FIG. 1. ... hird tall rack ... Color Slide Camera Remote Control Panel. Adjacent racks house the sync generator equipment, gamma amplifier, colorplexer, decoder and power supplies. For broadcast service, these racks of equipment (less the three-tube monitor and the rack-mounted master monitor) are supplied as accessories.

RCA COLOR SLIDE CAMERA, TK-4A

by W. E. TUCKER
Supervisor, Color Slide Camera Design Engineering

and F. J. JANDA
Development Design Engineer, Color Slide Camera

The Color Slide Camera converts the information on a color transparency into three separate video signals proportional to the red, blue and green components of the transparency. This type of reproduction is capable of high resolution and inherently perfect registration of the three video signals and is also suitable for reproducing color movies when used in conjunction with a fast pull-down or continuous projector mechanism.

Color Slide Camera Components

The block diagram in Fig. 2 shows the essential components of the Color Slide Camera. These components, except for the gamma amplifier, constitute the Color Slide Camera unit. The Kinescope, with its associated deflection chassis and 27 KV power supply, provides the light which passes through a lens to the color transparency. Color separation is accomplished in the pick-up unit where the color intensity variations are transformed into color video signals. The units which follow amplify and modify these signals so that they are proper for operating a simultaneous monitor or for feeding a colorplexer for eventual transmission.

The light-source Kinescope is a specially designed 5-inch flat faced tube (see Fig. 4). In order to perform satisfactorily as the light source, the spot must be small, the phosphor must have sufficient light output covering the entire visible spectrum (see Fig. 9A) and it must also have an extremely short persistence. The phosphor is specially screened so that any visible grain structure is extremely small and uniform. The gun alignment must be extremely accurate in order that the electron beam be circular, of small diameter and require minimum electrical centering. The ultor (second anode) voltage is 27 KV and the first anode voltage is about 6 KV. The beam current of the Kinescope is about 200 micro-amperes and is limited by phosphor saturation and focusing ability.

A cover over the Kinescope is provided for protection from X-rays and high voltage. An interlock turns off the high voltage when the hinged cover is opened. The Kinescope raster can be viewed through an X-ray glass window in the front of the cover when it is closed.

The 27 kilovolt ultor voltage for the Kinescope is produced by an R.F. type regulated supply (Fig. 5). It is capable of at least 750 μa output at 27 KV and also supplies the first anode voltage through a high resistance bleeder and focusing potentiometer. The high voltage oscillator operates at a frequency of about 75 KC and a voltage doubler rectifier circuit increases the high voltage to its required level. The entire supply is contained in a removable copper-plated housing which minimizes R.F. radiation from the oscillator. Finger type contacts provide good contact between the cover and chassis.

A course focus control is provided on the front panel of the supply while a fine adjustment is located on a remote control panel.

Fig. 6 shows the deflection chassis. Special features of this chassis provide for both horizontal and vertical deflection circuits which are capable of excellent linearity as in the case of any high quality camera device. Only a very small amount of defocusing can be allowed in the corners of the raster. Appreciable defocusing in addition to causing poor corner focus would also cause improper shading because a slightly defocused beam produces higher light output when the phosphor is operated near its saturation point. A blanking signal is developed on this chassis and is applied to the Kinescope grid to cut the beam off during the retrace interval. The control panel on this chassis contains size, centering, beam current control and a provision for metering the high voltage and beam current. Another provision is an electronic protection circuit which cuts the Kinescope off in the event of loss of either horizontal or vertical deflection, thus protecting it against phosphor burns.

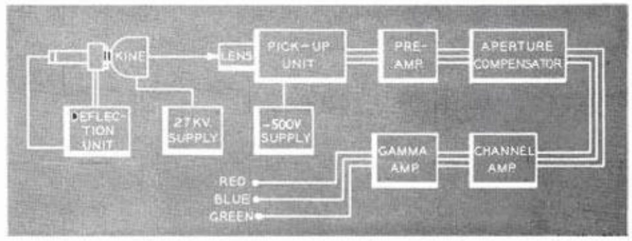


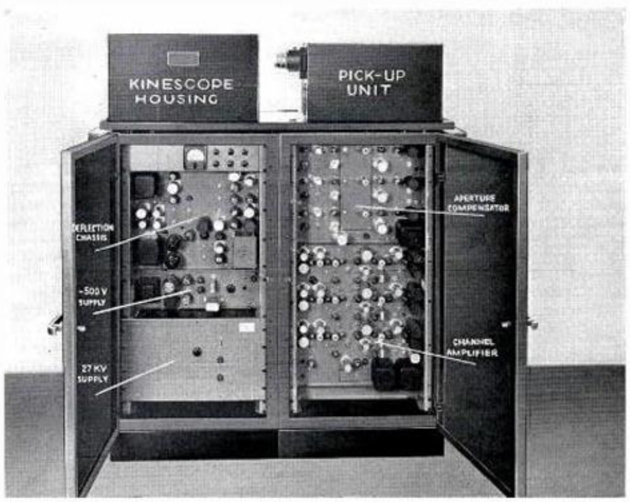
FIG. 2. Color Slide Camera unit diagram.

The deflection chassis is of the rack mounting type and, together with the 27 KV supply, is operated from a WP33B 280 volt power supply. Input signals required are horizontal and vertical drive and blanking. Two Twinax cables carry the deflection signals to the yoke on the Kinescope.

The actual optical assembly is shown in Fig. 8. For purposes of discussion Fig. 7 illustrates the optical parts in the pick-up unit. The blank raster which is produced on the Kinescope (A) is sharply focused by the objective lens (B) on a color transparency (C). The condenser lens (D) is located so that its focal point coincides with the exit pupil of the objective lens thus rendering the light rays parallel. Since color is a property of light involving 3 variables, it can be separated into its primary components (Red, Blue and Green) by means of the color selective dichroic mirrors (E, J). The separated primary components are condensed by lenses (G, K, N) which image the exit pupil of the objective on the photo cathodes of 3 photomultiplier pickup tubes (I, P, M). The photo multipliers thus receive varying intensity of light as the spot of light scans the color transparency; the raster itself being completely out of focus. The photomultiplier tube outputs are the required simultaneous color video signals which are amplified and processed similar to monochrome video.

The spectral sensitivity of each channel in the Color Slide Camera is adjusted to closely match the theoretical sensitivity

FIG. 3. Color Slide Camera front view.



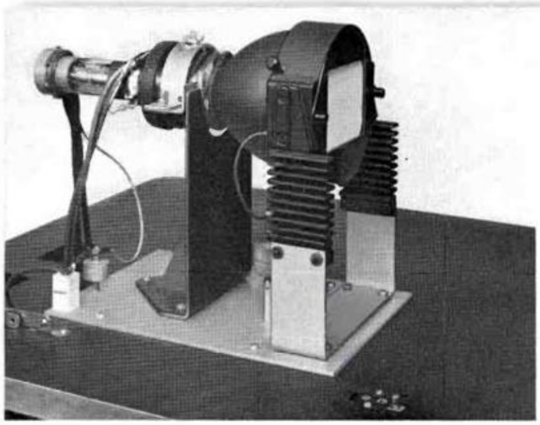


FIG. 4. Kinescope and mounting. Kinescope is used as light source for scanning slide transparency. See Fig. 7 for Kinescope position in relation to overall system.

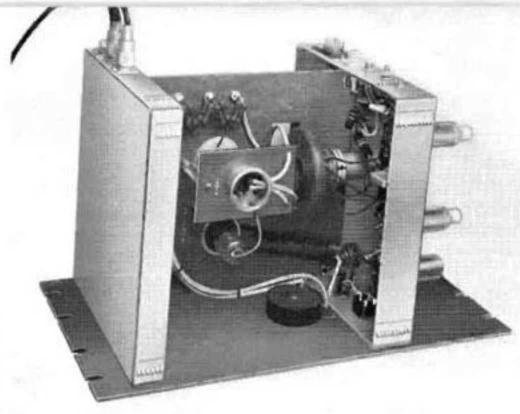


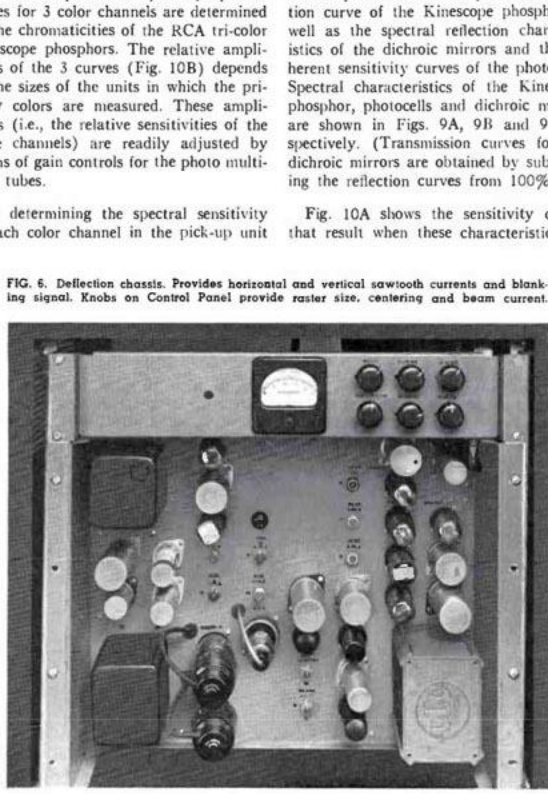
FIG. 5. 27-KV Power Supply used to furnish focusing and Ultor voltages (second anode voltage) for camera kinescope.

curves required for perfect color reproduction. The shapes of the primary spectral curves for 3 color channels are determined by the chromaticities of the RCA tri-color Kinescope phosphors. The relative amplitudes of the 3 curves (Fig. 10B) depends on the sizes of the units in which the primary colors are measured. These amplitudes (i.e., the relative sensitivities of the three channels) are readily adjusted by means of gain controls for the photo multiplier tubes.

In determining the spectral sensitivity of each color channel in the pick-up unit prior to correction by trimming filters, it is necessary to consider the spectral distribution curve of the Kinescope phosphor as well as the spectral reflection characteristics of the dichroic mirrors and the inherent sensitivity curves of the photocells. Spectral characteristics of the Kinescope phosphor, photocells and dichroic mirrors are shown in Figs. 9A, 9B and 9C respectively. (Transmission curves for the dichroic mirrors are obtained by subtracting the reflection curves from 100%.)

Fig. 10A shows the sensitivity curves that result when these characteristics are properly multiplied together for the three channels. The filters marked H, L and O in Fig. 7 are used to modify the spectral response curves to the shapes shown in Fig. 10B; these curves closely approximate the ideal curves required for good color reproduction.

FIG. 6. Deflection chassis. Provides horizontal and vertical sawtooth currents and blanking signal. Knobs on Control Panel provide raster size, centering and beam current.



The dichroic mirrors function by means of the interference phenomena of light. A thin dichroic coating is evaporated on optically flat glass, the thickness of coating and angle of incidence determining the spectral response; i.e., which colors will be passed and which ones reflected. Both mirrors in the unit are placed 45 degrees to the angle of incident light with a 45 degree silvered mirror (F) Fig. 7, used merely to condense the space the optics and photomultipliers occupy. The mirrors are nearly 100% efficient; that is the light that is not reflected is transmitted and a negligible amount is lost by absorption. To prevent multiple internal reflection within the mirrors the back sides are low-reflection coated.

The photomultipliers are the head-on variety. RCA 5819 type tubes are used in the green and blue channels while the RCA 6217 type is used in the red. A −500 volt regulated supply (Fig. 3) in addition to the standard +280 volts from the preamplifier power supply provides voltages for the 10 photomultiplier dynodes. Individual photomultiplier gain is accomplished by controlling the #4 and #5 dynode voltages. An f/1.9 50 mm Ektar objective lens is used. Variations in overall slide densities are compensated for with the iris in this lens.

Remote Control Panel

Remote adjustment of iris, photomultiplier gains, pedestal, and fine Kinescope

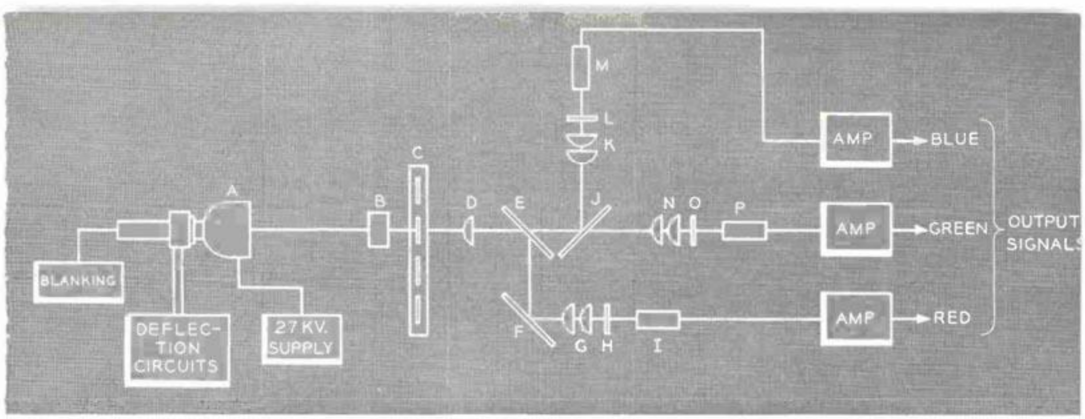


FIG. 7. Diagram showing elements comprising the slide camera optical system as illustrated in Figs. 4 and 8. Complete optical system is contained in the two table-top housings of Fig. 3.

focus are provided on a "remote control panel" located at the control console. This panel (Fig. 1) can also be rack mounted with the addition of a rack adapter. A push button switching system is necessary for level adjustment of the red, blue and green video signals with a provision for viewing each color individually on an RCA Master Monitor, MI-26136-A. There are several spare switching inputs to monitor other signals.

The Preamplifier

The preamplifier is shown in Fig. 8, upper right, partially hidden.

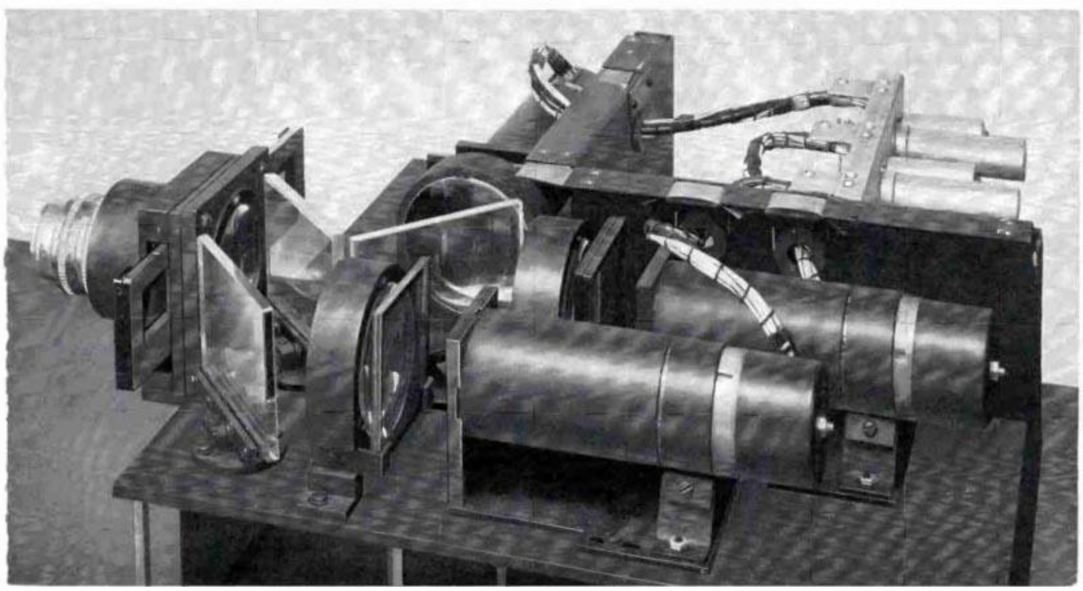
The photomultiplier output of .05 volt peak-to-peak signal is amplified to 0.2 volt peak-to-peak in the preamplifier. Three identical channels use 6AK5 input tubes for low microphonics and high gain followed by a 6AH6 video amplifier. The output stage is a 5763 tube feeding a 51 ohm coaxial cable which carries the video to the next unit. The frequency response is flat to 8 MC corresponding to 640 lines resolution.

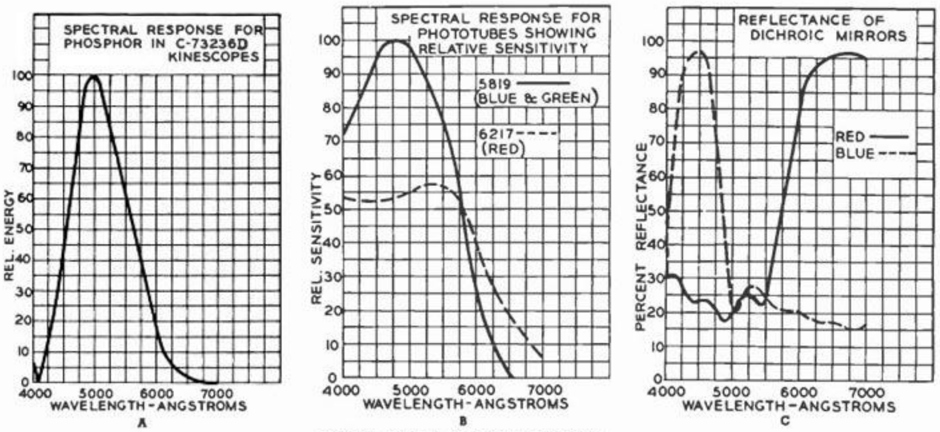
Each channel of the preamplifier contains 2 variable high peaking circuits to compensate for phosphor decay time. In an ideal system only one spot of the subject would be illuminated at a given instant by the Kinescope. However, practical phosphors although having extremely short persistence must always have a finite decay time so that each part of the screen continues to emit light in accordance with an exponential decay curve for an appreciable time after the scanning spot has passed. Thus the photocell output is not an instantaneous function of the transmission of the slide transparency from point to point.

Finite phosphor decay-time produces an effect similar to that of a low pass filter resulting in a loss of the high frequency response. This effect on a square wave is shown in Fig. 11.

Frequency compensation is accomplished in the first two stages of the preamplifier by using cathode peaking. Controls are provided to adjust the amount of compensation at both the low and middle range of the video spectrum.

FIG. 8. Pick-up unit. Consisting of objective lens, slide holder, dichroic-mirrors, condensing lenses, corrective filters, multipliers and preamp (partially hidden—upper right).





FIGS. 9A, B and C. Spectral response curves.

The preamplifier and the aperture compensator, discussed below, are powered by one WP-33B power supply.

Aperture Compensator

The video signals from the preamplifier are cabled to the aperture compensator (Fig. 13). This unit is designed to correct high frequency video information which is lost by virtue of the finite scanning beam size. The effect of a finite aperture in the slide camera is similar to inserting a low-pass filter in the video channel. Attenuation and phase shift also depend on the cross-sectional shape of the scanning beam and electron density distribution.

The aperture compensator must be restricted to a device which modifies the frequency response, yet maintains a constant or linear phase characteristic with frequency. Ordinary transmission lines fall into this category, but a lumped constant delay line of several sections is a very close approximation. A dispersionless line, designed to have an electrical length of one-half wavelength at 9 MC, is used. The sending end of the line is terminated in its characteristic impedance, while the receiving end is left open. The effective frequency response at the receiving end of the line is flat, but the response at the sending end follows a cosine law because of the reflection from the far end. Video signals from each end of the line are fed to a differential amplifier to produce a difference signal that follows a cosine law with minimum gain at low frequencies and a maximum gain at 9 MC. A maximum boost of about 10:1 is available with the peak occurring at about 9 MC. Two concentric pots act as a boost control, keeping the low frequency video constant.

With the aperture compensator in the circuit the video response of the slide camera can be made flat within 10% to 4 MC (corresponding to 320 lines resolution) in the center portion of the picture. Without aperture correction the response is down about 60% at 4 MC. By use of the aperture compensator the "limiting" resolution is extended to better than 600 lines. The unit contains four tubes per channel and is on a standard 19-inch rack mounting chassis. The frequency response is flat to 8 MC without correction and a feedback amplifier capable of terminating the sending end of a 51 ohm line is used for the output stage. The aperture compensator has unity gain and is designed to operate at a signal level of 0.25 volt peak-to-peak.

The Channel Amplifier

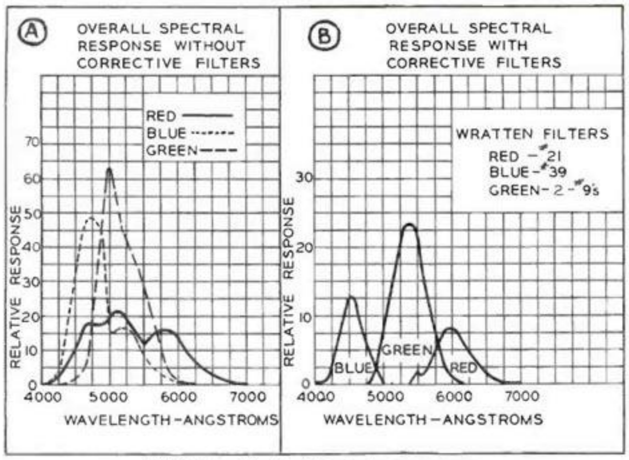
The next step in processing the color signal is to clamp, add blanking, clip and amplify to a standard RMA 1.0 volt peak-to-peak level. These operations are standard in any of the monochrome live pick-up or film camera equipment and are executed in this unit in the conventional manner. The channel amplifier has 3 identical channels with 2 video outputs per channel. An input gain control is provided in each channel and the output stages have gain controls to balance each to the same level. A four-position input switch provides for selection of a green signal to all 3 channels, standard operation and 2 test signals which are necessary in setting up the equipment. Pedestal adjustments are provided on the chassis to adjust the tracking of the pedestal controls on the remote control panel. One overall and three separate pedestal adjustments are provided.

The circuitry of a similar type of Channel Amplifier is thoroughly described in the article "RCA Color Camera Chain" by F. W. Millspaugh, Page 68.

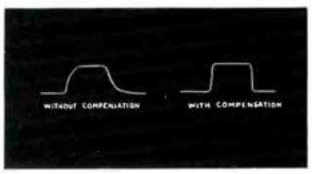
Gamma Amplifier

This unit (Fig. 14) is not located in the Color Slide Camera 42-inch racks, but it is very necessary in the production of a correct color picture. It is a unity gain gradient corrector commonly known as a gamma amplifier. The problem of gradient (or gamma) correction in color TV systems is more important than in monochrome. Non-linearities produce distortions in the gray scale or tone rendition of a monochrome picture, but both luminance (brightness) and chromaticity (color) distortions are introduced in the color process. The overall gradient of the Color Slide Camera is linear, the photocell output being linear with illumination and the video amplifiers are high quality linear devices. The RCA tri-color Kinescope has a static transfer characteristic that closely follows a 2.2 power law for each color. A non-linear amplifier must therefore be used in the Color Slide Camera chain in each channel to compensate for the transfer characteristic of the color Kinescope (Fig. 12).

The gamma amplifier essentially provides the inverse transfer characteristic of the tri-color Kinescope by changing its gain at three different video levels; the blacks and dark grays of the picture receiving greater amplification than the peak whites. This



FIGS. 10A and B. Overall spectral response curves.



A B

FIG. 11. Waveforms showing the effect of phosphor decay time. A. without compensation. B. with compensation.

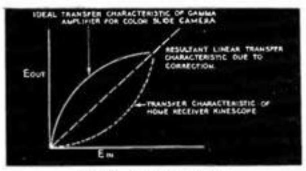


FIG 12. Gamma curves.

operation is accomplished by controlling the cathode impedance and hence the gain of a video amplifier by means of germanium crystals each one of which conducts and shunts the cathode degeneration resistor at a different video level.

The gamma amplifier is on a 19-inch rack mounting chassis and is operated from a standard WP-33B power supply. Two outputs, as in the case of the channel amplifier, are provided in each channel. The frequency response is essentially flat to 8.0 MC and the correction is variable from a power law of 2.0 to 2.5. The color signal can be viewed on a simultaneous monitor from one set of outputs while the others feed the colorplexer (described below).

Auxiliary Equipment

To obtain a complete color picture signal certain equipment is necessary. This equipment, which is common to the color television system, is briefly mentioned below.

The required sync signals are horizontal and vertical drive, RMA sync and blanking. These signals are obtained from a standard sync generator which is not 60-cycle controlled but is controlled by the 3.579545 MC frequency standard which counts down to a 31.5 KC signal; this signal is then used to synchronize the sync generator.

In order to produce a composite signal the three simultaneous signals must be fed to the colorplexer where the signals are "coded" and burst is added. The burst signal of 3.579545 MC comes from the frequency standard and is keyed into 9-cycle groups, at a horizontal line rate, by the burst flag generator. The burst is added in the horizontal blanking interval following the sync pulse. Sync can be added in the colorplexer or if desired delayed sync can be added after video switching.

Black-and-white monitoring equipment is required to set individual color levels and to check the colorplexer signal. A color monitor is necessary to view the line signal. This picture is equivalent to that on a color TV receiver.

FIG. 13 (below). Aperture Compensator. Serves to restore high-frequency video information—providing greater picture detail.

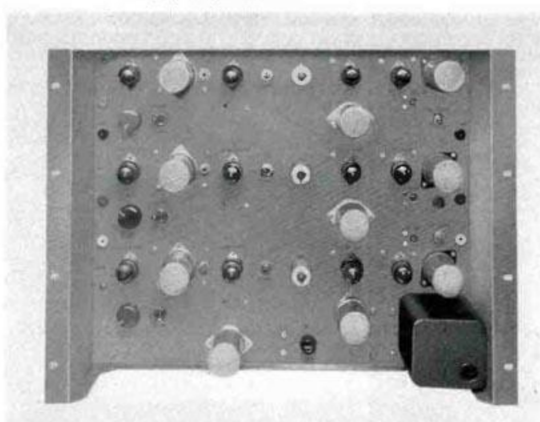


FIG. 14. Gamma Amplifier. A non-linear amplifier used to correct the video signals for the non-linear characteristics of the receiver kinescope.