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EVALUATION OF CATHODE-RAY TUBES FOR USE IN COUNTERMEASURES INDICATORS

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ABSTRACT

Investigations carried on to determine the most satisfactory gun structure for use in cathode-ray tubes for countermeasures indicators revealed that the DuMont type K1134P2 is at present the most suitable five-gun tube for inclusion in new equipment design. An improvement in performance might be made by incorporating sensitive deflection plates (from a gun structure like the K1134P2) with an electron gun (from a gun structure like the K1052P2) that gives a greater intensity for a given line width.

Because deflection plate cutoff prohibits the positioning of the spot over the entire useful screen area and limits the vertical deflection to less than two inches in tubes employing sensitive deflection structures, the JAN specifications are not applicable to some multigun tubes. An improved method of measuring line width and light output in which the measurements are made over a smaller area, and in which the writing speed is held constant, is suggested. This method would eliminate the ambiguity in the results obtained when using the JAN measuring procedure.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problems R06-09 and R06-47
RDB Projects NE 071-235, NR 506-090, and NL 460-076

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EVALUATION OF CATHODE-RAY TUBES FOR USE IN COUNTER MEASURES INDICATORS

INTRODUCTION

In modern cathode-ray tubes various electron gun structures are employed. Competition in industry keeps the mechanical details of the gun structures from being available. To determine which type of gun structure is most suitable for use in the cathode-ray tubes for countermeasures indicators, certain tests were performed.

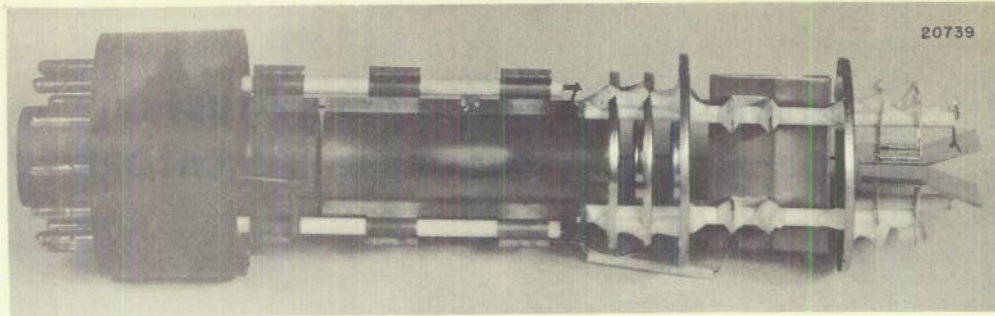
The following tubes were examined: 5XP2, 5XP11, 5RP11, K1052P2, K1126P2, K1134P2, 5CP11-A, and 5SP11 (manufactured by DuMont Laboratories); and 55JGP2, 7Z5P2, 51NRP11-5U, and 51NRP11-5R (manufactured by Electronic Tube Corporation). The gun structures of the 5CP11-A, the 5SP11, and the K1052P2 were found similar. For convenience, this type of gun will be referred to as the "CP" structure. Likewise it was found that the 51NRP11-5U, the 55JGP2, and the 7Z5P2 have similar structures. This type will be referred to as the "UP" structure. The 5RP11, 5XP2, 5XP11, K1126P2, K1134P2, and the 51NRP11-5R have similar structures. This type will hereafter be referred to as the "RP" structure. For comparison of these structures see Figure 1.

Four factors influence the selection of cathode-ray-tube electron guns for countermeasures use. Two factors are the line width and the light output. It is desired to produce the maximum light output with the minimum line width. The light output should be high to enable flash signals to be seen. For the best resolution of the displayed signal, it is desirable to have as fine a line as possible. Other factors to be considered are the deflection factors and the distortion. To reduce the power requirements of the associated electronic circuits, the tube should have as low deflection factors (high sensitivities) as possible. Distortion should be at a minimum to allow accurate interpretation of the displayed signals.

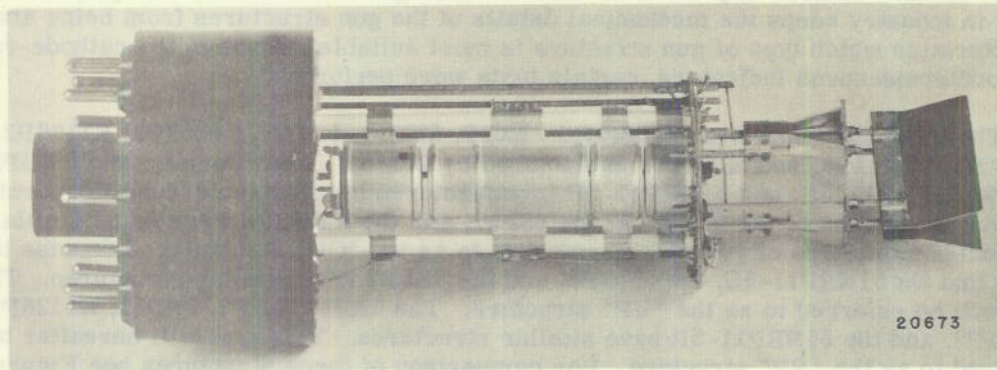
TEST PROCEDURE

The following paragraphs are a summary of the JAN procedure for measuring the line width and the light output of cathode-ray tubes.

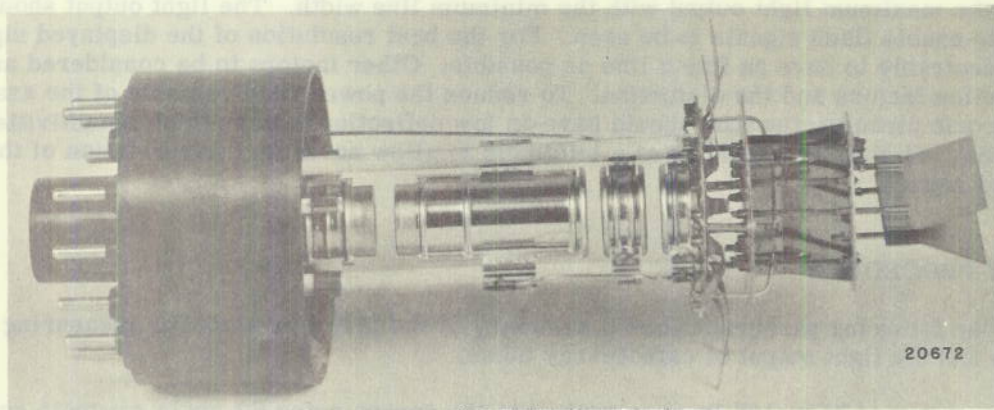
A raster of 35 to 105 lines is applied to the screen using 60-cycle sawtooth scanning on one axis and 2100- to 6300-cycle sawtooth scanning on the other axis. The pattern is focused at the center of the screen and the low-frequency scanning amplitude decreased until the line structure just begins to disappear or first overlaps at the center of the screen. The line width is given by the quotient of the width of the pattern perpendicular to the line structure by the number of lines in the pattern. The low- and high-frequency scanning-voltage connections to the deflection elements are interchanged and the line width redetermined without readjustment of the focus. The line width is determined at two positions on the face of the tube.



"UP" structure



"CP" structure



"RP" structure

Figure 1 - Cathode-ray-tube gun structures, not all to the same scale

The light output should be measured with the same pattern or raster on the screen. The mean potential of the deflection system should be that of the second anode. The pattern should be adjusted to a two-inch by two-inch size. The light output should then be measured by placing a photometer, corrected for the spectral response of the eye, against the face of the tube.

No mention was made in the JAN specifications of a way to measure either distortions or deflection factors.

To test these tubes for line width and light output, a modified form of the preceding method was used. In tubes employing sensitive deflection plates, deflection plate cutoff prohibits moving the spot or raster over the entire face of the tube. For this reason the line width determinations were made only at the center of the face of the tube. Deflection plate cutoff at times limited the deflection to less than two inches; therefore all light output measurements were made with a one-inch-square raster.

To be able to compare the light output of tubes measured with a one-inch-square raster to the light output of those measured with a two-inch-square raster required that the correlation between the two intensities be found. A tube had its light output measured with both a two-inch- and a one-inch-square raster. It was found that the light output measured with the smaller was twice that measured with the larger.

To check the comparison, the ratio of light outputs was calculated as follows. It can be assumed that the intensity (light output per unit area) is a linear function of beam current per unit area. The area of the two-inch-square raster is four times that of the one-inch-square raster. In the smaller raster the beam current density, and hence the intensity, is four times that of the larger. The diameter of the photocell is 1.5 inches and the area is 1.77 square inches. The total area of the smaller raster will be covered by the photocell, but only 1.77 square inches of the larger area will be covered. Since the intensity of the smaller is four times that of the larger, the ratio of the light measurements will be 1.77 to 4, or 0.44. The experimentally determined ratio was 0.504, which is in fairly close agreement. The difference in the two values of the ratio could be caused in part by light entering the photocell around the edges through the thick glass face of the tube and by the effective area of the photocell not being the full area. The values of light output shown in this report should be halved for comparison with values obtained by the other method.

Since no method of measuring the deflection factors was given, the following method was used. An a-c voltage was measured on an accurate voltmeter and applied to the deflection plates of the tube under test. The peak-to-peak value of the voltage was calculated and the peak-to-peak deflection measured. The deflection factor is equal to the peak-to-peak voltage divided by the peak-to-peak deflection.

With one exception, the circuit used to supply the cathode-ray tube under test with the proper voltages was conventional. The astigmatism control usually employed returns the second anode to some positive potential. The astigmatism control in the test setup varied the mean potential of each set of deflection electrodes independently. The astigmatism control is used to bring the deflection elements and the second anode to the same average potential. With the dual astigmatism control used here, very sharp focus was obtained. The circuit diagram of the test setup is given in Figure 2. In the line-width-determination tests, the focus and astigmatism controls were set for the finest line in both the horizontal and vertical directions. Neither the focus nor the astigmatism controls were readjusted when the connections to the horizontal and vertical deflection systems were interchanged.

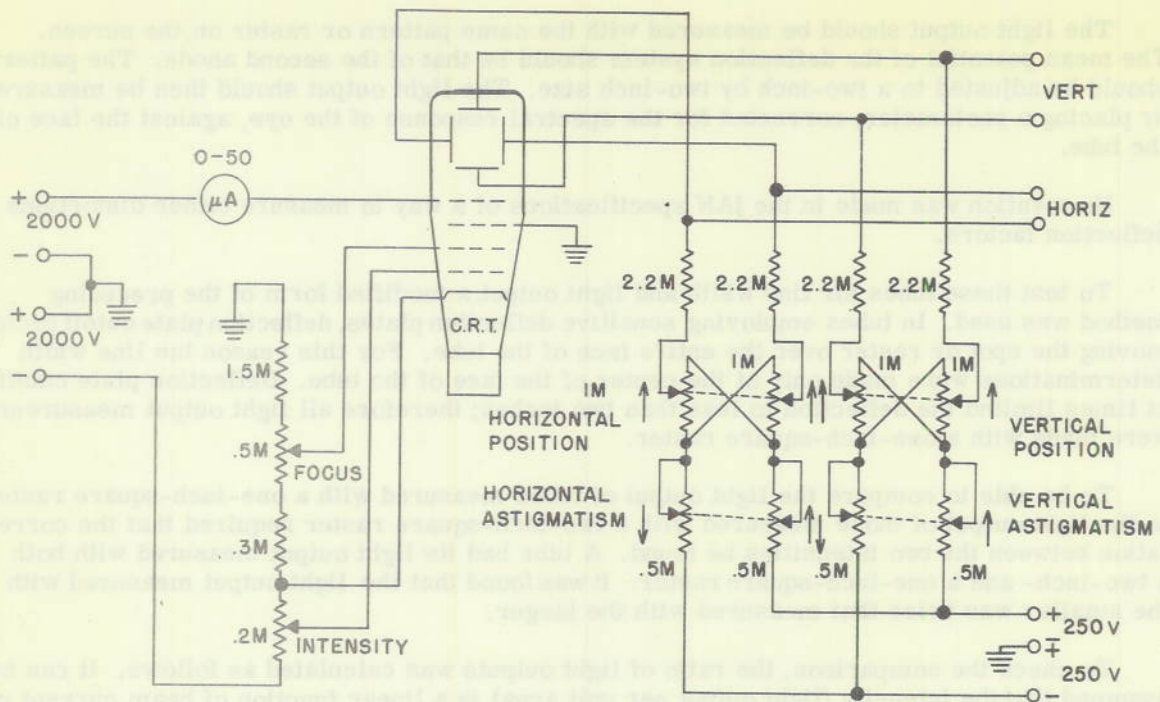


Figure 2 - C.R.T. power supply

In determining the light output, a Weston Illumination Meter Model 756 with a Viscor Filter was used. The Viscor Filter corrected the spectral response of the photocells to that of the human eye.

RASTER GENERATOR

A raster generator was specially designed to be used when performing line-width and light-output tests. Figures 3 and 4 are the block and schematic diagrams of the raster generator.

The general circuit performance can be traced on the block diagram. A thyatron sawtooth oscillator running at preselected frequencies in the range 1200 to 6600 cycles is direct-coupled to a split-load phase inverter, the output of which is applied through a dual-potentiometer gain control to the grids of a pair of push-pull, beam-power output tubes. The low-frequency oscillator is similar to the high-frequency oscillator. It oscillates at approximately 60 cycles. Its output is direct-coupled to a split-load phase inverter which drives a pair of push-pull pentode voltage amplifiers through a dual-potentiometer gain control.

To produce a stationary pattern on the face of the cathode-ray tube requires that the two oscillators be synchronized. It is impossible to sync the low-frequency oscillator directly from the high-frequency oscillator. Under usual conditions the ratio of frequencies that can be synced together in a circuit similar to this does not exceed ten to one.

A portion of the output of the high-frequency oscillator is differentiated, amplified, inverted, and used to sync a 600-cycle thyatron sawtooth oscillator. Over the range of

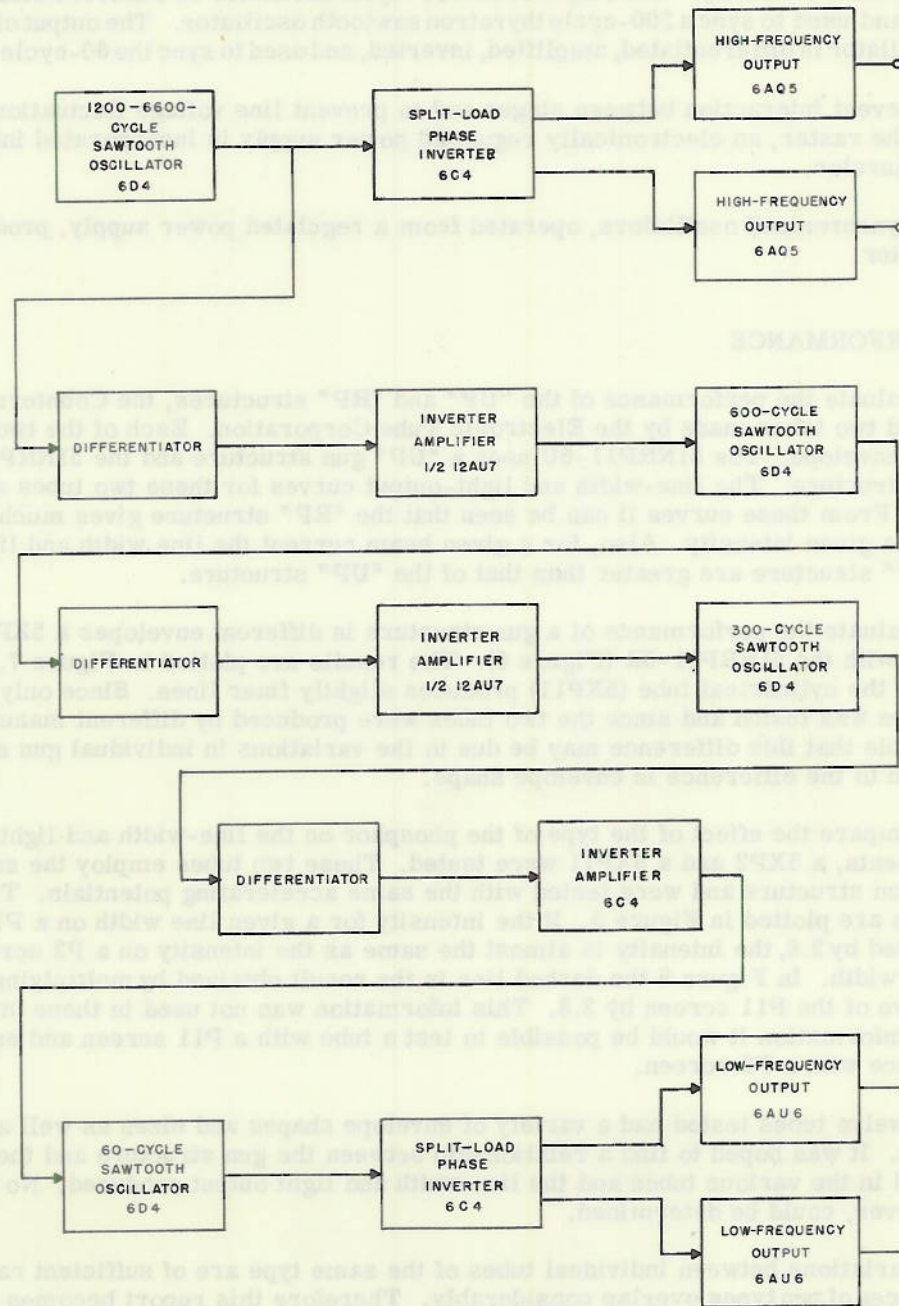


Figure 3 - Block diagram of C.R.T. raster generator



frequencies covered, the ratio of the high frequency to the 600-cycle frequency varies from 2:1 to 11:1. However, no difficulty is experienced in syncing down eleven to one and the circuit functions correctly. The output of the 600-cycle oscillator is differentiated, amplified, inverted, and used to sync a 300-cycle thyatron sawtooth oscillator. The output of the 300-cycle oscillator is differentiated, amplified, inverted, and used to sync the 60-cycle oscillator.

To prevent interaction between stages and to prevent line voltage fluctuations from affecting the raster, an electronically regulated power supply is incorporated into the raster generator.

The synchronized oscillators, operated from a regulated power supply, produce a very stable raster.

TUBE PERFORMANCE

To evaluate the performance of the "UP" and "RP" structures, the Countermeasures Branch had two tubes made by the Electronic Tube Corporation. Each of the two tubes has a JP-type envelope. The 51NRP11-5U uses a "UP" gun structure and the 51NRP11-5R uses an "RP" structure. The line-width and light-output curves for these two tubes are shown in Figure 5. From these curves it can be seen that the "RP" structure gives much greater line width for a given intensity. Also, for a given beam current the line width and light output of the "RP" structure are greater than that of the "UP" structure.

To evaluate the performance of a gun structure in different envelopes a 5XP11 was compared with the 51NRP11-5R (Figure 6). The results are plotted in Figure 7. At higher intensities the cylindrical tube (5XP11) produces slightly finer lines. Since only one tube of each type was tested and since the two tubes were produced by different manufacturers, it is possible that this difference may be due to the variations in individual gun structures rather than to the difference in envelope shape.

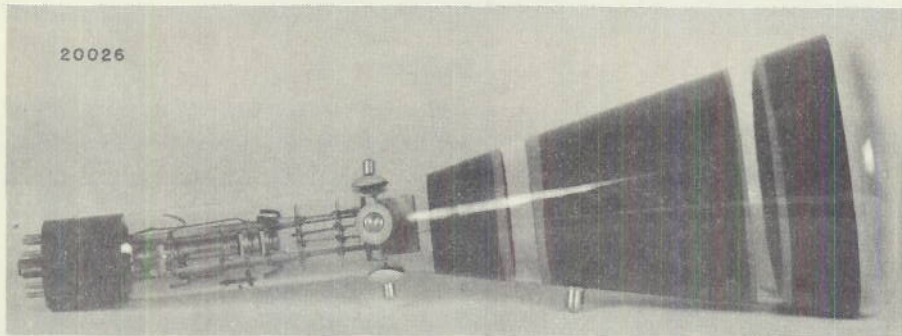
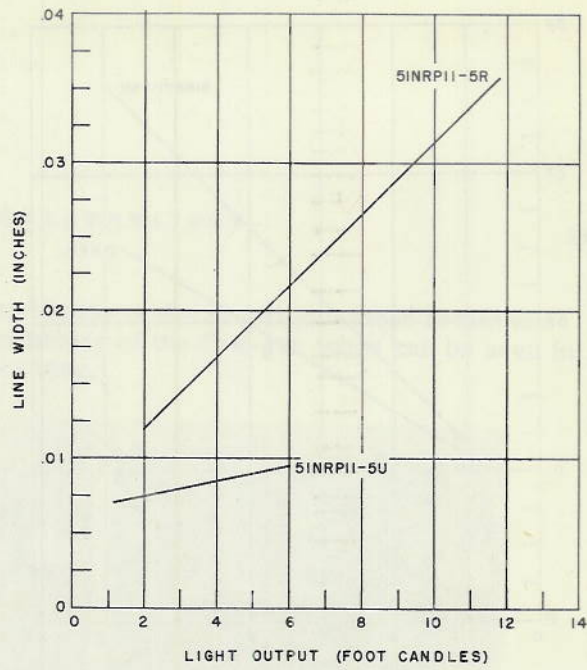
To compare the effect of the type of the phosphor on the line-width and light-output measurements, a 5XP2 and a 5XP11 were tested. These two tubes employ the same envelope and gun structure and were tested with the same accelerating potentials. The results of these tests are plotted in Figure 8. If the intensity for a given line width on a P11 screen is multiplied by 2.8, the intensity is almost the same as the intensity on a P2 screen with the same line width. In Figure 8 the dashed line is the result obtained by multiplying the abscissas of the curve of the P11 screen by 2.8. This information was not used in these investigations. With this information it would be possible to test a tube with a P11 screen and estimate its performance with a P2 screen.

The twelve tubes tested had a variety of envelope shapes and sizes as well as gun structures. It was hoped to find a relationship between the gun structure and the envelope shape used in the various tubes and the line width and light output produced. No such relationship, however, could be determined.

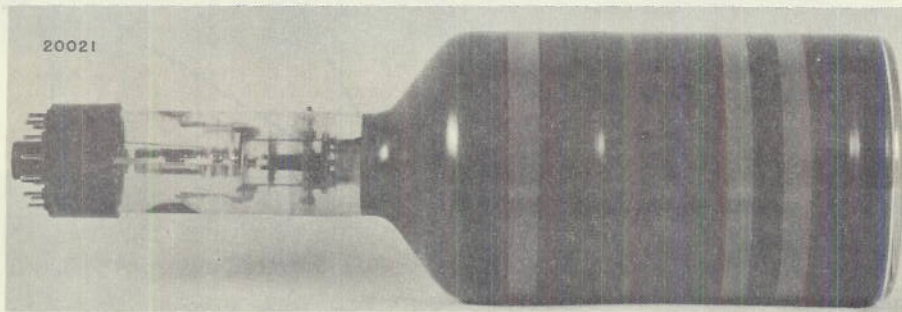
The variations between individual tubes of the same type are of sufficient range that the performances of two types overlap considerably. Therefore this report becomes only an evaluation of the tubes that are available at present for use in countermeasures indicators.

At present five-gun cathode-ray tubes are used in countermeasures indicators. The five-gun tubes available are the 55JGP2, 7Z5P2, and the K1052P2 (Figure 9) using standard deflection plates and the K1126P2 and the K1134P2 using sensitive deflection plates (Figure 10). The line-width and light-output curves of these tubes are plotted in Figure 11.

Figure 5 - Cathode-ray-tube comparison. E_{b2} , 2000 v; E_{b3} , 4000 v. Beam current range, 5-30 μ amp.



51NRP11 - 5R

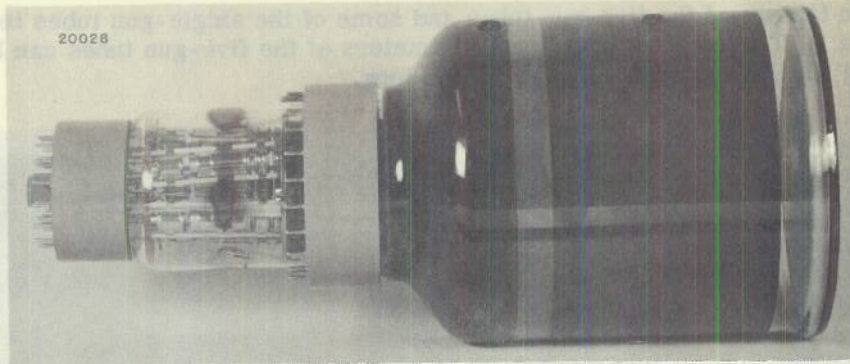


5XP11

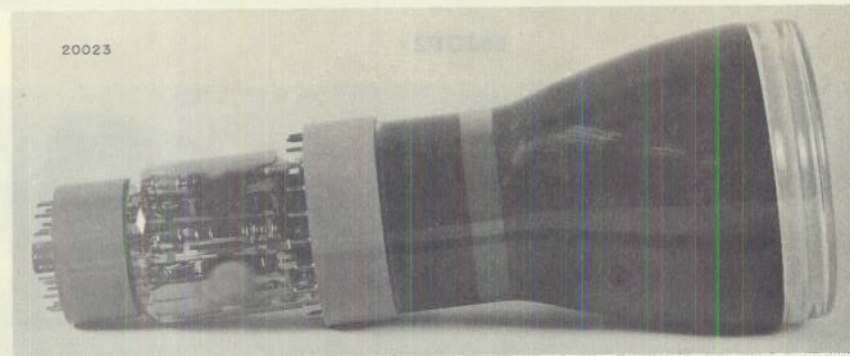
Figure 6 - Cathode-ray tubes employing "RP" structures



Figure 9 - Five-gun cathode-ray tubes employing standard deflection plates



K1126P2



K1134P2

Figure 10 - Five-gun cathode-ray tubes employing sensitive deflection plates

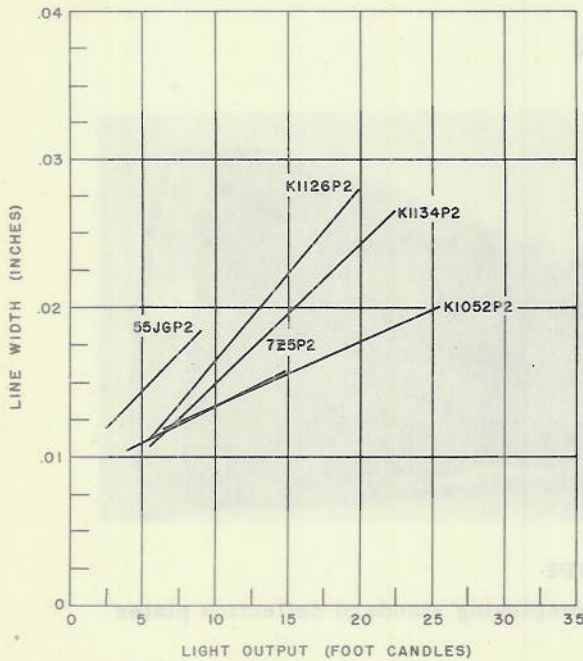


Figure 11 - Cathode-ray-tube comparison. E_{b_2} , 2000 v; E_{b_3} , 4000 v. Beam current range, 5-30 μ amp.

TABLE 1
Table of Deflection Factors

| Tube Type | Deflection Factors | |
|------------|-----------------------|---------------------|
| | Horizontal (v/in.) | Vertical (v/in.) |
| 51NRP11-5U | 83.3 | 36.7 |
| 51NRP11-5R | 83.2 | 37.1 |
| 5XP11 | 78.5 | 26.3 |
| 55JGP2* | 69.3 | 73.9 |
| 7Z5P2* | 85.8 | 85.6 |
| K1052P2* | 75.4 | 67.7 |
| K1126P2* | 78.2 | 30.8 |
| K1134P2* | 64.3 | 30.2 |

*Factors are the average of all guns

Only one five-inch, five-gun tube is available, the 55JGP2. The line width of this tube is comparable to the others tested, but the light output is considerably lower. Thus for a given light output the line width of this tube is greater than the others. Since the 55JGP2 and the 7Z5P2 use the same gun assemblies it is believed that the characteristics of the two tubes should be similar. The 55JGP2 used in these tests might have been a tube with below-average characteristics.

The line-width and light-output slope of the 7Z5P2 and the K1052P2 are close, but for a given beam current the 7Z5P2 gives less light output. The deflection factors of the 7Z5P2 are slightly greater than those of the K1052P2. Since the difference in deflection factors is not large and since the beam current requirements do not influence the selection of the tube, these two tubes would be equally satisfactory for use in countermeasures equipment except where a maximum of light output is required.

Tubes produced by the Electronic Tube Corporation have the screen phosphors applied in a very thin layer, in some instances thin enough to see light through. The screens of tubes produced by the DuMont Laboratories are considerably thicker. It is believed that the difference in light output of the K1052P2 and the 7Z5P2 is primarily due to the difference in phosphor thickness used by the two manufacturers.

The K1126P2 and the K1134P2, which use sensitive deflection plates, give greater line width for a given intensity than the 7Z5P2 or the K1052P2. This disadvantage is offset by the reduction in the power required from the deflection amplifiers. All guns in the multigun tubes employing sensitive deflection plates are so aligned that the undeflected spots are equally spaced along the vertical line through the center of the tube face. This alignment reduces pattern distortion and requires very little positioning voltage to bring the traces to their proper positions when the tubes are used in an AN/SLA type indicator. The K1126P2 was deemed unsatisfactory for use in countermeasures equipment because of its size and shape.

Although the K1052P2 and the K1134P2 have the same physical dimensions and basing, they are not directly interchangeable in all equipment. Unlike the K1052P2 the sensitive deflection plates in the K1134P2 limit the region in which the vertical deflection can be obtained. Thus there is a limit to the area in which the information from a given gun can be presented. In certain applications where the position on the screen of the information from a certain gun is important, circuit revisions may be necessary if the K1052P2 is replaced by a K1134P2. Thus it is not feasible to substitute the K1134P2 for the K1052P2 in AN/SLA-1 analyzers now in field use.



The light output of a cathode-ray tube is not a constant as the number of lines increases or decreases. With a constant beam-current the light output increases as the number of lines increases. To give constant results it is suggested that the number of lines to be used when making light-output measurements be fixed. All light outputs recorded in these tests were obtained with a one-half-inch raster on the screen.

CONCLUSIONS

To date no definite relationship between the gun structure, envelope shape, line width, and light output has been determined from the results of these tests.

The K102P2 and the K102P1 are suitable for use in constant-current equipment. The line width deflection factors, and distortion are comparable. The K102P1 has slightly greater light output, possibly because of the use of a thicker screen phosphor. The "CP" structure used in the K102P2 gives a greater line width for a given intensity than the "CP" structure used in the K102P1. A more satisfactory tube might be one that employed the "CP" structure with the variable "X2" type deflection plates.

The K102P2, although having a greater line width for a given intensity than the K102P1 and K102P1, is the logical choice for future deflection because of its lower deflection factor.

The general trends specified in the job specifications is unsatisfactory because the width measured are function of the amount of lines in the pattern. Varying the number of lines varies the line width by varying the writing speed. To maintain constant writing speed it is also necessary to keep a fixed line length when making all line-width measurements.

Positive deflection plates when provided a two-inch square raster from being developed. Although the deflection is completely adequate for the application intended. This means that the JAN method of measuring light output cannot be used.

RECOMMENDATIONS

It is recommended that an investigation be made of the feasibility of reusing the JAN specifications to permit measurements on tubes employing sensitive deflection electrodes. Limited low constant-current operation and to eliminate the possibility of varying the measured values of light output and line width caused by not having a fixed writing speed.

It is also recommended that future constant-current deflection tubes use cathode-ray tubes employing sensitive deflection electrodes and give output of producing line lines with high resolution. A definite type of tube would have each of its guns give the performance of the JAN method for this report (Part 2).

