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Sixth Partial Report on the Precipitation-Static Problem

NAVAL RESEARCH LABORATORY
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ABSTRACT

Facilities for the study of precipitation-static and other bad weather or northern flying problems are described. A special hangar has been built at Minneapolis, with equipment for hoisting large planes twenty feet from the floor and raising them to high electrical potentials for study of various electrical phenomena affecting aircraft. Two planes in which recording and other types of specialized equipment have been installed are in use at present in a precipitation-static research program. The planes are equipped with charging apparatus that permits them to be charged to over 250,000 volts while in actual flight.

INTRODUCTION

A. Authorization

1. This problem is authorized under Bureau of Aeronautics project order 832/43, dated 30 June 1943. The work is carried forward under the jurisdiction of the Joint Army-Navy Precipitation Static Committee consisting of:

Comdr. L. V. Berkner	Bureau of Aeronautics
Major T. S. Banes	Hq. Army Air Forces
Capt. C. I. Stafford	OCSigO
Lt. J. H. Willox	Bureau of Aeronautics
Mr. J. Weichbrod (Secretary)	OCSigO

B. Statement of Problem

2. The object of this report is to outline the special facilities available at Minneapolis for the investigation of aeronautical problems associated with bad weather flying and other related meteorological problems in Northern country. Its purpose is to provide various interested military and other government activities with a detailed description of the facilities and airplanes available for research.

LOCATION

3. Minneapolis, Minnesota, the home of the University of Minnesota, is a thriving industrial city of the Northwest served by several railroad systems with excellent service to the South and West. It is distinctly a cold weather city and normally has much snow and ice in winter. The city is served by Mid Continent Airlines and Northwest Airlines. This latter, which has its main service facilities centralized at the Wold-Chamberlain Field, is interested in all problems involving bad weather flight and has been of great assistance to the military services in the precipitation static investigations and in research on prevention of icing on aircraft. The Army Ice Research Base is located at Wold-Chamberlain Field. Minneapolis is the southern terminus of the Air Transport Command route to Alaska, operated in part by the Northwest Airlines. In general, one may conclude that Minneapolis is a center of northern and winter weather commercial air operations.

THE HANGAR LABORATORY

4. The Bureau of Aeronautics has recently built a large hangar with a 220 foot span, 130 feet deep and being clear 65 feet from the floor. Large roof trusses are provided and it is practical to suspend planes as large as the B-17 within the hangar for experimental purposes. The hangar is provided with two large wings, one for the maintenance crew and the other wing equipped with shop, laboratory and office facilities to carry on technical investigations. In one corner of the hangar is installed high voltage equipment, produced under contract with the Electrical Engineering Department of the University of Minnesota, that is capable of giving up to one million volts and up to ten milliamperes direct current. The whole equipment

may be re-connected as an impulse generator providing either high current or high voltage. With this change, the apparatus will provide transient high voltages and up to about fifty thousand amperes. The equipment, together with an especially large hangar with exceptional overhead clearance is suitable for the study of lightning hazards, both to plastic airplanes or to gliders, and to various airplane parts that might be subject to lightning discharge. Physiological studies of the influence of lightning on pilots in flight could also be carried on if desirable.

5. In order that direct radio communication for tests in precipitation static may be made in the vicinity of Minneapolis, a radio ground station has been incorporated in the hangar. The equipment is located in a small room at the top of the southeast door housing and is ideal for ground station operations since it is about 75 feet from the ground and affords excellent locations for the antenna installations. The station is equipped with standard army aircraft radio transmitters and receivers. These include the SCR 287 liaison transmitter and receiver covering a frequency range of 200 Kc to 12.5 Mc with power output of approximately one hundred watts; the SCR 274N transmitter and receiver which covers the band from 200 Kc to 9 Mc with power output of approximately 20 watts; and the SCR 522 Ultra High Frequency command transmitter and receiver which is crystal controlled and covers the band from 100 Mc to 156 Mc. With this representative radio installation, radio communication of any type can be checked during flights without depending on standard airway stations.

PROJECT AIRCRAFT

6. Two airplanes are assigned to the Minneapolis project by the Army Air Forces for use in precipitation static and allied problems. A Mitchell medium bomber B-25-D, manufactured by the North American Aviatión, Inc., has been in operation for several months and a Ventura RB-37 was received February 20 to expedite future work.

7. The entire operation to date has been conducted in a North American B-25-D, Mitchell mediùm bomber. This aircraft is a twin engine, mid-wing monoplane equipped with a conventional tricycle landing gear. It is powered by two 1750 HP Wright model R-2600 14 cylinder, double row engines. Fuel capacity of 970 gallons provides five hours range at cruising power plus one hour reserve. Normal indicated air speed is approximately 225 MPH at 60 percent power. The B-25 is a well designed combat aircraft with reliable flight characteristics. It has the usual high wing loading of all combat aircraft, and, of course, such wing loads dictate high approach and landing speeds. This factor limits the operation to weather conditions where visibilities are not below one-half mile. Maneuvering around an airport under conditions of poor visibility at speeds required by this machine often makes proper alignment with the landing strip very difficult. Since poor visibilities almost always accompany substantial snow falls the high landing speed must be considered in the selection of alternate airports, and this hasbeen a reason for cancelling some operations in areas where suitable landing strips were not available.

8. Operations in snow conditions are frequently accompanied by severe icing. Ice accretion on high performance, heavily loaded airfoils becomes

serious in much less time than the same accretion on a lightly loaded foil. This condition has not been directly responsible for the cancellation of flights, but has been a source of great concern to the crew. Moreover, it is felt that the carburetor de-icing system on this ship is not adequate. This statement is not meant to imply any criticism of the B-25 as a combat machine. Our experience with it has been generally good, and our opinions simply are based on the airplane as a research vehicle. It was felt that the addition of another airplane to supplement capabilities of the B-25 was desirable.

9. Because of some of the above outlined limitations of the B-25, another plane, an RB-37 is in the process of modification and soon will be operated in conjunction with the B-25. This RB-37 is also known as the Vega Ventura. Essentially it is a medium bomber version of the Lockheed Lodestar equipped with two 2000 HP Pratt-Whitney engines, model R-2800. Gasoline capacity of 815 gallons is being installed and will provide six hours range at cruising power. It would seem that this aircraft is ideally suited for the present research assignment. The wing loading is considerably less than that of the B-25 and the approach and landing speeds are correspondingly lower. It has an excellent carburetor de-icing system consisting of direct heat and alcohol. The large fuselage, open from nose to tail, provides ample room for research instrumentation and will allow easy access to all portions of the ship.

10. The two airplanes are being flown for the research project by pilots of the Northwest Airlines under an army contract. Chief Pilot John R. Galt and his assigned Co-pilot, Norman Hilson, have been very helpful in promoting the research already under way and have contributed a wholesome, practical, pilot's viewpoint to the research group. The airplanes are being maintained by a special maintenance crew of Northwest Airlines mechanics led by J. Earl Jones. This effective group of pilots and maintenance men have maintained and flown the airplane for most of the winter.

FLIGHT RESEARCH EQUIPMENT

11. The B-25 assigned to this project is equipped with various types of electrical devices designed to measure quantitatively the electrical phenomena associated with snow storms, rain storms, or thunderstorms. Plate 1 shows the location in the plane of units discussed in the following. It is anticipated the RB-37 will be similarly equipped in about two months.

A. Electric Field Indicators

12. The electric field measuring equipment used on the B-25 consists of two generating voltmeters, one of which is mounted on the belly just aft of the rear exit door (Plate 2); the other is mounted on top of the fuselage at about the same position (Plate 3). By the use of two of these devices, it is practicable to separate out electric fields due to a free charge on the airplane and those due to distributed free charge in nearby clouds. The principle of operation of these instruments is conventional, but there are some features incorporated in their design which are of interest. Each unit as mounted on the plane consists of the wind driven rotating vanes, an insulated electrode alternately exposed to and shielded from the electric field external to the

airplane, an insulated electrode inside the case of the instrument that is alternately exposed to and shielded from an auxiliary field electrode by internal rotating vanes operating in phase with the outside vanes, and a 1E5GP pentode amplifier. A six conductor shielded cable brings the amplified signal, the auxiliary voltage leads, and the necessary pentode connections into the interior of the plane.

13. The cables from the two units connect by means of Jones plugs to the Two Channel Rectifier Unit. This unit, in addition to the "A" and "B" supplies for the vacuum tubes, contains two 1G4 tubes used to rectify the signals from the pentodes, the auxiliary voltage supply with controls, a voltmeter to indicate the auxiliary voltage, and the gain controls for the pentodes. The auxiliary voltage supply is arranged so that the different voltages can be applied simultaneously to the two auxiliary field electrodes associated with the generating voltmeters; a selector switch enables the operator to measure either of these voltages with the voltmeter. The plate load of each pentode consists of a 0.5 megohm potentiometer, the center tap of which is coupled to the plate of the rectifier through a blocking condenser. The adjustment of this potentiometer varies the gain.

14. The output of the lower generating voltmeter rectifier is connected to the input of a one-stage D.C. cathode follower amplifier, the load of which consists of three 0-1 milliammeters in series with suitable padding resistance to total 1500 ohms. One of these meters is on the panel of the amplifier, one on the photo-observer, and one on the rear observer's panel. The output of the upper generating voltmeter rectifier is normally connected to a second current amplifier and the arrangement is such that connection can quickly be made to the amplifier driving the photo-observer milliammeter. As used at present, the instruments are calibrated so that full scale on the milliammeter represents an electric field of 1000 volts per cm. It will be noticed that the presence of a vacuum tube rectifier in the circuit causes the indicator to read "up scale" regardless of the polarity of the external field. The original purpose of the auxiliary field electrode was to correct this ambiguity. By the application of a sufficient auxiliary field voltage, the instrument could be made to read mid-scale at zero external field. In the presence of an external field of opposite polarity to the field caused by the auxiliary electrode,the instrument would read toward the left; if the external field were of the same polarity, the reading would be toward the right. Operated in this way, the instrument would be a 500-0-500 volts/cm. field indicator. It has been the experience of this group that the charge generated on the airplane by snow particles is practically always negative in sign; for this reason, the practice has been to "zero" the instrument at 100 volts/cm. by applying the proper auxiliary voltage. The arrangement is such that the needle of the meter reads 0.1 mA and the polarity of the auxiliary field is that of the external field when the airplane has a negative charge. Thus, nine-tenths of the full scale is available for indication of the field of the predominant polarity; if the needle dips below 0.1 mA the observer is warned that the charge on the airplane is changing in polarity. The auxiliary field also provides a very convenient means of checking the calibration of the instrument. A calibration check made by applying a known voltage to the auxiliary field electrode is independent of everything except the geometry of the generating voltmeter itself.

15. The response of the device was checked using the high voltage equipment of the Naval Research Laboratory, Washington, D. C. and it was found to be essentially linear over the entire range of the instrument. The frequency response is flat from 30 to 150 electrical cycles per second, which corresponds to 15 to 75 mechanical revolutions per second of the vanes.

16. The instrument as described has given remarkably stable and reliable operation during six months of aircraft use with practically no attention from members of the group. A circuit diagram of the generating voltmeter heads and rectifier units is given in Plate 4. The cathode follower current amplifier is shown in Plate 5.

B. Faraday Cage

17. Installed on the nose of the plane is a Faraday cage adapted to measure the free charge on snow or rain as the airplane sweeps through the precipitation (see Plates 6 and 7). With a knowledge of the airspeed and volume swept up in a given time and the weight of the precipitation swept up, it is possible to evaluate the charge resident on each precipitation particle. This is of the utmost value in the interpretation of electrical and meteorological phenomena. In a somewhat similar manner the currents charging an insulated plate or "patch" mounted on the nose of the airplane as it flys through precipitation are important in interpreting meteorological phenomena. Such a patch is shown in Plate 7.

C. Recording Equipment

18. The conditions under which precipitation static interference is encountered are, for the most part, so variable as to make recording of data by hand impracticable. Therefore, various types of semi-automatic recording have been considered.

19. Strip chart recorders are desirable because of the immediate availability of data in plotted form, but require amplifiers when used to record currents of the order of 100 μA or less. Since amplifiers would require maintaining extremely high insulation of the test circuits, this method of recording was not employed. The same disadvantage of securing high-sensitivity elements adaptable for aircraft use applies to recording string oscillographs which can provide as many as twelve or fourteen separate records on a single photographic sheet.

20. Voice recorders present an effective means of recording meteorological information, course or position, individual opinions on intensity of static in radio receivers, etc., but are not a solution to the problem of continuous recording of the electrical effects in static conditions. A Memovox disc recorder Model C-7 and an Armour Research Foundation Model 50 magnetic wire recorder are used for voice recording.

21. The photo-observer was chosen as the continuous recorder which could best be utilized for the problem since by proper shock mounting of the unit, sensitive microammeters readily available for use on the project could be mounted along with flight instruments for photo recording. Some of the electronic equipment used involves time constants of the order of one-half

second, so that a camera speed of about two frames per second has been chosen as most desirable. A 35 mm Bell & Howell camera, Air Corps Type A-4 with a one-inch f1.9 lens, was obtained. The camera speed has been adjusted to three frames per second, and has been used to record the data either in bursts of one frame per second or slower, or at continuous rates from three to twenty-four frames per second as desired. The photo observer is shown in Plate 8. A circuit diagram is shown in Plate 9.

D. Noise Measurement

22. Basic noise measurements are made with an RCA Model 312-B r-f Noise Meter, connected to read the noise signal in microvolts (usually at 300 kc) on the command antenna. The model 312-B Noise Meter is a 6-tube superheterodyne receiver with built-in calibration oscillator circuit for accurately adjusting the receiver gain. The receiver time constants can be selected to indicate either rms, or by changing a selector switch, the quasi-peak value of signal voltage. The installation of the noise meter and part of the photo observer is shown on Plate 10.

23. Noise measurements can also be made by means of output meters connected to the standard Signal Corps receivers in the airplanes. Particularly adaptable for this purpose is the BC-348, a locally controlled, 8 tube, 6-band superheterodyne receiver covering the frequency ranges of 200 kc to 500 kc and 1.5 to 18.0 mc, with provision for either manual or automatic volume control. Output measurements can be made on the receiver units of the SCR-522, a 4-channel crystal frequency controlled receiver covering the frequencies 100.08, 116.10, 126.18, and 155.70 mc.

24. Observations of the effect of static interference on ADF and shielded loop reception are made in the B-25 on dual installations of the radio compass SCR-269. One of these units has its shielded loop mounted on the top of the fuselage behind the navigator's compartment, and the other has the loop mounted on the under side of the bombardier's compartment, well forward of the propellers and other possible sources of large corona currents. The receivers for the SCR-269's cover three frequency bands, 200-410 kc, 410 to 850 kc, and 850 to 1750 kc, but are used primarily on the radio range band at 200-410 kc.

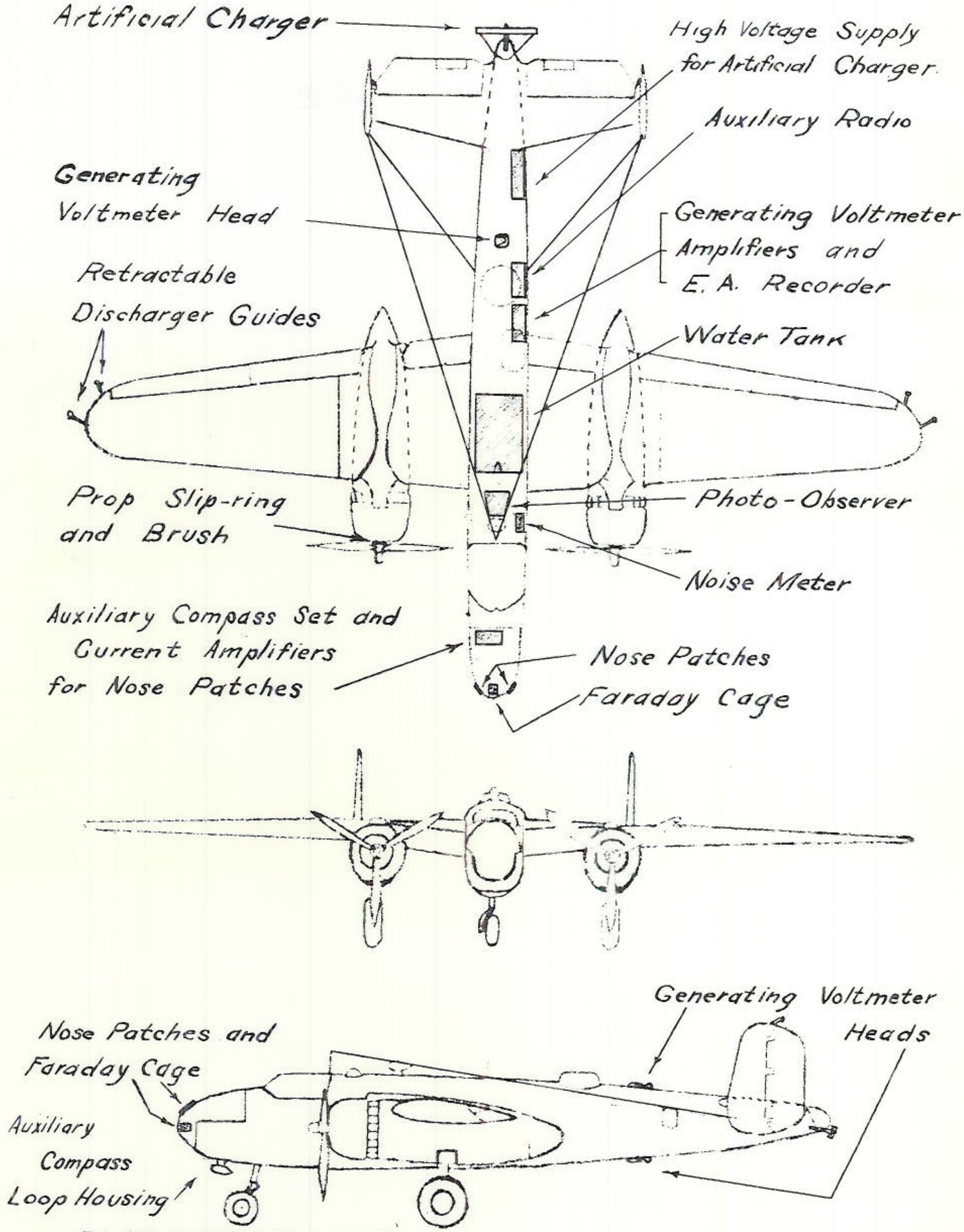
E. Retractable Dischargers

25. The Naval Research Laboratory has developed several types of electrical dischargers designed to bleed off static charge deposited on the airplane in flight. A series of six of these dischargers is arranged on the B-25 in such a manner that they may be retracted or extended in flight as desired by the operator in the airplane. Since these dischargers can be put into operation at will, comparisons of various combinations or types of wicks can be made under substantially constant conditions. The six dischargers are arranged and mounted as shown in Plate 11, two on each wing tip and one on each vertical fin. The retracting mechanism consists of an air tight cylinder and piston, connected to a pump by means of 1/4" aluminum tubing and suitable valves. The dischargers slide in a 1/2" tube which ends in a corona shield. The entire assembly is insulated from the plane and any currents from the wick holders can be measured. A typical installation is shown in Plate 12.

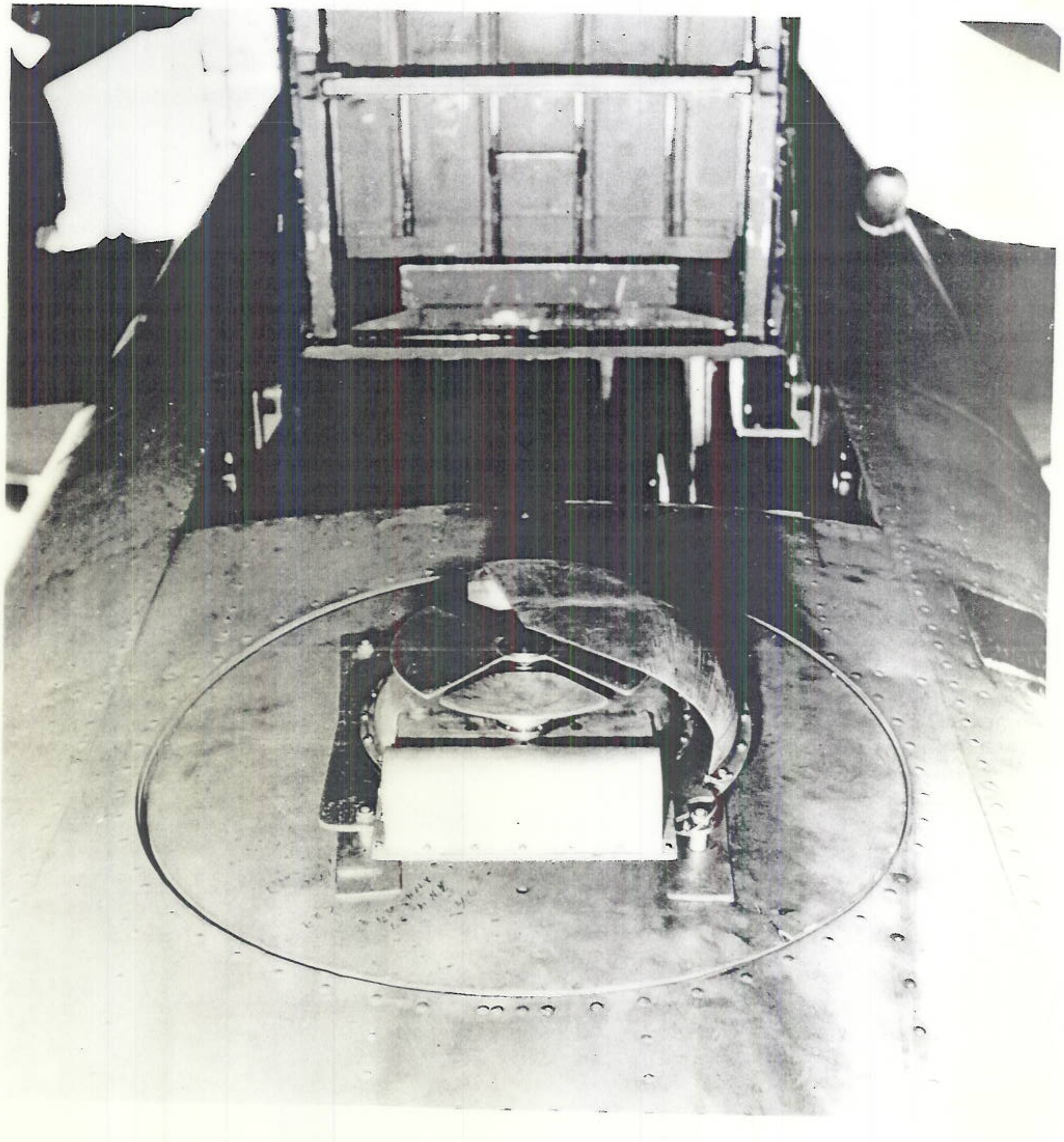
F. Artificial Charger

26. It has been found as a result of experiments at the Naval Air Station, Anacostia, and at Minneapolis that it is practicable to charge artificially an airplane in flight to potentials as high as 250,000 volts. The electric fields on the surface of the planes are sufficiently high under such conditions to cause sharp points to break into corona and thus to produce precipitation-static noises in the radio receivers. Thus, many preliminary tests of performance of radio equipment under precipitation static conditions may be made without spending hours searching for the correct meteorological conditions. The artificial charger also serves as a very efficient discharger under natural precipitation static conditions.

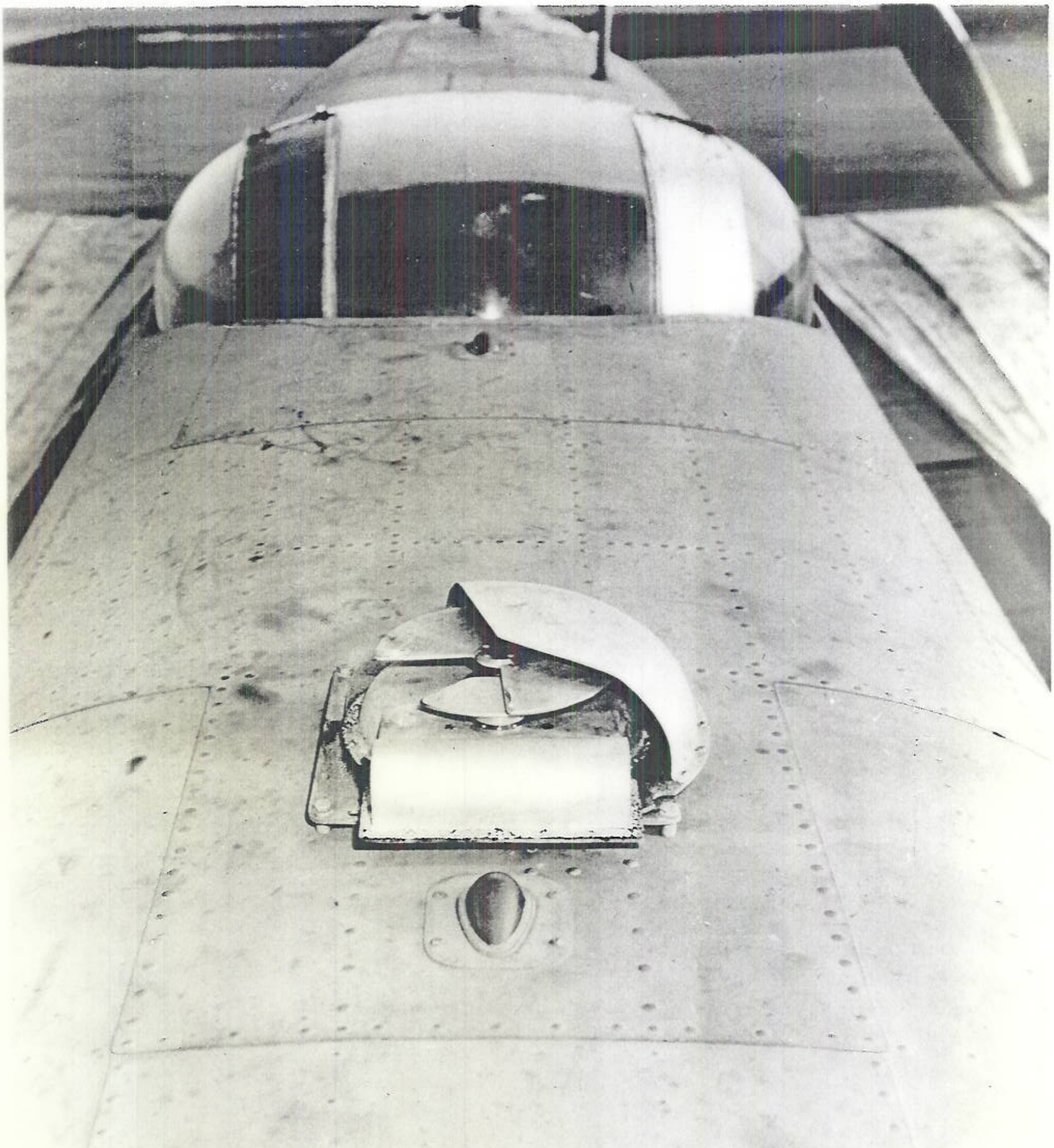
27. The artificial charger used on the B-25 airplane and shown in Plate 13 is essentially that described in NRL Report No. 0-2243. All high voltage wiring, including the voltmeter series resistor, is "shielded", and the shield tied directly to the low side of the high-voltage supply. The shield, therefore, must be insulated from "ground" on the plane to prevent shorting of the current meter. The primary purpose of this shield is to prevent any leakage currents from registering on the charging current meter. It also serves to suppress radio noise arising from sparking. The shield is so effective that with an inducing voltage of 15 kilovolts, no leakage is noticed on a meter on which one microampere is easily detected. A diagram of the electric circuit for the associated high-voltage equipment is shown in Plate 14.



PLAN SHOWING LOCATION OF INSTALLED EQUIPMENT



GENERATING VOLTMETER ON BELLY OF B25



GENERATING VOLTMETER ON TOP OF B25

PLATE 3

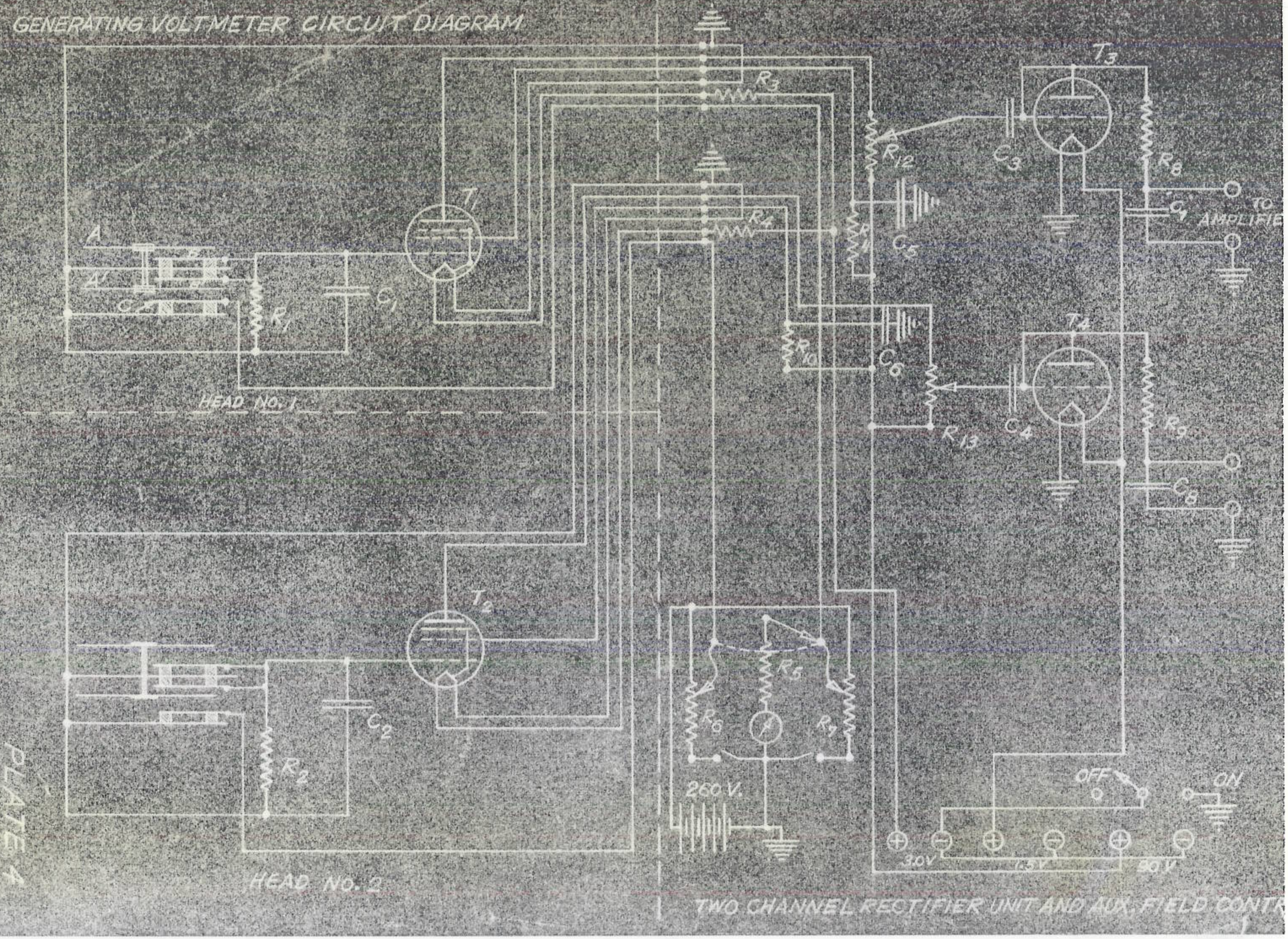
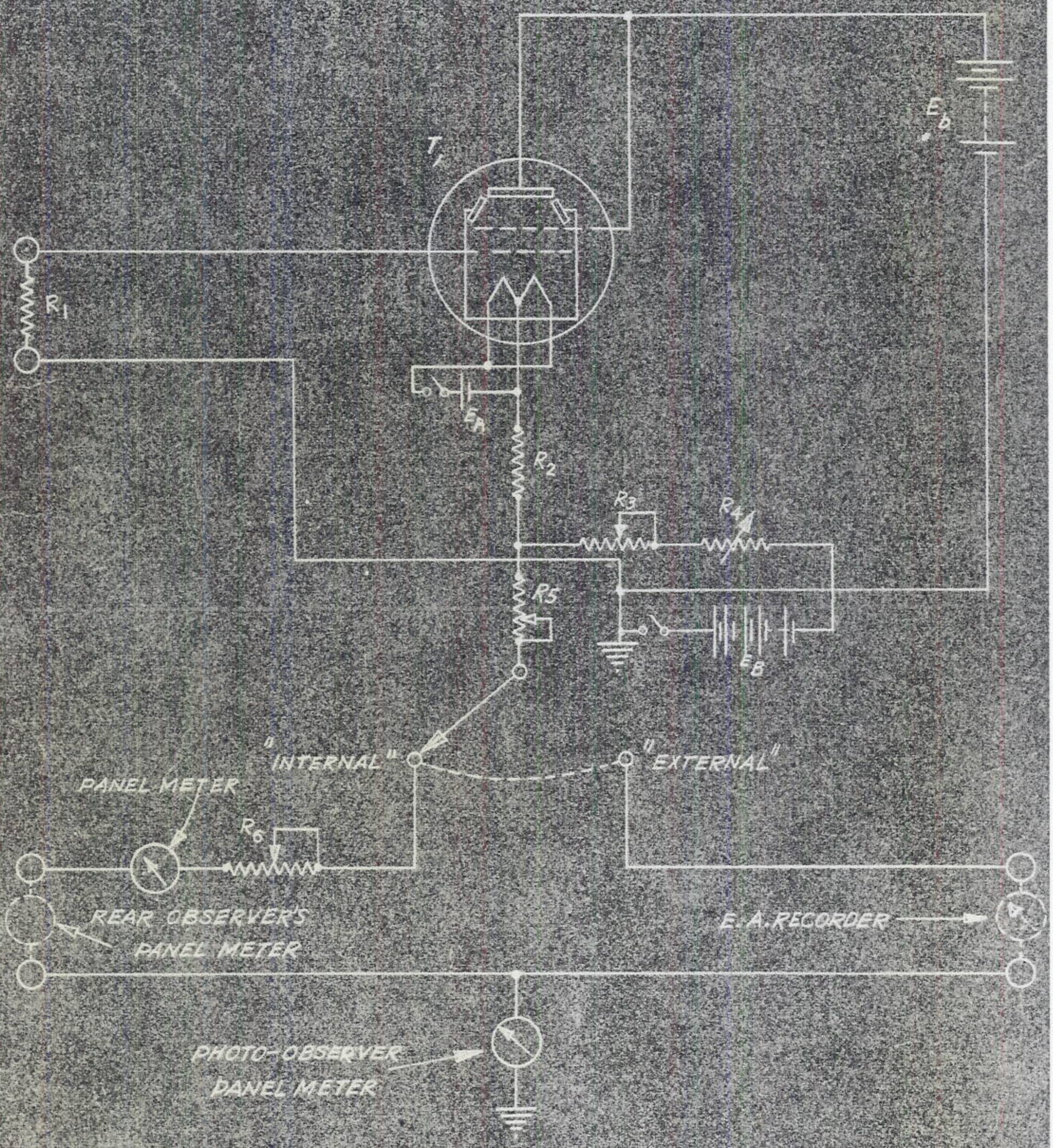

GENERATING VOLTMETER CIRCUIT DIAGRAM
A
A'
C
R_1
C_1
T_1
HEAD NO. 1
R_2
C_2
T_2
HEAD NO. 2
R_3
R_4
R_{12}
R_{11}
C_5
R_{10}
C_6
R_{13}
C_3
T_3
R_8
C_7
TO AMPLIFIER
C_4
T_4
R_9
C_8
R_5
R_6
R_7
260 V.
OFF
ON
30 V
13 V
30 V
TWO CHANNEL RECTIFIER UNIT AND AUX. FIELD CONTR

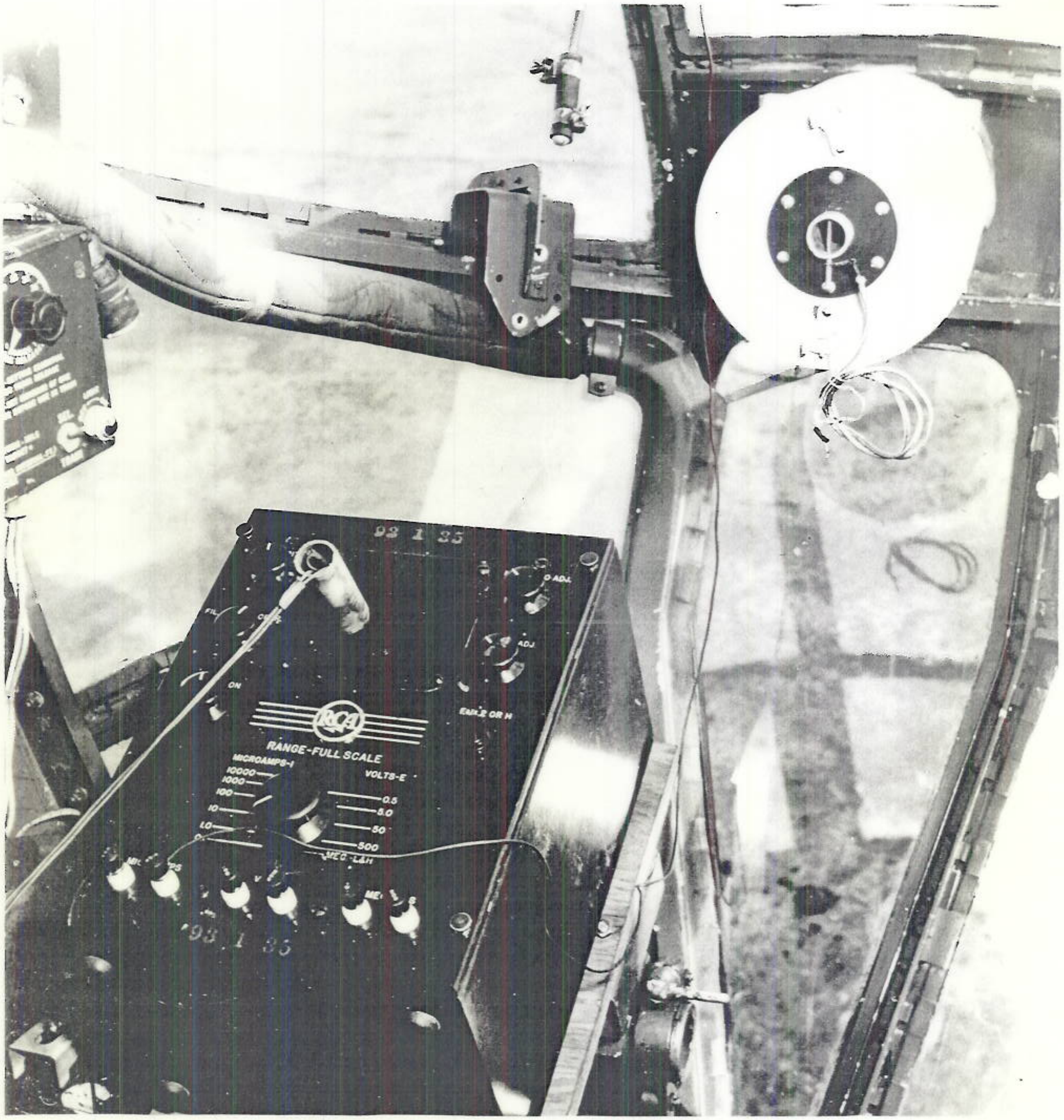
PLATE 4



CATHODE FOLLOWER CURRENT AMPLIFIER

PLATE 5

FARADAY CAGE AND INSULATED NOSE PLATE



SUPERSENSITIVE AMMETER FOR MEASURING
FARADAY CAGE AND "PATCH" CURRENTS.

PLATE 7

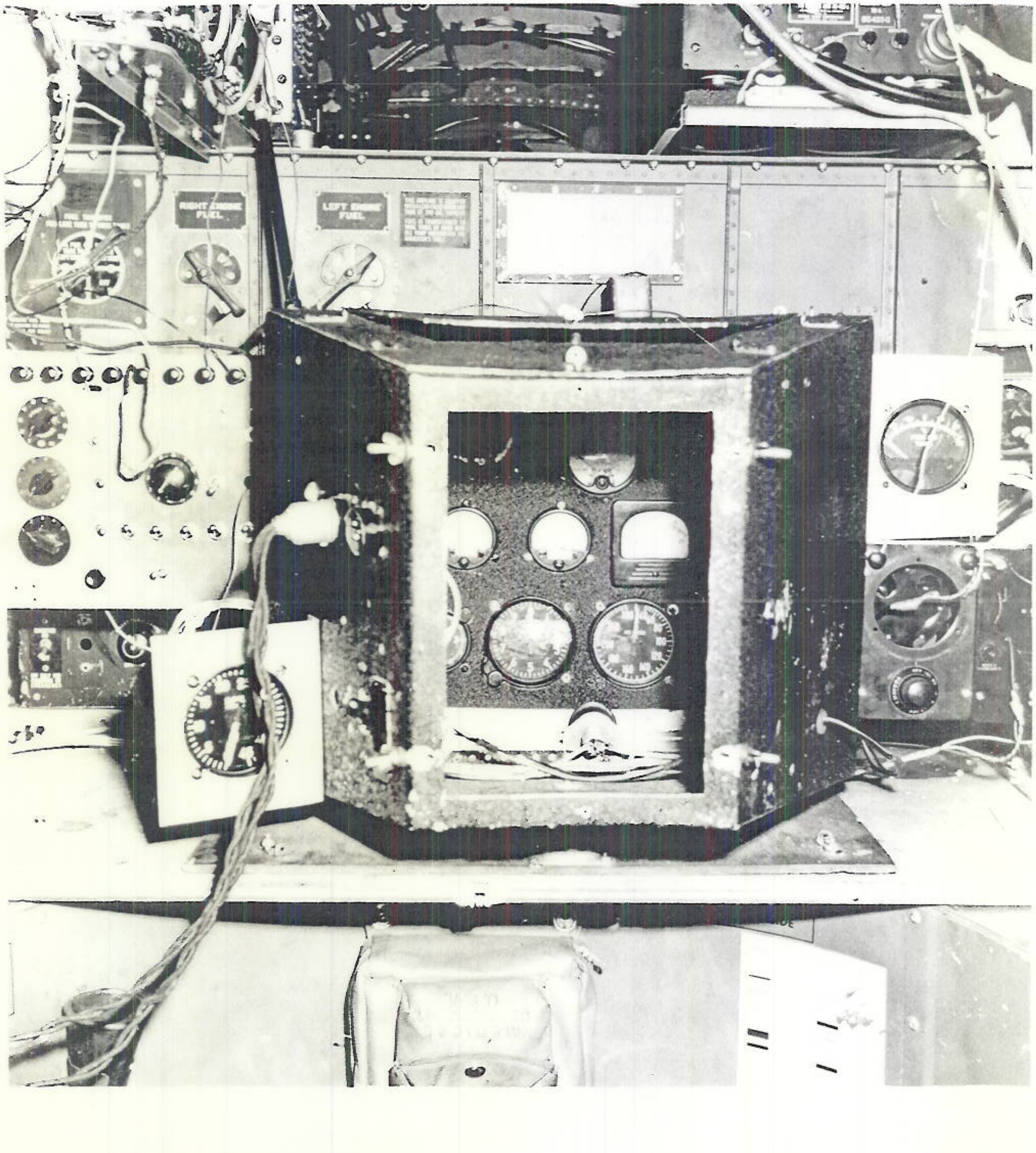
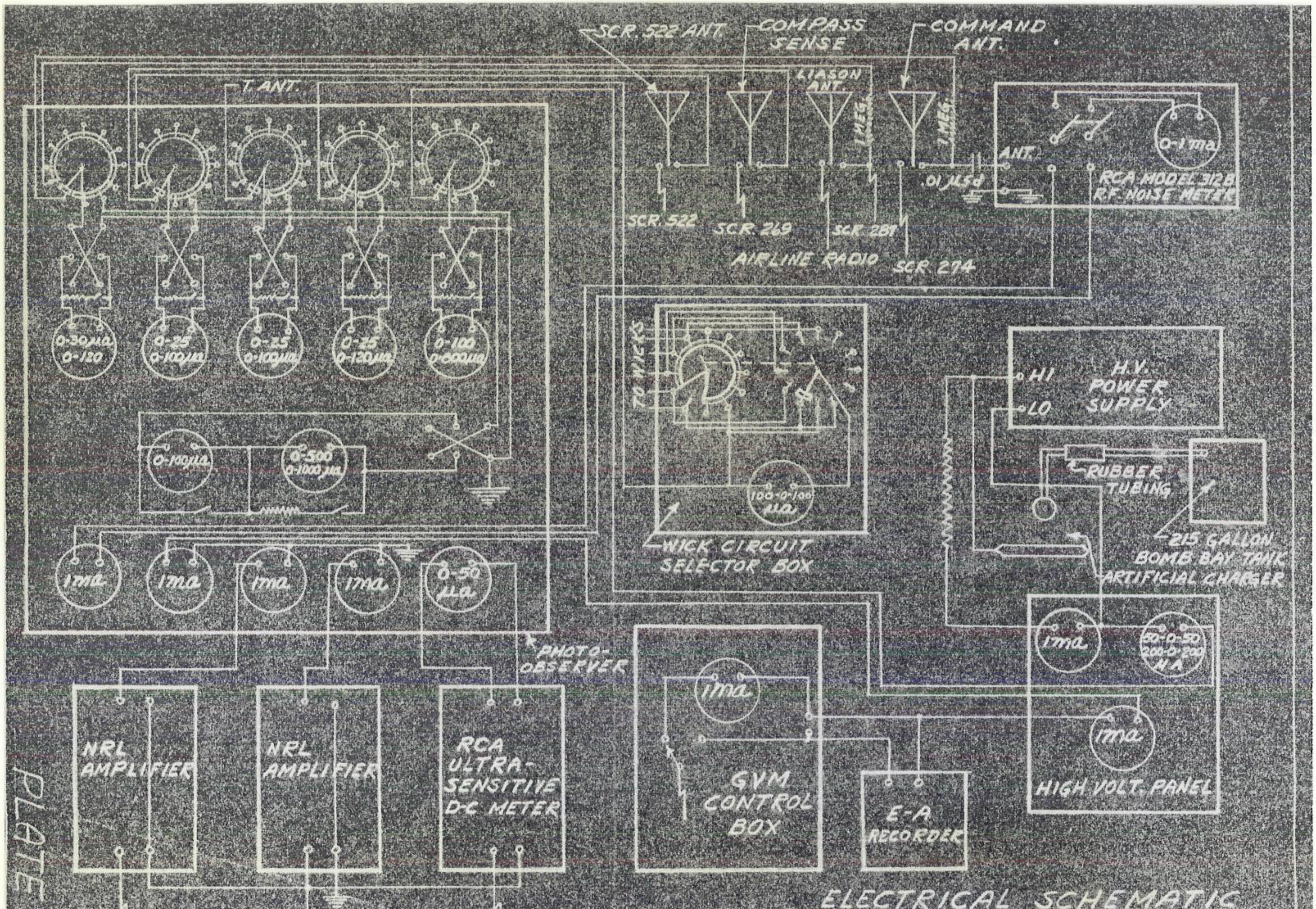


PHOTO OBSERVER PANEL

PLATE 8

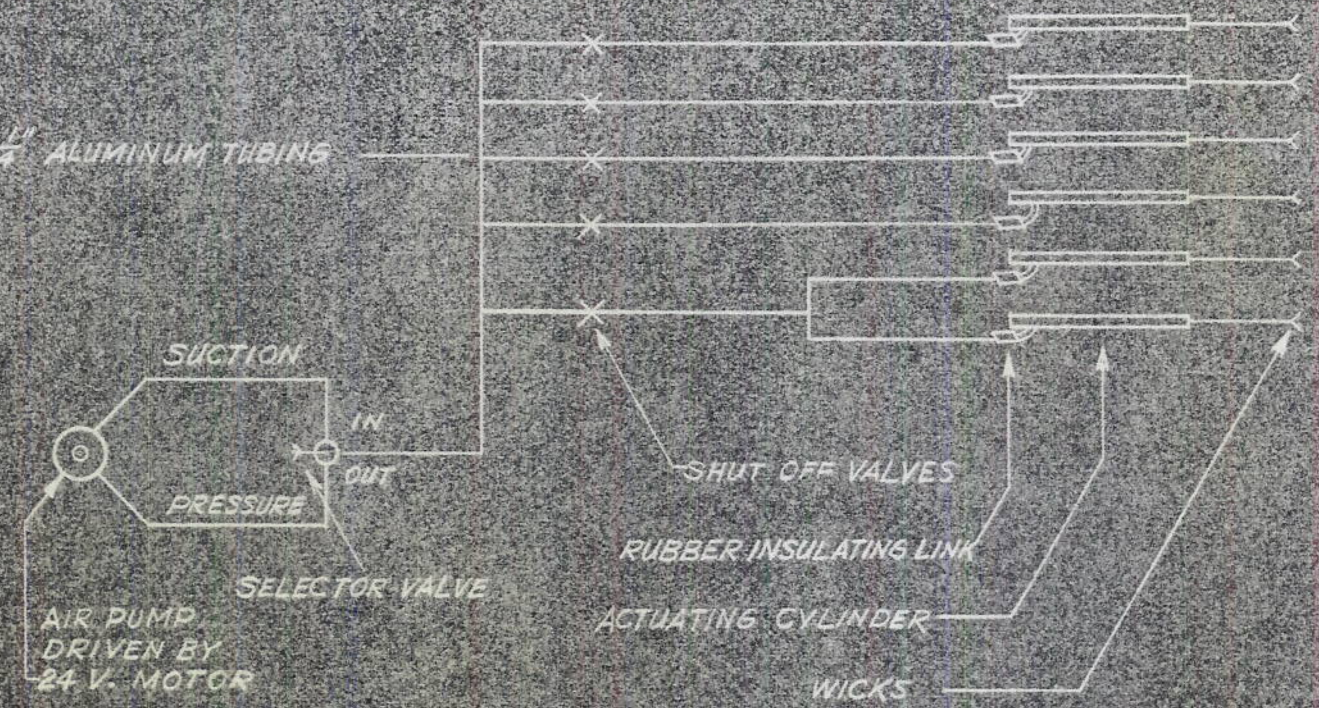


ELECTRICAL SCHEMATIC
B-25 TEST EQUIPMENT

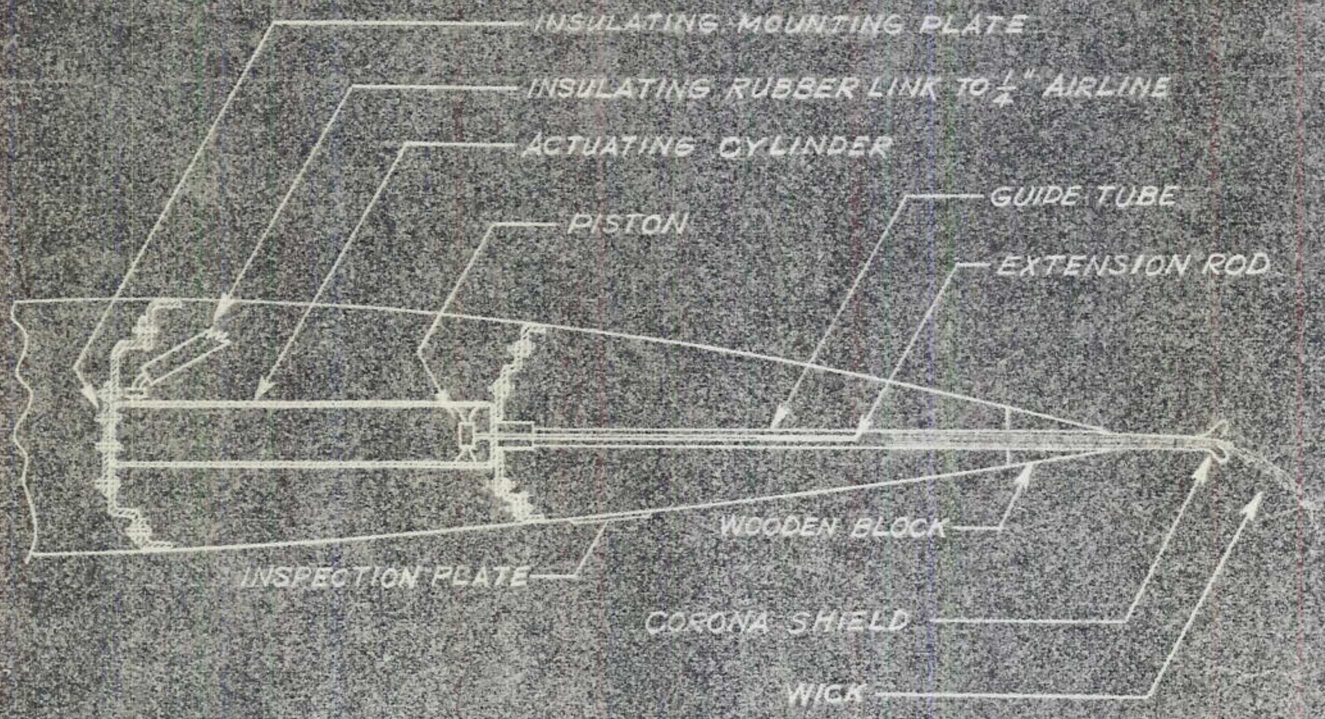
PLATE 9

INSTALLATION OF NOISE METER AND
PART OF PHOTO-OBSERVER.

PLATE 10

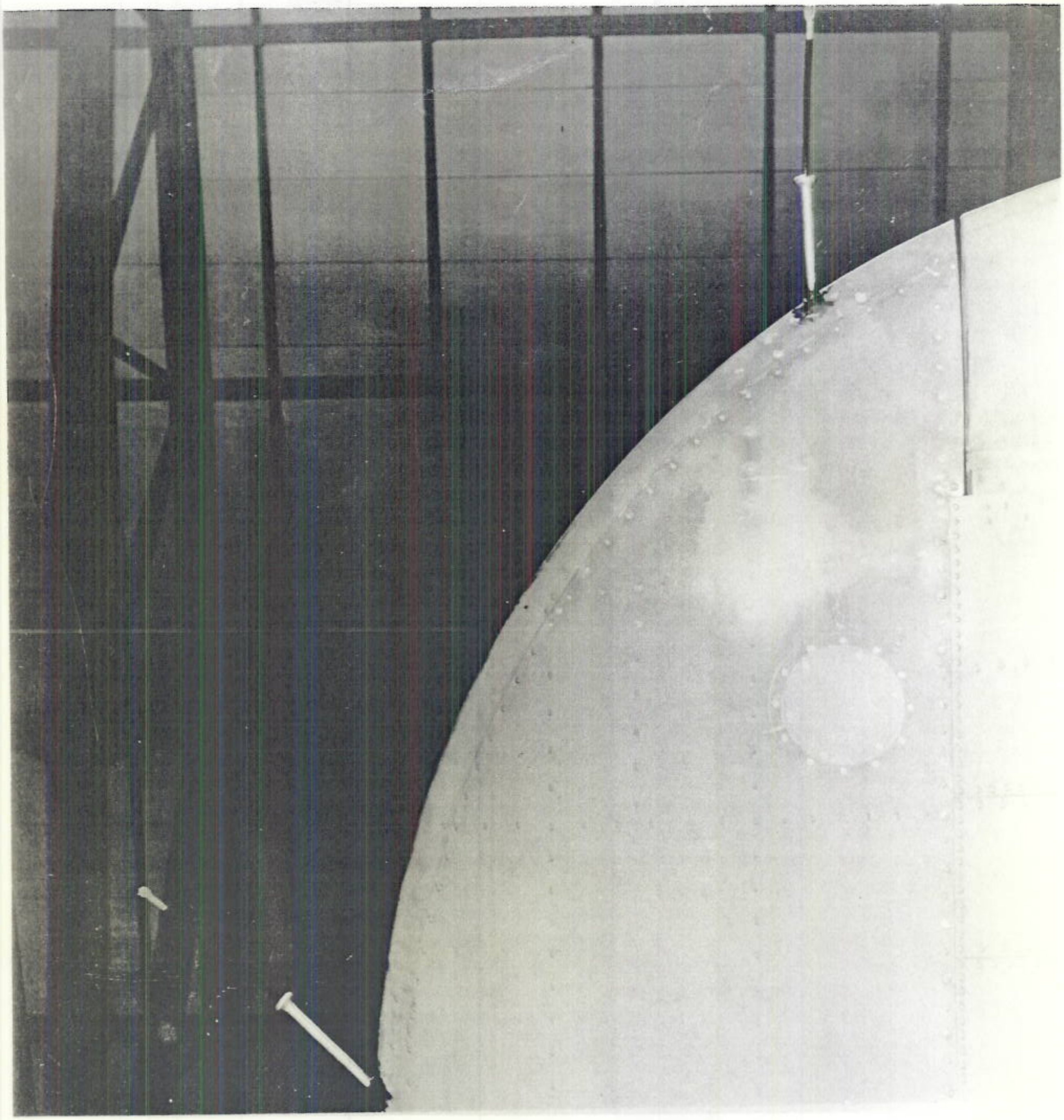


SCHEMATIC DIAGRAM OF RETRACTABLE DISCHARGER SYSTEM



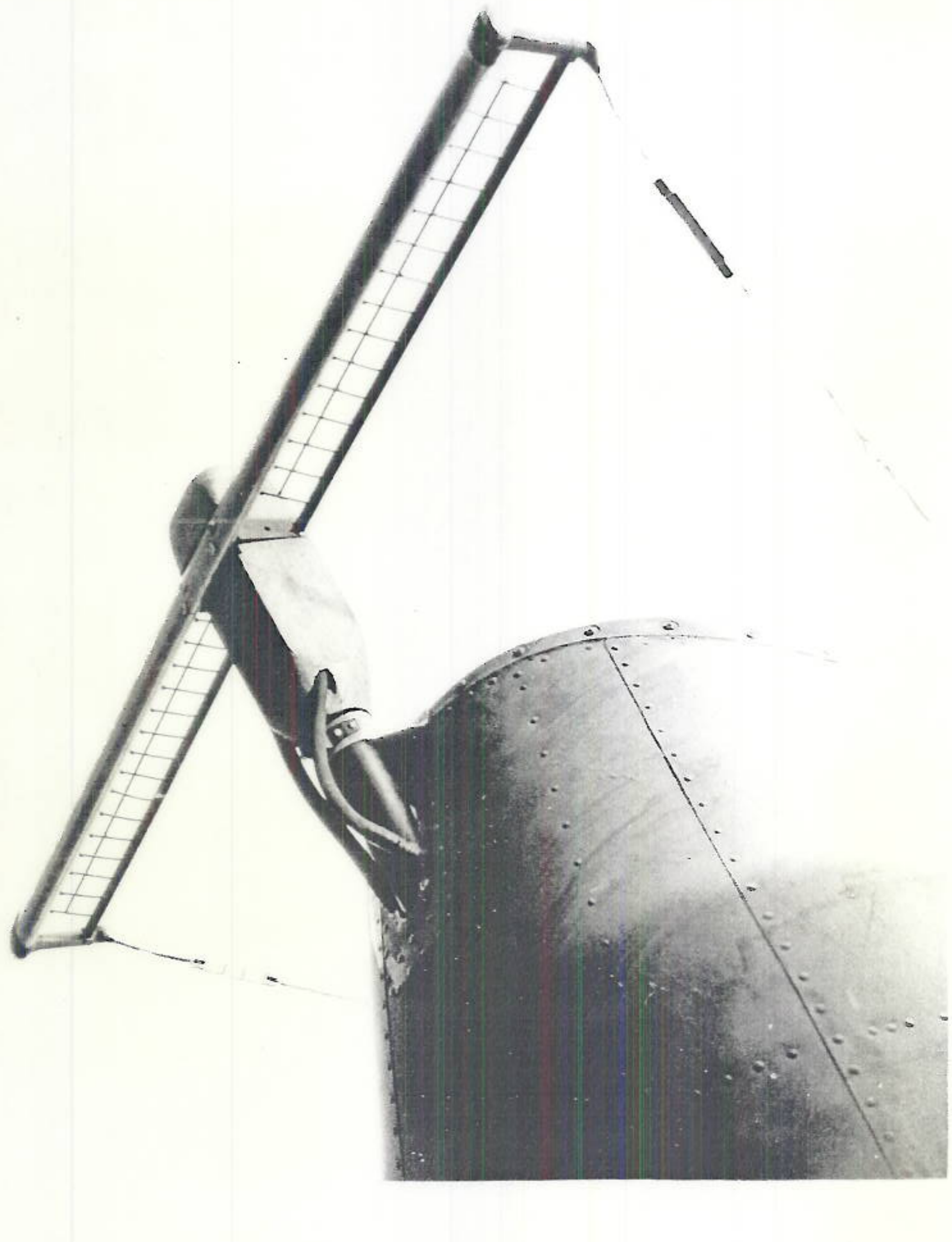
SECTION OF WING TIP SHOWING TYPICAL MOUNTING OF ACTUATING CYLINDER

PLATE 11



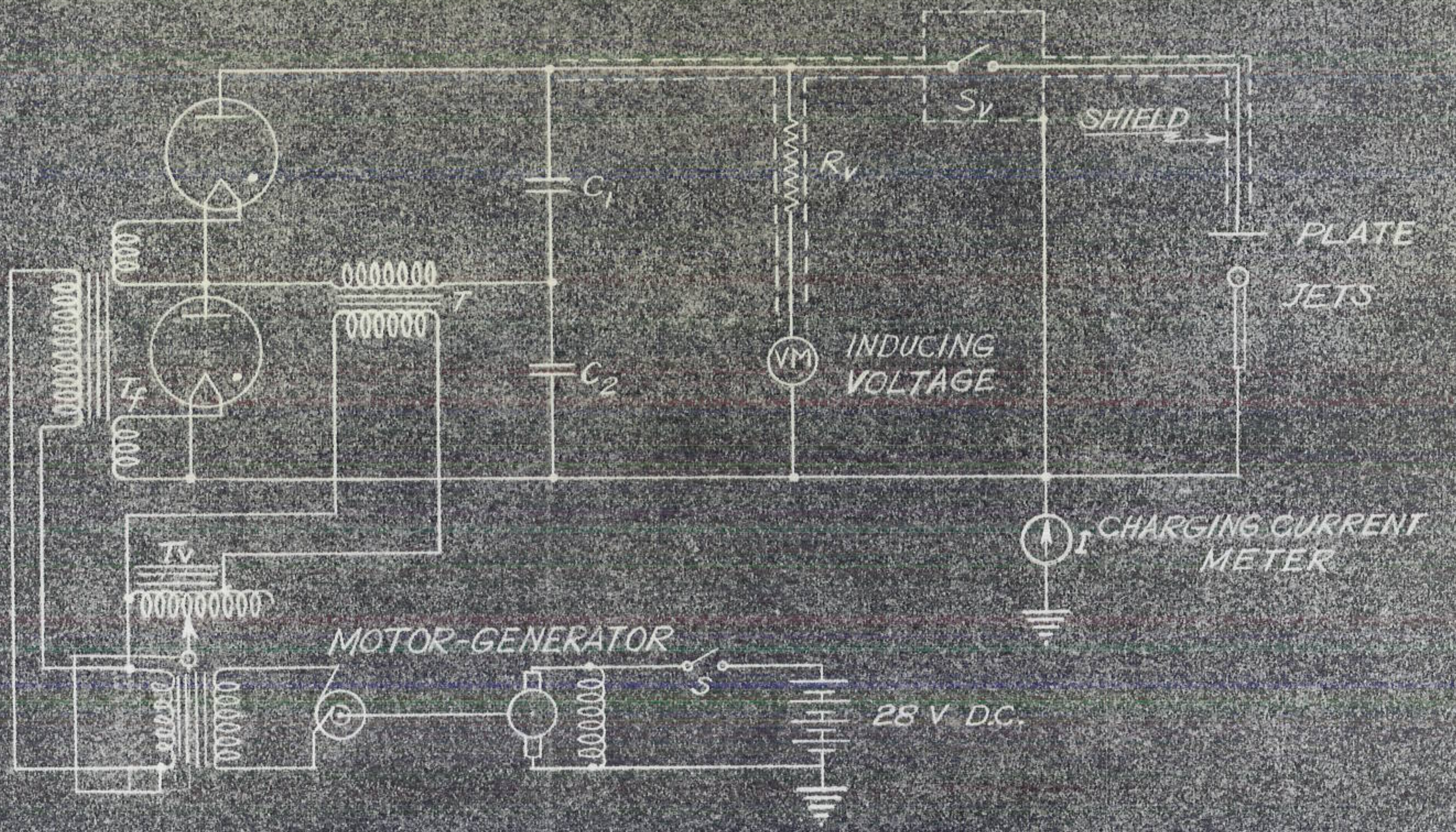
RETRACTABLE DISCHARGER ON WING OF B25

PLATE 12



ARTIFICIAL CHARGER MOUNTED ON THE TAIL OF THE B25

PLATE 13



ELECTRIC CIRCUIT FOR MULTIPLE JET CHARGER

PLATE 14