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FIRE CONTROL DIVISION - RADAR RESEARCH SECTION

13 September 1945

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AUXILIARY INDICATOR FOR
FIRE CONTROL RADAR SCOPE PHOTOGRAPHY.

By J. H. Greig and
E. J. Luoma

- Report R-2644 -

* * *

FR-2644

Approved by:

L. R. Philpott - Acting Head, Radar Research Section

DR. R.M. Page
Superintendent
Fire Control Division

Rear Adm. A.H. VanKeuren, USN (Ret.)
Director
Naval Research Laboratory

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ABSTRACT

An auxiliary indicator for use aboard ship to obtain 35 millimeter motion picture scope photography was developed. The auxiliary indicator unit with special camera and mounting provides for a compact unit for obtaining scope photography on fire control radar. The final unit consists of a scope complete with high and low voltage power supplies and a separate amplifier for each particular type of fire control indication.

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INTRODUCTION

1. A valuable means of bringing fleet experience to radar officers and operators who will be responsible for the use of new fire control radar equipments has been through the use of training films. Motion pictures of radar scopes, taken under the varied conditions encountered at sea and with the type of targets with which operators should be familiar, have proven to be one of the best means of presenting the necessary information.
2. A major problem in producing satisfactory training films has been the difficulty of obtaining realistic scope photography on fire control equipments aboard ship. All indicators are in use during tracking exercises or gunnery practices so that they are not available for photography without interfering with the normal routine of the ship's fire control radars.
3. From the photographic viewpoint, also, there were disadvantages in working with the actual radar set. If the camera and ordinary tripod were simply secured to the deck in front of the scope, differential vibration often caused a distractingly unsteady picture. Under those conditions, double exposure or optical printing was generally impracticable because of vibration. An absolutely steady base for camera and radar gear is essential for double exposure or optical printing.
4. Another problem was the elimination, or subdual, of objectionable reflections from the scope. The necessary front threshold exposure light, or lights, unless carefully handled, caused objectionable reflections from the rim of the tube frame, plastic covers, and other sources.
5. The intensity characteristics of tubes, particularly of those for the B-type presentations, represented another problem. The illumination was sufficiently low to create serious exposure difficulties when the photography was required to be at the comparatively fast shutter speeds of 1/30 to 1/50 second, necessary in motion-picture camera operation. The adjustments controlling tube intensity and focus are extremely critical from the viewpoint of the cameraman. The intensity adjustment, particularly, may be entirely different from that which would be used for ordinary operation. As far as the eye is concerned, as the intensity is increased the contrast in signals diminishes. However, because photographic emulsions are less sensitive than the human eye, the intensity of the scope can be increased considerably and proper signal contrast for photographic purposes can still be maintained.
6. The remote-indicator camera mount solves many of the problems encountered and enables the production of radar films aboard ship with a minimum amount of trouble.
7. To provide means of obtaining actual scope photography during periods of operation of fire control radar, an auxiliary

indicator unit, complete with camera and mounting, was desired which could be operated at any distance up to 50 feet away from the ship's indicator.

8. Such an auxiliary indicator which will work with almost all fire control radars at distances up to 50 feet from the ship's indicator has now been developed. Because of the number of different types of radar indication on existing fire control equipment, it was necessary to develop a separate amplifier for each particular type of presentation. The remote indicator developed consists of a scope complete with high and low voltage power supplies and an interchangeable amplifier for each type of fire control scope presentation.

DESCRIPTION OF UNITS

9. The unit, complete with indicator, camera and camera mounting, is pictured in Plate 1. The scope and one of the interchangeable amplifiers are shown in Plate 2 and Plate 3, respectively. In order to describe best the indicator and the various interchangeable amplifiers which make up the complete remote system, it will be convenient to study each separately.

(a) Scope with Power Supply

(1) The primary requisites for good motion picture scope photography are that the cathode-ray tube itself have high intensity, good focus and high resolution. To meet the first two requirements, the high voltage supply for the cathode-ray tube was designed so as to operate the tube at its maximum intensifier voltage (4400 volts), with the ripple in the supply being limited to approximately one volt. Operating the scope tube at such a high intensifier voltage increased the requirements on the amplifier, since the deflection sensitivity decreases with any increase in accelerator voltage. In order to obtain high resolution a five-inch cathode-ray tube was used instead of a three-inch tube, the use of which would have made the remote unit less bulky.

(2) The first indicator built contained a regulated "B" supply of 360 volts at 200 milliamperes, but later models included a 500-volt supply at 60 milliamperes to give the output required by the cathode-ray tube from the Radar Equipment Mark 8 and Radar Equipment Mark 13 Remote Amplifiers. The "B" supply had to be well regulated to allow for variations in shipboard voltage; the ripple in the output was less than one-tenth of a volt.

(3) A number of test runs were made with the camera, using the various types of cathode-ray tube screens available, to determine which screen would be most suitable for motion-picture photography. The P1 or green screen was found to be superior to all other screens tested, including the P5 or blue screen, which is usually noted for its good photographic properties. This

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preference between P1 and P5 screens may have come about because the individual tubes of the same type often vary considerably in their performance. The 5CP1 tube was chosen to be used in the remote indicator, and a large number of tubes were tested to determine which would give the best focus and intensity. The cathode-ray tubes actually used in the auxiliary equipment can therefore be considered "hand-picked".

(4) A photograph of the first auxiliary indicator is shown in Plate 2, and a circuit diagram of the high- and low-voltage power supplies for the scope is shown in Plate 7. The four plates, the grid, and the first anode of the cathode-ray tube are brought out to Jones plugs on the base of the indicator so that short leads can be brought up to make a connection to the amplifier. The second anode is connected to the arm of a potentiometer on the 500-volt supply so that its potential may be adjusted to the average d-c potential of the deflection plates, thus minimizing aberration. The 500-volt d-c, 300-volt, d-c, and 6.3-volt a-c leads are attached by an octal plug.

(5) Cathode-ray tubes vary in length from tube to tube therefore, the scope tube is mounted so that it will always rest flush with the top surface of the indicator.

(B) Radar Equipments Mark 28, Mark 29, Mark 34 and Mods

(1) The fire control Radar Equipments Mark 28, Mark 29, Mark 34 and Mods give the same type of scope presentation and use essentially the same type of indicator unit, so that the same amplifier for the remote indicator will work with any of them.

(2) In this series of fire control radars no convenient outlet is available for obtaining the sweep and video signals. A scheme was used whereby the signals were obtained directly from the plates of the cathode-ray tube in the radar indicator through a resistance-capacity attenuator and then through a cathode-follower to the amplifier in the remote indicator. In order to tap off the signals from the plates and grid of the cathode-ray tube in the radar indicator, an eleven-prong adaptor plug with leads coming out of the proper studs was inserted between the cathode-ray tube and socket. This made it necessary to move the scope and shield in the indicator forward about an inch. To bring out the cables from the resistance-capacity attenuator it was necessary to move the indicator as a whole forward in its case about three-quarters of an inch. This was accomplished by placing extension studs behind the indicator. (Moving the cathode-ray tube less than two inches forward did not in any way inconvenience the operator.)

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(3) The high-level signals which were taken from the plates of the cathode-ray tubes could not be connected directly to the 50 feet of cable because they were at high impedance. The resistance-capacity attenuator was used to reduce the impedance. A schematic diagram of the attenuator is shown in Plate 8, and a photograph of the actual attenuator installed in a shipboard unit with a similar attenuator resting nearby is shown in Plate 4.

(4) The first step in designing the attenuator was to determine how much loading could be tolerated and the next to determine the maximum signal that could be tapped from the attenuator without destroying the frequency response of the system. Maximum signal level was desired at the input to the amplifier to minimize the gain requirements of the amplifier. With high-gain amplifiers microphonic troubles are encountered, and these might prove to be troublesome with the shock and vibration present aboard ship. The first unit used lengths of 95-ohm coaxial line to connect directly from the attenuator to the amplifier, but later a cathode-follower (Plate 9) was employed to drive the 950-ohm RG-65/U cable from the attenuator, thereby increasing the input level to the amplifier. With the cathode-follower the input to the amplifier is approximately two volts, whereas, without it, the input is approximately one volt, because the cathode-follower grid does not load the deflection circuits as much and less attenuation is required.

(5) The circuit of the Radar Equipment Mark 28 Amplifier is shown in Plate 10. The step and video are mixed in a common-cathode phase-inverter stage and then amplified to give a balanced output. The sweep is sent through two stages of amplification and gives a balanced output to the scope. The blanking is sent through two stages of amplification and then applied to the grid of the scope on the remote unit.

(6) To obtain the spot presentation from these radars on the remote scope, it is necessary only to tie in parallel with the spot scope used on the radar. Since the spot-deflection voltages are only slowly-varying d-c voltages, no elaborate shielding or coaxial line need be used. A centering control is needed, however, and this is shown in the schematic diagram contained in Plate 11. The elevation signals are obtained from terminals 811 and 812, and the train signals are obtained from terminals 806 and 807.

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(c) Radar Equipment Mark 12

(1) The Radar Equipment Mark 12 employs three types of scope presentation, namely, "A" scan, pip-matching and spot. Here provision has been made for remote indication in various parts of the ship, and all of the signals to produce this presentation were available on the main frame.

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(2) With a few modifications the auxiliary amplifier circuits, Plate 12, were the same as those contained in the remote units of the radar. The 18 volts of sweep is applied to a common-cathode phase-inverter circuit to give balanced output, instead of to a transformer as in the radar because of transformer procurement difficulties and, also, because of the higher voltage requirements for the sweep in the auxiliary scope. The image-spacing voltage circuits, which are located in the director, were not available on the main frame, so that the voltages generated by the lobing motor (which were available) were applied to the same mixing circuits in the auxiliary amplifier to produce the image-spacing voltages. The image-spacing voltages were then applied to the input to the sweep amplifier instead of directly to the plates so as not to introduce any centering difficulties. This meant that a triode instead of a pentode could be used as an amplifier for image-spacing. The other half of this triode was then used to amplify the blanking voltages, which needed more amplitude in the auxiliary unit. Otherwise, the circuits in the remote Radar Equipment Mark 12 Amplifier were essentially the same as those in the radar. The connections for the wandering-spot circuits enter the amplifier on a 6-pronged Jones Plug. The cable from this plug to the main frame of the Radar Equipment Mark 12 has the connections: 1 to terminal 84, 2 to terminal 85, 3 to terminal 86, 4 to terminal 87, and 5 to terminal 74. The signals from the lobing motor are connected in a similar manner: 1 to terminal 36, 2 to terminal 37, 3 to terminal 34, 4 to terminal 33, and 6 to terminal 35 (which is ground).

(d) Radar Equipments Mark 8 and Mods

(1) The fire control Radar Equipments Mark 8 and Mods employ the "B" type of presentation, which consists of a range sweep on the vertical plates and a bearing sweep on the horizontal plates. In these radar equipments, a cathode-follower is already employed to feed range sweep, bearing sweep, and video signals to remote indicators located in other parts of the ship so it was only necessary to tie the 950-ohm coaxial line in parallel with these units by means of Jones Plug tees, and to feed the signals to an amplifier in the auxiliary unit.

(2) The circuit of the Radar Equipment Mark 8 Amplifier, Plate 13, is very similar to the circuit employed in the remote units of the radar. The only difference is that the auxiliary unit requires more gain (in both the range and bearing sweeps), which is obtained by using a higher voltage, "B" supply and a higher load resistance in the amplifier tubes.

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(e) Radar Equipment Mark 13

(1) The Radar Equipment Mark 13 is also designed to have a number of remote indicators in operation in various parts of the ship; so, just as with the Mark 8, it is only

necessary to tie in parallel with one of these units. These connections can be made at either the main console or at the amplifier panel. At the amplifier cabinet the connections are: main sweep terminals 33 and 32 (ground), precision sweep terminals 37 and 36 (ground), bearing sweep terminals 11 and 12, main video J4 and precision video J3. At the main console the connections are: main sweep terminals 151 and 152 (ground), precision sweep 149 and 150 (ground), bearing sweep terminals 165 and 166, main video J19 and precision video J18.

(2) The Radar Equipment Mark 13 Amplifier, Plate 14, was designed so that the inputs would be obtained by making parallel connections to the cables feeding the test indicator amplifier. This was done so that a switch could be located on the auxiliary amplifier, giving an independent control of the type of scan appearing on the auxiliary indicator (either main or precision sweep). The sweep input of about 10 volts is fed into a common-cathode phase-inverter amplifier stage and applied to the vertical plates on the remote scope. The bearing sweep is obtained from the bearing input to the test indicator. Phase and gain controls are placed in this channel before applying the sweep to the horizontal plates of the remote scope. The video input of 5 volts is sent through two stages of amplification and applied to the grid of the scope tube. Tube amplifiers were used rather than transformers for the range sweep and video because they are more versatile as to output voltage and transformers are hard to obtain.

(3) A much steadier presentation is given by this radar equipment, so the problems of photographing it are not as great as with the Radar Equipment Mark 8, which also employs a "B" scan. The higher degree of resolution given by the five-inch tube used with this radar equipment as compared with that given by the three-inch tube used with the Radar Equipment Mark 8 is particularly noticeable.

PHOTOGRAPHY

7. After it was decided to use the five-inch tube instead of the three-inch tube, because of the better resolution given by the former, tests were made of various tube screens to determine the one most suitable for scope photography. As was stated earlier in the report, the P1 screen with a greenish trace gave the best results. The most brilliance was actually obtained from a 3JPI tube but the focus was not very sharp and, of course, the resolution was not as good as could be obtained on a five-inch tube. The 5CP1 tube was then used on all equipment for which scope photography was required. In running tests on the "B" scan, numerous screens were again tried, but the P1 screen again gave the best results.

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8. Cameras: On production work to date, two types of 35-millimeter cameras have been used; a Mitchell and an Akeley Standard. The Mitchell was used on all work possible because of the accuracy of the film movement and registration. At normal speed, 24 frames per second, and full shutter, the exposure is 1/50 second. It was helpful at times to operate at 18 frames per second. This lower speed was necessary because, in some instances, the frequency of tube signals is such as nearly to synchronize with the camera shutter, resulting either in partial or in no exposure. It was necessary that the camera shutter turn at such speeds as to avoid stroboscopic effects. Operating the camera at a lower number of frames per second was not always possible because of resulting distortions. The only remaining solution was to increase the shutter opening beyond the 170-degree opening customarily available on such production cameras as the Mitchell. Therefore, for photographing scopes such as the "B" type in the Radar Equipments Mark 13 and Mark 8, it was necessary to use the Akeley camera that had been altered to give a fast film movement and a shutter opening of 295 degrees. A shutter speed was chosen that would not cause "blackouts" of some frames due to out-of-phase synchronization between exposure and signal frequency. With the Radar Equipments Mark 13 and Mark 8, which have a scan frequency of 10 cycles per second, a camera speed of 16 frames per second was used, giving, at 20 frames per second, a normal presentation, only slightly speeded up, on the screen.

9. Lenses: The lenses used were 50-millimeter and 75-millimeter Zeiss Sonnar with a maximum aperture of f/1.5. Almost invariably the lenses were operated at full aperture. The lenses had been treated with hard non-reflective lens coatings of magnesium fluoride applied to all surfaces. These coatings increase transmission approximately 18 percent and reduce flares and ghosts usually brought about by photographing a source of light such as a cathode-ray tube.

10. Film Stock: Panchromatic film, such as Plus X or Ansco Supreme, was used for all scope photography. All types of film had been tested and in nearly every case Plus X was the preferred emulsion. It reacted to the necessary type of processing better than any faster emulsion. Processing in normal positive developer for 8 minutes gave sufficient speed and contrast. Film was carefully selected in advance by sensitometric tests, and only those emulsions exhibiting high speed and low fog levels were used.

11. Fog Lights: To the eye, a cathode-ray tube in operation assumes its greatest brilliance when viewed in complete darkness. It is, therefore, customary to assume, because of what the eye sees, that photography should be carried on in total darkness. However, it has been found that if a certain measured amount of light is projected on the face of the tube, the amount depending

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upon the tube, the intensity and the quality of the image on the emulsion is definitely improved. The intensity of this light varies with the emulsion, lens aperture, tube intensity, processing, and camera speed, but is usually in the range between 0.25 and 1.5 foot candles. An accurate method of adjusting such fog-light levels is required.

12. To supply the necessary light for the work done to date, two small six-watt, 110-volt lamps were secured directly to the scope unit (See Plate 2) opposite each other, about 5 inches away from, and above the tube face. To eliminate reflections from the glass surface, a flat metal ring, 1/2-inch wide, was placed over the tube to cover the curved edge. The two lights were controlled individually by rheostats and then together by another rheostat so they could be easily balanced and adjusted to proper intensity. The intensity of the light was measured by a Model 603 Weston Foot-candle Photoelectric Meter.

13. Vibration: The problem of vibration is eliminated by shock absorbers on the bottom of the mount, and the mount itself is sturdy enough to hold the camera and scope in perfect alignment. Therefore, the image on the film stays in the same position at all times, giving a rock-steady picture on the screen. This gives perfect registration and steadiness, which is important for optical work when the finished film is made.

14. Optical Printing: Frequently it is necessary not only to obtain a satisfactory image of signals on the scope but also to produce a fully-lighted image of adjacent panels, control knobs, switches, and the geography surrounding the face of the scope. This is accomplished in the motion-picture laboratory by combining optically on a special printer the scope image made in the remote indicator with a film showing the desired panel of the radar gear. During this procedure other effects can be added, such as cross hairs, markers, or other lines. In the finished film the scope image is registered in the correct position in the radar set, giving an appearance of actual operation. Plates 15, 16, and 17 are enlargements from single frames of motion-picture films exposed in the remote indicator mount. Plate 15, Figure 1, is a picture of the Radar Equipment Mark 8 scope with fog lights but no optical printing. Plate 15, Figure 2 and Plate 16, Figures 1 and 2 are a close-up, a medium and a long shot, respectively, of the Radar Equipment Mark 13 scope indicator with the scope picture inserted. Plate 17 illustrates photography of the Radar Equipment Mark 12 scope. Figure 1 on this plate shows the pip-matching scope with no fog lights on the indicator. Figure 2 shows the spot presentation with cross wires and the surrounding geography attached optically.

PERFORMANCE

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15. The first complete unit was taken aboard the USS New Orleans and installed on a Radar Equipment Mark 28. The complete installation aboard this ship for taking "A" scan and spot photography is shown in Plate 5. Plate 6 shows the operator taking

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pictures. Scope photography for training films on the Radar Equipment Mark 28 were obtained during tracking exercises and gunnery practices without interfering with the normal routine of the ship's fire control radar operation.

16. The minimum attenuation allowable in the attenuator was untermiated by the length of the untermiable coaxial line which constituted a lumped capacity. In order to obtain greater fidelity in the shipboard installation, the coaxial line had to be shortened to about 10 feet. To eliminate this difficulty a set of cathode-followers was built, and higher impedance coaxial line was used. Because of the delay present in the higher impedance cable, all cables were required to be cut to the same length.

17. The test runs made with "B" scan presentation on the scope proved to be very staisfactory. In fact, more details were picked up by the camera than met the eye when looking directly at the scope.

18. In its initial installation aboard ship the equipment was used intermittently over a period of one month and suffered no breakdown.

19. The equipment with all the amplifiers and the cathode-followers for the Radar Equipment Mark 28 was taken to Pearl Harbor for a two-month period. During this time scope pictures were obtained on the machine-gun, and main battery radars.

20. No trouble was experienced with any of the equipment except the Radar Equipment Mark 8. The auxiliary indicator was connected to the same jacks as were the Radar Equipment Mark 8 remote indicators. There was enough a-c pick-up at this point to cause the transmitter pulse, range line, and echo to have wavy lines instead of straight lines. This a-c was in the range sweep output of the radar, as it appeared on all the remote indicators of the radar. This was not a satisfactory presentation for photography because the problem called for the presentation of the main indicator, not a remote indicator. Some of the a-c was picked up on a short length of coaxial line in the main indicator; when the output of the main indicator was taken from J2B inside the indicator instead of from J2A on the front panel, this a-c pick-up was reduced. A parallel-tee 60-cycle rejection filter on the input to the range sweep amplifier was effective in eliminating this pick-up.

21. Both the bearing sweep and the range sweep were directly connected to the cathode-followers; therefore, variation in the voltage from the cathode-follower caused some decentering of the picture on the auxiliary indicator. This could be compensated for

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by adjusting the centering controls, but rapid fluctuation in voltage could not be eliminated.

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CONCLUSION

22. The remote indicator has greatly facilitated the taking of motion-picture scope photography aboard ship. Tests of proper lighting and exposures for given radar presentations can be made on shore so that, when the actual pictures are taken aboard ship, one can be almost positive of the results that will be obtained. The unit is compact and does not affect the performance of the radar or the efficiency of the crew operating the radar.

ACKNOWLEDGEMENTS

23. The assistance given by Ensign George Klotzbaugh of the Electronics Section of the Naval Research Laboratory in the choice of the cathode-ray tubes to be used in the equipment, and the cooperation given by the members of the crew of the USS New Orleans, on which the remote indicator was initially used, greatly aided the work on the project. The assistance of L. W. Riley, C. Sp. (X), USNR, of the Photo Science Laboratories in furnishing the information on the photography details for this report are greatly appreciated.

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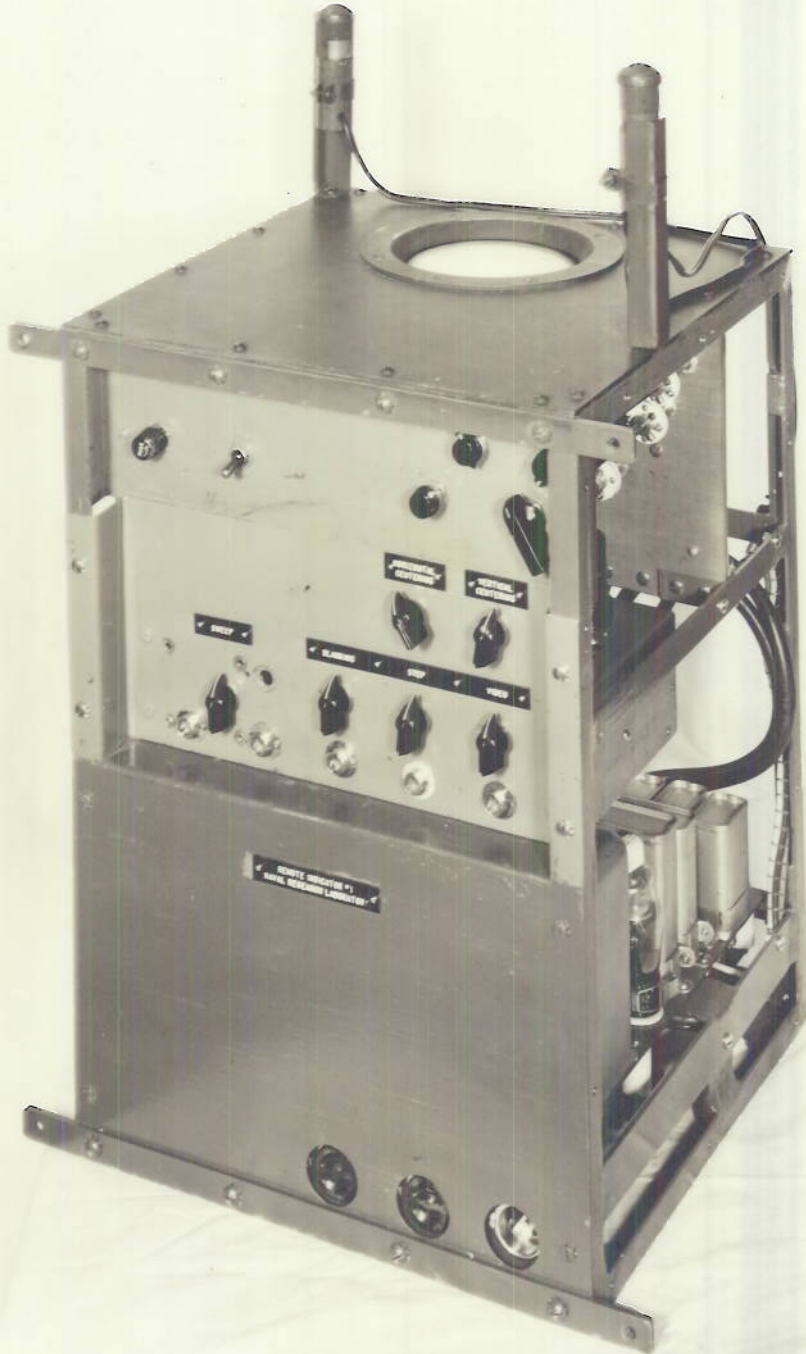
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CAMERA, MOUNT, AND SCOPE

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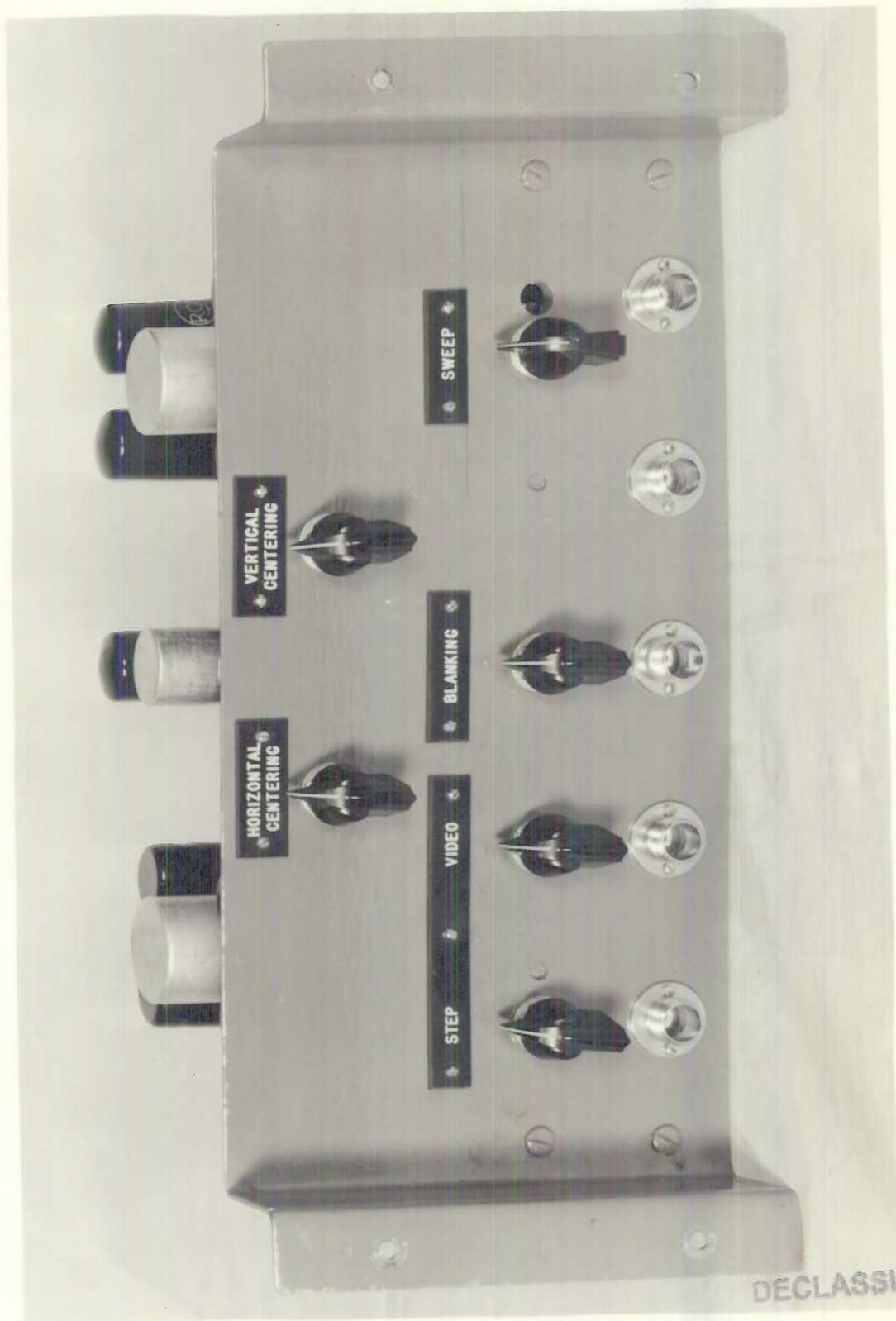
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REMOTE INDICATOR

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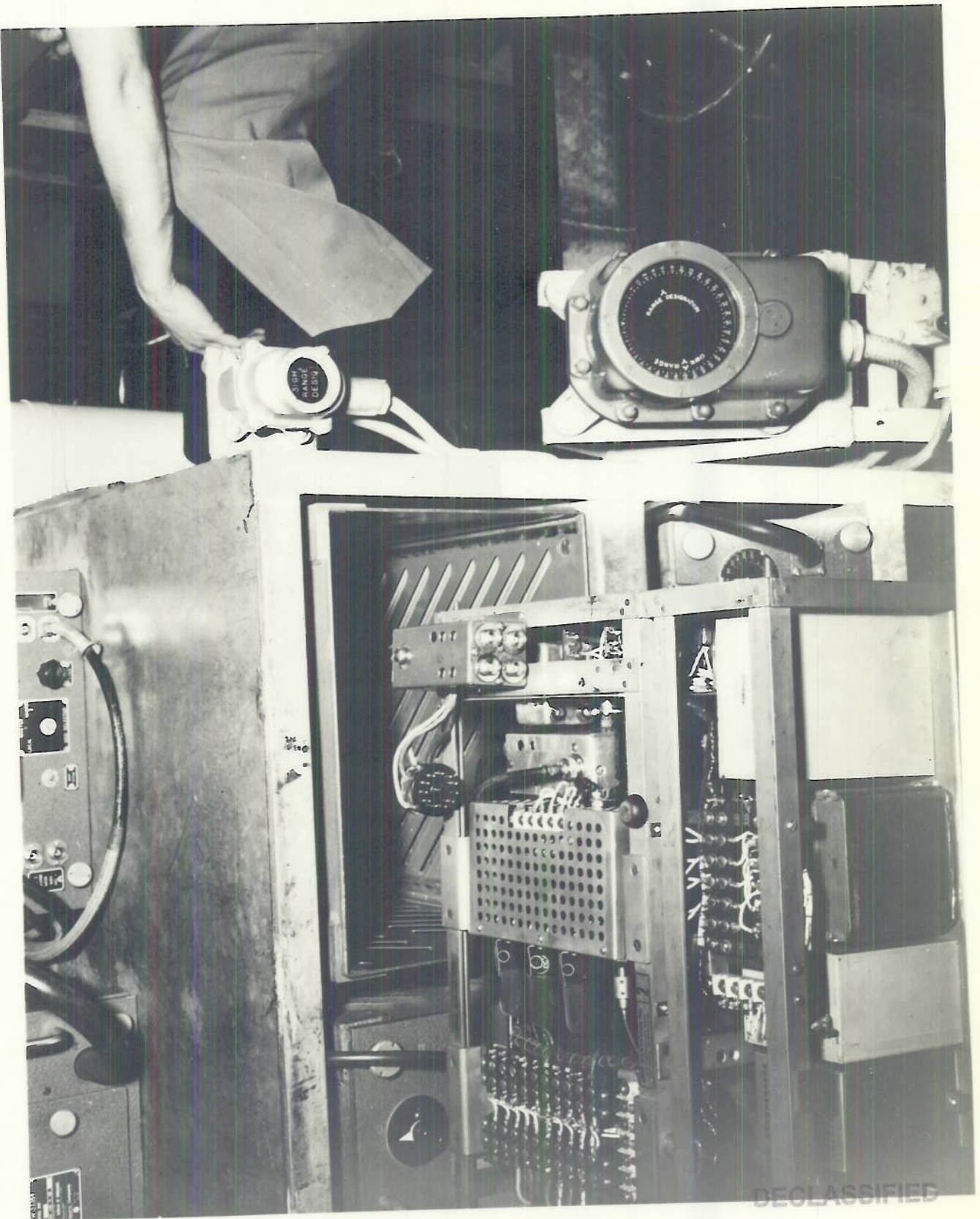
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RADAR EQUIPMENT MARK 28 REMOTE AMPLIFIER

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INSTALLATION OF ADAPTER

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COMPLETE INSTALLATION

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PLATE 5

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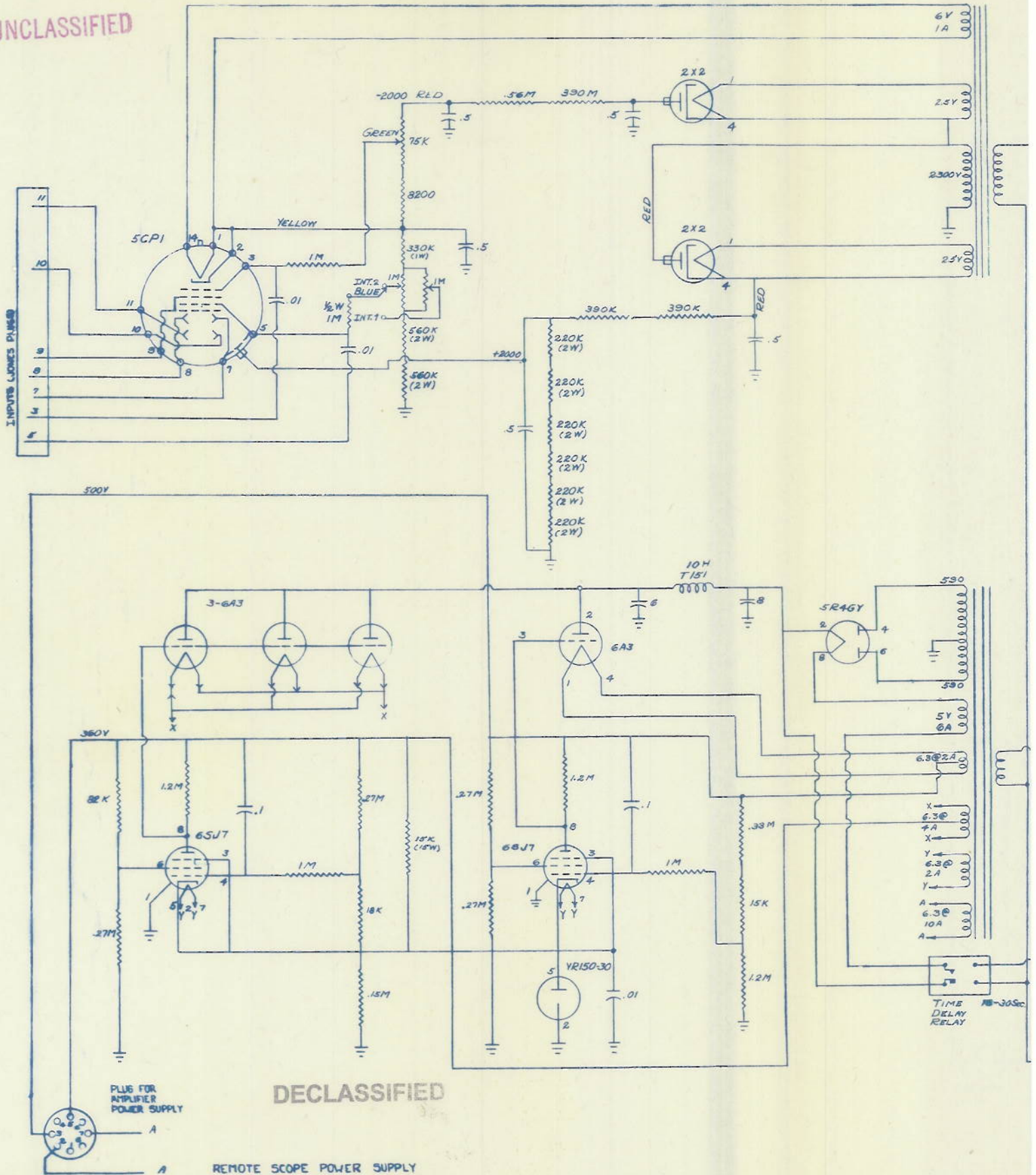
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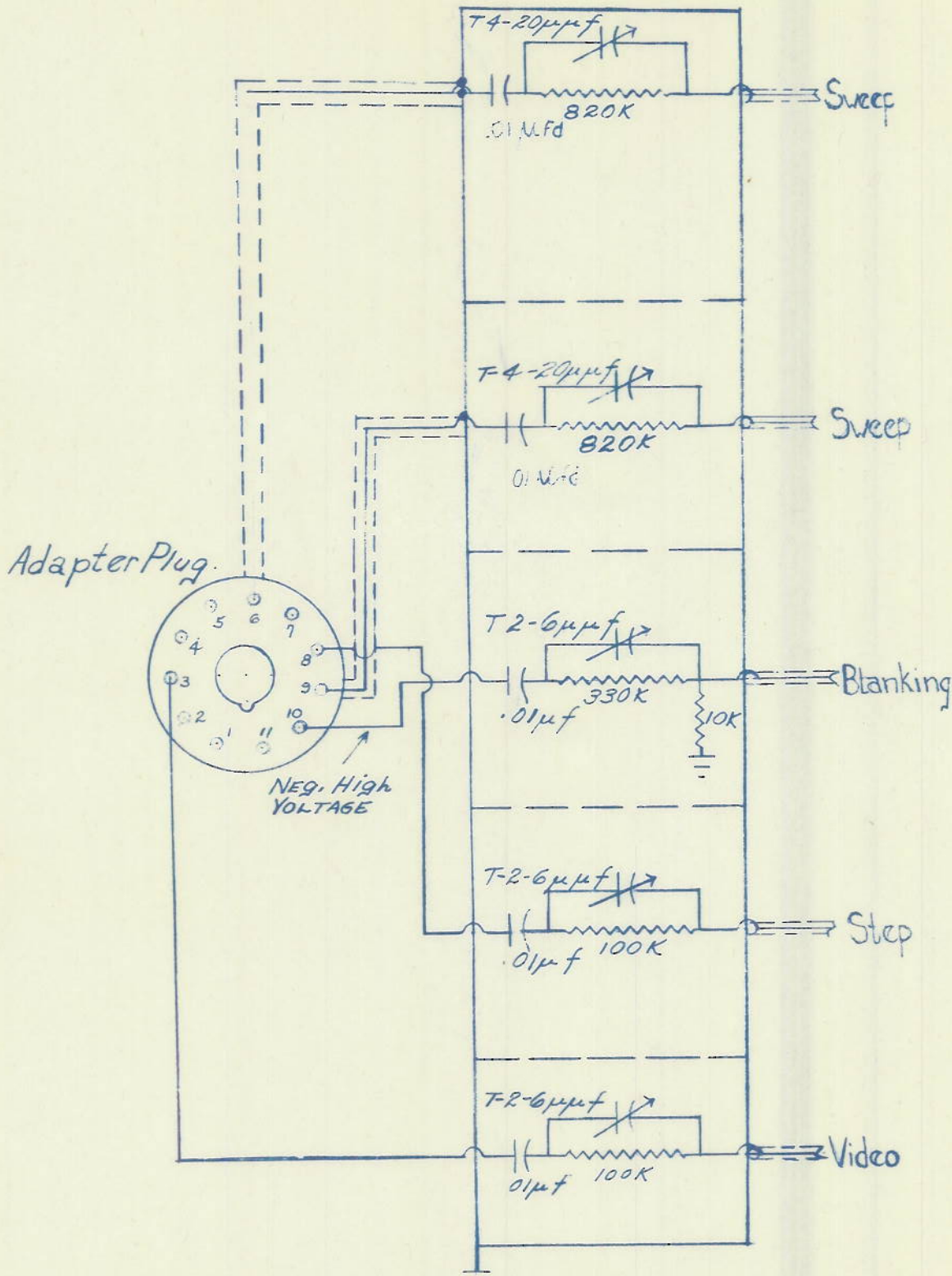
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PLATE 7

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RADAR EQUIPMENT MARK 28 (SERIES) ADAPTER

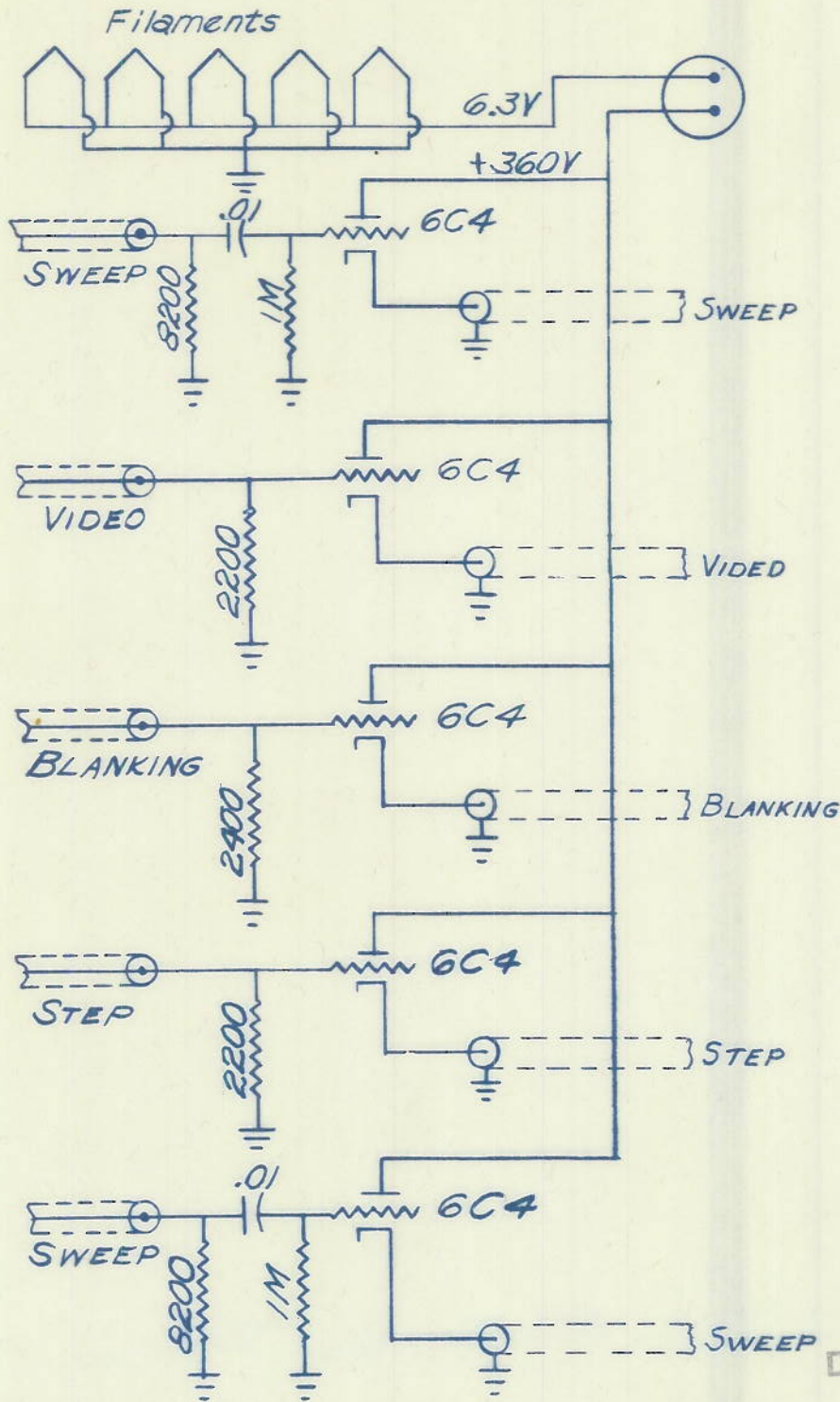
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	E.L. 7 JUNE 45 R-2644	

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INPUT FROM RADAR EQUIPMENT Mk. 28 ADAPTER



OUTPUT TO RADAR EQUIPMENT Mk. 28 AMPLIFIER

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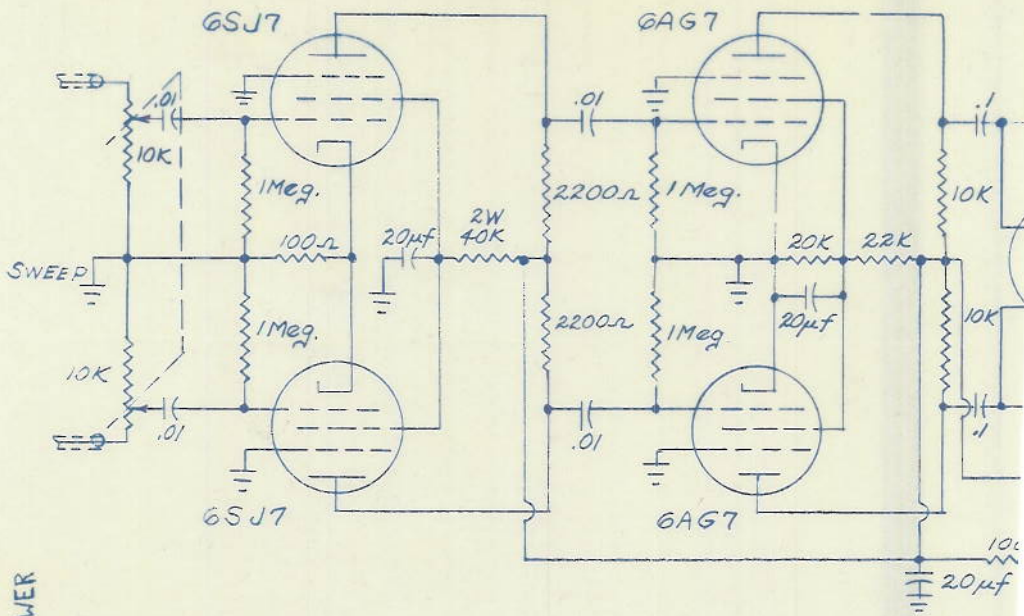
RADAR EQUIPMENT MK.28 CATHODE FOLLOWER

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	E.L. 5 JUNE 45 R-264A	

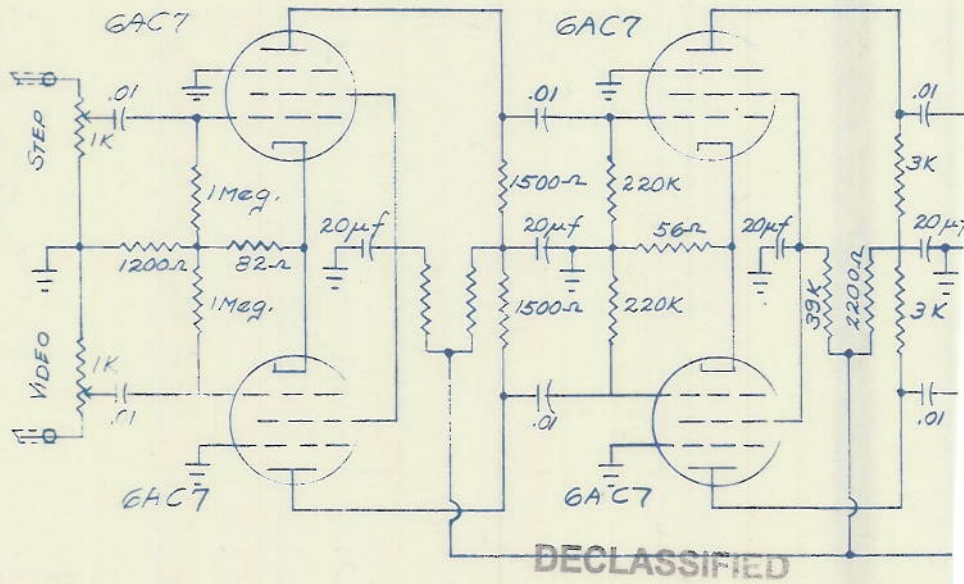
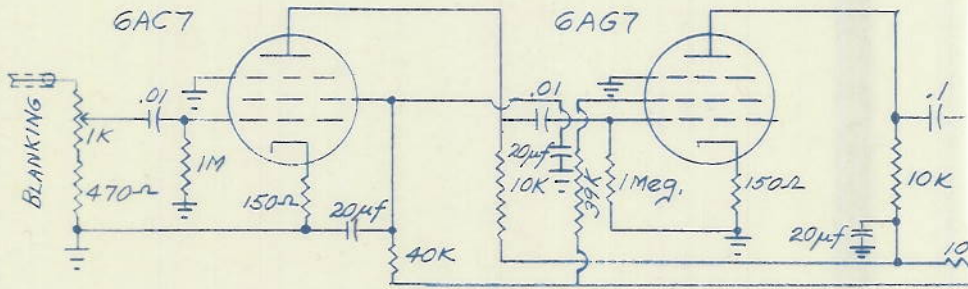
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INPUT FROM RADAR EQUIPMENT MARK 28 CATHODE FOLLOWER

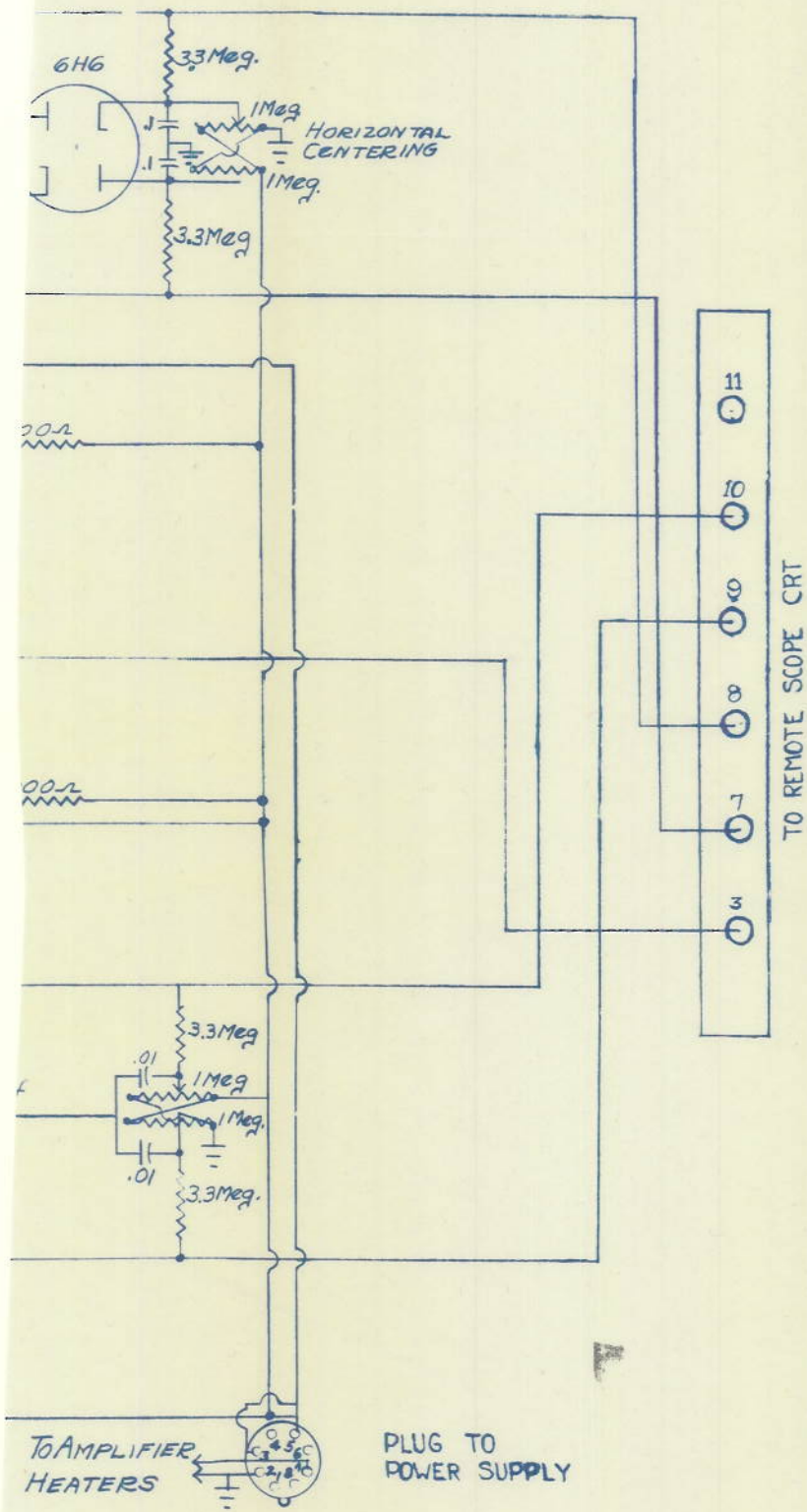


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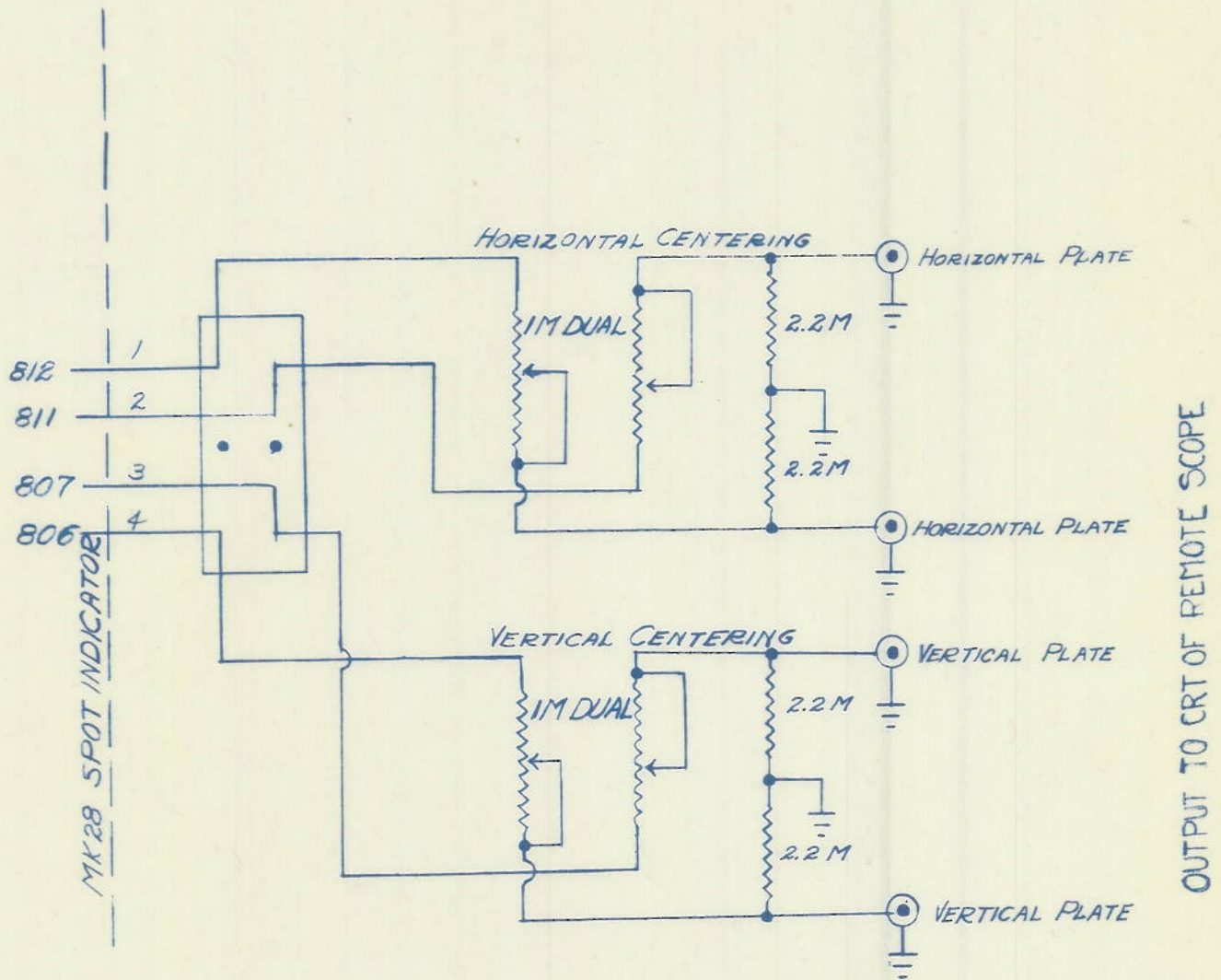
RADAR EQUIPMENT MARK 28 SERIES AMPLIFIER CHASSIS

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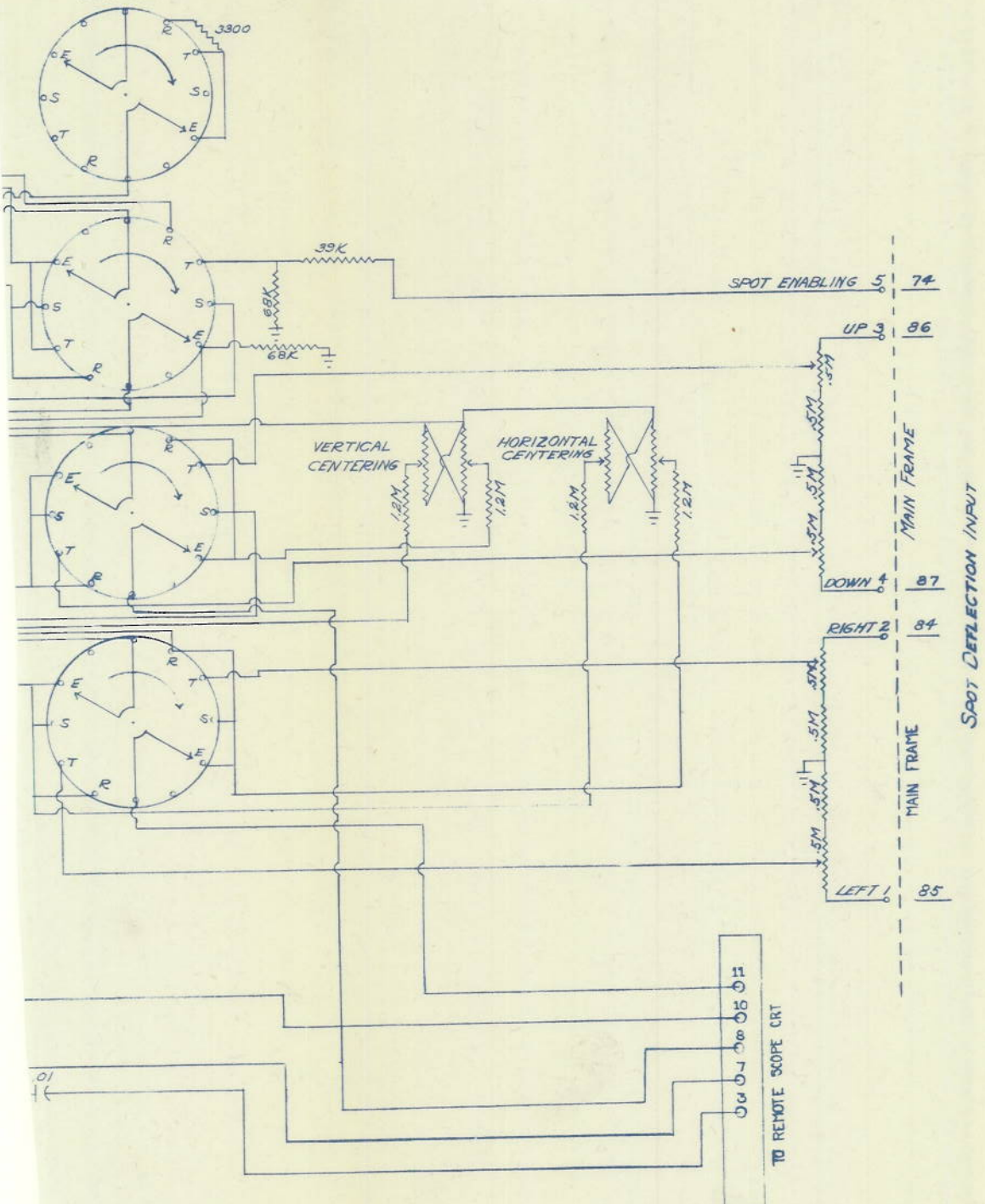


RADAR EQUIPMENT MARK 28 SPOT ADAPTER

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	E.L. 11 JUNE 45 R-2644	

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4 SECTION
WAFER SWITCH.



SPOT DEFLECTION INPUT

SPOT ENABLING 5 74

UP 3 86

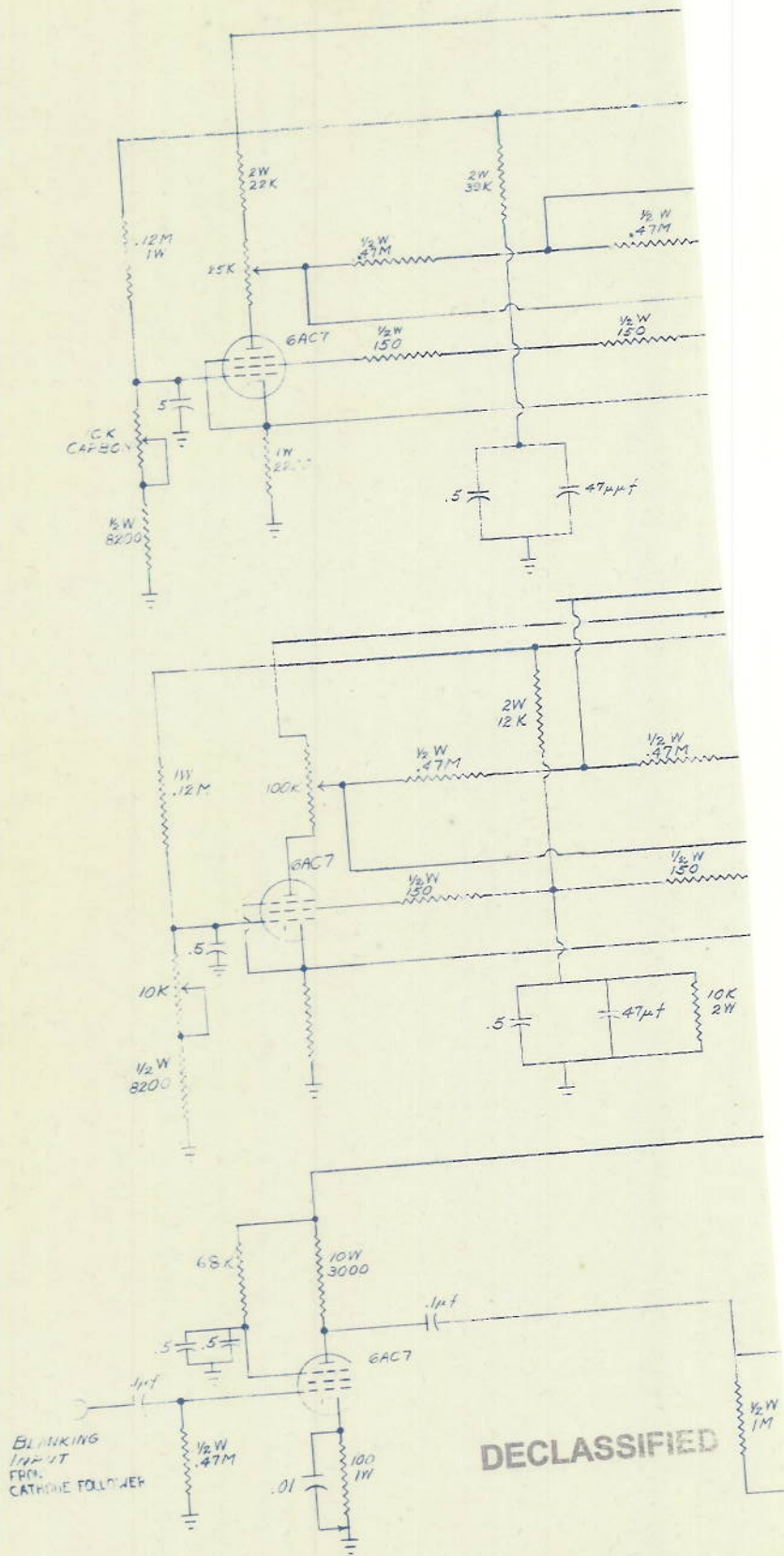
DOWN 4 87

RIGHT 2 84

LEFT 1 85

TO REMOTE SCOPE CRT

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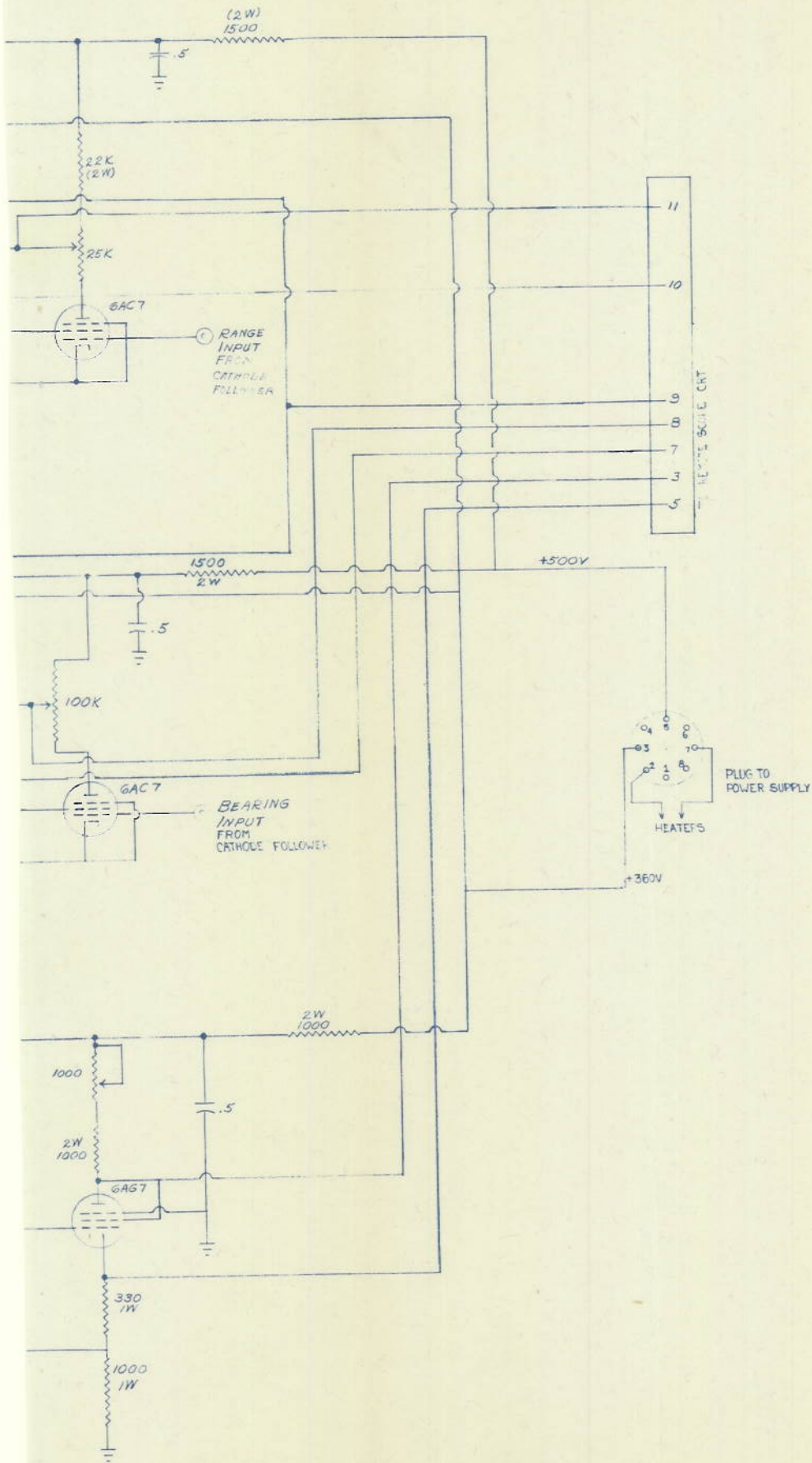


RADAR EQUIPMENT MARK 8 (SERIES) AMPLIFIER

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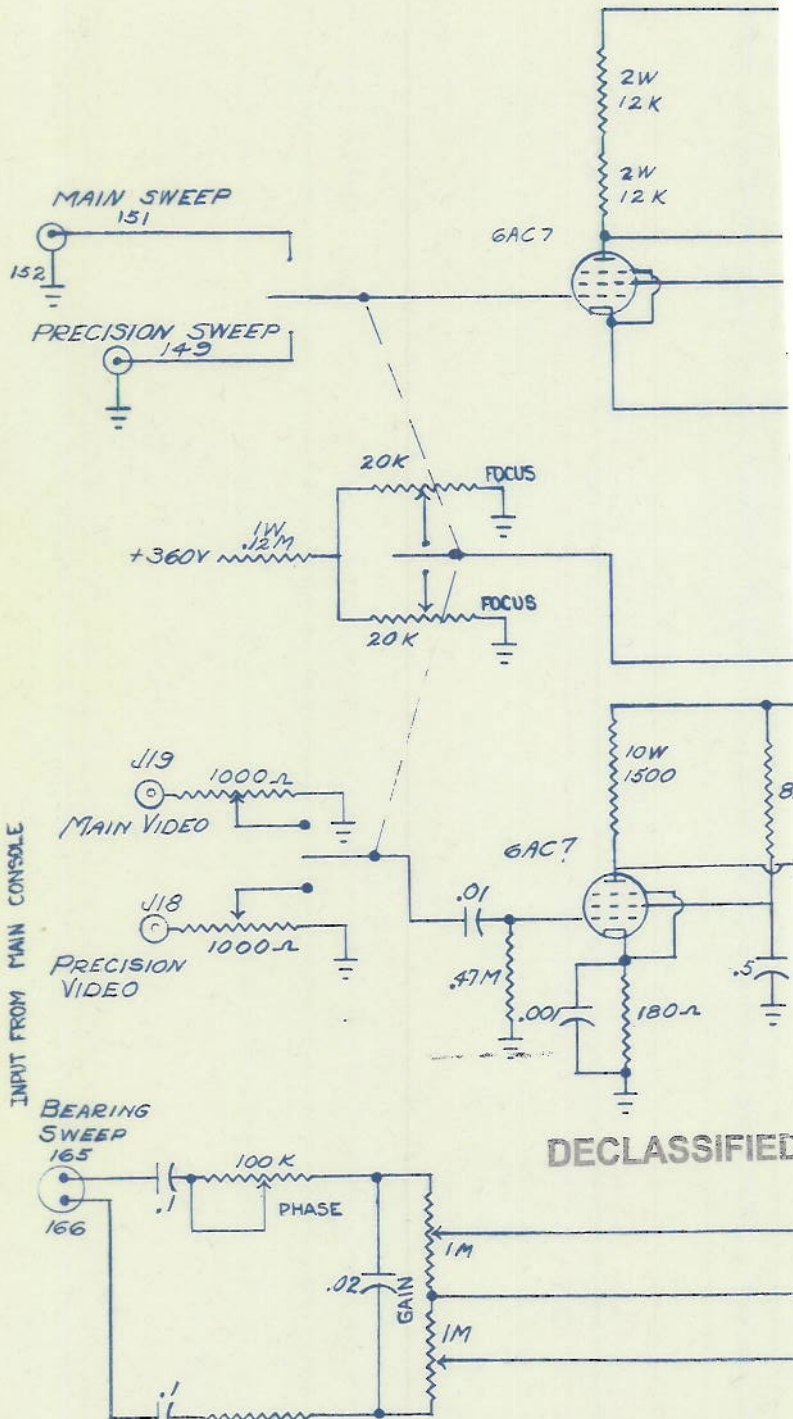
NRL FIRE CONTROL DIVISION
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PLATE 13



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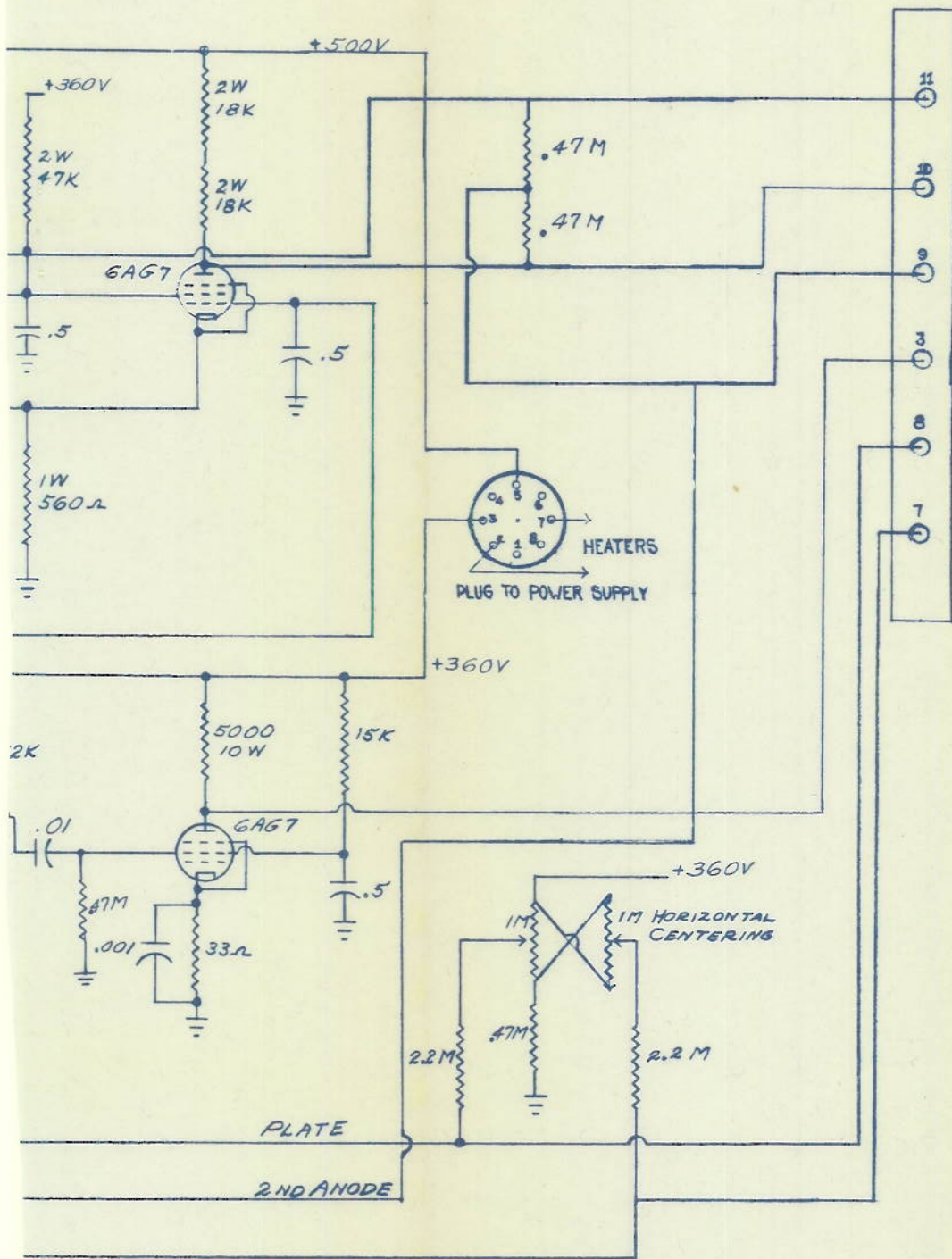


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RADAR EQUIPMENT MARK 13 AMPLIFIER

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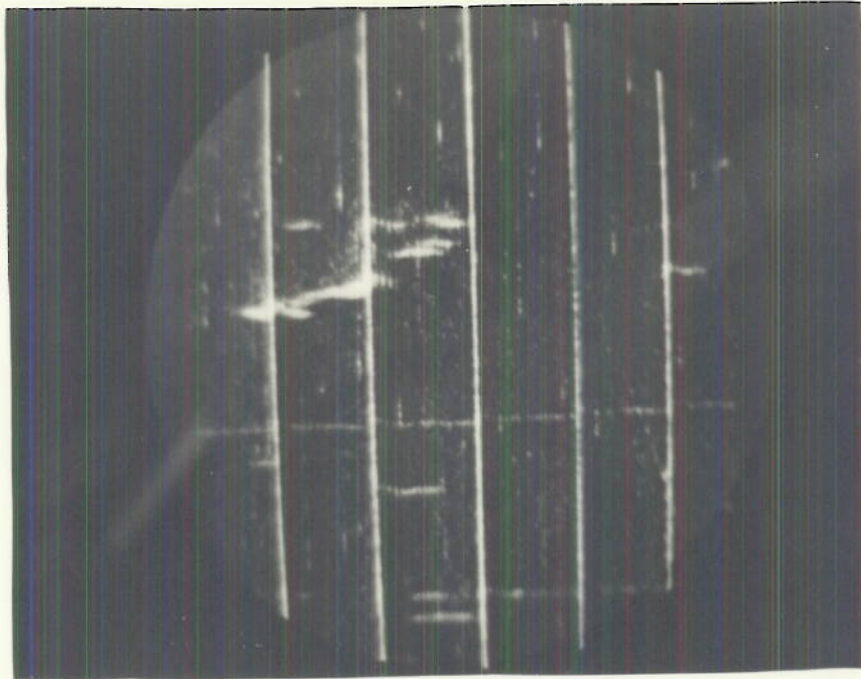


FIG. 1 RADAR EQUIPMENT MARK 8 SCOPE WITH FOG LIGHTS

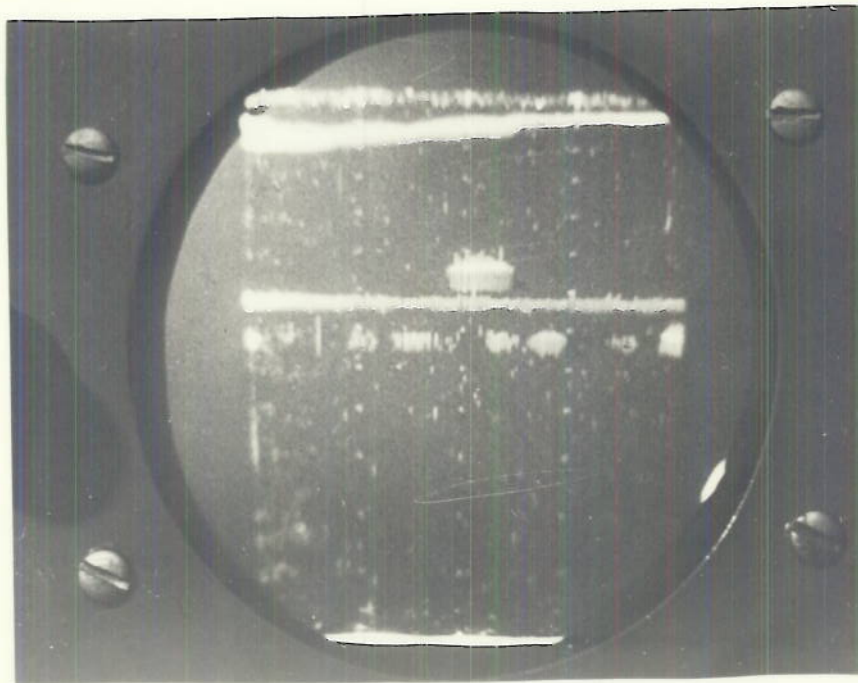


FIG. 2 CLOSE SHOT OF RADAR EQUIPMENT MARK 13 SCOPE WITH OPTICAL WORK

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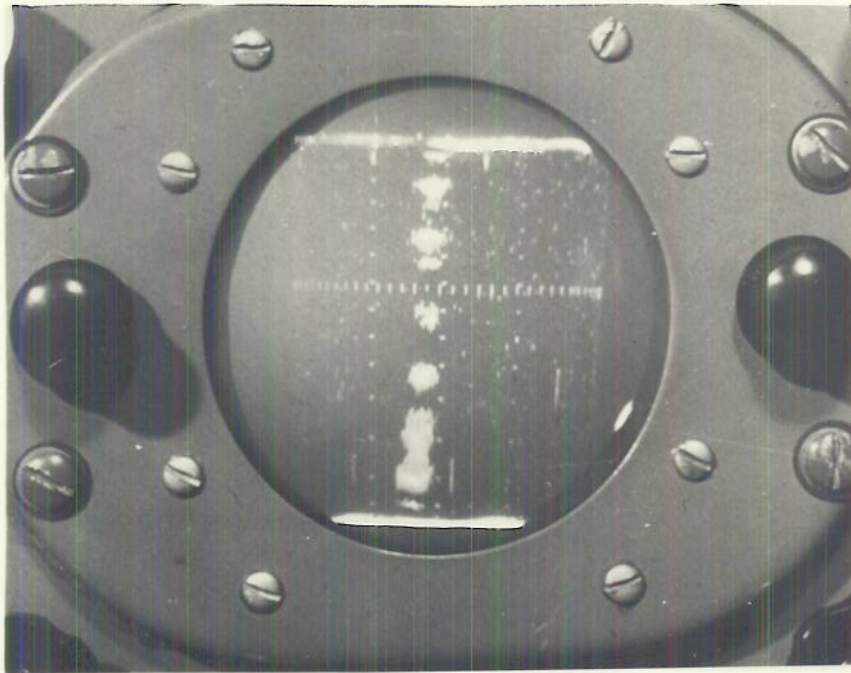


FIG.1 MEDIUM SHOT OF RADAR EQUIPMENT MARK 13 SCOPE WITH OPTICAL WORK

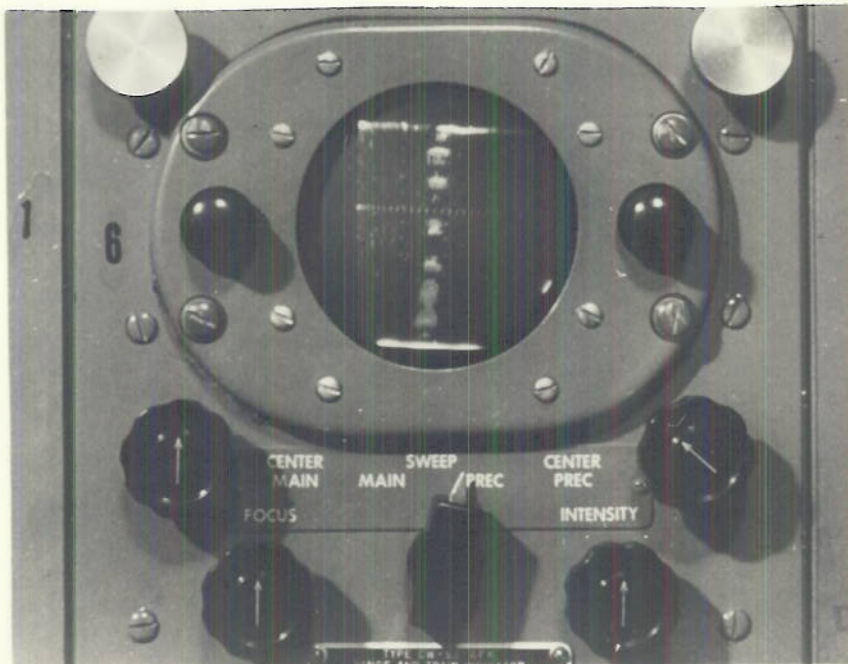


FIG.2 LONG SHOT OF RADAR EQUIPMENT MARK 13 SCOPE WITH OPTICAL WORK

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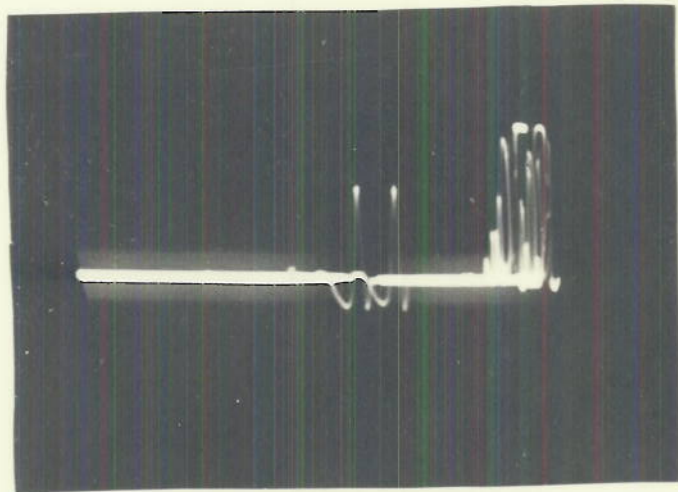


FIG.1 RADAR EQUIPMENT MARK 12 SCOPE WITH NO FOG LIGHTS

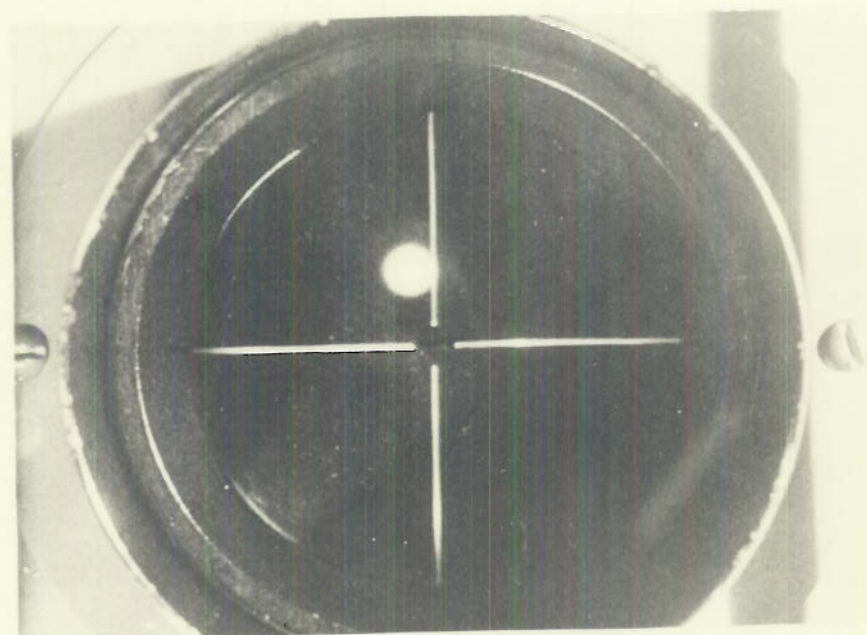


FIG.2 RADAR EQUIPMENT MARK12 SPOT SCOPE WITH CROSS WIRES AND SURROUNDINGS ADDED

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