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1 October 1946

UPPER ATMOSPHERE RESEARCH
REPORT NO. I
-PART II-

by

M. Becker, R. E. Bourdeau
T. R. Burnight, and W. F. Fry

Report R-2956

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ABSTRACT

Installations to measure the X-band attenuation of the V-2 exhaust are described, and design considerations of the equipment are given. Results of the June 28, July 9, July 19, and July 30 flights are discussed and the value of 18 db/meter is shown to be in qualitative agreement with predicted values.

UPPER ATMOSPHERE RESEARCH
REPORT NO. I

PART II

IONIZATION EXPERIMENTS IN THE V-2

by

M. Becker, R. E. Bourdeau,
T. R. Burnight, and W. F. Fry

1. Introduction. The extremely hot exhaust of a rocket frequently contains a sufficient quantity of ionized material to produce large attenuations in electromagnetic waves propagated through the jet. Such attenuations raise serious practical problems in the development of adequate control and communication systems for guided jet propelled craft. For this reason considerable interest attaches to the general study of the effect of flames upon electromagnetic radiation.

2. The Rocket Sonde Research Section has begun a series of experiments, described in this report, to determine the attenuation produced by rocket exhausts on radio waves. The object of these measurements is to determine the general level of attenuation and to develop equipment for making these and related experiments. The experimental work is paralleled by theoretical considerations.

3. Previously to the use of the V-2, experimentation on the problem was done at Johnsville, Pa. Ground tests made there on JATOS and acid-anilin engines, as well as some laboratory flame tests, emphasized the fact that large attenuations may be encountered. Similar ground measurements with the V-2 exhaust could provide valuable data regarding modulation, and would constitute a natural preliminary to a detailed study of the exhaust during a rocket flight. The means for making such ground studies have not been available, however, and experimentation with the V-2 has accordingly proceeded directly with the taking of measurements during flight.

4. Theoretical considerations indicate that at the exit of the rocket venturi the maximum attenuation of electromagnetic radiation should occur in the frequency region near 6000 mc, and that for the expected degree of ionization in the exhaust it should be of the order of 20 to 40 db/meter. Furthermore, at most a 2 to 1 variation of this value of attenuation should be encountered in the frequency range from 1500 to 12,000 mc. It was decided to make the

measurements at 10,000 mc. The use of such a frequency had the very practical advantage of ensuring convenient sizes for the components involved.

5. All of the equipment used for experimentation during the flight of the V-2, must be designed to meet severe mechanical and electrical requirements. Vibrations of .08 inches amplitude at a 70 cycle frequency exist and preclude the use of any circuit or component which is subject to microphonic noise. Battery voltage fluctuations of at least 10% may be expected, so that delicately adjusted circuits should be avoided if possible. High temperatures and blast pressures around the tail at take-off, make it necessary to use specially constructed antennas.

6. The system developed for making attenuation measurements uses a 723 A/B klystron as the transmitter. The transmitter is modulated by a 100 kc oscillator and the modulated output is fed to a high gain antenna located at the exit of the venturi with its beam directed across the flame. The signal is received by an identical antenna located on the opposite side of the venturi. The received signal is then fed to a crystal detector and the resultant 100 kc output is amplified to provide a voltage the maximum value of which is 5 volts as required by the telemetering system. Since a 40 db range is desired from the amplifier it is necessary to have an a.v.c. system to overcome the square law detection of the crystal. This gives an essentially linear amplifier. A fixed gain amplifier with crystal probe is inserted in the transmitter wave guide to monitor the output.

7. <u>Equipment Specification</u>: <u>Transmitter and Monitor</u>. The transmitter uses a 723 A/B klystron operated from a voltage regulated power supply of 250 volts. The repeller grid potential is adjusted by a one megohm potentiometer connected across a negative potential of 270 volts. The repeller grid is modulated by a 917 oscillator using an LC circuit tuned to 100 kc. The modulation voltage is about 30 volts, which amplitude modulates the output between 50 and 75%. There is also some frequency modulation but the system is sufficiently broad so that this can be neglected. The klystron and modulator are shown in Figs. 1 and 2.

8. To ensure that the fluctuations in the received signal are not caused by changes in the transmitter level a monitor unit which consists of a section of wave guide terminated by a IN23 crystal is coupled to the wave guide close to the klystron. The detected output is fed to a one stage 100 kc amplifier which uses a 6AK5 tube with a gain of 150, and a 6AL5 diode detector as shown in Figs. 3, 4, and 5. One section of the diode acts as a clipper to prevent more than six volts being fed to the telemetering system.

9. Receiving System. The receiving system consists of a crystal detector terminating the receiving antenna. The circuit is given in Fig. 6. The detected signal is fed to a two stage 100 kc amplifier which uses 6AK5 tubes and provides a maximum gain of 20,000. An a.v.c. system is provided which gives an effective range on the detector output of .5 to 4 volts for a 40 db range of input voltage. A clipper circuit prevents the output level from going above six volts. The physical layout is shown in Figs. 5 and 7.

10. Antenna System. The transmitting and receiving antennas are identical in construction, as seen in Fig. 8. They are wave guide fed slot antennas modified by the addition of two flanges which serve to narrow the beam in the plane perpendicular to the length of the wave guide. It is necessary to use a high gain system of this sort since the antennas are so located that they have only a limited solid angle which is bounded by the movable graphite vanes. The diffraction effects produced by these bounding surfaces become serious when a beam of more than 20° width is used. The sharp beam makes it possible to study a limited portion of the flame.

11. Installations. The problem of installing the measuring equipment is a twofold one. First the installation must be mechanically simple; and secondly, it must be easily accessible. Also, the equipment must be in a pressurized compartment to prevent the occurrence of a glow type discharge with a resultant change in voltage, and in the case of the tail installation, with a very real danger of an explosion resulting from the fumes of the alcohol and oxygen being ignited by the discharge.

12. Two types of installations have been used. In one type all the equipment is installed in the warhead which is pressurized. This is shown in Fig. 9. The wave guide is fed through the base of the warhead and is kept pressurized by means of mica windows. The guide is installed in three sections of the vehicle and is joined together upon final assembly of the rocket. Twenty-two foot lengths of guide are installed in the mid-section. They are joined to the warhead by appropriate bends and twists. The juncture is effected by utilizing the doors of the control quadrants which provide ready access. The guide is also installed in the skin of the tail section assembly. Upon final assembly the guide, purposely installed so that it can be slipped readily, is pushed until it butts against the end of the mid-section guide. The antennas are installed after the rocket is placed on the launching platform.

13. The second type of installation consists of four pressurized boxes which contain the transmitter and modulator, the receiver, the transmitting monitor, and the relays. These and the associated wave guide and antenna are mounted as shown in Figs. 10 through 14. The

equipment is calibrated by inserting a variable attenuator just ahead of the antenna and reading the receiver output as the attenuator is set to various values. The use of this installation has presented some difficulties, and is generally considered to be less reliable than the warhead installation, especially since the equipment in the tail is subjected to very severe vibration.

14. Experimental Results: June 28, Warhead Installation. Visual observation of telemetering meters showed that at 5 minutes before launching the equipment turned on, and that at 1.5 minutes before take-off both the transmitting monitor and the receiver dropped to zero. This meant that both channels were dead since with no signal there is a reading of about 0.5 volts on the monitor and 0.1 volts on the receiver due to the Edison effect.

15. July 9, Tail Installation. Receiver failed.

16. July 19, Warhead Installation. The relay switching equipment failed and no voltages were applied.

17. July 30, Tail Installation. This is the first flight in which all parts of the circuit functioned normally. The power was applied at 3 minutes before flight and the channels gave constant readings until 4 seconds before take-off. Just as the igniter stage was turned on the calibrating voltages of telemetering system were applied to the receiver channel and no record was obtained for this interval of 2.5 seconds. The channel then showed violent fluctuations which are thought to be due to the igniter. Another 2.5 second interval of calibration intervened as the 8 ton stage was turned on, and when the channel cleared the rocket had full thrust. The receiver level was some 16.5 db down with fluctations of 4 db. The monitor could not be read accurately because 22 channels were recorded on 9 inch paper. The values remained constant until 30 seconds after launching when both channels subsided to their Edison effect values, indicating failure of the klystron.

18. Conclusions. The information thus far obtained is extremely sketchy. The one partially successful flight gives values of attenuation of 16.5 ± 2 db/meter, which seems to be reasonable. Theoretical calculations indicate that for a concentration of 15 parts per million of sodium in the alcohol, the following values of attenuation are to be expected:

Exhaust Temperature (°Kelvin)	Attenuation
2300°*	36.5 db/meter
2250°	27.4
2200°	18.0
2150°	10.4

*Temperature computed by the German rocket development organization at Peenemünde.

19. The mechanical and electrical problems are very difficult, the primary problem being the susceptibility of the klystron to vibration and the delicacy of the voltage adjustments required to operate at full output. It is expected that with future refinements and modifications of the techniques developed to date, these difficulties can be overcome to a considerable extent.

ACKNOWLEDGMENT

It is desired here to express gratitude for kind assistance and cooperation given the members of the Rocket Sonde Research Section by various agencies. The General Electric Company very kindly permitted the installation of the Naval Research Laboratory ionization equipment in three of their V-2's, and actually assisted in that installation. The Applied Physics Laboratory of Johns Hopkins University also graciously made available space in their V-2 for the installation of Naval Research Laboratory equipment.

Thanks are due to the Chemistry Division of the Naval Research Laboratory for valuable assistance and information in connection with the analysis of the rocket fuel used in the V-2's fired at the White Sands Proving Ground.

It is also desired to thank Mr. F. T. Haddock of the R. F. Research Section at the Naval Research Laboratory for furnishing the design of a slot type antenna.

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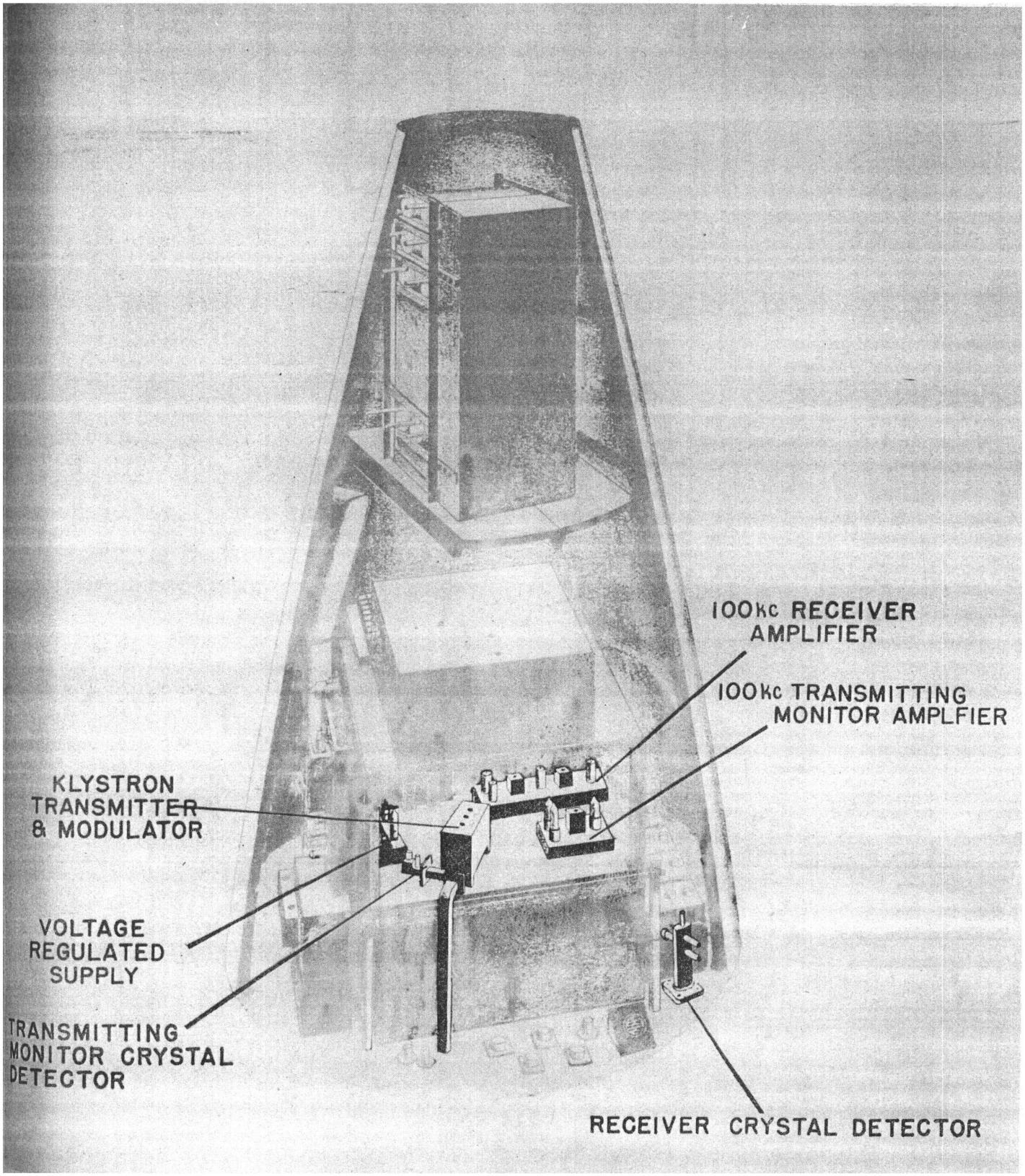

IONIZATION WARHEAD INSTRUMENTATION

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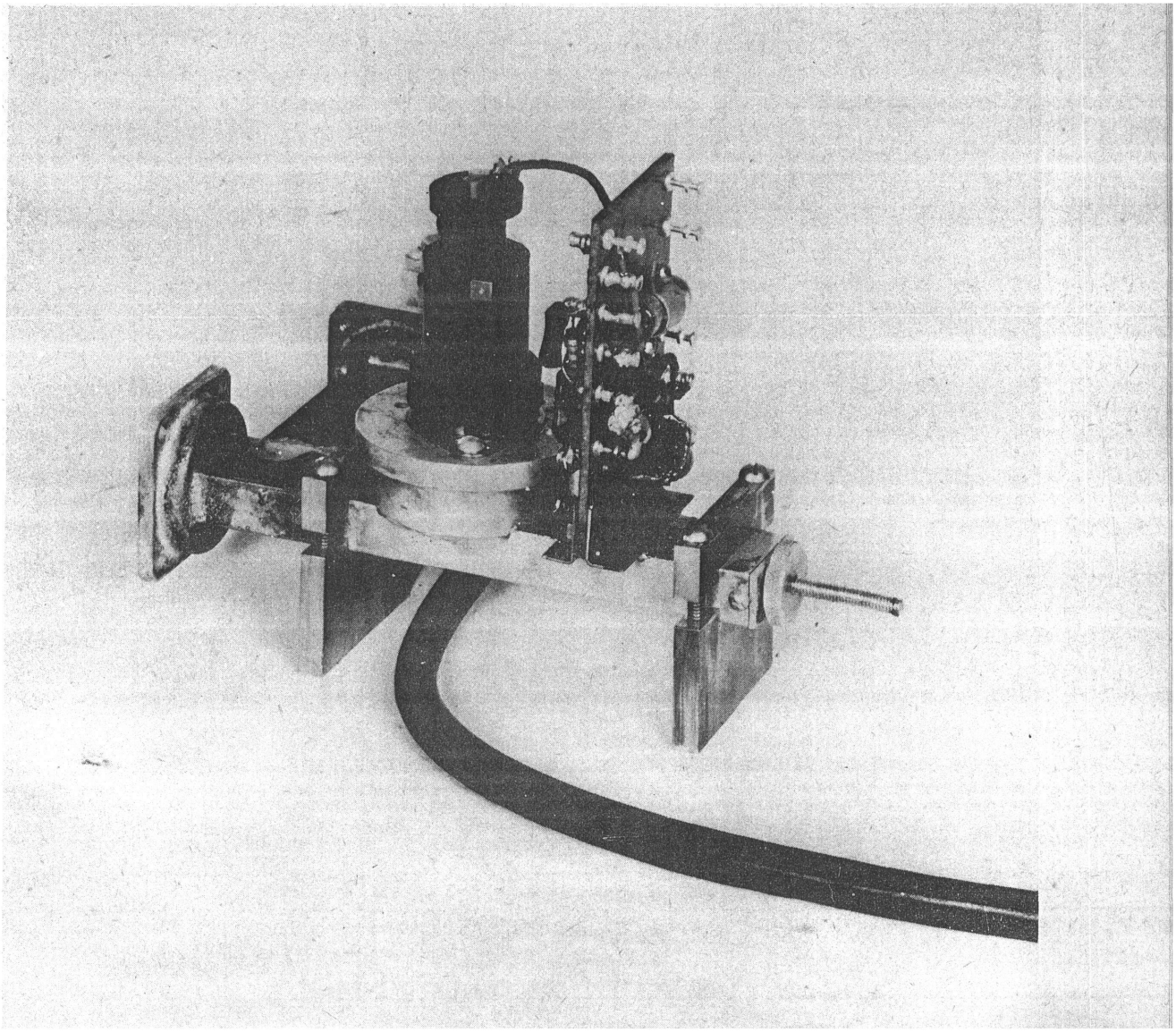
FIGURE 1



KLYSTRON AND MODULATOR

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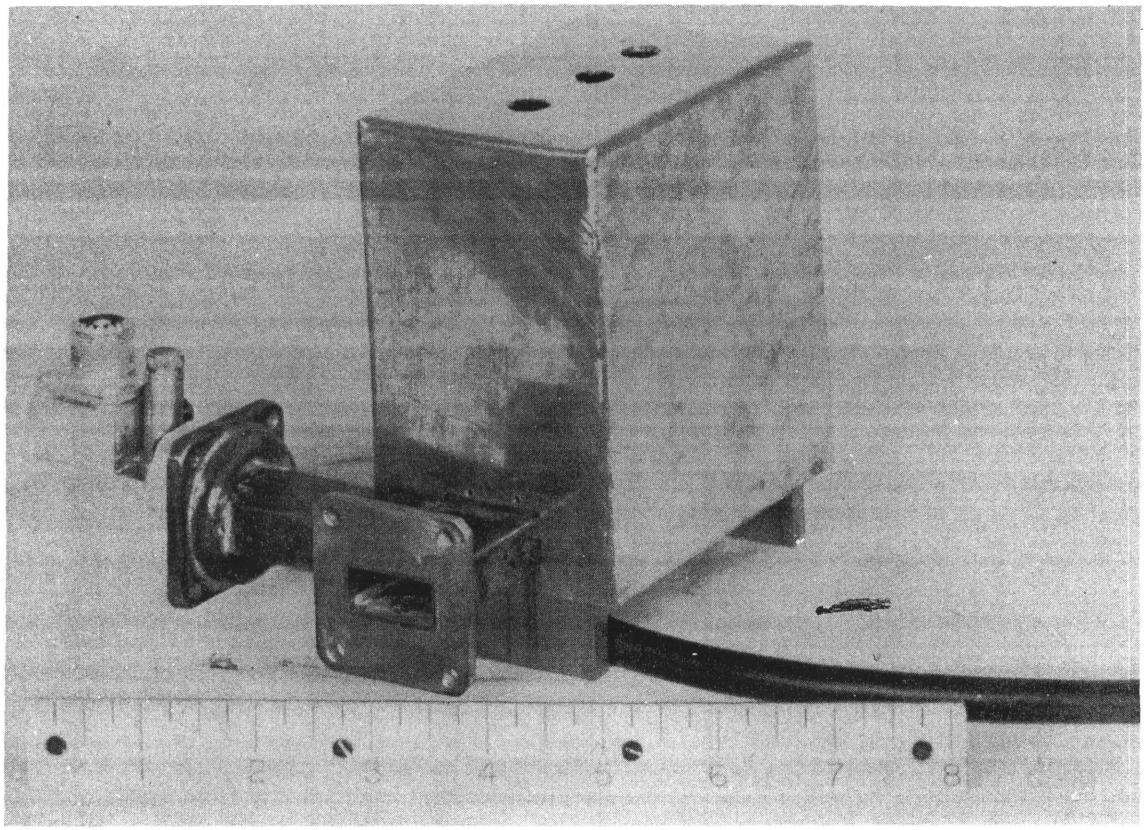
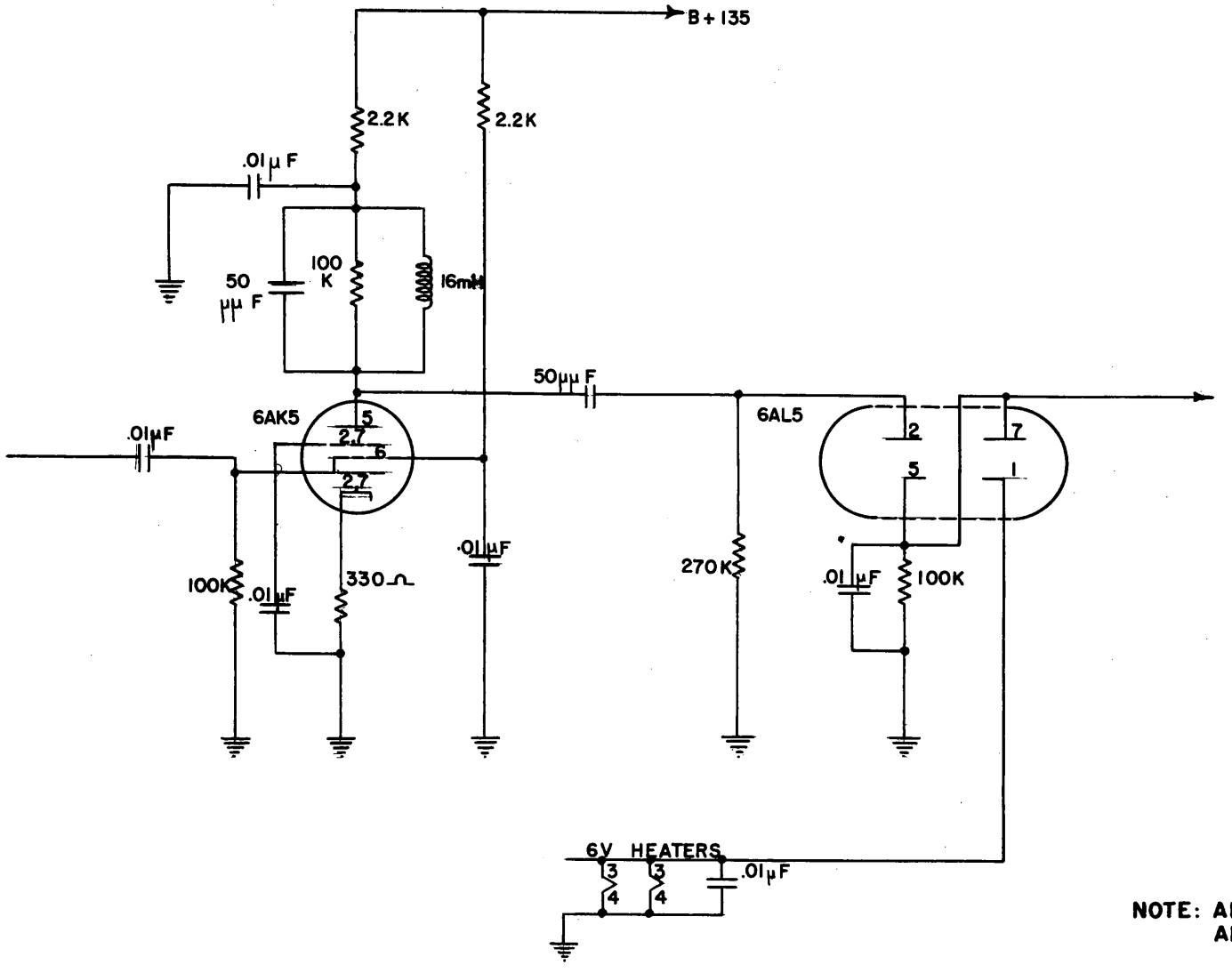
FIGURE 2



TRANSMITTING AND MONITOR ASSEMBLY

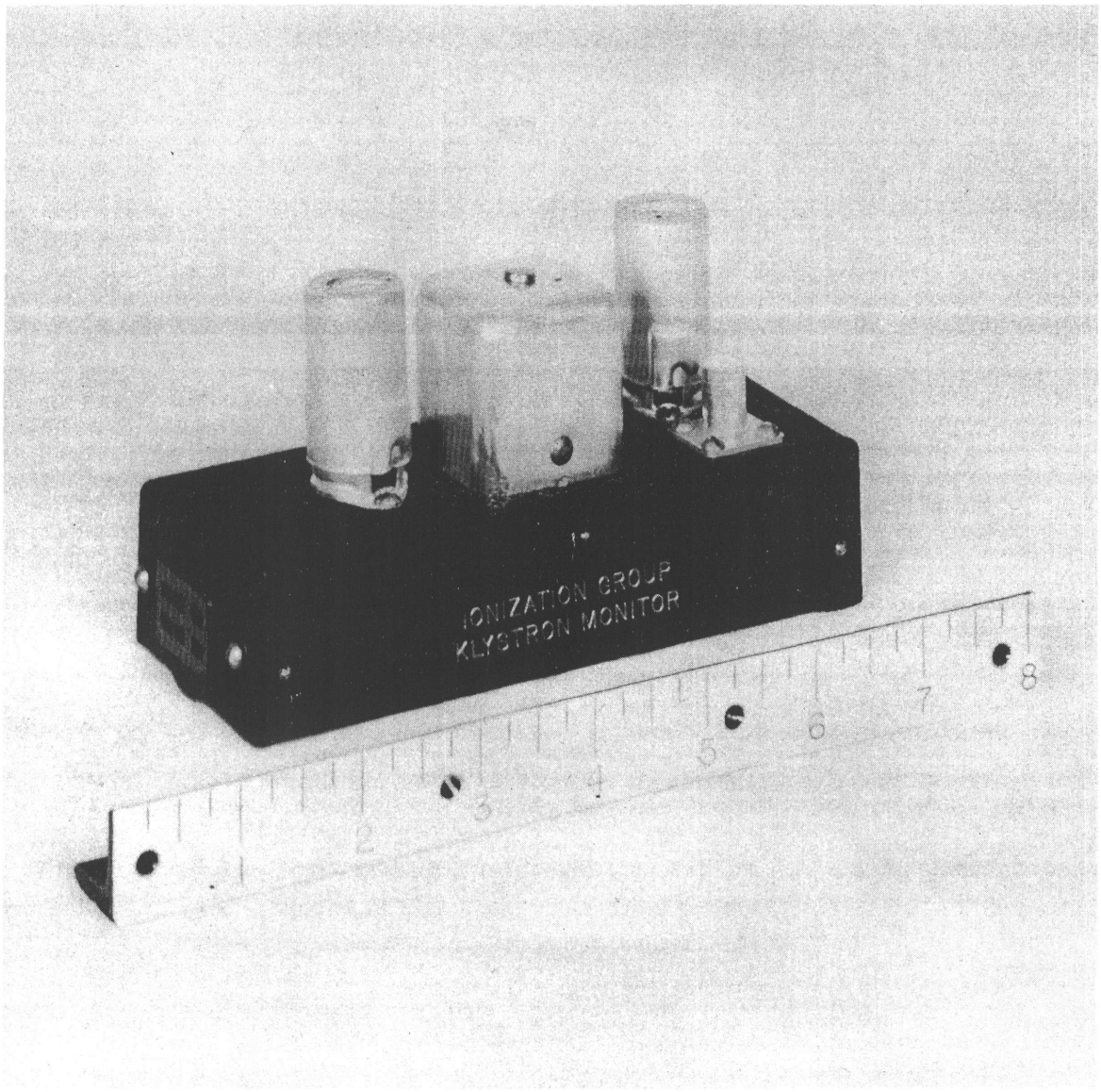


NOTE: ALL 100K RESISTORS 1/5 WATT
ALL OTHERS 1/2 WATT

CIRCUIT DIAGRAM OF TRANSMITTER MONITOR

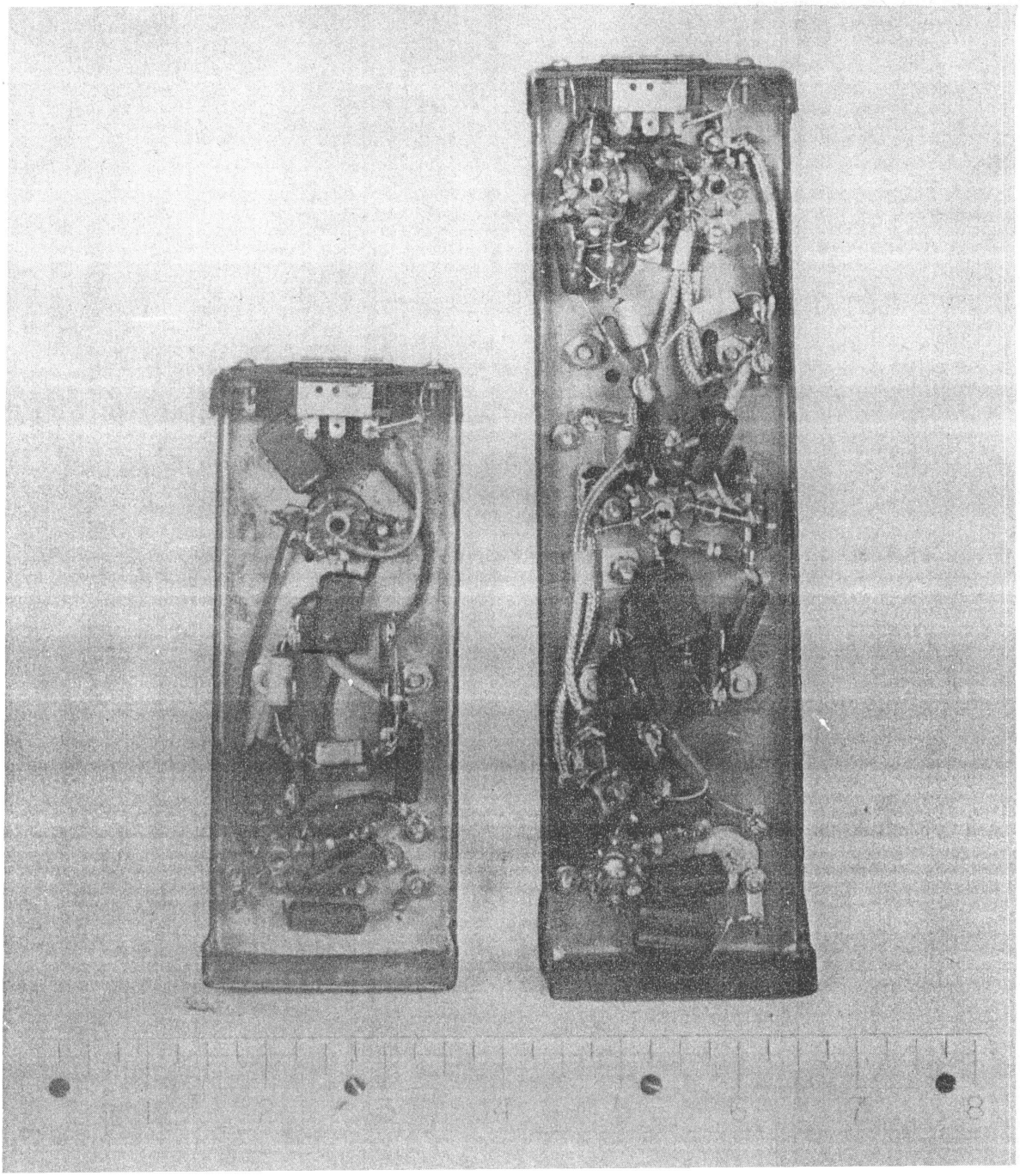
FIGURE 4

R-2956



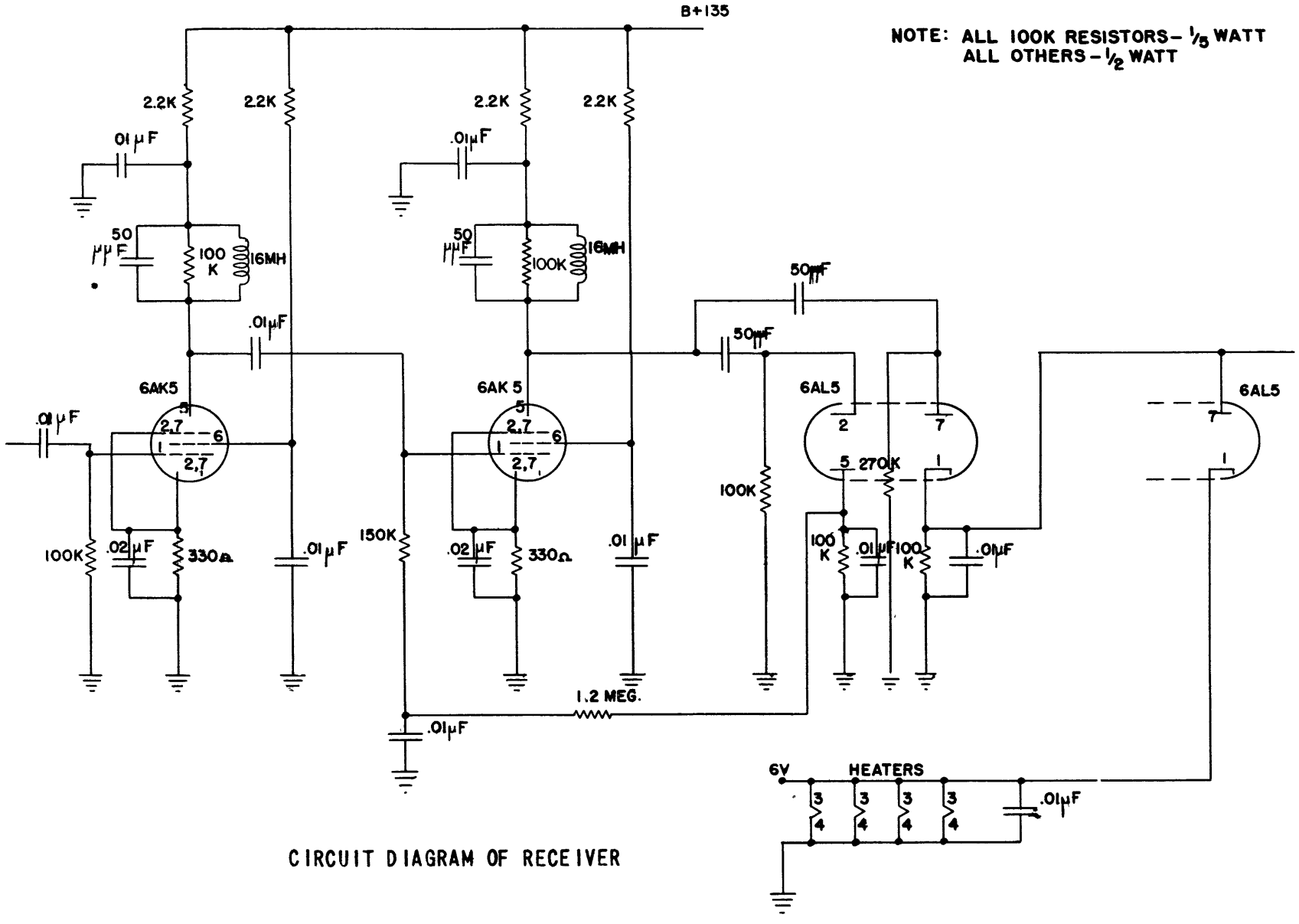
TRANSMITTER MONITOR

FIGURE 5



BOTTOM VIEW OF TRANSMITTER, MONITOR AND RECEIVER

FIGURE 6



CIRCUIT DIAGRAM OF RECEIVER

FIGURE 7

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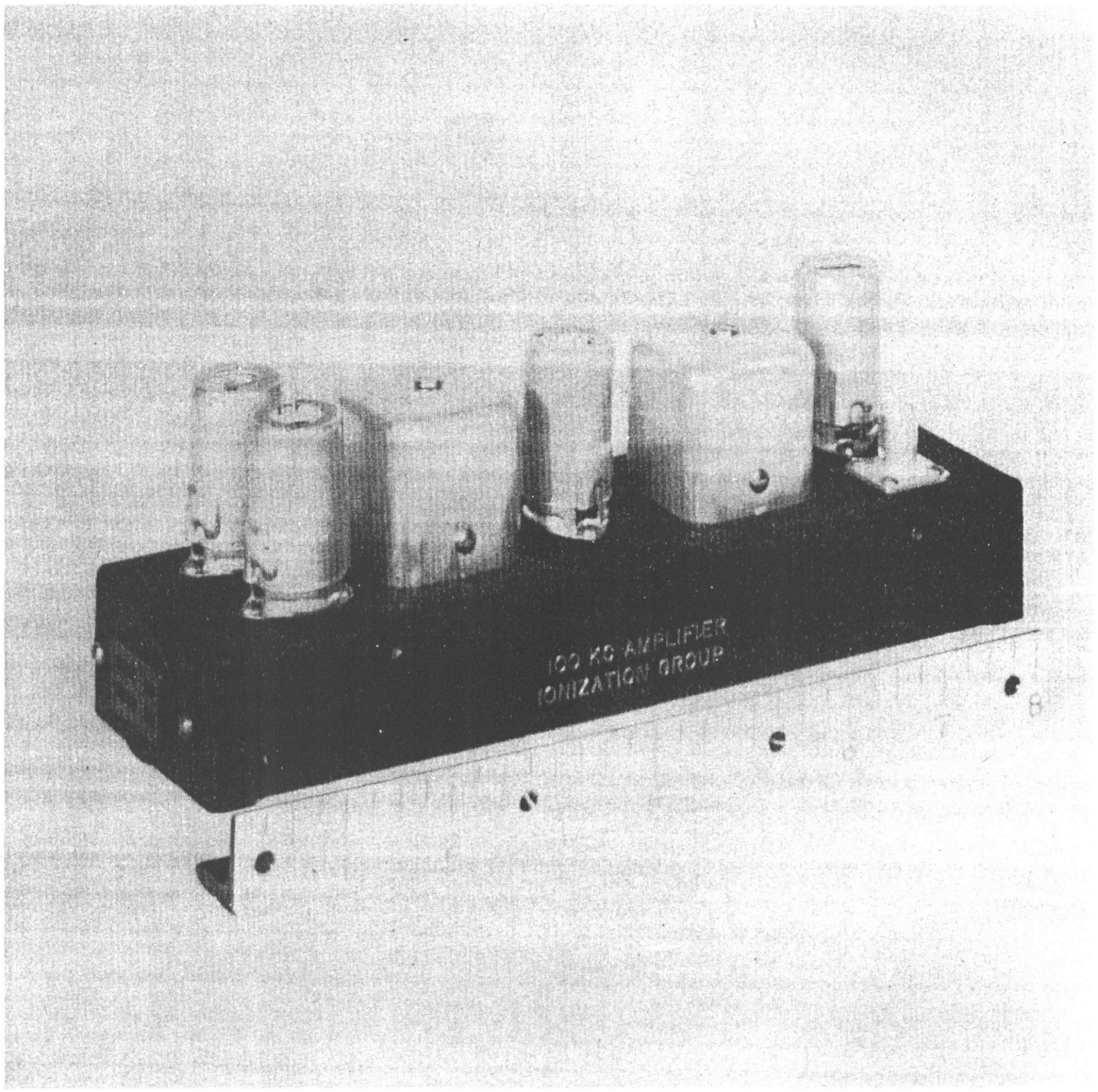

RECEIVER

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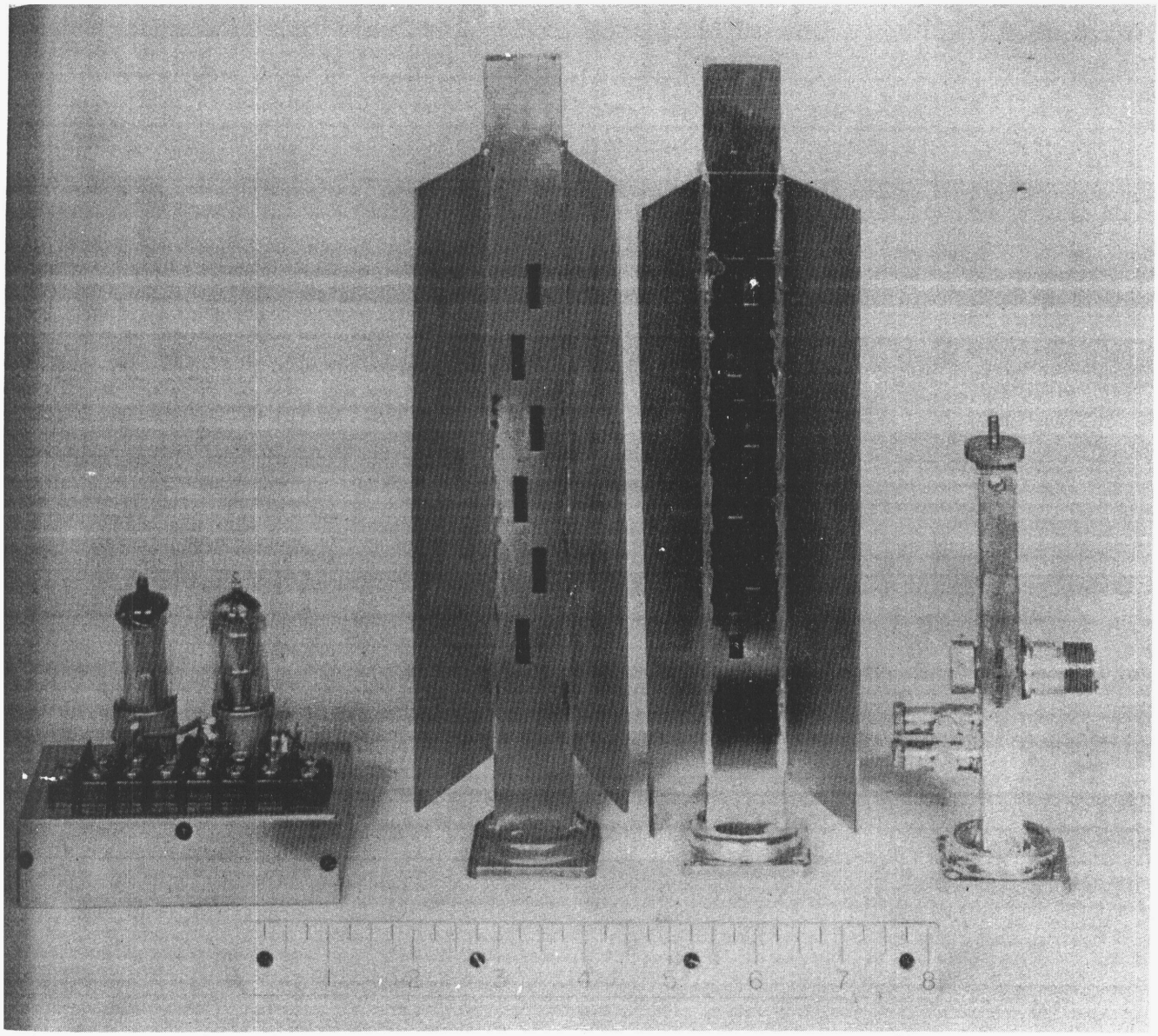
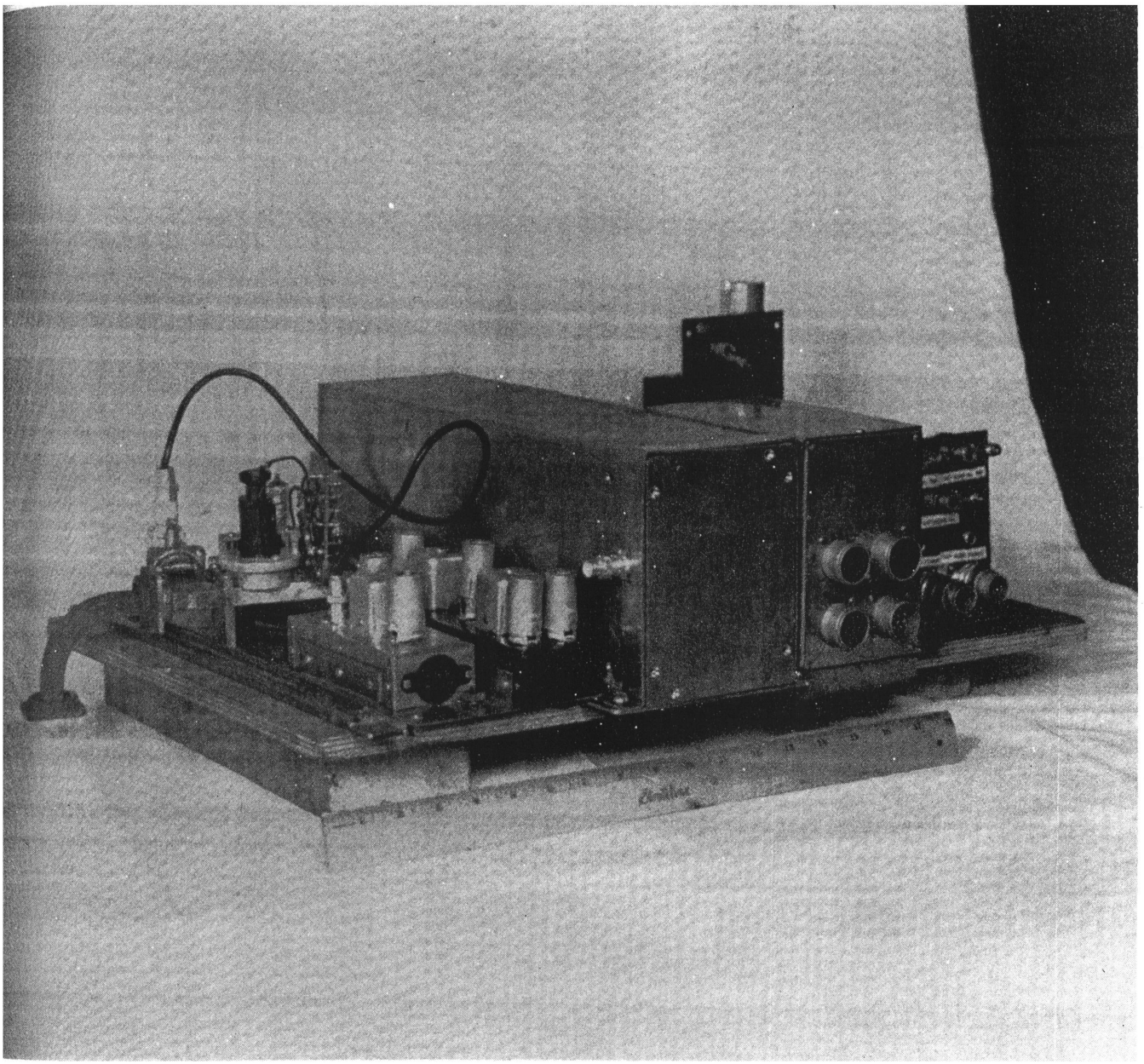
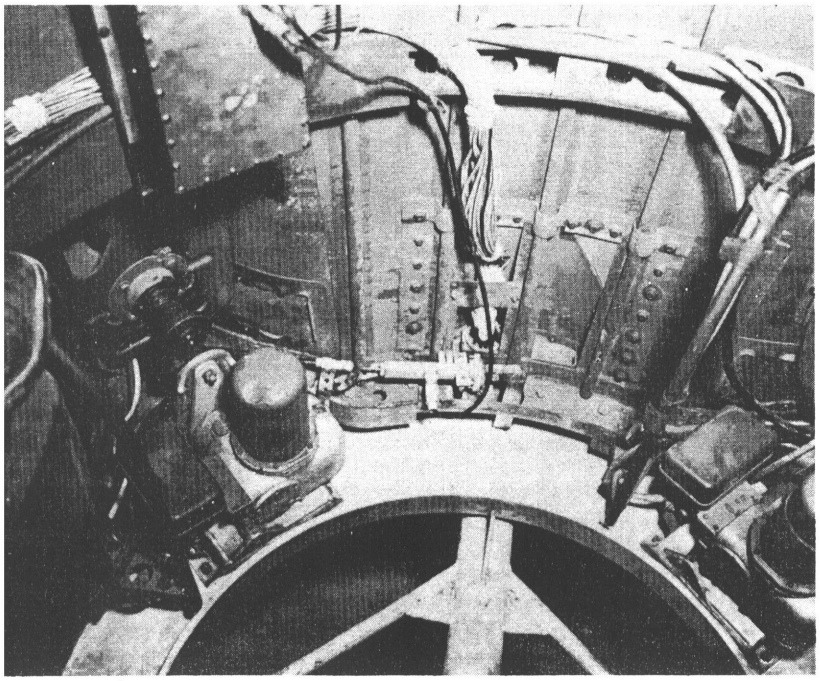
FIGURE 8



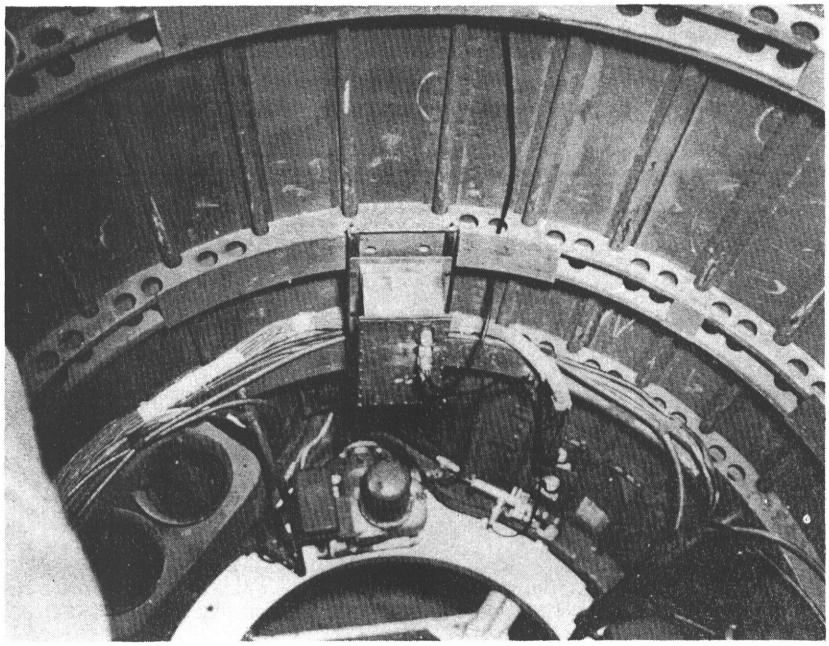
POWER SUPPLY VOLTAGE REGULATOR, SLOT ANTENNAS AND CRYSTAL DETECTOR



WARHEAD ASSEMBLY



(A)
CRYSTAL DETECTOR



(B)
RECEIVER UNIT

TAIL INSTALLATION

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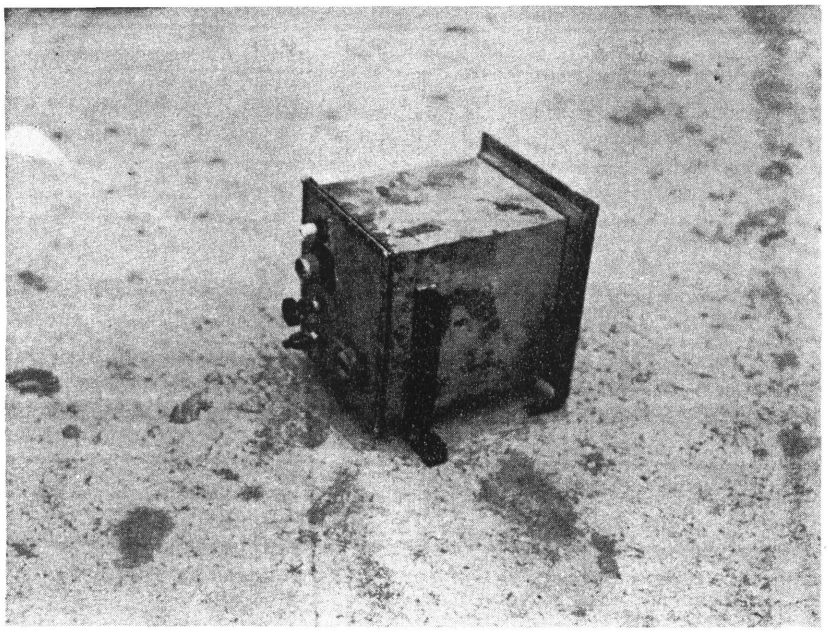
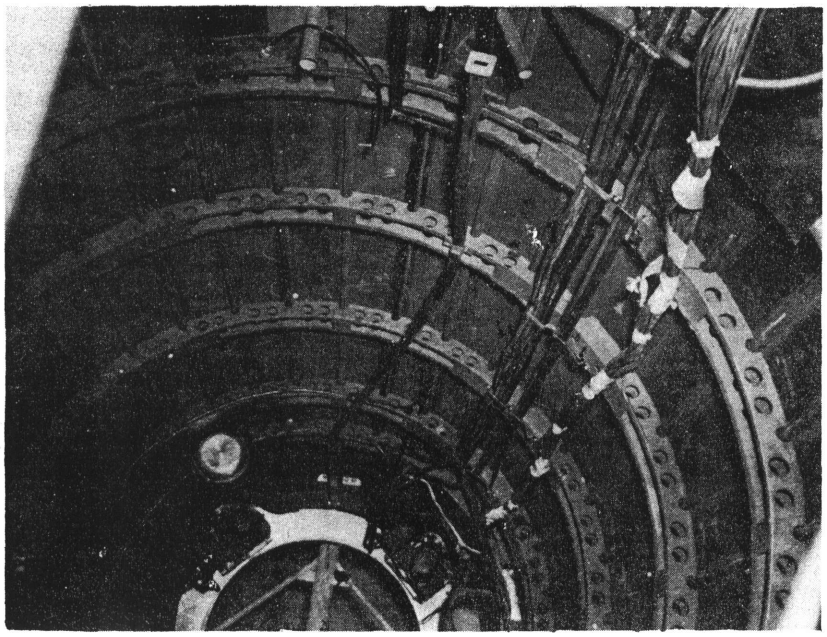
FIGURE 11



(A)
PRESSURIZED UNIT HOUSING KLYSTRON AND MODULATOR

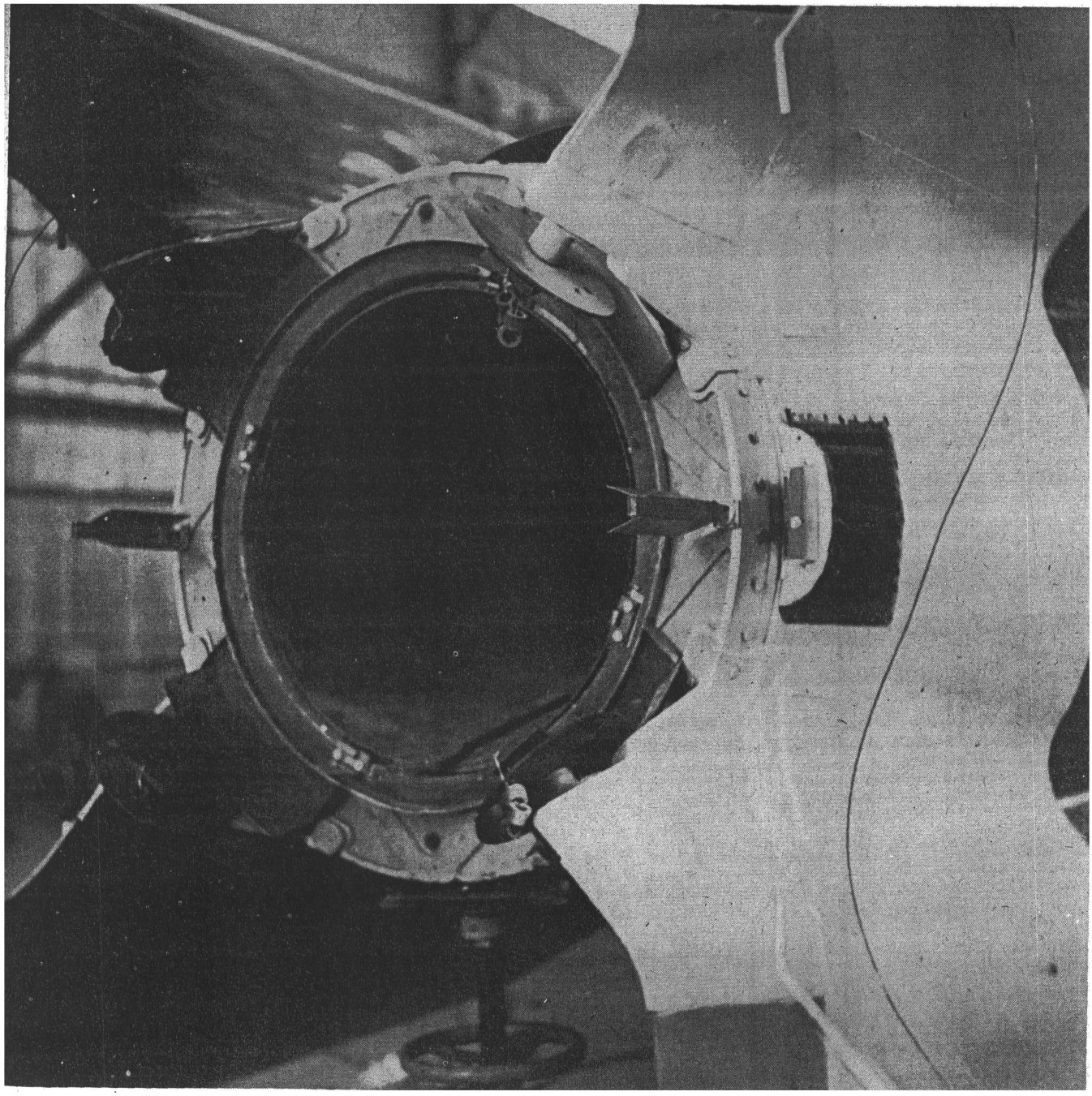


(B)
WAVEGUIDE FEED TO TRANSMITTING ANTENNA

TAIL INSTALLATION

R-2956

FIGURE 12



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