THE CONSTRUCTION AND ANALYSIS OF A MONOSCOPE CAMERA

by

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INTRODUCTION

The past decade has witnessed the evolution of television from the research laboratory to a proved medium of visual communication. This evolution has been achieved through the combined efforts of scientists and engineers, whose objective has been the realization of television's full possibilities. To accomplish this objective, and to facilitate the advancement of the art, the development of test equipment for television devices and circuits arose as a logical and necessary undertaking. Accordingly television test equipment has been designed to satisfy the various needs of the industry.

One such piece of test equipment is the monoscope camera, a static-image signal-generator. It is the purpose of this camera to produce a fixed picture and blanking signal output, which may be combined with synchronizing pulses to provide a composite video signal. This composite signal conforms to R. M. A. standards.[1] The monoscope camera is, therefore, a complete television camera which may be used interchangably, in a standard television system, with the studio cameras.

The monoscope was designed primarily for the purpose of aligning and checking television equipment such as receivers, transmitters, monitors or other associated circuits. The picture signal from the camera makes it possible to observe contrast, system resolution and to detect nonlinearily in the deflections circuits. It excels the iconoscope for this

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[1] Radio Manufacturers Associations

this purpose since it is inexpensive to manufacture and requires no auxiliary source of lighting. The signal is exceptionally strong, equal to 10 times that obtained by a conventional iconoscope with 1 foot candle of plate illumination.

It is apparent that the decision to construct a monoscope camera was well justified. The construction of this camera has been completed, and it is now installed as an integral unit of WØXBV's television system. This paper presents, therefore, the construction and design considerations of the camera and a theoretical analysis of the monoscope tube and the circuits fundamental to its operation.

THE MONOSCOPE TUBE

General Description

The monoscope is a special type of cathode ray tube resembling the iconoscope in general principle, but differing in that the video signal is derived from a printed pattern electrode enclosed within the tube. Accordingly, it cannot be classified as a pick up tube since it is unable to develop a video signal which represents action, but is necessarily restricted to one particular still picture or pattern. The limitations of such a tube are apparent, and if a comparison of the monoscope and the iconoscope is to be made, then their characteristics should be evaluated in the light of the purpose for which the monoscope was intended. This, primarily, is the testing of television system performance, and the ability of the monoscope to generate a strong video signal, rich in harmonic content, that

is dependent of light conditions and free of spurious signals, is identically commensurable with its purpose as a piece of test equipment.

There are in general two basic types of static-image signal-generating tubes. The first of these employs a change in primary beam current to develop an output signal. Briefly this type of tube has a signal plate of some designed configuration cut from a conducting surface. When the plate is scanned, a signal current is obtained each time the beam strikes the plate. As a result this video signal will produce a picture of the plate when applied to the grid of a kinescope.

The second class of tube can be made in a number of workable combinations: In general, two materials having different secondary emission ratios are used to make the signal plate. As the plate is scanned, one magnitude of secondary emission current is obtained from one material and another magnitude is obtained from the second. The difference in the magnitudes of those secondary emission currents determine the amount of video signal. Therefore, if two materials which have a numerical difference in secondary emission ratios greater than one are used, it is possible to develop more video current than would be possible if only the primary current of the beam were utilized. Because of this advantage, a number of combinations of two materials having different secondary emission ratios were investigated by the tube manufactures. The end result was a technique of preparing signal plates which permitted the accurate reproduction of all types of subject material (2).

Physical Characteristics

The static-image signal-generating tube employed in the
monoscope camera is an RCA type 2F21. It has an overall length
of 13 inches, a maximum bulb diameter of 5 inches and a phys-
ical appearance characteristic of magnetic deflection type cath-
ode ray tubes. The base is a long-shell medium six-pin base
that fits a standard six contact socket. The electron gun con-
nections are made to the base, while the collector and pattern
leads are brought out two recessed small ball caps. The pattern
electrode cap is located at the center of the face of the tube
and the collector cap on the side of the bulb near the neck of
the tube. The entire tube, except for a small portion near the
base, is coated externally with an insulating moisture-repellent
coating, which serves to prevent condensation of water vapor in
a conductive film over the glass surface. Erratic surface
sparking, which may be produced by such a film when a high volt-
age gradient is present, is thus eliminated.

Design Considerations

Internally the 2F21 consists of an electron gun, a pattern
electrode and a collector. These are shown diagrammatically in
Plate I. The electron gun, which produces, accelerates and
focuses the electron beam, must be of high quality if the best
video signal is to be obtained. In particular, the gun structure
must have been designed electrically and mechanically to be com-
mensurable with two objectives. The first of these would

be that of producing the maximum output signal. Since the output signal is a function of the secondary emission current, the potential of the pattern electrode and the magnitude of the beam current are important factors. The second objective is to secure a beam whose diameter does not limit the resolution of the system.

It is of interest to investigate the particular choice of beam current and final accelerating voltage employed in the monoscope tube, since it is essentially these values that will determine the resolution and strength of the video signal fed to the video amplifiers. The final accelerating voltage, which is the potential of the target plate with respect to the cathode, is given by the manufacturer to be 800 volts. The choice of this particular value may be justified by realizing that the accelerating voltage employed should be consistant with two primary objectives. The first of these is that of obtaining the maximum coefficient of secondary emission for the white or aluminum portion of the target, and a minimum secondary emission coefficient for the black or carbon portion of the picture. Here a good approximation is that the secondary emission coefficient for a given surface is a function only of the primary electron energy and thus of the accelerating potential. The actual secondary emission current will be to some extent dependent upon space charge effects, the angle of incidence of the primary electrons, residual gas in the bombarded material, and possibly temperature, but these effects are negligible (7). Curves representing the desired relationship are plotted in Plate I for carbon and for a typical composite oxidized layer

EXPLANATION OF PLATE I

Fig. 1. Simplified schematic of the monoscope tube

Fig. 2. Secondary emission characteristics of the materials
comprising the signal plate (13)

PLATE I

ELECTRON GUN

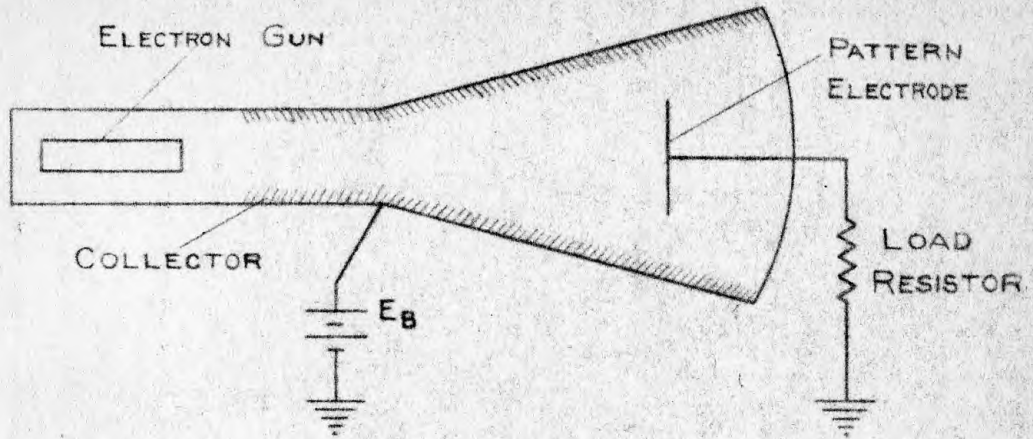PATTERN ELECTRODE

COLLECTOR

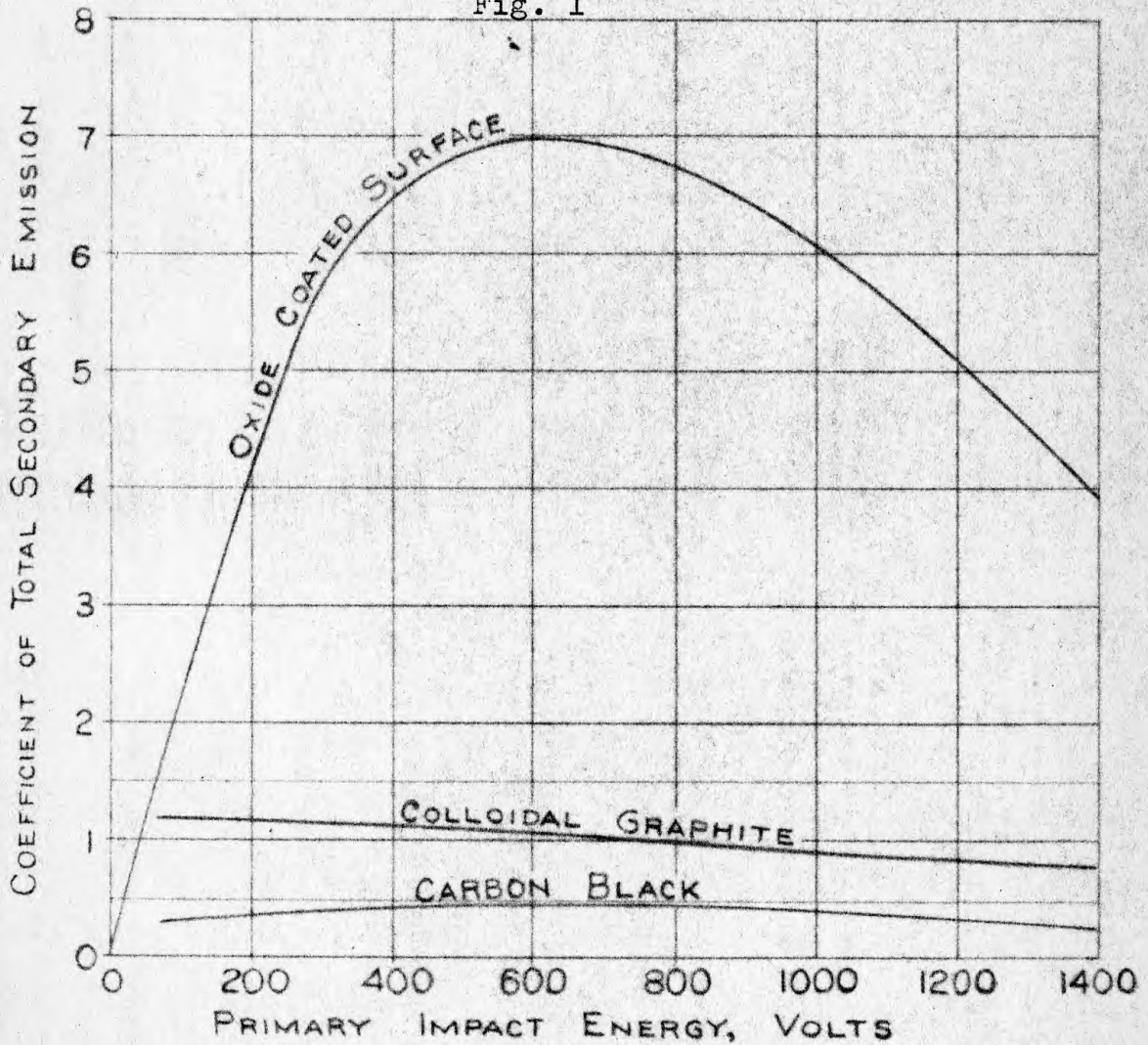E_B

LOAD RESISTOR

Fig. 1

Fig. 2

(13). Since the secondary emission coefficient for carbon is practically independent of the primary electron energy, the accelerating potential should be chosen so as to correspond with that value which will give the maximum secondary emission coefficient for the alumminum oxidized layer. This maximum occurs at potentials in the vicinity of 600 volts.

The potential of the pattern electrode also influences the resolution of the camera in that it is instrumental in determining the diameter of the electron beam. Accordingly this potential must be chosen to be consistant with a resolution exceeding 525 lines. This in itself is analogous to the problem of predicting the change in beam diameter with a change in accelerating potential. The answer to this seems to be provided in some earlier papers and in the well-known textbooks by Zworykin and Morton (14). The general opinion expressed seems to be that the spot size should decrease in proportion to the square root of the increase in the accelerating voltage of the electron beam, all other conditions being held constant. Thus the formula

$$r^2 E_a = \text{constant}$$

Where: r is the radius of the electron beam

E_a is the accelerating potential

This theoretical prediction, however, does not agree at all with the change of spot size actually observed; the experimentally found change of spot size with a change of accelerating voltage is very much smaller than required by this theory. A rather thorough investigation of this subject was undertaken

by G. Liebmann, and it is of interest to note the result of his [1]
work since it provides an answer to the foregoing question.
Briefly, Liebmann proposed a new equivalent-optical system con-
sisting of three lenses to represent the electron optical
system. On this basis the conclusion is reached mathematically
that the spot size is an image of the cathode and that its
diameter is not a function of the accelerating voltage. This
prediction was checked experimentally on a number of typical
cathode ray tubes employing both types of deflection. The ex-
perimental results indicated that for accelerating voltages
above 1000 volts, the spot size remains unchanged within the
error of measurement. Below a final accelerating voltage of
1000 volts, the obtainable resolution decreases, although the
decrease is not as great as that predicted by the cross over
theory.

The 2F21 uses accelerating voltages in the vicinity of
1000 volts. From the above arguments it is seen that a de-
crease from this figure, while resulting in a slightly in-
creased secondary emission coefficient for the aluminum oxid-
ized layer, would also produce a decrease in resolution.
Similiarly, higher accelerating voltages would be to no par-
ticular advantage. The definition would not be increased and
the secondary emission coefficient would be adversely effected.

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[1]Liebmann, G., "Image Formation in Cathode Ray Tubes and
the Relation of Spot Size and Final Anode Voltage", Proc.
I.R.E., 33:381, June, 1945.

The magnitude of the beam current is another important consideration and here again a compromise is made. A high beam current is desired since a percentage increase in beam current results in a like percentage increase in signal output. However, the beam current is primarily a function of the control grid voltage. This voltage while determining the magnitude of the current, simultaneously determines the size of the emitting area of the cathode. Since the spot at the pattern electrode is an image of this cathode area, then an increased beam current results in poorer resolution. The size of the beam should not be sacrificed to obtain high beam currents.

As a first appromamation it might well be argued that the signal output from the monoscope tube could be increased by enlarging the area of the pattern electrode. With an increased area, beam diameter could be correspondingly increased without adversly effecting the 525 line resolution. The allowable beam current, which is proportional to the beam diameter, is greater, and the secondary emission current and thus output voltage is also increased. While the above argument is valid, two objections manifest themselves. The first is the well-known defocusing of the beam as the deflection angle is increased. The second is the variation of the secondary emission coefficient for any surface as the angle of incidence of the primary electrons in changed. This effect becomes appreciable at primary impact energies above 100 electron-volts (13), and as such would be evident in the monoscope tube. The degree of this effect is a function of the bombarded material and is

determined experimentally, although an increase in the secondary
emission coefficient for increasing angles of incidence is
characteristic of all substances. For carbon the coefficient
of secondary emission is practically independent of the angle
of incidence, while for aluminum it can be considered constant
if the angle of incidence is not greater than 20 degrees.
At 30 degrees the coefficient of secondary emission has in-
creased to about 16 per cent of its normal incidence value,
and thereafter rises rapidly. If the effective center of
deflection is considered to lie at the mid-point of the coil
yoke, then the maximum angle of incidence in the monoscope
tube is 17 degrees, so that the effect described could be
neglected. However, this variation in the secondary emission
coefficient might well be a limiting factor in increasing
the signal strength by an enlargement of the pattern electrode
area.

The Pattern Electrode

The heart of the monoscope tube is the signal plate or
pattern electrode, as it is sometimes called. The signal
plate is made from aluminum foil and carbon. The surface of
the aluminum has a natural coating of aluminum oxide which has
high secondary emission ratio while the carbon has a relatively
low ratio. Reference to Plate I confirms this and shows the
relative ratios obtainable. Experimentally the manufacturers
found that aluminum foil developed for advertising and packing

purposes as well as special inks developed for printing on metal foils were satisfactory materials for the signal plate. This was extremely fortunate since the advantages and flexibility of commercial printing could be utilized. The desired picture or pattern is printed on a piece of aluminum foil approximately .004 inch thick with a blackfoil ink. The only other process necessary before sealing the signal plate in the tube is to fire it in hydrogen. This process removes the volatile material from the ink and leaves it practically pure carbon (2).

Subject matter for reproduction on a signal plate can be divided into two classes: black and white, and half tones. Cartoons are a good example of the first, while snapshots, which contain tones between black and white, illustrate the half tone group. Photo-engravings are made of the subject matter for printing the signal plate. 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 for which the tube is designed. As a result, 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 actual pattern is printed on the signal plate as a

negative. The pattern is printed as a negative in order to
add to the convenience of the tube's use in testing iconoscope
equipment. The iconoscope has a signal output of negative
polarity. That is, when a picture is transmitted by an icon-
oscope, a highlight in the picture is represented by a negative
value of the iconoscope's signal output voltage. In the monos-
cope, however, a white portion of the pattern is represented by
a positive value of signal output voltage. This is because the
aluminum oxide has a secondary emission ratio greater than car-
bon. In order to make the signal output of the 2F21 correspond
to an iconoscope, the pattern is printed as a negative in the
2F21. The result is that when the signal from a 2F21 is applied
to the input of a chain of amplifier stages between an iconoscope
and a kinescope, the pattern appears on the kinescope as a
positive. The negative printing therefore is a convenience in
tests of iconoscope equipment. In tests of any television equip-
ment, a positive reproduction of the pattern can be obtained
by using an odd number of video amplifier stages between the
monoscope and the kinescope.

Beam Deflection

The 2F21 employs electromagnetic deflection and the standard
rectilinear system of scanning. Sawtooth scanning currents are
supplied to the respective coils by horizontal and vertical de-
flection circuits which are a composite part of the unit. These
are described separately in detail. The vertical, horizontal,
field and frame frequencies as well as the geometry of the inter-

laced pattern, number of scanning lines and the aspect ratio all conform to the present R. M. A. standards.

Physically the deflection yoke is situated so as to cover the neck of tube, extending from the end of the electron gun structure to the beginning of the bulb. Two wing bolts were made to support the yoke on either side, and two slots cut in the tube shield so that the yoke might be positioned to correctly scan the pattern electrode.

The coils are formed within the yoke in the following manner. Each coil is wound rectilinear in form, and is made up of several concentric sections each having the proper number of turns so that the magnetic field will be uniform in the finished yoke. The two horizontal coils are placed on the inside, 180 degrees apart, and the vertical coils are formed over them and displaced 90 degrees from the horizontal coils. Thus the horizontal coils provide a magnetic field at right angles to that of the vertical coils, so that the resultant horizontal deflection is at right angles to the vertical deflection (3). An important design criteria is that the deflecting coils provide a uniform flux distribution across the neck of the tube. If this requirement is not satisfied, then that portion of electron beam which passes through the stronger region of the field suffers a greater deflection, and a beam of circular cross section is distorted into an eclipse.

An electrostatic shield is provided between the horizontal and vertical coils to minimize any cross coupling. The coils are entirely enclosed within a case of magnetic material to

insure shielding and also to increase the inductance of the vertical coils.

In order to prevent stray electric and magnetic fields from effecting the deflection and focussing of the electron beam, a galvanized iron shield was constructed to enclose the entire tube and the deflecting yoke. A wall was built within this case encircling the monoscope tube between the pattern electrode and the yoke. This shields the pattern electrode from the electrostatic field of the coils and minimizes pick-up by the pattern electrode and video amplifiers of high frequency components of the voltage across the yoke. Care was taken in spacing this wall from the pattern electrode and its terminal, since too close spacing would result in an in-crease in the output capacitance of the tube and thus the re-duction of output voltages at high frequencies.

GENERAL DESCRIPTION OF CAMERA CIRCUITS

The fundamental arrangement of circuits in the monoscope camera is shown in the block diagram, Plate II. The vertical deflection generator consists of four tubes and their assoc-iated circuits. The first of these tubes amplifies the driv-ing signal received from the synchronizing generator and gen-erates a sawtooth voltage which is amplified in the second tube. The fourth provides negative feedback to improve the scanning linearity.

The horizontal deflection generator includes three tubes and their associated circuits. The first tube is the driving

signal input amplifier and sawtooth generator; the second and third amplify the output wave and feed it to the horizontal deflecting coils of the monoscope tube.

The blanking amplifier is used to provide the proper level and polarity of the blanking pulses received from the synchronizing generator before these pulses are fed into the video amplifier for mixing with the video signal.

Video amplification is provided by compensated stages, and the monoscope output signal is fed to the first of these. A clipper stage is included to provide variation of the d-c component of the camera signal. This is accomplished by controlling the vias on the clipper which in turn determines the height of the blanking pedestal. Two output stages are provided. One may be used to feed a monitor, while the other is connected to the system under test.
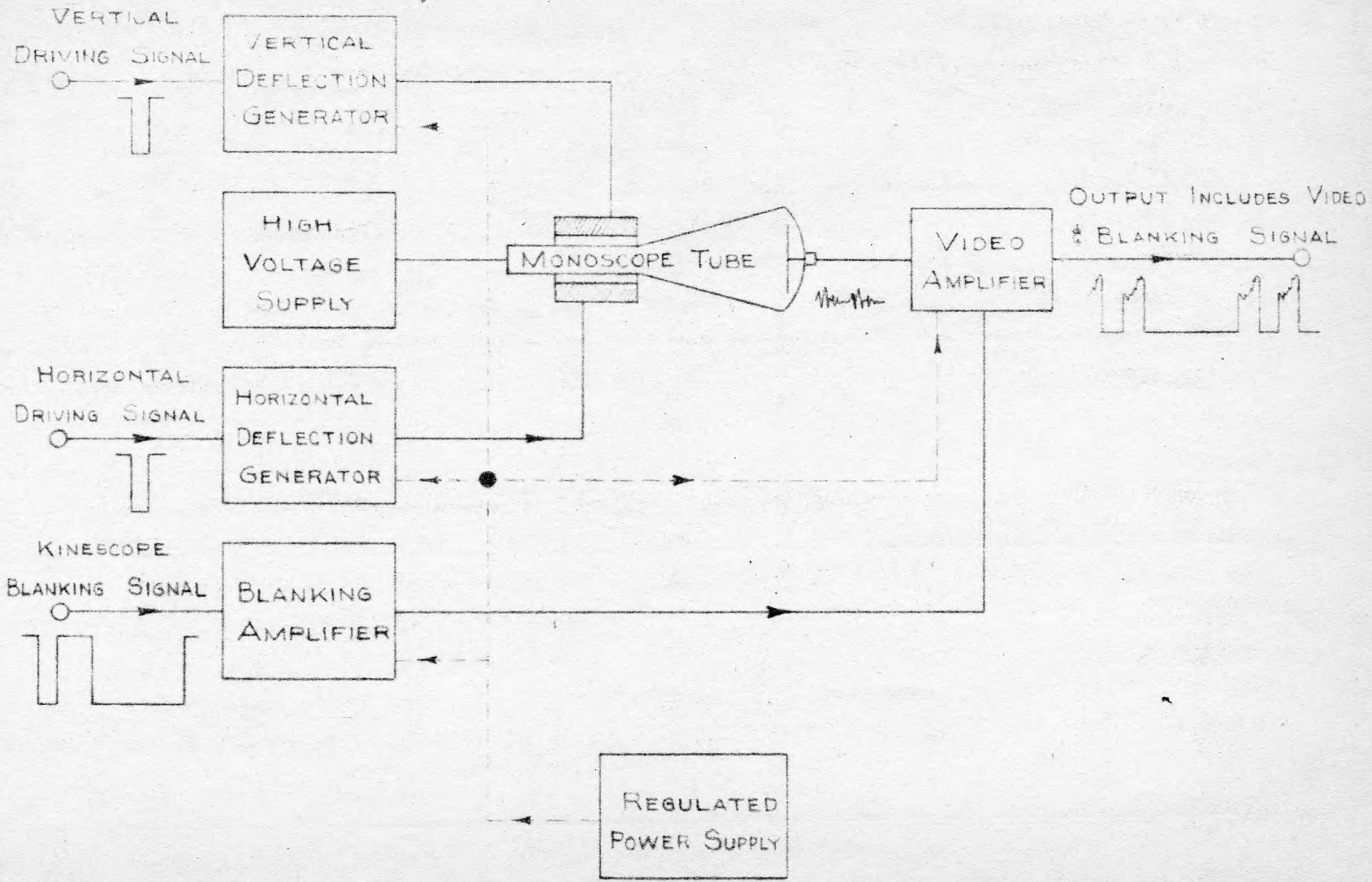
VIDEO AMPLIFIERS

High- Frequency Compensation

The video amplifiers consists of a nine tube resistance-capacity coupled amplifier, compensated so as to insure good frequency response. Actually only the first eight stages are compensated amplifiers, no compensation being required in the output stage, since it operates into a 75 ohm coaxial line. Theoretically, these amplifiers may be adjusted so as to obtain a response uniform to 8 megacycles. Actually, however, difficulty was experienced in extending the response beyond

EXPLANATION OF PLATE II

Fig. 2. Block diagram of the monoscope camera showing
input and output voltage wave forms

Fig. 3

VERTICAL DRIVING SIGNAL

VERTICAL DEFLECTION GENERATOR

HIGH VOLTAGE SUPPLY

HORIZONTAL DRIVING SIGNAL

HORIZONTAL DEFLECTION GENERATOR

KINESCOPE BLANKING SIGNAL

BLANKING AMPLIFIER

MONOSCOPE TUBE

VIDEO AMPLIFIER

OUTPUT INCLUDES VIDEO & BLANKING SIGNAL

REGULATED POWER SUPPLY

PLATE II

6.5 megacycles without peaking at the high end. However, the maximum video frequency generated by the monoscope, assuming equal horizontal and vertical resolution, is given by the formula (6)

$$f = N^2 ra/2$$
$$f = (525)^2 (30) (^4/3)/2$$
$$f = 5.5 \text{ megacycles}$$

Where: N is the number of scanning lines

r is the frame repition rate

a is the aspect ratio

f is the maximum video frequency.

The resolution of the system, therefore, will not be limited by the video amplifiers.

It is important to realize that the high frequency performance of the Amplifier determines the quality of the picture so far as the resolution and detail are concerned. If both gain and delay characteristics are flat, the picture is reproduced exactly. If the gain is constant in the video band and the time delay varies with frequency, all the high frequency components are reproduced exactly in their proper relative amplitudes, but the location of the various picture elements is not correct, because of the different amounts of time taken for passage of the different frequencies. This results in inferior reproduction of detail.

The signal plate of the monoscope tube is connected to the grid of the first picture amplifier tube through a compensating network composed of the transformer, T1, and the

resistors, R3 and R4, as shown in Plate V. A similar network is included in the plate circuit of each additional amplifier tube. The compensating circuit is a four terminal network that presents a constant load impedance to the tube over the required bandwidth. A mathematical analysis of the network appears to be rather complex and will not be attempted. It may be stated, however, that there exists essentially two methods to reduce the effect of the load capacitance which is the principle cause of loss of gain at the high frequencies. One method involves the use of a very small load resistor, whose resistance is so low compared to the reactance of the load capacitance at the highest video frequency, that the reactance has no effect on the gain or phase characteristics. This arrangement would possess no practical advantages, because of the great loss in gain per stage entailed by the use of a small plate resistor. The second method is that of employing a circuit containing inductance and utilizing the resonance effect to extend the gain at high frequencies. This, basically, is the principle employed by the compensating network.

In the actual construction of the video amplifiers all possible precautions were taken as to the placement of component parts and the length of leads to insure a minimum of stray capacitance. Coupling condensers and lead wires were held well off the chassis. It was found experimentally that the capacitance between a component having axial symmetry, such as paper coupling condenser or a wire, and the chassis varies approximately as the function $Ce^{x/A}$; Where x is the distance of separation, C is the capacitance at x equal to zero, and

A is a constant proportional to the surface area of the component. Thus the rate at which the capacity changes with respect to distance, evaluated at any point, is proportional to the capacity at that point. This relationship is useful, inasmuch as it indicates the advantage gained in increasing the distance for small initial values of x.

Low-Frequency Compensation

In the frequency range below 200 cycles, the gain and phase shift of the video amplifiers are both subject to a variation from the mid-band values. The phase shift is particularly objectionable at low frequencies and it is necessary to compensate for this. The relationship between phase shift and time delay for a particular frequency is

$$\phi = \omega t = 2 \pi t f$$

Thus for a given phase shift the time delay is seen to increase rapidly as the frequency is lowered.

At low frequencies it is necessary to compensate for phase shift in the cathode circuit, the screen circuit and in the coupling network. Complete compensation may be obtained by means of a network in the load circuit for any one, but only one, of these. In the video stages constructed for the monoscope no compensating network is employed; however, precautions are taken to effectively eliminate any phase shift that might arise due to the above causes.

The 6AC7's use 18,000 ohm screen dropping resistors which are bypassed by 20 microfarad condensers. The 6AC7's use 56,000

ohm dropping resistors which are bypassed by 10 microfarad
condensers. This may be verified by reference to Plate V.
The frequency response is thus not effected by the screen grid
circuit for frequencies exceeding approximately 5 or 6 cycles.
In the coupling network o.25 microfarad condensers are employed
with grid resistors of approximately 500,000 ohms. Here again
the phase shift is negilible down to a few cycles per second.

In the cathode circuit no phase shift whatsoever is intro-
duced. This, however, is accomplished at the expense of the
gain of the stage. The method employed to accomplish this
is simply to omit the cathode bypass condenser. Since the gain
of the stage at low frequencies is given by (5)

$$G^1 = \frac{uR_L}{R_L + r_p + (1+u)\left[R_K / (1 + JWC_K R_K)\right]}$$

Where: G' is the gain of the stage taking into consideration
the effect of the bias network

R_L is the load resistance

R_K is the cathode resistor

C_K is the cathode bypass condenser

and u, r_p and g_m are the tube parameters

then if C_K equals zero, the gain is real and independent of
frequency. This equation, with C_K equal to zero, is equivalent
to

$$G^1 = \frac{G}{1 - BG}$$

Where: G is the gain of the amplifier without feedback

BG is the feedback factor

This, of course, is the well-known equation of an amplifier
stage employing inverse feedback. An approximation of the
gains realized in the video stage will be made. A typical
value of load and cathode resistance are 100 ohms respect-
ively. Considering the transconductance of a 6AC7 to be
approximately 10,000 micromhos, then the absolute value of
the feedback factor is 1 and the gain of the stage neglecting
feedback is 10. Thus the gain is decreased by a factor of
two and the overall gain of the stage is 5. As a first ap-
proximation it may be thought that this decrease in gain is
not commensurable with the result achieved. There are, how-
ever, other advantages to be had by using an unbypassed cathode
resistor. The first of these is a decrease in input capacit-
ance, since the gain of the stage has been lowered. This
effect is desirable since it improves the high frequency res-
ponse of the preceding stage. The transfer characteristic
curves of the tube also become more linear and a sharp cut off
is obtained.

It should be mentioned that the function of the very low
video frequencies is to supply the background of the picture.
If the video stages fail to pass these frequencies without
distortion the result will appear as a gradual shading of the
picture from the top to bottom (6)

Output Stage

The output of the video system is fed to the paralleled
grids of V8 and V10, the picture output and monitor output

tubes. The two output stages are identical, the additional output stage being provided so that the picture signal may be viewed on a monitor while the signal is being fed to the equipment being checked. No attempt is made to achieve high-frequency compensation, since both stages operate into a 75 ohm coaxial line. The necessity of feeding into a coaxial line reduces the voltage gain of the output stages to a value less than unity.

Blanking

The blanking signal is also mixed in the video amplifiers. The composite vertical and horizontal blanking pulses are derived from the synchronizing generator and initially fed to V7, the blanking amplifier. The blanking pulses must be of negative polarity and should conform to the R.M.A. standard. The composite pulses are mixed with the picture signal in the fourth video stage through the use of a common plate load resistor.

It is of interest to note here that during the time the monoscope tube is blanked, the polarity of the output video signal from the 2F21 corresponds to that of a white section of the picture. Therefore, when the actual blanking pulses are mixed with the video signal, the polarity of the monoscope signal corresponding to the blankinking time is opposite that of the blanking pulse. The two voltages are then subtractive rather than additive. This necessitates that the blanking pulse be of much greater amplitude than the pulse generated by the monoscope tube during the blanking time at the point where they are mixed. After the mixing takes place, the polarity of

the signal during picture blanking is in the true black direction.

PICTURE BRIGHTNESS

Following five stages of video amplification the signal is fed to the clipper tube, V4. The clipper tube operates only on the blanking pulses, which have previously been mixed with the video signal, to establish a black level, and thus control the light intensity that will correspond to any particular amplitude of the video signal. When the blanking pulses are mixed with the video signal the level of the signal during the blanking period is raised far above the level of the actual signal containing picture information. The clipper tube, therefore, has a wide range over which to operate on the blanking pulse, and the average picture brightness can be adequately controlled.

The importance of the clipper tube in controlling the black reference level cannot be overestimated, and an analysis of the camera signal at this point may be well justified. Fundamentally, the information contained in the camera signal consists of two components. One is the a-c component, whose relative instanteous amplitude contains the picture element brightness corresponding to that point on the pattern electrode being scanned. The second is the d-c component, which is defined as that value of voltage existing between a fixed black reference level and the average of the camera signal (5). The d-c component, therefore, corresponds to the average brightness of the picture, since it is an average voltage which would correspond to an average light intensity. It is advantageous

to be able to vary these two components independently of each other. The relative amplitude of the a-c component is controlled by the gain of the video amplifiers. This control is incorporated by making the screen grid voltage of the first video amplifier variable with the potentiometer, R7. While this control is labled "Gain" it is in a sense also a contrast control, since a variation in contrast is an inevitable result of varying the amplitude of the a-c component of the video signal.

It now remains to be shown how the d-c component of the signal can be varied. This is readily accomplished once the fixed black reference level is defined. This black reference will be taken as the height of the blanking pulse. Thus by varying the difference between the picture average and the blanking level, the d-c component corresponding to the average picture brightness is controlled. The average picture brightness of the test pattern in the monoscope tube is obviously a constant value. Once the d-c component corresponding to this average brightness is set for a satisfactory picture as viewed on a kinescope, further adjustment will not be necessary. Reference to Plate III will help to clarify this discussion.

The brightness control, R55, is a potentiometer that controls the grid bias on the clipper tube. Clipping is accomplished by setting the grid bias of V4 to such a value that the top of the blanking pulse drives the tube into cut off. An even number of stages is had between the blanking input and the clipper, so that the blanking pulses appear negative on the

EXPLANATION OF PLATE III

Fig. 4. Control of the average picture brightness by
varying the average of the camera signal with
respect to the black reference level. Average
light intensity of the scene being transmitted
is high

Fig. 5. Average light intensity of the scene being
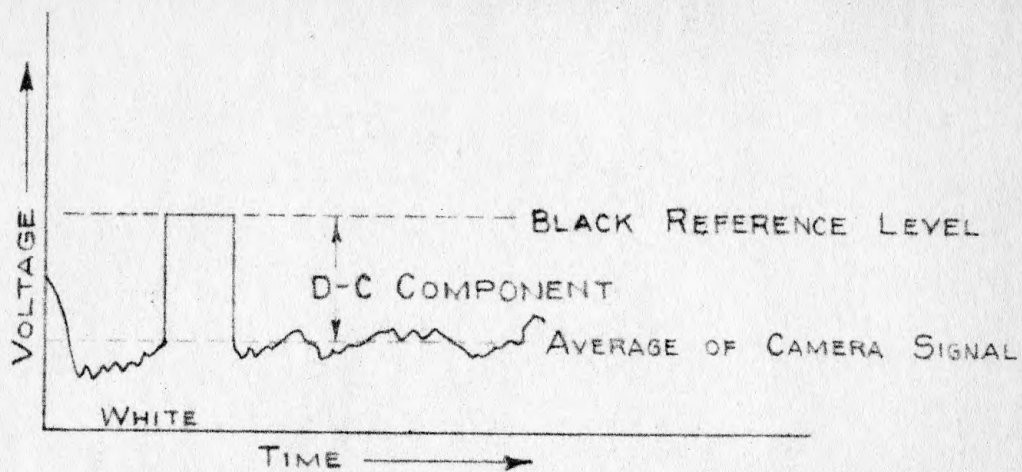transmitted is low
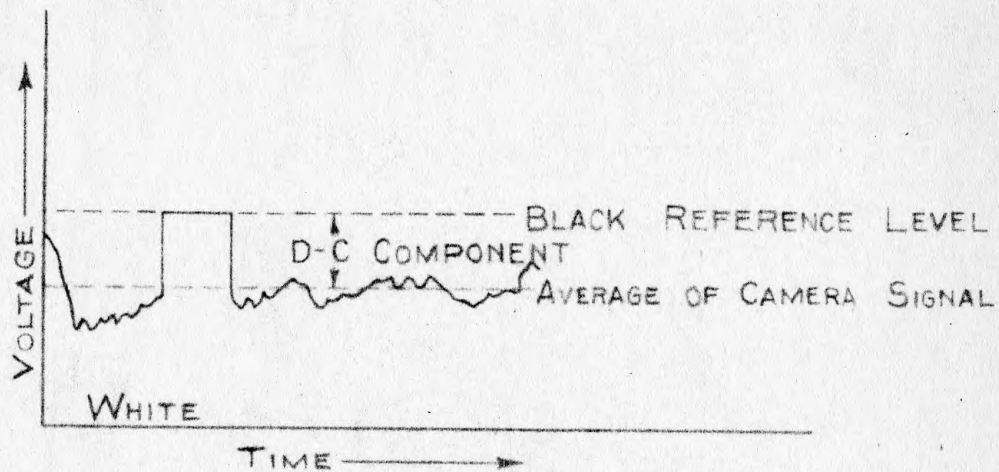
PLATE III

Fig. 4

Fig. 5

of V4. R55, in varying the bias on V4, determines the clipping level and consequently the d-c component contained by the signal. The action of the clipper is improved by using a 1000 ohm unbypassed cathode resistor. This gives a sharp cut off characteristic and thus a well defined blanking level.

CLAMPER TUBE ANALYSIS

Fundamental Theory

A clamp circuit using a 6H6 operates on the grid of the third picture amplifier tube, V6. The function of this circuit is to establish the peaks of the blanking pulse at a fixed reference level in the video signal or at some potential fixed with respect to this reference level during the retrace time. Coincidental with this action, spurious low frequency signals such as microphonics, power supply surges or 60 cycle hum which may have been introduced in the preceding low level picture amplifier stages are reduced to a negligible amplitude (7).

The activation of any clamp circuit can be controlled either by the signal to be clamped or a signal independent of the clamped signal (12). The particular clamp circuit employed in this equipment uses the latter method of clamping, deriving the keying signal from the horizontal driving circuits. By using a keying signal it is possible to obtain greatly improved d-c restoration. Keyed circuits can be made very fast with low distortion and high immunity from noise. They operate satisfactorily with signal levels much lower than for the sim-

ple restorer circuits (7).

The operation of the clamp circuit may be understood more easily by reference to the idealized equivalent of a keyed d-c restorer or clamp circuit shown in Plate IV. They key is operated, or closed, for an interval of time corresponding to the width of the horizontal driving pulse. The horizontal driving pulse width is approximately 10 per cent of the horizontal cycle or 6.35 microseconds. When the key is closed the output voltage goes to ground potential. A charging or discharging current flows through C limited only by R. C is small enough so that before they key is opened, it becomes completely charged, and the 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 the 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, 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. This keyed circuit thus restores the d-c component by holding the signal during the keying pulse at a fixed voltage which may be considered the d-c axis. The signal extends always in one direction from this axis, and has a d-c component exactly as in all d-c restorers or clampers (7).

In the light of the foregoing analysis the operation of

EXPLANATION OF PLATE IV

Fig. 6. Idealized equivalent of a keyed d-c restorer
        or clamp circuit

Fig. 7. Simplified diagram of the double keyed diode
        clamp circuit used in the monoscope camera.
        Keying pulses are derived from the grid and
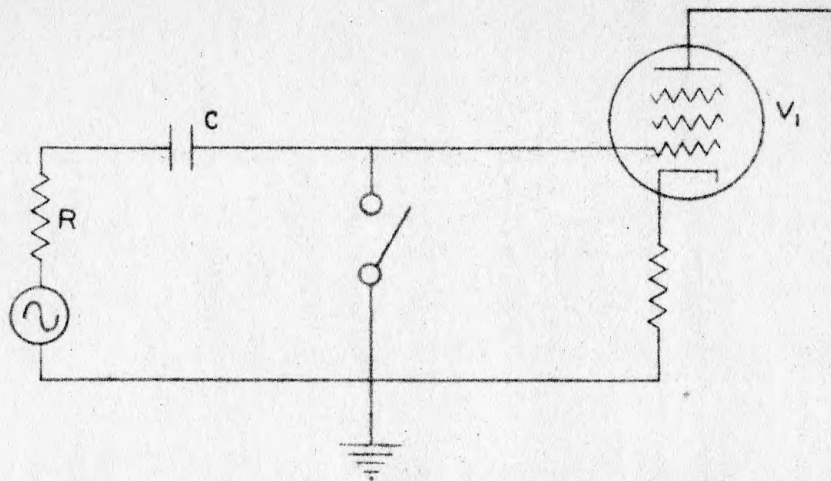   plate circuit of the horizontal pulse amplifier

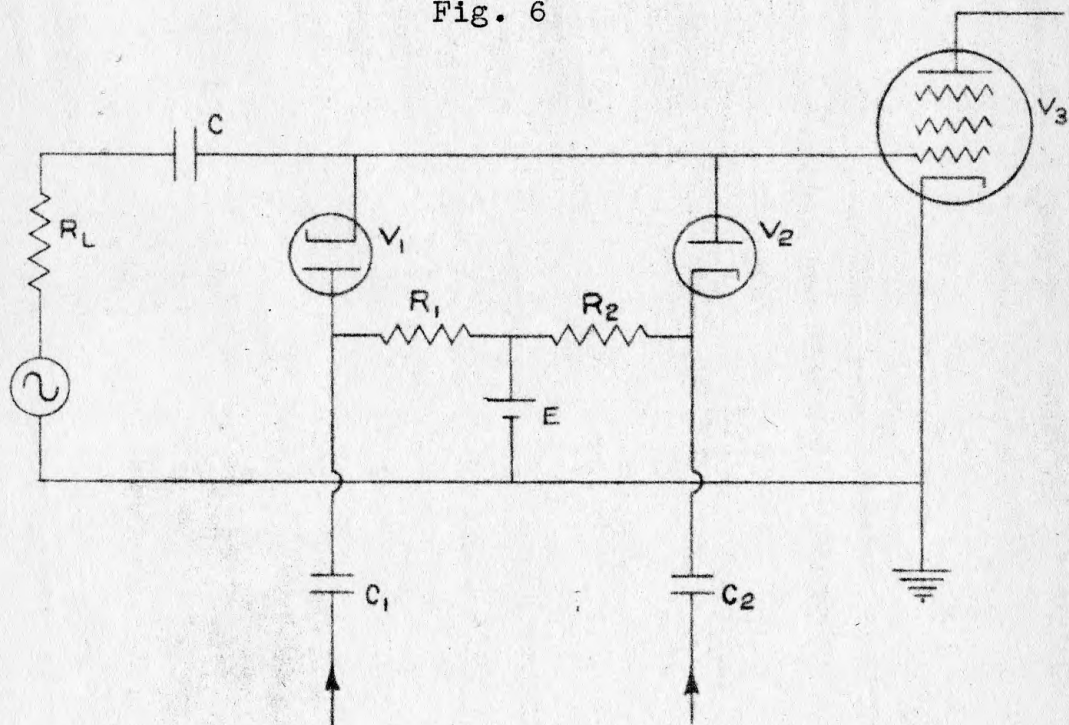PLATE IV

Fig. 6

Fig. 7

the monoscope clamp circuit may be discussed. The key is closed
at the beginning of the horizontal retrace period which corres-
ponds to the leading edge of the horizontal driving pulses.
These driving pulses while employed as the keying signal are
simultaneously applied to the control grid of the 2F21 as blank-
ing pulses. The grid of V6, Plate V, is now at zero signal
level or ground potential and this, as previously stated, is
the clamping action. Just prior to the end of the monoscope
blanking pulse, the key is opened and the grid of V2 is float-
ing. The remainder of the blanking pulse, therefore, falls
on a predetermined point on the grid voltage-plate current
characteristic of V6. This portion of the blanking pulse there-
fore falls on the same point during successive cycles of hor-
izontal or line frequency. In other words, undesirable low
frequency changes in preceding amplifier stages are removed by
resetting the level at the end of each line. The desired low
frequency characteristics of the picture signal are at the same
time restored by resetting the base of the blanking pedestal
at a fixed reference level at the end of each line.

Except for the difficulty in closing and opening the key
at the proper time, the keyed circuit fulfills the requirements
for a satisfactory clamp circuit. The advantages associated
with a keyed clamp are that d-c level at which the blanking is
held can be easily adjusted, and that the same circuit will han-
dle either positive or negative polarity signals.

It is of interest to note that the capacitor, C8, in the
actual circuit is of low value. This keeps the time constant

EXPLANATION OF PLATE V

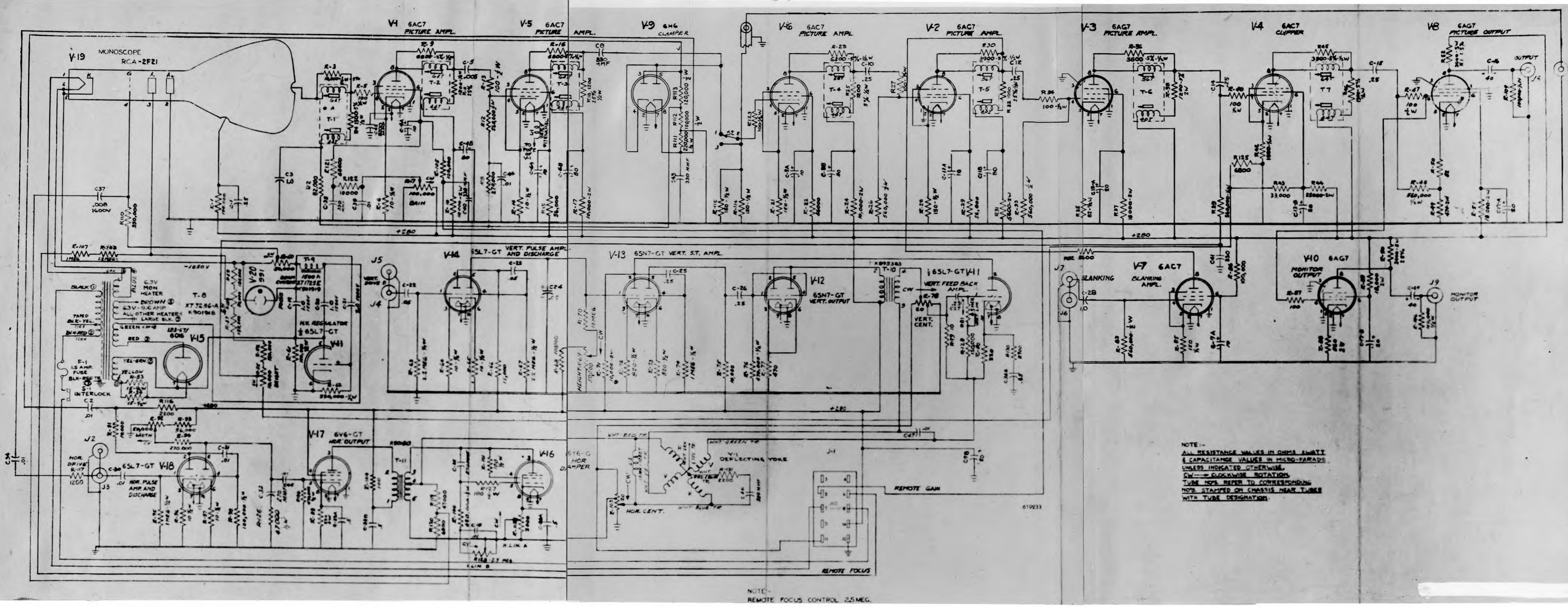Fig. 8. Actual circuit diagram of the monoscope camera

PLATE V

Fig. 8

of the circuit to a suitable low value with respect to the duration of the keying pulse. The low frequency response is not deteriorated during the picture signal interval as the open circuit resistance of the diode reaches a high value, and the new RC value is of the proper order to pass these frequencies.

The Double Keyed Diode Clamp

In the actual circuit shown in the schematic diagram, Plate V, the switching action is accomplished by keying two diodes by means of the horizontal driving pulses. These driving pulses are 180 degrees out of phase and are obtained from the input and output circuits of the horizontal pulse amplifier section of the tube, V18. An analysis of the keying pulses, and their particular requirements will be given later.

The simplified diagram of Plate IV is consistent with the actual circuit. The two diodes are driven through two condensers, C1 and C2, and are connected by two resistors R1 and R2, the common point of which is grounded through some voltage E for supplying the bias to the amplifier. The time constants R1C1 and R2C2 are long compared to the duration of the horizontal cycle.

For an analysis this circuit is best redrawn in bridge form as shown in Plate VI. The circuit and letters designations are the same as in the previous figure, except that the two pulses are indicated by P1 and P2 with the center point of the two pulses at ground. The two pulses are equal in this case, and of opposite polarity. In the actual circuit R1 and R2 are 220,000

ohms, C1 and C2 are .01 microfarads, and C is 330 microfarads.

During the pulse time the diodes are driven into conduction by the positive pulse on the plate of D1 and the negative pulse on the cathode of D2. A current i_1 flows through the diode and the capacitance C1 and C2. A current i_3 will flow into or out of C until point 1 is brought to an equilibrum voltage which is the clamping level. Between pulses a current i_2 flows through C1, C2, R1 and R2 slightly reducing the charge on C1 and C2.

The clamping level or output voltage to which point 1 is brought during the pulse time is equal to E under the conditions of equal pulse amplitudes, equal resistances, and similar diodes. The voltage to which condenser C is charged or to which point 1 is brought during the pulse time, depends upon the a-c and d-c voltage applied to the diodes at points 3 and 4. These voltages are shown in Plate VI. By way of illustration, the pulses are shown as 20 volts peak to peak, and of 5 percent width, which would give them a peak value of 19 volts from the d-c values measured at points 3 and 4. During conduction time points 3, 1, and 4 are all approximately the same instantaneous potential, which is the clamping level. The axis or d-c voltage at 4 is then minus 19 volts and that at 3 is plus 19 volts from the clamping level. The clamping level is therefore midway between the d-c voltage at 3 and 4. If R1 and R2 are equal, E is also midway between these voltages, and equal to the clamping level. If the pulses are unequal, the clamping level will equal E whenever

EXPLANATION OF PLATE VI

Fig. 9. Double keyed diode clamp circuit redrawn in
bridge form to simplify analysis

Fig. 10. Clamp circuit designed to supply grid bias for
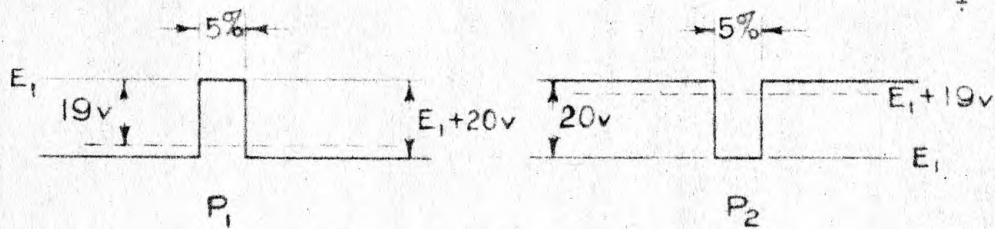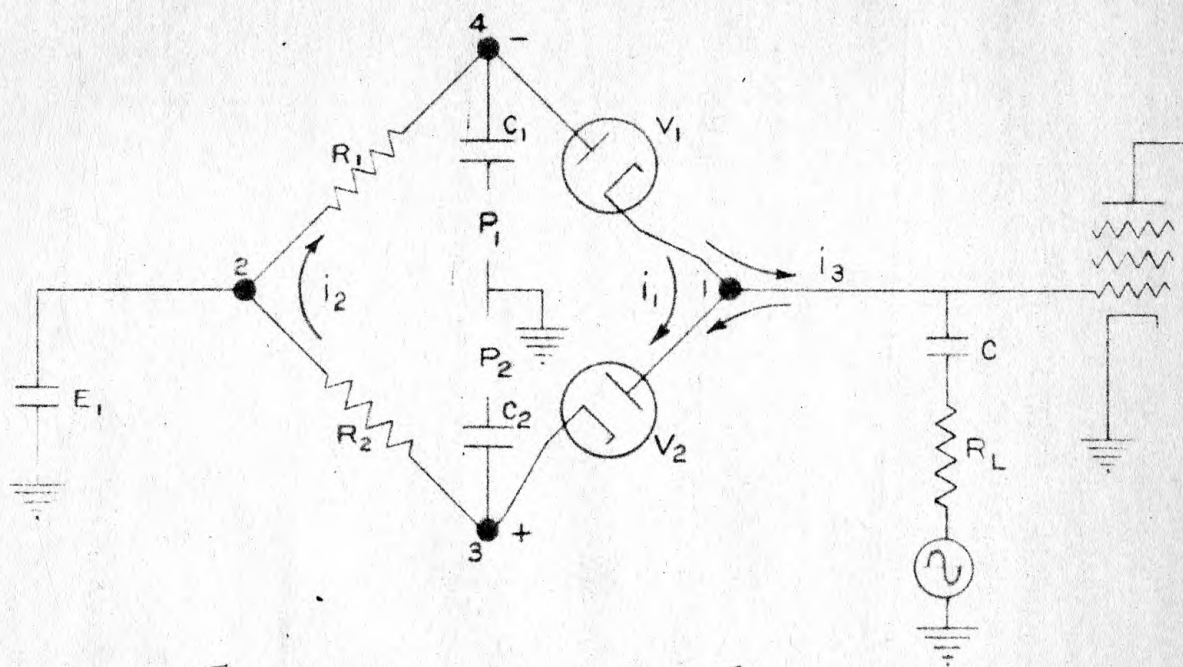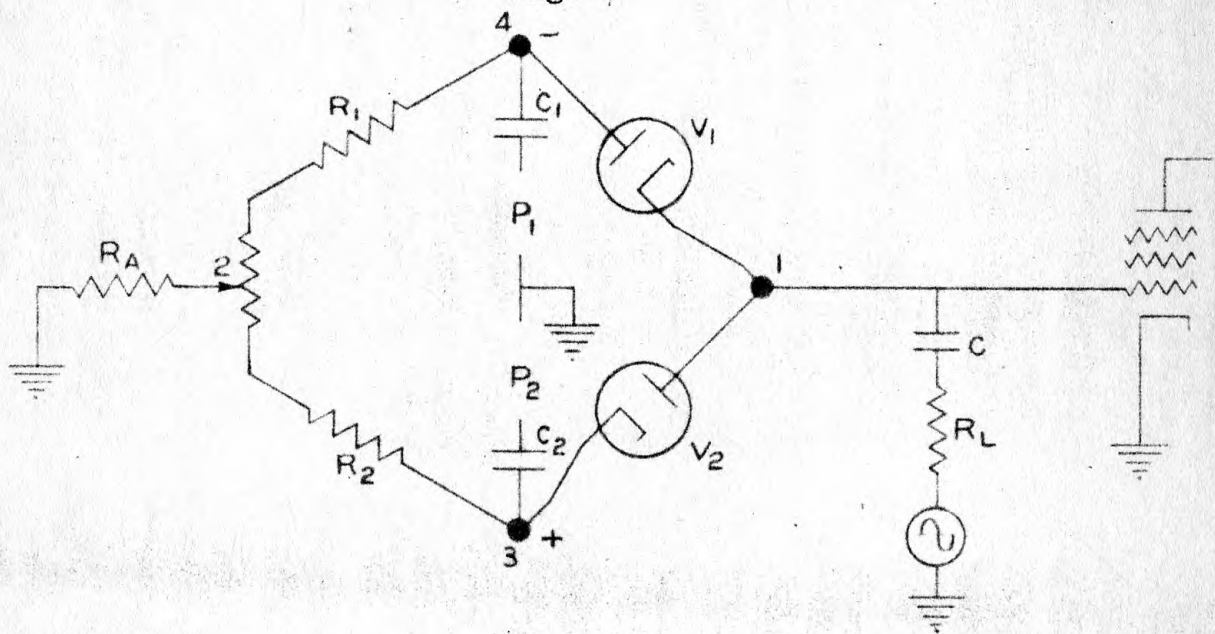the following amplifier stage

PLATE VI

Fig. 9

Fig. 10

$$\frac{P_1}{P_2} = \frac{R_1}{R_2}$$

Clamp Level $\quad$ (C.L.) $= E_1 + P_1 - i_{2p}R_1$

Since $\quad\quad\quad\quad i_2 = \dfrac{P_1 + P_2}{R_1 + R_2}$

Then $\quad\quad$ C.L. $= E_1 + P_1 - \dfrac{(P_1 + P_2)R_1}{R_1 + R_2}$

$$= E_1 + \frac{P_1R_1 + P_1R_2 - P_1R_1 - P_2R_1}{R_1 + R_2}$$

Assume $\quad\quad \dfrac{P_1}{P_2} = \dfrac{R_1}{R_2} \quad\quad$ or

$$P_1R_2 = P_2R_1$$

Then $\quad$ C.L. $= E_1 + \dfrac{P_1R_1 - P_2R_1 - P_1R_1 - P_2R_1 - E_1}{R_2 + R_1}$

If the resistors are unbalanced, C_1 and C_2 should be very large, or unbalanced so that

$$\frac{R_1}{R_2} = \frac{C_2}{C_1}$$

If the two keying signals are constant in amplitude, E may be obtained in effect from the diode circuit itself and the voltage E eliminated, point 2 being grounded. Such an arrangement is shown in Plate VI, where the center portion of the R1R2 combination has been replaced by a potentiometer. There is a point 2 on this potentiometer which has the same

potential as the clamping level. It is the junction of the now
hypothetical resistors R1 and R2 which have the same ratio as
P1 and P2. If some other point on the potentiometer is ground-
ed, a voltage will exist between the arm and point 2, since a
d-c voltage exists across R1 and R2. In the example shown, a
negative voltage exists at point 2, since the positive portion
of R1, R2 is ground. Any part of R1, R2 may be grounded, except
that as the grounding point leaves point 2, an increasing por-
tion of the pulse voltage also appears on the arm. A resistor
RA should therefore be inserted between the arm and ground in
order to avoid loading the pulse (7).

Keying Pulse Requirements

The accurate timing of the keying pulses is of obvious
importance. This requirement, however, is fulfilled by cir-
cuits external to the monoscope camera and will not be dis-
cussed. Incorrectly timed pulses to the keyed circuit are re-
vealed by a strong dark or light horizontal streaking effect on
the kinescope which varies erratically.

The pulses must, of course, be synchronous with the signal.
The front edge of the keying pulse should occur approximately at
the beginning of the portion of the signal to be clamped. Since
the monoscope derives the keying signal and the blanking pulse
which is clamped from the same source, this requirement is
automatically satisfied. The keying signal should end well be-
fore the end of the blanking pulse. A tolerence is allowed
here, such that under no conditions will the key last beyond

the signal reference level.

The keying pulses must also be large enough so that under maximum signal swings, neither diode will conduct between keying pulses. It is apparent that even though the pulses place a large blocking voltage on the diodes, the signal also swings the other element of each diode, and will decrease at least on one of them the bias provided by the keying pulse.

Greatly increased noise immunity is given by the keyed restorer, since noise occurring between the keying pulses has no effect on the circuit. Since the keying pulses are approximately 10 percent of the horizontal cycle, the circuit is effectively improved by a factor of 10.

THE HORIZONTAL DEFLECTION CIRCUITS

The Horizontal Pulse Amplifier and Sawtooth Generator

The horizontal driving signal, derived from the synchronizing generator, is a square pulse of negative polarity, the duration of which is 10 per cent of the horizontal cycle or 6.3 microseconds. Its peak amplitude is from 3.5 to 5 volts held within a tolerance of .5 volts.

The driving pulse is applied to the grid of V18, a 6SL7, used as the pulse amplifier. The time constant of the grid circuit, C30 and R95, is long (10,000 microseconds) compared to the duration of the horizontal driving pulse. As such, grid leak bias is developed and the signal is effectively clamped at ground potential. The clamping action of the cir-

cuit is a result of the low static grid resistance of the 6SL7, which can be approximated as 1000 microseconds, and the coupling condenser changes quickly to a value equal to the amplitude of the input signal above its a-c reference level. The bias on the tube is then zero and the signal is said to be clamped to ground potential. At the time of the next negative pulse the time constant of the grid circuit is, of course, its original value of 10,000 micro-seconds, and the waveshape of the negative pulse is preserved. If the amplitude of the input signal is above 4 volts the tube is probably driven into cut off during the negative pulse since

$$E_{co} = \frac{e_b \ (\text{at the time of cut off})}{u}$$

$$E_{co} = \frac{280}{70} = 4 \text{ volts}$$

The input horizontal driving pulse is also fed directly to one section of a 6H6, which is used in a keyed diode clamp circuit in the video amplifiers. A voltage divider in the plate circuit of the input section of V18 supplies a signal of opposite polarity but of equal amplitude to the other diode section of the 6H6.

The total output of the pulse amplifier sections of V18 is fed to the second section of the 6SL7 which acts as the discharge tube for the sawtooth generating circuit. The peak to peak amplitude of the driving pulse from the pulse amplifier is 20 volts, which drives the discharge tube into full conduction

during the driving pulse period. The tube remains cut off during the interval between the driving pulses.

Clamping is not had in the grid circuit, as in the previous case, due primarily to two reasons. The first is that the time during which the signal goes positive corresponds to 6.4 microseconds rather than 57.1 microseconds, since the waveform has been inverted by the pulse amplifier. To determine whether clamping action is present the time contant of the grid circuit must be compared to this. However, the resistance used to calculate the RC product is no longer merely the static grid resistance of the tube, but must also include the internal impedance of the driving source, which in this case is the plate load resistance of the pulse amplifier. This consideration could be neglected in the grid circuit of the pulse amplifier since the internal impedance of the driving source is only the characteristic impedance of the coaxial cable. Thus the RC product, as determined during the time which the grid is positive, has increased greatly and the time to which the RC product must be compared has decreased. The result is a long time constant in the grid circuit during the period of the positive driving pulse and no clamping action is obtained.

The sawtooth generating circuit actually produces a trapazoidal voltage waveform. This is necessary to produce the sawtooth of current in the inductive-resistive circuit of the deflection coils. The method employed to develop this voltage waveform is conventional and is based on the gradual accumulation of charge on a condenser, $C32$, following by its rapid dis-

charge. The output voltage is then taken across the condenser and a peaking resistor, R126, and applied directly to the grid of the horizontal output tube, V17. The horizontal width control is incorporated in this circuit by varying the potential to which C32 charges. This potential is controlled by the setting of the arm of the potentiometer, R92, since the potentiometer is part of a bleeder across the low voltage power supply. R92 will also control to a certain degree the horizontal linearity.

The Horizontal Damper Circuit

An analysis of the horizontal damper circuit will now be undertaken. The actual circuit is simplified to a fundamental damper circuit shown in Plate VII, Fig. II, and reference will be made to this and to the associated waveforms in Plate VII, Fig. 12. The tubes, VI and V2, correspond respectively to tubes, V17 and V18, of the actual circuit diagram.

The initial assumed condition will be that V2 is not conducting and that V1 is conducting but with an absence of signal on its grid. If a linearly increasing voltage is now impressed on the grid of V1, the plate current, i_1, will rise in accordance with the grid signal. This plate current flowing through the horizontal deflection coils, L_h, builds up an assumed positive magnetic field, the magnitude of which is increasing with respect to time. When the magnetic field strength is such as to give the desired deflection, the plate current of V1 is cut off by driving its grid into cut off. This time is designated

EXPLANATION OF PLATE VII

Fig. 11. A fundamental damper circuit diagram employ-
ing an inverse power control tube as the
damping resistance. The direction of electron
current flow is assumed

Fig. 12. Associated current and voltage waveforms of
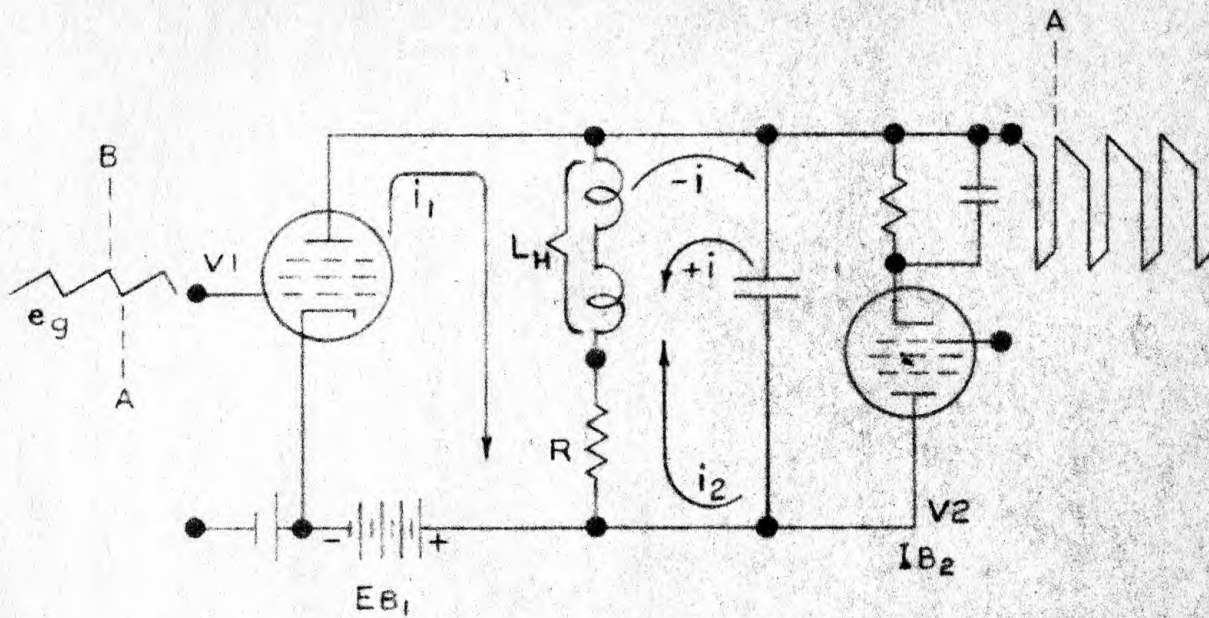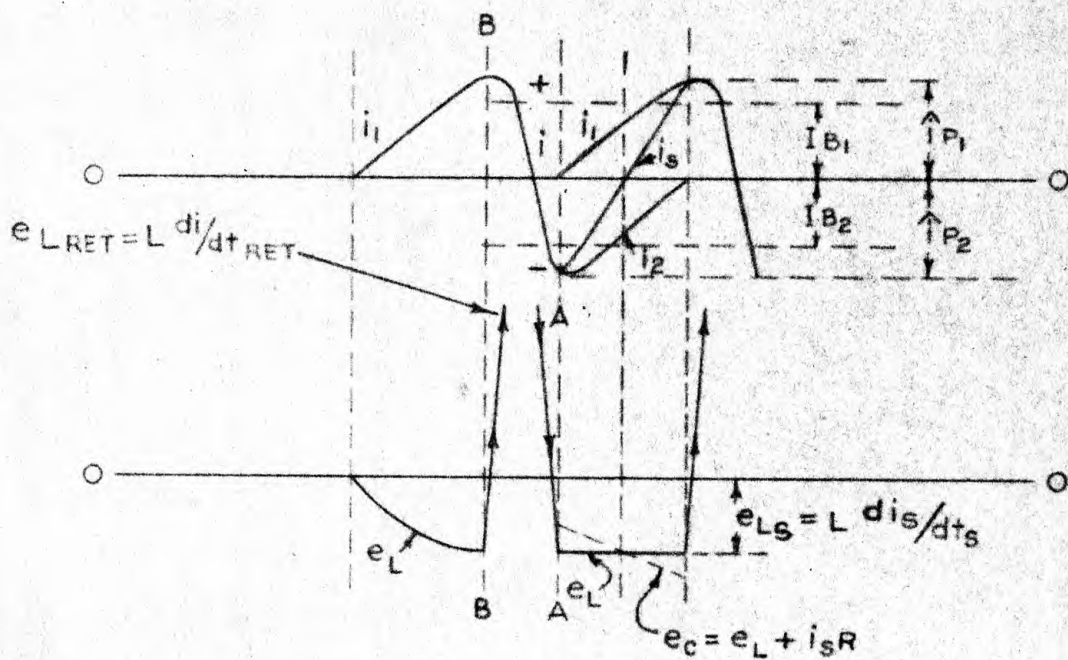the fundamental damped circuit

PLATE VII

Fig. 11

Fig. 12

by the letter B in Fig. 12. A period of energy reversal is now
initiated in the tuned plate circuit, L_hC, corresponding to the
retrace period. Thus the magnetic field surrounding L_h collap-
ses, inducing a voltage in the coil. By virtue of this induced
voltage the coil now appears as a voltage source, the polarity
being such as to drive current in the same direction as it was
originally flowing. This current is designated as i and must
necessarily go to charge the capacity C since V1 is no longer
conducting. The voltage across the condenser is now increasing
in accordance with the formula $e_c = 1/C \int i\,dt$, and reaches a
maximum when i equals zero. The voltage appearing across L_h
is also a maximum at this time, since the expression di/dt is
large. The actual peak value of voltage across the deflection
coils is so large as to warrant its omission from the waveforms
of Fig. 12. The potential energy, now stored in the condenser,
is released in the form of a condenser discharge current, -i.
has increased to a value which is approximately 70 per cent of
the original value of i_1 at point B. This decrease is a result
of the power loss that is inevitable in a tuned circuit with a
finite Q. Since the rate of change of current with respect to
time is now zero the voltage across L_h is zero and the waveform
representing e_L is seen to cross the zero axis. The system has
now completed a complete cycle of energy reversal or one half
cycle of free oscillation.

Again the magnetic field collapses and a voltage is induced
in the coils such as to substantiate the current -i. This ne-
cessitates that the coil, now appearing as a voltage source,

have a polarity such that point 1 is negative with respect to point 2. Thus the plate of the inverse power control tube, V2, becomes positive and the tube will conduct. The low plate resistance of V2 now shunts C and the circuit is highly damped. As a result of the shunting effect of the tube, free oscillation is damped out at point A. The current that now flows through L_h and V2 as a result of this action will be called i_2. This current is forced to decrease in any desired manner by controlling the plate resistance of V2 with a proper signal voltage on its grid.

At point A the tube V1 is simultaneously driven into conduction by its control grid voltage. The current that flows through the deflection coils is therefore the summation of the two currents, i_2 and i_1. These combined currents result in a larger and linearly changing total scanning current, i_s. This summation current, i_s, produces the field which causes the forward trace of the horizontal sweep. Its characteristics determine the amplitude and linearity of the horizontal deflection.

The results obtained with this type of damper circuit are superior to that had when a conventional diode damper is used. Apparently better utilization of available power is secured and certainly better control of the deflection linearity is provided by being able to control the effective damping resistance.

Plate VIII shows the actual horizontal damper circuit for comparison. The modifications and refinements made to the fundamental damper circuit will now be justified.

The insertion of the coupling transformer, T11, between the

EXPLANATION OF PLATE VIII

Fig. 13.   Actual circuit of the monoscope horizontal
damper.   "C" is the lumped coil and circuit
capacities in shunt with the deflection
coil.   R126 and R102 are linearity adjustments
for the horizontal sweep, and control the
bias and grid voltage waveforms respectively
of V16, the inverse power control tube
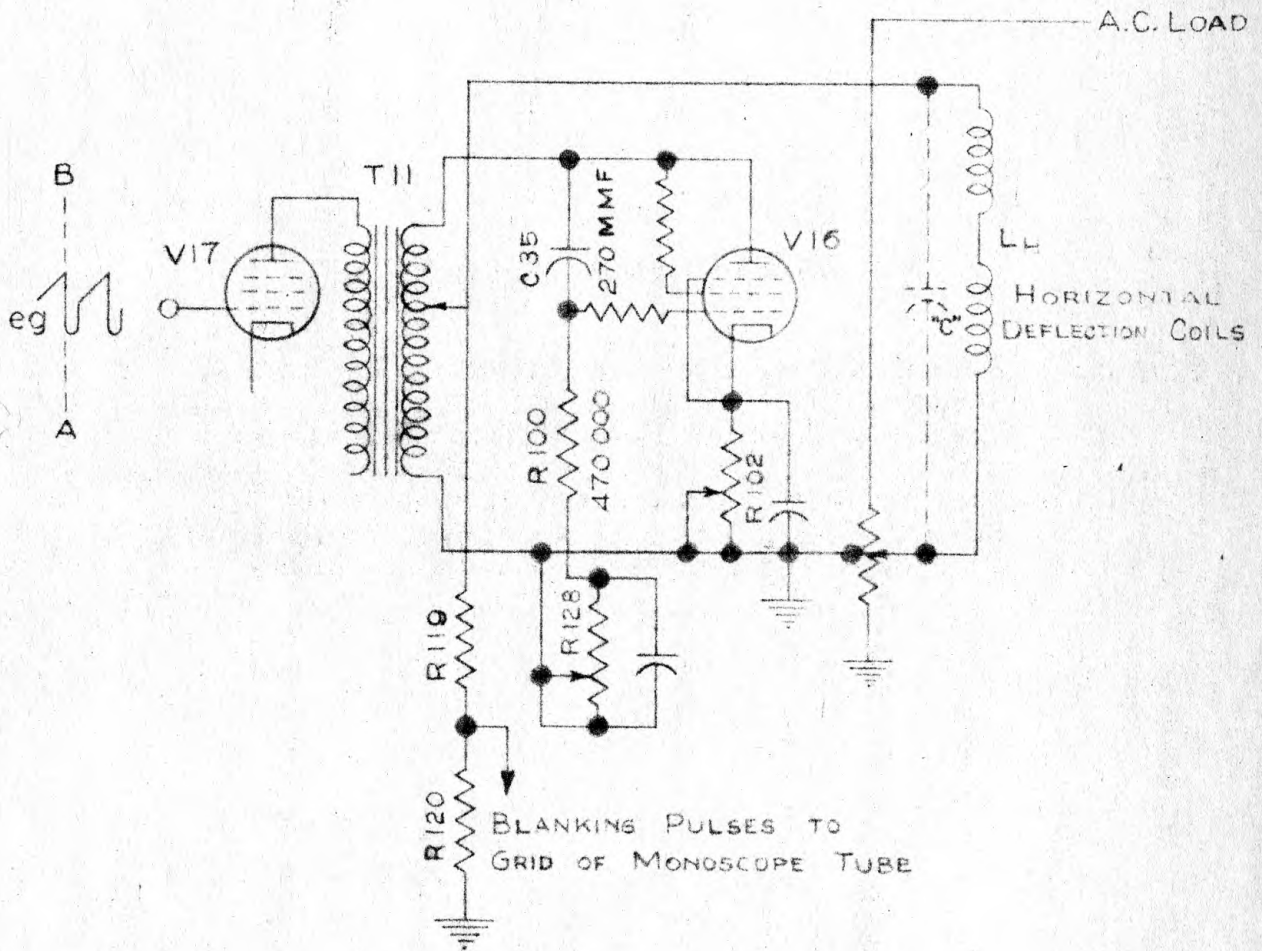
PLATE VIII

Fig. 13

power tube, V17, and the damper tube, V16, allows the damper tube to be reinverted. This in turn eleminates the necessity of operating the cathode of V16 at a relatively high potential above ground. Thus it is unnecessary to use a special heater voltage supply transformer.

The design requirements of the transformer, T11, are quite critical (3). First the transformer should have a primary and secondary winding of low inductance and low distributed capacity. This is necessary if the natural resonant frequency of the horizontal sweep. It is desirable that this frequency should be high since it insures that the half cycle of free oscillation, which results in the retrace of the beam, will be short. A high ratio of retrace to scanning velocity is consequently obtained. The transformer, T11, should also have good frequency and phase characteristics. It should be designed for the frequency range between the fundamental frequency of the deflecting current and at least the tenth harmonic of this frequency. It has been found (5) that magnetic deflection amplifiers give satisfactory performance when the fifteenth harmonic is transmitted and may serve adequately when only the tenth harmonic is included. For 525-line scanning with 30 frames per second, the transformer should be designed for the frequency range between 15,750 and 160,000 cycles.

The capacitor, C35, and the resistors, R100 and R128, form a differentiating circuit across the output of the transformer, T11. This provides the correct sawtooth control voltage on the grid of V16 necessary to obtain the desired

current change of i_2. The adjustment of i_2, and thus the linearity or the deflection, is accomplished by varying the bias on the inverse power control tube by means of resistor, R102.

Approximately 12 percent of the half sine wave negative pulse voltage appearing across the horizontal deflection coil is taken from the junction of R120 and R119. This is applied to the monoscope tube control grid for the purpose of blanking out the picture during the retrace time. In this manner, the fixed reference level is established on which the clamp circuit of V9 is set at the end of each line. If this were not done the clamping circuit would operate on some erratic transient voltage generated as the beam swept the pattern electrode on the retrace.

The resistor, R103, is the horizontal centering control. It supplies a steady d-c current of controllable polarity and magnitude to the deflection coils. By the adjustment of the control, the beam can be centered horizontally on the pattern electrode. The method employed to obtain the large current required for the horizontal centering control was to use the entire resistance of R103 as the ground return for the 40 and 50 microfarad filter condensers in the low voltage power supply. R103 was then bypassed with a 500 microfarad condenser to provide adequate filtering of the d-c deflection coil current. Actually R103 is a 20 ohm variable copper alloy resistor, so that a condenser of low voltage rating can be used.

THE VERTICAL DEFLECTION CIRCUITS

The vertical driving pulses, derived from the synchronizing generator are applied to the grid of V14 through the input jack, J4. The driving pulses are critical as to width and amplitude. The duration of the pulse should correspond to 4 per cent of the vertical cycle and the amplitude may vary, within a tolerance of .5 volts, from 3.5 to 5 volts.

The vertical deflection circuits are essentially the same as those employed throughout the horizontal deflection system. Therefore, only a brief description is given in order to avoid repetition. In general, the circuit constants employed will differ because of the difference in time between a horizontal and vertical cycle. The lower repetition frequency of the system also precludes the use of a damper circuit across the output tube, since the transient voltage developed across the coil is greatly reduced.

Amplification of the input signal is obtained from the first triode section of V14, a 6SL7 employed as the pulse amplifier. The RC product of the grid circuit, C22 and R63, is notably large, since the repetition frequency is but 60 cycles. The second triode section of this tube is utilized as a sawtooth generator. The amplitude of the sawtooth waveform is determined by the height control, R69. The two triode sections of the tube, V13, are connected in a cascade coupled amplifier circuit to increase the sawtooth voltage to the proper driving level for the output tube, V12. Both sections

of this output tube, a 6SN7, are connected in parallel and coupled to the vertical deflection coil through the transformer, T10.

One half section of the tube, V11, is used as a vertical feedback amplifier to improve the linearity of the sawtooth waveform. The grid and cathode section of V11 is connected through the capacitor, C27, across the resistance, R79. This resistance is in series with the vertical deflection coils. The plate of this tube is connected in parallel with the plate of the input section of V13. The variable resistor, R81, is part of the grid leak, and determines the operating bias of the tube. This is the vertical linearity control and has effect over the whole raster.

THE LOW VOLTAGE POWER SUPPLY

The low voltage power supply was constructed as a composite part of the monoscope camera. While this feature may be considered undesirable from the standpoint of the stray magnetic fields introduced by the power transformer and choke, it was felt advantageous to have a self-contained unit. All precautions were taken to insure the exclusion of the fields produced by the power supply from the monoscope tube and from the deflection circuits. The specifications of the power supply are given as follows: input, 110-120 volts a-c 60 cycles; output voltage, 280 volts regulated d-c; maximum load current, 250 milliamperes; power consumption, 75 watts.

No particular difficulty is encountered in constructing

a power supply to meet these requirements. However, a discussion of the theoretical and practical design considerations is of interest.

The necessity of voltage regulation for the d-c source should be apparent when the ultimate purpose of the monoscope camera is considered. Obviously every refinement should be taken in the design of this equipment to insure the perfection of the test pattern generated. Poor regulation would react on the deflection circuits resulting in linear displacement or a change in picture size and on the video amplifiers causing a variation in signal strength. In addition to supplying a staple voltage under change in load, the inherent property of a voltage regulated supply to practically eliminate ripple is also of marked importance.

The theoretical aspects of the voltage regulating section will first be considered. Reference is made to Plate IX, Fig. 14, which shows a generalized circuit of a degenerative or cathode follower type of regulator. Assuming ideal tube characteristics it is found that the output voltage can be expressed by the following equation (1)

$$E_o = R_1 \left[\frac{E_1(R_2 + rp_2) + u_1 u_2 R_2 E_c}{(R_2 + rp_2)(R_1 + rp_1) + R_1 R_2 u(1 + Au_2)} \right]$$

Introducing the approximations that

$$Au_2 \gg 1$$

$$u_1 u_2 R_2 E_c \gg E_1(R_2 + rp_2)$$

EXPLANATION OF PLATE IX

Fig. 14. Basic circuit diagram of a degenerative type
voltage regulator

    Where: E_1 is the rectified and filtered direct
voltage to be regulated

        E_o is the regulated output voltage

        E_c is the negative bias voltage required
for VT2

        R_1 is the parallel resistance of load
circuit including bleeders, control
potentiometers, and actual load

        R_c is the adjustable control for E

        R_L is the load

        AE_o is the voltage from grid tap to
ground; A representing a percentage
of E_o

Fig. 15. Actual circuit of the regulator section of the
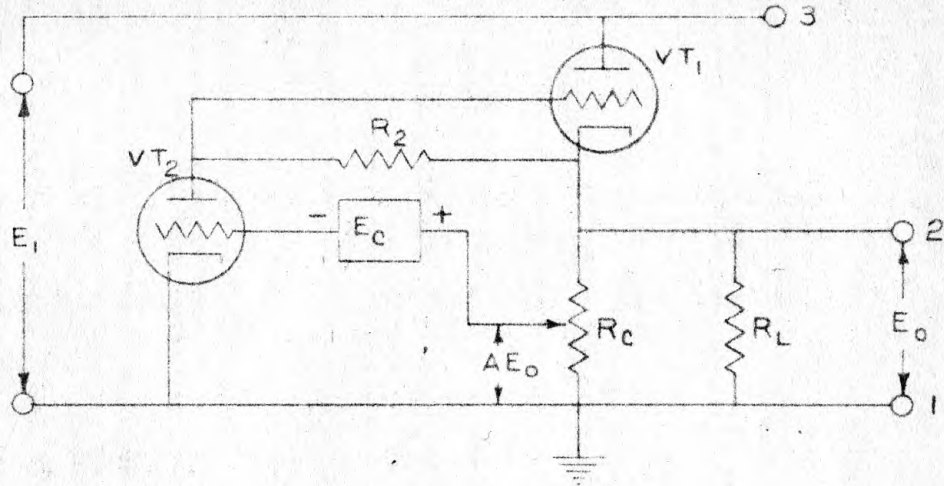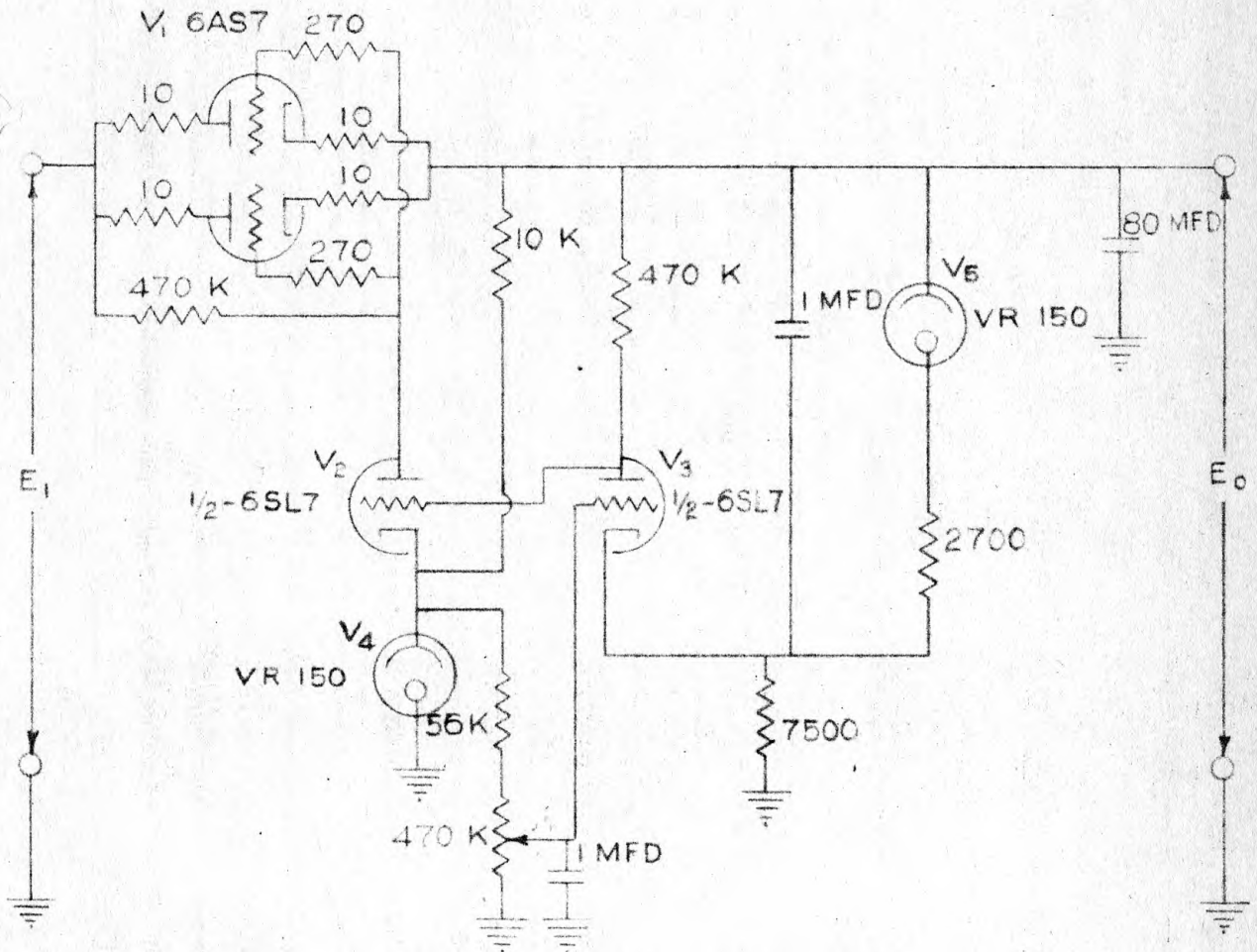monoscope power supply

PLATE IX

Fig. 14

Fig. 15

$$R_1 R_2 u_1 A u_2 \gg (R_2 + rp_2)(R_1 + rp_1)$$

then the equation will reduce to the form

$$E_o = E_c/A$$

This relationship is an important design equation irrespective of the fact that it predicts perfect regulation. From an inspection of the equation several features of the regulator become evident. The first is that smooth control of the output voltage can be obtained by manually varying the value of E_c or A. Reference to the actual circuit diagram, Plate IX, Fig. 15, shows that this control is incorporated through the use of a 470,000 ohm potentiometer in the grid of the second amplifier tube. This is a front panel control and through it the output voltage can be varied from 230 to 300 volts without the loss of regulation.

The range through which the output voltage may be varied is limited. Obviously, the output voltage is the difference between the input voltage and the drop across the pass tube, which in turn is a function of its control grid bias and plate current. One limit is therefore reached when the amplifier tube is biased to cut off resulting in zero bias on the pass tube. The output voltage will then be at its maximum value and will be determined by the load current. From the tube characteristics of the pass tube, the voltage drop across it can be found by finding the plate voltage required to support the desired load current, which will be its plate current, under zero bias conditions. It may be noted that when the amplifier tube, VT2, is cut off its plate resistance is in-

finite. Thus the equation expressing the output voltage transends from that of perfect regulation to

$$E_o = E_1 R_1 / R_1 + rp_1$$

and the output voltage is now a function of the input to the regulator.

The other limit is reached when an attempt is made to adjust the output voltage to a very low value. In this case the voltage across the pass tube is high. Thus a negative bias is required on the pass tube when the output current amounts only to that of the bleeder. However, the output voltage must supply this bias, which is developed across R2 in addition to the plate potential for VT2. Hence it becomes impossible to reduce the output voltage below a certain value determined by E_1, bleeder load, VT1, and VT2 characteristics.

The choice of the pass tube, VT1, is an important consideration since the characteristics of the regulator are essentially determined by it. The recently introduced 6AS7, a twin triode, was chosen, since it was expressly designed for this service. Their extremely low plate resistance allows the use of a lower voltage drop across them, and thus a higher output for a given input voltage. The heater cathode rating of 300 volts is advantageous in eliminating the necessity of a separate filament transformer. However, a separate filament transformer was employed in the power supply constructed, since the 6AS7 is an expensive tube. Among its other advantages are its extremely high current handling capacity. Previously four 2A3's were

connected in parallel as pass tubes to supply a load current of 250 milliamps. One 6AS7 with its triode sections in parallel will suffice.

Standard practice dictates the use of suppressors in grid and plate circuits when pass tubes are paralleled for greater current capacity. Their elimination results in highly unstable or erratic operation. It is preferable that these suppressors be mounted with one end directly supported by the tube socket lug to which it connects. Resistance values of 10 to 50 ohms for the plate and 100 to 300 ohms for the grid prove satisfactory.

The circuit diagram, Plate IX, Fig. 15, shows a 6SL7, a high mu twin triode, used in a two stage direct-coupled amplifier. The grid of the first amplifier tube should receive as large a percentage as possible of the total fluctuation present on the output. Variations in the output voltage are developed across the 7500 ohm resistor in the cathode of V3. The 1 microfarad coupling condenser represents a low inpedance path for high and medium frequencies. Attempts to feed back a greater portion of the output voltage by increasing the value of this condenser will result in erratic operation or oscillations

THE HIGH-VOLTAGE POWER SUPPLY

The high voltages necessary for the operation of the monoscope tube are obtained from a self-contained high voltage power supply. The high-voltage power supply is conventional in that it consists of an iron-core step up transformer, energized from

the power line, and a rectifier circuit with a smothing filter. Half-wave rectification as obtained using a 2X2 and the filter circuit consists of a 1500 henry choke, T9, and two 1 microfarad condensers, C19 and C20. The filter is in the negative side of the circuit, the positive side of the high voltage being grounded so that the signal plate of the monoscope tube may be at ground potential. This placed the heater and cathode of the 2X2 at a high potential and necessitated the use of a high-voltage socket and a heater transformer with a high voltage rating. However, this system is desirable for safety reasons in that the high potentials are made less accessible. It is also advantageous in that the pattern electrode can be connected directly to the grid of the following video amplifier without a high-voltage blocking condenser intervening.

Fairly elaborate filtering of the high-voltage power supply is necessary since the ripple voltage must be kept considerably smaller than the video signal generated. Since a video signal of 100 millivolts is about the maximum obtainable under usual operating conditions, the ripple voltage should be no more than 5 millivolts and preferably be no more than 1 millivolts (5). The required degree of filtering is acheived by the use of one half of a 6SL7, V11, as a voltage regulating tube. A degenerating type circuit is used, with V11 merely inserted in series with the output voltage. The regulating action of V11 is restricted in that the voltage fed back to its control grid is through an RC network. If the d-c level of the output voltage changes it will not, therefore, be corrected by the regulator

tube. This, however, is not particularly important since the load on the power supply, which is essentially the beam current of the monoscope tube, is constant. Any ripple voltage appearing in the output, however, will be fed through C21, a 2 microfarad coupling condenser, to the grid of V11 and thus reduced in magnitude through the regulating action. The tube, V11, is also bypassed by a 100,000 ohm resistor for safety reasons.

The output voltage of the power supply is approximately 1500 volts and it is capable of supplying 5 milliamperes. All voltages for the monoscope tube are obtained from a tapped bleeder resistance across the output of the power supply. Because the beam current for the 2F21 is small, large bleeder current is not required.

A 991 glow tube is shunted across R60, the beam current control potentiometer. The potentiometer arm is connected to the control grid of the monoscope and the positive side of the potentiometer is connected to the cathode. This is a precaution against excessive beam current should the output voltage of the power supply change, since the 991 provides a constant drop of 50 volts across R60.

The high-voltage power supply is also used to provide the negative bias for the clipper tube, V4, in the video amplifier.

TEST PATTERN ANALYSIS

The correct interpretation of the test pattern is fundamental to the intelligent use of the monoscope camera in testing television equipment. The particular test pattern contained

in the 2F21 is shown in Plate X, and reference is made to this
in the following discussion. The pattern is simple, yet so de-
signed that a comprehensive analysis of the equipment under
test may be made.

The ratio of the pattern's width to height is four to three
in accordance with the standard aspect ratio. The outside di-
ameter of the largest circle is, therefore, three fourths of the
width of the pattern, so that when the deflection is adjusted to
give an undistorted form to this circle, the standard aspect
ratio will be established.

In the center of the pattern there are six concentric cir-
cles, the center of which is labled 30. The radial spacing be-
tween the circles is the same spacing that would exist between
300 horizontal lines equally spaced in the vertical dimension
of the pattern. If the equipment undertest can reproduce the
pattern with these central circles separate and distinct, then
the equipment is capable of resolving 300-line detail.

The four resolution wedges radiating from the central cir-
cles are calibrated in a similar manner. The resolution lines
are of equal width in both the horizontal and vertical direc-
tions. Thus the total number of lines which can be contained
in the width of the picture is greater than that which can be
contained in the height of the picture by a factor equal to the
aspect ratio or 1.33. The center line of each wedge is dashed
so that the resolution corresponding to any radial distance is
more readily determined. The break in the center line occurs
at the same distance from the center as the arc of the resol-

EXPLANATION OF PLATE X

Fig. 16. Test pattern which is transmitted by the mono-
          scope camera using a 2F21
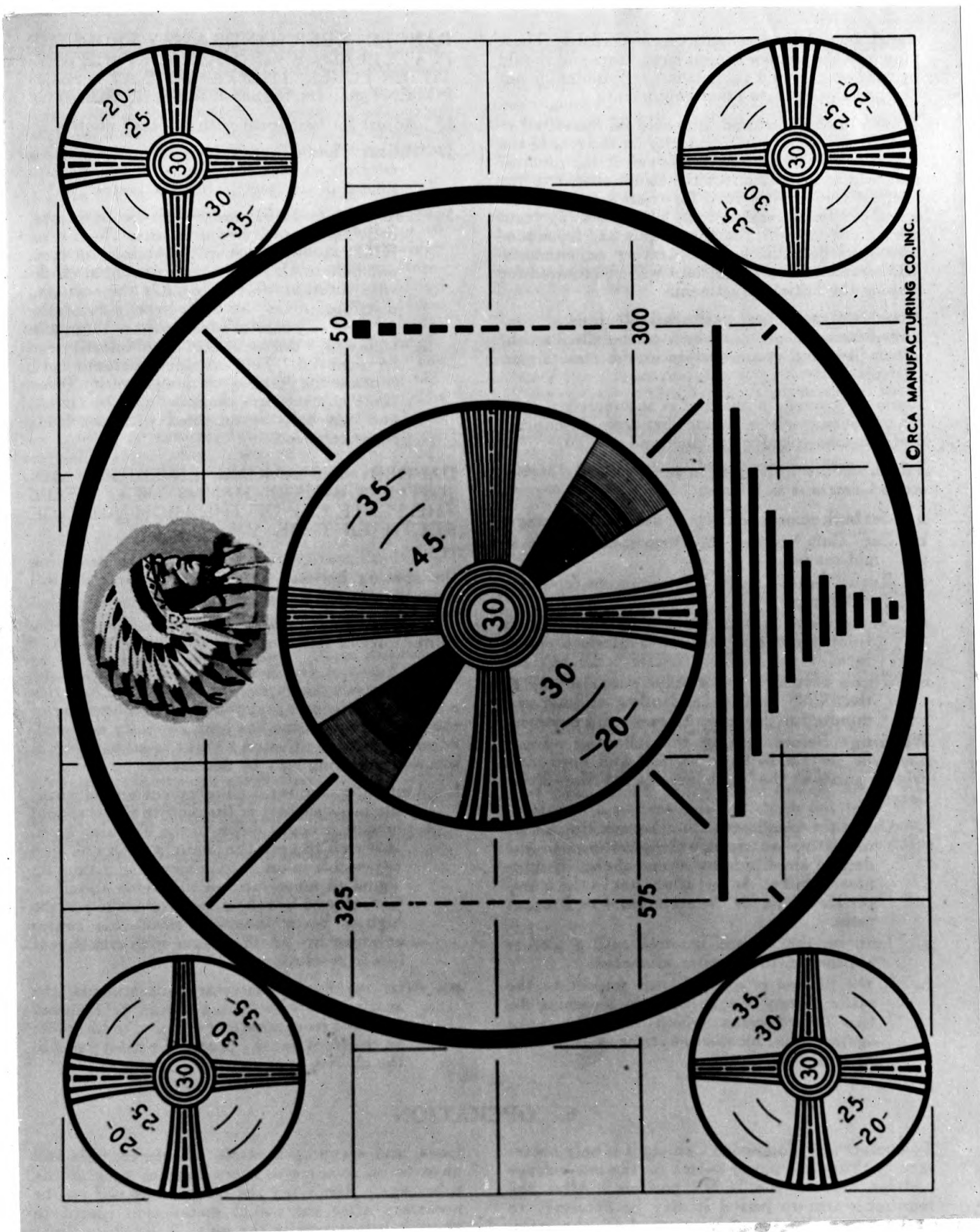
PLATE X

Fig. 16

ution numbers, and the distance between the breaks in the center
line corresponds to a change in resolution of 50 lines. The
calibration numbers should be multiplied by 10 to obtain the
number of lines resolution. The upper vertical and right hand
horizontal wedges vary in spacing from 300 lines at the outer
ends of the wedge to 500 lines at the inner end. The lower
vertical and left-hand horizontal wedges vary from 150 to 350
lines. In all four wedges, the number of equivalent lines
varies linearly along a radius. The point in the wedges where
distinction between individual lines just disappears, indicates
the resolution of the system under test

In measuring resolution, distinction must be made between
the ability of the equipment under test to resolve detail along
a horizontal line is necessarily measured by the vertical wedges
and resolution along a vertical line is indicates by the hor-
izontal wedges. If the situation should arise where the vert-
ical resolution of the system under test is comparable to the
number of scanning lines, then a spurious diamond-shaped pat-
tern appears in the reproduction of the horizontal wedges. This
spurious pattern is made up of the intersections of wedge lines
with scanning lines and the resultant pattern should not be re-
garded as a defect in the reproducing equipment.

Also enclosed within the inner circle are two wedges set
on a 45 degree angle to the horizontal. Each wedge is composed
of four distinct sections, the difference between each section
arising in the degree of shading. The variation ranges from
100 per cent black to 25 per cent black in equal divisions.

These wedges provide a test for amplitude distortion of the video signal.

To the right end to the left of the central wedges are two vertical rows of small rectangles. The figure 50 above the right hand column indicates that the top rectangle has a width equal to 1/50 times the height of the pattern, and is thus indicative of 500-line detail. The rectangles in the right hand column progressively decrease in width in steps equivalent to 25 lines up to 300-line detail, and similarily on the left hand column from 325 lines to 5"." lines. These two rows of rectangles are useful in testing for undesired transients, since trailing is sometimes shown up more clearly by the rectangles than by the wedges.

Below the central wedges is a set of 11 horizontal lines whose length varies logarithmically. The length of each line is 71 per cent of the length of the line above it. The shortest line has a length 1/50 times the heigth of the pattern; the longest line is 1/1.5 times the height. These lines are useful in observing defective low frequency responses in the video range, and trailing in the reproduction of these lines is indicative of the improper adjustment of the low-frequency compensating circuits.

Above the central wedges is an Indian head which provides a test of the general quality of the reproducing system. This is especially true with respect to contrast and average brightness which are most easily judged on a pictorial subject.

The largest circle and the circle surrounding the central

wedges provide a test of linearity of scanning in the horizontal and vertical direction. If the circles have an egg-shaped outline, then the rate of scanning is nonlinear, in the vertical direction when the axis of symmetry is vertical and in the horizontal direction when the axis is horizontal. Linearity of scanning is also tested by the 45 degree lines and by the grid squares into which the pattern is divided. The fine lines which form these squares have a width of 1/600 times the height of the pattern and will immediately reveal any orthogonal distortion in any part of the image.

In each of the four corners of the pattern there are resolution wedges. If the resolution in the corners of the pattern is poorer than that given by the control wedges, the conclusion is that spot defocusing is present. Since some spot defocusing is inherent to all kinescopes, the resolution in the corners as compared to the resolution of the system is a measurement of the relative defocusing present.

USES OF THE MONOSCOPE

The monoscope camera is a comprehensive piece of television test equipment and may be used for a variety of purposes. In commercial applications, the television transmitting station may employ the camera to transmit a test pattern during warm-up and stand-by periods. Station identification can be simultaneously provided if the station call letters are printed on the pattern electrode.

Another interesting commercial application is the use of

the monoscope in obtaining a fixed background for studio work. The final signal is a combination of the video signal from an iconoscope, which might represent action, and that from the monoscope for background.

The monoscope camera is also used in many laboratories and factories to obtain a television signal which can be used to test television receivers. In conjunction with a synchronizing generator and a distribution amplifier it produces a standard R.M.A. video signal for use in testing video amplifiers and picture tubes. With the addition of an I-F sweep generator and an R-F generator it produces a complete television picture signal simulating that received off the air and thus provides a means of testing receivers under conditions equivalent to actual use. Plate XI, indicates the arrangement of the necessary equipment.

Primarily, however, the main application of the monoscope camera remains in testing television transmitting systems. It furnishes the transmitting station with an always available source of video signal of known quality which can be substituted for the studio cameras whenever it is desired to check or adjust the operation of the following units in the system. In this respect the monoscope has aided materially in the advancement of the television art.

EXPLANATION OF PLATE XI

Fig. 17.   Equipment arrangement for testing a television
          receiver fed from a monoscope camera
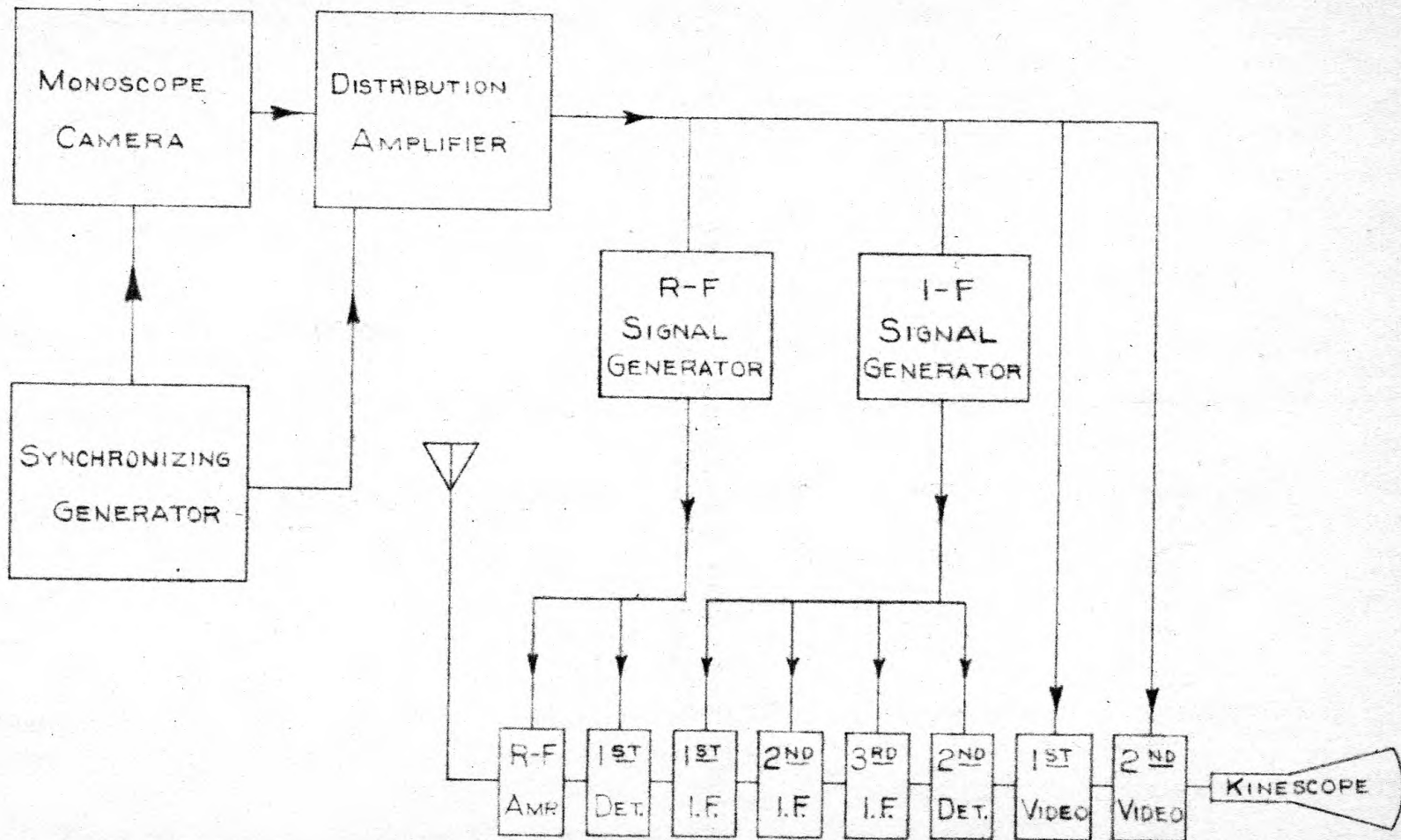
PLATE XI

Fig. 17

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