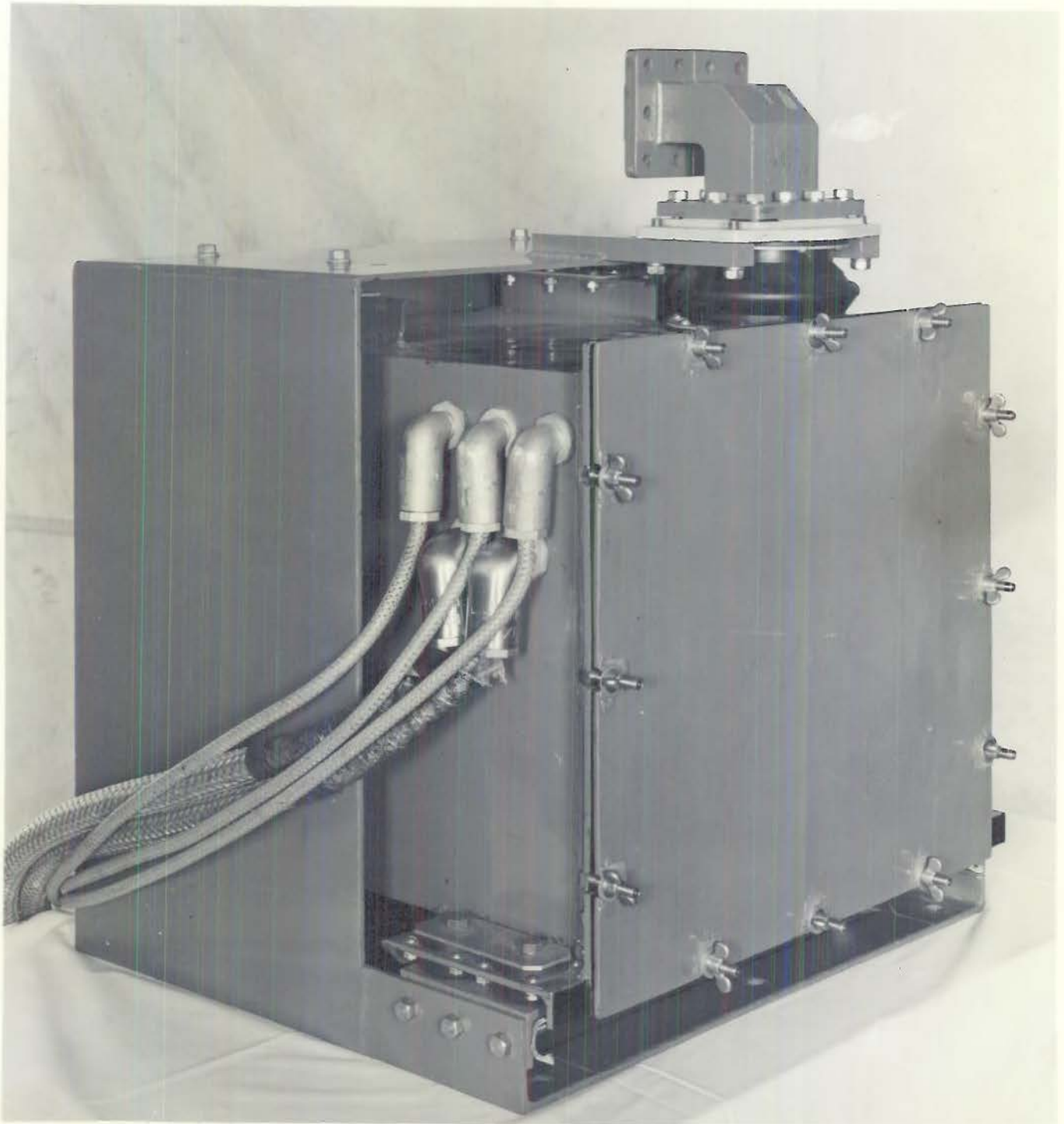


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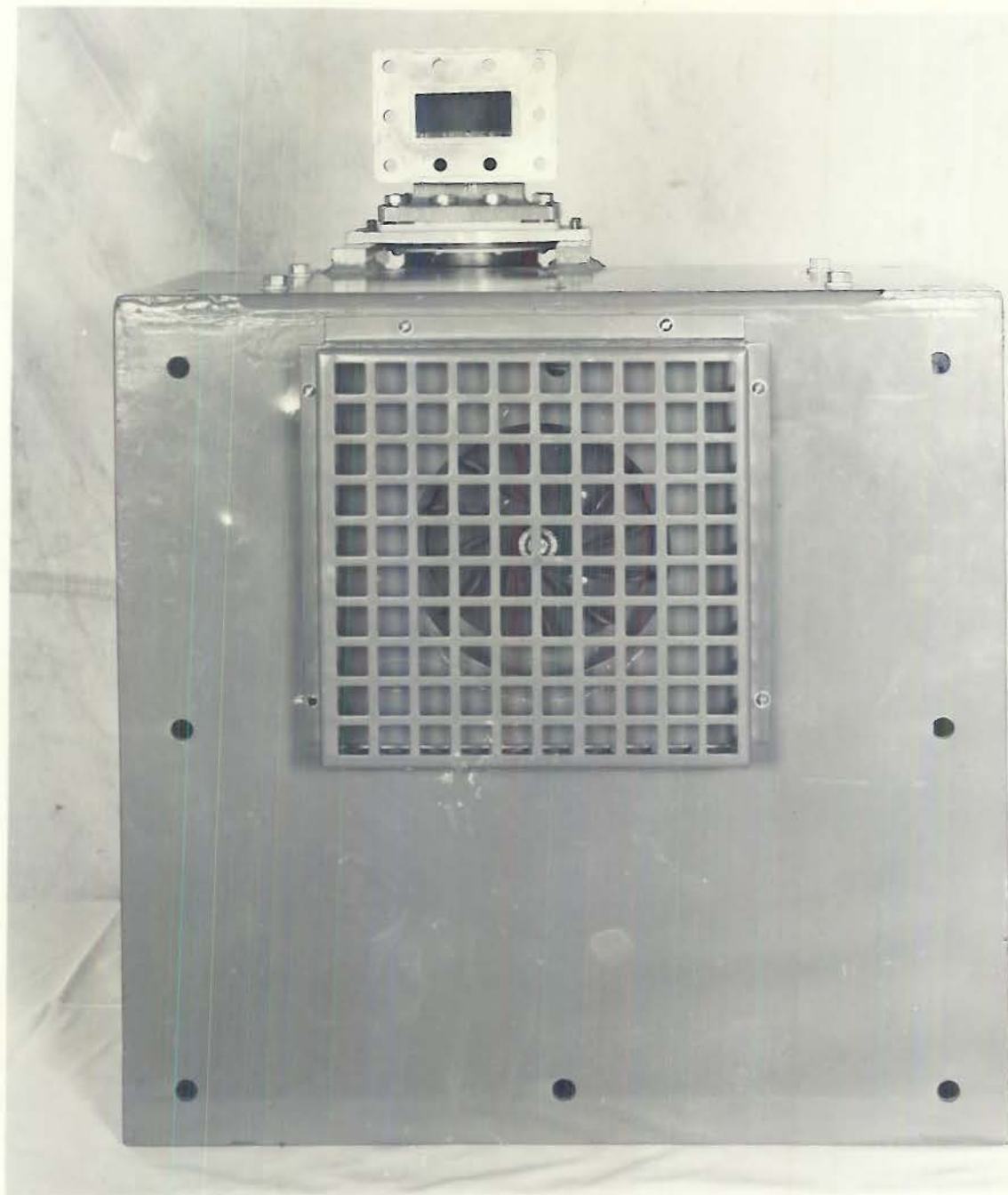


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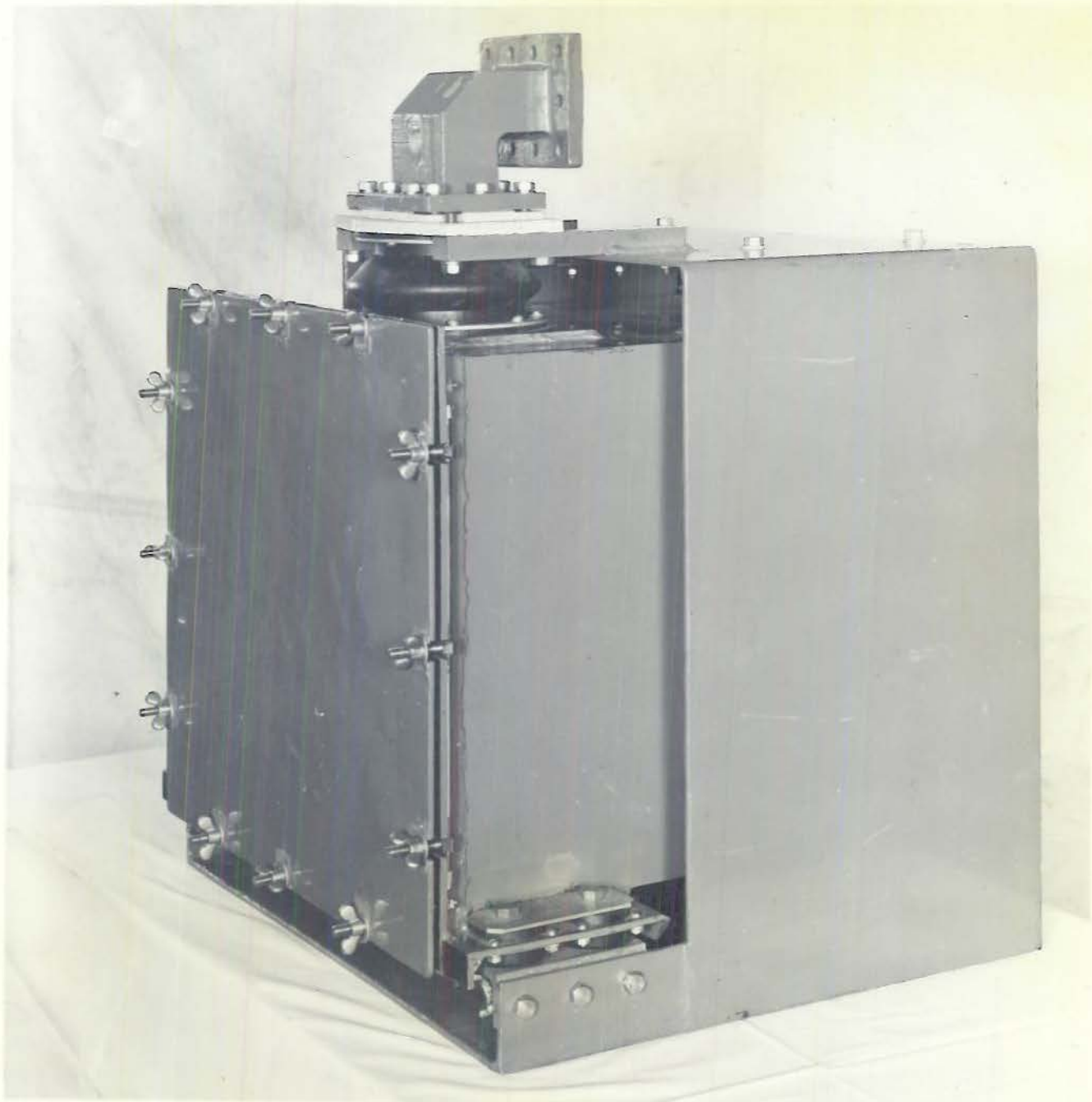


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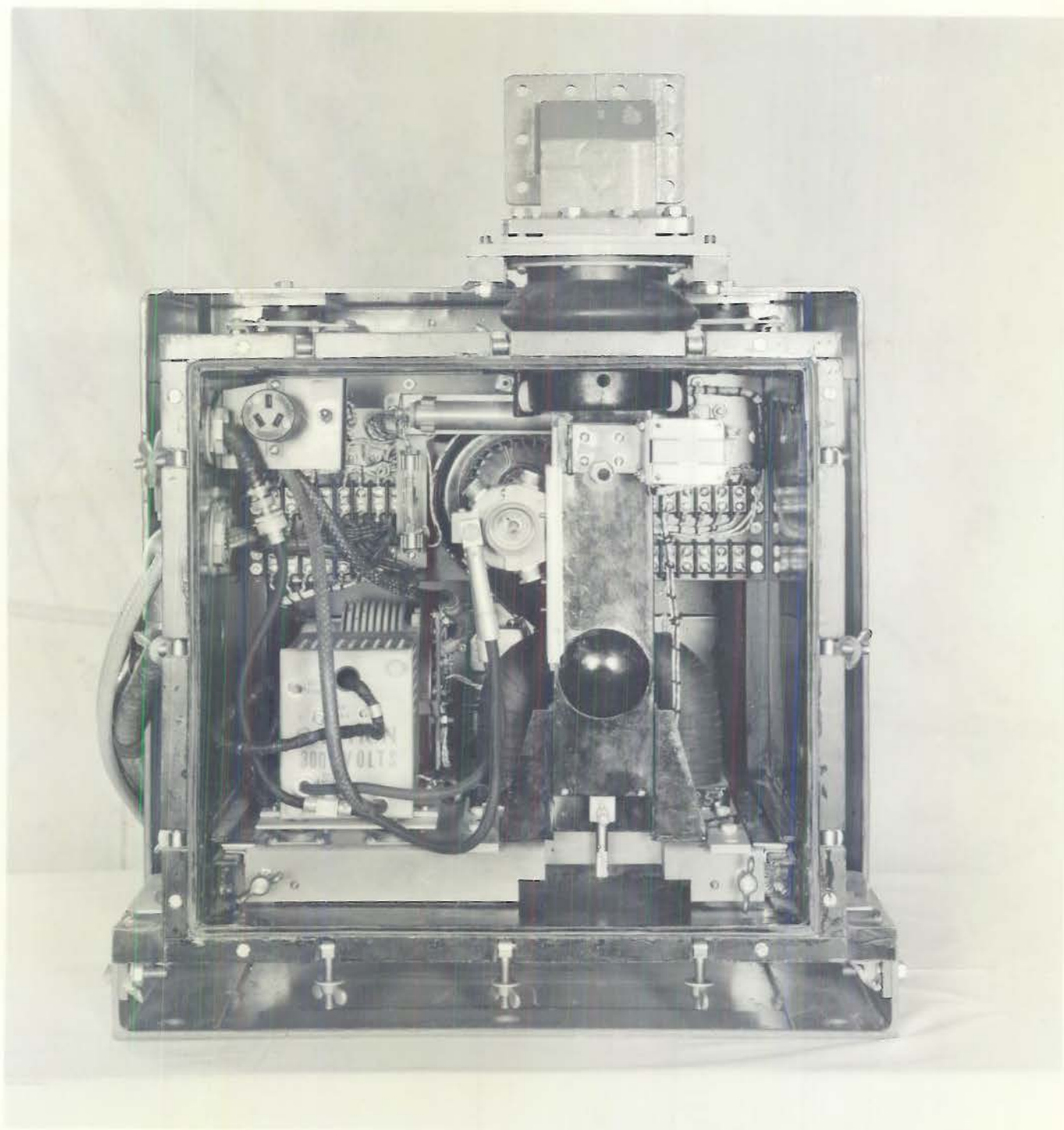


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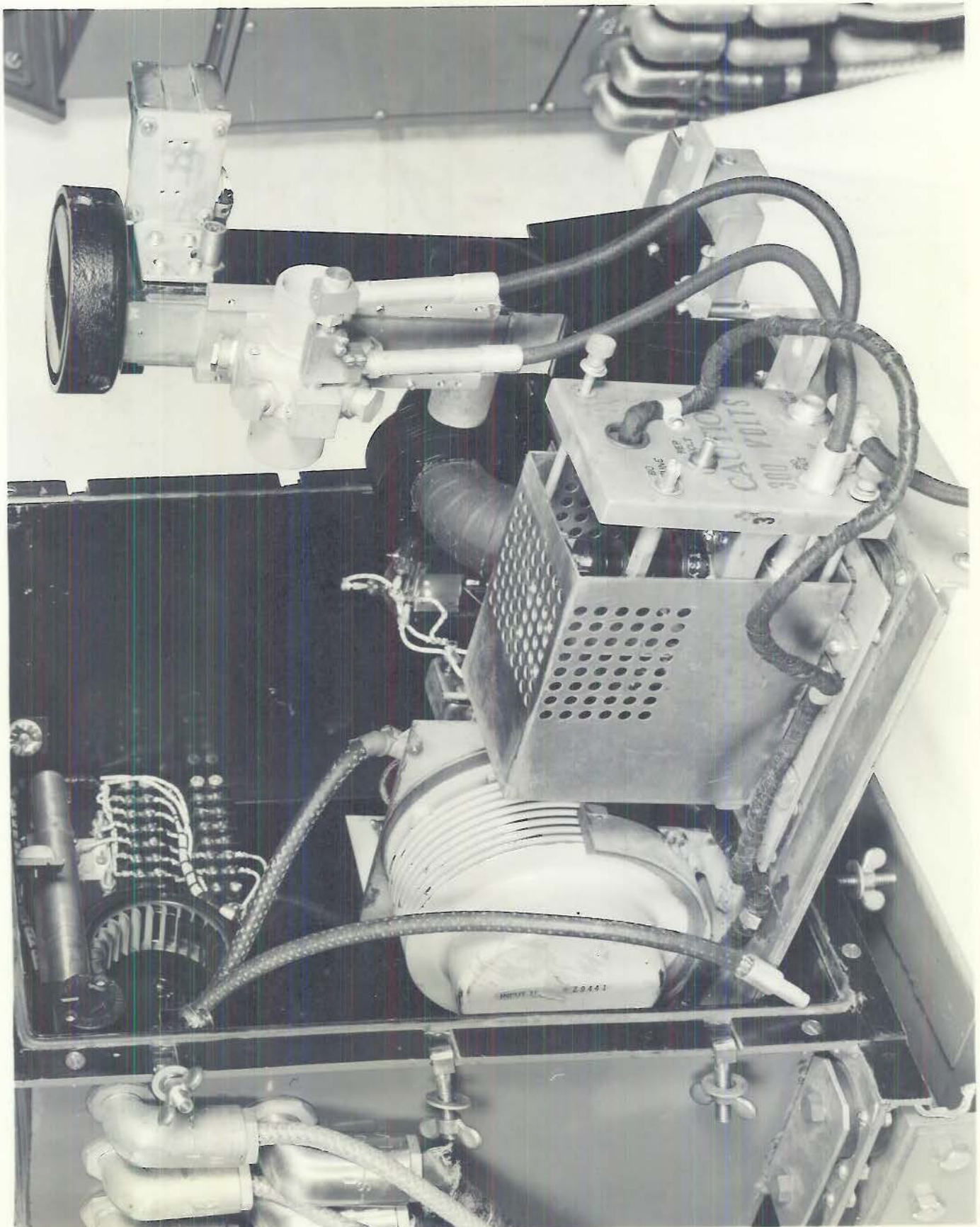


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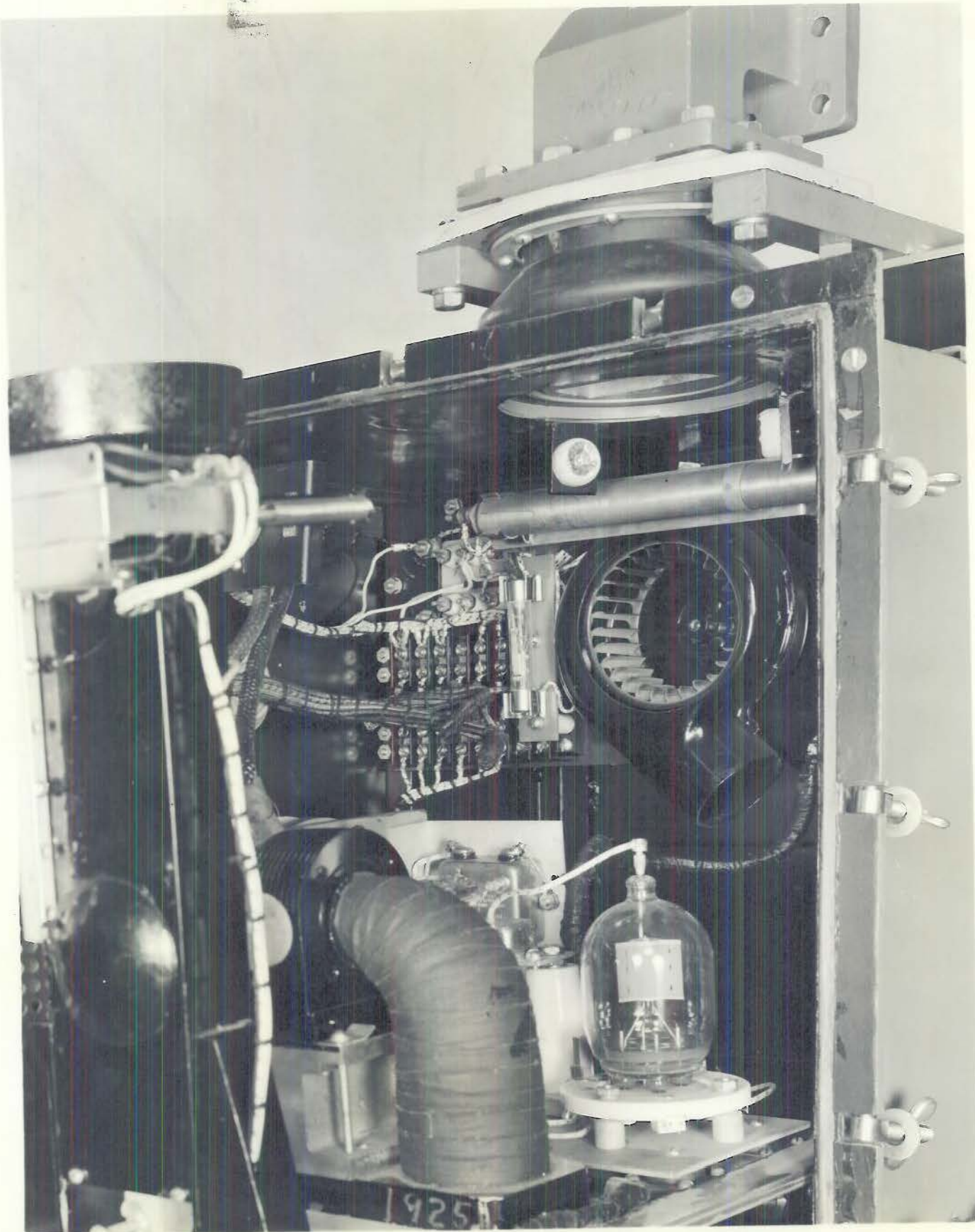


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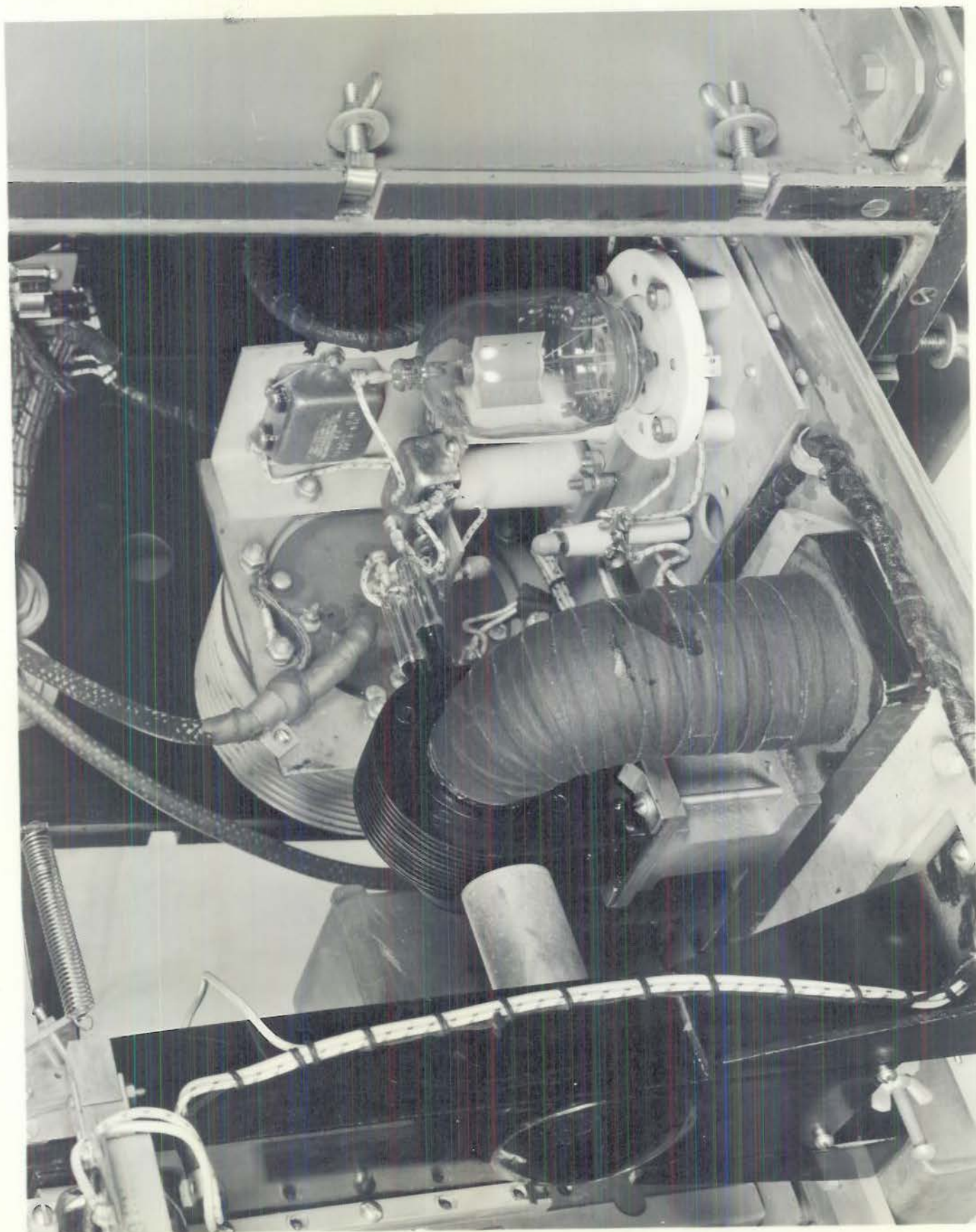


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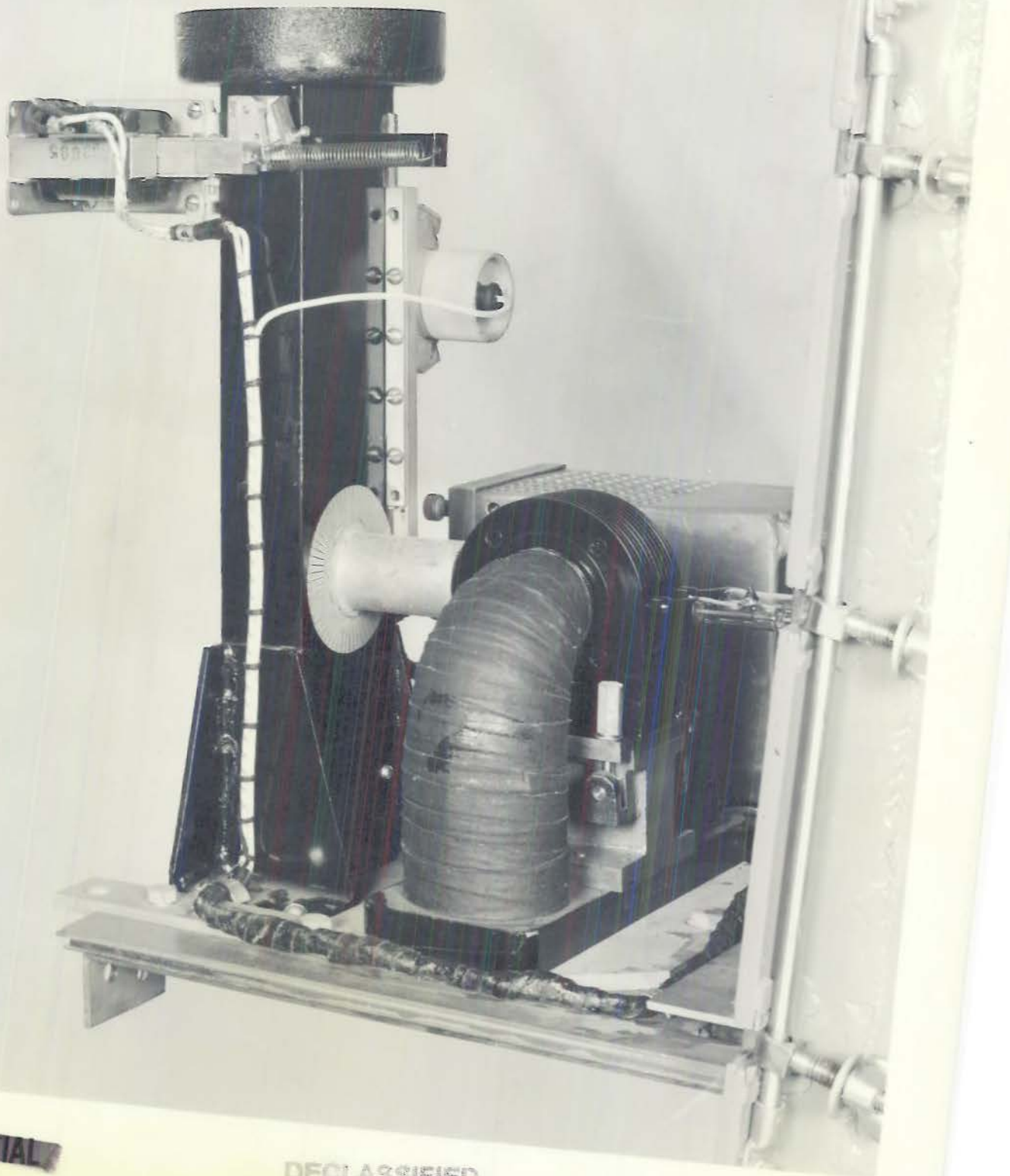


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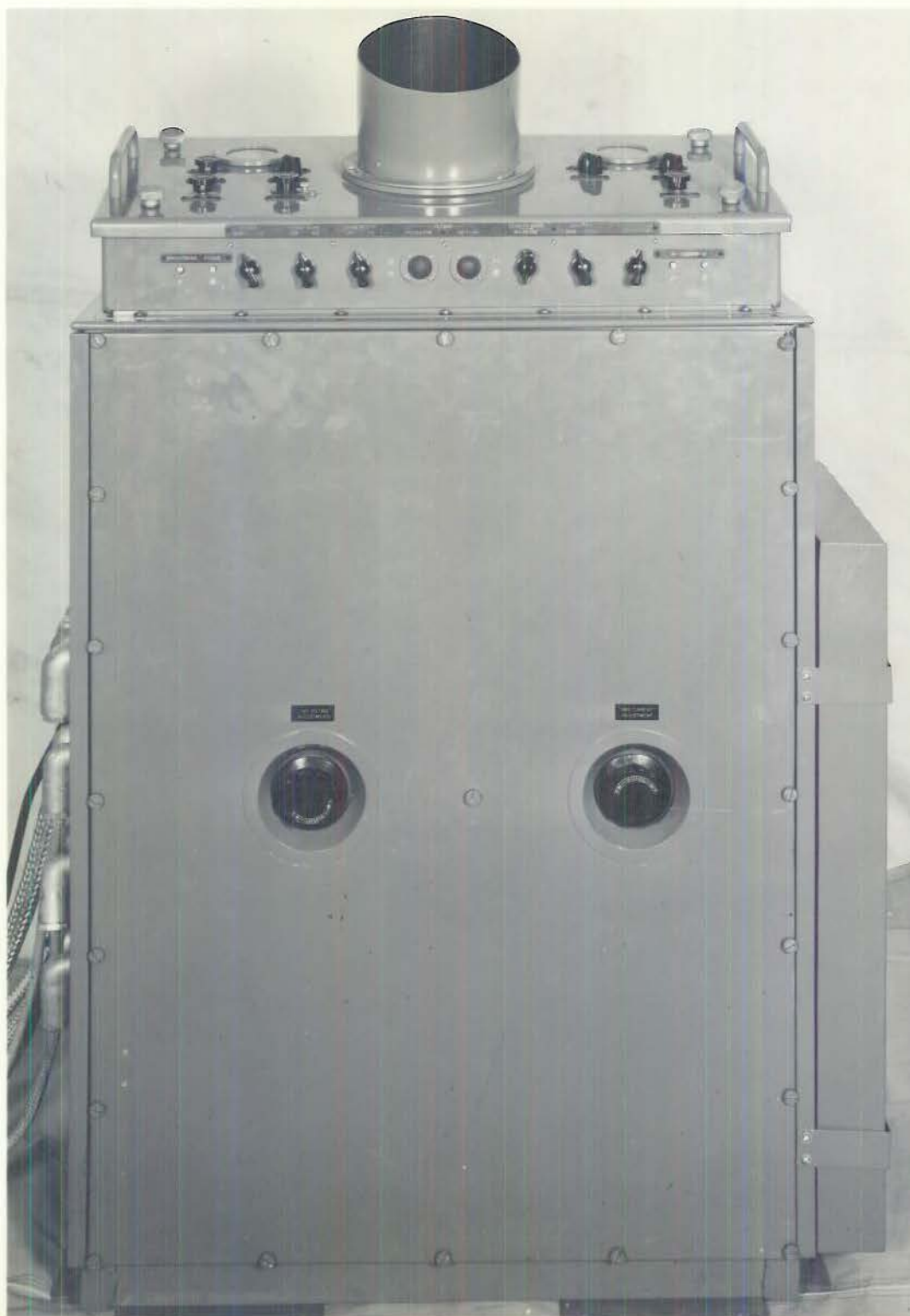


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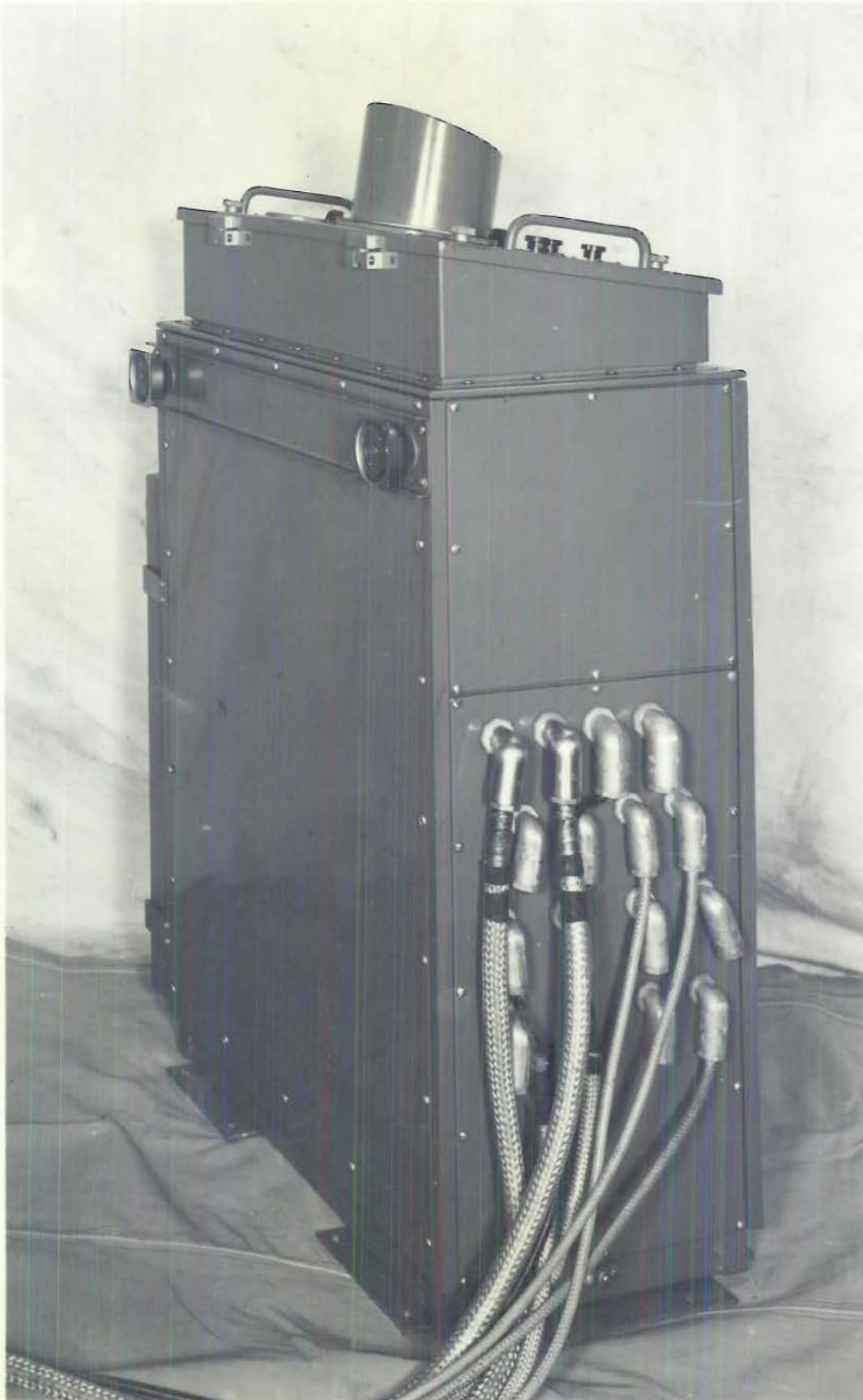


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PLATE 17 SEC. 2

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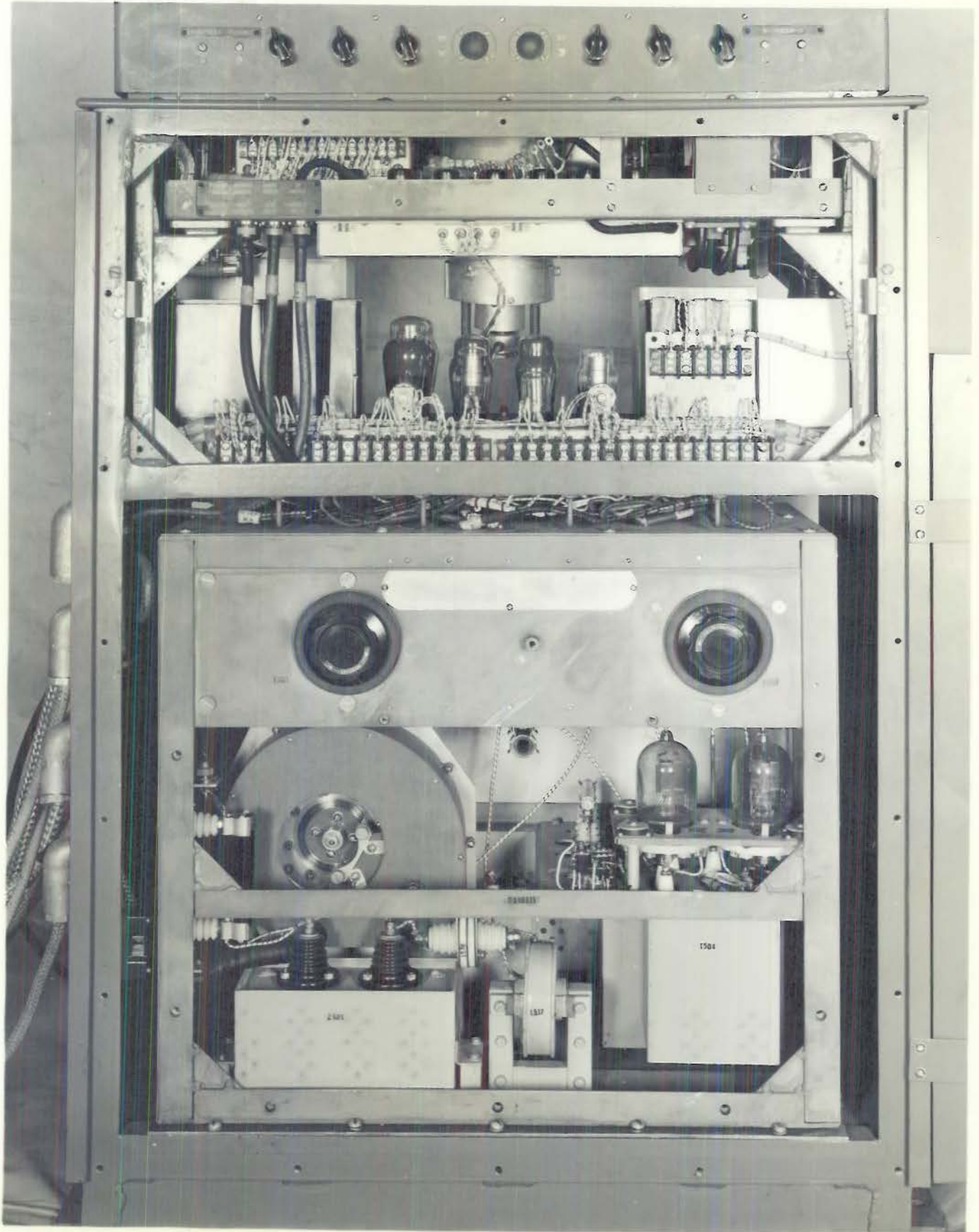


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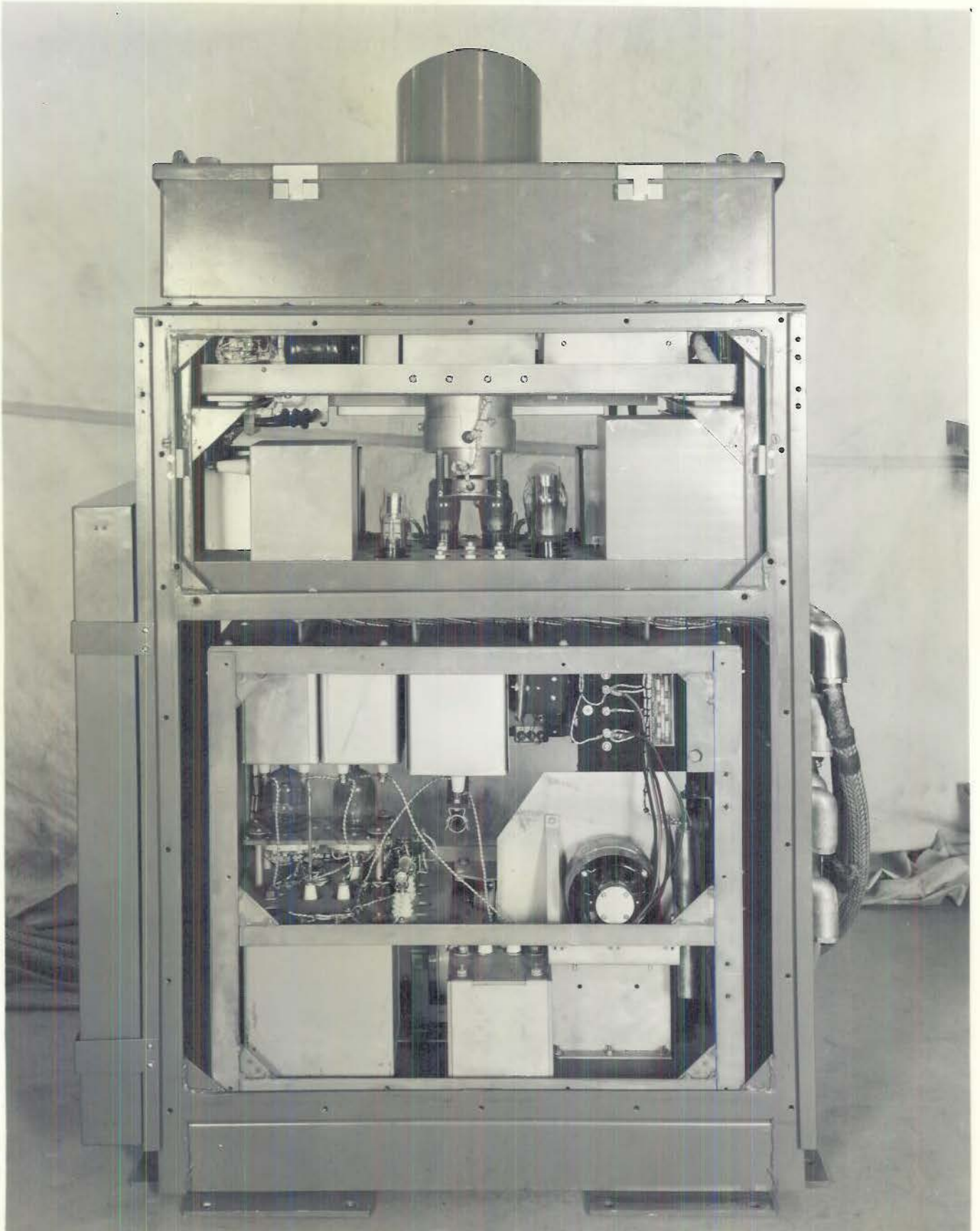


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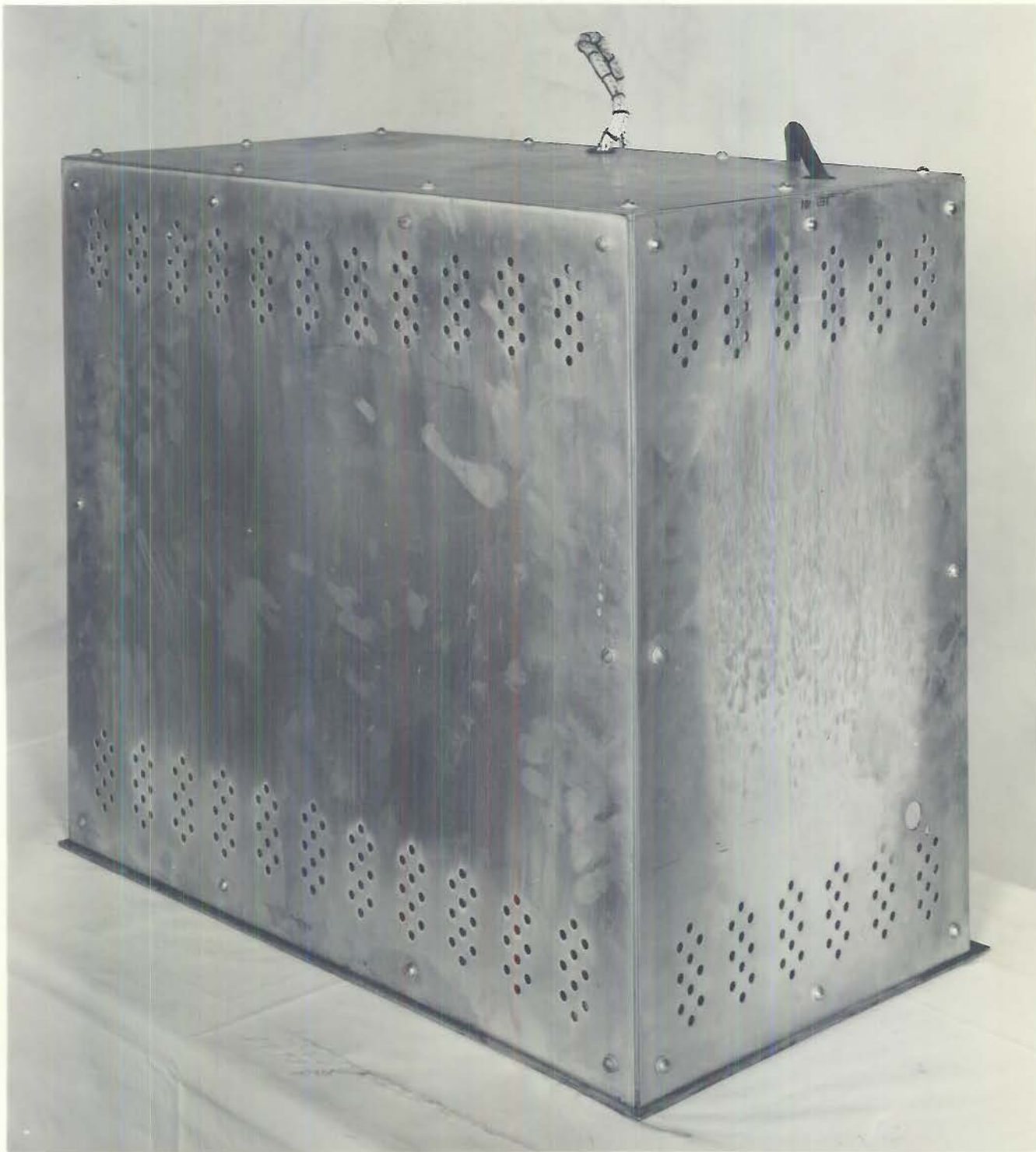


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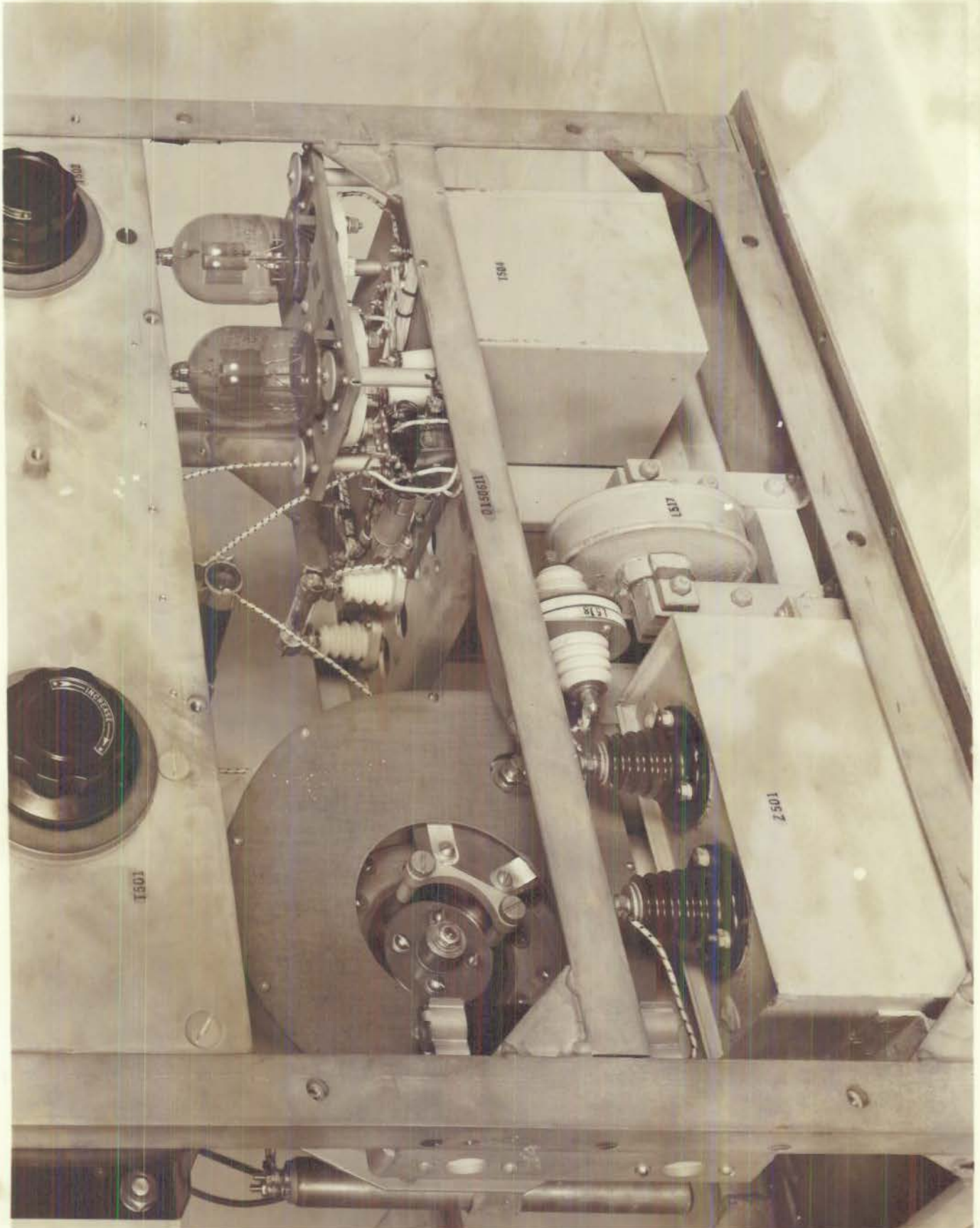


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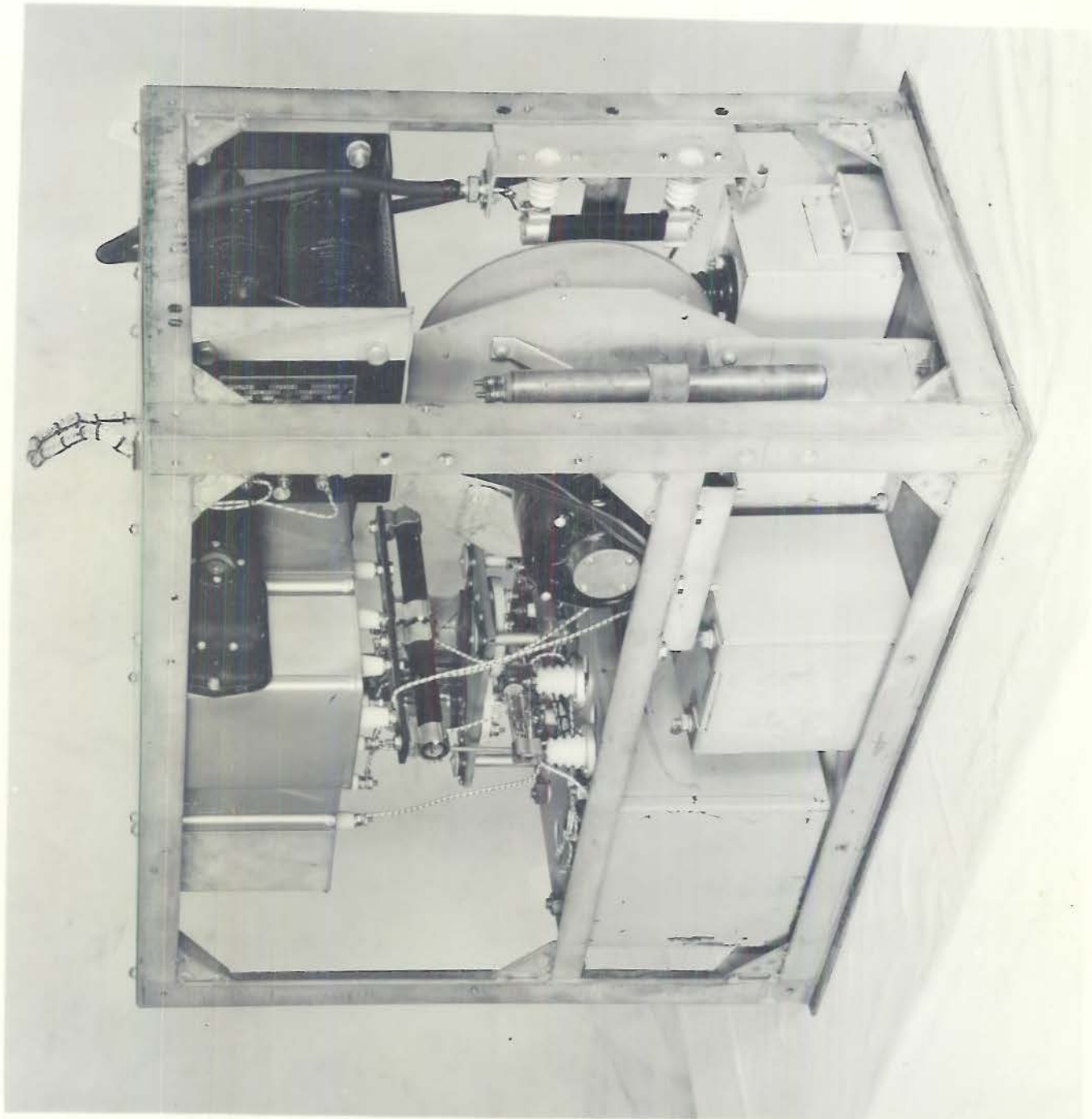


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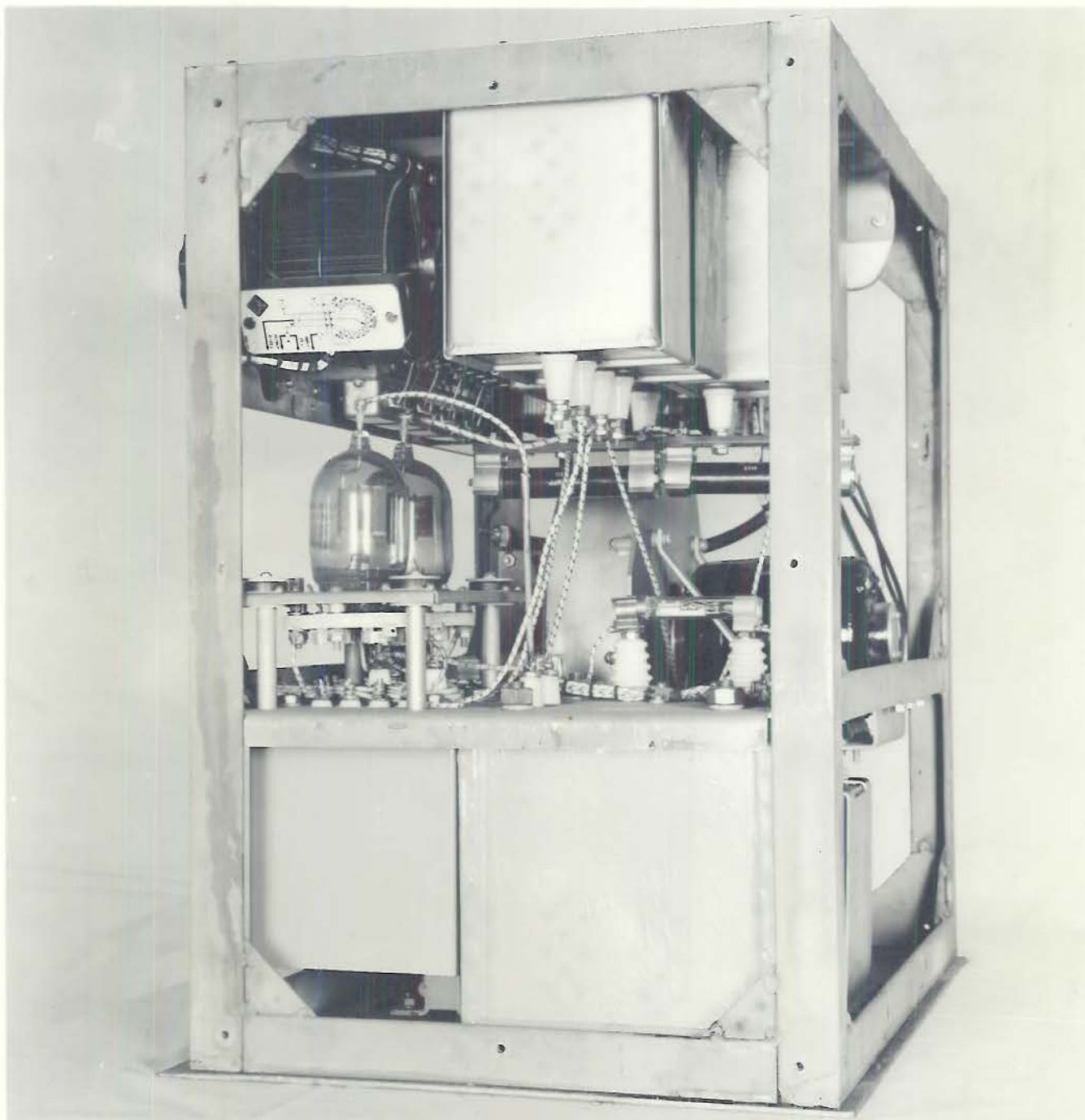


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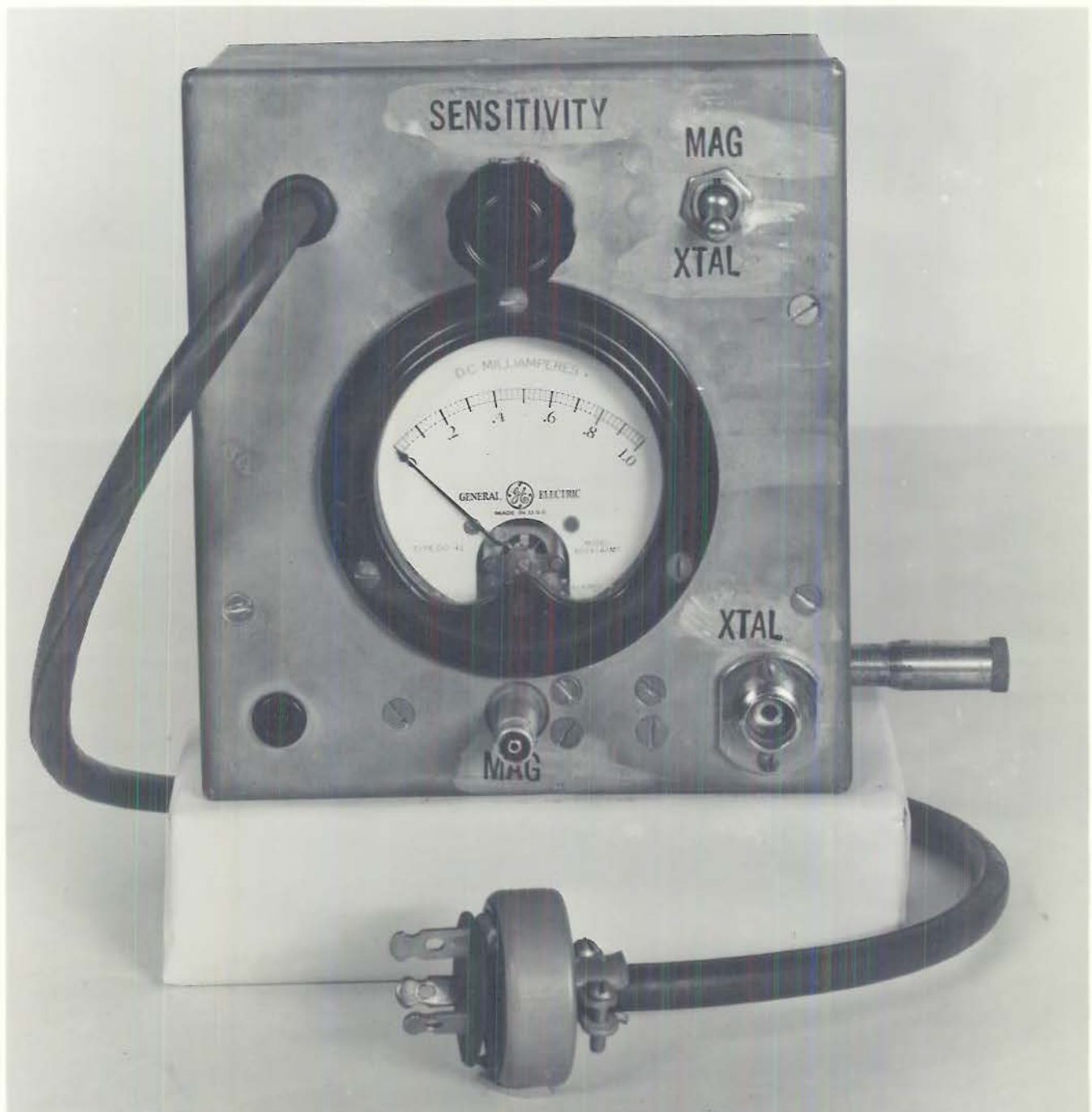


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PLATE 26 SEC.2

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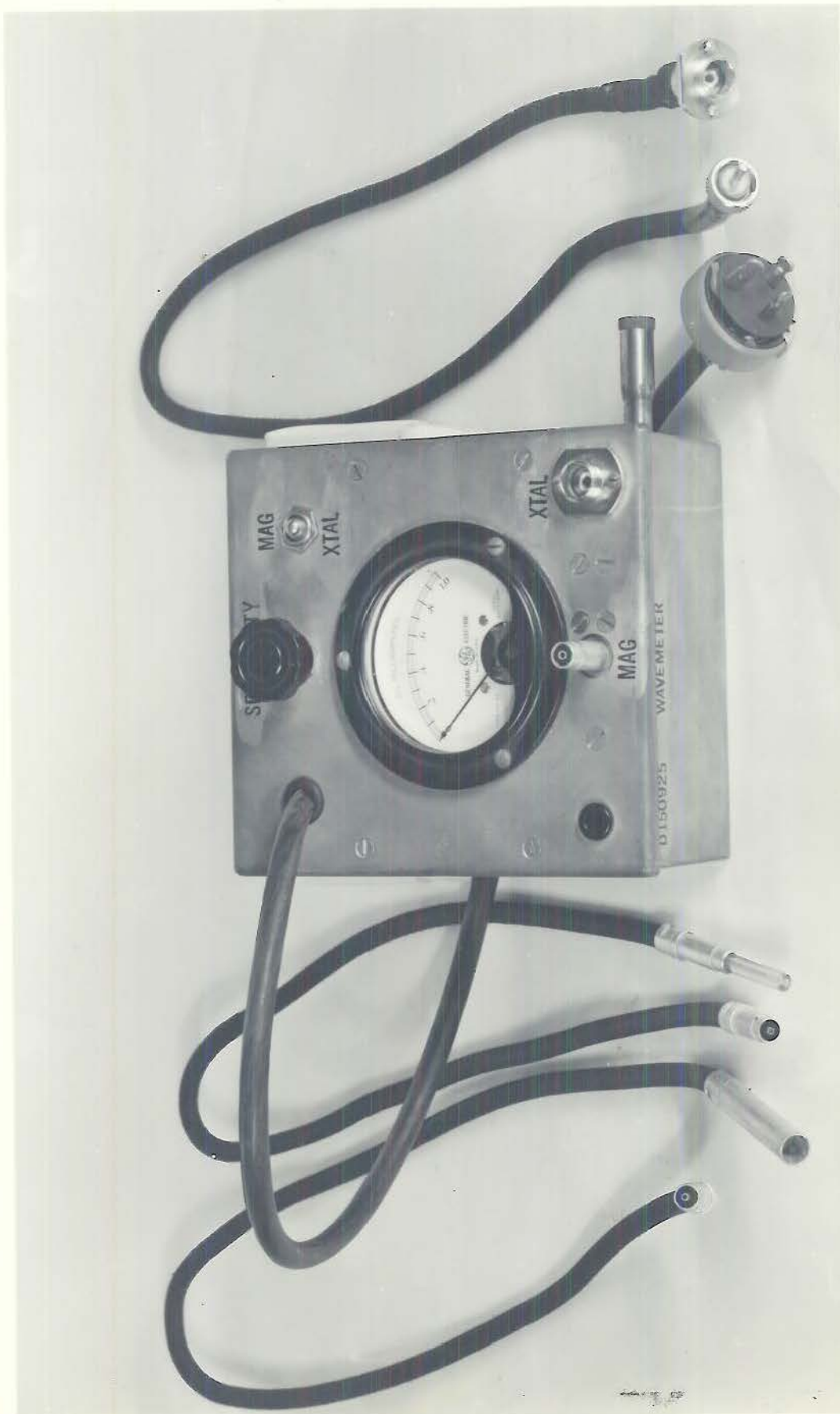


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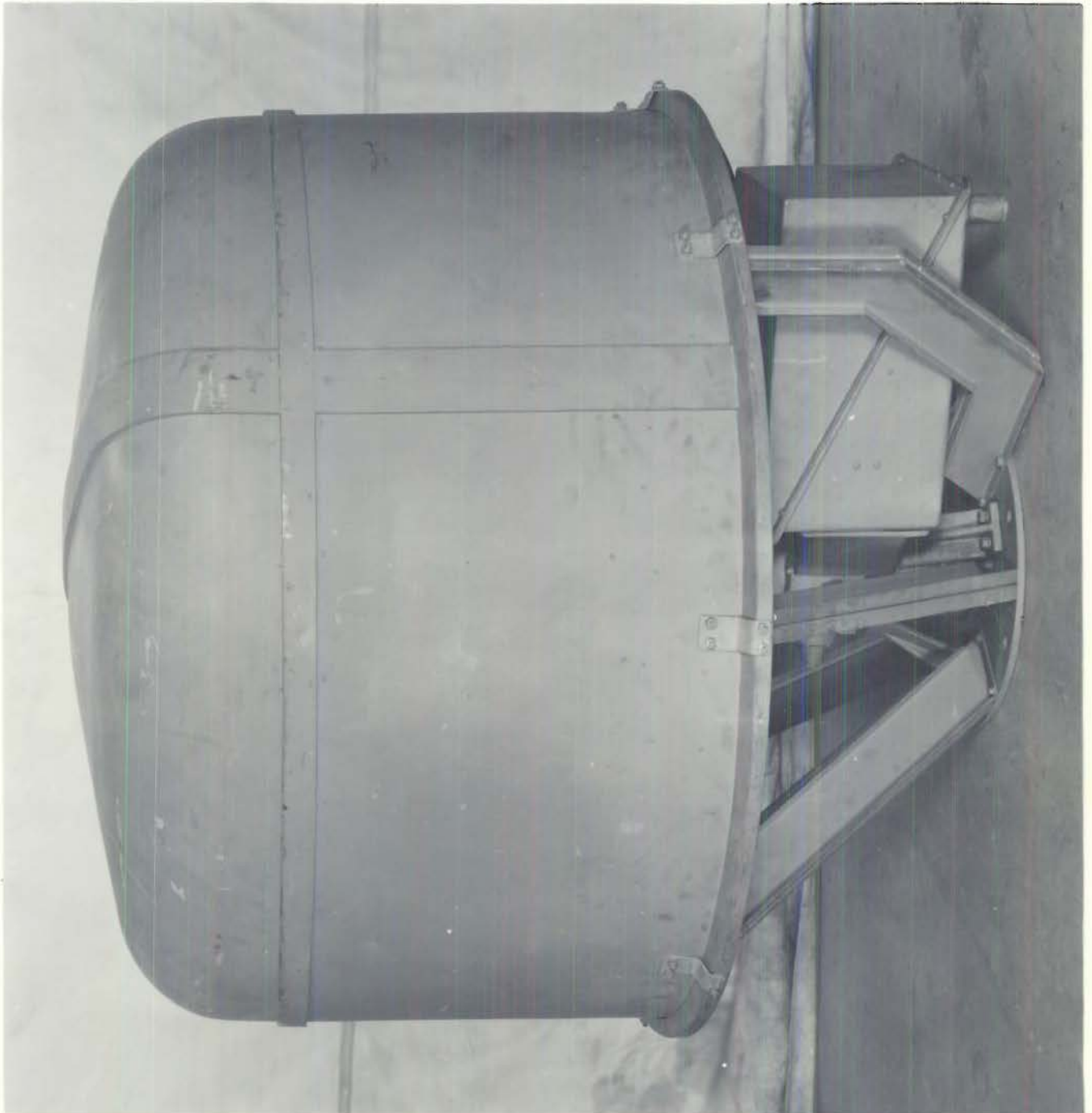


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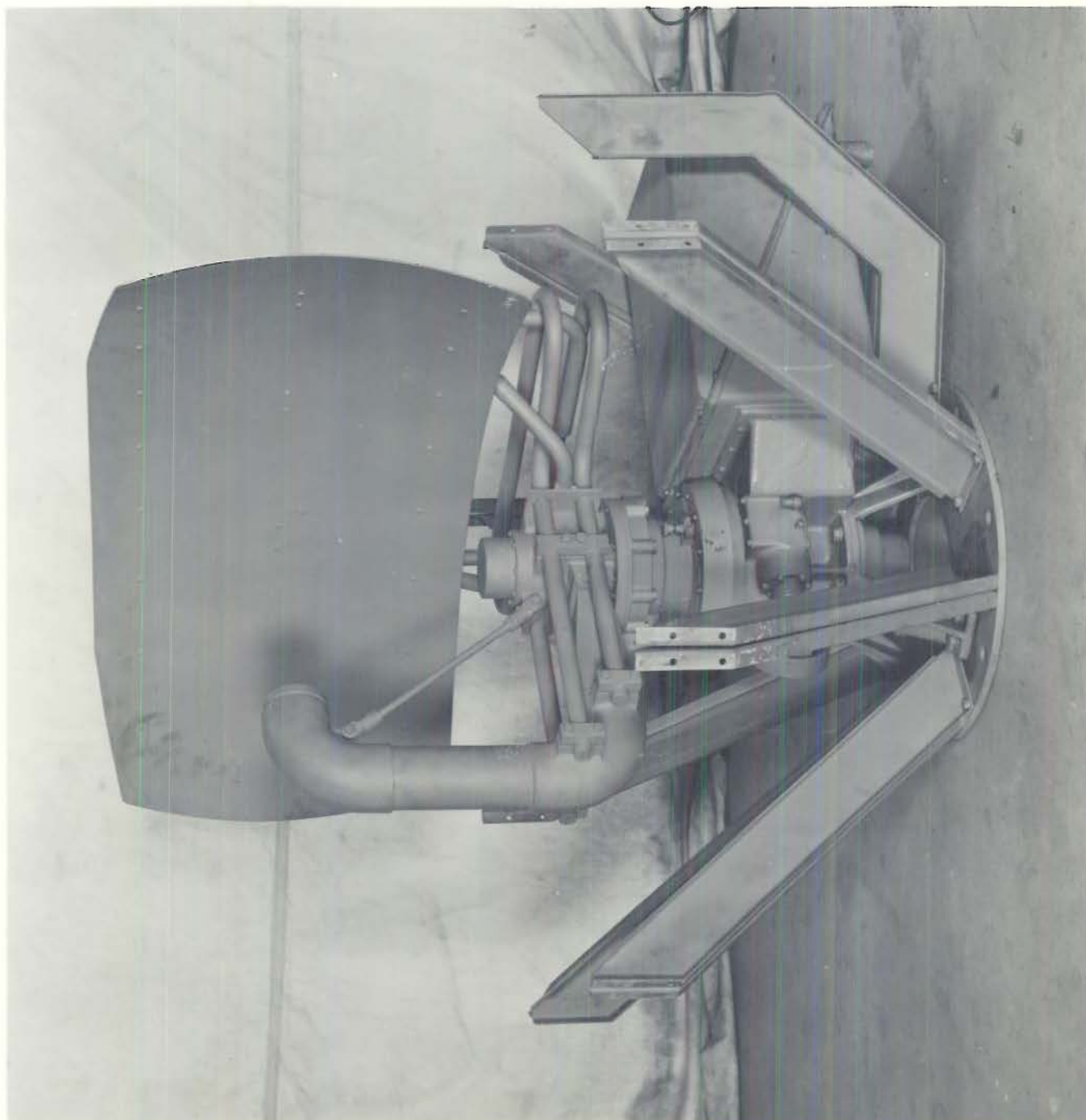


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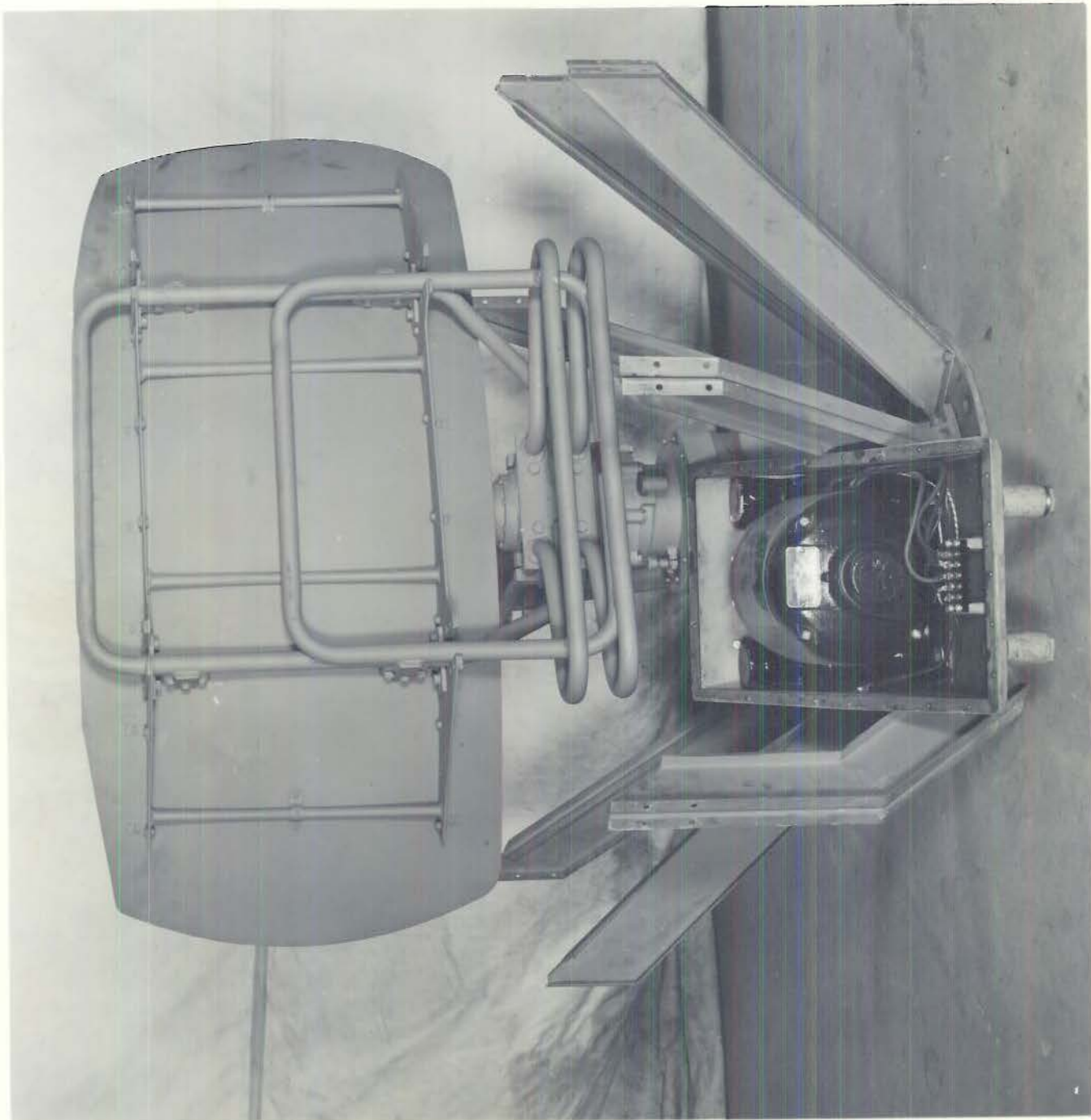


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PLATE 30 SEC.2

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PLATE 31 SEC.2

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PLATE 32 SEC.2

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PLATE 33 SEC. 2

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SECTION 3

REPORT ON ELECTRICAL AND MECHANICAL TESTS OF MODEL SL RADAR RECEIVER-INDICATOR EQUIPMENT

Enclosures: Plates 101 to 107, and 201 to 224.

- References:
- (a) Western Electric Company letter 1725-HTS-MM to Bureau of Ships of November 4, 1942.
 - (b) Descriptive Specifications of Model SL Radar Equipment prepared for Western Electric Company by Bell Telephone Laboratories.
 - (c) Enclosure B of Naval Research Laboratory letter to Bureau of Ships C-S67/36 of December 11, 1942.
 - (d) Memorandum for File signed by Mr. B. O. Browne of Western Electric Company, December 26, 1942 - 1723-BOB-AAR.
 - (e) Enclosure B of Naval Research Laboratory to Mr. H. T. Budenhop, Bell Telephone Laboratories, February 12, 1943. C-S67/36(380).

3-1. INTRODUCTION - The Model SL Radar Equipment was first submitted to this Laboratory for test on November 4, 1942 as Bureau of Ships Problem X92C. Tests were halted on November 11, 1942 and a report of these tests can be found in reference (c). The equipment was again submitted for test on January 11, 1943 and tests completed on March 5, 1943. Western Electric Company, Inc. is to manufacture the Model SL Radar Equipment for U. S. Navy Department, Bureau of Ships, under contract No. NXs-5579.

3-1-1. The following is an index of tests conducted and the page on which the description may be found:

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<u>Subject</u>	<u>Paragraph</u>	<u>Page</u>
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3-2. LIST OF TUBES EMPLOYED IN RECEIVER-INDICATOR

3-2-1. Indicator Power Supply

<u>No.</u>	<u>Type</u>	<u>Function</u>
1	705A	Rectifier
2	5U4G	Rectifier
2	6Y6G	Variable Impedance
1	6SL7GT	D-C Amplifier
2	VR150/30	Voltage Regulator
1	VR105/30	Voltage Regulator
1	6X5G	Rectifier
1	6L6G	Variable Impedance

3-2-2. Sweep chassis

<u>No.</u>	<u>Type</u>	<u>Function</u>
2	6SN7GT	Pulse amplifier
2	6N7GT	Prepulser
		Stop Pulser
1	6L6	Cathode follower
1	6H6GT	Rectifier
1	6AG7	Sweep generator
2	6AC7	Video amplifier
1	7BP7	Plan-position indicator

3-2-3. I-F Amplifier

<u>No.</u>	<u>Type</u>	<u>Function</u>
7	6AC7	6 - I-F amplifiers
		1 - Detector

3-2-4. Oscillator-Amplifier - TR Box

<u>No.</u>	<u>Type</u>	<u>Function</u>
1	726B	Beating Oscillator
2	717A	I-F Amplifier
1	721A	TR Box

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3-2-5. Total List of Tube Types in Receiver-Indicator

<u>No.</u>	<u>Type</u>
1	705A
1	721A
2	5U4G
2	6Y6G
1	6SL7GT
2	VR150/30
1	VR105/30
1	6X5G
1	6L6G
1	6L6
2	6SN7GT
2	6N7GT
1	6H6GT
1	6AG7
9	6AC7
1	7BP7
1	726B
2	717A

3-3. EFFECTS OF VIBRATION - The Radio-Frequency Unit and the Indicator-Modulator Unit were bolted to the vibration table by means of the base mounts provided and a framework provided to which the bulkhead snubbers of the latter unit were fastened.

3-3-1. Method of Test - After allowing sufficient time for the equipment to stabilize, the alignment procedure outlined in the temporary instruction book was followed. Echoes were tuned in and the following data recorded: (1) indicated range of all echoes, (2) indicated range of the range mark, (3) position of the azimuth mark, (4) crystal current, (5) relative values for supply voltages of the type 726B klystron, (6) klystron oscillator frequency. Test number (4) was made with the Weston Electrical Instrument Corp. Model 301 milliammeter mounted on the top panel of the Indicator-Modulator Unit; test number (5) was made with Weston Electrical Instrument Corp. Model 430 serial 714 d-c voltmeter; test number (6) was made with the NRL Receiver Section calibrated wavemeter. The equipment was then vibrated at frequencies from 0 to 2000 cpm, noting the resonant frequencies and amplitudes of vibration of the various components. At all frequencies where relatively large amplitudes of vibration occurred, the frequency of vibration was held constant for at least 30 minutes while the equipment was closely observed for signs of failure.

3-3-2. Results of Vibration Tests.

(a) When vibrated at a frequency of 1200 cpm, the protective cover rattled violently in its rack at the right side of the Indicator-Modulator Unit.

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- (b) The sweep chassis in the Indicator-Modulator Unit was resonant from 1200 to 1300 cpm and reached an amplitude of about one-half inch from side to side at 1250 cpm. At a frequency of 1475 cpm this chassis vibrated from front to back with an amplitude of about one-fourth inch.
- (c) After vibrating at various frequencies for twenty-five minutes, the cathode-ray tube showed no trace. The equipment was shut down for inspection and functioned normally when turned on again.
- (d) The largest amplitude of vibration of the cathode-ray tube was about one-sixteenth inch at a frequency of 1250 cpm.
- (e) The local oscillator frequency shifted approximately 4 Mc after one hour of vibration. The indicated ranges of echoes, indicated range of the range mark, crystal current, and klystron supply voltages remained essentially constant.
- (f) The shock mounts on the sweep chassis were inverted by Mr. P. T. Sprowl of Bell Telephone Laboratories. This, it was claimed, provided snubbing action in both directions. Further vibration tests showed the chassis to have an amplitude of vibration of only one-sixteenth inch from 1800 to 2000 cpm; no other resonant points were found. Vibration was continued at 1800 cpm for fifteen minutes with no apparent harmful effects.

3-4. EFFECTS OF SHOCK - Using the same equipment (paragraph 3-3) the following procedure was followed to determine the effects of shock:

3-4-1. Method of Test - Echoes were tuned in and data recorded as in paragraph 3-3-1. Shocks equivalent to 250 g. were delivered by a pneumatic hammer to the table to which the equipment was fastened. Twelve such shocks were delivered in each of four directions, data being recorded after each shock.

3-4-2. Results of Tests - Operation of the receiver and indicator appeared to be normal throughout all forty-eight shocks with the exception of one feature. The position of the cathode-ray deflecting coil changed relative to the antenna, causing the azimuth mark to appear in an incorrect position. The error increased as much as 7° after some shocks. A failure as a result of shock was later found in the cathode-ray deflecting coil assembly. The bearing ring, shown at the left on plates 201 and 202 was firmly clamped in place, but the deflecting coil assembly shown at the right had dropped about 1/8 inch so that it rested on the focus coil assembly. This was possible because the deflecting coil assembly depended on friction with the inner ring of the bearing for support. Subsequent rotation during the temperature and humidity tests caused the scoring on the deflecting coil and focus coil assemblies shown on plate 203. Other views of the cathode-ray tube assembly are shown on plates 204, 205, 206 and 207.

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- 3-5. VIDEO FIDELITY - In order to make the video amplifier continuously operative, it was necessary to simulate the "gate" voltage which is applied to the plate of V307 when the equipment is in a receiving condition. Since the grid of V302 is driven negative and the rise in screen grid voltage used to provide the "gate", V302 was removed from its socket, and a steady state operating condition created which closely approximates actual operating conditions. A General Radio Company Beat Frequency Oscillator type 713A, serial 141, was used to supply the lower frequency voltage, through a resistance divider network, to the cathode resistor of the reflex detector where it was held constant at 0.20 volts as measured on General Radio Company Vacuum Tube Voltmeter type 726A, serial 319. The higher frequency voltage was supplied by General Radio Company Wide Range Beat Frequency Oscillator type 700A, serial 240. The video amplifier output was measured at terminal 315 on the sweep chassis by General Radio Company Vacuum Tube Voltmeter type 726A, serial 628. As shown by plate 101 of Section 3, the response of the two stage video amplifier is down 3 db at 50 cycles and at 800 kc. The amplifier apparently has adequate bandpass to amplify with sufficient fidelity pulses of 1-1/2 microseconds length such as those delivered by the Model SL Radar Transmitter.
- 3-6. INTERFERENCE TO COMMUNICATION FREQUENCIES - A test was made to estimate the amount of interference that the Model SL Radar Equipment might cause at communication frequencies.
- 3-6-1. Method of Test - The receiving antenna of a communications receiver was installed approximately five feet above the Indicator-Modulator and Radio-Frequency Units of the Model SL equipment. The communication receivers, a Marine Radio Receiver type 128A, serial 41625 for low frequencies and a National Company, Inc., type HRO for the higher frequencies, were placed in a screened room about thirty feet away from the radar equipment. Filters with high r-f attenuation were used in the a-c line supplying the receivers. The capacity of the antenna to ground was measured with General Radio Capacitance Test Bridge type 740 BSI, serial 178, and a fixed capacity of this amount, equal to 162 micromicrofarads, was used in series with a signal generator to act as a dummy antenna. Ferris Instrument Corporation Signal Generator type 180, serial 44, was used for this purpose. The local noise level without the radar equipment operating was measured by noting first the noise output of the receiver with the antenna connected and then substituting the signal generator in series with the dummy antenna to find the input voltage required to give the same receiver output. The output noise level of the receiver was taken with the receiver antenna terminals short-circuited. The receiver input voltage, which is equivalent to the local noise level voltage, was plotted in decibels as ordinates against frequency as abscissa on plate 102. The Marine type 128A receiver was used from 15 to 650 kc and the National type HRO was used from 600 kc to 30 Mc. The radar equipment was then put into operation, and the test repeated. These results were plotted on the same scale as the local noise level on plate 102.

3-6-2. Results of Tests - The difference in ordinates of the curve, at some frequencies as much as 60 db, is an indication of the amount of noise produced in the antenna of the communications receiver due only to the Model SL Radar Equipment. With the beat-frequency oscillator off, an 800 cycle tone could be heard in the receiver. Therefore, it would be difficult to copy code through this interference. The receivers used in this test are not provided with power line filters as standard Navy receivers would be but it is felt that the filter in the power line to the screened room may afford sufficient attenuation to make this source of noise negligible. Since, in most installations, the antennae are brought to the communications receivers in continuously shielded lines, it is not likely that the conditions for interference pickup would be as severe as those imposed in this test. Some filtering and shielding is afforded in the SL Radar Equipment but no attempt was made to improve the results by further grounding and bonding. It is also possible that there was some coupling through the ground leads since this test was made at a considerable distance from a good earth ground connection.

3-7. INTERMEDIATE-FREQUENCY SELECTIVITY - It is necessary to know the bandpass of the receiver in order to determine its noise factor. However, sufficiently stable and accurate equipment for measuring the overall selectivity is not available so that the selectivity of the intermediate frequency amplifier is assumed to be the main factor determining the overall bandpass of the receiver.

3-7-1. Method of Test - In order to measure the selectivity of the intermediate-frequency amplifier, the output cable of Ferris Instrument Corporation Microvolter type 18B, serial 134 was connected across several inches of the converter assembly to induce ground currents. RCA Voltomyst Jr. Vacuum Tube Voltmeter number 1951 was used to measure the voltage developed across the detector load resistor. A 0.01 microfarad condenser was used to bypass the cathode of the detector to ground to prevent regeneration in the i-f amplifier due to insertion of the voltmeter leads. The receiver gain control was adjusted to give 3.0 volts of noise at the detector and the input adjusted to give a constant output of 3.4 volts as the input frequency was varied.

3-7-2. Results of Tests - The i-f amplifier selectivity curve is shown on plate 103. Since the curve is not symmetrical, the fractional ratio of the voltage input was squared and plotted against frequency, the area under the curve found by means of a planimeter, and this area divided by the maximum ordinate to give the width. This is the width of the equivalent rectangular bandpass characteristic. The bandwidth was 1.79 Mc by this method. It is to be noted that the selectivity curve shows a "double hump" which is undesirable because of the difficulty it presents in tuning the receiver.

3-8. SENSITIVITY - The sensitivity of the receiver is expressed as the ratio of the actual noise present in the output to that which would be present in the output of a theoretically perfect receiver having no source of noise other than the thermal noise in the antenna circuits.

3-8-1. Method of Test - The output of NRL S-band Signal Generator serial 1 was coupled into the receiver by two methods. First, a coupling loop was mounted on a plate covering the window in the TR cavity and its position adjusted for maximum output. Since this position was approximately the position of maximum coupling, a two turn loop was tried but found to give no better results. A 0.01 microfarad condenser was shunted across the detector cathode resistor and the voltage developed across this resistor measured by Precision Apparatus Company Vacuum Tube Voltmeter Pattern EV10 serial 5158. The receiver gain control was adjusted to increase the cathode voltage of the detector by 3.00 volts, there being no input to the receiver. The input was then raised until the output was increased by a factor of 1.41, at which point the input represents the equivalent noise. The same procedure was followed in the second method of test except that the TR Box and converter assembly were placed in their proper position and the input was applied by exciting the waveguide. Measurements were made with the magnetron in place and with it removed. In the latter case, the opening left in the waveguide was covered by a suitable sheet of copper.

3-8-2. Results of Tests - An input of 6 microvolts was necessary to double the output energy when feeding into the receiver in either of the methods described above. When exciting the waveguide with the magnetron in place an input of 10 microvolts was required. When compared to the theoretically perfect receiver the Model SL receiver is found to have a noise factor of 18.3 db.

3-9. IMAGE REJECTION RATIO - The sensitivity of the receiver was measured at the image frequency by the same methods as described in paragraph 3-8-1. An input of 280 microvolts was required, giving an image rejection ratio of 33 db. This measurement does not include that selectivity which might be gained by the transformers etc. in the antenna assembly.

3-10. RESONANT OVERLOAD - Using the equipment described in paragraph 3-8-1, data was taken to show receiver output for various values of cw signal input. The resonant overload characteristic is shown on plate 104.

3-11. TUNING RANGE - It is difficult to express the tuning range of the Model SL receiver simply, since the amount of voltage variation obtainable by means of the tuning control at the operating position is a function of the position of potentiometer R610 in the converter-oscillator-amplifier chassis in the r-f unit.

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- 3-11-1. Method of Test - (a) After allowing sufficient time for the equipment to stabilize, the procedure described in paragraph 3.6 of the temporary instruction book under the title "TUNE HEATING OSCILLATOR" (sic) was followed. The REC. TUNE control, R468, was set in the middle of its range and the BO TUNE and REP VOLT controls adjusted so that maximum crystal current was obtained when the receiver was correctly tuned for the reception of echoes. The frequency of the type 726B oscillator was measured with NRL Receiver Section calibrated S-band wavemeter as the REC TUNE control was varied throughout its range. This test was repeated with each of the two spare beat oscillator tubes furnished. (b) A test was made on each of the type 726B tubes furnished to determine the wavelengths at which useable outputs could be obtained.
- 3-11-2. Results of Tests - The frequency range obtained under conditions described in 3-11-1(a) was about 60 Mc for all three tubes. Useable outputs could be obtained from the beat oscillator throughout the specified range of the transmitter with two of the three type 726B tubes tested. The third tube failed to oscillate at the extreme lower frequency end of the band.
- 3-12. RANGE ACCURACY - By means of the switch marked RANGE, the Model SL indicator can be made to show a maximum range of 5, 25, or 60 miles.
- 3-12-1. Method of Test - A Western Electric Company Special Delay Circuit type D-150268 was triggered by the voltage appearing at the IFF SYNCH jack, and the delayed output applied through the second video amplifier to the grid of the cathode-ray tube. The counter on the delay circuit was adjusted so that at zero range the simulated echo, or range marker, coincided with the bright spot at the center of the cathode-ray tube. Following the procedure described in paragraph 5.3 of the temporary instruction book, the delay circuit was set to give a range of 8000 yards to simulate a target of known range. With the range switch set in the 5 mile position, the RANGE ADJUSTMENT control varied to make the target appear at the 4 mile ring on the PPI. The SWEEP LENGTH control was then adjusted to make the range mark generated within the Radar equipment appear at 5 miles. The range of the simulated target was then varied from 0 to 20 miles and the indicated range shown on the PPI recorded. The entire procedure described above was repeated in order to check the results and to determine the reliability of this method.
- 3-12-2. Results of Tests - A range error curve is shown on plate 105 on which the results of the tests are plotted. It is realized that some error is introduced in calibrating the zero range point which is not the fault of the Radar equipment. However, the two sets of data check fairly well. Reset and parallax error account for the fact that the four mile calibration is not perfect. Since the 5 mile range error is negative from 0 to 3.6 miles and positive from 3.6 to 5 miles, it would seem that the sweep speed had been incorrectly adjusted. This fact is not borne out, however, by the error shown on the 25 and 60 mile ranges, indicating that the range multiplier is not correct.

3-13. EFFECTS OF LINE VOLTAGE VARIATION - Although a manually operated voltage controlling device is built into the Model SL Radar Equipment, it is quite possible that an operator would not attempt to regulate a fluctuating supply voltage. Therefore, the line voltage was varied and results noted as described below.

3-13-1. Method of Test - The calibration of the a-c voltmeter, M451, on the top panel of the Indicator-Modulator was checked by comparing its reading with that of Weston Electrical Instrument Corporation model 433 serial 34591 connected in parallel. The Precision Apparatus Company Vacuum Tube Voltmeter Pattern EV10 serial 5158 was used to monitor the cavity and repeller supply voltages to the klystron oscillator while NRL Receiver Section calibrated wavemeter was used to monitor the output frequency. The range calibrating method described in paragraph 3-12-1 was used to measure the change of indicated range. Line voltage was varied from 105 to 125 volts and readings made at 105, 115, and 125 volts.

3-13-2. Results of Tests - Neither the voltages applied to the klystron oscillator nor its output frequency was affected by the variation of supply voltage. However, the indicated range proved to be inversely proportional to the supply voltage as shown on plate 106. This is probably due in part to the fact that the inverse feedback in the sweep amplifier is not great enough to counteract the change due to variation of plate supply voltage of V304, the last sweep amplifier.

3-14. EFFECTS OF TEMPERATURE VARIATION - Both the R-F Unit and the Indicator-Modulator Unit are apt to be mounted in such a position that they will be exposed to the outside temperature, therefore, the equipment was tested from +50° C to -25° C.

3-14-1. Method of Test - The equipment was set up in the temperature-controlled room and the following provisions made for measurements:

- (a) Weston Electrical Instrument Corporation d-c voltmeter model 430 serial 714 was used to measure the relative supply voltages to the beat oscillator.
- (b) The Special Delay Circuit was used to measure the indicated range as described in paragraph 3-12-1.
- (c) Frequency of the output of the beat oscillator was monitored with NRL Receiver Section calibrated S band wavemeter.
- (d) The position of the azimuth mark was noted at fifteen minute intervals. Excitation was applied to the compass repeater selsyn and the COMPASS REPEATER switch left in the OFF position.

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Data were recorded at fifteen minute intervals as the temperature was varied from +50° C to -23° C in six steps, the relative humidity being held below 30% at all times. Then the equipment was shut down and the heaters left on while the temperature was held at -25° C for two hours. At the end of this time power was again supplied to the entire equipment and its operation noted.

3-14-2 Results of Test - The frequency drift of the beat of oscillator is shown compared to the ambient temperature on a common time base on plate 107. The voltage output from the regulated power supply is shown in the same manner on plate 107. At a temperature of -14° C the compass repeater selsyn failed to hold position and began to rotate while the deflecting coil mechanism stood still. After the equipment had been idle for two hours at a temperature of -25° C the deflecting coil driving motor would not run and it was necessary to refocus and recenter the trace on the cathode-ray tube before the range accuracy could be measured. The difficulty encountered with the deflecting coil mechanism is partially the result of the damage inflicted in the shock and vibration tests (paragraph 3-4-2), so that it is not possible to conclude, from the present tests, whether or not the faulty mechanism would be adversely affected, by low temperatures. However, plate 204 shows how the potting compound in the focus and centering coil assembly has melted.

3-15. EFFECTS OF HUMIDITY VARIATION

3-15-1 The same equipment described in paragraph 3-14-1 was used and the same general test procedure followed. The temperature was kept at 40° C as the relative humidity was varied from 17% to 97% and then to 20%, allowing a period of about one hour for the equipment to stabilize after each change. Then the equipment was shut down and the heaters left on while the temperature was held at 40° C and the relative humidity at 97% for two hours. At the end of this time power was again supplied to the entire equipment and its operation noted.

3-15-2 Results of Test - After operating for one-half hour at 97% relative humidity, it was necessary to readjust the focus control to bring the trace on the cathode-ray tube into focus. The setting of this control was then at a maximum clockwise position. When starting the equipment after the two hour shut-down it was necessary to readjust the focus control frequently during the first fifteen minutes of operation.

3-16. VACUUM TUBES

3-16-1 There are four tube types used in the Model SL Radar Equipment which do not appear on the Army-Navy Preferred List of Vacuum Tubes or the Army-Navy Preferred List of Classified Vacuum Tubes, both Lists dated March 1, 1943. These four types are 6N7, 6L6, 717A, and 726B.

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- (a) A tube interchange test was made for the 6L6, substituting four metal type 6L6 tubes and then four glass type 6L6G tubes. This tube, V304, serves as a sweep voltage cathode-follower, therefore, any major change of performance could be detected by observing the trace of the cathode-ray tube. Only in the case of one 6L6G, one which was removed from the regulated power supply chassis, could any difference in operation be noted, this difference being a slight enlargement of the zero range circle at the center of the face of the cathode-ray tube. These results do not seem to justify the use of a now-preferred tube, the type 6L6.
- (b) Two Western Electric type 717A vacuum tubes, V601 and V602, are used as i-f amplifiers. Unless greatly improved performance is obtained from this tube type, which does not seem to be the case, their use is not advised.
- (c) The three Western Electric type 726B klystron oscillator tubes were interchanged as described in paragraph 3-11, and their frequency drift with temperature is shown on plate 107. This tube type is not included on the list previously mentioned, although the type 726A is included.

3-16-2. In general, the tubes are well supported by their sockets and clamps are used where necessary; however, the tube clamps used in the indicator power supply are difficult to release since they are countersunk beneath the regular chassis. It is understood that, in the production model, this construction has been altered,

- 3-16-3. (a) The cathode-ray tube was marked with a paper sticker containing an RCA experimental number, no other identification was provided on the tube.
- (b) The vertical centering control, resistor R456, is at its maximum clockwise position when the spot is correctly centered. There should be enough latitude provided to offset the differences encountered in cathode-ray tubes and in positioning the scale which fits over the face of the tube.
 - (c) The setting of the FOCUS control, R454, must be readjusted for a period of fifteen minutes after the equipment is turned on before a stable focus condition is reached, probably due to the increasing of the resistance of the focus coil caused by heating. This trouble could probably be eliminated by the use of a larger size wire in the focus coil.

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3-17. GENERAL PHYSICAL CONSTRUCTION

- 3-17-1. Converter-Oscillator-Amplifier - These parts are located in the R-F Unit and are accessible through the removable side of that unit, as shown on plates 208 and 209. The chassis containing the beat oscillator and first two i-f amplifier stages can be removed from its cabinet by loosening the two front panel thumb screws, thus making the chassis readily available for servicing. Other views of this chassis are shown on plates 210, 211, 212, and 213. The crystal converter and TR box assembly are shown in place, mounted on the waveguide by plates 208 and 209. The partially disassembled components are shown on plate 214. All parts are accessible and replacements can be made readily. The R-F Unit, with the cover in place, is shown on plate 215.
- 3-17-2. Indicator - The indicator and its associated power supplies occupy the top part of the Indicator-Modulator Unit, and may be lifted into the position shown on plate 219 for servicing, or may be entirely removed from the supporting framework for major repairs. It would be necessary to remove this part of the Unit before the moving parts of the Plan Position Indicator could be properly serviced. The sweep chassis can be easily removed from its shock mounts and set in an upright position as shown on plate 223. Other views of this Unit are shown on plates 216 to 224, inclusive.

3-18. MECHANICAL DEFECTS

- 3-18-1. On the sweep chassis in the Indicator-Modulator Unit V304, a metal type 6L6 vacuum tube, is very close to terminal lugs on terminals 316 and 317. The base of the tube overlaps the terminal lugs and could easily cause a short circuit. The identifying markings on these terminals are hidden by V304 and by the wiring.
- 3-18-2. The function of switch S456, mounted on the top shelf inside the Indicator-Modulator Unit, is not indicated by the chassis marking. This switch is used to connect the true bearing feature if desired, and is labelled merely "OFF-ON".
- 3-18-3. The cathode-ray tube furnished with the equipment was not properly marked and the designation 7BP7 did not appear on the tube. Ref. par. 3-16-3(a).
- 3-18-4. Those fuses which are mounted beneath the top panel of the Indicator-Modulator Unit are not marked with a functional number and current rating, making it difficult to find each fuse on the schematic diagram.
- 3-18-5. The panel marking of meter M452 does not indicate that a multiplier is introduced when reading converter current.

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- 3-18-6. On the wavemeter, switch S901 is labelled MAG-XTAL. This is confusing because, in the MAG position, the meter is used as a r-f indicator and, in the XTAL position, reads crystal current.
- 3-18-7. The tube line-up in the indicator power supplies does not agree with that shown in the schematic diagram. In the equipment V409 is a VR105/30 and is so labelled on the chassis; V410 is a VR150/30 and is so labelled. The schematic diagram in the temporary instruction book designates V409 as a VR150/30 and V410 as a VR105/30.
- 3-18-8. In many locations the controls and tube sockets are not labelled beneath the chassis.
- 3-18-9. The schematic diagram in the temporary instruction book shows the tubes in the Converter-Oscillator-Amplifier assembly as V601, V602, and V603. The chassis of this assembly is stamped V1, V2, and V3.
- 3-18-10 Individual terminal boards are not given numbers, and it is possible to confuse the terminals, since the terminal numbers are duplicated in several cases.
- 3-18-11 When the equipment is in operation, the protective top cover of the Indicator-Modulator Unit is held in a rack at the right of that Unit and the viewing hood is in place above the cathode-ray tube. It is not clear, however, what is to be done with the viewing hood when the equipment is not in use, since this hood must be detached before the protective cover can be seated in position.
- 3-18-12 The "B.O. TUNE" control shaft, located on the panel of the oscillator-amplifier chassis in the R-F Unit, is made of a linen bakelite dowel which has been slotted to admit a screwdriver. After a short period of normal turning this shaft split so that a screwdriver would no longer turn the control (Plate 212)
- 3-18-13 The tube clamps used in the indicator power supply are difficult to loosen. Ref. par. 3-16-2.
- 3-18-14 Since the wavemeter provided is always used at the R-F Unit, it should be stowed at that point or built into the R-F Unit. As furnished there was no means of stowage provided.
- 3-18-15 A 1/4 watt 120 ohm resistor was used to load the end of the transmission line which couples the beat oscillator to the converter. Because of the physical size of the resistor, it was necessary to file two sides of the case flat before it could be placed in the coaxial fitting. This resistor was damaged during tests, and no pre-filed resistors were found in the spare parts. The schematic diagram does not show this component, hence it has no functional number.

3-19. OPERATIONAL DIFFICULTIES

- 3-19-1. The main power switch, S451, does not disconnect the power supplied to the compass repeater selsyn when in the OFF position. A separate switch is evidently necessary for this purpose to completely disconnect the power from the equipment. Since the antenna position must be reset with respect to the PPI each time the equipment is shut down, there is no advantage gained by leaving the selsyn excited.
- 3-19-2. Considerable trouble was experienced with the compass repeater selsyn during tests at this Laboratory; however, most of it can be blamed on the damage inflicted in the shock test (paragraph 3-4-2). The selsyn winding burned out due to the extra friction and drag, and the system failed to function at low temperatures (paragraph 3-14-2). Further tests with an undamaged equipment will be necessary before typical performance can be judged.
- 3-19-2. The cathode-ray vertical centering control is at its limit in a clockwise direction when the spot is correctly centered.
- 3-19-3. The range switch on the top panel is capable of making the maximum range of the PPI 5, 25, or 60 miles. Since five concentric circles are provided to help the operator approximate the range of a target, these circles represent, respectively, 1, 5, and 12 miles each. The fact that on the longest range each circle represents 12 miles is apt to confuse an operator and cause him to estimate the range incorrectly because of inconvenience in interpolation.
- 3-19-4. The rigid viewing hood which fits on the top panel of the Indicator-Modulator Unit is apt to cause injury to an operator under gunfire and adverse weather conditions. A padded hood or one with a rubber rim would be less likely to cause injury to an operator accidentally thrown against the equipment.
- 3-20. TEMPORARY INSTRUCTION BOOK - "Preliminary Instruction Book for SL Radar, No. 2" was supplied to the Receiver Section of this Laboratory.
- 3-20-1. In this book Figure 103, referred to in paragraph 5 as "the schematic for d-c power supply voltages," is actually the schematic diagram of the converter, oscillator, and i-f preamplifier. The indicator power supply schematic is a part of Figure 104.
- 3-20-2. The wavemeter furnished has a meter with a 0-1 ma. scale. Paragraph 2.13 in the preliminary instruction book states that the meter has a 0 - 2.5 ma. scale.
- 3-20-3. The second detector circuit, V207 and its associated components, is not wired as shown in Figure 105.

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- 3-20-4. In the sweep chassis of the Indicator-Modulator Unit potentiometers R321 and R329 are used to adjust for correct range and correct sweep length, respectively. In the text of the book they are correctly referred to as RANGE ADJUSTMENT and SWEEP LENGTH. In the "List of Controls" on page 67, the names and functions assigned these controls are incorrect and serve only to confuse the reader.
- 3-20-5. The 1.2 megohm resistor in the grid circuit of V-301-1 is labelled R316 on the Sweep Circuit Schematic and R353 on the Indicator Unit-Schematic.
- 3-20-6. The Indicator Unit Schematic shows V409 and V410 interchanged with respect to the way they are in the equipment.
- 3-20-7. The above mentioned schematic is not clear as to which compass repeater circuits are used in the equipment. The diagrams shown are very confusing.
- 3-20-8. The Converter-Oscillator-Amplifier Schematic designates the tubes as V601, V602, and V603. The chassis of this unit is stamped V1, V2, and V3.
- 3-20-9. The instructions for making the range adjustments, page 63, mention an alternate method using a "Standard 60 Mc pip generator." So far as is known there is no standard instrument of this type used by the Navy. If this method is to be recommended it would seem that a description of the test instrument and where it might be obtained should be included.
- 3-21. CONCLUSIONS - Although many minor defects have been found in the Model SL Radar receiving and indicating equipment, it can be expected to give reasonably reliable performance under the conditions encountered in Naval service if the more serious defects are corrected. In addition to those defects listed in paragraph 11 of reference (e), the following are considered serious enough to merit immediate attention.
- 3-21-1. The failure of the PPI mechanism described in paragraph 3-4-2.
- 3-21-2. The use of non-approved tubes described in paragraph 3-16.
- 3-21-3. The relatively poor sensitivity of the receiver. Other equipment of this type has shown that an improvement of about 4 db could be expected.
- 3-21-4. Those features which make the PPI rotating mechanism difficult to service.
- 3-21-5. The inaccurate range indications caused by the absence of a reliable method of range calibration, the relatively large effect of line voltage variation, and the confusing relation of the three ranges provided.
- 3-21-6. The effect of warmup on the focus adjustment of the cathode-ray tube.

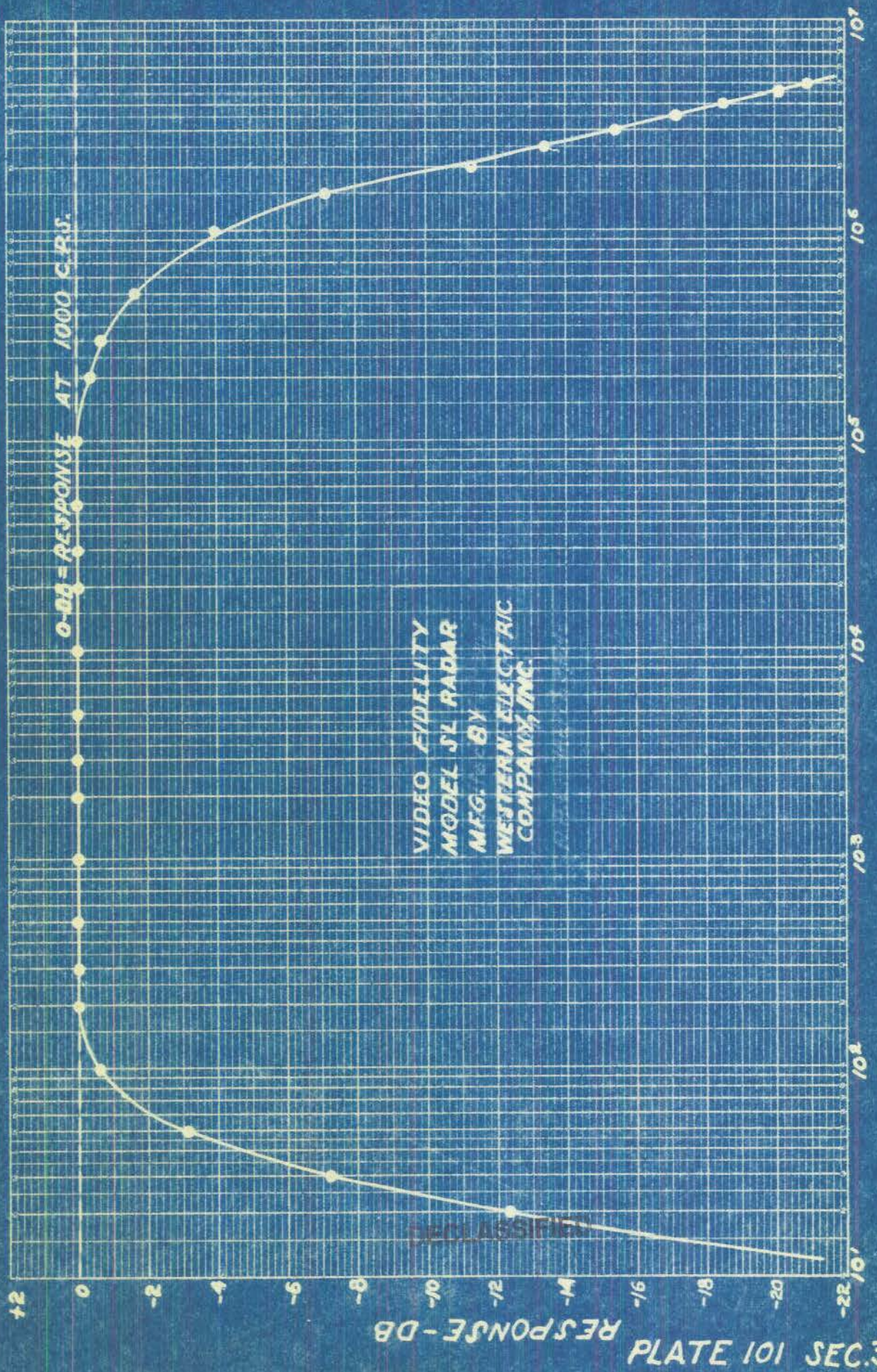
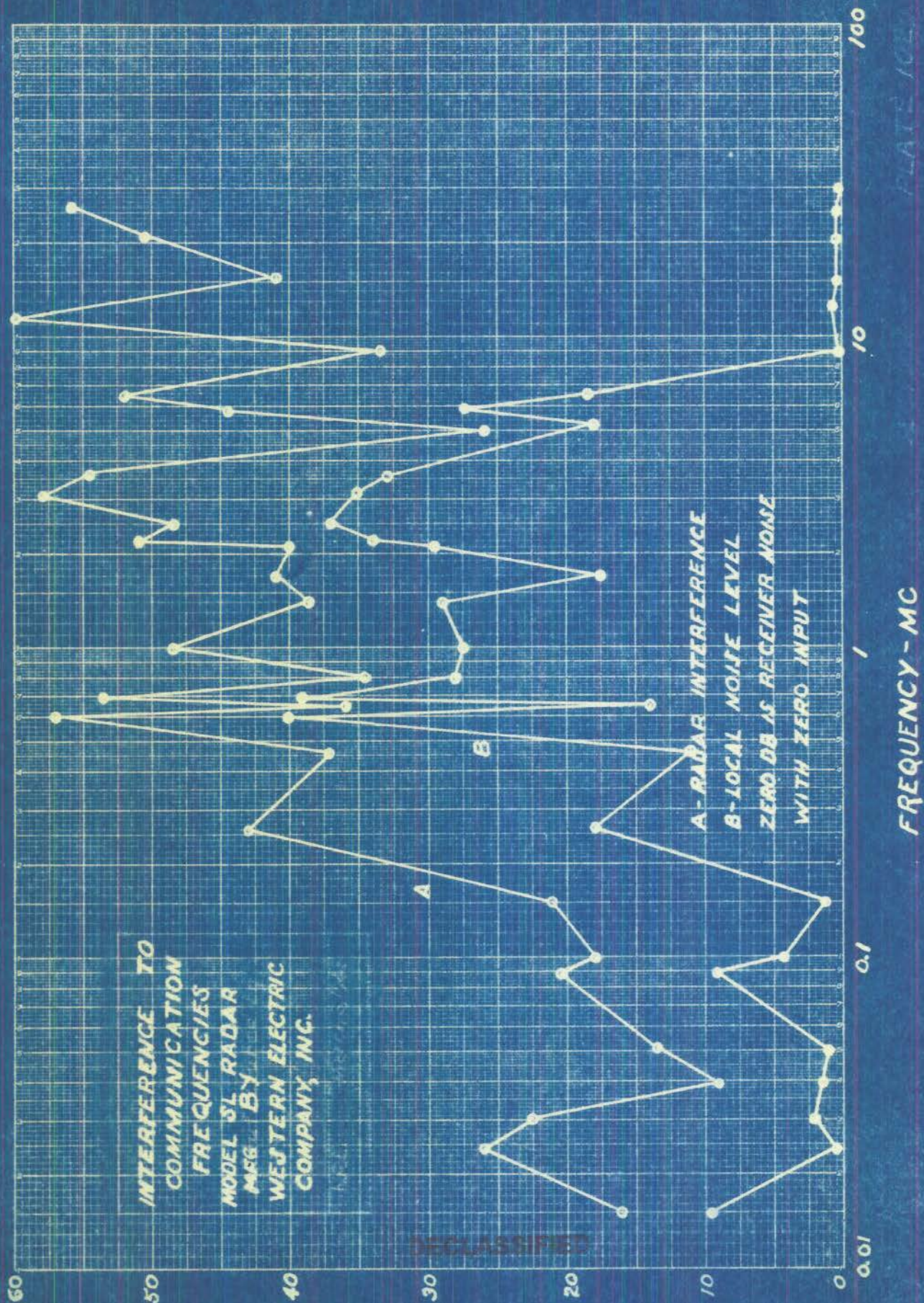


PLATE 101

PLATE 101 SEC. 3

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PLATE 102

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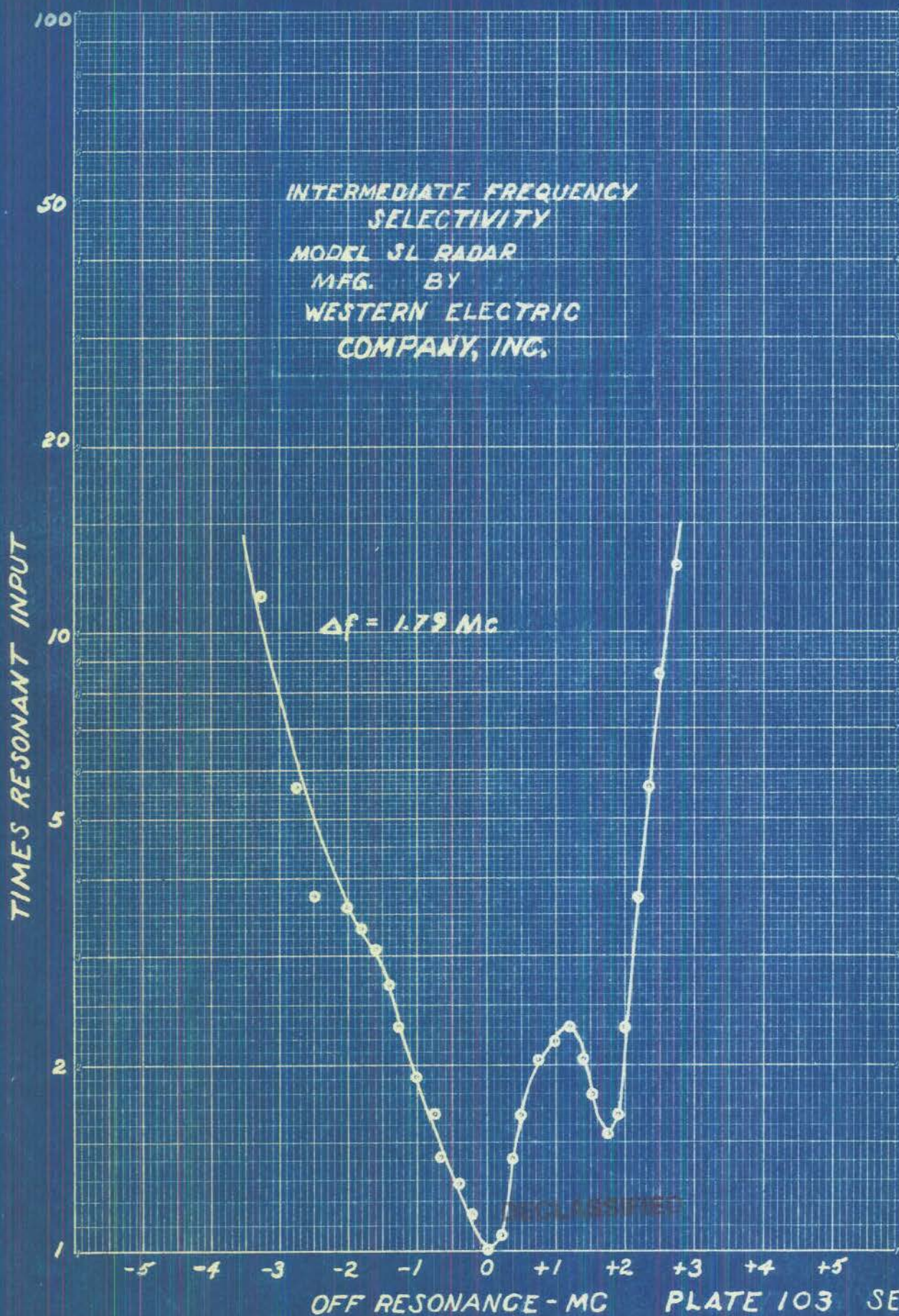
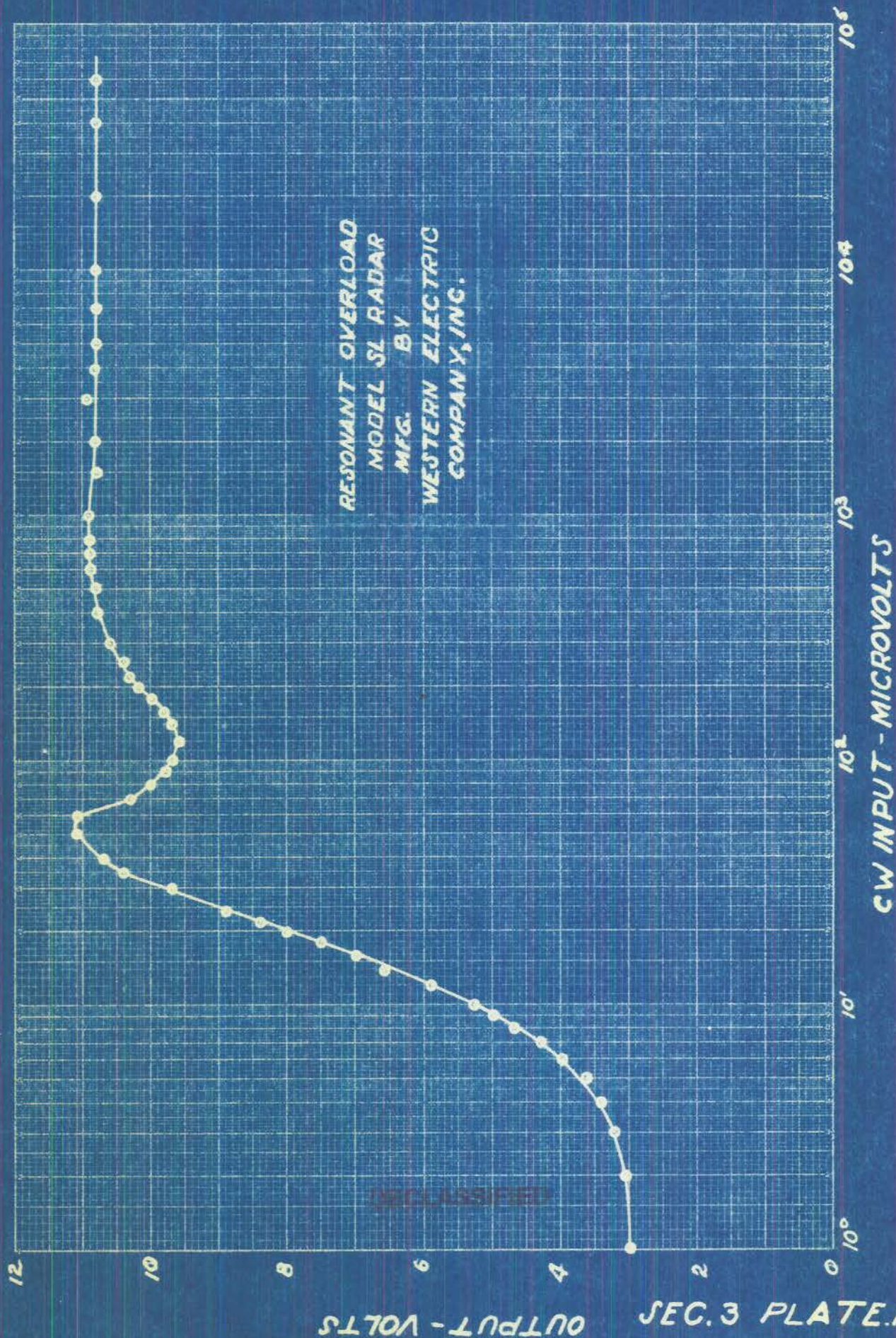


PLATE 103 SEC.3

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RESONANT OVERLOAD
MODEL SL RADAR
MFG. BY
WESTERN ELECTRIC
COMPANY, INC.

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OUTPUT - VOLTS

SEC. 3 PLATE 104

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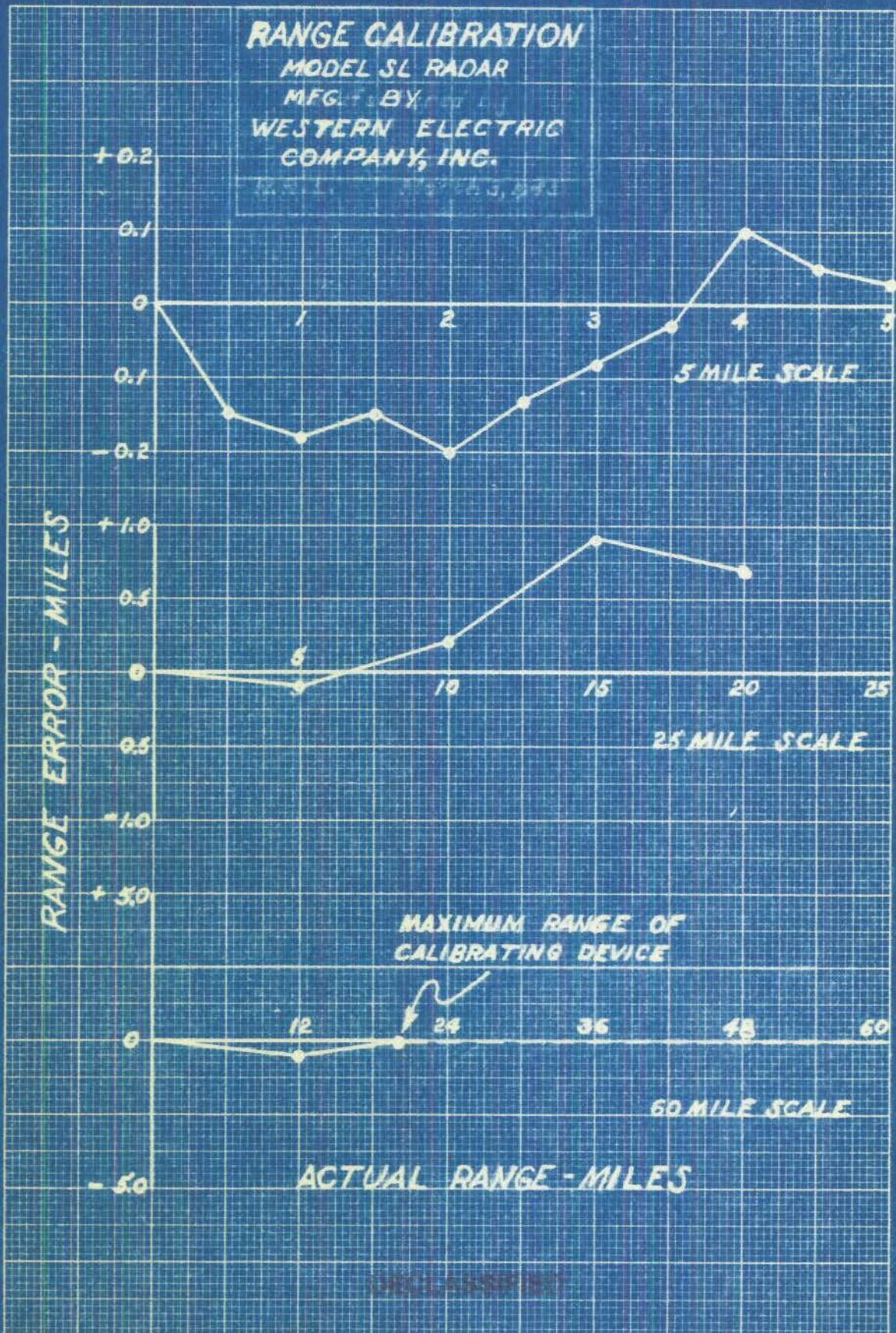
RANGE CALIBRATION

MODEL SL RADAR

MFG. BY

WESTERN ELECTRIC
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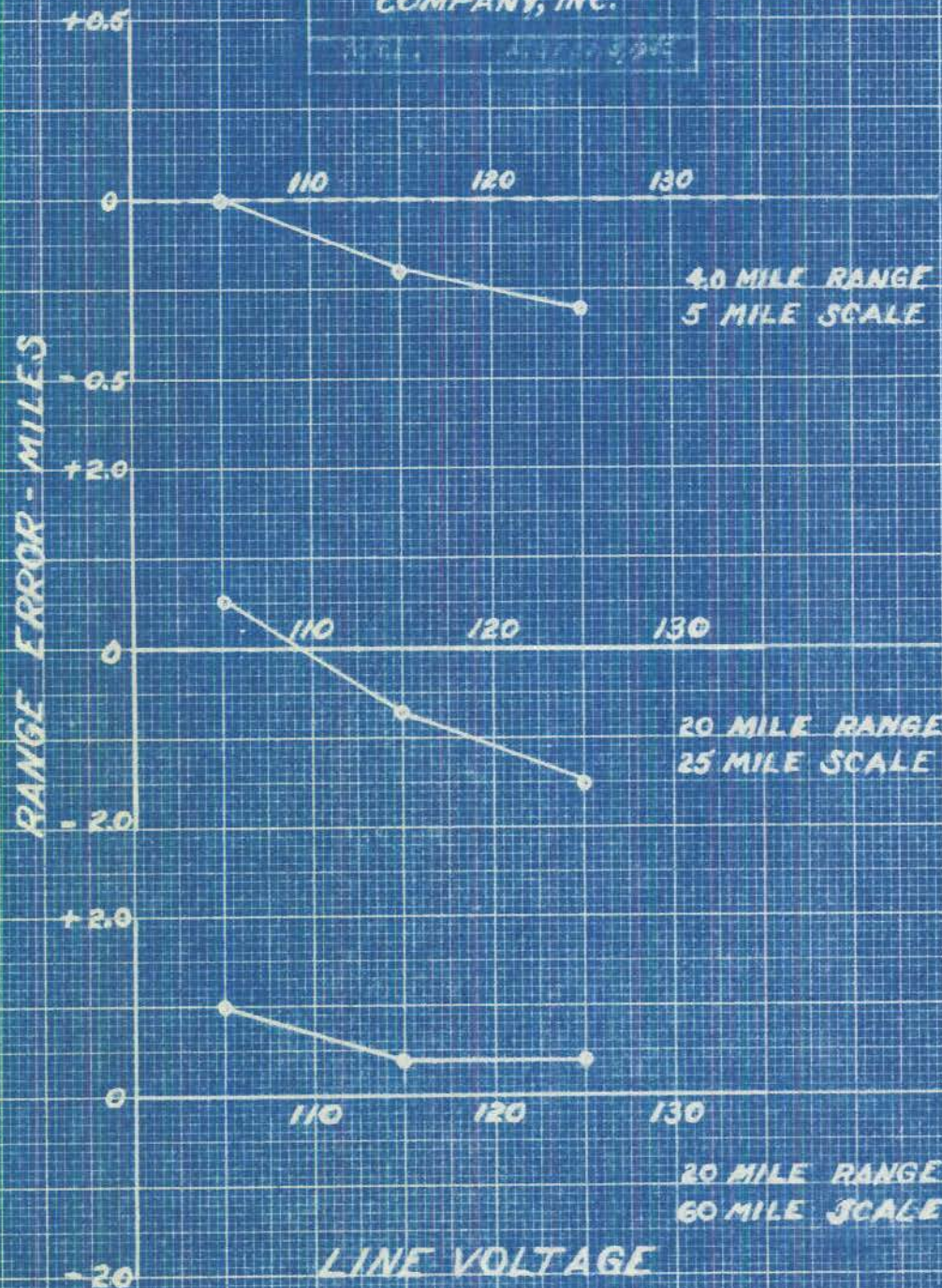
12-5110-1 57-753, 543



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**RANGE ERROR VS
LINE VOLTAGE
MODEL SL RADAR
MFG. BY
WESTERN ELECTRIC
COMPANY, INC.**



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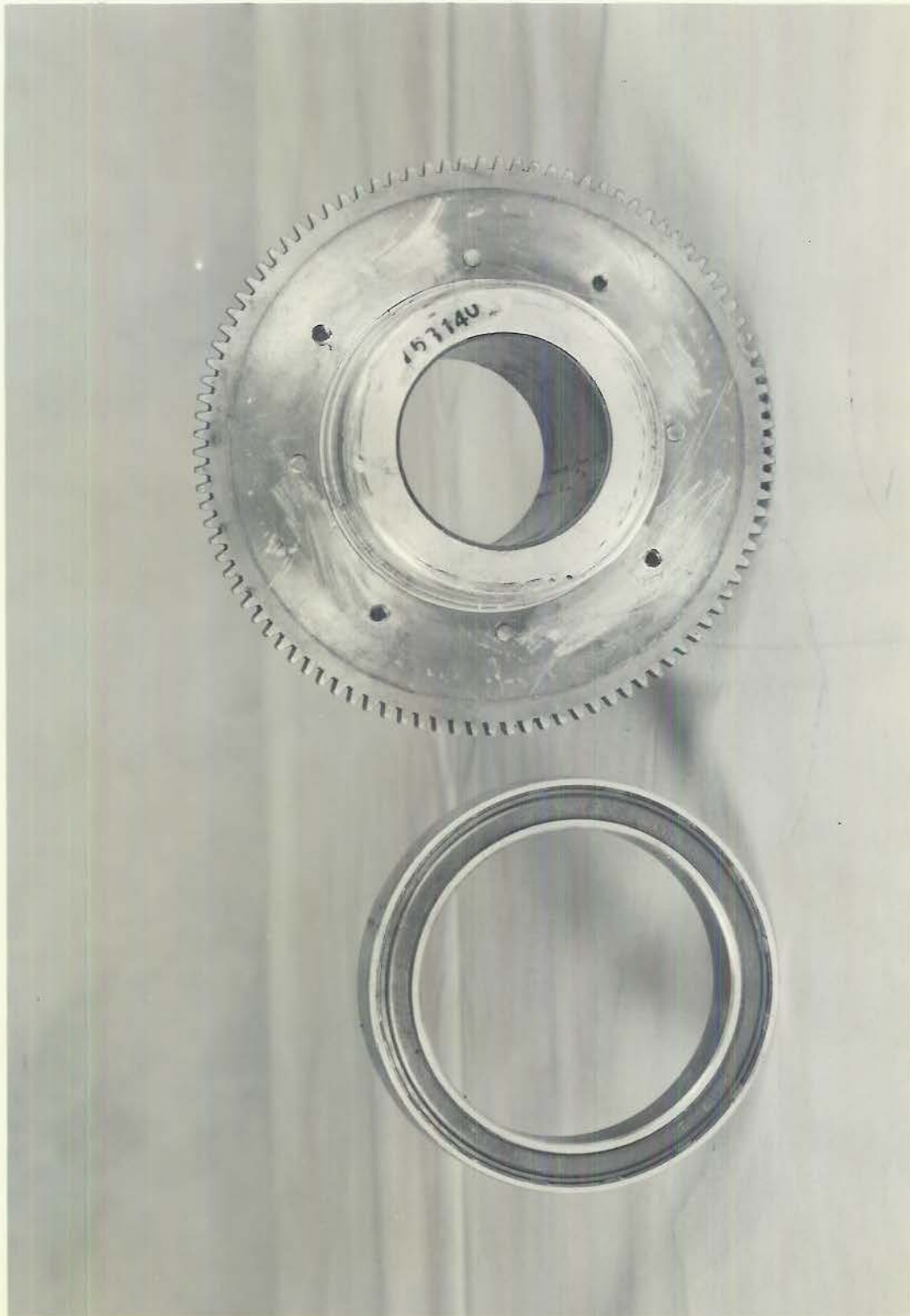


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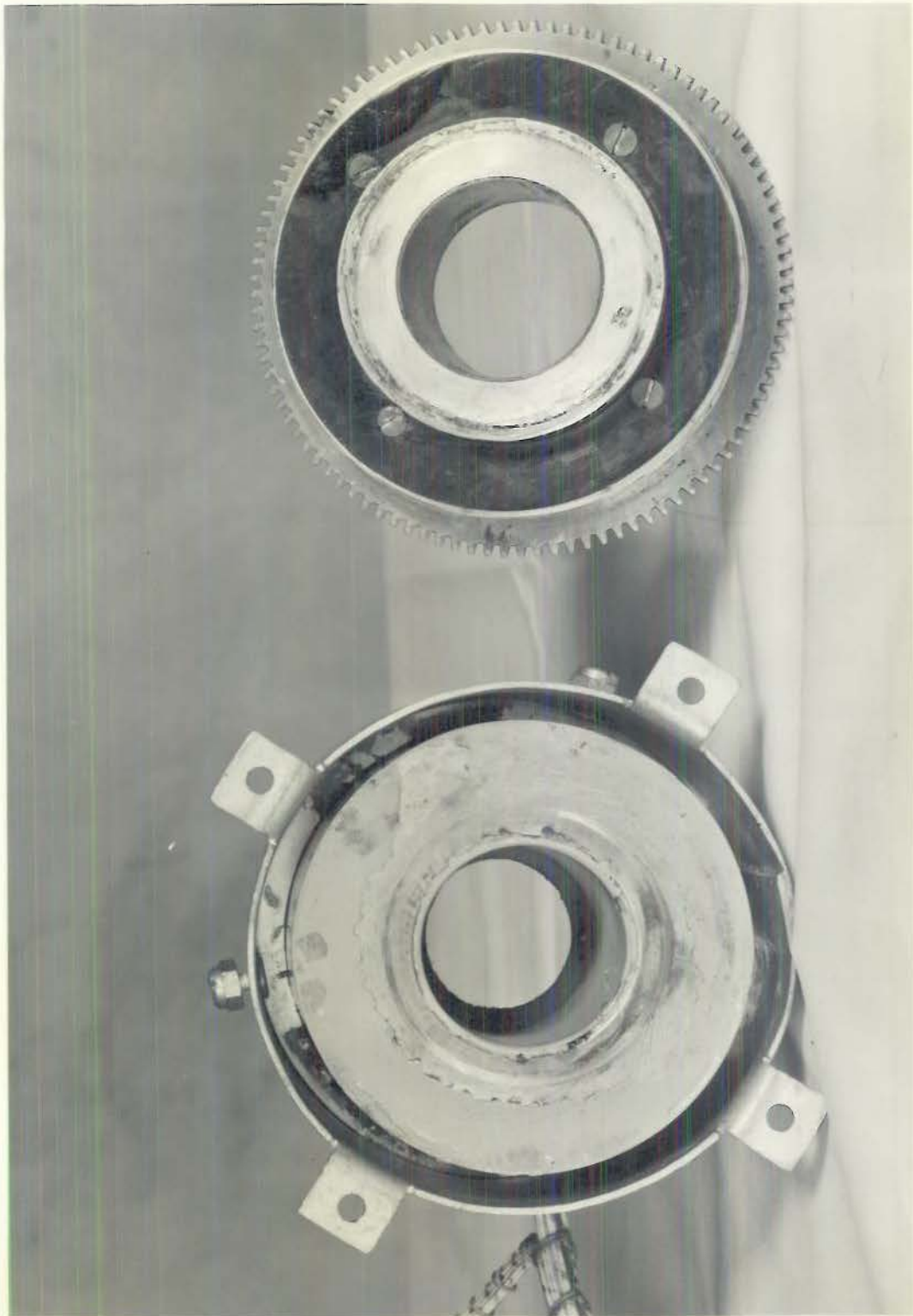


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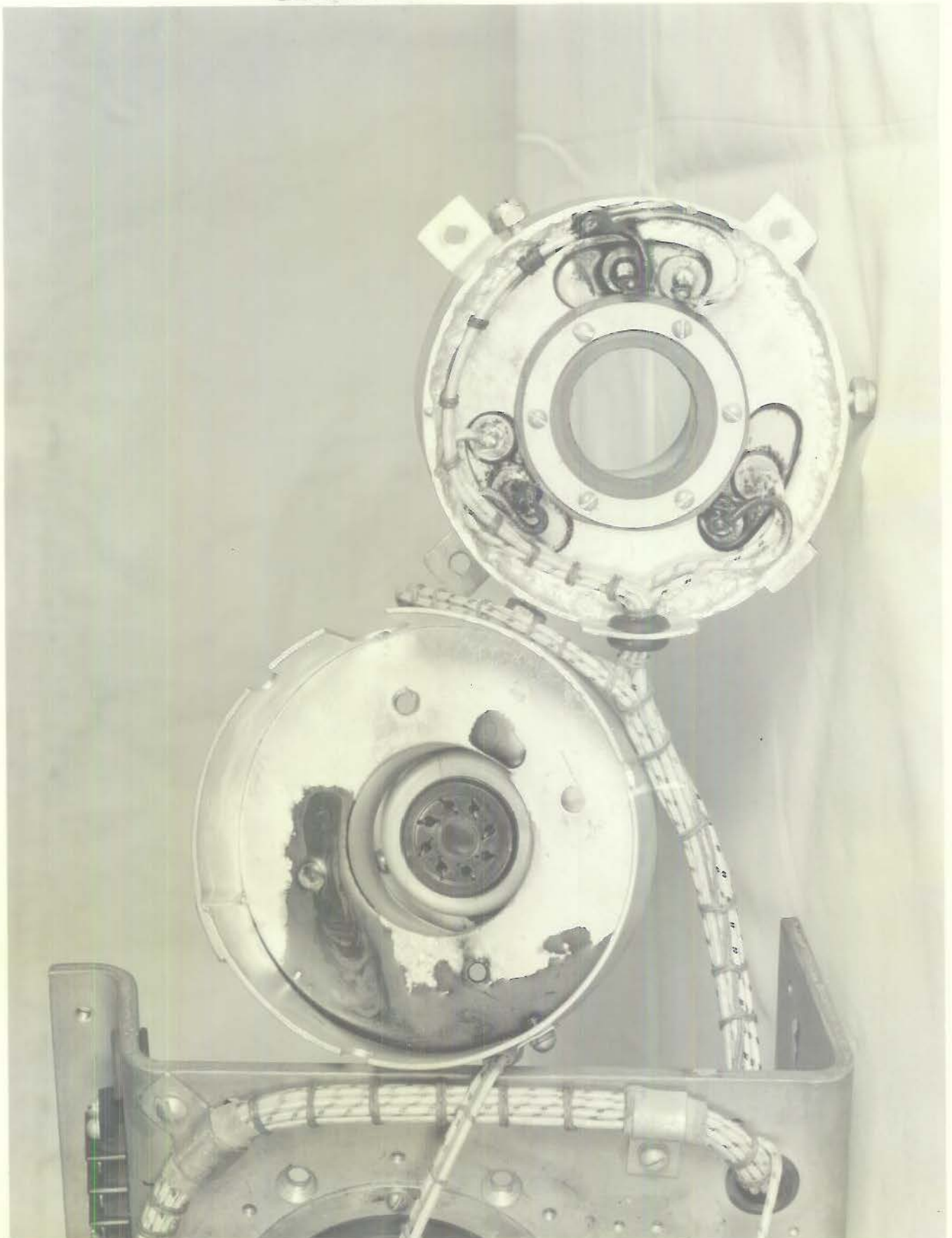


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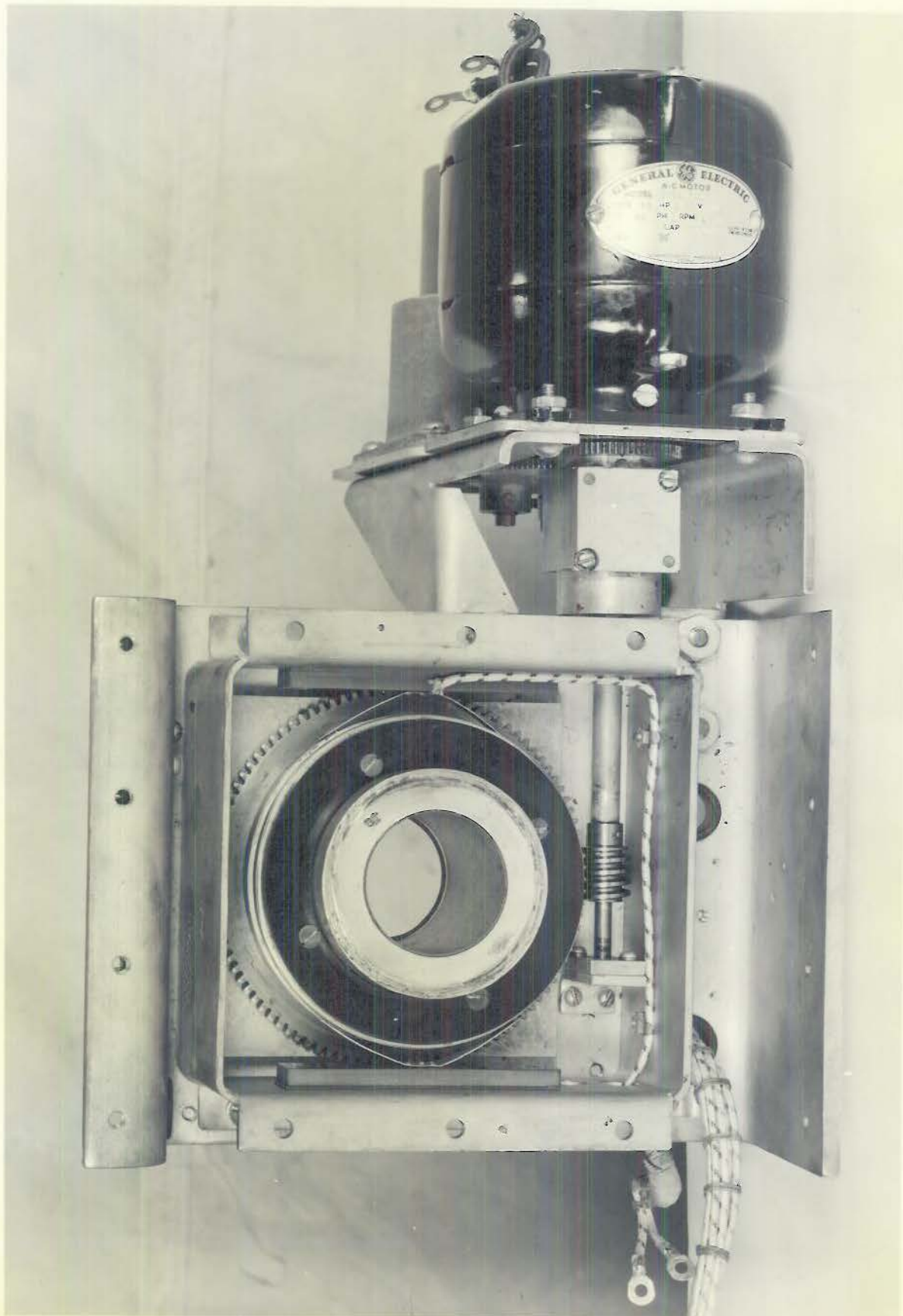


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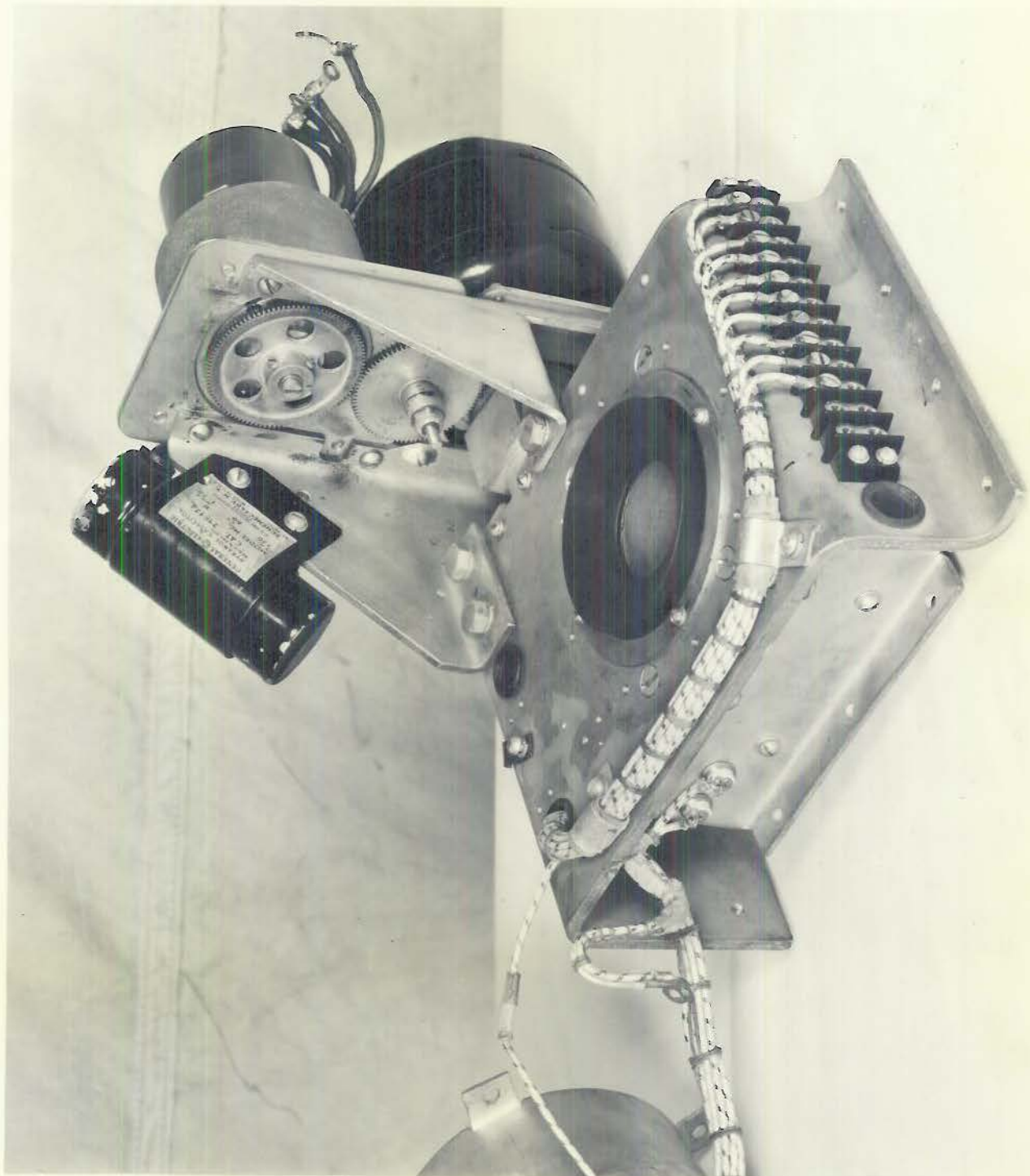


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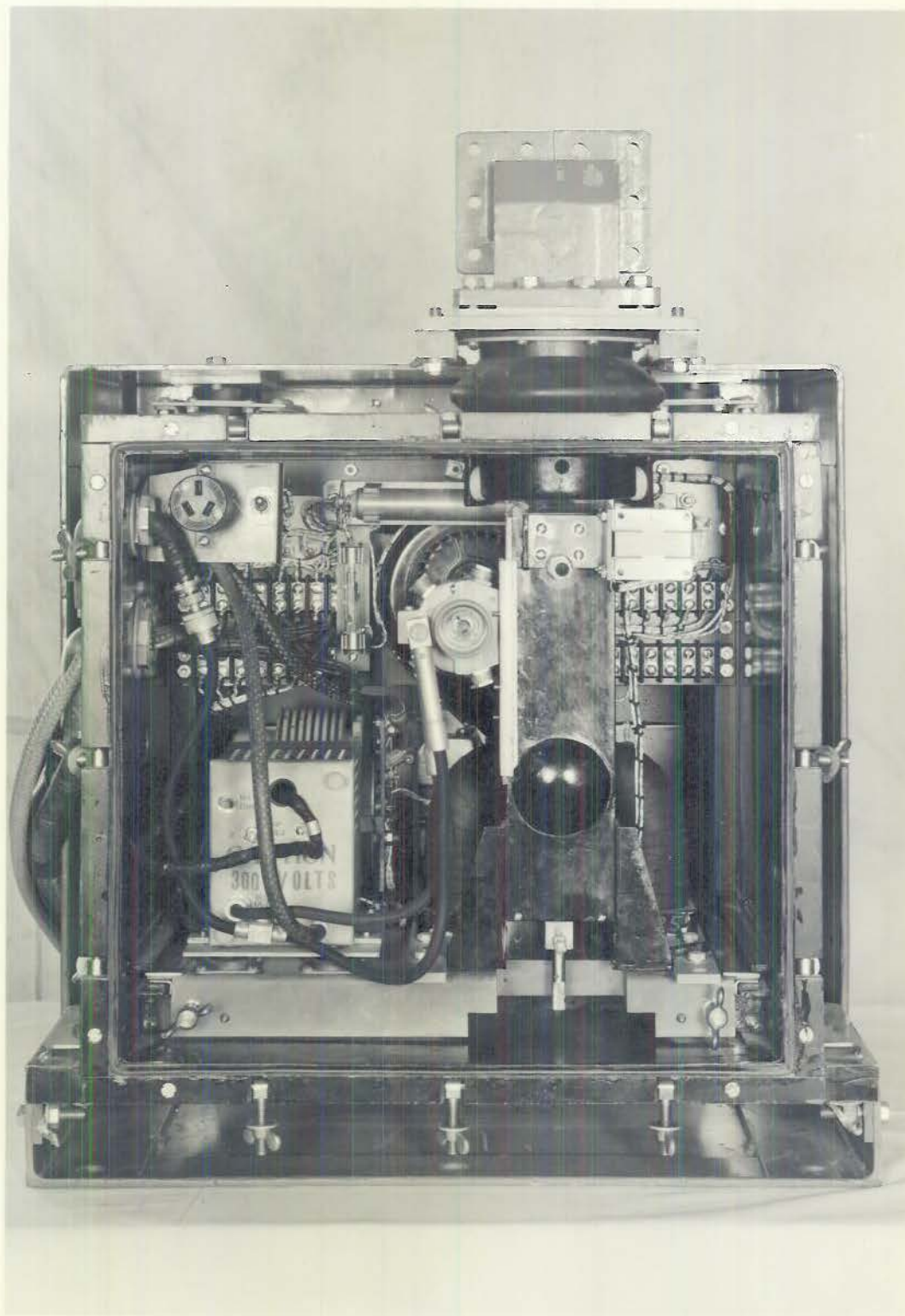


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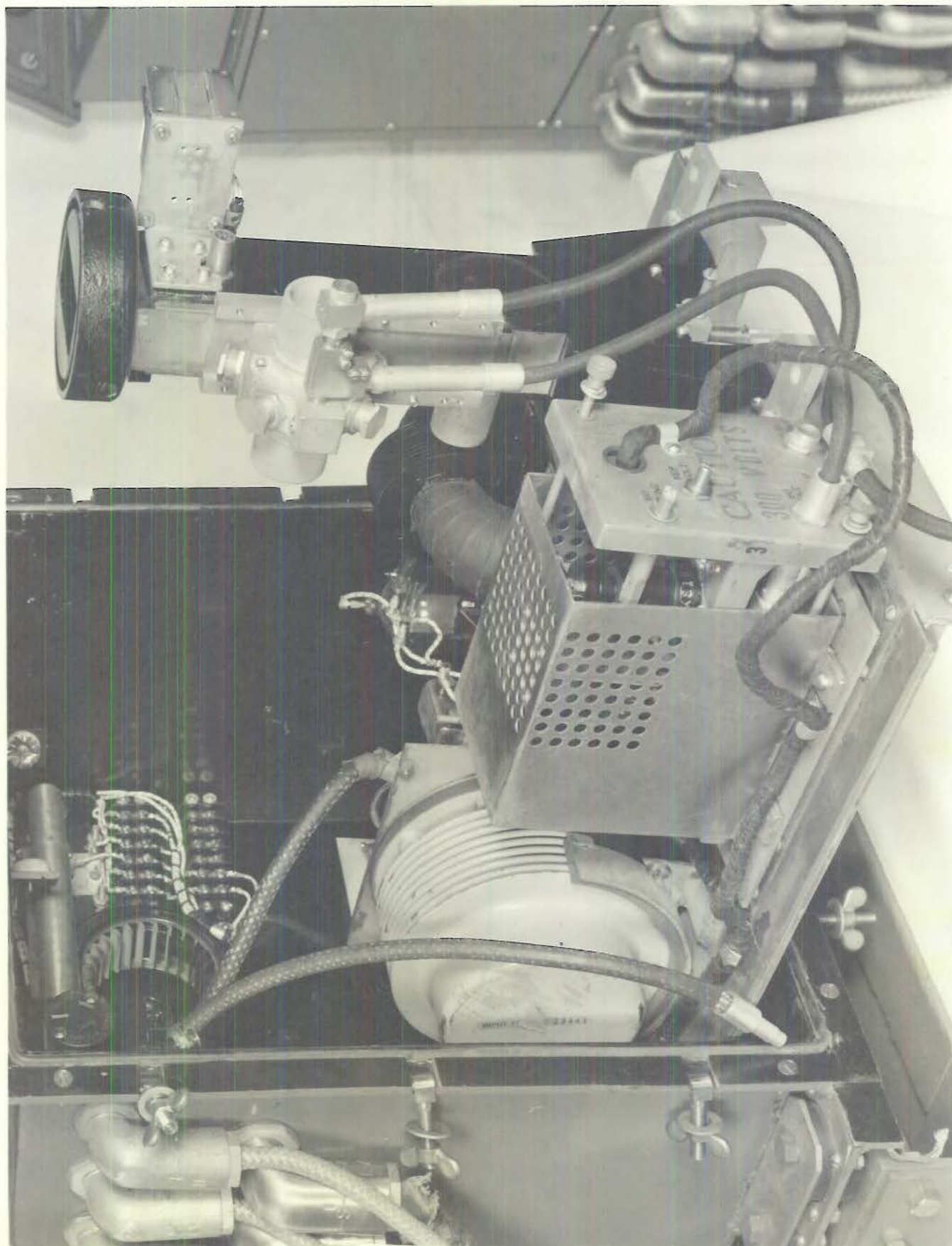


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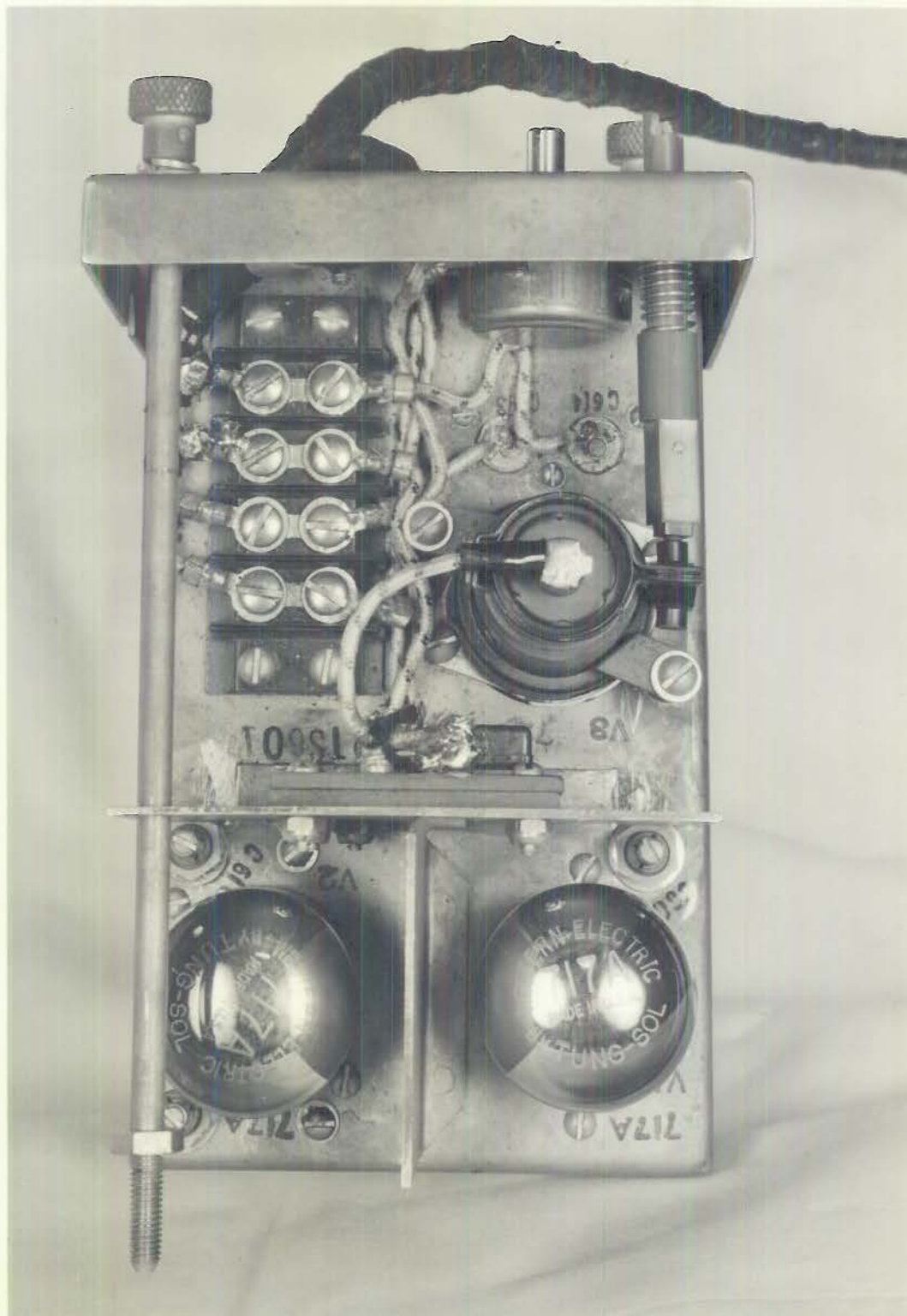


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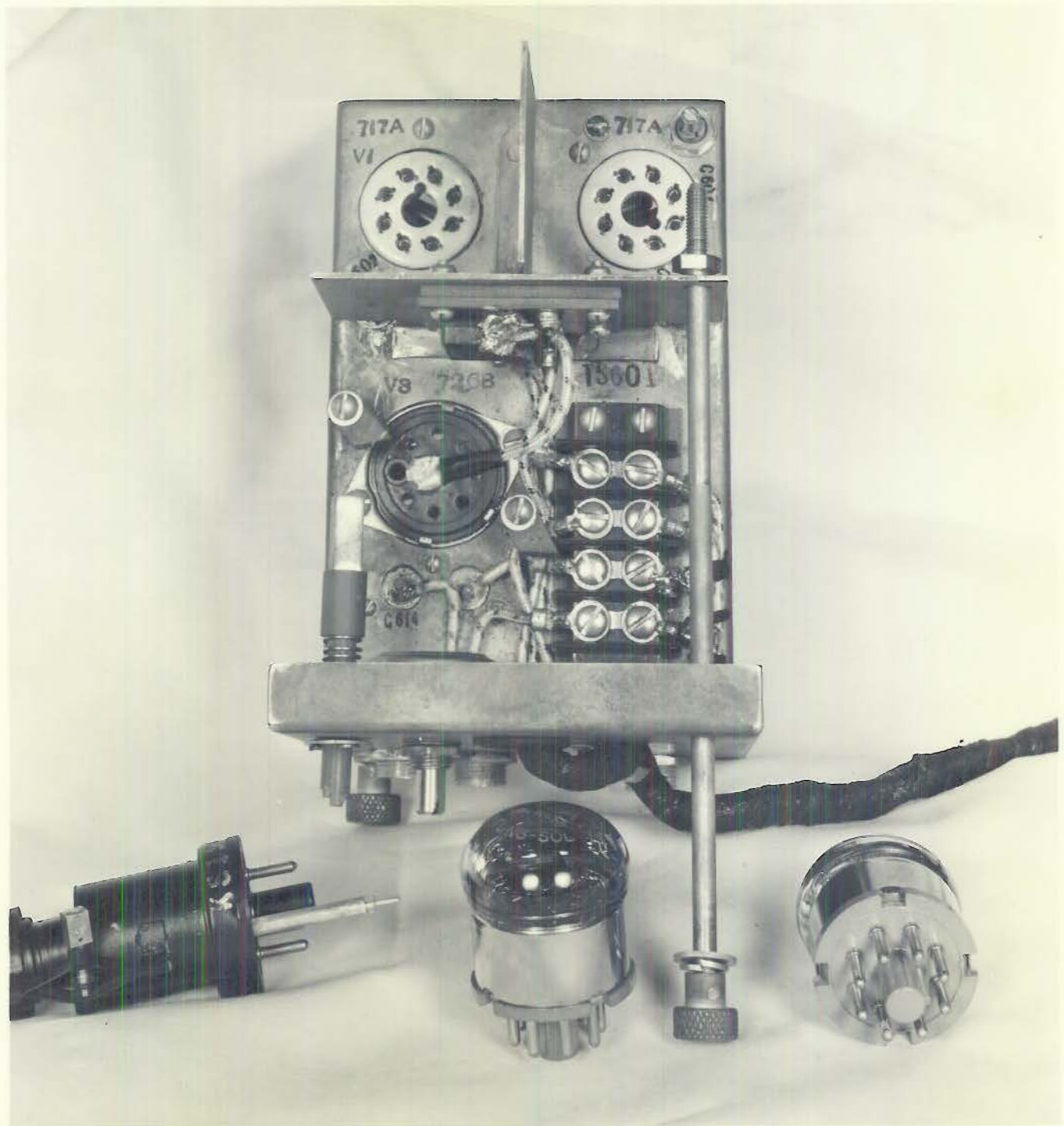


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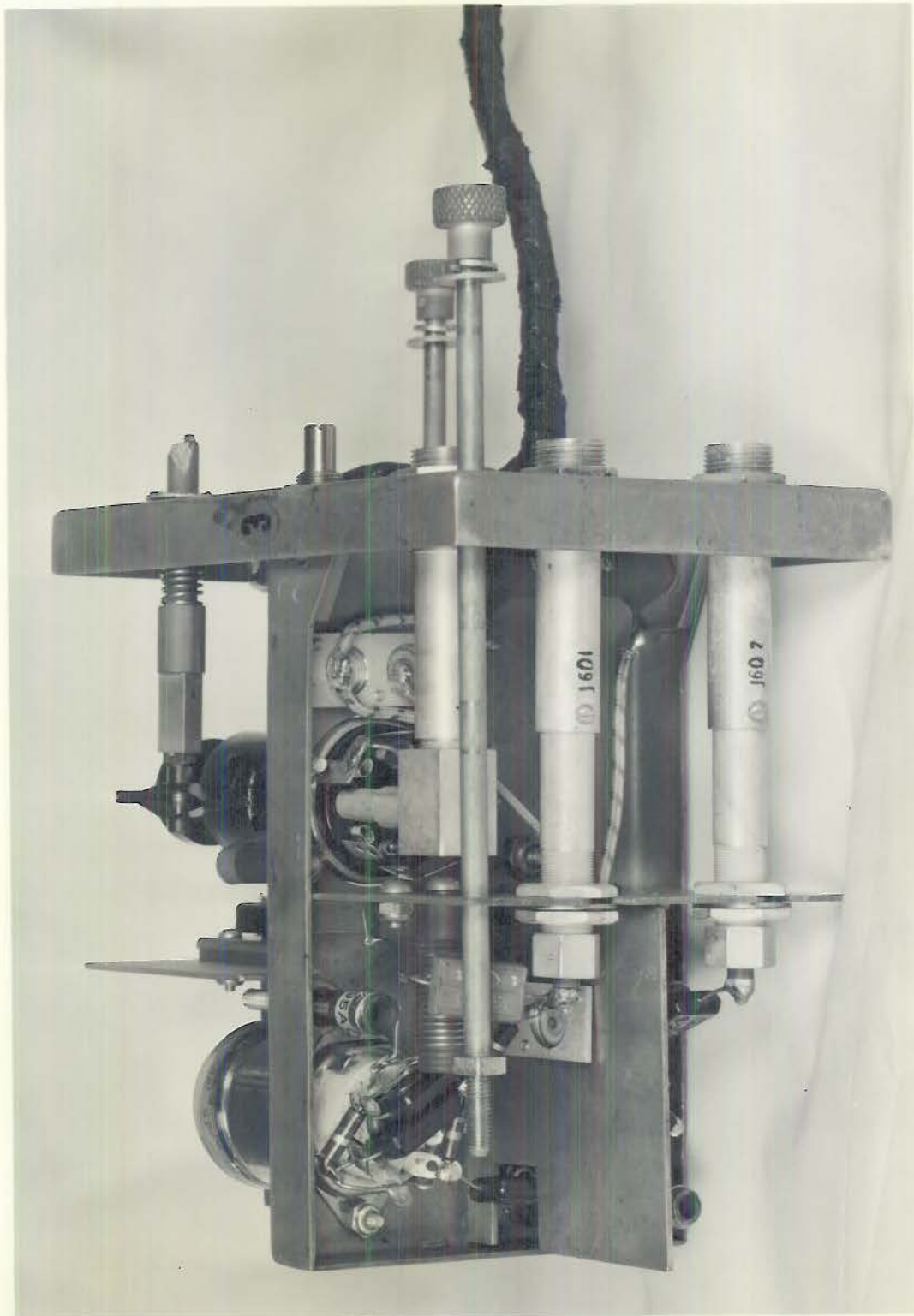


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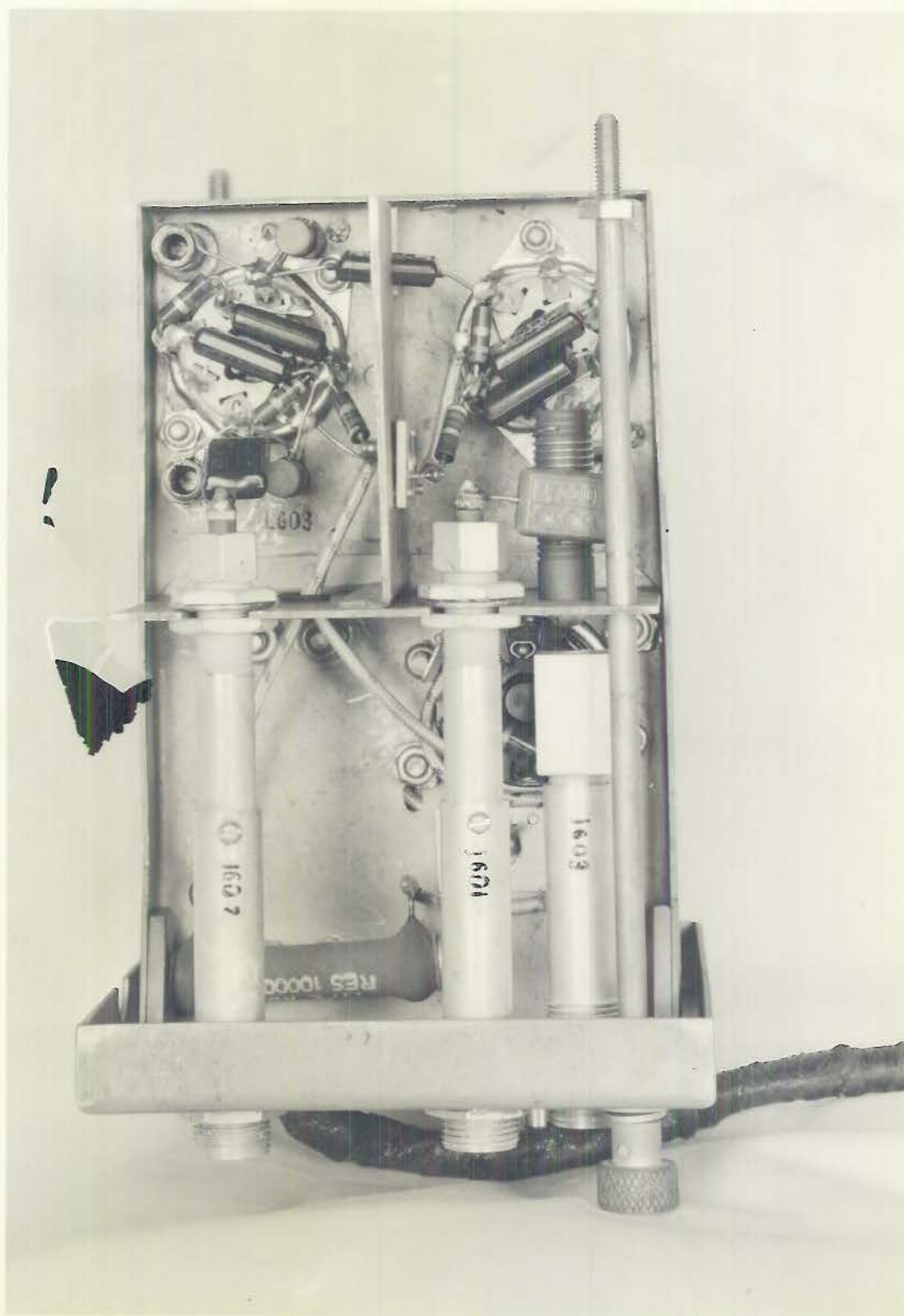


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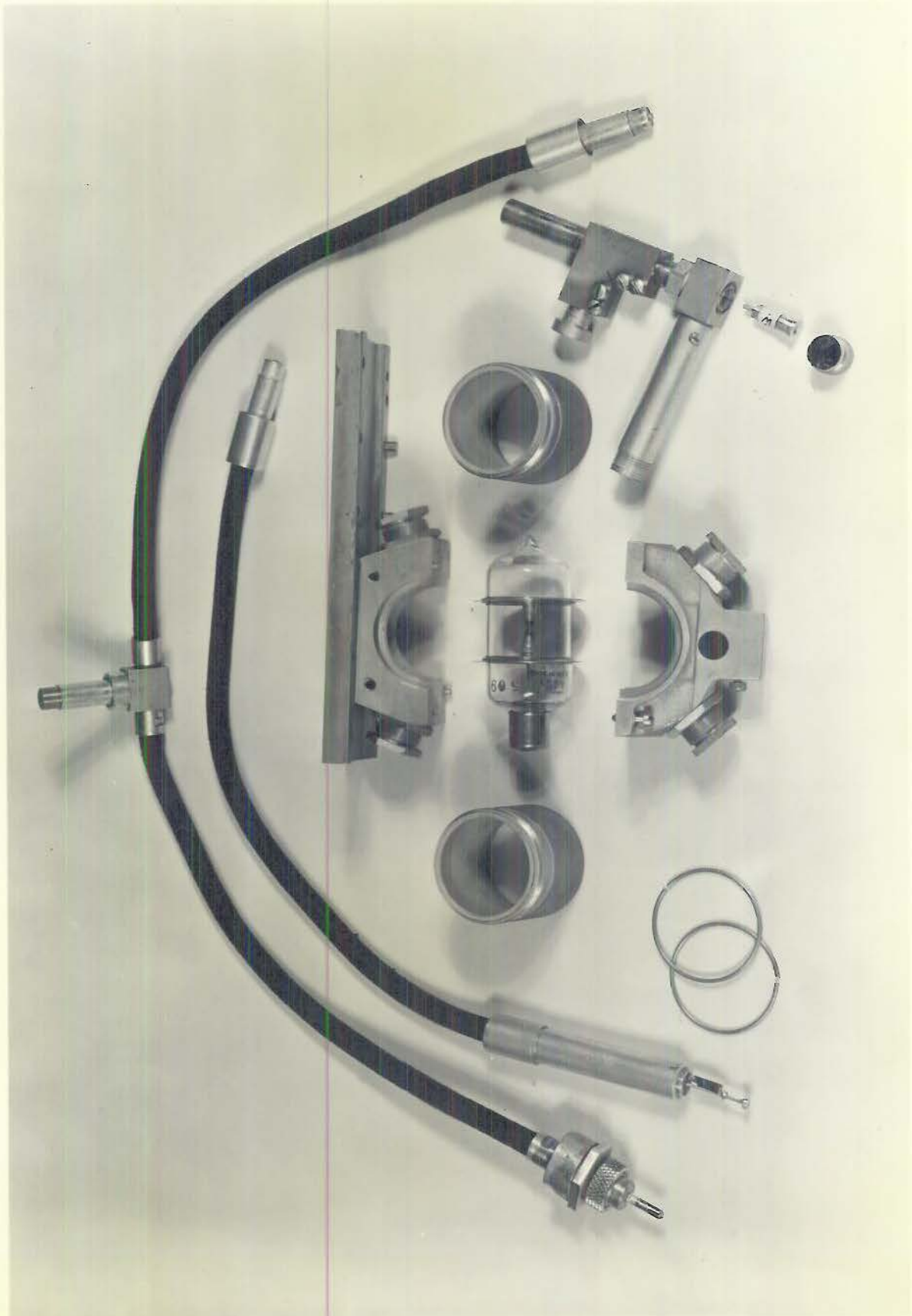


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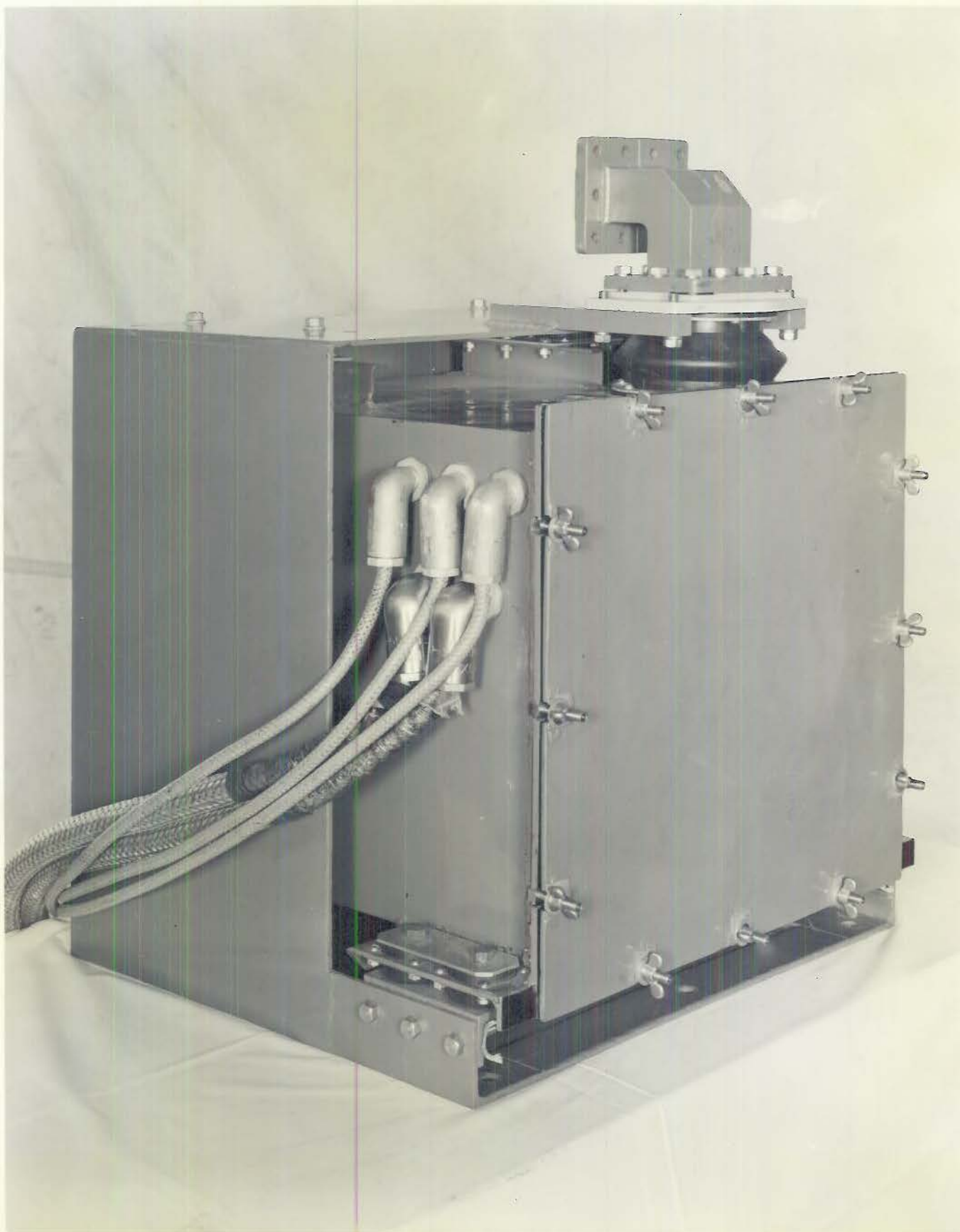


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PLATE 214 SEC3

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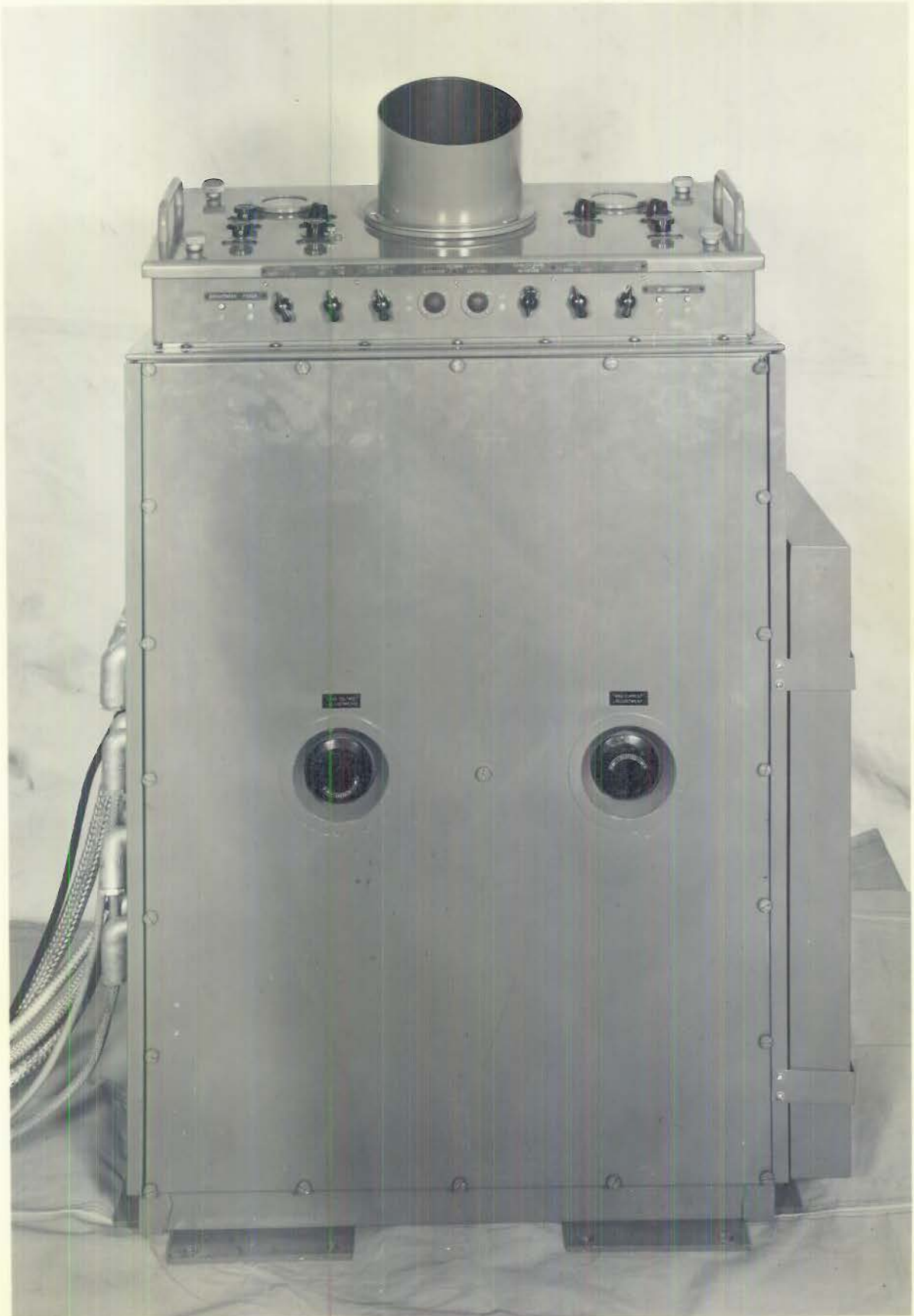


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PLATE 216 SEC.3

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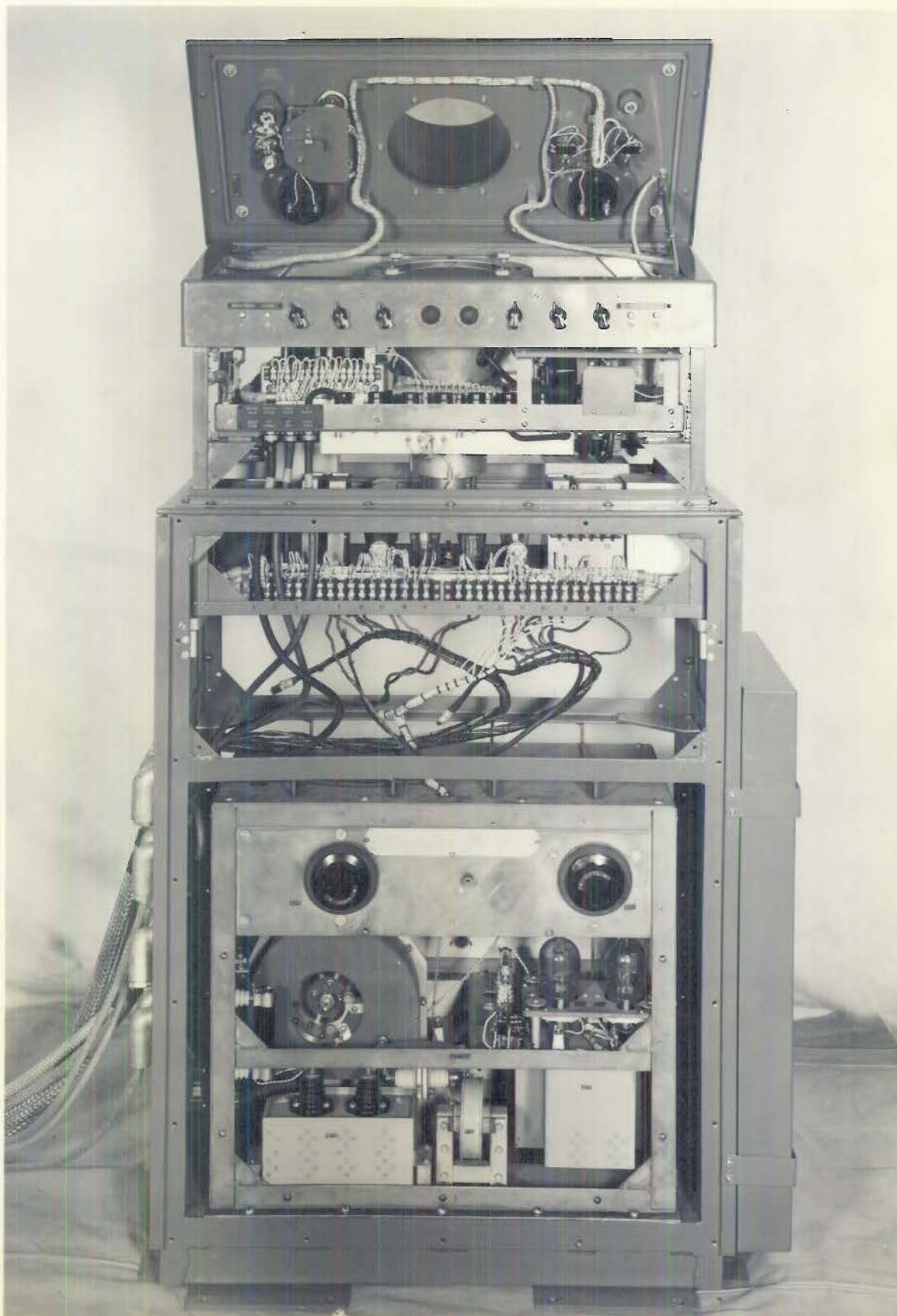


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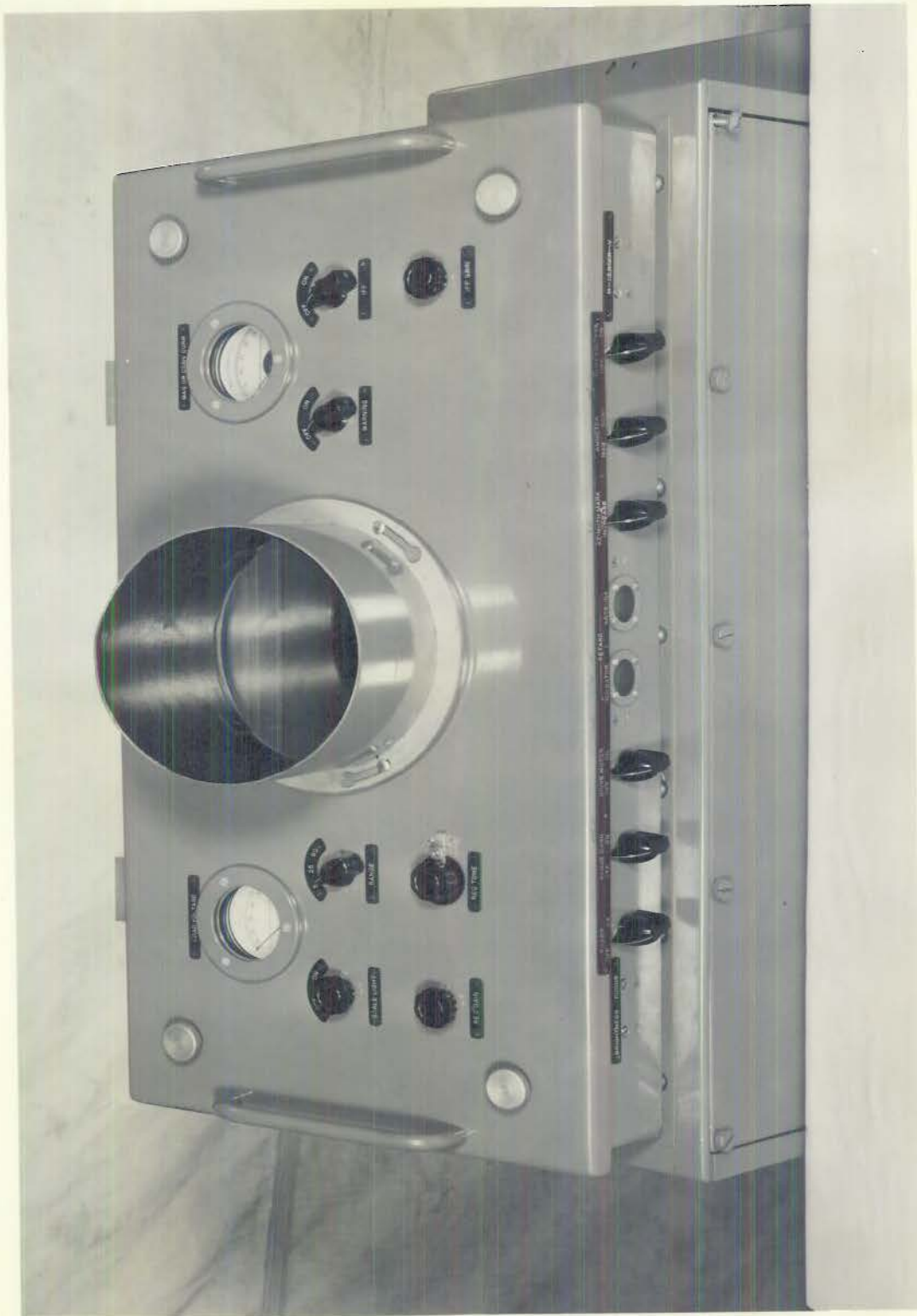


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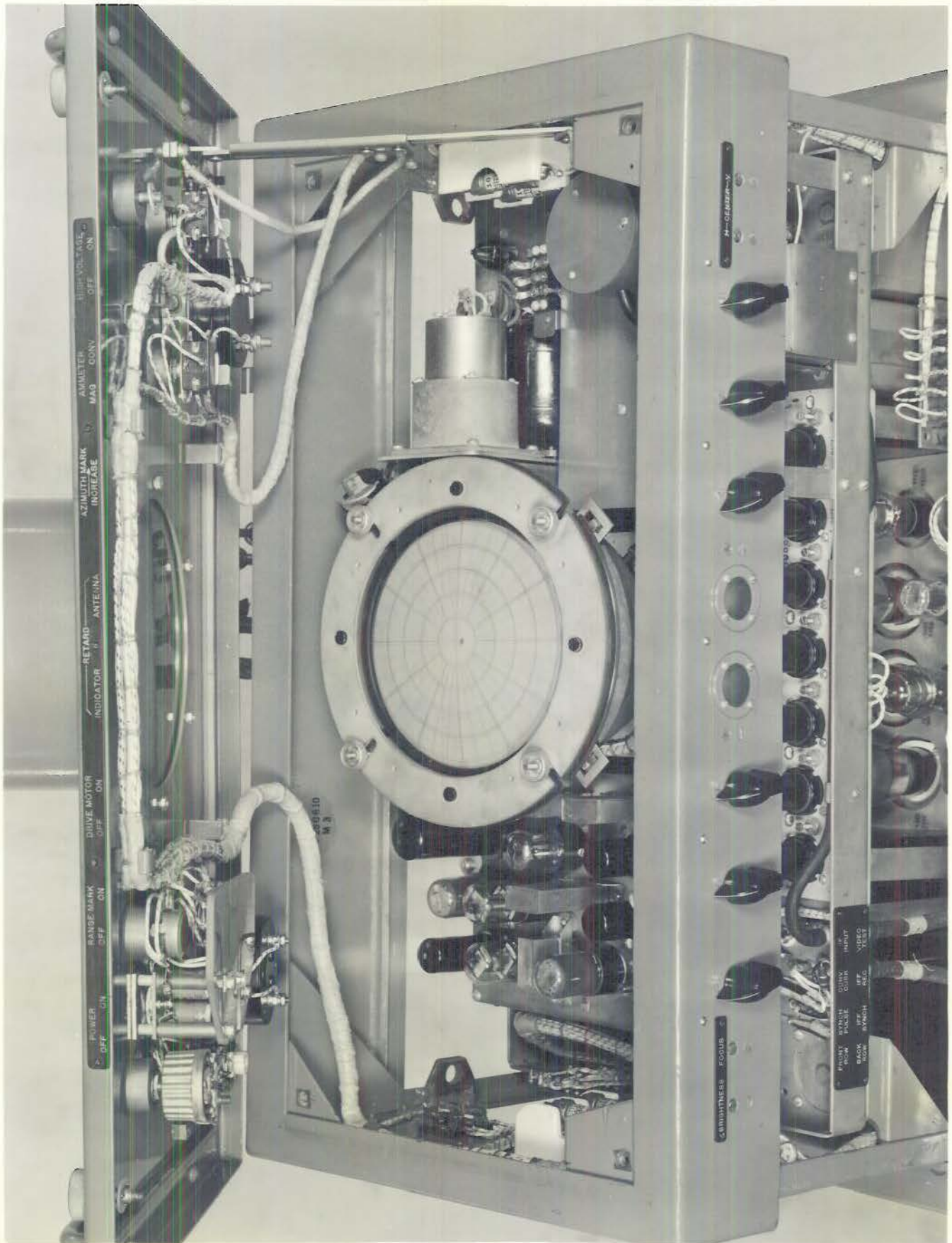


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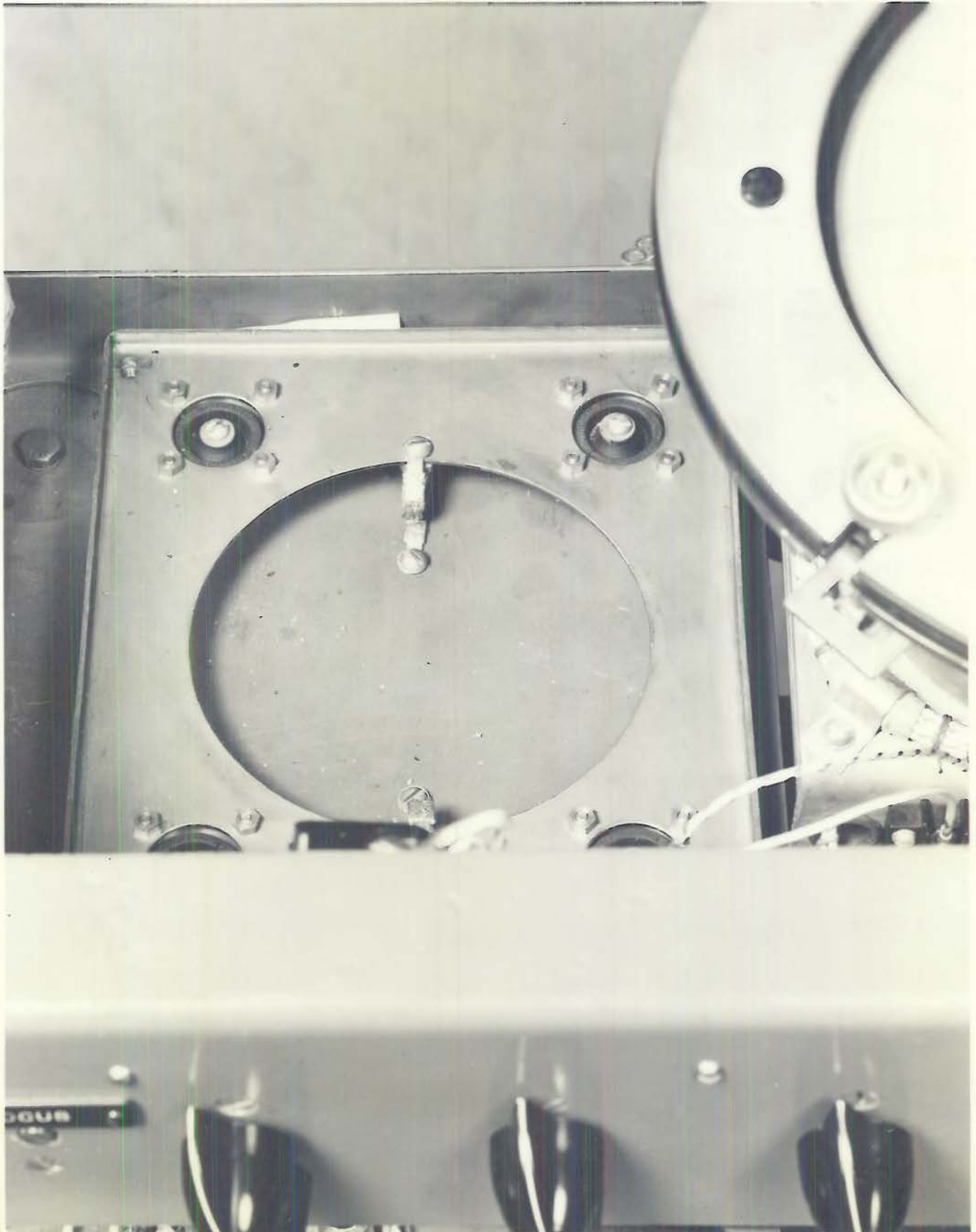


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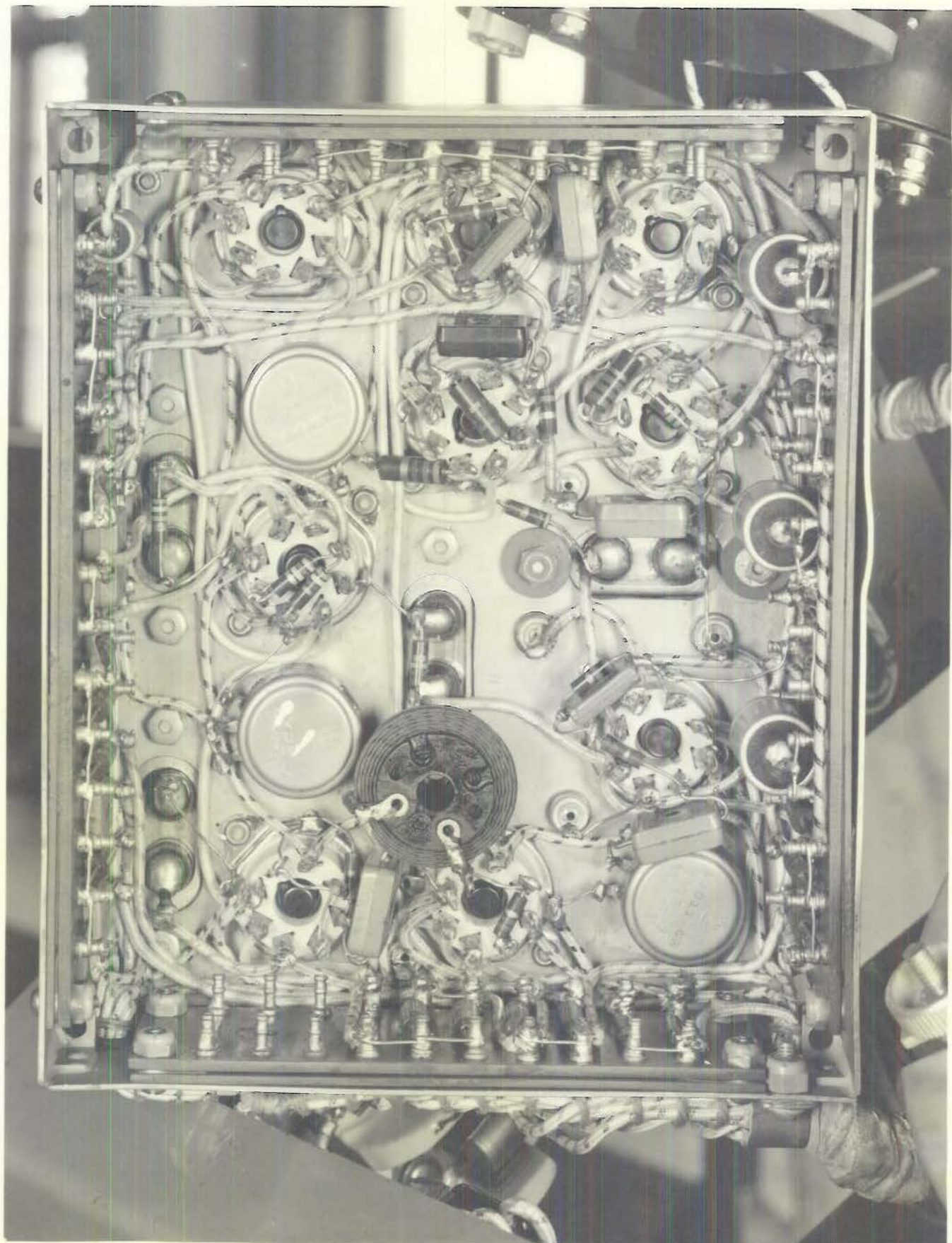


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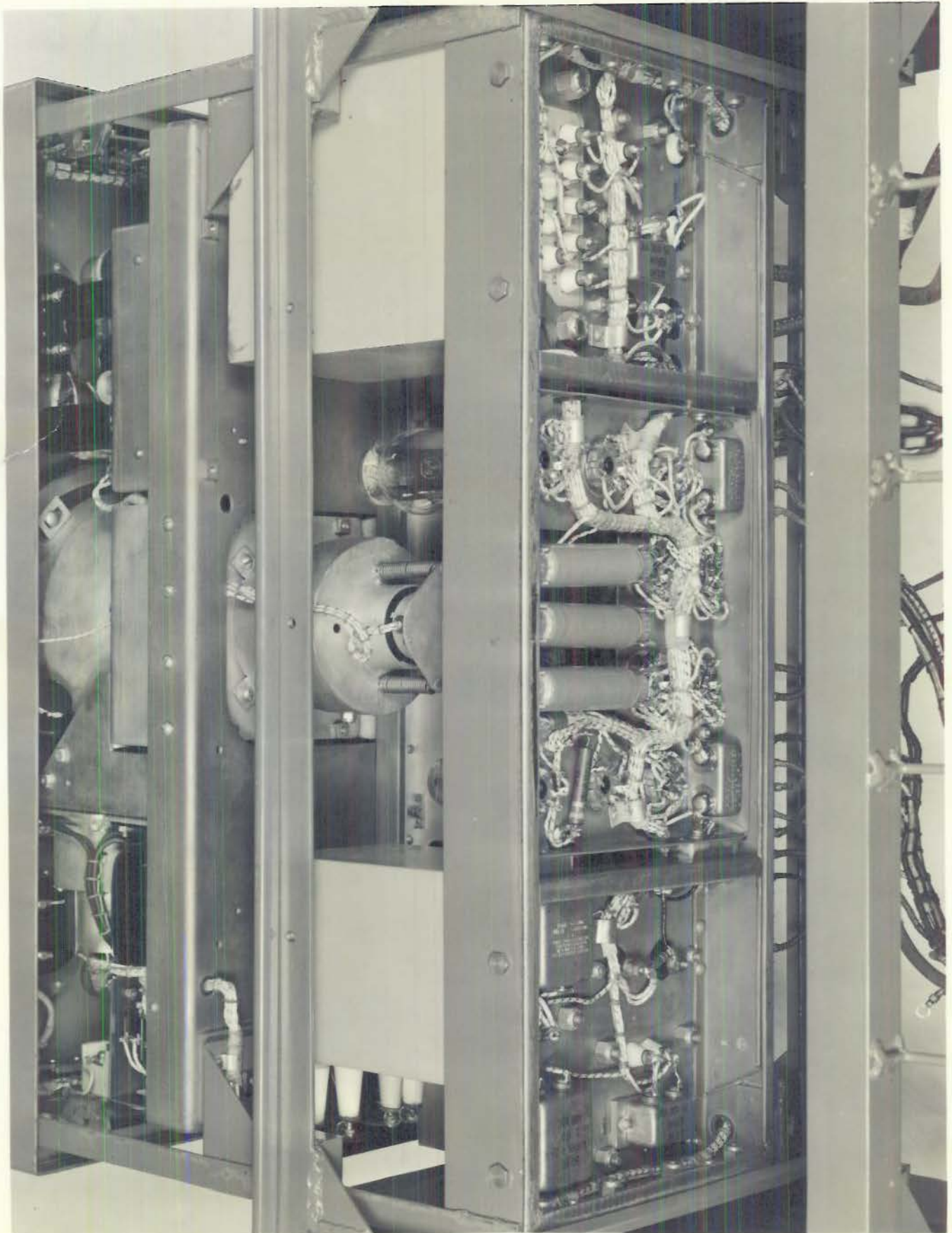


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