RECENT DEVELOPMENTS IN COLOR-TELEVISION CAMERA EQUIPMENT

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Summary

The many factors which have brought color television to its present state of enthusiastic acceptance in the United States are reviewed. A detailed description of a recently developed color-television camera is presented. This camera, operating within the already established United States color television standards, achieves improved performance, higher stability, and ease of operation.

Introduction

It has been eight years since standards for commercial operation of color television were adopted in the United States--eight years which have been devoted to continuous improvement of apparatus and techniques, and unceasing investigation of procedures to attain the studies casualness of operating methods that comes only with complete confidence in the system. Networking problems have practically disappeared.

Today's color television cameras represent important and extensive improvements to the original concept but operate on the same basic principles. Dichroic mirrors and appropriate lenses are used to split the light from the scene into three channels of red, green, and blue light. These channels enter three camera tubes, thus producing three electrical signals corresponding to the three picture components. Then the components of these three signals with frequencies below two megacycles are processed to produce a subcarrier which transmits hue and chrominance information. This frequency limitation of the signal is possible because of the principle of "mixed highs" as applied to human vision. The total signals from the three camera tubes are combined to form a luminance signal which insures compatible operation of black-and-white receivers. The RCA TK-41 color-television camera, using three three-inch Image Orthicons, has gone through an evolution of improvement in the dichroic light-splitting methods and in circuit stability until it is capable of a high peak of performance.

However, the growing emphasis on video-taping of color TV shows, while offering commercial and artistic advantages, places an increased burden on color cameras, which are required to operate for long periods of time at peak performance without the need for re-registry or readjustment.

The requirements may be classified into major categories:
(1) obtain three color picture components of geometrical identity with respect to size, linearity and other geometric features; (2) superpose these three picture components; (3) maintain these conditions for long periods of time; (4) stabilize quickly. The degree of precision required is quite high. If the two primary colors are displaced in opposite directions by one-tenth of one per cent from the third color, the limiting resolution occurs at 300 TV lines, even though the three pictures have perfect geometric matching.

Circuits and novel schemes for eliminating or minimizing the various instabilities were developed by starting with detailed studies on the color camera itself. As an example, the horizontal deflection circuits were found to be well-behaved as originally built.

The vertical deflection circuits showed serious variations of linearity with time or operating temperature. This was caused by change of resistance of the vertical copper windings with temperature.

By placing thermistors of suitable negative coefficient within the coil structure and in series with the windings it is possible to make the variations of resistance negligibly small over the operating temperature range, solving the problem of vertical mis-registry due to this cause. Certain critical electrolytic capacitors whose impedance changes with temperature affected the sweep linearity were replaced with tantalytic capacitors. These have negligibly small temperature coefficients. A considerable increase in component cost appears completely justified in removing an effect with high nuisance value.

By the use of stable mechanical vertical and horizontal centering or registry adjustments, one can use electrical registry as a vernier adjustment, with great improvements in long-term stability.

Theoretical and experimental studies were made on the image-orthicon tube and its circuits to determine the precision control and stability characteristics required for various electrical parameters of the tube to produce and maintain optimum resolution, signal-to-noise ratio, and video output level within limits adequate for even the most critical observers.

Square wave burst patterns are used to measure aperture response and the results can be transformed into "sine-wave" or N_e values at a given line number. A burst pattern used for such measurements and typical video output waveform is shown in Figure 1.

A typical response curve of precision-built image-orthicon tubes such as the RCA-7513 three-inch tube is shown in Figure 2. Burst techniques will measure degradation of response due to circuit drifts which are imperceptible to a critical viewer.

In order to meet this resolution the magnetic focus fields must be held to within 0.2 per cent of optimum value and the focus voltages to within 0.5 per cent of optimum value. This precision must be maintained on a recycling basis from cold starts and must include compensation for all effects due to changes in component values with operating and normal line voltage drifts.

The signal-to-noise ratio of the image-orthicon video output current is directly proportional to the percentage of beam current modulation obtained at the target, and the amount of beam current itself. Percentage of modulation is governed by the operating light level relative to the knee, and the target-to-mesh spacing. It is a fixed value for a tube of given target spacing under a given operating condition. The signal-to-noise ratio of the tube may fluctuate rather widely during the first 15 minutes of the warm-up cycle, and thereafter may show random variation of about 20 per cent. Fluctuation of beam current is directly responsible for this behavior with the image-orthicon tube, due to the relatively long thermal time constant of the electron gun structure. The inherent beam current stability is insufficient even if all of the operating voltages concerned are stabilized. Means were devised to stabilize the beam current rather quickly during the warm-up cycle and to minimize the amount of fluctuation by a feedback loop utilizing the transconductance between beam control electrode (G-1) and aperture (G-2) of the image-orthicon tube itself. Behavior of beam current during the warm-up cycle with and without such stabilization is shown in Figure 3.

Cameras modified to have the features discussed here have verified the results in picture sharpness and registration obtained in our experimental developments. Controlled tests of these modified camera systems have shown the stability and recycling characteristics to be consistent from day to day.

A practical outgrowth of this development has been that the habitual realignment of cameras is no longer required. It is possible that set-up controls will be inaccessible to the future program video operator. Thus he can devote all of his efforts to producing better color pictures.

The same general approaches to performance stabilization have also been applied to the 3-vidicon color film chain and to color monitors. It is our belief that improvements of the type described will be used in all new camera designs to provide recycling performance at a high technical level of excellence. Only minor readjustments on a long-range basis as determined by critical tests will be required. In day-to-day operation the cameras should require no readjustments.

All RCA color live and film cameras now being manufactured have the recycling and stability features we have described. In addition, the RCA Service Company has complete information, "know how", and the required components for modification of earlier color cameras now in the hands of broadcasters.

Alternative means of producing color pictures are continually being explored. Considerable work was done on cameras which produce the luminance signal directly from a conventional black-and-white camera tube, using two other camera tubes for obtaining two colors, and then obtaining the third color by subtraction of these two color signals from the luminance signal. This approach revealed improvements of reception on black-and-white receivers, where the pictures were of great sharpness and practically independent of the accuracy of registry of the three tubes. Because the tube characteristics were non-linear, the subtraction process introduced large unwanted signals in the color information. An examination of the correction circuitry required to achieve acceptable color pictures revealed that the cure might be worse than the disease.

In April of this year, we demonstrated at the Convention of the National Association of Broadcasters an experimental model of a camera which achieves much that we have hoped for in a color-television camera. Basically, the camera consists of one ordinary three-tube color camera plus one monochrome camera. Figure 4 is a schematic diagram which shows the principle of operation. With the switch in Position A, we have conventional three-tube camera operation where the three color-camera tubes produce red, green, and blue signals which are in turn processed to produce the luminance signal and the signals which modulate the color subcarrier. When the switch is in Position B, the output of the three color-camera tubes is used only in modulating the color subcarrier, while the luminance signal is derived only from the large black-and-white camera tube.

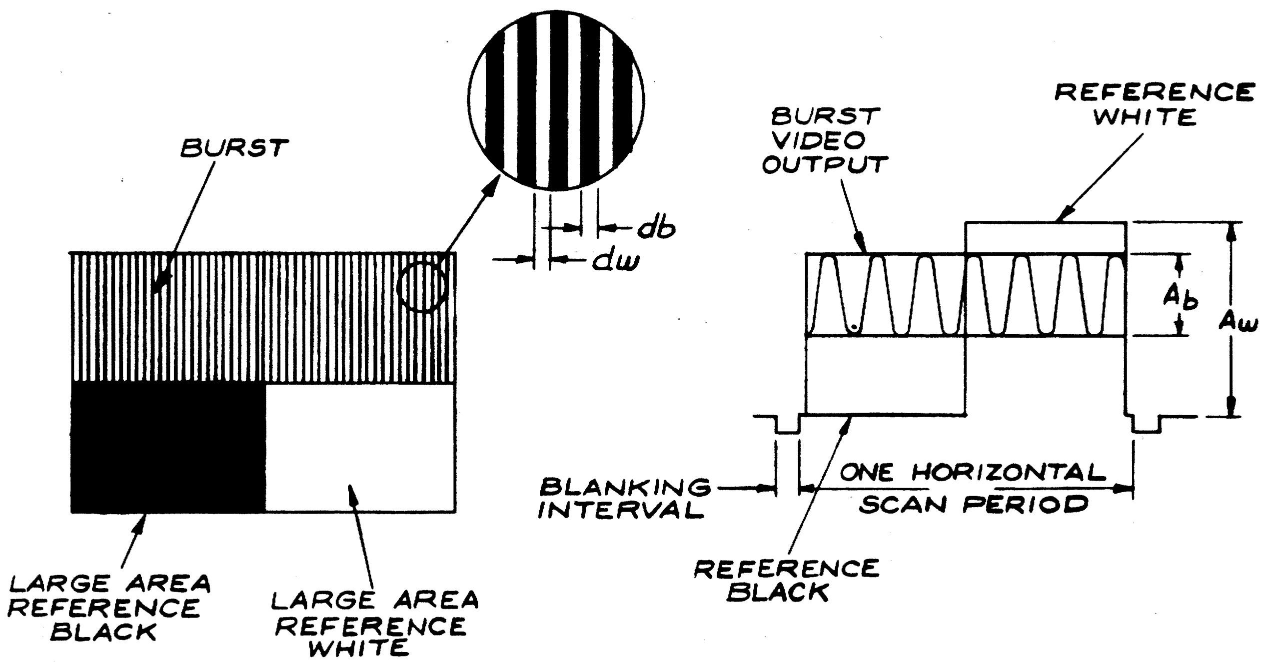
In this experimental camera we used a 4 1/2-inch Image Orthicon for the monochrome pickup and three 1-inch vidicons for the color pickup. The vidicons are a developmental type having electrostatic focus and deflection.

Since the monochrome signal is derived solely from the monochrome pickup tube, the picture quality as seen on a black-and-white receiver is identical to that from an ordinary black-and-white camera except for any effects due to the color subcarrier.

Figure 5 shows the optical layout of the experimental model camera using a built-in Taylor, Taylor, Hobson Varotal lens with a total range of focal length from 1.6 inches to 40 inches. The lens has the advantage of a very long back focal length - about 12 inches - which simplifies the light-splitting problems. The light emerging from the lens is first split so that 20 per cent is passed to the monochrome pickup tube and the remaining 80 per cent is divided by means of dichroic mirrors and passed to the three vidicons. Since the three color paths are symmetrical, no discrimination due to polarization of light occurs, an effect which so often results in "green hair" in the older camera.

Figure 6 shows an operator's view of the experimental camera, while Figure 7 is a front view. The present four-tube camera requires a scene illumination of 250 foot-candles with a lens opening of f.8. The amount of light required is of course determined primarily by lag in the vidicon. With the present light division and 250 foot-candles of illumination, the subjective effect of the lag in the vidicons is noticeable but not particularly annoying.

Our limited laboratory experience with this experimental camera indicates that the four tube approach to color cameras is fundamentally sound, and it appears ultimately capable of the improved performance required for a commercial product. Our critical tests have disclosed many detailed problems connected with vidicon tubes, ultimate sensitivity, instrumentation, optics and probable broadcasting operation requirements. These problems are now being studied thoroughly by our Advanced Development activity. Only when these problems are solved in a satisfactory manner can one seriously consider a product design. Since we plan to continue our engineering effort and policy of improving and updating the present TK-41, three I.O. color camera, it is assured of a continuing long and honorable career in the production of live color video programs.



dw = WIDTH OF WHITE LINE

db = WIDTH OF BLACK LINE

$$dw = db = \frac{\text{PICTURE HEIGHT}}{\text{TV LINE NUMBER}}$$

A_b = AMPLITUDE OF BURST OUTPUT

A_w = AMPLITUDE OF REFERENCE WHITE

$$\frac{A_b}{A_w} \times 100 = \text{\% APERTURE RESPONSE}$$

Fig. 1

TYPICAL SQUARE WAVE
APERTURE RESPONSE
TYPE 7513 IMAGE ORTHICON
MEASURED WITH PRECISION
DEFLECTION COMPONENTS

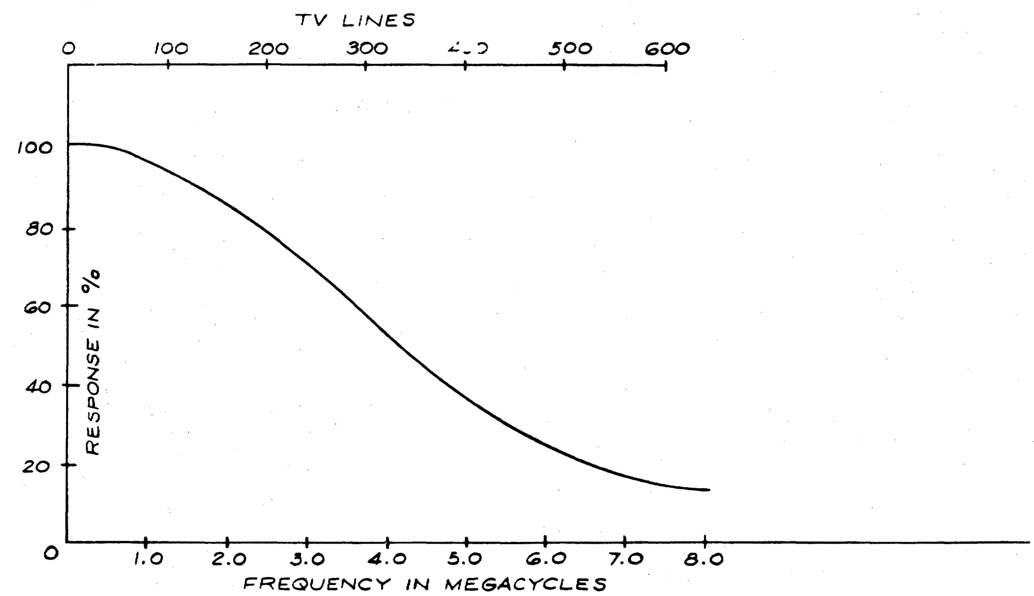


Fig. 2

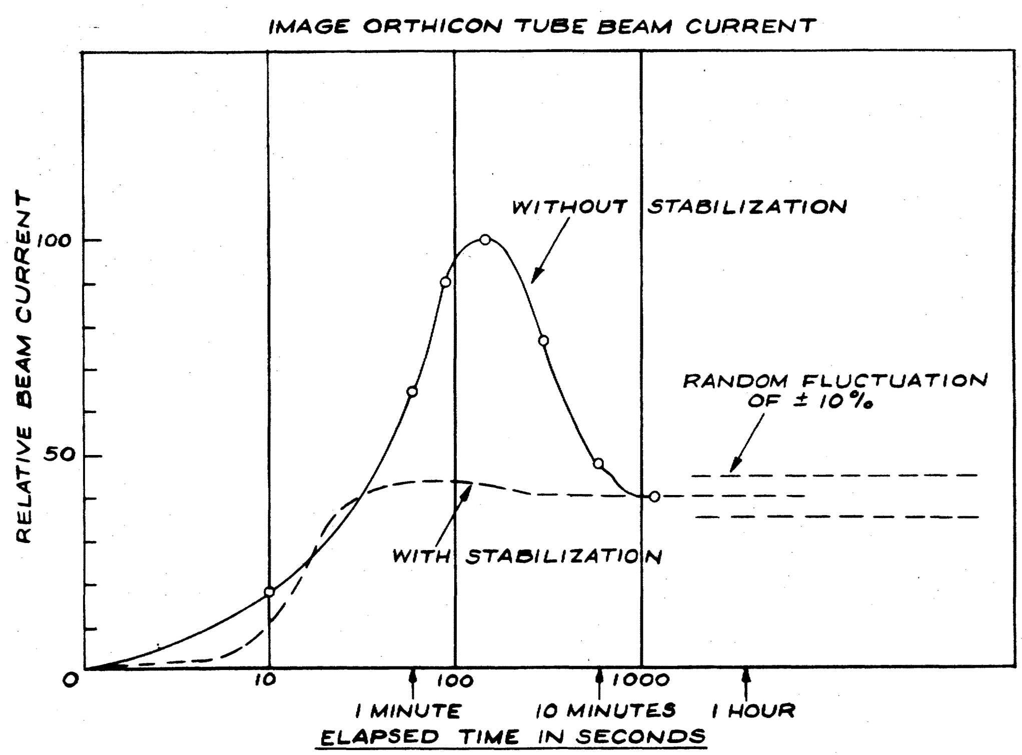
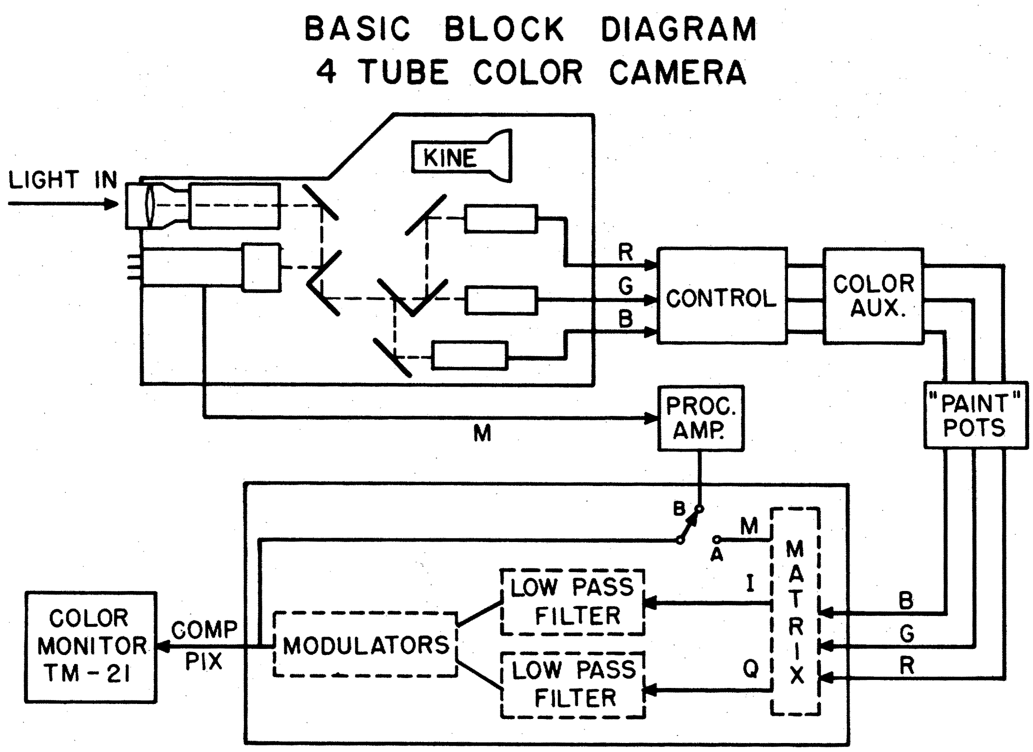
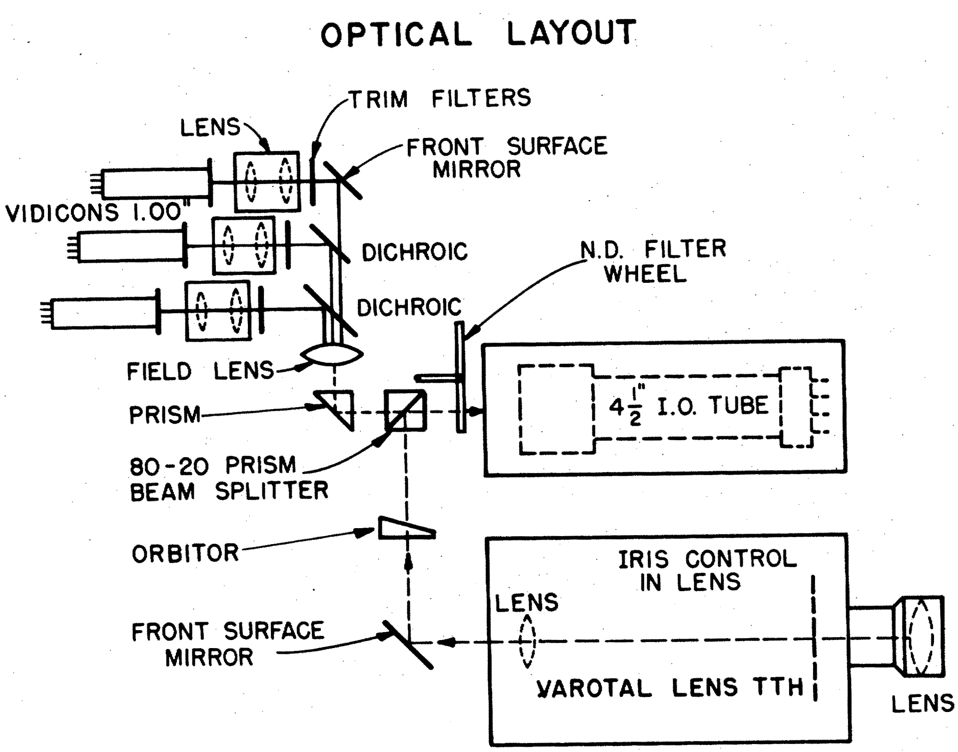


Fig. 3



BASIC BLOCK DIAGRAM
4 TUBE COLOR CAMERA
LIGHT IN
KINE
R
G
B
CONTROL
COLOR AUX.
"PAINT" POTS
PROC. AMP.
M
B
A
M
I
Q
MATRIX
LOW PASS FILTER
LOW PASS FILTER
MODULATORS
COMP PIX
COLOR MONITOR TM-21
B
G
R

Fig. 4



OPTICAL LAYOUT
TRIM FILTERS
LENS
FRONT SURFACE MIRROR
VIDICONS 1.00"
DICHROIC
DICHROIC
N.D. FILTER WHEEL
FIELD LENS
PRISM
$4\frac{1}{2}$" I.O. TUBE
80-20 PRISM BEAM SPLITTER
ORBITOR
IRIS CONTROL IN LENS
LENS
FRONT SURFACE MIRROR
VAROTAL LENS TTH
LENS

Fig. 5

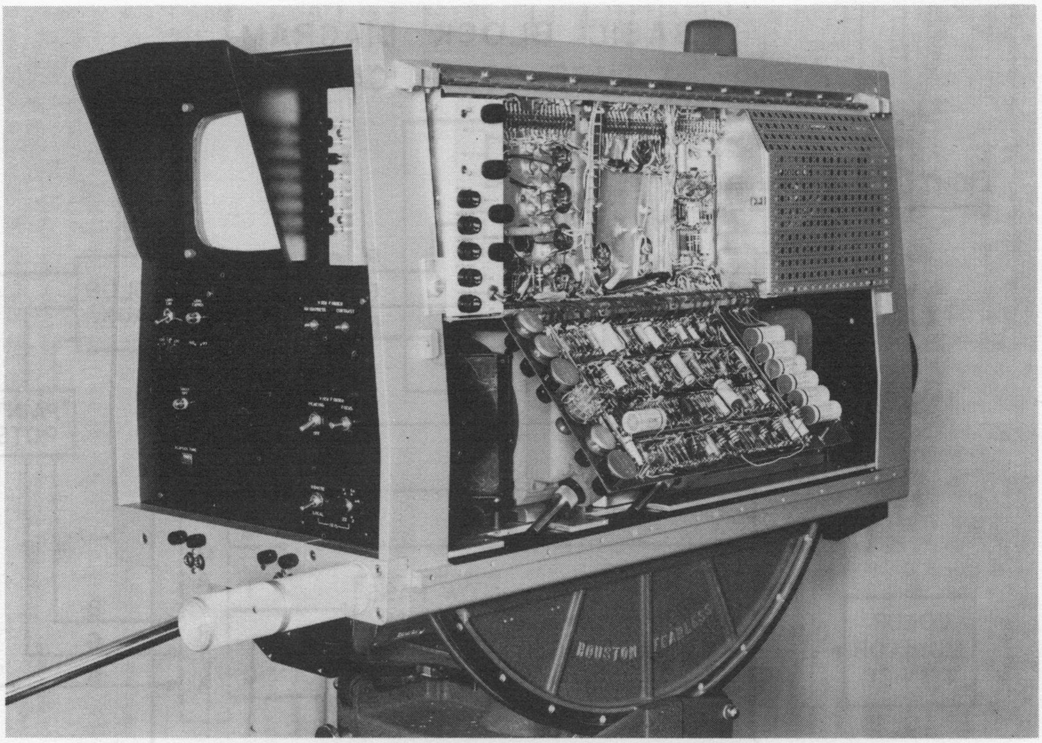


Fig. 6

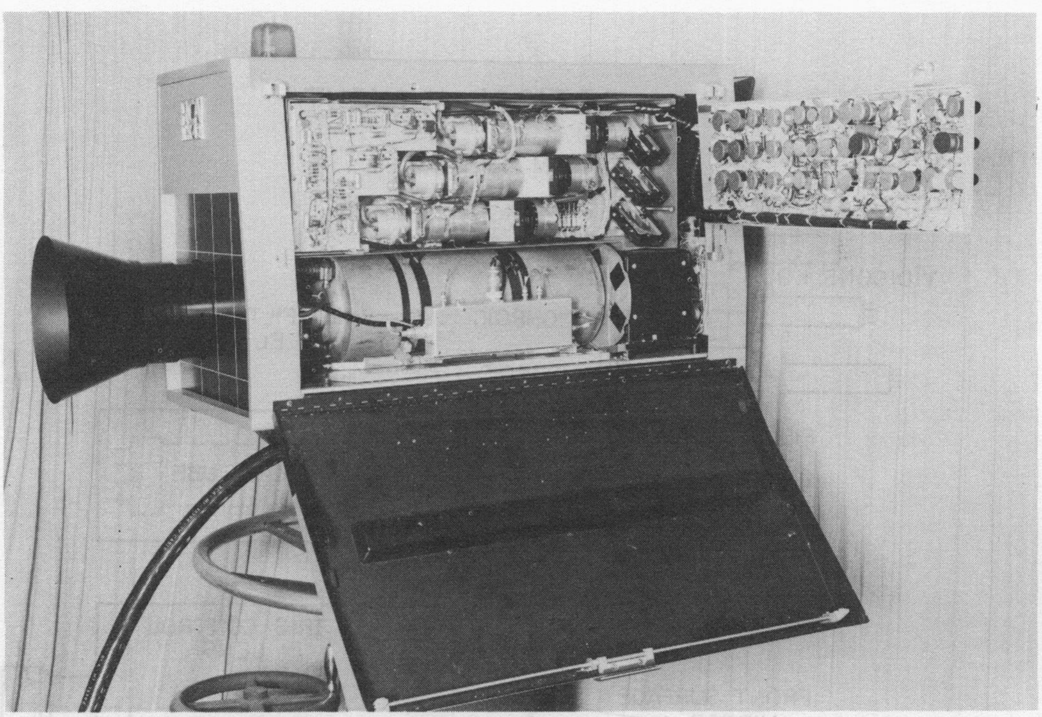


Fig. 7