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NAVY DEPARTMENT
Preliminary Report

of
Plot Room Television System

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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Fig. 6 Scope. White markings on a black screen, 75 ft.-candles illumination of screen. AGC removed.

I. AUTHORIZATION

1-1. The original request for the project is contained in a letter from the Chief of the Bureau of Ordnance to the Director of the Naval Research Laboratory dated 16 January 1943 [F42-1(Relief)]. Further information was obtained in several conferences between Naval Research Laboratory personnel and Lt. Bridges of the Bureau of Ordnance.

II. DESCRIPTION OF EQUIPMENT

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

- 2-1-1. A camera, consisting of optical lens, iconoscope, pre-amplifier, and associated equipment. Some controls are in this unit.
- 2-1-2. A main monitor unit, consisting of kinescope, video amplifier, sweep and shading circuits. The majority of the controls are in this unit.
- 2-1-3. Main power supply.
- 2-1-4. Six remote monitors. These consist of a kinescope, together with necessary scanning and video circuits. The controls on each remote monitor are independent, that is to say, the controls of one monitor do not affect the operation of the other monitors.
- 2-1-5. Necessary coaxial cables and connectors.

2-2. The manufacturer is the Radio Corporation of America. All the above units, except the camera, are mounted on lord vertical snubbing holders.

2-3. A detailed description of the apparatus is contained in the instruction manuals "Plotting Room Television Equipment Proposition 23018-B" by W. J. Poch and F. E. Cone, and "Seven-Inch Television Monitor Equipment" by R. V. Little, Jr. Two copies of these manuals were delivered to the Naval Research Laboratory by Messrs. Poch and States of RCA. These gentlemen demonstrated the operation of the equipment at the Anacostia Station of the Naval Research Laboratory on 23 March 1943.

III. PURPOSE OF PLOT ROOM TELEVISION

3-1. In the fleet, present methods of communicating information concerning the bearings and ranges of targets from the Anti-aircraft

Plotting Room are ordinarily by telephone or synchro transmission. These methods have proven inadequate for handling a multiplicity of high speed targets.¹ Several plans for solving this problem are in the experimental stages of development. Television scanning of the master plot in the Anti-aircraft Plotting Room (or in the Combat Information Center) and the reproduction of the plot on remote scopes, located at desired positions, is one of these plans.

IV. OUTLINE OF TEST PROGRAM

4-1. The test program was divided into four general parts:

4-1-1. Detailed analysis of performance and operating characteristics. This involves the quantitative measurement of various aspects of performance and the effect on performance of various factors which can be expected to be met in service. Information of this kind can be obtained only by holding all parameters constant and varying one at a time. From the data obtained in this way an accurate estimate can be made of the service performance of the equipment.

4-1-2. From the results of 4-1-1, certain alterations in operating conditions and circuits appeared desirable. Such of these as were practical to incorporate in this particular equipment were put into effect and tested.

4-1-3. Overall check of performance with a special plotting board designed for this equipment. This involves the actual use of the plotting board and television equipment in fire control. The possibility of making this part of the test awaits the arrival of the special plotting board at the Naval Research Laboratory.

4-1-4. Shock and temperature tests. The chance of damaging the equipment has caused this part of the test to be postponed until all other tests are completed.

¹ A discussion of the Target Designation Problem -- Proposing a System for Radar Target Designation Transmission, BuOrd (Relif), dated 22 Jan. 1943.

4-2. The following parts of the report give the results of tests 4-1-1 and 4-1-2.

V. GENERAL CONSIDERATIONS

5-1. The construction appears to conform to the usual standards of commercial apparatus. The most obvious deficiency is the absence of any holes on the camera for mounting.

5-2. It was found necessary to remove the protective rubber tube from the lens barrel. With this in place it was not possible to focus on a plane giving a one meter vertical image, which is equal to the diameter of a plotting board. The equipment is relatively compact. The requirement that the remote monitors operate in series (with a line from the main monitor to the first remote, from the first remote to the second remote, etc.) would make shipboard installation somewhat difficult.

5-3. A warm-up period of about ten minutes is required before a steady operation condition is reached. One of the remote monitors had a tendency to fall out of synchronism with the system. This caused its picture to "jump". None of the other monitors exhibited this effect under normal conditions.

5-4. The shading controls required an excessive amount of adjustment, even under steady-state conditions. Any motion of the main cable connectors (going from the camera to the main monitor unit) was found likely to affect the shading. At times the shading would change, from no ascertainable cause, by an amount sufficient to seriously impair the visibility of a large portion of the image. As a rule, each time the equipment is turned on some adjustment of shading is either necessary or desirable.

5-5. A prolonged initial lining up process was necessary to get best reproduction of the image. Contrast, brightness, optical focus, iconoscope focus, kinescope focus, linearity, etc. were adjusted for optimum results and kept in adjustment throughout the test. Suitable test patterns were used for this work.

VI. TEMPERATURE

6-1. The following equilibrium air temperatures were measured above the chassis and inside the cabinets with the cover plates on:

<u>Apparatus</u>	<u>Position</u> (facing the front panel)	<u>Temperature</u>
Master Monitor	Rear-Right	85° C.
Master Monitor	Front-Left	48° C.
Remote Monitor	Center	65° C.
Power Supply	Center	45° C.
Room		23° C.

The temperatures varied somewhat with the position in the various units. Approximately one-half hour was required for the units to come to temperature equilibrium. 115 volts were applied to the units.

VII. LINE VOLTAGE VARIATION

7-1. The apparatus was placed in normal operation with 115 volts supplied to the units from a variac. At 120 volts, there was some difficulty in studying the reproduced pattern because of jumping of the frames. This motion resulted from "lock in" failures. At 108 volts, the vertical motion of light and dark bands on the scope became noticeable and distracting. The motion of lines and bands and "lock-in" failures were so pronounced at 104 volts that the scope could not be read.

VIII. LINE FREQUENCY VARIATIONS

8-1. The apparatus was placed in normal operation at 115 volts and 60 cycles per second. At 60 cycles per second varying the voltage gave the results indicated above. As the frequency and voltage were varied, the results given below were observed:

<u>Frequency</u> (cycles/sec.)	<u>Voltage</u> (Volts)	<u>Remarks</u>
55	115	Readable but below normal performance.
55	110	Readable but below normal operation.
55	105	Becomes unusable with lock-in failures and motion of dark bands.
55	118	Lock-in failures become very pronounced.
65	106	Becomes unusable with motion of bands and lock-in failures very pronounced.
65	120	Lock-in failures very pronounced.

8-2. At normal voltage, the apparatus was not particularly sensitive to frequency changes. The beats produced faint dark lines that moved across the field of view of the remote scopes, but these bands were not sufficiently pronounced to be very disturbing to the operator.

IX. SHOCK AND BLAST

9-1. The video stages of amplification in the master monitor are very sensitive to shocks and blasts. Though shock mounting is provided, rapping the table with the hand develops microphonics that obscure the reproductions on all the scopes. The units other than the master monitor appear to be relatively insensitive to shock. In a room across the hall from Room 1, and approximately 30 feet distant, ballistic tests of a 30 calibre rifle were in progress. The charges being used were standard

and below. Reproductions on all the scopes were always obscured following the blast. These shock tests are not those referred to in section IV.

9-2. The shading on all the scopes appeared to be changed to some extent when the coaxial cables leading from the master monitor to the remote monitors were removed.

X. RADAR INTERFERENCE

10-1. The apparatus was set up in the Penthouse of Building 12 for operation near the XAF radar (prototype for CXAM). The resultant interference patterns are shown in the prints of Plate 1. The negative bias on the electron gun in the cathode ray tube, which is controlled by the brightness knob, was fairly effective in "cutting off" the low voltage interference. The various pictures of Plate 1 were taken with different settings of the brightness control. The apparatus was about 5 feet from the XAF when these pictures were taken. With the apparatus 60 feet from the XAF, satisfactory reproduction on the scopes without radar interference was obtained for a limited range of the brightness control. The interference appeared to be due to radiation pick-up and not due to fluctuations in the a-c line arising from the pulsing of the radar oscillator, as the a-c line connections were essentially the same for the two distances.

10-2. A portable 400 mc pulsed oscillator of low power output was employed to explore the interference sensitive regions of the master monitor. The output power of the oscillator was not sufficient to give a noticeable interference pattern when the cover plate was on the master monitor. When this cover was removed, the oscillator gave a pattern of vertical rows of bright dots on the scopes, each dot corresponding to one pulsing of the oscillator. The initial stages of video amplification were very sensitive in picking up the radiation.

XI. REFLECTED AND TRANSMITTED LIGHT TESTS

11-1. There are two general ways in which the plotting board can be illuminated. These are by reflected light and by transmitted light. Reflected light is the usual way by which opaque objects are viewed. Viewing the plotting board by reflected light involves illumination from the "front", or the same side of the board that the camera is on. An image is formed on the iconoscope mosaic by reason of the different coefficients of diffuse reflection of the lines and other marks, and the background of the plotting board.

11-2. Transmitted light viewing depends on the use of a transparent, diffusing background on which opaque marks are made. In this case the illumination is from the rear. Here the image is formed by reason of the difference in the coefficients of light transmission of the marks and the background.

11-3. The principal criteria of excellence of one method over the other depend on the relative and absolute values of the coefficients of light transmission and diffuse reflection of the marking materials and the backgrounds. The absolute values of the coefficients determine the amount of illumination needed, and the relative values of contrast obtained.

11-4. A secondary consideration is that with transmitted light practical limitations dictate the use of diffuse light sources, while with reflected light filament-type bulbs can be used.

11-5. In the tests, except where explicitly stated, every effort was made to get maximum contrast between patterns and backgrounds. This involved the use of India ink on white paper in the white-background reflected light tests. Similar methods were used in the other tests.

XII. DIFFUSELY REFLECTED LIGHT TESTS

12-1. It was desired to evaluate the resultant reproductions on the scopes under various light intensities. For this purpose, a screen of white drawing paper was set up. Test patterns of interest in the present consideration were constructed; Fig. 2a, 2b, and 2c are reproductions, approximately to size, of the parts of the test pattern. Fig. 2a shows the resolution chart which is set up for a vertical field of view of one meter on the screen. It is customary to express the vertical resolution in terms of the number of lines resolved in the vertical field of view; i.e., the number per meter in the present case. Number 2 corresponds to a resolution of 200 lines per meter; number 3, 267 lines per meter; and number 4, 400 lines per meter. A vertical field of view of one meter was chosen as it is desired to reproduce a circular plot 3 feet in diameter. Fig. 2b has lines of $1/32$, $1/16$, and $1/8$ inch widths. Black paint was used on thumb tack heads and wire crosses soldered to tacks to give the elements that are reproduced to size in Fig. 2c. In the upper right of the screen, a figure composed of circles and lines of varying widths provided a reasonable check of the linearity of the reproduction near the outer portions of the scope, where distortions are the most pronounced. The chart in the lower left corner of the screen was a standard lens testing chart. The line connecting the black crosses was made with China marking pencil; all the other lines were made with India ink.

12-2. The screen was illuminated with General Electric Mazda, No. 2, photo floods at a color temperature of approximately 3800° C. The lamps were conveniently arranged in reflectors to provide uniform illumination of the screen with facility for varying the illumination. The illuminations were read with a Macbeth illuminometer.

12-3. The pictures of the scope were taken with a Zeiss Tessar, 1:3.5, $f = 15$ cm, lens at $f 5.6$ and $1/10$ second on Panatomic film without any filters.

12-4. The data on resolutions and illuminations are supplied in Table I. The resolutions, as estimated at the time the pictures were taken, are entered under "eye" in Table I; "film" indicates that the resolution has been estimated from the print. At the light intensity for taking Fig. 3d, the rise of the noise became apparent with an accompanying loss of contrast, this effect increased in Fig. 3e and 3f. The automatic gain control operates to maintain the same overall brightness as the illumination is reduced, but contrast drops and random noise increases.

Table I

Fig. No.	Illumination (ft.-candles)	Vertical Resolution		Horizontal Resolution	
		Eye	Film	Eye	Film
3a	116	250	255	270	280
3b	83	250	265	270	275
3c	42	250	255	270	275
3d	20	250	255	270	270
3e	13	250	250	270	275
3f	6	250	250	260	270

12-5. An illumination of 40 to 60 ft.-candles of the screen is recommended, as there is little if any improvement in performance at greater illuminations. Illuminations in this recommended range should be satisfactory for making the plot without too much discomfort to the plotter, as 15 ft.-candles are ordinarily recommended for drafting rooms.² A search light bulb of the type TQ-19 (in use in the fleet) was used as a light source in a few tests; the performance appeared to be as good as with photo floods. Plotting with black thumb tacks or wire crosses is recommended as a rapid method of producing black points of sufficient size to show on the scopes.

XIII. FLUORESCENT LIGHTING IN THE PLACE OF PHOTO FLOODS

13-1. Four General Electric Mazda, 40 watt, white light, fluorescent bulbs, 3500° C. color temperature, were arranged to illuminate the screen. The performance of the television apparatus with fluorescent lamps was as satisfactory as with photo floods, except that the flickering of the fluorescent lamps gave a pattern of horizontal dark bands on the scope. These bands were not very pronounced, but they might prove distracting to the operator. The bands arose from optical flickering, not electrical interference, and were not dependent on the distribution or directions of the axes of the lamps. The bands appear with a screen illuminated by transmitted as well as reflected light. These bands might be eliminated by use of d-c on the fluorescent lamps; however, this would be an additional complication to the apparatus for shipboard installation.

² Cady and Dates, Illumination Engineering (Wiley) p. 275.

XIV. TRANSMITTED LIGHT

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14-1. For the tests with the light transmitted through the plotting board, a screen of Imperial tracing cloth was set up. The vertical field of view was again approximately one meter. The black wire crosses and the thumb tacks of Fig. 2c were placed in a column on the upper right of the screen. The center thumb tack was larger than those shown in Fig. 2c. The cross in the upper left was formed of 3/8" India ink lines. All the other lines were made with China marking pencil. There was considerable difficulty in making black lines for television purposes on the screen with either China marking pencil or India ink.

14-2. Two photographs were taken with transmitted light and the data are given in Table II. The screen was illuminated with photo floods.

Table II

<u>Fig. No.</u>	<u>Illumination (ft.-candles) Behind Screen</u>	<u>In Plotter's Eye</u>
4a	1060	140
4b	340	63

The illumination in the plotter's eyes included some light that was being diffusely reflected about the room, and is accordingly somewhat higher than may be expected if these reflections are minimized. An illumination of 300 to 400 ft.-candles is required behind the screen to provide satisfactory performance. This given 50 to 70 ft.-candles in the eyes of the operator. Comparing this value with the illumination recommended for diffusely reflected light, it is shown that the operation of the iconoscope is essentially dependent on the amount of diffuse light leaving the screen and essentially independent of the distribution of lamps that produce the diffuse light.

14-3. A glass plate from a Hamilton Plotting and Tracing Board was set up as a screen. The glass was glazed on one surface and frosted on the other surface. Markings on the glazed surface were not satisfactorily reproduced because of reflections. In marking on the frosted surface with China marking pencil, the failure of the China pencil to fill in all the pits in the glass reduced the contrast to a remarkable extent; India ink filled these pits and the reproductions showed contrasts comparable but no better than those secured with reflected light.

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15-1. Measurements were made of the detail brightness contrast ratio³ on the scope by using a Macbeth illuminometer with a green filter for color matching. A screen prepared by making a large spot of India ink on white drawing paper, was illuminated with about 150 ft.-candles from photo floods. The resultant black spot on the scope was slightly larger than the tube of the illuminometer. Detail brightness contrast ratios from 6 to 9 were measured.

XVI. DIAL REPRODUCTION

16-1. The dial shown in Fig. 5a was observed and photographed on the scopes. The print is shown in Fig. 2b. The dial illuminated with 265 ft.-candles from photofloods with the screen 18 inches from the camera lens. The distance of 18 inches from the camera was chosen because this gave a vertical field of 17 inches which is approximately the height of an instrument board. The dial of Fig. 5a forms a considerably better image than the usual instrument dial under glass. There was much improvement in the reproduction when a white background was used. This improvement was due to the action of the automatic gain control. With this removed, the following section indicates the black field can be expected to be by far the better.

XVII. AUTOMATIC GAIN CONTROL REMOVED

17-1. The automatic gain control was removed and a potentiometer was arranged to provide a variable grid bias on V₆ (type 6AC7). This change permitted the investigation of white marks on a black background without the automatic gain control raising the noise to an intolerable level. When a white background was used with the automatic gain control removed, results that were somewhat better than those reported in the preceding section were achieved by turning the contrast control (control of gain in video stages) to the maximum setting and placing a very negative bias on the kinescope (brightness control).

17-2. A black screen of thick blackboard paint on white drawing paper was arranged with test patterns as shown in Fig. 2a and thumb tacks with heads painted white and of the size shown in Fig. 2c. The vertical field of view was again approximately one meter.

17-3. The print of Fig. 6 indicates the improvement in performance achieved with white on black as contrasted with black on white. The resolutions, as estimated by the eye at the time the pictures were taken, are: 400 lines per meter on the screen for the horizontal and

³ Ratio of brightness of light region to brightness of dark region when the area of the bright region is large compared to the area of the dark region.

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280 lines per meter for the vertical. It was not possible to remove all the shading secure lines of desired brilliance on the screen. The picture was taken with 75 ft.-candles on the screen. Under more intense illumination the signal-to-noise ratio and contrast are increased and improved reproduction is achieved.

17-4. Blackening out of most of the field of view on the scope adds to the comfort of the operator by improving the contrast and resolution, and making the flicker not noticeable to the eye. The black background reflects less light into the plotter's eyes than the white background and is accordingly much more satisfactory from his point of view. Lighting the detailed points of interest is more effective in attracting the attention of the operator than darkening these details. Another improvement is that the image is less affected by shock.

XVIII. CONCLUSIONS

18-1. On the basis of the foregoing tests, the following conclusions have been reached:

- 18-1-1. The required manipulation of the shading controls is too great to be convenient for service conditions. A man would be required permanently stationed at the main monitor, and even so there would probably be periods of several seconds or more when up to half the screen area would be blacked out or have its visibility impaired due to shading variations.
- 18-1-2. Certain portions of the equipment develop excessive temperatures. With ambient that may occur in service, no definite predictions can be made as to the possibility of failure from this cause until runs are made in the temperature room.
- 18-1-3. The equipment is limited to the range 108 to 120 volts in its tolerance of line voltage variations. The apparatus is relatively insensitive to line frequency variations in the range from 55 to 65 cycles per second.
- 18-1-4. Even comparatively insignificant shocks cause the image to jump disagreeably. By using a white-mark-on-black-background plot this situation is improved. Until complete shock tests are made no prediction can be made as to the possibility of failure or inferior performance with conditions as found in service.

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- 18-1-5. Under most service conditions, interference from radar should not be a serious factor.
- 18-1-6. Performance with reflected light and a white background is below the minimum standard which appears useful, for any naval purpose. With the automatic gain control in operation, the best resolution is 250 vertical lines and 270 horizontal lines with 40 to 60 ft.-candles on the screen. Contrast is around 6 to 9.
- 18-1-7. Transmitted light gives results inferior to 18-1-6.
- 18-1-8. Fluorescent light gives a slightly objectionable pattern with used on a-c.
- 18-1-9. There appears to be no possibility of using the system for remote indicating of 3" instrument dials.
- 18-1-10. Great improvement in quality and reduction in eye strain is made by having a black background with white marks. Successful operation under these conditions involve substituting for the automatic gain control a manual gain control (which need be set only occasionally) and a change in value of the shading voltages. Whether or not this form of operation gives acceptable performance for plotting room use is doubtful, but the final decision must await tests with the plotting board.
- 18-1-11. The choice of an aspect ratio of 4:3 is unfortunate. 1:1 would be preferable.

XIX. RECOMMENDATIONS

19-1. The possibility of radical improvement in performance by a new design is so great that, even if this equipment is able to meet minimum standards, its adoption is not recommended.

XX. GENERAL DISCUSSION OF THE PLOT ROOM TELEVISION PROBLEM

20-1. Scope: The development of television for the reproduction of a master plot on remote scopes presents problems sufficiently different from the problems of commercial television to merit their enumeration and consideration. The problems taken into account in

the development of commercial television are well known.^{3,4} For the present purposes, wire transmission of the signals and the nature of reproduction that is feasible, introduce significant simplifications in the electrical features of the desired apparatus. But shipboard installation presents problems of line voltage fluctuations, shocks, and blasts such as are not encountered in the commercial developments.

20-2. Contrast and Resolution: Contrast and resolution are the two most important points in analyzing the scopes for the type of information desired under the present consideration. The major portion of the field of view on the scope should be dark with the points of interest on the plot appearing in light. As amply discussed in television publications,^{3,4} and pointed out in the tests of plot room television, this procedure provides a brightness ratio 5 or more times greater than may be expected when a considerable portion of the field of view on the scope is bright. This type of field may be produced, either (a) by using a black background and white marking on the plot, or (b) by using a white background with markings in black with an inversion of white into black in the television circuits. The black background is believed to be the more suitable of the two for the comfort of the plotter and the fidelity of the reproduction. The vertical resolution depends on the number of scanning lines; the horizontal resolution depends on the frequency band pass of the circuits and the time required to scan one line. These quantities are inter-related and present problems of compromise.

20-3. Number of Scanning Lines: It is pertinent to consider the requirements of the television system that would provide as much detail as possible on the scope of convenient size. The cathode ray tube must provide the smallest possible spot diameter. DuMont manufactures some cathode ray tubes that are designed for low beam currents and small spot diameters. On a 7-inch DuMont tube, which is of convenient size for most applications, 550 to 600 scanning lines can be advantageously used if the aspect ratio is 1:1 and the unnecessary corner portions of the reproduction are made to extend at least partially out of the field of view. Five hundred fifty scanning lines would provide a vertical resolution of approximately 400 lines. Commercial Iconoscopes that will accommodate 550 scanning lines are available. Accordingly, 550 scanning lines on a DuMont 7-inch scope are recommended as reasonable.

20-4. Frame Frequency: A frame frequency of 30 per second with interlaced scanning is in use in commercial television, but it is recognized that it is desirable to reduce the frame frequency to as low a value as will be consistent with tolerable flickering. Recent experiments by the author with a line of light on a dark background on a scope with a P1 screen, showed that retrace rates as low as 15 per second did not give particularly objectionable flickering for normal and below normal intensities of the electron beam. With a scope of

³ Television, by Zworykin and Wilson, (Wiley)

⁴ Principles of Television Engineering, by Fink, (McGraw-Hill)

longer persistence screen than P1, frame frequencies of 15 per second, or less if desirable, should be adequate. (The plotter should wear a black sleeve and black gloves to avoid "smearing" a long persistence screen.) Interlaced scanning reduces flickering but should not be necessary, and is not desirable if it must add greatly to the complexity of the apparatus.

20-5. General Requirements of Video Amplifier: The design of the video amplifier is much simpler from the electrical point of view for the present desired reproductions than for commercial television. This simplification arises in the present considerations because intermediate shades between black and white are neither necessary nor desirable. Accordingly, the video amplifier should provide full response for any signal above a certain minimum amplitude and no response for signals below this minimum. One early stage of the video amplifier should feed into a stage of class C amplification for the elimination of the "noise"; the negative bias on the kinescope (brightness control) has this function but it is desirable to have the brightness control setting independent of the "noise" level. A "squarer" amplifier may be introduced near the kinescope to provide pulses of constant amplitude to the kinescope; this "squaring" action removes the requirement of keeping the response-frequency curve flat and improves the horizontal resolution. It is more important to avoid phase distortion than amplitude distortion in the video amplifier design.

20-6. Video Frequency Band Pass: In an ideal amplifier, pulses from the camera are transmitted to the kinescope without change in wave form. For wave forms that are nearly square, such as those encountered in the present consideration, practical operating characteristics must naturally fall far short of the ideal conditions. The high frequency cut-off must not be at too high a frequency if a suitable signal-to-"noise" ratio is to be achieved and if design difficulties are to be held to a minimum. However, the high frequency limitations of the amplifier limit the horizontal resolution on the scope; i.e., the greater the number of harmonics of the square waves that are passed the greater the horizontal resolution. In commercial television transmitters, the high frequency response of the video amplifiers have been designed (whenever possible) to provide a horizontal resolution that is approximately equal to the vertical resolution. The frequency band pass, being a function of the frame frequency, cannot be determined until a desirable frame frequency has been chosen. However, it is of interest to consider the frequency band passes required for frame frequencies in the range from 10 to 30 per second. The following formula has been found satisfactory for computing the frequency characteristics for picture transmission: (See Zworykin and Wilson, p. 191)

$$f_c = \frac{\sqrt{2} N^2 n w}{4 h}$$

Where N is the number of scanning lines, n is the frame frequency, w/h is the aspect ratio, and f_c is the maximum frequency for which the response-frequency curve must be flat with the response-frequency curve gradually decreasing to zero at $2f_c$. This curve provides approximately

equal horizontal and vertical resolutions in ordinary commercial operation. For the old standards of the Radio Manufacturers Association of 441 scanning lines at 30 frames per second, f_c is 2.75 mc and $2f_c$ is 5.50 mc. However, it has been found possible to reduce the cut-off frequency from $2f_c$ to 4.25 mc without very serious reduction in the horizontal resolution. The elimination of the noise and the "squaring" action mentioned above improve the horizontal resolution to such an extent that cut-off at $1.5f_c$ should provide approximately equal horizontal and vertical resolutions. However, there is no objection to having the horizontal resolution appreciably greater than the vertical resolution; accordingly, cut-off at $2f_c$ should prove desirable. The data for the table below were prepared from calculations with the above formula for 550 scanning lines and an aspect ratio of 1:1, which is desirable for a circular plot.

<u>Frame Frequency</u> <u>(frames per sec.)</u>	<u>f_c</u> <u>(mc)</u>	<u>$2f_c$</u> <u>(mc)</u>	<u>$1.5f_c$</u> <u>(mc)</u>
30	3.2	6.4	4.8
25	2.6	5.2	3.9
20	2.1	4.2	3.1
15	1.6	3.2	2.4
10	1.1	2.2	1.6

In the present consideration the low frequency response below that necessary to reproduce a continuous horizontal line one-half the diameter of the plot is not only not necessary but leads to objectionable sensitivity to shock and blast. In the analysis of this pulse, the Fourier integral shows that all frequencies from zero to infinity must be passed by the transmission system to provide a square wave output for the square wave input. However, it is anticipated from the analysis that frequencies below one-half the line frequency may be highly attenuated without too serious difficulties with the amplitude or the phase response in view of the operation of the "squarer" amplifier on the output pulse. The low frequency end of the response-frequency curve should be nearly flat at line frequency and then gradually decrease to cut-off at a frequency that is above the range of powerful harmonics of mechanical vibrations. The most satisfactory low-frequency cut-off can be best determined by experiment.

20-7. Synchronizing, Blanking, and Scanning Pulses: It is suggested that the synchronizing, blanking, and scanning pulses be generated at the master monitor and transmitted over wires (separate from the video signal wires) to the camera and the remote monitors, where amplification and phasing as necessary may be accomplished. This provides for improved synchronizing, blanking, and scanning and is less likely to be sensitive to voltage and frequency changes on the a-c line. All sensitive and bulky parts of the apparatus should, if possible, be removed from the remote monitors. The master monitor, camera, and power supply can be placed deep in the "bowels" of the ship some distance from the guns and where space is available for

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bulky apparatus, but the remote monitors must be designed to operate near big guns and fit into limited spaces, such as are encountered in directors.

20-8. Parallel Operation of Remote Monitors: The remote monitors should be arranged to operate in parallel for more convenient shipboard installation and to avoid the possibility of rendering all the remotes inoperative in case part of one cable is damaged in battle. The principal difficulty encountered in parallel operation is that each line must be terminated in its characteristic impedance to prevent standing waves in the line. One method, although cumbersome, for achieving parallel operation is to provide that the last stage of video amplification in the master monitor feed into a parallel set of tubes, one leading to each remote monitor.

20-9. Camera: The possibility of using the Orthicon instead of the Iconoscope in the camera should be considered. The features of greater signal-to-noise ratio and the elimination of shading are very important in the present considerations. Possibly the Iconoscope can be arranged to operate without shading if the plotting table is black, and white lines are used.

20-10. Aspect Ratio: The aspect ratio should be 1:1 for the reproduction of a circular plot.

20-11. Line Fluctuations: As line voltage variations as great as 10% may be expected under battle conditions, voltage regulation of some type may be necessary. The circuits should be designed to provide normal operation with a frequency change of 10% on the a-c line.

20-12. Screen Color: A screen providing red fluorescence is advisable in case the operator must have his night vision unimpaired. Such screen materials have been developed. (See Zworykin and Wilson, p.56) The use of a white screen equipped with suitable red filters for night operations may prove as satisfactory as red fluorescent screens and should be considered.

20-13. Shock and Blast: The video stages of amplification must be carefully constructed to provide ample insensitivity to shock and blast. The elimination of the low frequency response in the amplifier is beneficial in this respect. Significant development has been made in developing video amplifiers for shipboard radar gear and many of these findings should prove equally applicable in the present considerations.

20-14. The major problems of plot room television, as pointed out previously, are not radically different from problems of this type that have already been solved. Accordingly, the development of plot room television on a practical basis should be possible.

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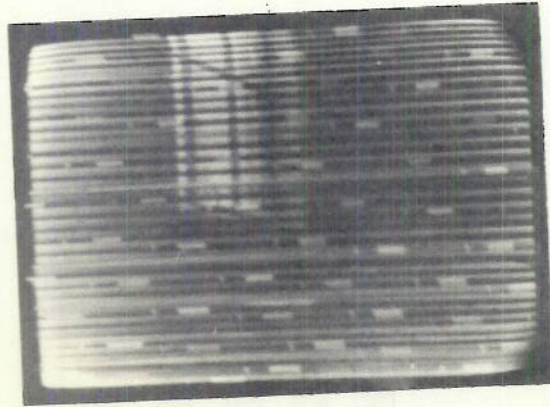


Fig. 1a. Scope. Interference from XAF Radar. Bias on kinescope very negative.

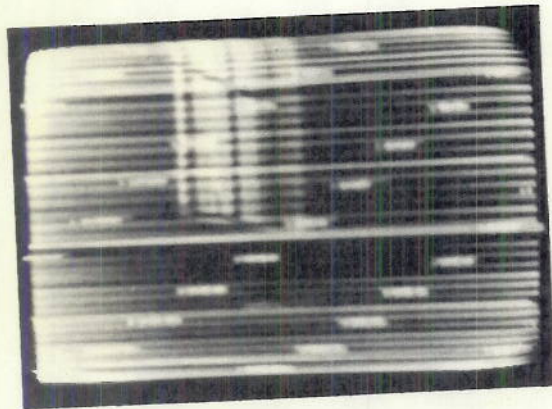


Fig. 1b. Scope. Interference from XAF Radar. Normal negative bias on kinescope.

PLATE 1

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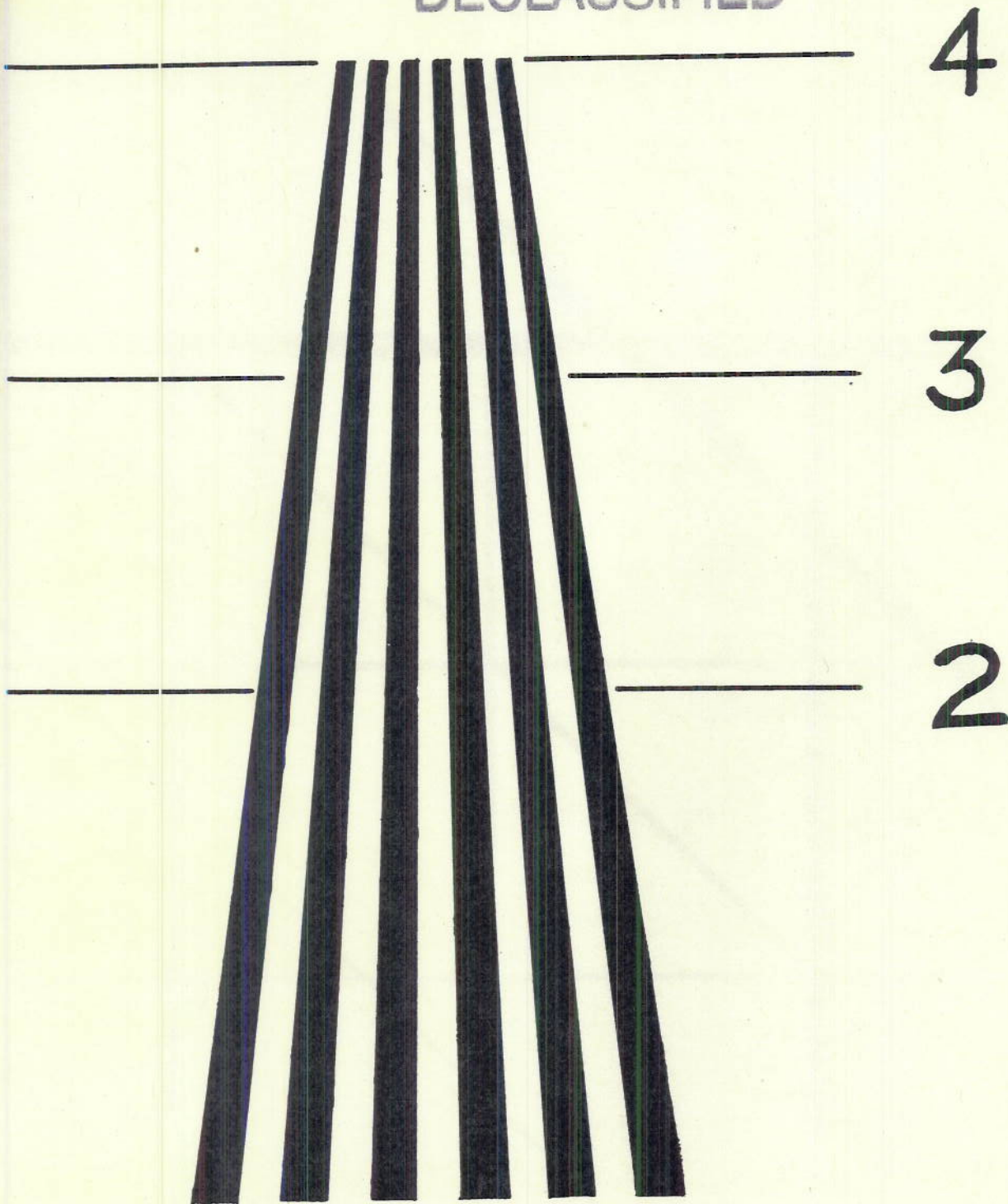


Fig. 2a. Resolution chart. The numbers represent resolutions of: 2 -- 200 lines; 3 -- 267 lines; 4 -- 400 lines for a vertical field of view of one meter.

PLATE 2

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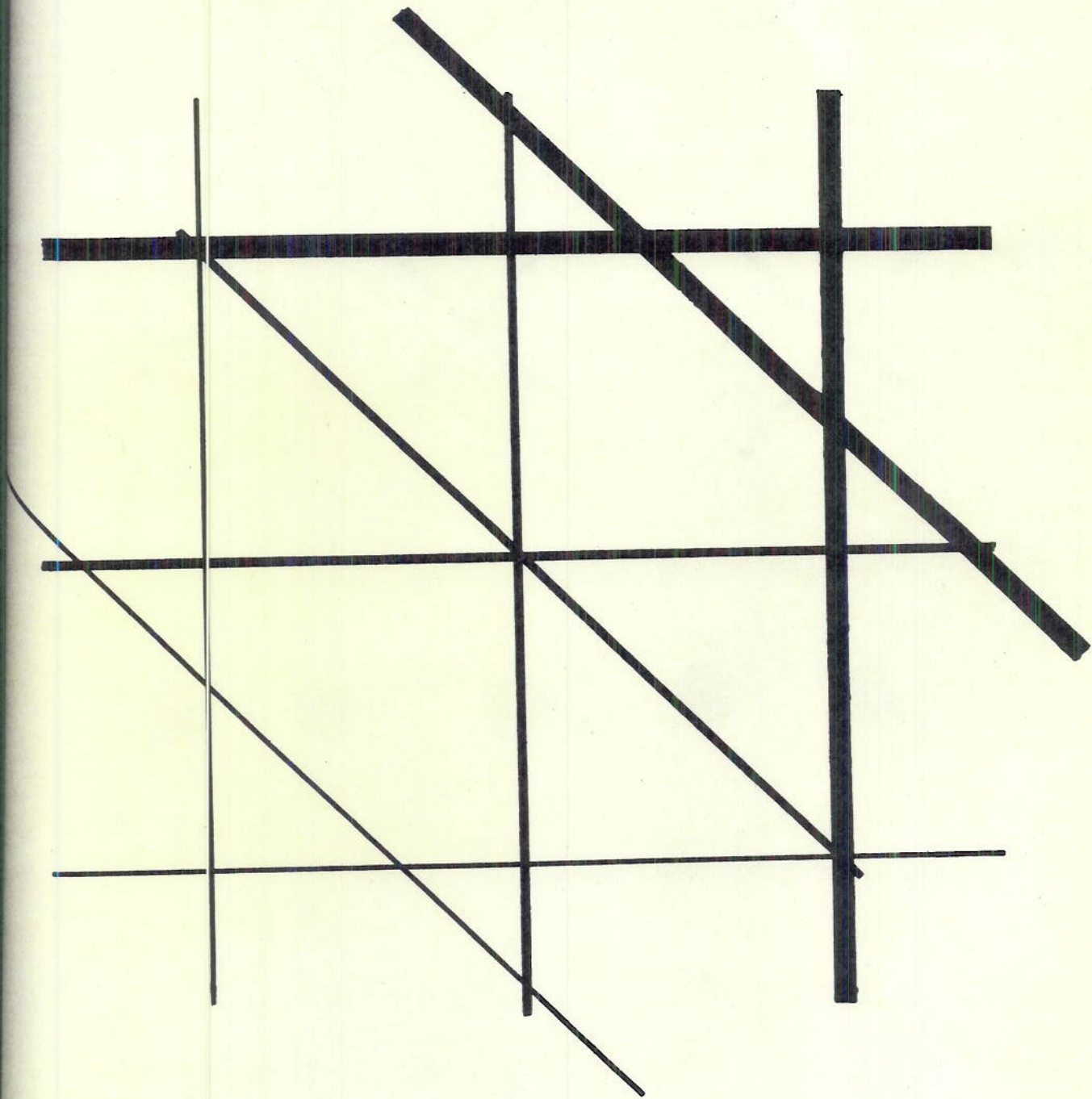


Fig. 2b. Array of lines of widths
 $1/32$ in., $1/16$ in., and $1/8$ in.

PLATE 3

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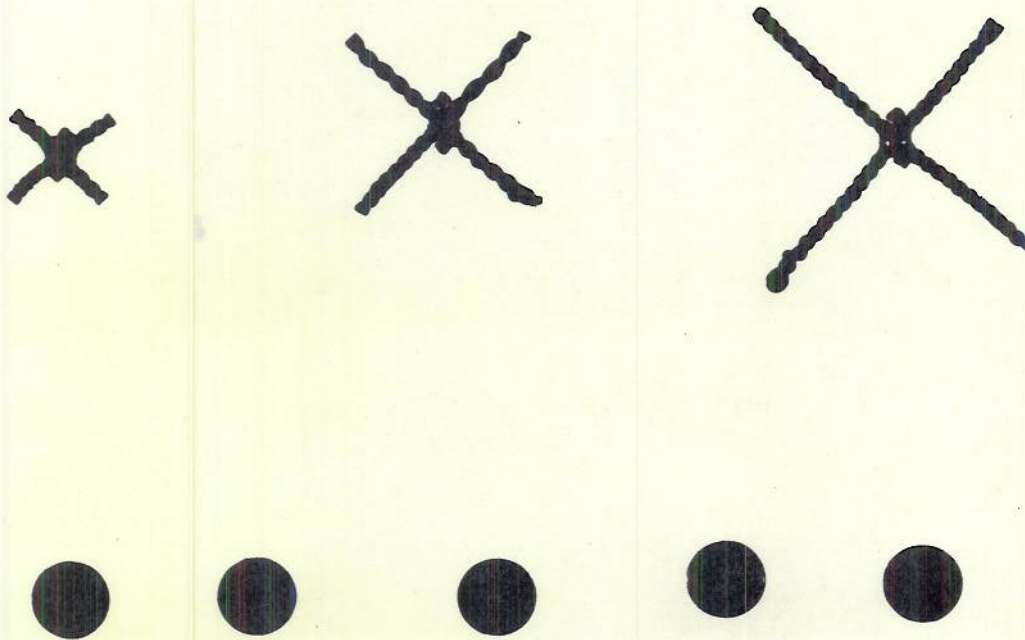


Fig. 2c. Thumb tacks and wire crosses with heads painted black for convenient plotting.

PLATE 4

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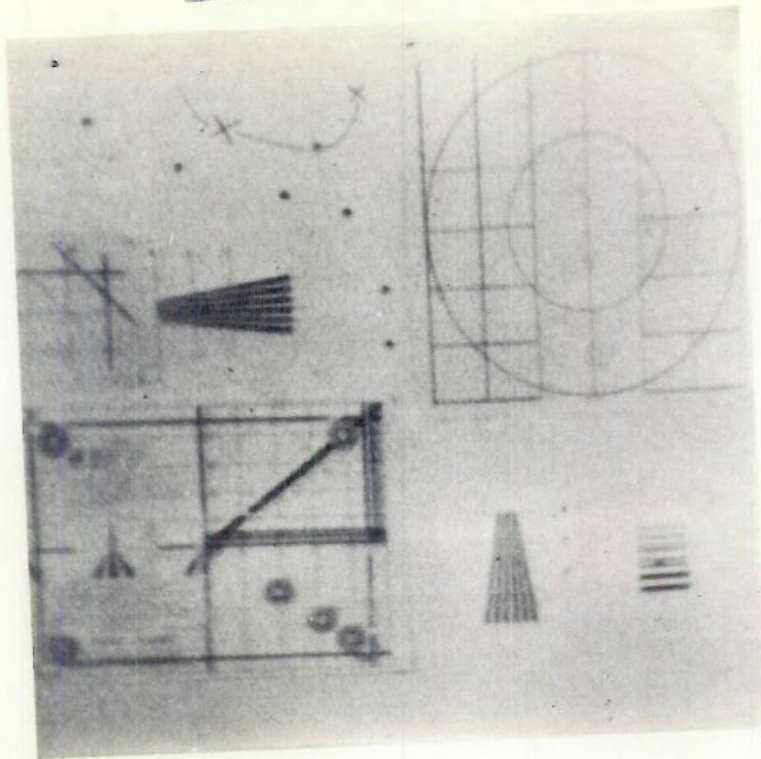


Fig. 3a. Scope. Diffusely reflected light, 116 ft.-candles illumination of screen.

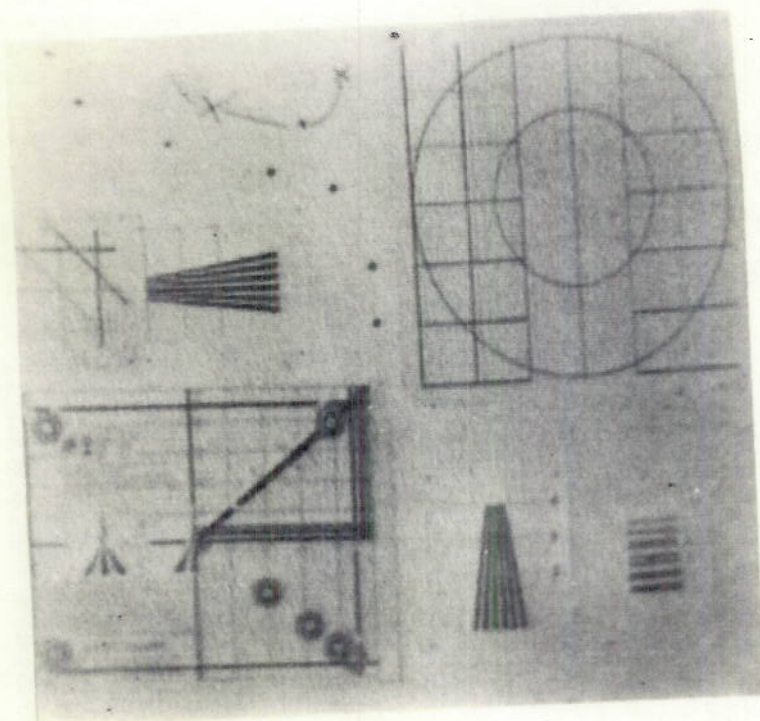


Fig. 3b. Scope. Diffusely reflected light, 83 ft.-candles illumination of screen.

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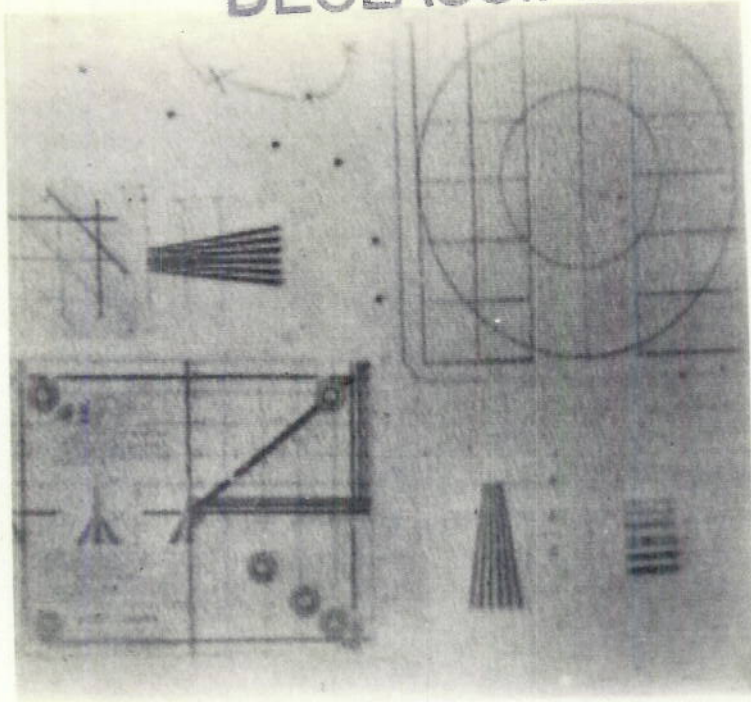


Fig. 3c. Scope. Diffusely reflected light, 42 ft.-candles illumination of screen.

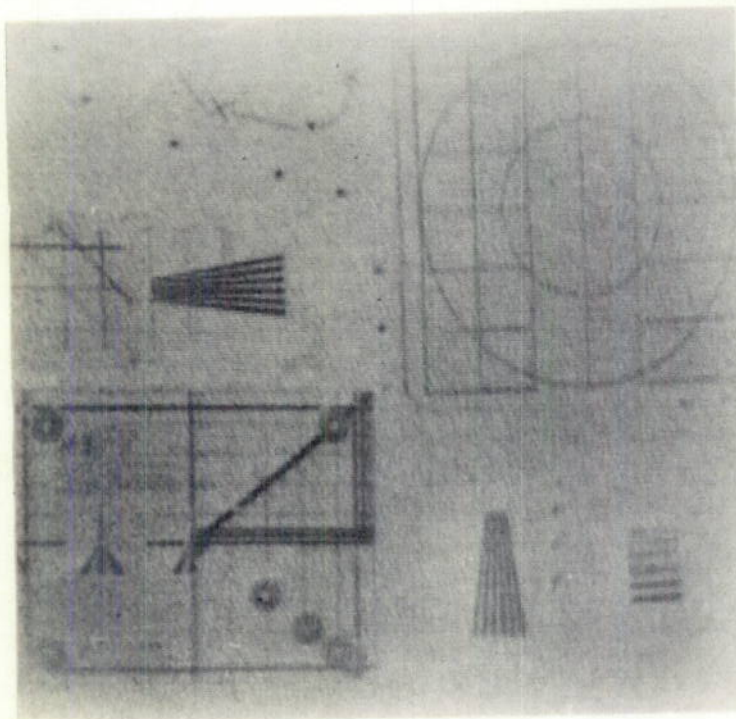


Fig. 3d. Scope. Diffusely reflected light, 20 ft.-candles illumination of the screen.

PLATE 6

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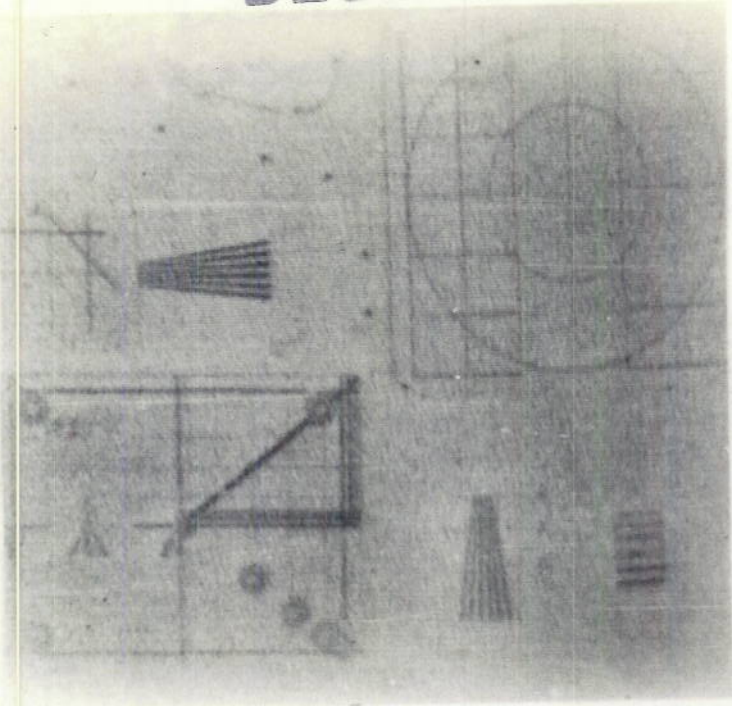


Fig. 3e. Scope. Diffusely reflected light, 13 ft.-candles illumination of the screen.

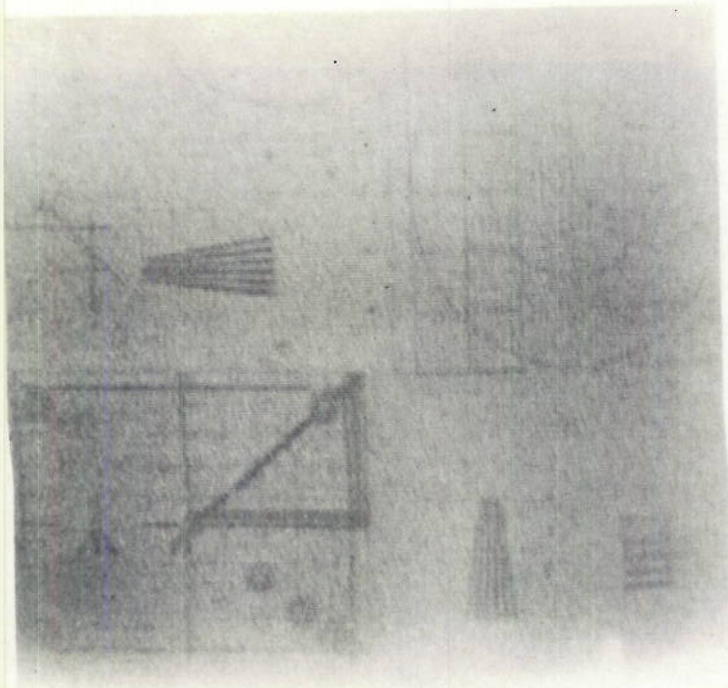


Fig. 3f. Scope. Diffusely reflected light, 6 ft.-candles illumination of screen.

PLATE 7

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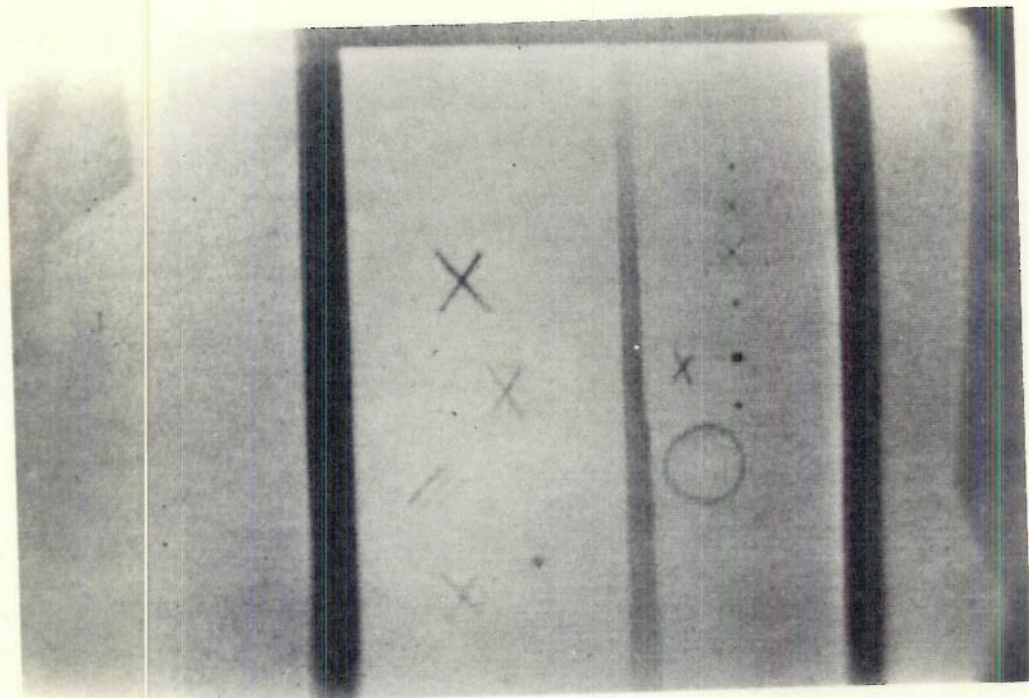


Fig. 4a. Scope. Transmitted light. 1060 ft.-candles of light behind the screen.

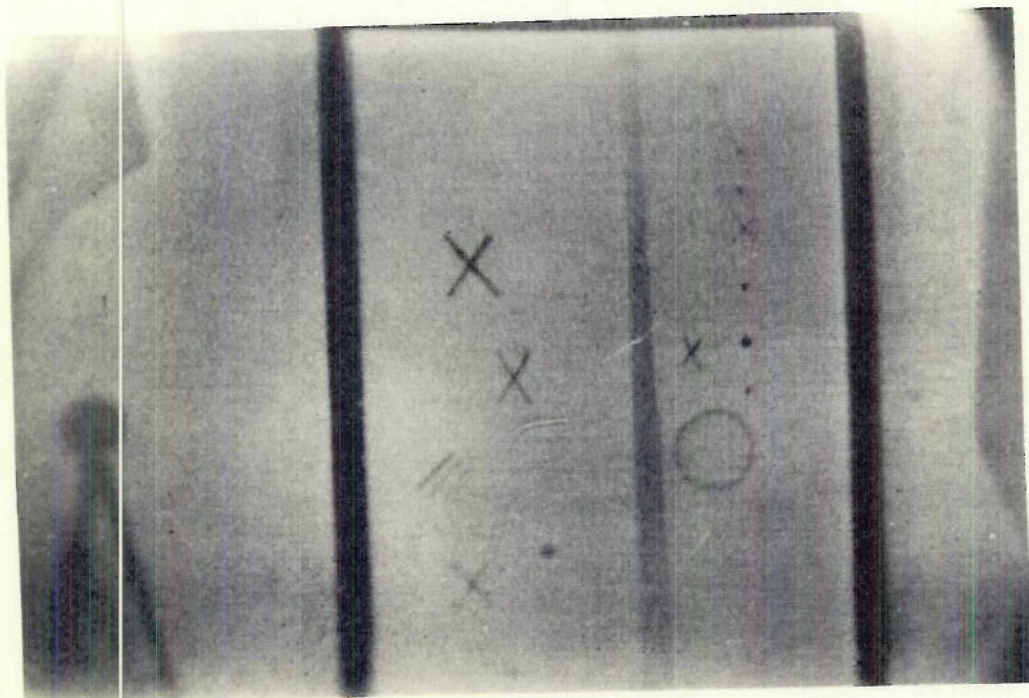


Fig. 4b. Scope. Transmitted light. 340 ft.-candles of light behind the screen.

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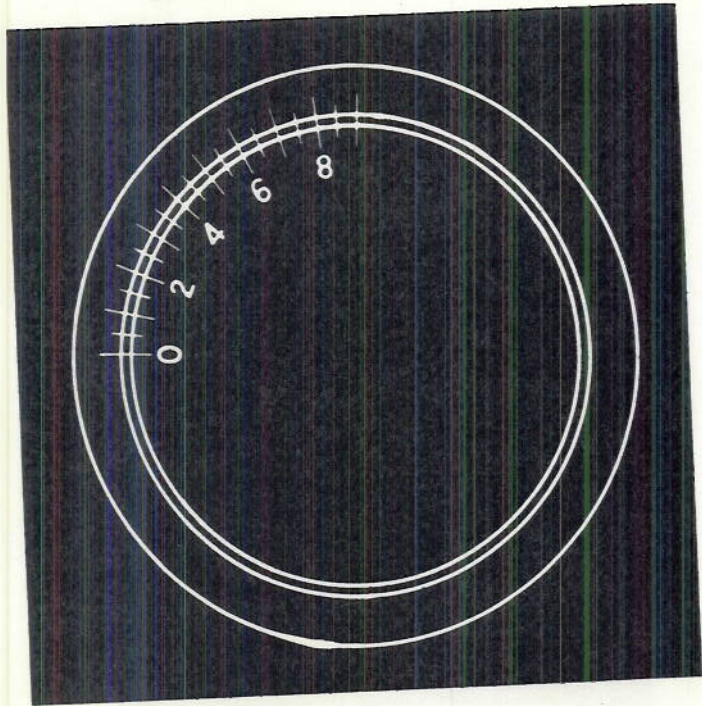


Fig. 5a. Dial

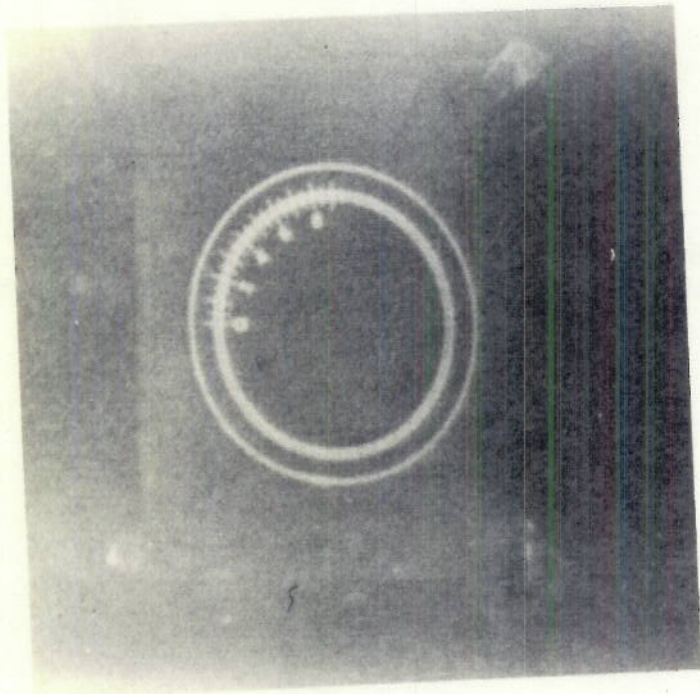


Fig. 5b. Scope. Reproduction of dial.

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PLATE 9

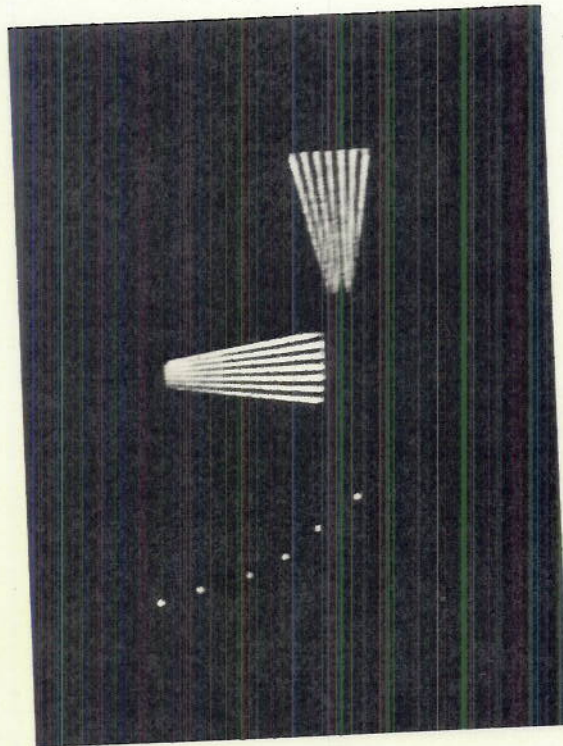


Fig. 6. Scope. White markings on a black screen,
75 ft.-candles illumination of screen.
AGC removed.

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PLATE 10