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Hancotte, John Joseph

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BY

JOHN JOSEPH HANCOTTE, JR.

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-

J. J. Hancotte, Jr.

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John Joseph Hancotte, Jr.
Lieutenant, United States Navy

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PREFACE

During the winter term of the third year of the postgraduate Electronics course I was stationed at the General Electric Company plant in Syracuse, New York, developing a monoscope camera. During this time I became interested in different methods of test pattern generation.

I am indebted to Mr. J. H. Wiggin, engineer, for assistance and suggestions while I was with the General Electric Company, and to the engineering personnel of the Radio Corporation of America for their help in obtaining information. I am also indebted to Professor P. E. Cooper of the Postgraduate School for advice and assistance in preparing this thesis.

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INTRODUCTION

One of the greatest requirements of the television industry is a means of insuring that set standards for broadcasting and manufacturing be upheld. In order to accomplish this purpose a quick and easy method of testing for quality is most desirable. It is difficult to determine the cause of imperfect reproduction of scanned objects if the televised image is moving rapidly and is not familiar to the viewer. Accordingly, several forms of static test charts have been devised for use in testing the resolution and geometrical form of the generated image.

Of equal importance is the necessity for a fairly simple and reliable means of converting test pattern information into a video signal of excellent quality. A device that accomplishes this is termed a pattern generator.

CHAPTER I

TEST PATTERNS

1. Functions.

Television test patterns are designed to provide checks on resolution, linearity, phase shift, ringing, quality of interlacing, focus, aspect ratio, picture size, shading, cathode-ray tube spot characteristics, and optical systems of projection receivers.

Resolution is a measure of the frequency response of a system. It is measured in "lines", indicating the maximum number of equally spaced black and white lines that could be accomodated in the vertical height of the pattern, each line being distinguishable. Ringing refers to undesirable oscillations in sweep circuits or in video amplifiers due to poor transient response. The quality of interlacing is a measure of how well the horizontal lines of one field fit between the lines of the next field. Aspect ratio is the ratio of picture width to picture height and is set at four to three in this country. Shading refers to the corrective measures necessary to obtain a uniform picture from a uniform distribution of light. It is desirable to reproduce gray shades as accurately as possible.

2. RMA test pattern.

The television test pattern or resolution chart illustrated in Figure 1 was designed by the Radio Manufacturers' Association to standardize television resolution measurements.

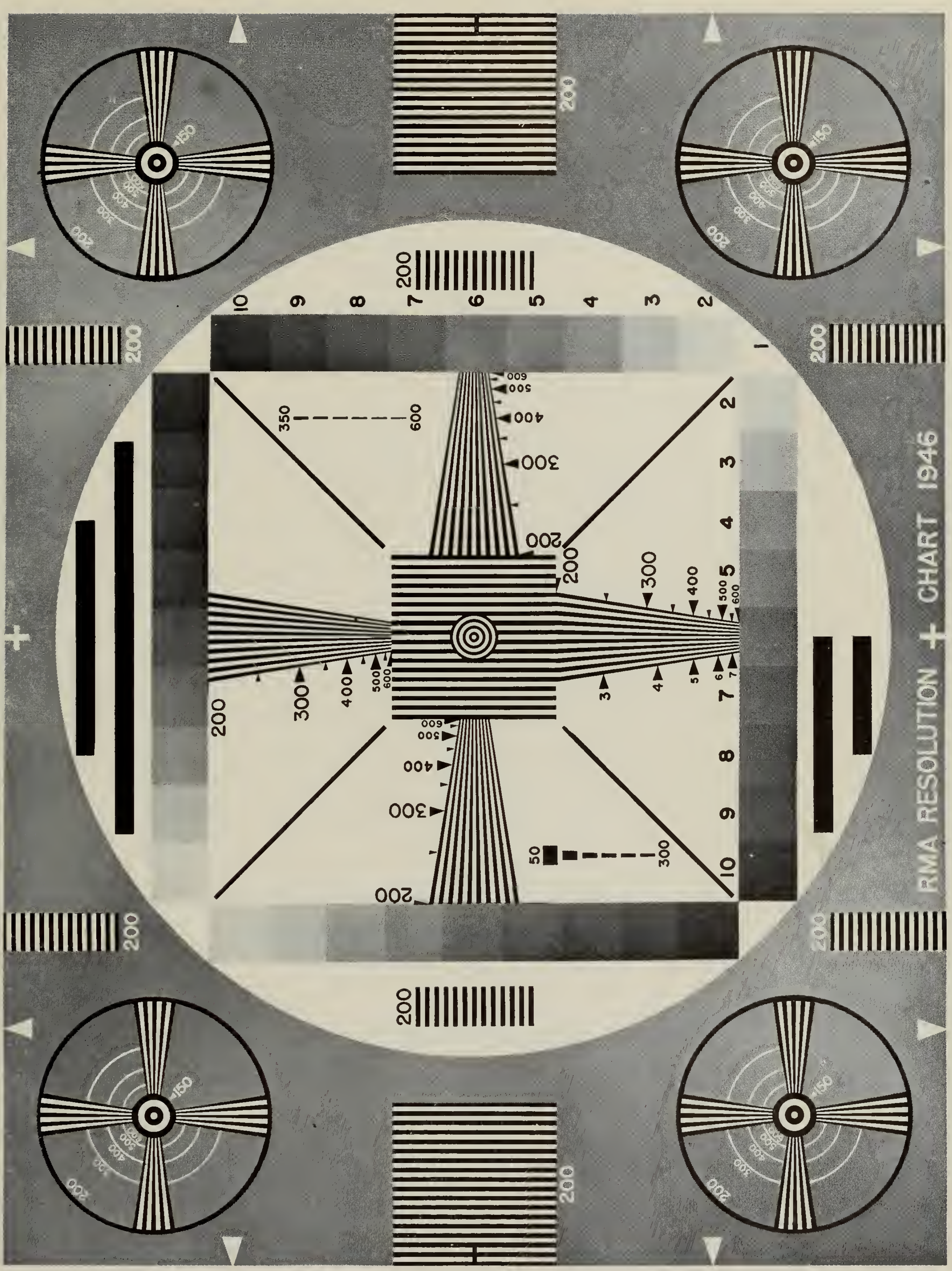
RMA RESOLUTION + CHART 1946
1
2
3
4
5
6
7
8
9
10
200
300
400
500
600
350
50
150

Figure-1

To provide maximum utility, various branches of the television engineering field were canvassed and suggestions obtained for its preparation. In using this or any other test pattern, resolution should be read only after equipment has been adjusted to have a minimum of distortion. Scanning, shading (if the system employs shading), low frequency phase shift, and focus, should be adjusted before reading resolution.

Size, linearity, and aspect ratio are included in the scanning adjustment. Whatever the type of pattern generator used, the exact total area of the pattern, whose boundaries are indicated by arrow heads, should be utilized. Vertical sweep linearity is checked by comparing the spacing of the short horizontal bars at both top and bottom of the picture with that of the bars midway between. Similarly, horizontal sweep linearity is checked by comparing the spacing of the vertical bars in the square at each side of the picture with the spacing of the bars in the center square. Aspect ratio is checked by measuring the lengths of the gray scales in the central circle. If the horizontal and vertical scanning is linear and the horizontal and vertical scales are equal in length then the aspect ratio is correct.

If the pattern generator uses shading, check it by examining the monitor to see if the background is an even gray, or use a waveform monitor and note if the average picture signal axis is parallel to the black level both at line and field frequencies. To further aid in obtaining correct shading, adjust it until the gray scale reading is a maximum

and the same for all four scales.

If black streaking follows either of the two horizontal black bars at the top or bottom of the large circle, it is an indication of low-frequency phase shift. The presence of bright vertical lines closely following the black bars indicates high-frequency phase shift.

Cathode-ray beam focus adjustments are made for a maximum resolution reading, first of the horizontal scanning and then of the vertical. Due to beam characteristics a maximum adjustment for one may not be the maximum adjustment for the other. A compromise adjustment should then be made.

Resolution is read by taking the maximum numerical readings on the wedges at which the separate lines can be resolved. Horizontal resolution is read on the vertical wedges and vertical resolution on the horizontal wedges. Resolution in the central portion of the picture will usually be greater than that measured by the wedges in the four corner circles. This may be due to failure in achieving optimum results for one or more of the previously mentioned adjustments or due to inherent cathode-ray tube distortion.

All bars for checking sweep linearity are spaced for 200 lines resolution. The resolution circles in the center and in the four corners are used to test spot ellipticity on cathode-ray tubes. The resolution of the circles in the corners (150) was made less than the resolution in the center (300) because of added deflection defocusing in these areas.

The two sections of single line widths, 50-100-150-200-

250-300, and 350-400-450-500-550-600 provide an accurate means of checking for ringing. The multiple lines in the wedges could prove confusing if used for this check. These sections also test the ability of the system to reproduce isolated details.

One of the wedges is calibrated in megacycles as well as in lines. The following development shows how the conversion is made from lines to megacycles. If there are N number of equal width black and white lines that can be accomodated in the vertical height of the pattern, then there will be $\frac{4N}{3}$ lines that can be accomodated in the horizontal width of the pattern or $\frac{2N}{3}$ lines of each color. Assuming a sine wave will represent black to white variations, and that the active time of horizontal trace is 0.84H = 53.3 microseconds, then the frequency corresponding to N lines is $f_n = \frac{2N}{3} \times \frac{10^6}{53.3} = 0.0125 \times 10^6 N$ cycles per second = $0.0125N$ megacycles.

The four diagonal lines are used to check the quality of interlacing. Pairing of the interlaced lines is indicated by jagged lines. This is not effective if there is no interlacing whatsoever.

The four crosses, one on each edge, are used for alignment of the optical systems of projection receivers. The four corner circles are so positioned that they should be visible on receivers whose picture corners are masked.

The gray scales vary approximately logarithmically from maximum white brightness to about 1/30th of that value.

These shaded areas indicate nonlinear amplitude distortion in the system. The gray background of the chart provides a satisfactory balance with the whites so that a studio system set up by the use of this chart will televise an average scene without the need for additional adjustments.

3. R.C.A. Indian head test pattern.

The test pattern illustrated in Figure 2 has been one of the most popular in the industry. It is used in the 2F21 monoscope tube. Television stations often have their identification letters added to it. The large circle has a radius three quarters of the pattern width so that the standard aspect ratio is maintained. The circle also shows the geometrical symmetry of the scanning motion and reveals nonlinearity in the vertical or horizontal scanning directions. The four circles in the corners have the same purpose and are situated in the four regions of the pattern where geometrical distortions, as well as defocusing of the scanning beam, are most likely to occur. The whole pattern is crossed by a grid of fine lines which reveal any orthogonal distortion at any part of the image.

Five sets of resolution wedges are included. The main wedges within the central circle are calibrated by the numbers 20, 30, 45, and 35 which stand, respectively, for 200, 300, 450, and 350 line resolution. Open spaces in the centermost line of each wedge indicate the position of the calibration within each wedge. The central concentric circles have 300 line resolution, indicated by the number 30. The

Figure 2—RCA Indian head test pattern

four sets of resolution wedges at the corners have similar calibration markings.

The two oblique wedges within the center circle are tonal values, having different degrees of shading. By taking the innermost or black section of each wedge as 100 per cent, the degrees of shading of the other sections, reading outward, are 75, 50, and 25 per cent, respectively.

The horizontal black bars below the central circle have lengths that are logarithmically related. The length of each bar is 71 per cent of the length of the line above it. As mentioned in discussing the RMA chart, streaking following any of the bars is an indication of low-frequency phase shift.

The two sections of single line widths arranged in two vertical columns on either side of the central circle have the same purpose as do those in the RMA chart. The numbers indicate the width in lines of the nearest rectangle.

The Indian head is useful for judging over-all performance, especially contrast and average brightness which are most easily judged on a pictorial subject. The ends of the diagonal lines mark the edges of a pattern having half the width of the over-all pattern. The lines are checks on the interlace.

Test patterns containing wedges are sources of square waves at controllable frequency. If no scanning is used in the vertical direction, and the beam current is reduced to prevent possible burning of the signal plate by electron bom-

bardment, the horizontal scanning motion will pass in a single line over one of the vertical resolution wedges, and in so doing produce a rectangular signal wave. The horizontal trace is positioned by varying the amount of direct current through the vertical deflection coils. The frequency of the square waves produced by the horizontal scanning can be adjusted from roughly 50 kilocycles to 5 megacycles depending on the positioning of the horizontal trace and on the horizontal scanning amplitude and frequency. The vertical sweep may be used in a similar way to produce frequencies ranging from 300 cycles per second to 10 kilocycles.

4. Crosshatch test pattern.

In order to make certain that deflection systems of pattern generators and cameras are linear, a bar or crosshatch generator is utilized. The generator may be used in conjunction with a monitor to test the sweep linearity of pattern generators or of iconoscope or image orthicon cameras. The simple check of observing a test pattern, transmitted by the generator under test, on a monitor that has been previously adjusted for linearity is not entirely satisfactory. Any error in adjusting the monitor will be duplicated in adjusting the generator deflection. It is only necessary for the beams in the pattern generator and the monitor tube to travel at the same velocity across a picture to give proper distribution in the reproduced picture. This velocity is not necessarily uniform.

In order to determine when constant scanning velocity

has been achieved in the device that generates the pattern it is necessary to make a comparison between space intervals marked upon the pattern and intervals of time. To accomplish this, two pictures are superimposed on a standard picture monitor. One picture is the generated pattern, and the other picture is a crosshatch time pattern, synchronized by the sweep synchronizing pulses. Using the time pattern as a standard, various sections of the test or space pattern can be measured and compared. For example, if the Indian head test pattern is used, the diameters of each of the four corner circles should measure the same and should equal one-quarter of the diameter of the large, central circle, all measured in intervals of the crosshatch time pattern. The results will be dependent upon the linearity of the pattern generator scanning, but will be independent of the linearity of the monitor scanning. Figure 3 illustrates the appearance of a personalized test pattern and crosshatch pattern on a monitor. The unequal spacing of the vertical bars of the crosshatch pattern indicate that the horizontal sweeps of the pattern generator and monitor are equally nonlinear.

For still more accurate testing of a camera or pattern generator a special test pattern may be devised. Let us assume that the bar generator controls are set so that the crosshatch lines on the monitor are about the width of one scanning line. If every seventh scanning line of the raster is blanked, and the vertical blanking period is 7.5 per cent, then the number of visible horizontal lines of the crosshatch

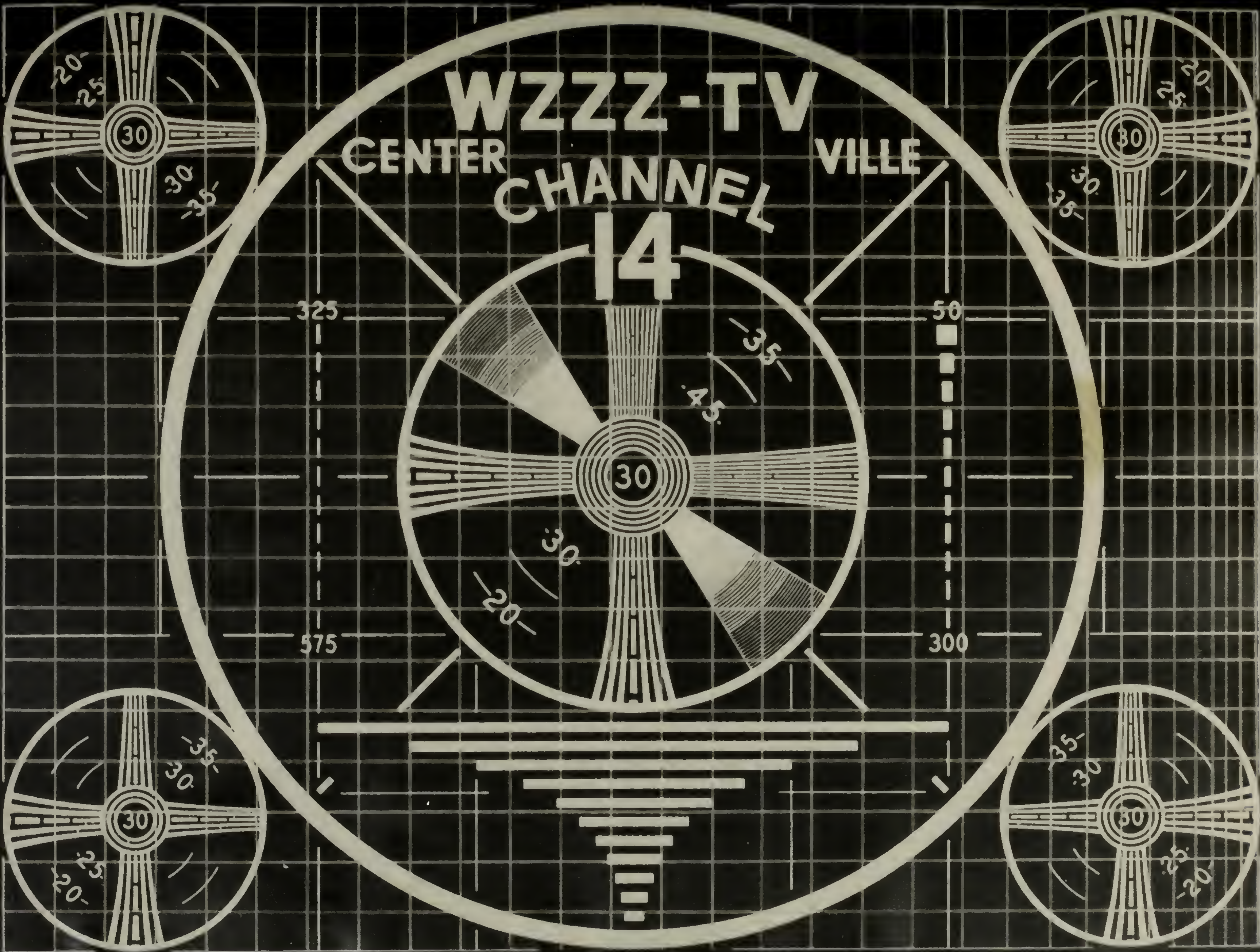

Figure 3-RCA personalized test pattern, with crosshatch pattern superimposed

pattern will be $\frac{525}{7}$ x 0.925 = 69.4, or 69 full horizontal lines will be seen. If the vertical lines of the time pattern mark intervals of one one-hundredth of the horizontal scanning cycle, and the horizontal blanking period is 16 per cent, then the number of visible vertical lines of the crosshatch pattern will be 100 x 0.84 = 84. The raster being 4 units wide and 3 units high (aspect ratio of 4 to 3), then each horizontal interval will measure 4/84 or 1/21 unit, and each vertical interval will measure 3/69 or 1/23 unit.

Now a test pattern must be designed consisting of a system of black diamond-shaped dots on a white field as in Figure 4. The dots are spaced so as to bear a definite relationship to the crosshatch pattern. If each tenth vertical and horizontal line of the crosshatch pattern is to be represented by a dot then there will be 9 dots in each horizontal row across the chart and 7 dots in the vertical rows. Since the test chart will also have an aspect ratio of 4 to 3 then the separation of the horizontal dots will be 10/21 unit with a space of 2/21 unit at either end of the row. The separation of the vertical dots will be 10/23 unit with a space of $4\frac{1}{2}/23$ or 9/46 unit at either end of the column. The units, of course, will depend upon the scale to which the test pattern is constructed.

When the test pattern is fully scanned by the pattern generator, the pattern generator sweeps will be exceedingly linear when each successive dot, vertically and horizontally, corresponds to each successive tenth line of the crosshatch pattern as illustrated in Figure 4. The pattern generator

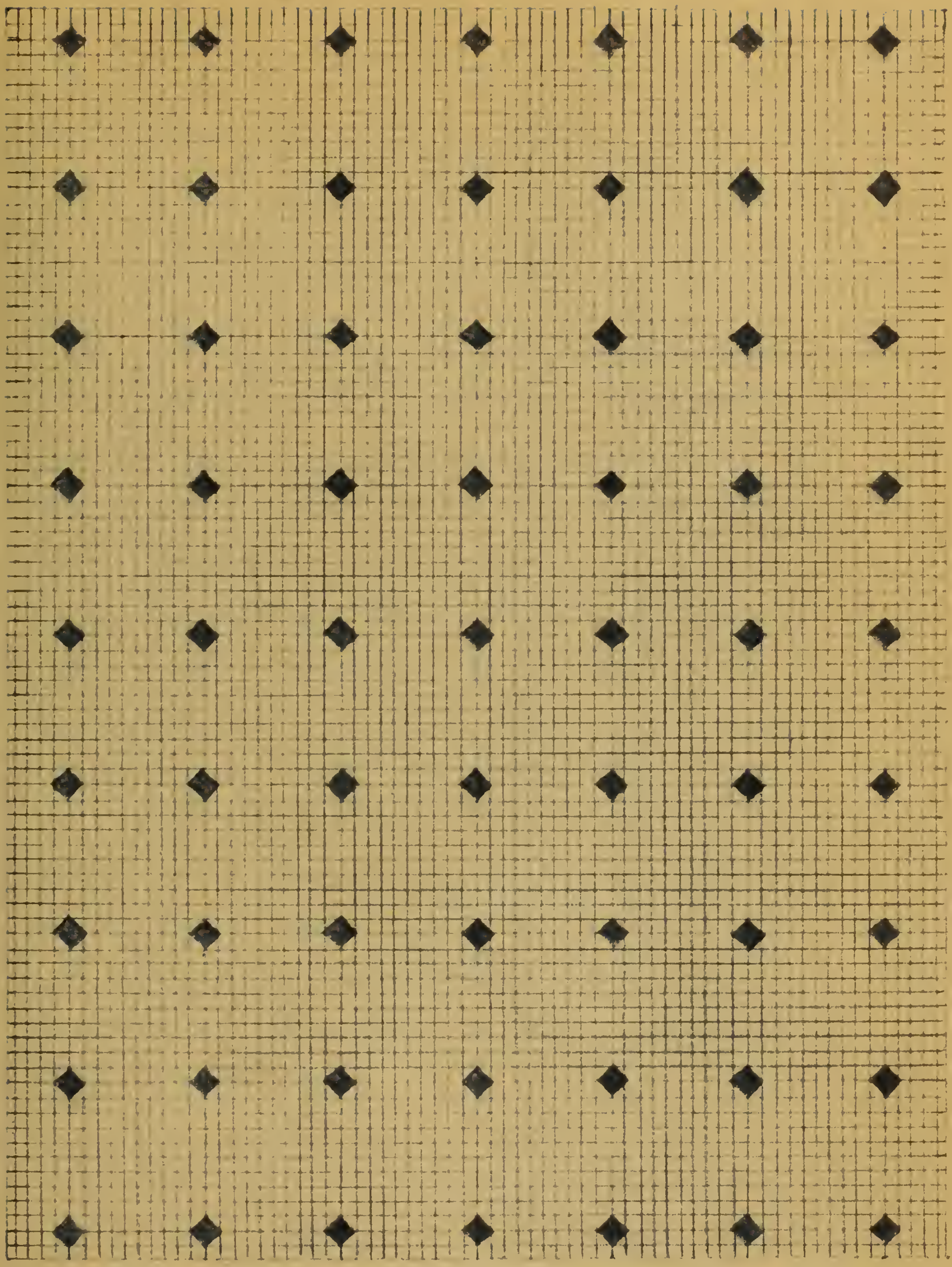

Figure 4- Special test pattern to check linearity,with crosshatch pattern superimposed

centering controls may be adjusted to bring about the coincidence.

The scanning of the monitor may be overdriven to magnify the picture for close inspection of a portion of it. The centering controls of the monitor may be adjusted to permit examination of a portion of the picture at a time.

A crosshatch generator may be designed to present a pattern consisting of any number of vertical and horizontal lines. The horizontal bars are formed by broad blanking pulses, whereas the vertical lines are formed by narrow pulses. In most crosshatch generators the bars are about 10 per cent of the space between bars. The bars are of the order of from one to two lines in width if the system has good high-frequency fidelity. Due to the sharpness of the vertical lines in the crosshatch pattern, a poor high-frequency characteristic in the monitor amplifier or beam defocusing of the kinescope can be observed.

The pattern provides a good check on uniformity of focus if the deflection yoke has no defects. Stray magnetic fields in the vicinity of the kinescope will show up as curvature of the scanning lines. This is often caused in the yoke by assymetrical capacitances of the coil sections.

5. Equipment tests.

Test patterns are very helpful in the television manufacturing industry. A manufacturer of television equipment is concerned with how well his product will perform when reproducing video signals. Short-cut tests have been tried,

but give poor correlation with the results obtained when an actual picture is reproduced. However, the quality of the latter is difficult to reduce to a quantitative basis unless the test pattern or picture has a specific character which can be accurately converted into a reliable video signal. The test pattern is admirably suited for this purpose.

Simple tests insure the quality of the video signal used for rating a cathode-ray tube or kinescope. If the scanning on the test pattern is reduced and that on the kinescope is maintained at normal, an enlargement of the scanned portion of the signal plate will be seen on the kinescope. This enlargement removes the possible limitation of kinescope resolution. Also, the reduced scanning lowers the frequency band of the video signal so that the video amplifier does not limit the resolution. Under these conditions, the focus of the scanning beam of the pattern generator can be accurately set to give high resolution, from 500 to 600 lines. If the finest detail in the pattern can be resolved, it is evidence that the scanning spot in the pattern generator is smaller than the finest detail to be transmitted, and, therefore, that the pattern generator spot size is not limiting resolution.

After the focus of the pattern generator is set for maximum resolution, the resolution of the pattern generator's video amplifier can be checked. This is done by making the pattern generator's scanning normal size and increasing the scanning on the kinescope. The latter is necessary to remove the possible limitation of kinescope resolution. The resolu-

tion of the amplifier is easily checked on the test pattern by noting the resolution of the upright "V's". The overall resolution of the pattern generator should be appreciably more than the resolution to which the kinescope is to be rated. When the scanning of the kinescope is reduced to normal, the limits of the kinescope resolution can be determined and reliable test data obtained. If more detail is visible in the enlarged pattern than in the normal pattern, then the kinescope spot size is limiting resolution.

Since the resolution in all parts of the scanning pattern on a kinescope may not be uniform, a test pattern is available for checking all parts of the pattern under similar conditions. The pattern is divided up into several sections, each one of which carries "V's" corresponding to resolutions of 150 to 450 lines. Also, tones between black and white are included to give a check on the modulation characteristic of the kinescope. With such a pattern, the kinescope can be rated under different bias conditions with various amounts of video signal input. An illuminometer can be used to check the light output for a definite signal.

In the development and production testing of receivers a standard source of high-quality signal has numerous advantages. The previously mentioned test patterns serve as good "yardsticks" for measuring receiver characteristics. By modulating a small transmitter with the pattern generator output a very useful test signal can be obtained for readily checking receivers. A test similar to that mentioned for

kinescopes will indicate whether or not the receiver amplifiers are limiting resolution. If on enlarging the receiver scanning amplitude no improvement in detail results, then the amplifiers are limiting the resolution.

When a television system is installed, numerous tests must be made to adjust the various circuits. Test patterns materially aid such testing. For instance, any extraneous signals entering the grid circuit of an iconoscope or image orthicon can be detected by substituting a monoscope tube in the circuit to generate a test pattern. The beam current in a monoscope tube should be constant. Since the video signal from the monoscope is directly proportional to the beam current, any variation in beam current is revealed as a modulation of the video signal. Therefore, any unwanted signal or hum in the circuits is revealed.

When the shading signals which are sometimes added to the iconoscope or image orthicon video signal are removed, the video-amplifier can be checked for pick-up and frequency response by using an externally generated test pattern for a video signal. Such tests help to separate confusing factors which often combine to give poor over-all operation.

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CHAPTER II

METHODS OF GENERATING TEST PATTERNS

1. Monoscope camera.

In this chapter various methods of test pattern generation will be described. Emphasis will be placed on the generation of the low level video signal, and the methods of amplification and correction will be discussed in the following chapter.

Probably the most widely used method of test pattern generation is the monoscope camera. A monoscope is a type of tube designed to produce a video signal of a test pattern or a picture that is permanently enclosed in the tube. Although not suitable for developing a signal which represents action, excellent fidelity can be obtained for a still picture which contains half-tones or consists only of lines.

The monoscope tube to be described is the most recent type, the RCA 2F21. It is similar in appearance to an ordinary cathode-ray tube. It consists of an electron gun, a signal plate, and a collector enclosed in a highly evacuated envelope. The electron beam is scanned over the signal plate by an electromagnetic deflection system. The video output is taken directly from the signal plate. Electrostatic focusing is used.

When the target of the electron beam is a flat surface such as in the monoscope tube, electrostatic focusing is superior to magnetic focusing. Magnetic focusing utilizes the principle that an electron entering a magnetic lens system

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will be deflected if the electron possesses a component of velocity that is radial with respect to the axis, as shown in Figure 5(a) for paths "a", "b", and "d". The electron will spiral, and for a correct value of magnetic field strength, will intersect the axis at a point P on the target. This action is independent of the radial component of velocity of the electron. If the target is a plane, then for correct focusing at the target center there will be a defocusing of the spot at other points on the target as the beam is deflected. At point Q all paths will be longer. As a result, an end view of the paths, as illustrated in Figure 5(b) would show that an electron traveling with a radial component of velocity would have described path oe"f if path oe"e represents its path when the beam is not deflected. Thus electrons that do not travel the main path "c" in the electron beam will result in a defocusing action when magnetic focusing is used. There is a slight defocusing action in the picture corners when electrostatic focusing is used caused by the mutual repulsion of the electrons in the beam. This action, however, is also present in magnetic focusing.

The electron gun which supplies the scanning beam is of high quality in order to obtain a superior video signal. The electron beam must be very small when it strikes the signal plate to obtain good resolution. The beam current is reasonably high in order to make the output video current as large as possible. The beam size is the more important factor, however, and limits the beam current. The final anode of the gun operates at 1000 volts, and a beam which focuses to a

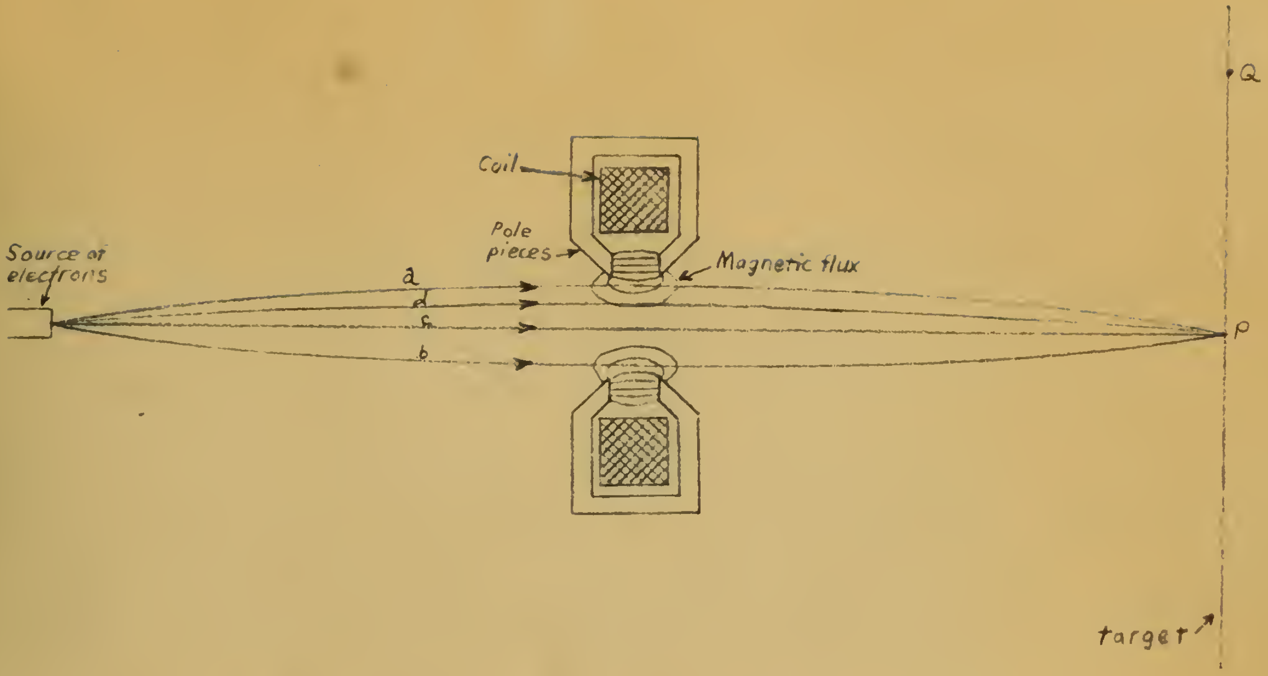


Figure 5(a)-Focusing system using localized magnetic field

oe"e represents end view of undeflected path "a" to point P.
oe'e represents end view of undeflected path "d" to point P.
oe"f represents end view (relative to deflected path "c") of path "a" deflected towards point Q.
oe'g represents end view (relative to deflected path "c") of path "d" deflected towards point Q.

Figure 5(b)-End view enlarged

spot, the width of which is about 1/500th of the pattern height, can be obtained for currents of several microamperes. Figure 6 shows the internal construction and operating voltages of the 2F21.

The 2 5/16" x 3 1/16" signal plate is located at the end of the tube remote from the electron gun. It is made from aluminum foil 0.004" thick and carbon. The surface of the aluminum has a natural coating of aluminum oxide which has a reasonably high secondary-emission ratio while the carbon has a relatively low ratio. As the plate is scanned the difference in the magnitude of secondary-emission currents determines the amount of video current. Since this difference is greater than unity, more video current is developed than if only the primary current of the beam were utilized.

Aluminum foil developed for advertising and packing purposes as well as special inks developed for printing on metal foils make satisfactory materials for signal plates. Thus the advantages and flexibility of commercial printing processes can be utilized. The desired pattern or picture is printed on aluminum foil with a black-foil ink. Before sealing the signal plate in the tube it is fired in hydrogen. This removes the volatile matter from the ink and leaves it practically pure carbon. In order to have the output of the monoscope correspond to outputs from iconoscopes and image orthicons the picture on the signal plate has blacks and whites reversed, since in the outputs of these tubes black is positive. Although the aluminum oxide is white in appearance, it

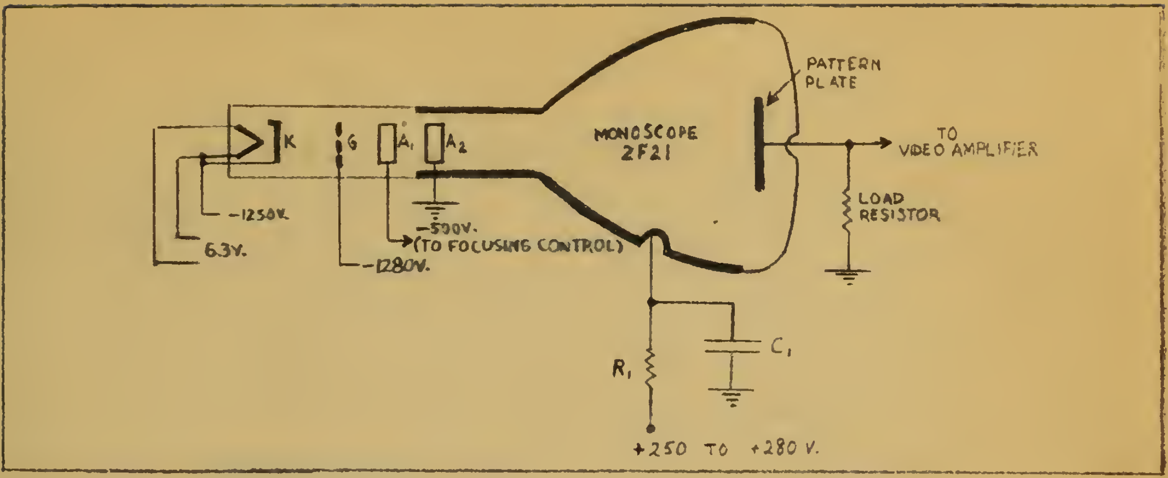


Figure 6-Internal construction and operating voltages of the 2F21 monoscope tube

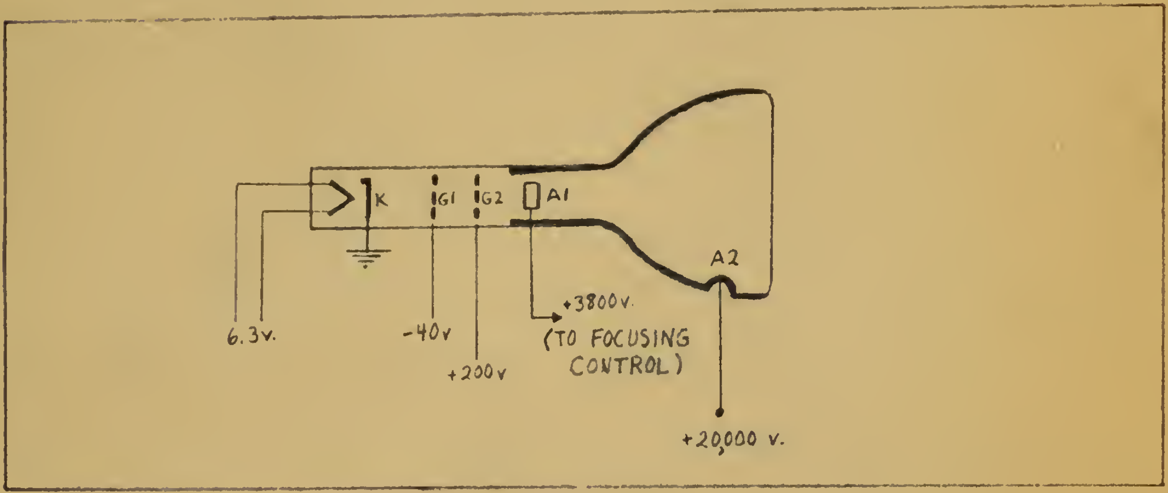


Figure 7-Internal construction and operating voltages of the 5WP15 flying-spot cathode-ray tube

has a higher secondary-emission ratio than carbon and, therefore, produces a signal which corresponds to black.

The following proceedure is used to print the signal plates. Photo-engravings are made of the subject matter. The black-and-white material is treated as a line-cut, but the half-tone material must be broken into a number of dots of various sizes depending on the half-tone value. This is done when the photo-engraving is made by photographing the material through a suitable screen. A screen is used which will break the picture into more elements than are used in the television scanning system. Thus this technique of obtaining half tones does not limit the resolution of the television system, and the half-tone effect is reproduced, just as in a newspaper photograph. The picture is made up of numerous dots of various sizes.

The secondary emission current from the signal plate is collected by a conductive aquadag coating on the bulb wall. This coating is operated at a potential positive with respect to the signal plate. The secondary electrons are fed through a side connection to R_1 and C_1. See Figure 6. Here the current divides, some going back to the cathode through the high-voltage power supply, the rest going to ground and up through the grid resistor of the first video amplifier back to the signal plate. The latter electrons form the video signal across the grid resistor.

The peak to peak value of the pattern-electrode signal-current is approximately 0.5 microamperes. The beam current

is about 30 per cent greater. Usual practice is to operate the monoscope with the pattern electrode at ground potential to avoid undesirable pick-up of extraneous signals, including hum, at the first video amplifier grid. Adjustment of output signal level is made by means of the control of the first grid voltage which regulates the beam current. A transformer with a high-voltage heater winding must be used for supplying the heater power to this tube since the cathode is operated about 1000 volts below ground potential.

Resolution capability of the monoscope is about 500 lines, but it is possible to get higher resolution from some tubes with low orders of beam current and signal output. Because there are not any half-tones in the video signals from a monoscope except those that are created by the limitation of resolving power of the beam, the signal is rich in the higher-order harmonics which make up the corners of a square wave. This type of signal is exceptionally good for showing the transient response of video amplifiers.

2. Flying-spot scanner.

Another type of test pattern generator, much more recent than the monoscope, is the flying-spot scanner. Early experimenters with cathode-ray systems found an easy way of televising fixed pictures by placing photographic negatives against the fluorescent screen of a tube whose beam was swept in a conventional manner. A phototube placed in front produced a series of video pulses that could be applied to a second cathode-ray tube circuit. Dispersion of the light

spot through the glass introduced one of the main difficulties toward attaining good reproduced detail, however, so some sort of lens system was often introduced between the screen of the transmitting tube and the film.

These early experiments had the advantage of simplicity, but at scanning speeds suited to televising live scenes the delay characteristics of the phosphorescent screen caused a smearing effect with accompanying loss of detail.

A solution to this difficulty has been provided by the RCA 5WP15 tube, a five inch cathode-ray tube intended primarily for use as the scanner in a flying-spot video-signal generator. It has the advantage of permitting a change of picture or test pattern at will, and of reproducing the picture with the halftone fidelity of photographic film.

The type 15 phosphor with a metallized back has a spectral-emission characteristic with peaks in the blue-green and near-ultraviolet regions as shown in Figure 8. The ultraviolet radiation has a persistence characteristic which is appreciably shorter than that of the visible region. Thus, by utilizing only the ultraviolet radiation, it is possible to minimize blurring or trailing in the reproduced picture. The metallized back effectively doubles the radiant energy of the flying spot compared with the energy obtainable from an unmetallized screen.

Magnetic deflection and electrostatic focusing are used with the 5WP15 to obtain essentially uniform focus over the useful screen area. Optically, the tube face has a quality

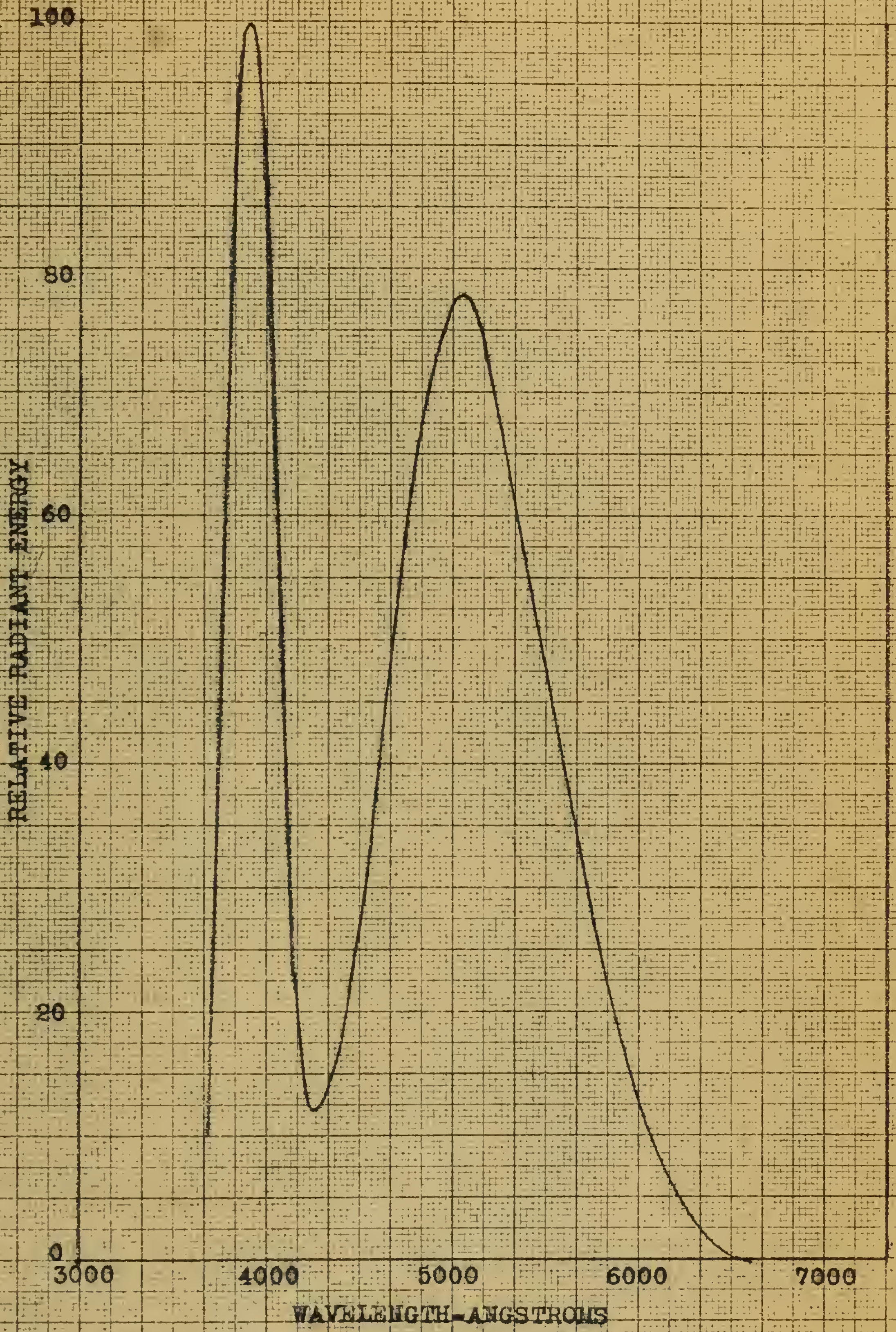


Figure 8

Spectral-energy emission characteristic of phosphor P15

and flatness which will not limit the performance of a high quality objective lens needed to provide maximum signal resolution.

There is an external conductive coating on the neck of the tube which, when grounded, prevents corona between yoke and neck. Corona would damage the yoke insulation and cause breakdown in the glass of the neck. The neck also has an internal coating which is at the high potential of anode 2. The resistance of these coatings is high enough that damping of the yoke deflection energy is negligible. The capacitance between the two coatings is in the range of 100μμf to 500μμf. It serves as a filter capacitance for the high-voltage power-supply unit.

An external moisture-repellent insulating coating on the bulb cone minimizes sparking over the glass bulb under conditions of high humidity. When humidity is high, a continuous film of moisture has a tendency to form on untreated glass. If a high-voltage gradient is present, this film may permit sparking to take place over the glass surface. The tube should be protected as much as possible from contamination such as finger prints and dust which might absorb moisture and provide electrical leakage paths that increase in conductivity with high humidity. The dust also reduces the amount of radiation through the bulb face.

The internal construction and operating voltages of the 5WP15 are shown in Figure 7. Anode 2 should be operated between 15,000 and 27,000 volts, brilliance and definition de-

creasing with decreasing voltage. The ultraviolet output of the tube with anode 2 at 20,000 volts is shown in Figure 9(a), and with anode 2 at 27,000 volts in Figure 9(b). The size of the arbitrary units is the same in both figures. Also shown is the effect of variation in grid 1 voltage on anode 1 current and on anode 2 current.

Soft x-rays are produced when anode 2 voltage is above approximately 20,000 volts. Experiments conducted at the RCA laboratories have shown that at most they are very weak. These rays can, however, constitute a health hazard unless the tube is adequately shielded. Relatively simple shielding should prove adequate.

Grid 2 is incorporated in the 5WP15 to prevent interaction between the fields produced by grid 1 and anode 1. It may also be used to compensate for the variation in the grid 1 voltage for cutoff in individual tubes. By adjusting the voltage applied to grid 2, with due consideration to its maximum rated value of 350 volts, it is possible to fix the grid 1 bias at a desired value, and obtain almost the same anode-current characteristics for individual tubes having different cutoff voltages. Adjusting grid 1 cutoff in this way not only makes grid drive more uniform, but also reduces variations in anode 1 current. Since grid 2 at most draws only negligible leakage current, its voltage may be obtained from a potentiometer inserted in the anode 1 voltage divider mentioned in the next paragraph.

Focusing is controlled by adjustment of the ratio of anode 1 voltage to anode 2 voltage. This ratio is ordinarily

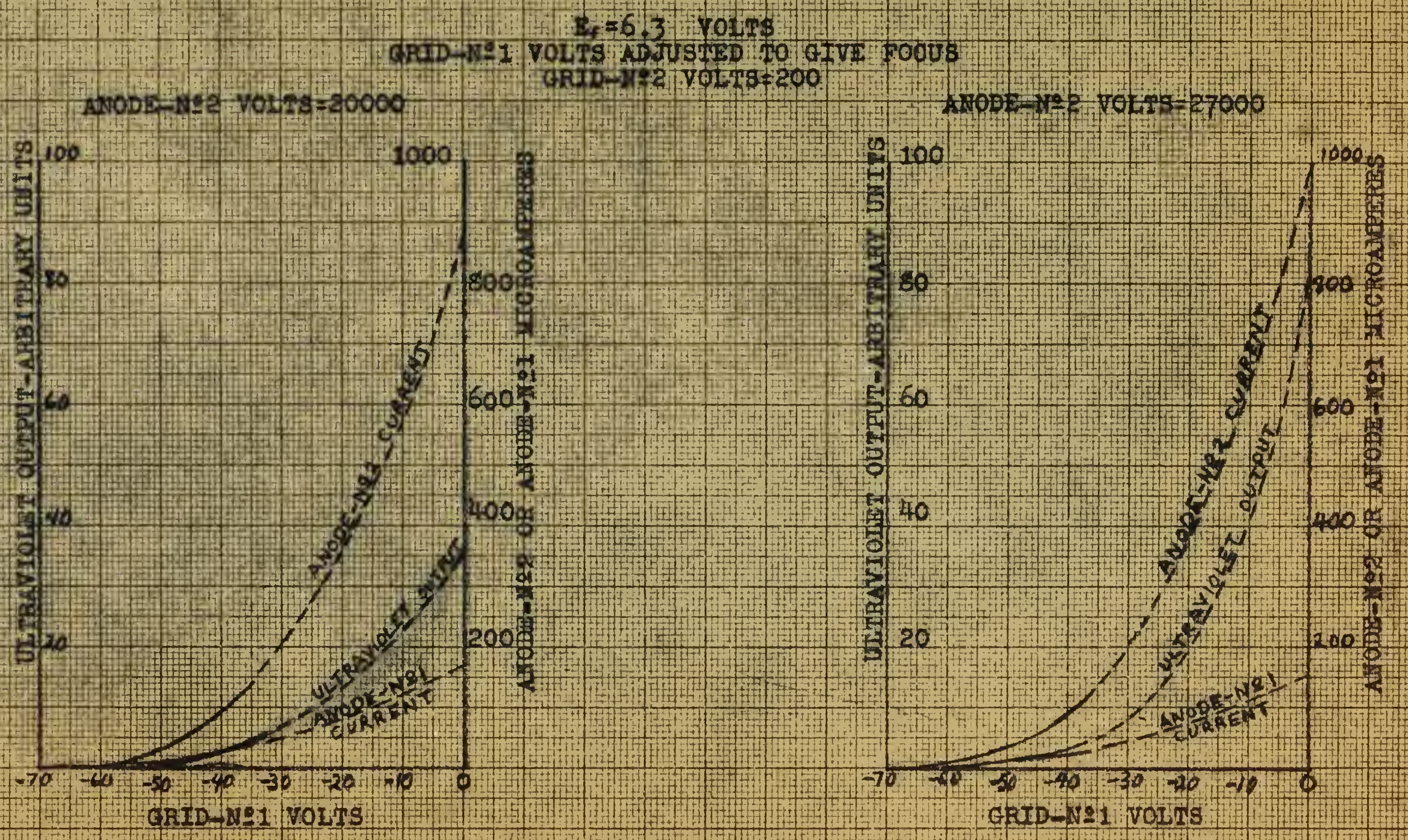


Figure 9-Average characteristics of the 5WP15 flying-spot cathode-ray tube

adjusted by variation of anode 1 voltage. Anode 1 voltage can be obtained from a potentiometer in a voltage divider across the high-voltage supply. Because the ultraviolet efficiency of phosphor P15 increases somewhat faster than the beam-current density, the signal output rises as the flying-spot is brought to focus. It is, therefore, desirable to provide uniformity of focus over the entire scanned raster in order to obtain optimum signal output as well as to obtain good resolution.

Resolution of better than 700 lines at the center of the reproduced picture can be produced by the 5WP15. To obtain such resolution in the horizontal direction, it is necessary to use a video amplifier having a band-width of about 9 megacycles.

By the use of the control grid in the 5WP15, a modulation pattern can be superposed on that from the transparency. A great many unusual artistic effects and double-image effects are possible by this addition. Studio directors, after a few experiments using simple equipment, can devise many spectacular background effects without preparing extensive artwork.

The blue-green radiation of the 5WP15 decays hyperbolically to about 30 per cent of its initial value in 1.5 microseconds. The ultraviolet radiation has an equivalent exponential decay with a time constant less than 0.05 microseconds. The frequency response of the ultraviolet radiation is substantially constant for a range of 3 megacycles and then decreases exponentially toward zero at approximately 100 megacycles.

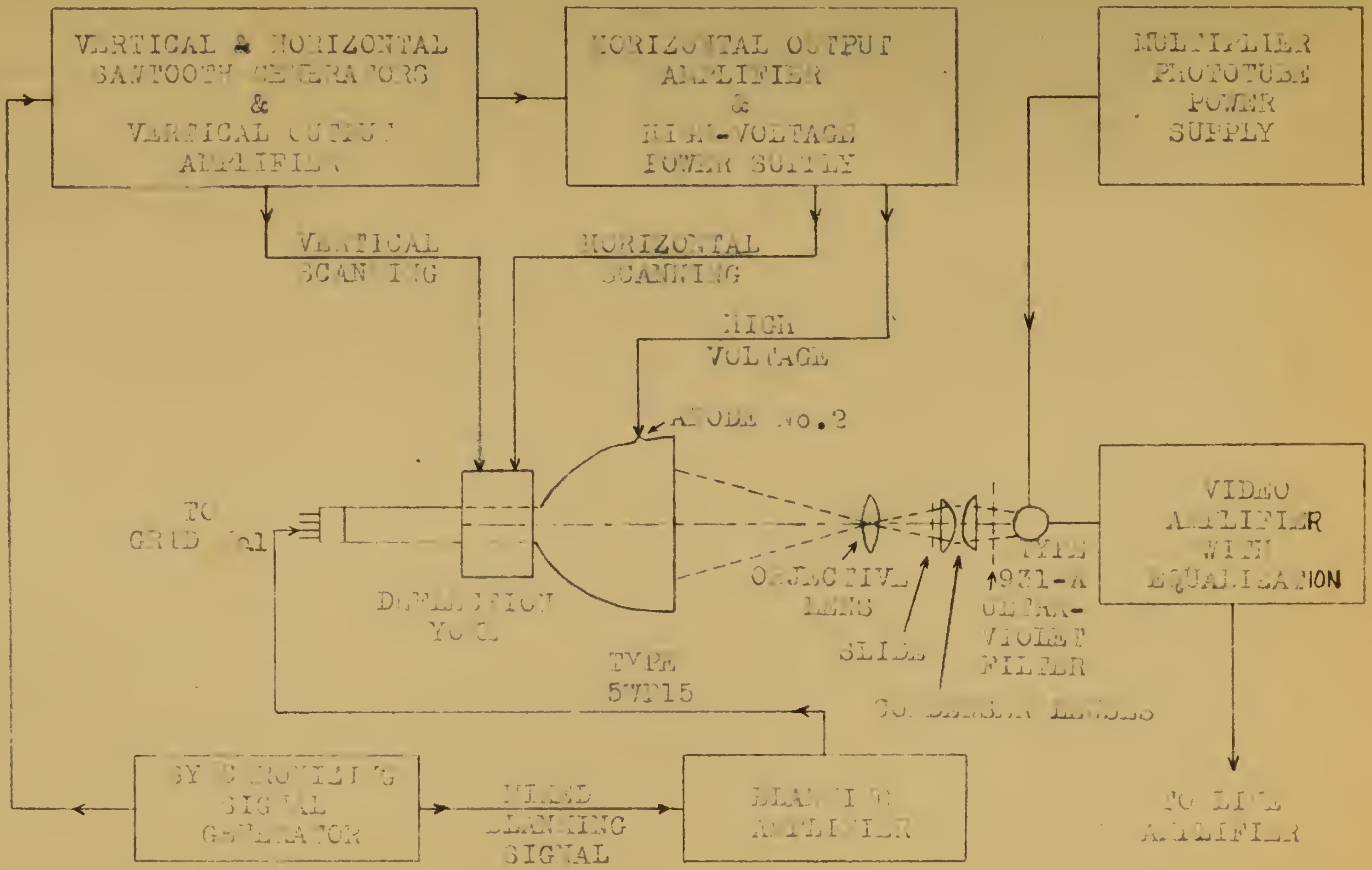


Figure 10-Block diagram of flying-spot video-signal generator.

A flying-spot video-signal generator consists essentially of (1) a flying-spot cathode-ray tube with associated power supplies, deflection yoke, and scanning circuits to provide a small, rapidly moving source of radiant energy; (2) an optical system arranged to project the raster on the subject to be scanned; (3) a multiplier phototube with associated power supply to intercept the radiation transmitted or reflected by the subject and convert it into video signals; and (4) a video amplifier. The subject may be a slide transparency, motion picture film, or an opaque object.

A block diagram of such a system arranged for use with a slide transparency is shown in Figure 10. Several of the details of this diagram will be covered in the next chapter. For best results, the enlarger type objective lens should be designed for low magnification and, preferably, be corrected to handle ultraviolet radiation. The diameter of the objective lens should be adequate to cover the slide to be scanned. For use with 35 millimeter slides the Kodak Enlarging Ektar f:4.5 lens with focal length of 100 millimeters, or equivalent, is suitable.

Satisfactory filters for absorbing the visible and passing the ultraviolet radiation of the screen are any of the following: Eastman Wratten Nos. 18A, 34, and 35, as well as the Corning Nos. 9863 and 5970. The choice of filter for a particular generator design is affected by a compromise between the permissible loss of signal output through absorption by the filter on the one hand, and the amount of trailing which can be tolerated, or the extent of equalization

needed, on the other hand.

Trailing results from the lag in buildup and decay of output from the screen. As the flying-spot moves across a boundary from a light to a dark area of the subject being scanned, the persistence of energy output from the screen results in continued input to the phototube from the light area during the time the dark area is being scanned. Thus, the light area trails into the dark area in the reproduced picture.

Similarly, as the flying-spot moves from a dark area to a light area, the lag in buildup of the screen output causes the dark area to trail over into the light area.

As a result of these effects, the reproduced picture has an appearance similar to that produced by a signal deficient in high frequencies. Therefore, it is necessary to enhance the high-frequency response of the video amplifier by introducing equalizing networks of the resistance-capacitance type with suitable time constants. Sufficient equalization should be provided to give the desired square-wave response.

The decay characteristics of most standard phosphors are such as to require considerable equalization provided by networks with different time constants in several stages of the video amplifier. Their relatively long decay generally results in appreciable reduction of the useful signal-to-noise ratio.

Compared with standard phosphors the persistence of the P15 screen is comparatively short so that less equalization is needed. If the P15 is used without an ultraviolet filter,

less equalization is required than for other standard phosphors, but a complex network is nevertheless needed because the decay characteristic is not a simple exponential curve, but a curve of a complex function. When used with a filter to pass only the ultraviolet radiation, the P15 has a persistence so extremely short that the small amount of equalization needed can be supplied by a single network. As a result, circuits and adjustments are simplified, and substantially the same signal-to-noise ratio is obtained, in spite of filter absorption, as with the arrangement using the total radiation from the phosphor.

3. Iconoscope and image orthicon cameras.

Another method of generating test pattern or still picture information is to focus it on the mosaic of an iconoscope or the photocathode of an image orthicon pickup tube. The monoscope camera has been used extensively for the generation of test patterns for several years. The flying-spot scanner is such a recent development, however, that it is not yet in general use. Thus, in many instances the desired picture is placed on a stand or suspended from a wall, and a standard television camera is used to televise it, the correct lens for the distance involved being used to focus the picture on the mosaic or photocathode of the camera tube. Considerable caution must be exercised, particularly with an image orthicon, since a still picture that is focused for any length of time on the photocathode will tend to "burn" an image of the picture on it. Considerable time will thereafter be required to allow this image to fade away.

[illegible]

[illegible]

[illegible]

There are two other methods of focusing still pictures on a camera tube. A recent development by the Radio Corporation of America is called the Video Announcer. It is a device designed to facilitate camera alignment in television field operation particularly during adverse weather conditions. It also provides a means of presenting static pictures.

The Video Announcer being small and light can be quickly and easily installed on most television field cameras, using the 50 millimeter lens normally supplied with the camera. It uses single frame exposures of 35 millimeter film strip, with adjustments provided for proper alignment, framing, and illumination of the film.

The equipment can accomodate a film of approximately 70 frames. RMA and local station test patterns are generally included at the ends of each strip along with a few transparent frames which can be used to wipe off any images burned on the image orthicon tube of the camera. Camera alignment is done with the RMA test pattern.

The other method is used with television film cameras. Iconoscopes are usually used in these cameras since they are capable of a better signal-to-noise ratio than are image orthicons. Iconoscopes give poor performance under insufficient lighting conditions, but that difficulty is not serious when televising film. Most film cameras may be used with a motion picture projector or a slide projector. The slide projector presents a convenient arrangement for quick changing of still pictures. It can be used in the studio in much the

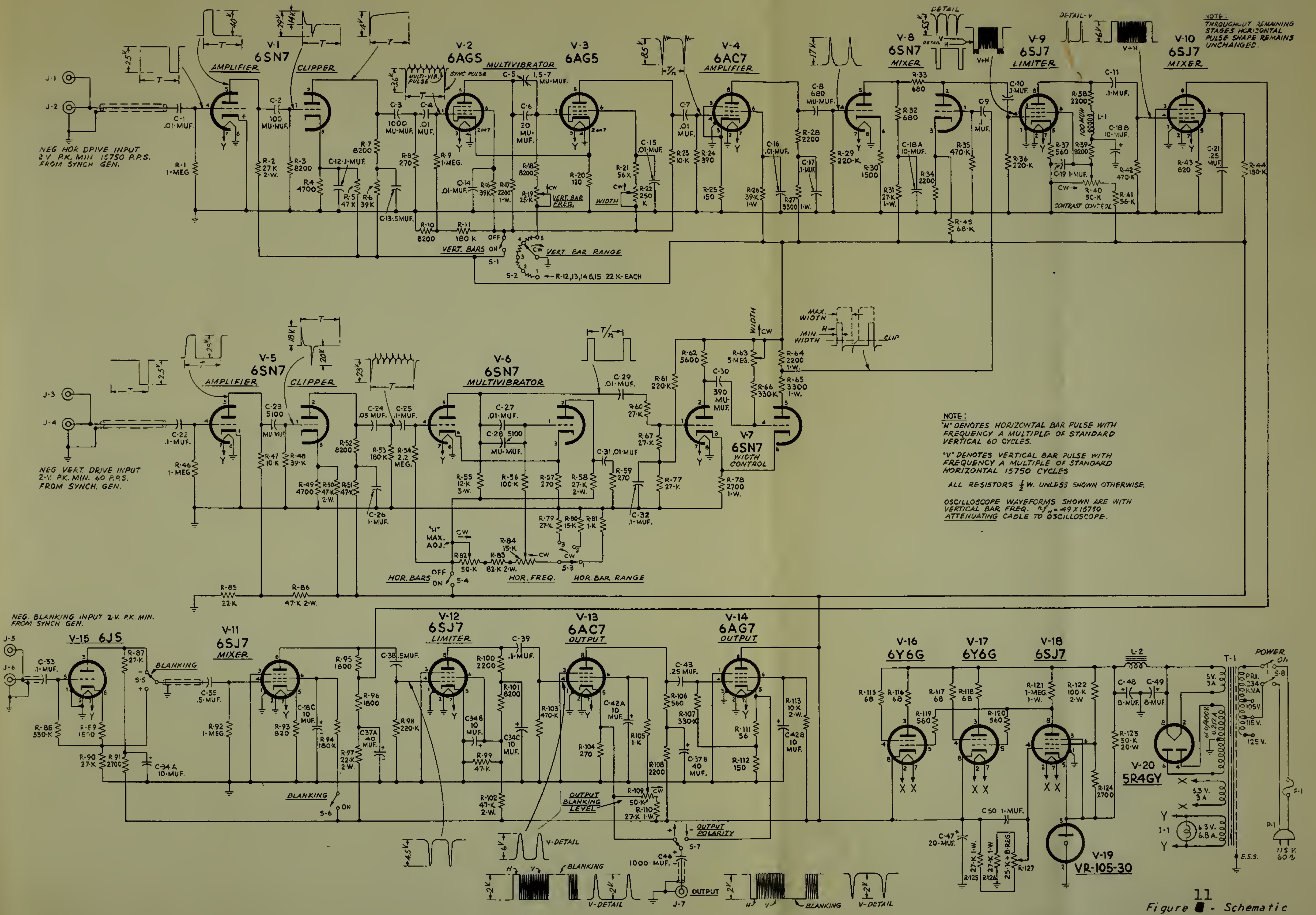
same way that the Video Announcer is used in the field.

4. Grating generator.

In order to generate the crosshatch pattern which is used to check the linearity of pattern generators a special type of pattern generator is used. As previously mentioned the output of this generator as viewed on a monitor is a series of horizontal and vertical bars equally spaced in time. As a typical example the RCA type WA-3A grating generator will be described. A schematic diagram of this unit is shown in Figure 11.

Signal inputs from a sync generator are negative horizontal driving pulses of 15,750 c.p.s., negative vertical driving pulses of 60 c.p.s., and negative mixed blanking pulses. There is an internal power supply using a full wave rectifier regulated to produce 250 volts plate supply.

To form the vertical bars, negative horizontal driving pulses are inverted and amplified by the first half of V-1 and differentiated and clipped by the second half. The output of V-1 synchronizes a free running cathode coupled multivibrator composed of V-2 and V-3 of such a configuration that V-3 conducts for only a relatively short period of time, and hence the output taken from the plate of V-3 consists of narrow negative pulses. The "VERTICAL BAR RANGE" switch, S-2, is a coarse control of the multivibrator frequency, and the "VERTICAL BAR FREQUENCY" potentiometer, R-19, is for fine adjustment of the multivibrator frequency. The "WIDTH" control, R-22,varies the screen potential of V-3, determining



NOTE:
THROUGHOUT REMAINING STAGES HORIZONTAL PULSE SHAPE REMAINS UNCHANGED.

NOTE:
"H" DENOTES HORIZONTAL BAR PULSE WITH FREQUENCY A MULTIPLE OF STANDARD VERTICAL 60 CYCLES.

"V" DENOTES VERTICAL BAR PULSE WITH FREQUENCY A MULTIPLE OF STANDARD HORIZONTAL 15750 CYCLES

ALL RESISTORS $\frac{1}{2}$ W. UNLESS SHOWN OTHERWISE.

OSCILLOSCOPE WAVEFORMS SHOWN ARE WITH VERTICAL BAR FREQ. $nf_H = 49 \times 15750$
ATTENUATING CABLE TO OSCILLOSCOPE.

W-232763-0

Figure 11 - Schematic
WA-3A Grating Generator

how heavily the tube conducts. It affects the multivibrator frequency and hence necessitates readjustment of the "VERTICAL BAR FREQUENCY" control. The "WIDTH" control provides adjustment of bar width down to 10 per cent of the space between bars. A "VERTICAL BARS" on-off switch, S-1, provides plate supply voltage for the multivibrator.

The output of the multivibrator is amplified and inverted in V-4, whence it appears on the grid of the first half of a mixer tube V-8 as positive pulses of vertical bar frequency.

To form the horizontal bars, negative vertical driving pulses are inverted and amplified by the first half of V-5 and differentiated and clipped by the second half.

The output of V-5 synchronizes a free running cathode coupled multivibrator composed of the two halves of V-6. The "HORIZONTAL BAR RANGE" switch, S-3, is a coarse control of the multivibrator frequency, and the "HORIZONTAL FREQUENCY" potentiometer, R-84, is for fine adjustment of the multivibrator frequency. A "HORIZONTAL BARS" on-off switch, S-4, provides plate supply voltage for the multivibrator.

The output of V-6 synchronizes a one-shot cathode coupled multivibrator composed of the two halves of V-7 whose purpose is to provide a width control for the horizontal bars. The "WIDTH" control, R-63, determines the duration of conduction of the output half of V-7 and provides adjustment of bar width down to 10 per cent of the space between bars.

The output of V-7 feeds one half of V-8 which is a mixer for the horizontal and vertical bar pulses, the two halves of

the tube having a common load.

The output of V-8 is fed to V-9 where the mixed signals are held to equal levels by the limiting action of driving the tube to cutoff. In the plate circuit there is a peaking coil, L-1, to boost the high frequency response. The "CONTRAST CONTROL" potentiometer, R-40, varies the plate supply and hence the amplitude of the output signal.

The output of V-9 appears inverted across the load of mixer, V-10. The input to V-15 is mixed negative blanking. The output of this tube can be taken from either plate or cathode through switch, S-5, to provide either polarity whence it is fed to mixer, V-11. This tube has a common load with mixer, V-10. The bar signals and blanking signals appear across this load and are fed to V-12 where they are held to equal levels by the limiting action of driving the tube to cutoff.

V-12 drives the output tube, V-13. The "OUTPUT BLANKING LEVEL" potentiometer, R-109, varies the screen voltage of V-13, and thus determines the output amplitude. A positive blanking output can be taken from the cathode of V-13. There is coupling from the plate of this tube to the output tube, V-14. A negative blanking output can be taken from the cathode of this tube through the "OUTPUT POLARITY" switch, S-7.

For a signal of negative polarity the "POLARITY" switch should be set to the "—" position, and the "BLANKING" switch should be set to the "—" position. For a signal of positive polarity the "POLARITY" switch should be set to the "+" position, and the "BLANKING" switch should be set to the "—"

position. In order to produce white bars the "POLARITY" switch should be set to the "+" position and the "BLANKING" switch should be set to the "+" position. When the crosshatch pattern is to be superimposed on a video test pattern, the "BLANKING" switch should be off.

To use a crosshatch generator for setting the linearity of pattern generators the two outputs are injected into a receiver or monitor video amplifier. The monitor's linearity controls are then adjusted for maximum equality of bar spacing, and then the pattern generator's linearity controls are adjusted to make equal space intervals of the test pattern occupy equal time intervals of the crosshatch pattern.

CHAPTER III

SWEEP CIRCUITS, POWER SUPPLIES, AND VIDEO AMPLIFIERS OF PATTERN GENERATORS

1. Monoscope camera.

In order to make the description of pattern generators complete, a discussion of power supplies, the generation of sweeps, and video amplification must also be included. They are common to all systems of test pattern generation excluding the crosshatch generator. A complete monoscope camera will be described, following which items peculiar to other systems of pattern generation will be discussed.

A block diagram of the RCA monoscope camera type TK-1A is shown in Figure 12. Standard RMA pulses are obtained from a synchronizing generator to drive the vertical and horizontal deflection circuits which supply the sweep currents for the monoscope deflection yoke. The synchronizing generator also supplies mixed blanking pulses which are added to the video signal in the video amplifier. An external power source of 280 volts at 200 milliamperes, d.c., is required to supply all tubes. The accelerating voltage for the monoscope beam is obtained from the internal high voltage supply.

Figure 13 is a schematic diagram of the TK-1A monoscope camera. High voltage for the monoscope tube is obtained from a self-contained power supply. The power transformer, T-8, supplies all filament voltages, and the high voltage for the monoscope tube. A 1B3GT/8016 tube is used as a half-wave rectifier to obtain the high d.c. voltage necessary for op-

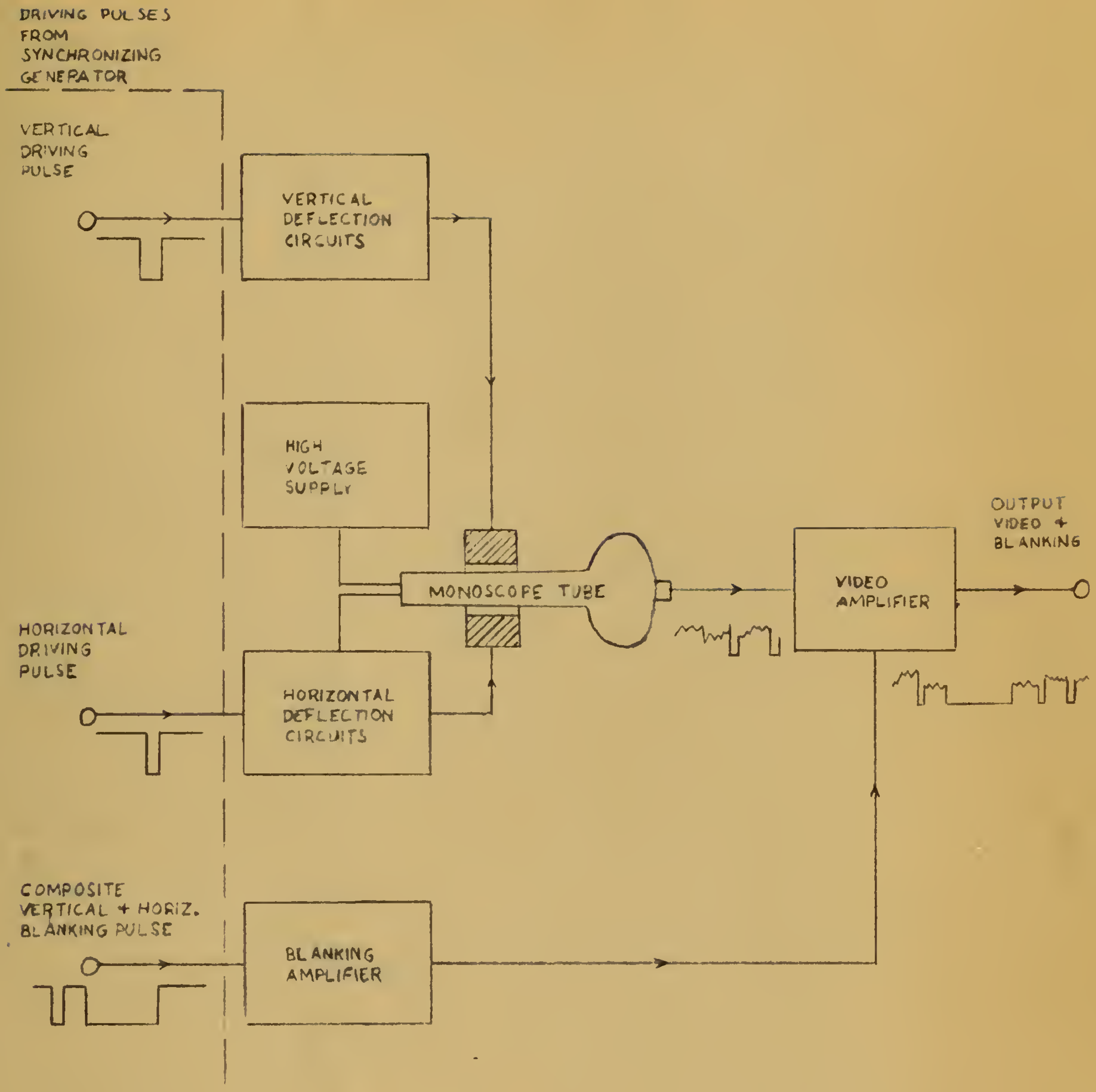


Figure 12-Block diagram of RCA type TK-1A monoscope camera

NOTE:-
ALL RESISTANCE VALUES IN OHMS ½ WATT
& CAPACITANCE VALUES IN MICRO-FARADS
UNLESS INDICATED OTHERWISE.
CW ⟶ CLOCKWISE ROTATION.
TUBE NO'S. REFER TO CORRESPONDING
NO'S. STAMPED ON CHASSIS NEAR TUBES
WITH TUBE DESIGNATION.

NOTE:-
REMOTE FOCUS CONTROL 2.5 MEG.
REMOTE GAIN CONTROL 100,000 ~ 2W
BOTH VARIABLE RESISTORS TO GROUND

13
Figure [redacted]—Schematic Diagram of Monoscope Camera

[redacted]

eration of the monoscope tube. The positive side of the high voltage supply is grounded so that the signal plate of the monoscope tube may be at ground potential, and the output of -1250 volts is connected directly to the cathode of the monoscope tube. Since one side of the monoscope filament is tied to the cathode, a separate filament winding of high voltage rating is required on the power transformer. The control grid is tapped at a point about 30 volts more negative than the cathode voltage. The setting of the potentiometer, R-60, from which the grid derives its voltage determines the amount of monoscope beam current. The potentiometer is shunted by a 991 voltage regulator tube which maintains the grid cathode voltage and hence the beam current constant. Focusing is controlled by the voltage on anode 1 which is obtained from a tapped bleeder resistance, R-38, across the output of the high voltage supply. There is also provision for remote focusing by a high resistance shunt between anode 1 and pin number 6 of the connector jack, J-1. A 2.5 megohm variable resistor connected between this point and ground serves as a remote focus control.

Filtering of the rectifier voltage is accomplished by the 1500 henry choke, T-9, and the 1 microfarad capacitors, C-20 and C-21, in the negative side of the circuit. Effective filtering is required to prevent modulation of the generated video signal. The power supply is voltage regulated by one triode section, V-11A, of a 6SL7. All of the return current for the power supply flows through the load resistor, R-61, of the triode. The voltage across R-61, in series with

that across capacitor C-20, represents the total voltage of the power supply. The function of tube, V-11A, is to vary the voltage across R-61 so as to offset any variation in total voltage. If, for example, the total output becomes more negative, this change is transmitted through C-21 decreasing the current through V-11A and raising the plate voltage of the tube. This increase across R-61 tends to offset the negative rise across C-21.

To obtain vertical deflection negative vertical driving pulses are applied to one grid of V-14. These are amplified, inverted, and applied to the grid of the other half of V-14, a sawtooth generator. Between pulses C-24 charges towards the plate supply voltage, and is discharged during the pulses through the low impedance of the tube. The time constant of charge of C-24 is relatively large, and since only a small part of this rise is utilized, the voltage sawtooth applied to one grid of V-13 is quite linear. The vertical sweep amplitude is varied by means of the "HEIGHT" control, R-69, which changes the slope of the sawtooth.

After two stages of amplification in V-13 the positive going sawtooth is applied to the grids of the dual triode, V-12, both halves of which are connected in parallel. This tube drives the vertical deflection coil through the transformer, T-10. One-half of V-11 is used to provide negative feedback, its plate being connected in parallel with the plate of the input section of V-13. Input voltage for this half of V-11 is obtained from R-79 which is in series with the

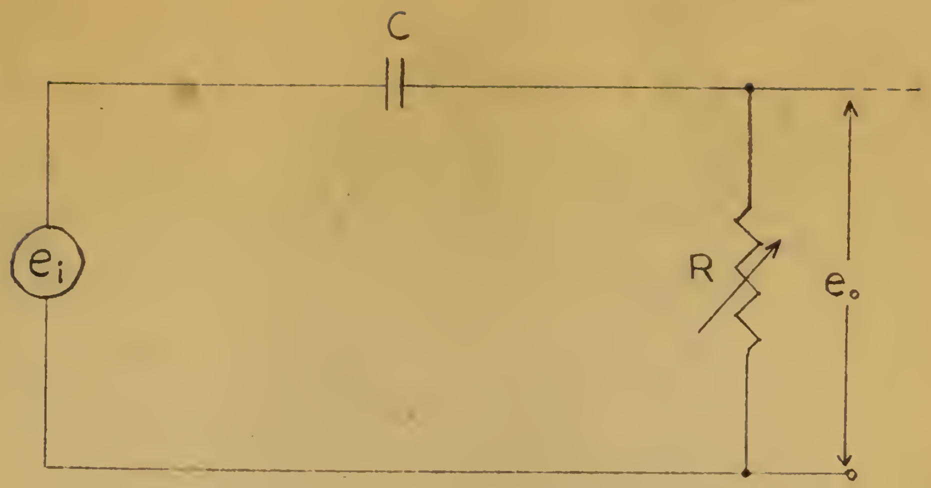


Figure 14(a)-Grid circuit of vertical sweep feedback amplifier in monoscope camera

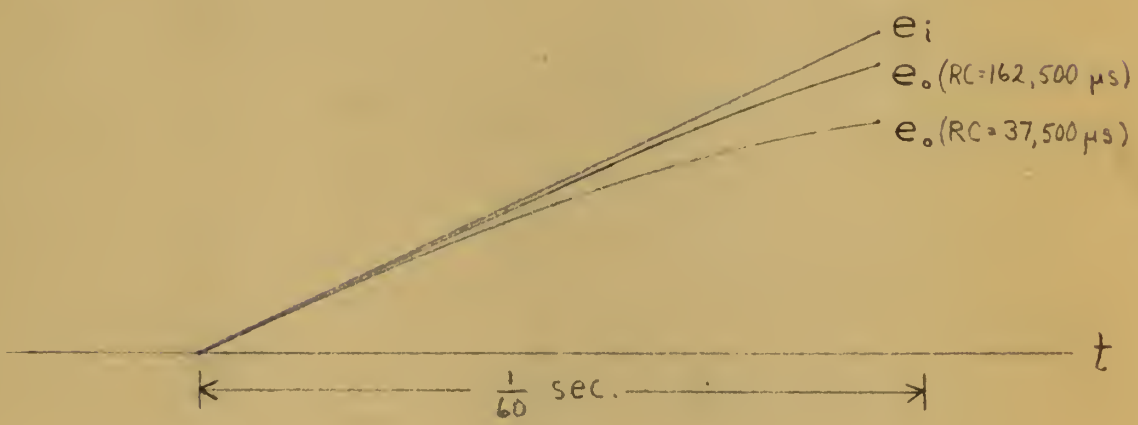


Figure 14(b)-Grid signal waveforms of vertical sweep feedback amplifier in monoscope camera

vertical deflection coils. A sawtooth voltage is developed across R-79 by the deflection current. The potentiometer R-81 is the "VERTICAL LINEARITY" control. To illustrate how it functions consider the circuit shown in Figure 14(a), where the input is a voltage increasing linearly with time. Let C represent C-27 and R represent R-81 and R-128 in the grid circuit of the feedback amplifier.

To obtain the output voltage, e_o, across R:

Letting $e_i = at$

Then: $E_i = \mathcal{L}[at] = \frac{a}{s^2}$

$$E_o = \left(\frac{R}{R+\frac{1}{Cs}}\right)\left(\frac{a}{s^2}\right) = \frac{a}{s\left(s+\frac{1}{RC}\right)}$$

$$e_o = \mathcal{L}^{-1}[E_o] = a\left(RC - RC\,e^{-\frac{t}{RC}}\right) = aRC\left(1-e^{-\frac{t}{RC}}\right)$$

The output voltage or the signal on the grid of the feedback amplifier can be varied by varying RC between the limits of 37,500 and 162,500 microseconds. A plot of the two extremes of grid signal is shown in Figure 14(b) for the duration of one field. Thus, essentially, the circuit provides variable attenuation of low frequencies with respect to high frequencies back at the vertical saw tooth amplifier to compensate for the greater attenuation of high frequencies through the amplifier and driver stages.

To obtain horizontal deflection negative horizontal driving pulses are applied to one grid of V-18. These are amplified, inverted, and applied to the grid of the other half of V-18, a trapezoid generator. Between pulses C-32 charges toward the plate supply voltage, and is discharged

during the pulses through the low impedance of the tube and R-126. The horizontal sweep amplitude is varied by means of the "WIDTH" control, R-92, which changes the slope of the rising portion of the trapezoid.

The trapezoid is applied through the driver tube, V-17, and transformer, T-11, to the horizontal deflection coils. When the retrace interval commences, the horizontal deflection coil charges up its shunt capacitance, which then discharges back through the deflection coil and commences to charge the shunt capacitance in the opposite direction. At this point another trapezoidal voltage is applied across T-11. The damper tube, V-16, is cut on, and the oscillation in the deflection coil and its shunt capacitance is damped through V-16. The signal on the grid of the damper tube is a partially differentiated sawtooth whose shape can be varied by adjustment of "LINEARITY CONTROL", R-128, to control the rate of damping current through the tube. The bias is varied by "LINEARITY CONTROL", R-102, to vary the amount of damping current through the tube. The current through the horizontal deflection coils actually reverses in direction during the sweep.

A fraction of the voltage across the horizontal deflection coils is taken from the junction of R-119 and R-120 to blank the monoscope grid during retrace time. "CENTERING" controls are provided in both sweep circuits which determine the amount of direct current through the deflection coils.

The video amplifier consists of seven stages of signal amplification and also includes provisions for clamping and the addition of mixed blanking to the signal which can be

clipped at the desired level. The amplifiers utilize combined shunt and series compensation giving a response that is fairly uniform from about 30 c.p.s. to 8 megacycles. The overall gain of the video amplifier is about 1000.

The signal plate of the monoscope is connected to the grid of the first amplifier tube, V-1, through a compensating network composed of coil, T-1, and resistors, R-3 and R-4. A similar network is included in the plate circuit of each additional video amplifier tube. Overall gain is controlled by potentiometer, R-7, which varies the screen voltage of V-1. There is also provision for remote gain control in the form of a shunt resistance, R-105, from the screen of V-1 to the number 5 pin of the chassis connector, J-1. A 0.1 megohm variable resistance connected between this point and ground serves as the remote gain control.

A clamping circuit follows the second stage of video amplification. The purpose of clamping is to establish a set or fixed voltage which will represent the black level for the signal. The level must be the same for all lines delivered by the pattern generator. This is accomplished by bringing the signal to the same potential during each blanking period. Thus all values of light must then be represented by various signal levels, extending in only one direction from the black level.

Figure 15(a) shows a signal which, for the first few lines, is all black and consists of only the sync pulses which extend beyond the black level. At time t_1 the signal goes to all white and remains there except as it is inter-

Figure 15(a)-DC component present

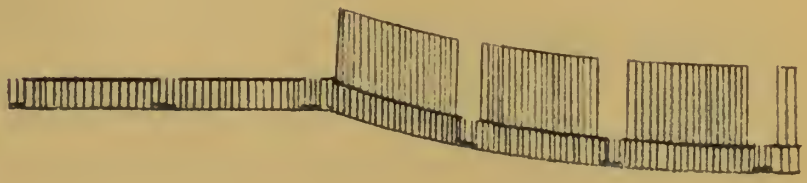


Figure 15(b)-DC component lost

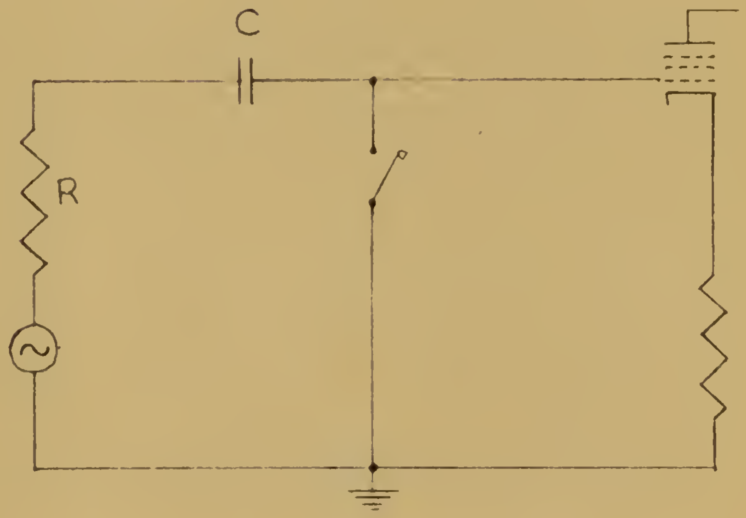


Figure 16-Idealized keyed clamp circuit

rupted by the horizontal and vertical blanking pulses. If the signal were passed through a capacitor and the dc component lost, it would appear as in Figure 15(b). The white has slipped to dark gray, and the black is far beyond the true black level.

Besides establishing the black level, clampers perform another function. Since the amplifiers preceding the clamp attenuate the low frequencies by coupling with small capacitors, troubles from hum and low frequency noise are minimized. The dc restoration will insure that each field contains the same amount of light or average voltage. This amounts to the reinsertion of low frequencies above 30 cycles per second.

Figure 16 shows an idealized equivalent of a keyed dc restorer. The key is closed for a small portion of the blanking interval. When the key is closed the output voltage goes to ground. A charging or discharging current flows through C, limited only by R. C is small enough so that before the key is opened, it becomes completely charged, and current through it has dropped to practically zero. C now possesses a charge representing the difference between the signal voltage and ground. After the key is opened the charge cannot change since no path exists for current to flow. The signal is transmitted through C as if it were infinite in size. When the keying interval again returns, the signal may be at an incorrect level, but the key, when closed, will force the output to the correct level, and the charge will be changed to agree with the new difference between the input voltage and the correct output voltage. If the level, however, needed no changing no current would flow into or out of C. The

keyed circuit thus restores the dc component by holding the black level at a fixed voltage during the blanking interval which may be considered the dc axis. The signal extends always in one direction from this axis.

The actual clamp circuit of the monoscope camera as shown in the schematic diagram, Figure 13, consists of a twin diode, V-9, both halves of which are driven into conduction by push-pull pulses, one set of pulses being horizontal driving pulses, and the other set being inverted horizontal driving pulses. The latter are obtained from across part of the load of the horizontal pulse amplifier in the horizontal deflection circuit. The two sets of pulses are essentially equal in magnitude. The two halves of V-9, are driven through capacitors C-2 and C-34. The time constants (C-2)(R-113+R-112) and (C-34)(R-111) are long compared to the pulse duration, and therefore these capacitors do not charge up appreciably. When both halves of V-9 are driven into conduction the plate side of R-113 and the cathode side of R-111 rise and fall by the same amount. C-8 charges or discharges quickly due to a small time constant, and the grid of the following amplifier, V-6, is brought to ground potential.

A negative bias voltage of about 1/2 volt for the two preceeding stages is taken from the junction of R-112 and R-113. Following the clamper there are two more stages of amplification before mixed blanking is added to the video signal. In the grid circuit of the first of these two amplifiers, V-6, there is a switch, S-2, which makes it pos-

sible to remove the partially amplified output of the monoscope tube, and insert a test signal, such as a square wave, for checking the response of the remainder of the video system.

The blanking pulses are combined with the video signal in the plate circuit of V-2. Blanking pulses from the sync generator are amplified and inverted by V-7. The pulses are then combined with the video signal across the load resistor, R-32, common to V-2 and V-7. The blanking pulses extend in the positive direction at this point as does the black level of the video signal. They are added to the signal at the positions corresponding to monoscope blanking.

After another stage of amplification in V-3, the signal is fed to the grid of a clipper tube, V-4. The signal has black in the negative direction and is clipped to the desired level by adjustment of the "BRIGHTNESS" control, R-55. This control is a potentiometer in the high voltage power supply bleeder network. It is used to adjust the negative voltage on the grid of V-4, and hence determines where the tube will cut off. If the negative bias is set high, then the image will become darker because the negative blanking voltage will drive the tube into cut-off rather quickly. This effectively decreases the voltage variation between bright and dark and hence brings the brighter portions of the image closer to the black level. It is the blanking level which determines the black or reference level.

The output of V-4 is coupled to the parallel grids of V-8 and V-10. These two output tubes are provided so that

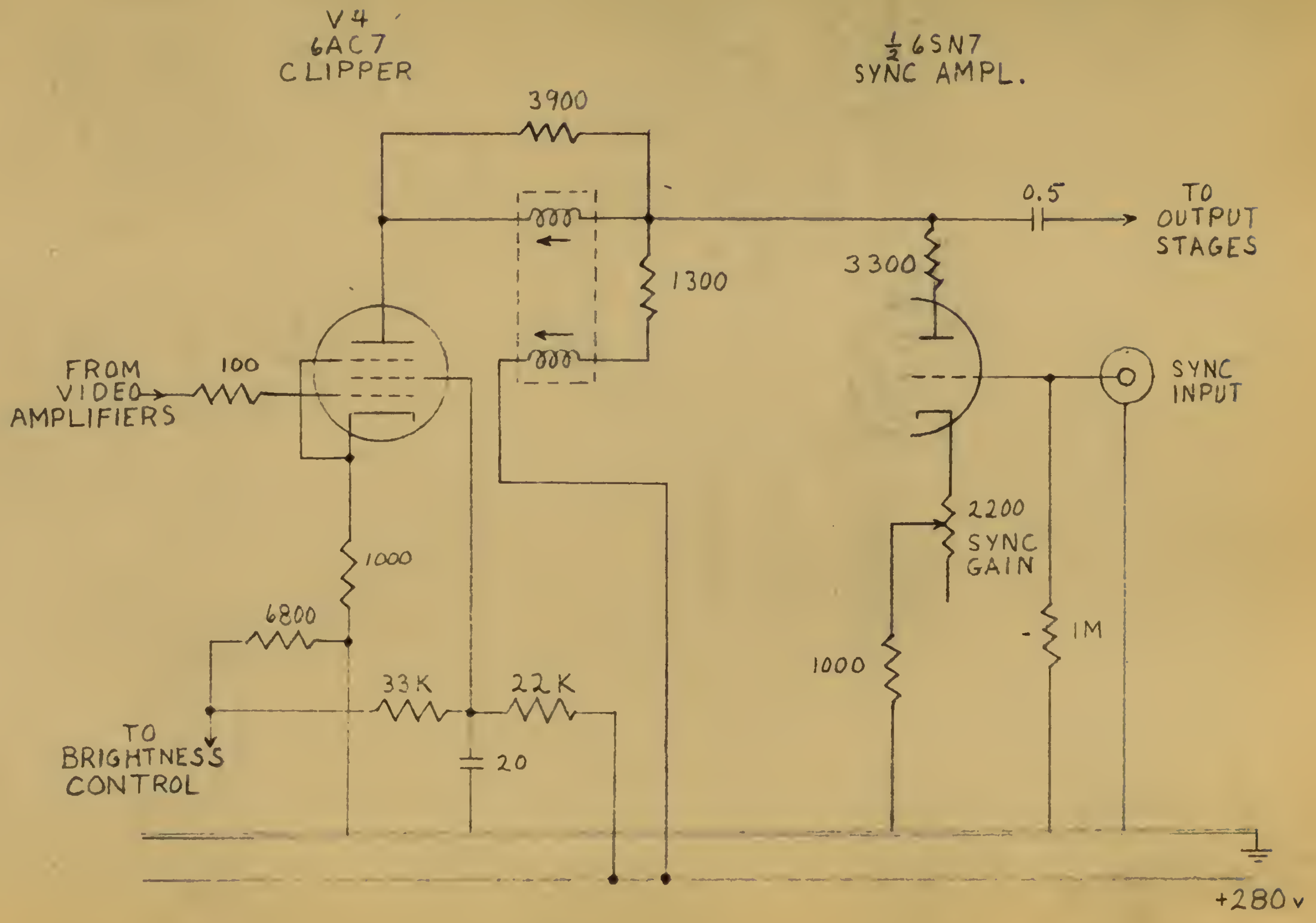


Figure 17-Method of adding synchronizing pulses to RCA TK-1A monoscope camera

the picture signal may be viewed on a monitor while the output is being fed to the equipment being checked or to the modulator of a transmitter.

It is necessary to use standard synchronizing pulses in conjunction with the output of the RCA TK-1A monoscope camera in order to synchronize the sweeps of the receiver or monitor on which the pattern appears. If the output of the monoscope is to be transmitted then the synchronizing information must be added to the video signal. Some manufacturers cause the synchronizing information to be added in the monoscope camera itself.

Synchronizing information could be added to the output of the RCA TK-1A monoscope camera by the addition of ½6SN7 tube as illustrated in Figure 17. Negative synchronizing pulses are amplified and inverted by the sync amplifier. Through use of a common load with the clipper stage synchronizing information is added to the video information. The potentiometer in the cathode circuit of the sync amplifier is a "SYNC GAIN" control.

2. Flying-spot scanner.

A flying-spot scanner uses a similar system of power supplies, sweep circuits, and video amplifiers. RCA is planning to demonstrate a flying-spot scanner in the near future. Although not completed at this writing, enough information is available to discuss how a flying-spot signal generator differs from a monoscope camera. Similar power supplies and sweep circuits can be used. The d.c. power supplies for the

5WP15 tube should consist of 20 kilovolts for recommended anode 2 supply, and a negative supply of about 100 volts, depending on equipment design, for grid 1. Voltage for anode 1 is obtained by tapping from a bleeder resistance across the 20 kilovolts supply. The high voltage for the multiplier phototube can also be obtained from a tap on the bleeder resistance. The only fundamental differences are in the video amplifier of the flying-spot scanner.

In describing the 5WP15 flying-spot scanner it was mentioned that an equalizing network would be necessary to compensate for the short delay characteristics of the P15 phosphor. This equalizing network would be complex if the entire radiation of the tube were used. By making use of only the ultraviolet radiation, however, the equalization can be supplied by only one network.

When a transition from black to white is scanned, the spot in time has an exponential shape and a changing position. Since the buildup of the spot intensity is practically instantaneous, when the spot moves from behind a mask into an opening, at first only the light from the spot being hit by electrons strikes the phototube. An instant later, as the spot moves farther into the opening, the light from the spot being hit by the electrons has the light from the spots which had been hit a short time before added to it, since they are still emitting some light. The light input to the phototube is therefore proportional to the integral of the light-decay characteristic. Since the decay curve is an exponential func-

tion, its integral is also exponential. As the scanning spot moves from white to black, the light falling on the phototube decreases exponentially. That is, both the rise and fall signals follow the same law.

Figure 18(a) shows how a signal would appear as a result of scanning a white bar on a black background without equalization. The voltage is zero up until time t_1. At t_1 when the beam reaches the white bar the voltage waveform becomes $E(1-e^{-\frac{t-t_1}{0.05}})$ where E is the ultimate value for white, t is measured in microseconds, and 0.05 microseconds is the time constant of decay for the ultraviolet radiation from the P15 phosphor. At time t_2, when the beam again reaches the black, the voltage wave form becomes $Ee^{-\frac{t-t_2}{0.05}}$, or the complete expression for the voltage is:

$$e(t) = E\left[\left(1-e^{-\frac{t-t_1}{0.05}}\right)u(t-t_1) - \left(1-e^{-\frac{t-t_2}{0.05}}\right)u(t-t_2)\right]$$

If now an equalizing network is made up as shown in Figure 18(c), where RC equals the time constant of decay of the ultraviolet radiation = 0.05 microseconds, and r is made considerably smaller than R, it will be shown that the output $e_0(t)$ is very nearly a squarewave when the voltage $e(t)$ of figure 17(a) is the input.

Using Laplace transforms:

$$E(s) = \mathcal{L}[e(t)] = E\left[e^{-t_1 s}\left(\frac{1}{s} - \frac{1}{s+\frac{1}{0.05}}\right) - e^{-t_2 s}\left(\frac{1}{s} - \frac{1}{s+\frac{1}{0.05}}\right)\right]$$

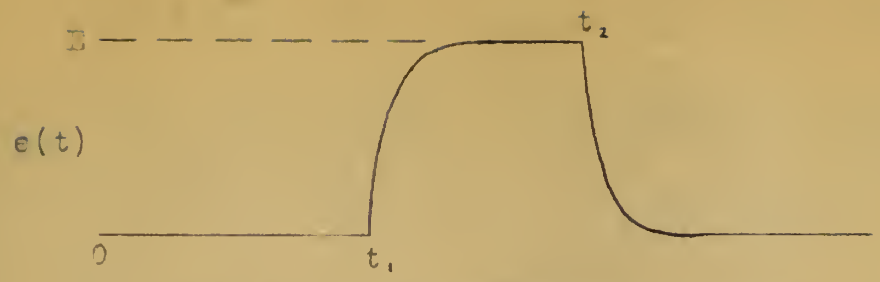


Figure 18(a)-Unequalized waveform

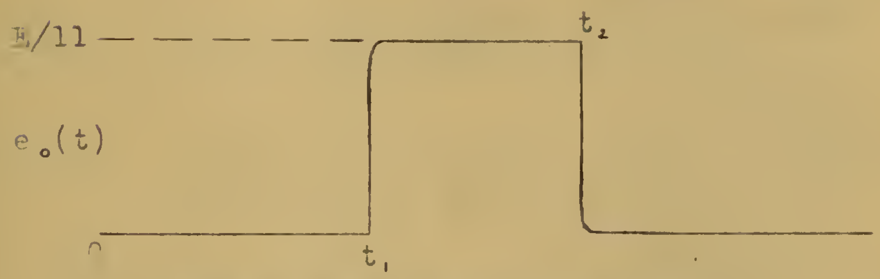


Figure 18(b)-Equalized waveform

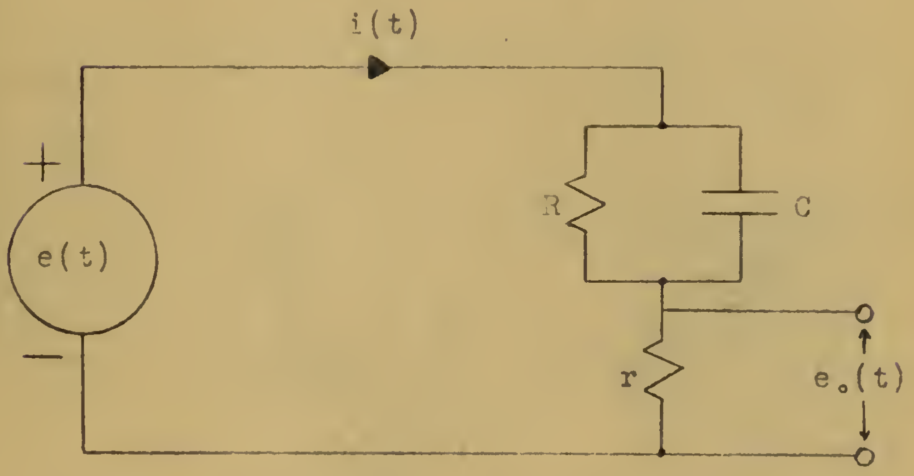


Figure 18(c)-Equalizing network

$$Z(s) = \mathcal{L}\left[\frac{\frac{R}{j\omega C}}{R+\frac{1}{j\omega C}} + r\right] = \frac{R}{RCs+1} + r = \frac{r+R+rRCs}{RCs+1} = \frac{r\left(s+\frac{r+R}{rRC}\right)}{s+\frac{1}{RC}}$$

$$E_o(s) = \mathcal{L}[e_o(t)] = \frac{rE(s)}{Z(s)} = \frac{rE\left[\frac{\frac{1}{0.05}e^{-t_1 s}}{s(s+\frac{1}{0.05})} - \frac{\frac{1}{0.05}e^{-t_2 s}}{s(s+\frac{1}{0.05})}\right]}{\frac{r\left(s+\frac{r+R}{rRC}\right)}{s+\frac{1}{RC}}}$$

$$= \frac{E}{0.05}\left[\frac{e^{-t_1 s}}{s\left(s+\frac{r+R}{rRC}\right)} - \frac{e^{-t_2 s}}{s\left(s+\frac{r+R}{rRC}\right)}\right], \quad \text{since } \frac{1}{RC} = \frac{1}{0.05}$$

$$e_o(t) = \mathcal{L}^{-1}[E_o(s)] = \frac{E}{0.05}\left\{\left[\frac{rRC}{r+R} - \frac{rRC}{r+R}\, e^{-\left(\frac{r+R}{rRC}\right)(t-t_1)}\right][u(t-t_1)]\right.$$

$$\left. - \left[\frac{rRC}{r+R} - \frac{rRC}{r+R}\, e^{-\left(\frac{r+R}{rRC}\right)(t-t_2)}\right][u(t-t_2)]\right\}$$

$$= \frac{Er}{r+R}\left\{\left[1-e^{-\delta(t-t_1)}\right][u(t-t_1)] - \left[1-e^{-\delta(t-t_2)}\right][u(t-t_2)]\right\}$$

$$\text{where} \quad \delta = \frac{r+R}{rRC}$$

If r is made considerably smaller than R then $e_o(t)$ is nearly a square wave. For instance, if

$$C = 10\,\mu\mu f \qquad R = 5000\,\Omega \qquad r = 500\,\Omega$$

$$\text{then} \quad \delta = \frac{500+5000}{(500)(5000)(10\times10^{-12})} = \frac{11\times10^{6}}{0.05\ \text{sec.}} = \frac{11}{0.05\,\mu s}$$

$$\text{and} \quad e_o(t) = \frac{E}{11}\left\{\left[1-e^{-\frac{11(t-t_1)}{0.05}}\right][u(t-t_1)] - \left[1-e^{-\frac{11(t-t_2)}{0.05}}\right][u(t-t_2)]\right\}$$

A plot of this voltage is drawn in Figure 18(b) to the same time scale as for e(t). It can be seen that at the expense of an attenuation of 11 to 1, that the time constant

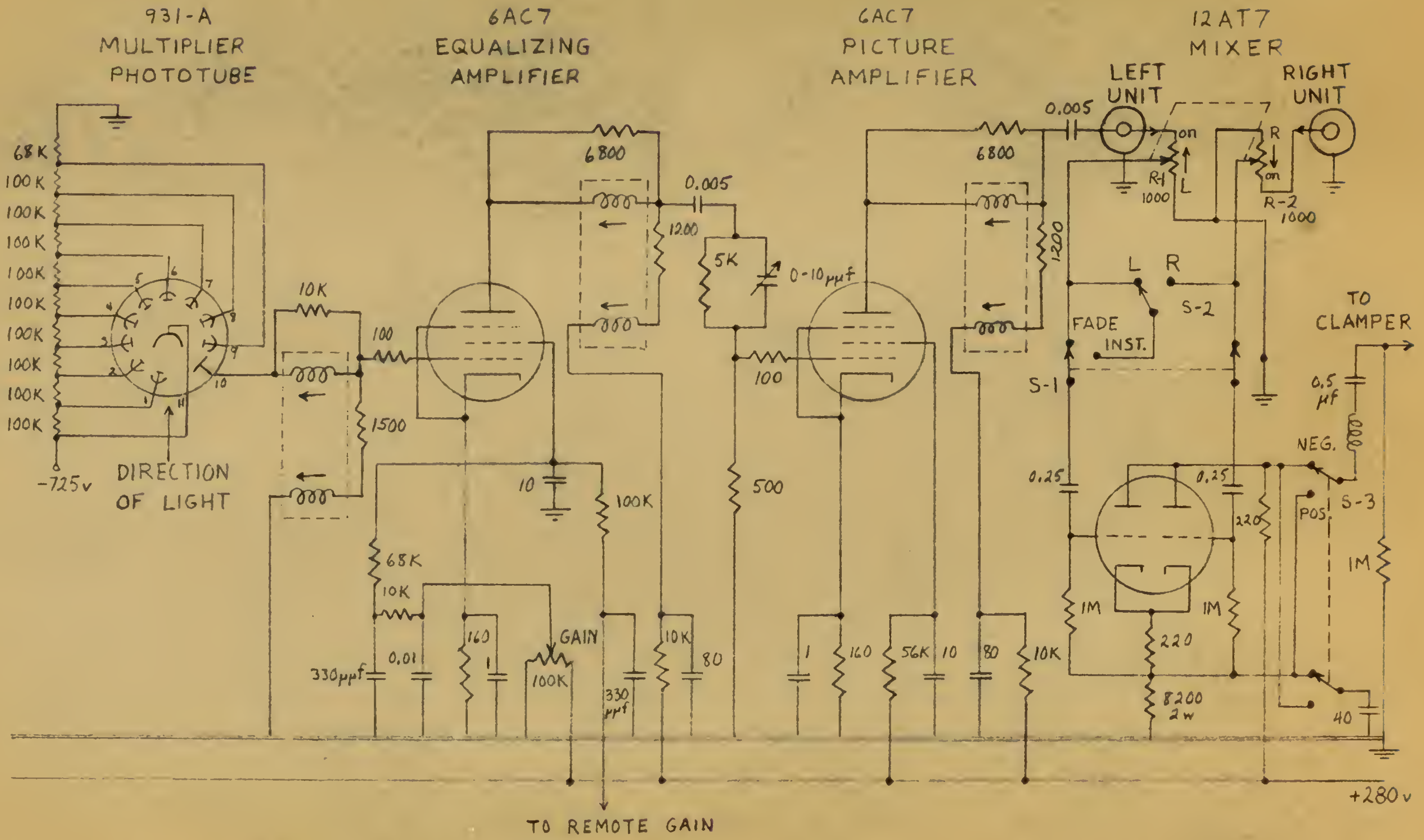


Figure 19-Schematic diagram of an equalizing amplifier and video mixer

of the response to a square wave of the flying-spot scanner has been reduced by the same factor.

Figure 19 is a schematic diagram of an equalizing amplifier using the above method of equalization. The ultraviolet light from the flying-spot tube is focused on the cathode of a 931-A multiplier phototube. The cathode is connected to a regulated supply of -725 volts, and each successive dinode is approximately 75 volts more positive. The anode is approximately 50 volts more positive than dinode 9. The output of the multiplier phototube feeds the equalizing amplifier through a compensating network. Equalization is accomplished by the method of coupling to the following amplifier. There are "GAIN" and "REMOTE GAIN" controls in the equalizing amplifier identical to those in the RCA TK-1A monoscope camera.

Also shown in Figure 19 is a 12AT7 video mixer. This circuit will be included in the RCA flying-spot scanner. By focusing the light output of a flying-spot tube on the edge of a mirror that is formed from two mutually perpendicular surfaces, the light output of the flying-spot tube can be split, half of it going to one phototube and half to another. With such an arrangement a studio can fade or switch from one slide to another. Shown in the diagram is one of the phototube multipliers with its associated amplifiers. Referring to this as the "left unit" there are also provisions for inserting a "right unit". By means of the potentiometers, R-1 and R-2, on a common shaft a fade can be made from one unit to the other, or one picture can be superimposed on another. The left half of the mixer tube passes the video signal from

the left unit and the right half passes the picture from the right unit. If it is desired to change from one picture to another without fading then switch, S-1, is switched from the "FADE" position to the "INSTANTANEOUS" position. By use of switch, S-2, the signal from either unit can be selected. In the "INSTANTANEOUS" position the left half of the mixer tube is used for both units. At the output of the mixer there is a switch, S-3, for selecting either polarity depending on whether the picture is a positive or a negative.

The circuits shown in Figure 19 can be substituted for the monoscope tube and its first two amplifiers, V-1 and V-5, in the RCA TK-1A monoscope camera. The output of the mixer will then feed into the clamper tube, V-9.

There will be an additional type of amplifier in the RCA flying-spot scanner that does not generally appear in monoscopes although it well could. In order to obtain maximum fidelity of shade reproduction, the light output of a television receiver should be directly proportional to the light input to the photosensitive device. That is, the "gamma" should be unity. In the flying-spot pickup, the voltage output is directly proportional to the light input. Since the beam current of a flying-spot tube is unmodulated, there is no opportunity for the introduction of amplitude distortion in the output of the tube. Nor is there amplitude distortion in the output of the multiplier phototube, since it is characteristically a linear device. Therefore if linear amplifiers are used, the output voltage of the flying-spot video-signal generator will have voltages pro-

portional to light input.

A kinescope, however, is not linear, since it requires more volts to give the same change in light output at low light levels than at high light levels. Figure 20(a) shows the light output plotted against signal input for a typical kinescope, the 16AP4. If a nonlinear amplifier is provided in the flying-spot video-signal generator with the reciprocal of the kinescope characteristic, then the relation between input and output light will be linear. Such an amplifier is called a gamma-correction amplifier.

Figure 21 is an example of a gamma-correction amplifier. It is being used by RCA in their flying-spot scanner. The input to the two grids of the 12AU7 from a clipper stage is a video signal with black positive. The various crystal diodes, D-1, D-2, D-3, and D-4 are biased to different voltages by their associated potentiometers. For small signals (white level) the only conduction path to the grid of the following amplifier is through the 11K resistor R-1. For a slightly larger signal let us assume the bias on D-1 is such that it will conduct. An additional current path is thus provided to the grid of the following stage. As the input signal gets larger or approaches the black level more current paths are opened and the signal on the grid of the following stage has been amplified more strongly. The cutoff biases of the crystal diodes are independently controlled so that the gamma-correction characteristic may be set as desired. A typical plot of amplification for this stage is shown in Figure 20(b).

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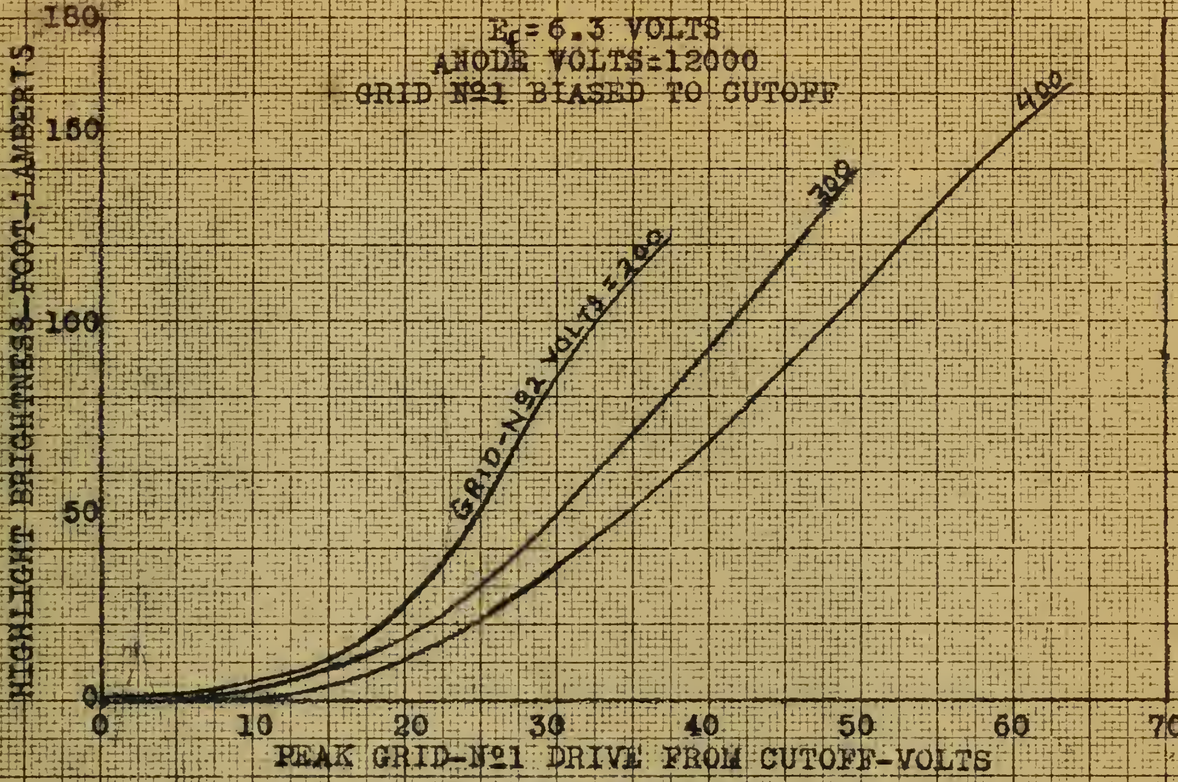

Figure 20(a)
Average grid-drive characteristics of type 16AP4 kinescope

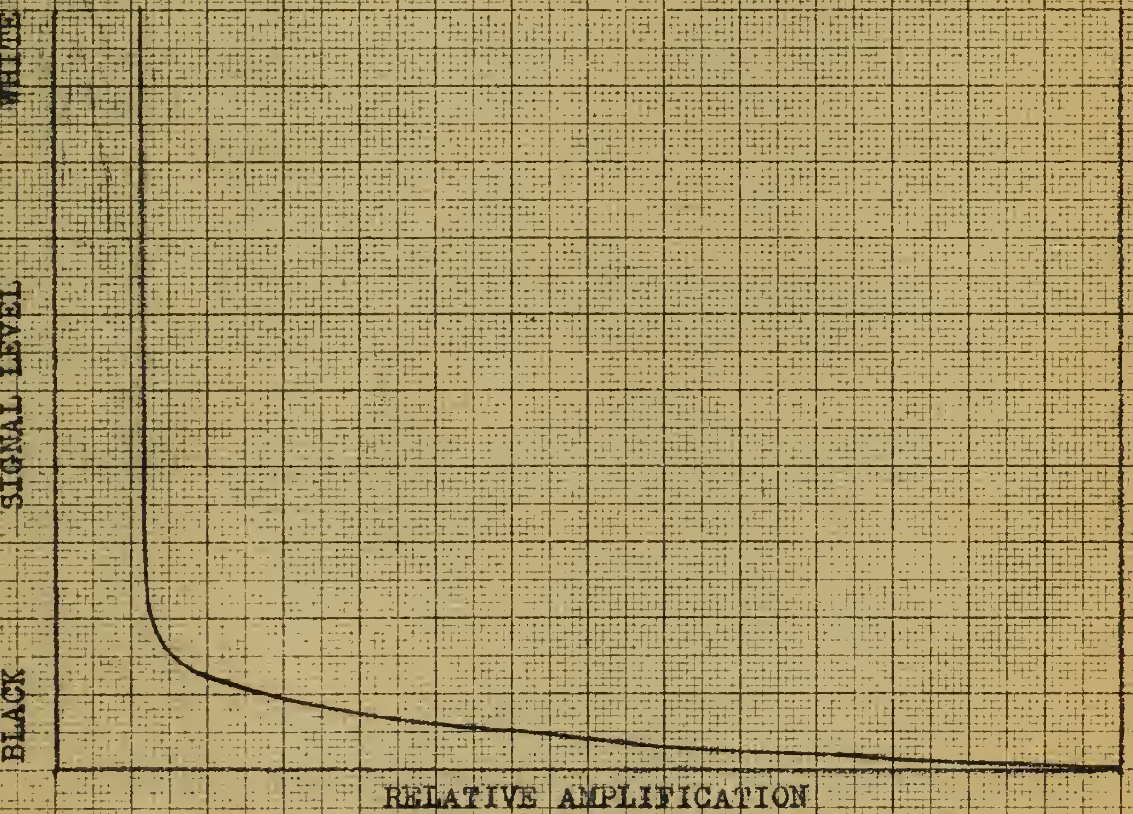

Figure 20(b)
A typical amplitude response of a gamma-correction amplifier

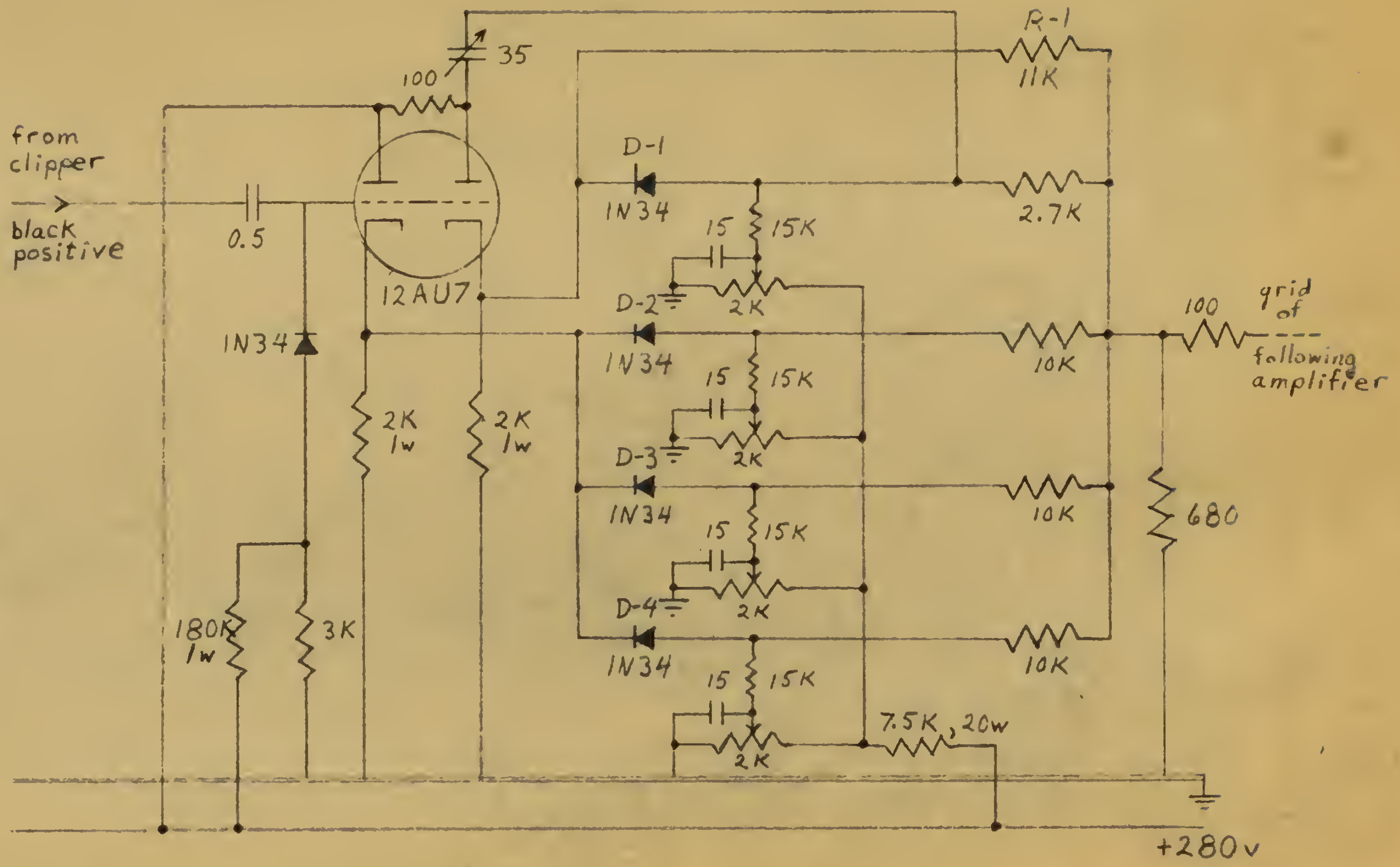

Figure 21- Schematic diagram of a gamma-correction amplifier

It is important that the signal-to-noise ratio in the black region be very good, as it is in the flying-spot scanner, in order for this type of amplification to be practicable since the signal voltages corresponding to the dark regions are amplified more than the voltages corresponding to the white regions.

This amplifier could be inserted in the video amplifier of the TK-1A monoscope camera between V-4 and the two output tubes. It can be used with either the monoscope or the flying-spot scanner. Due to the poorer signal-to-noise outputs of image orthicons and iconoscopes it has not been used in conjunction with them to any great extent.

3. Image orthicon and iconoscope cameras.

Image orthicon and iconoscope cameras are very similar to monoscope cameras and flying-spot signal generators, differing mostly only in the method of pick-up. Due to the peculiarities of the iconoscope tube, an iconoscope camera requires modifications to its sweep circuits and a type of compensation in the video signal known as shading.

Because the mosaic of an iconoscope is scanned on the same side that the light enters, the scanning beam is tilted at a 30 degree angle. This necessitates "keystone" or vertical sweep modulation of the horizontal sweep and distortion of the vertical sweep in order to get a resultant sweep of the mosaic that is linear. Also, due to uneveness in the secondary emitting properties of the mosaic surface, and due to uneveness in the attracting fields adjacent to this sur-

face, secondary electrons fall on the mosaic in an uneven shower. A variation in charge distribution results over the mosaic which gives rise to uneven picture signal components known as "dark spot". Shading signals must be inserted in the video amplifier and adjusted on a trial-and-error basis to give a uniform picture output when a uniform distribution of light falls on the mosaic.

CHAPTER IV

COMPARISON OF METHODS OF PATTERN GENERATION

The monoscope camera and the flying-spot scanner are capable of producing test patterns of the highest quality. Both methods have an excellent signal-to-noise ratio, and both are able to produce resolutions of about 500 lines. Image orthicon cameras are inferior in that they have a lower signal-to-noise ratio while iconoscope cameras have poorer resolution. In addition neither tube is as capable of reproducing half-tones as faithfully as a monoscope or flying-spot tube.

The monoscope camera provides the simplest method of pattern generation. Once set up it requires little upkeep and few adjustments. The same video signal can be obtained from day to day, and the quality is not affected by such variables as poor optical focus, dark spot, and amplifier noise. In addition it is reasonably small and light and can be moved about. It is the ideal equipment for factory or studio testing. The flying-spot scanner can be equally adapted to testing, but is more complicated and expensive than a monoscope camera. The optical system of the flying-spot scanner requires that it be kept free from vibration and shock, and that the focus of the lens system be carefully adjusted.

There are several factors that limit the use of image orthicons and iconoscopes for testing. Primarily there is the item of expense. The life of an image orthicon varies

from 200 to 500 hours, and a tube costs about $1400. The life of an iconoscope varies from 500 to 2000 hours and a tube costs about $500. Monoscopes, however, have a life of about 10,000 hours and cost about $100. A flying-spot pick up tube has the short life of an image orthicon, but only costs about $70 to replace.

There is also the objection that a still picture focused on the photocathode of an image orthicon for just a few minutes will burn in an image of the picture. This objection entirely eliminates the image orthicon for lengthy testing. An iconoscope is capable of generating a fairly high quality picture, but it requires very careful alignment and compensation.

The flying-spot scanner is the most versatile of all the pattern generators in presenting still pictures. The monoscope camera is necessarily confined almost exclusively to the generation of a test pattern since it would require a separate tube for every different picture. Slides can be changed at will in the flying-spot scanner so that the unit may be used to air a station's test pattern when no programs are being televised, and then used during the programs to televise any still pictures such as advertisements. Mention was made that the flying-spot scanner could be used with opaque pictures and moving picture film. The use of opaques, however, requires excellent technique and is not yet commercially feasable. A special projector is required for moving picture film, and to date the flying-spot scanner has not been used for this purpose.

Ultimately, it seems quite likely that the image orthicon camera will be used exclusively for televising action, in the studio and outside, the flying-spot scanner will be used for televising motion pictures and stills, and the monoscope will be confined to factory testing and possibly generation of a television station's test pattern.

BIBLIOGRAPHY

1. Bauer, J.A. Television receiver production test equipment. Communications. 27:8-11, September 1947.

2. Bedford, A.V. Figure of merit for television performance. R.C.A. Review. 3:36-44, July 1938.

3. Bertero, E.P. Video announcer. R.C.A. Review. 10:304-309, June 1949.

4. Burnett, C.E. The monoscope. R.C.A. Review. 2:414-420, April 1938.

5. Committee on Television Transmitters. RMA resolution chart 1946. RMA Bulletin ED-2502-A, September 1947.

6. Duke, V.J. A method and equipment for checking television scanning linearity. R.C.A. Review. 6:190-201, October 1941.

7. Kiver, M.S. Television production line testing-part II. Radio-electronic engineering. 12:6-9, January 1949.

8. Kiver, M.S. Television production line testing-part III. Radio-electronic engineering. 12:16-21, February 1949.

9. Radio Corporation of America. Grating generator type WA-3A instructions. Camden, New Jersey, Engineering Products Department.

10. Radio Corporation of America. Monoscope camera Type TK-1A instructions. Camden, New Jersey, Engineering Products Department, 1948.

11. Radio Corporation of America. 5WP15 tentative data. Harrison, New Jersey, Tube Department, 1948.

12. Sziklai, G.C.; Ballard, R.C.; and Schroeder, A.C. An experimental simultaneous color-television system-part II. Proc. I.R.E. 35:862-870, September 1947.

13. Terman, F.E. Radio engineering. New York, McGraw-Hill, 1947.

14. Wendt, K.R. Television dc component. R.C.A. Review. 9:85-111, March 1948.

15. Zeluff, V. Tubes at work. Electronics. 21:124-126, June 1948.