W. E. TURK, B.Sc, C.Eng, F.I.E.E*

CAMERA TUBES—THE CHOICE FOR MONOCHROME

INTRODUCTION

Only two types of pick-up tube currently merit serious consideration for use in live, broadcast quality, monochrome television cameras, namely the lead-oxide vidicon and the image orthicon. Introduced comparatively recently, the lead-oxide tube has been outstandingly successful and has practically supplanted all other types in colour cameras. At first sight this tube might easily appear the obvious choice for monochrome cameras, particularly as the alternative, the image-orthicon was first used some 30 years ago. However, broadcasters continue to show a marked preference for the image-orthicon. This apparent paradox is discussed by reviewing the various attributes of the two types of tube.

GENERAL

Accurate, pleasing reproduction in colour imposes stringent demands on the whole technical and production process. Engineering, Set Design, Lighting, Make-up, etc, each must work within fine limits. On the technical side, circuit art is now sufficiently advanced such that the camera tube is the main limiting factor. Consequently fine limits are imposed upon its characteristics. For diverse technical reasons, the lead-oxide tube comes nearest to providing the precision demanded by the colour camera. The question is whether this necessarily means it also provides the best pictures in monochrome where matching several tubes in one camera is unnecessary. Unfortunately, an answer in objective terms is not possible as black-and-white pictures are judged purely subjectively. Were this not so celluloid photographers would have forsaken single colour film stock long ago. In this latter medium there is undoubtedly greater latitude and flexibility than exists with colour film; the degree of expression is infinite. The same may be said of monochrome television provided the correct pick-up tube is chosen. Television producers and directors in monochrome have, in effect, an additional dimension in which to work.

The associated aesthetic factors could be discussed *ad infinitum* but the main technical characteristics of the two types of camera tube and their differences can be segregated under various headings, those following being suggested as the more relevant.

GAMMA

The appeal of a monochrome picture lies entirely in its tone scale — always assuming its main features are recognizable. Kinescope screens have a gamma law of around 2·5 so that, to provide an overall system gamma of 1·1, the generally accepted preferred figure, a camera gamma of about 0·5 is desirable.

The natural transfer characteristics of the image-orthicon is such that a figure of 0·5 is readily obtainable.

Figure 1 shows a typical curve for an image-orthicon although the various types of tube will show variants on this basic curve. For example, as the target capacity is increased the unity gamma portion increases in length, the transition point or knee becomes sharper and the signal saturation point occurs at a higher level. Low capacity target tubes tend to have a shorter unity gamma portion and the whole curve approximates to one of a half gamma law. Figure 2 shows the invariable transfer characteristic for a lead-oxide tube.

These points illustrate the first important advantage of an image-orthicon — the ability to select the right tube for any particular requirement — be it high contrast scenes such as are encountered on outside broadcasting, or the controlled contrast usual in studio work. The lead-oxide

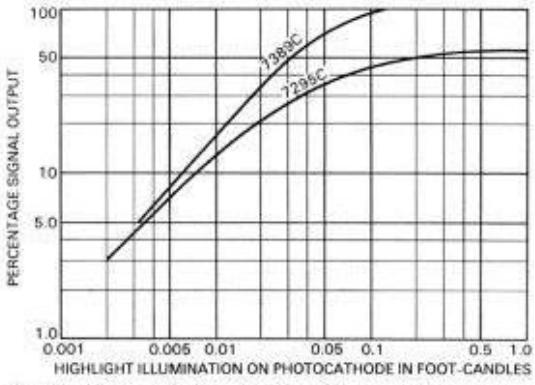

Fig.1 Typical transfer characteristics of image-orthicon camera tubes.

*English Electric Valve Company Limited

tube with a fundamental gamma of unity is much less adaptable — except by employing complicated circuitry.

Figure 1 also illustrates the flexibility of operation of the image-orthicon. At lower light levels where scene contrast is low the image-orthicon tends to emphasize. At high light levels signal compression occurs but signal differentiation is preserved due to the secondary target capacitance. In lead-oxide tubes signal saturation prevents the maintenance of detail in highlights. Figure 2 illustrates this point and should be compared with figure 1.

COLOUR REPRODUCTION

The spectral sensitivities of lead-oxide and the photo-emissive materials commonly used in the image-orthicon are different. The panchromatic response of the latter's photo-emitter is very near to that of the human eye and that which is universally accepted as 'correct' for photographic film. This is not so with lead-oxide unless optical filters, which reduce sensitivity, are used. For the pleasing reproduction of flesh tones in monochrome, this is a very important factor.

RESOLUTION

At the photo-cathode of an image-orthicon there is negligible reduction in optical sharpness in the photon/electron conversion process. At the target of the tube a slight enhancement of information edges occurs, due again to the in-built secondary capacitances. The signal read-out process preserves these edges so that in the 4½in image-orthicon a degree of 'aperture correction' occurs. This feature is a valuable property of the image-orthicon inasmuch as it helps the circuit designer and assists in the 'travelability' of the signal. Long distance remotes are consequently more satisfactorily handled. Resolution in the lead-oxide camera tube is almost entirely dependent upon uncontrollable internal target processes and responds less effectively to modifications in the electron optics of the tube. Fortunately, the extremely low noise level of lead-oxide tubes enables adequate electronic correction to be inserted for colour cameras and it can be argued that high-bandwidth signals are not necessary in these cases.

In basic terms, limiting resolutions of over 800 lines in an image-orthicon are to be compared with 500 lines in an uncorrected lead-oxide tube.

DYNAMIC RESOLUTION

Lead-oxide as a photoconductor possesses an inherent signal inertia — both in the build-up and decay. An image-orthicon of normal target capacity has virtually no lag but sometimes exhibits a multiple edging in fast moving objects. This is not unlike the phenomenon in cinefilm and is not objectionable.

SENSITIVITY

For a television camera the most meaningful measure of sensitivity relates incident light, signal-to-noise ratio and operational depth of

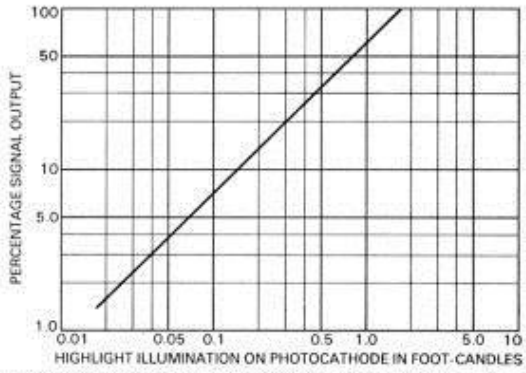

Fig.2 Typical transfer characteristics of lead-oxide camera tubes.

focus. For example, a convenient focal depth is achieved by using equivalent lens apertures of f/8 for the image-orthicon and f/4 for the 30mm lead-oxide tube. Then, by specifying an operating output from the camera tube, a comparison of sensitivities may be derived in terms of relative illumination. The comparison must take account also of the character of the two types of noise, (it is generally accepted that the triangular noise associated with vidicon-type tubes must be given a 5dB positive weighting factor over the white-noise characteristic of the image-orthicon).

For peak-white monochrome operation such a comparison results in a sensitivity for the lead-oxide tube some two-and-a-half times greater than the (7389C) image-orthicon, that is, just over one lens stop.

SIZE

As the modern trend for miniaturization in electronic equipment continues, the lead-oxide tube undoubtedly gains high marks. Image-orthicons of comparable size had poor performance but, in this area, it is useful to extend the consideration beyond the pick-up tube. There is an optimum size for television cameras and it can be said that the Marconi Mark V and Mark VIII are typically good examples. The first has the largest image-orthicon while the second contains three lead-oxide tubes. Herein lies one important fact — the lead-oxide tube earned popularity for itself and for colour television generally because it allowed colour cameras to be built of acceptable size. Image-orthicon colour cameras of necessity were very large. If the small volume of the lead-oxide camera tube is fully exploited in a monochrome camera then the resulting camera is ideal to pack, store and transport, but less convenient operationally — lens mounting is difficult and the low inherent inertia does not assist in obtaining mechanical stability in panning, tilting etc. For hand-held cameras, of course, it is an ideal choice — subject to the performance limitations already discussed. It might be asked — 'Can a larger lead-oxide tube be made to overcome some of the deficiencies in smaller versions?' The answer involves complicated considerations of solid-state physics but, briefly, it may be said that a larger target would have a

capacitance and, consequently, lag of an unacceptable level. It is also unlikely that a larger target would have appreciably higher resolution for reasons mentioned earlier.

OPERATIONAL CONVENIENCE

It is still occasionally said that the image-orthicon is difficult to operate, a valid criticism with early tubes and cameras. With current tubes, incorporating all the design and processing philosophies available in modern vacuum technology and modern cameras, this long ago ceased to be a problem, (the first 'hands-off' television camera, introduced nearly fifteen years ago by Marconi's, employed the image-orthicon tube). There is currently little practical difference between the two tubes from an operational standpoint.

COST

Tube life is an important factor when considering cost and, to the best of the author's knowledge, all EEV image-orthicons currently carry a longer guaranteed life than that for lead-oxide tubes. Furthermore, the initial cost of an image-orthicon is generally lower and hence its cost per guaranteed hour is less. In the sphere of operational life it is most difficult to give definite comparative statistics there being a very wide variation in the degree of picture quality degradation acceptable. Field reports indicate no significant differentials between the two tube types, however.

AVAILABILITY

Each type of tube is available from several manufacturers, while the demand for new cameras employing both types remains strong, and appears likely so to continue. Thus no supply difficulties seem likely, within the foreseeable future, for either type of tube.

CONCLUSION

A quantified comparison between lead-oxide and image-orthicon tubes for monochrome broadcasting cannot indicate a definite preference. Majority world opinion favours the image-orthicon strongly because of the aesthetic appeal of its pictures.