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TECHNOLOGICAL REPORT No. T-134

1964/54

THE BRITISH BROADCASTING CORPORATION

PRIVATE AND CONFIDENTIAL

ENGINEERING DIVISION

AN APPRAISAL OF THE R.C.A. FOUR-TUBE COLOUR TELEVISION CAMERA TYPE TK 42

Technological Report No. T-134

(1964/54)

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SUMMARY

The authors of this report spent three days in Camden, New Jersey, in order to be able to make measurements and subjective appraisals of the performance of the R.C.A. four-tube colour camera type TK 42. The results achieved are recorded in what follows.

1. INTRODUCTION

A colour television system for the United Kingdom will be adopted either at the CCIR interim meeting of Study Group XI in Vienna in the early Spring of 1965, or failing agreement at Vienna, a choice will be made, by and for the United Kingdom only, by the Postmaster General in order that a colour service may start in 1966. Whatever system is chosen it will be necessary to have a number of colour cameras ready for the start of the new service. With this end in view, much attention has been paid to the assessment and comparison of performance of various colour cameras put forward by their respective manufacturers. In particular Research Department Technological Report No. T-132 describes comparison tests undertaken at Lime Grove between the Marconi Co. three-tube, 3-inch image-orthicon colour camera, the three plumbicon colour camera from Philips of Holland, and the E.M.I. four-tube camera using one 4½-inch image orthicon and three vidicons.

The work described in the present report undertaken in the R.C.A. laboratories at Camden, New Jersey, was based upon the methods employed at Lime Grove, and for a detailed description of the methods of measurement and assessment the reader is referred to Technological Report No. T-132. In cases where the methods employed in Camden differed from those used at Lime Grove, mention will be made of this fact and a sufficient description of the Camden methods will be included.

The majority of the time spent in the R.C.A. laboratory was occupied with subjective appraisals, but some objective measurements were made, e.g. the resolution of frequency bars on a test card, the sensitivity of the camera measured in terms of the studio illumination and various signal-to-noise ratios. The latter measurements were, however, far from satisfactory because no noise measuring instrument was available, and noise levels were assessed by observation of the quasi-peak values of the noise as it appeared on a waveform monitor. Confirmatory assessments of signal-to-noise ratios were undertaken by judgement of the level of the noise as it appeared on the screen of a black-and-white picture monitor.

The subjective assessments were made on a multiple criterion basis in accordance with the impairment scale shown below:

DEGREE OF VISIBILITY OF THE IMPAIRMENT	GRADE
The impairment is imperceptible	1
The impairment is just perceptible	2
The impairment is definitely perceptible but not disturbing	3
The impairment is somewhat disturbing	4
The impairment is definitely disturbing	5
The impairment has rendered the picture unusable	6

The R.C.A. four-tube camera type TK 42 has been designed to accommodate either a 3-inch image-orthicon tube or a 4½-inch image-orthicon tube for the luminance signal, and during the tests carried out by the writers, the camera used a Fernseh 3-inch close-spaced image orthicon. The reason why the camera was demonstrated to us using a 3-inch rather than a 4½-inch tube was that the camera had been promised to the N.A.B. Convention in Chicago, and simultaneously with this decision it had also been agreed that it would be demonstrated in a completely transistorised form. The 4½-inch image-orthicon tube requires more scanning power than does the 3-inch tube and at the time of the N.A.B. Convention a suitable transistor circuit for line scanning was not available. The R.C.A. engineers stated that this omission had now been remedied and that the camera could be ordered with either a 3-inch or 4½-inch image-orthicon tube for the luminance signal.

The line scanning, which is delivered by a single transistor, R.C.A. type TA 1928A with associated damper diode R.C.A. type TA 115, was stated to be entirely adequate for a 4½-inch image orthicon, but no work has been dome with this size of tube. In view of the screening problem it was clear that considerable development effort would be required to use a 4½-inch tube and R.C.A. were very emphatic that the design of a high quality yoke with adequate screening for a 4½-inch tube is considerably more difficult than for a 3-inch tube. Although space has been left for a 4½-inch yoke within the camera, it seems likely that the TK 42 will go into its first production run with a 3-inch image orthicon as the luminance tube.

The price is of the order of $70,000 complete with the items detailed hereunder:

QTY	DESCRIPTION	QTY	DESCRIPTION
1	Colour Camera and Viewfinder, less vidicons and image orthicon	1	Colour Control Panel
		1	Console House, 22-inch
		1	Monochrome Picture Monitor
1	Auxiliary Assembly to provide:	1	Waveform Monitor
	Colorplexing	1	17" Colour Monitor type TM-27
	Signal Processing	1	Camera Cable 50 feet
	Power	1	Colour Camera Cradle Head
	Monitoring Feeds	1	Pedastal, type TD-9BC
	Cable Equalization	1	4½" Image Orthicon
1	Remote Control Panel	3	1-inch Vidicon

The price of the camera and control unit alone would be of the order of $50,000. The camera has been beautifully engineered and apart from further screening or whatever may be required to reduce mis-registration due to Earth's magnetic field it may be regarded as almost in its final form. The stability of performance of the camera was impressive. During the time of the visit, so far as was known, no adjustments other than balancing the white on a particular scene was made.

In particular, the stability of the registration appeared to be impeccable. Although the bandwidth of the chrominance signals was lower than in a camera specifically designed for three-tube operation, nevertheless the picture produced from the three vidicons was adequate for a reasonable assessment of mis-registration to be made. At no time was there any evidence whatever of mis-registration occurring on the signals from the three vidicons. Similarly, no evidence of drift between luminance and chrominance signals was detected.

The lens fitted to the camera at the present time is a Varotal III with a wide-angle adaptor, the latter being mounted on the front face of the camera box and is demountable. The range of focal lengths is:

With the wide-angle adaptor	1·6" to 8"	- maximum aperture f/4
	3·2" to 16"	- maximum aperture f/8
Without the wide-angle adaptor	4" to 20"	- maximum aperture f/4
	8" to 40"	- maximum aperture f/8

The combination with the wide-angle adaptor is intended for studio use. The Varotal III lens has the advantage of possessing a long back-focus, enabling the colour analysis system to be arranged without a relay lens. On the other hand, the lens has two severe disadvantages, a minimum distance at which an object can be focused of about 6 ft and a maximum aperture of f/8 in the 3·2-inch to 16-inch focal length range.

R.C.A.'s policy with respect to the type of lens to be used for production cameras is obscure.

The present camera has no arrangement for quick conversion to black-and-white working at full sensitivity by diverting all the light leaving the lens to the luminance tube. R.C.A. have done no work on this problem but felt that the optical splitter determining the ratio of light to the luminance and chrominance tubes could be changed relatively easily for one giving nearly 100% reflectance of the light to the luminance tube.

It is clear that R.C.A. have put a great deal of work into the design of the colour analysis and of the spectral response of the luminance channel. Understandably, details of these responses were not available for distribution. The spectral responses of the colour analysis and luminance filters have been established experimentally. The shape of the luminance response, although not that of the photopic curve, was nevertheless not very broad band; a flat-topped response is employed in the red channel while the blue and green are apparently not very different from the positive lobes of the ideal responses.

In its present condition the camera uses absorption-type filters in the light splitter and thus is less sensitive than would be a similar camera without such filtering. The R.C.A. engineers stated that they might replace the absorption-type filters by ones using the dichroic principle so that some of the light rejected from the path leading to the luminance tube could be diverted to whichever of the vidicon chrominance tubes could make best use of it. Whether this will increase the sensitivity significantly or not is at present uncertain.

As is well known there are many ways of coding the four signals emerging from a four-tube camera because only three signals are really required and there is thus a redundancy. The R.C.A. four-tube camera was demonstrated operating in the Livingston mode. The equation of the composite colour signal was as follows:

$$E_s = E_{Yw}^{1/\gamma_1} + K\left[\frac{E_{Bn}^{1/\gamma_2} - E'_{Yn}}{2\cdot 03}\sin\omega t + \frac{E_{Rn}^{1/\gamma_2} - E'_{Yn}}{1\cdot 14}\cos\omega t\right]$$

where

E_{Yw}	is the wideband luminance signal from the image orthicon tube before gamma correction
$1/\gamma_1$	is the exponent of the power law of the luminance signal from the image-orthicon tube after gamma correction
E_{Bn} & E_{Rn}	are the narrow-band chrominance signals presumed to have magnitudes proportional to the scene brightnesses
$1/\gamma_2$	is the exponent of the power law relating vidicon-tube output signal after gamma correction, if any, to scene brightness
K	is a constant which is unity for standard NTSC coding but exceeds this value in the R.C.A. four-tube camera.

In the experiments undertaken during our visit to Camden $\gamma_1 = 2$ and $\gamma_2 = 1\cdot 3$.

2. TEST RESULTS

2.1. Sensitivity

The aperture of the camera lens was set to f/8 and the camera was focused on to a standard E.I.A.* grey-scale chart having a maximum reflexion coefficient of 60%.

The exponent of the contrast power law to which the 3-inch image-orthicon luminance signal was set to operate was $0\cdot 5$, i.e. $\gamma_1 = 2$. The luminance tube was then exposed so that the white brought the tube to its so-called 'knee'. In fact, this operating point required about half a stop extra exposure as compared with BBC practice due to an interpretation of the meaning of the word knee which differs from

* Electronic Industries Association (U.S.A.)

ours. The chrominance channels were then balanced to produce null output. The camera was then panned on to a face; it is at this point that American practice differs significantly from our own, which is to leave the stop setting unchanged. However, the Americans like their faces to be reproduced more brightly and their practice is to open the aperture by something rather more than half a stop. Thus, with a given scene which includes human faces, the required lighting level in American practice is about twice that in British practice for equivalent stop settings. The consequences of this rather generous lighting may be seen in the relatively high value of studio illumination given below and in the excellent subjective marking given to noise.

Table 1 shows the sensitivity of the R.C.A. TK 42 colour camera in terms of incident illumination in foot candles and luminance of reflective surfaces in foot lamberts.

TABLE 1

INCIDENT ILLUMINATION ON E.I.A. GREY-SCALE CHART		LUMINANCE OF WHITE PATCHES OF E.I.A. GREY-SCALE CHART	
TOP RIGHT	BOTTOM LEFT	TOP RIGHT	BOTTOM LEFT
280 ft-C	230 ft-C	160 ft-L	160 ft-L

Some discussion with regard to sensitivity was held with the R.C.A. engineers, and it is thought that the figures shown in the table could be reduced significantly if the incident illumination was such as to operate the luminance tube up to rather than round the knee of its characteristic, and if a tri-alkali photo cathode were used in the image orthicon. It should be added, nevertheless, that Dr. Kozanowski had not had much success with tri-alkali photo cathodes, but said that what with 'dynamic gamma' and other unexplained effects he would describe the tri-alkali version as a 'rubber photo cathode'. The expression 'dynamic gamma' is believed to refer to a change of the position of the knee of the characteristic as the lens iris is opened or closed.

2.2. Picture sharpness

For this test the camera was focused on to the R.E.T.M.A./S.M.P.T.E. test chart and the modulation depth of the frequency bars in the luminance signal at the output of the coder was measured with the results shown in Table 2.

The results were obtained with the luminance tube feeding into a contrast law circuit having a gamma of one-half as for the tests described in Section 2.1. No aperture correction was employed and the modulation depths were measured on a waveform monitor.

Table 3 shows the modulation depth of the luminance signal as obtained directly from the camera. This included gamma correction.

TABLE 2

<table>
<tr><th>FREQUENCY OF TEST BARS ON R.E.T.M.A. CHART</th><th colspan="8">DEPTH OF MODULATION</th></tr>
<tr><td>0·5 Mc/s</td><td colspan="8">100%</td></tr>
<tr><td>1·5 "</td><td colspan="8">90%</td></tr>
<tr><td>2·0 "</td><td colspan="8">74%</td></tr>
<tr><td>2·5 "</td><td colspan="8">64%</td></tr>
<tr><td>3·0 "</td><td colspan="8">48%</td></tr>
<tr><td>3·5 "</td><td colspan="8">40%</td></tr>
<tr><td>4·0 "</td><td colspan="8">28%</td></tr>
<tr><td rowspan="4">General scene with detail</td><td colspan="8">SUBJECTIVE ASSESSMENTS</td></tr>
<tr><td colspan="4">COLOUR PICTURE</td><td colspan="4">BLACK-AND-WHITE PICTURE</td></tr>
<tr><td>M</td><td>S</td><td>W</td><td>AVERAGE</td><td>M</td><td>S</td><td>W</td><td>AVERAGE</td></tr>
<tr><td>3</td><td>2·5</td><td>3</td><td>2·8</td><td>3</td><td>3·5</td><td>3</td><td>3·2</td></tr>
</table>

TABLE 3

FREQUENCY OF TEST BARS ON R.E.T.M.A. CHART	DEPTH OF MODULATION
0·5 Mc/s	100%
1·0 "	100%
1·5 "	94%
2·0 "	79%
2·5 "	60%
3·0 "	50%
3·5 "	40%
4·0 "	35%

The modulation depths shown in Tables 2 and 3 are rather disappointing in that they correspond closely to those which would be expected from a 3-inch image orthicon tube rather than from a 4½-inch tube or from the Fernseh 3-inch tube which is claimed to have a resolution which does not differ significantly from that of a normal 4½-inch tube. The R.C.A. engineers pointed out that they were using a R.C.A. scanning yoke which was not in its final form. It had been modified for the suppression of coupling between the scanning coils and the image section of the tube. They said that better resolution had been obtained with another yoke, and they gave the impression that they thought that adequate resolution could be obtained from a Fernseh 3-inch tube. Nevertheless they pointed out that the camera was designed to accommodate a 4½-inch image orthicon if the purchaser so desired, although some comment upon this has already been made.

No measurement was made of vertical resolution but the R.C.A. engineers told us that they had made a test of the readability of newspaper print. This test had revealed to them that 4½-inch image-orthicon camera type TK 60 could resolve newspaper print with a vertical definition of sixty lines of print, whilst their four-tube colour camera type TK 42 with the Fernseh 3-inch image orthicon as the luminance tube gave a vertical definition of forty-five lines of newspaper print.

2.3. Noise

In this test a scene containing a number of everyday items including a tailor's dummy bust as well as the EBU colour fabrics was used. Table 4 shows the results. These were obtained with no aperture correction employed and at a viewing distance of six times picture height. In this and other tables in this report the letters M, S, W refer to the names of the writers: Maurice, Stanley, Watson.

The results are very good indeed and they reveal what had been felt by one of the writers for many years, namely that, at least with regard to the N.B.C., noise is regarded with greater distaste than is lack of picture sharpness. There is little doubt that in BBC circles pictures with more noise on them than that indicated by Table 4 would be regarded as acceptable for broadcasting.

An attempt was made to measure and assess the various relevant signal-to-noise ratios. First the vidicon target currents were measured and were as follows:

Blue:	0·02 μA
Red:	0·06 μA
Green:	0·06 μA

The signal-to-noise ratios measured in difficult circumstances on a waveform monitor and then guessed by viewing on a black-and-white screen were as follows:

Blue vidicon:	26 dB
Red vidicon:	34 dB
Green vidicon:	36 to 37 dB
3-inch image-orthicon luminance signal $E_Y^{1/2}$:	35 dB

TABLE 4

PICTURE CONTENT	SUBJECTIVE ASSESSMENTS															
	COLOUR PICTURE								BLACK-AND-WHITE PICTURE							
	CHROMINANCE ON AT CODER				CHROMINANCE OFF AT CODER				CHROMINANCE ON AT CODER				CHROMINANCE OFF AT CODER			
	M	S	W	AVERAGE	M	S	W	AVERAGE	M	S	W	AVERAGE	M	S	W	AVERAGE
Large area of saturated red	1	1·5	1	1·2	1	1·2	1	1·1	1	1	1·3	1·1	1	1·2	1	1·1
Large area of saturated green	1·8	2·2	2	2	1·4	1·2	1	1·2	1	1·5	1	1·2	1	1·2	1	1·1
Large area of saturated blue	1	1·8	1·5	1·4	1	1·2	1	1·1	1	1	1	1	1	1·2	1	1·1
Large area of grey	1·8	2	2	1·9	1·6	1·5	1·7	1·6	1	1·5	1	1·2	1	1	1	1

The signal-to-noise ratio of the luminance signal, that is 35 dB, is greater than would normally be assumed to be obtainable from a 3-inch image orthicon operated in the BBC mode that is just up to the knee of the characteristic, but as has been stated earlier, the American method is to operate a half stop above the knee.

The head amplifiers of the chrominance channels employed transistors only (field effect type Texas Instruments 2N 2386) and were stated to have a noise factor as good as could be obtained from valves. The bandwidth was stated to be 4 Mc/s at the 3 dB point. With the best known design of head amplifiers, signal-to-noise ratios some 4 dB better could have been anticipated but, nevertheless, the presence or otherwise of the chrominance signals appeared to make no difference to the subjective assessment of the noise of coloured areas, from the BBC light box, on the picture monitor. From the point of view of noise, therefore, the design appears to allow an undue amount of light to the vidicons thus making the camera less sensitive than it need be.

An experiment was carried out in which the ratio of light division between luminance and chrominance was effectively made 1:2 instead of the normal 1:4. Under this condition, noise contributed by the chrominance signals, as judged on the picture monitor still appeared to be small. It might therefore be assumed that greater sensitivity might be obtainable.

2.4. Errors of colour reproduction

2.4.1. Research Department light box as picture source

For this test one light box was set up in front of the camera and another was placed above the colour picture monitor, care being taken to ensure correct colour temperature of the monitor screen. For a brief description of the light box reference should be made to Report No. T-132.

Table 5 shows the results.

This table should be compared with Table 4 in Report No. T-132. It will be seen that the R.C.A. four-tube camera is significantly better than the E.M.I. four-tube camera as regards colour reproduction.

The reason for the poor (high) mark given to high luminance orange is not known and the reason for the poor mark given to high luminance green is believed to be the relatively high saturation of the green light emerging from the light box. It should perhaps be added, however, that all the chromaticities of the colours produced by the light box are within the colour triangle formed by the sulphide phosphors used in present-day colour display tubes.

There was some discussion relating to an apparent difference in colour reproduction observed on the colour monitor in the studio and that in the adjacent viewing room. In a later test in which the two monitors were placed side by side the existence of this difference was confirmed, but it was not sufficient to make a significant alteration to the figures given in Table 5. The colour reproduction was assessed in the adjacent viewing room on a colour monitor using the 21-inch shadow-mask display tube type 21 FJP 22, which is the present standard tube using a

TABLE 5

COLOUR	SUBJECTIVE ASSESSMENTS															
	FOUR-TUBE OPERATION								THREE-TUBE OPERATION							
	HIGH LUMINANCE				LOW LUMINANCE				HIGH LUMINANCE				LOW LUMINANCE			
	M	S	W	AVERAGE	M	S	W	AVERAGE	M	S	W	AVERAGE	M	S	W	AVERAGE
Green	4	2·8	3·8	3·5	2	3·5	2·4	2·6	3·3	2·5	2·5	2·8	1·7	2·5	2	2·1
Yellow	1·3	2·2	2	1·8	3	3	2·5	2·8	3	3	3	3	2	3	2	2·3
Orange	4·3	3·5	4·2	4	3	4	3·5	3·5	3·8	3·5	3	3·4	3	3·5	3	3·2
Cyan	2·8	2·5	3	2·8	3	2·5	3	2·8	3	2·5	3	2·8	3	2·5	3	2·8
White	1	1·5	2	1·5	2·8	1·8	2	2·2	2	1	2	1·7	1·8	2	2	1·9
Red	2	2·5	2·3	2·3	2·5	3·5	3	3	4	4	4	4	4	4	3·5	3·8
Blue	2·8	3·5	3·5	3·3	3·3	5	4·5	4·3	3	4	4	3·7	5	5	4	4·7
Magenta	3	3·5	3·5	3·3	3·2	4·5	3	3·6	2·5	2·5	3	2·7	4	4	3·5	3·8
Light Magenta	2	3	2·5	2·5	1·7	3·5	2·5	2·6	2·5	2	3·5	2·7	3·2	2·5	3·5	3·1

bonded face plate. A comparison of the R.C.A. four-tube camera with the three-tube plumbicon (Table 4, Report No. T-132) shows a slight advantage to the plumbicon camera, but the difference between the three-tube 3-inch image-orthicon camera and the R.C.A. four-tube camera is hardly significant.

The performance of the four-tube camera used in a three-tube condition, that is to say using the three vidicons to produce a normal NTSC type of signal is surprisingly poor as will be seen from Table 5. In general, the poor marks given to the various colours during three-tube operation was due to an apparent lack of saturation rather than to errors of hue. This result is surprising in view of the fact that no gamma correction was applied to any of the vidicon channels and three-tube operation in the absence of gamma correction of the primary colour signals should lead to over-saturation rather than under-saturation, because the contrast law applying to a vidicon tube in the absence of gamma correction may be regarded as having an exponent of approximately 1·2.

During later discussions it turned out that the R.C.A. engineers adjust the ratio of chrominance to luminance signals in order to improve the colour reproduction of the camera used in the four-tube mode. This explains the factor K which multiplies the chrominance signal in the equation in the composite colour signal given in the Introduction. It may, at first glance, be thought that there is no harm in adjusting the ratio of chrominance to luminance signals to a value which gives satisfactory four-tube colour reproduction, but such action might reduce compatibility by increasing the visibility of the dot structure on monochrome screens, and it might also result in excessively deep modulation by the chrominance signal of the radio-frequency carrier in broadcasting transmitters.

2.1.2. EBU fabrics as picture source material

For this test a duplicate set of coloured fabrics was set up in the viewing room and illuminated with light having the colour temperature of Illuminant C.

Table 6 shows the results.

TABLE 6

COLOUR	SUBJECTIVE ASSESSMENTS							
	FOUR-TUBE OPERATION				THREE-TUBE OPERATION			
	M	S	W	AVERAGE	M	S	W	AVERAGE
Yellow	3	3·2	3	3·1	3·5	3·5	3·5	3·5
Cyan	5·5	4·6	5	5	5·5	4·8	5	5·1
Magenta	1·5	3	2·5	2·3	1	2·5	1	1·5
Red	2	2·5	2	2·2	2·5	3·5	2·5	2·8
Blue	1	2	2	1·7	1	2·5	2	1·8
Green	1	2	2	1·7	2	2·5	2	2·2

These results should be compared with Table 4 of Technological Report No. T-132. The cause of the poor marking of the reproduction of the cyan-coloured fabric is probably due to the rather saturated green contained within the cyan light reflected from the fabric. This fabric was reproduced as a blue colour, and this would indicate lack of adequate camera response to green and might be regarded as confirmation of inadequate colour analysis in the camera particularly with regard to green (see Table 5).

2.4.3. General studio scene as picture source

For this test a tailor's dummy, mentioned earlier, along with EBU fabrics and various common household articles were used. The colour of the tailor's dummy, which was a woman's bust of the type used in hat shops, was of a rather brownish yellow, quite unlike the kind of flesh tint normally seen in British television studios. In response to a request one of the young women staff of the R.C.A. laboratories kindly agreed to act as model, and the scene was rebuilt round her. In spite of the best efforts of the engineers present the scene lacked that artistic touch which the presence of someone connected with programme production could have supplied, and this rendered the assessment of it rather difficult; nevertheless the results are shown in Table 7.

TABLE 7

PICTURE CONTENT		SUBJECTIVE ASSESSMENTS							
		FOUR-TUBE OPERATION				THREE-TUBE OPERATION			
		M	S	W	AVERAGE	M	S	W	AVERAGE
Detailed appraisal of particular feature	Overall appearance	2	2·5	2·5	2·3	2	3	2·5	2·5
	Saturated colours	2	2·5	2	2·2	2	2·4	2	2·1
	Flesh tones, etc.	2	2·6	3	2·5	2	2·4	3	2·5
	Grey areas (light)	2	2	-	2	2	2	-	2
	Grey areas (shadows)	2	2·5	-	2·3	2	3	-	2·5

2.5. Registration errors

For this test a registration chart similar to those used during the Lime Grove tests was employed. It contained ½-inch wide strips of coloured material stuck on to a black card. The test was set up with the camera pointing from east to west and the panning angles were related to this initial direction. For the tilt test the camera was panned -90° so that it was pointing in a south to north direction. Table 8 shows the results. These were obtained using a viewing distance of six times picture height.

TABLE 8

PICTURE CONTENT	CAMERA ATTITUDE	SUBJECTIVE ASSESSMENTS							
		COLOUR PICTURE				BLACK-AND-WHITE PICTURE			
		M	S	W	AVERAGE	M	S	W	AVERAGE
Registration Bars	Normal	1·8	2	2	1·9	1	1	1	1
	Panned ± 90°	2	2·2	2	2·1	1	1	1	1
	Tilted 30° downwards	2·5	2·2	3	2·6	2·7	2·5	3·5	2·9
	Tilted 30° upwards	4	4	4·5	4·2	3·8	4·4	4·5	4·2

It will be seen from the table that the upwards tilt of 30° caused significant mis-registration which was visible on both the black-and-white and the colour picture. Such mis-registration would be inadmissible, but we were assured that this fault would be overcome in the near future. The R.C.A. engineers told us that due to the existence of an N.B.C. studio in New York, which was situated quite close to the Subway (Underground), the specification to which they were working was written in terms of satisfactory registration performance in a magnetic field of 10 Gauss. The Earth's magnetic field is less than one Gauss so that it seems likely that this particular difficulty can be resolved.

On the general subject of registration R.C.A. stated that, in their view, four-tube operation reduced the requirement for accuracy of registration by a factor of three times as compared with three-tube operation.

2.6. Lag

For this test it was unfortunately not possible to set up the coloured pendulum arrangements which had been used at Lime Grove, so instead the camera was panned at a rate considered adequate to reveal any lag that it might possess. Various coloured objects were set up in front of the camera, including the EBU fabrics cut into strip form so as to make a card of colour bars similar to those used as an electronic test signal. Table 9 shows the results.

In general, the lag which was revealed could be ascribed as being due to the luminance tube alone. It was therefore regarded as quite acceptable for broadcasting.

2.7. Compatibility

The studio scene for this test was similar to that described in Section 2.4.3 and it therefore contained the saturated colours of the EBU test fabrics as

TABLE 9

PICTURE CONTENT	SUBJECTIVE ASSESSMENTS										
	RIGHT-TO-LEFT MOVEMENT OF DISPLAYED OBJECT				LEFT-TO-RIGHT MOVEMENT OF DISPLAYED OBJECT				COLOUR OF TRAILING 'COMET'		
	M	S	W	AVERAGE	M	S	W	AVERAGE	M	S	W
Light object on dark background	3·8	3·8	3	3·5	4	4	3	3·7	white	white and blue	-
Dark object on light background	3	4	3	3·3	3	4	3	3·3	yellow for R to L magenta for L to R	yellow for R to L magenta for L to R	yellow for R to L magenta for L to R
Dark object on less light background	-	2	-	2	-	2	-	2	-	-	-
EBU Colour flag	3	3	3	3	3	3	3	3	patch trails its own colour	edges desaturate	-

well as flesh tones, etc. The results are shown in Table 10, and are perhaps slightly worse than might have been expected.

TABLE 10

PICTURE CONTENT		SUBJECTIVE ASSESSMENTS											
		SUBCARRIER PATTERNS				EDGE EFFECTS				ORTHOCHROMATISM			
		M	S	W	AVERAGE	M	S	W	AVERAGE	M	S	W	AVERAGE
Detailed appraisal of particular features	Overall appearance	3	2	2	2·3	1	1	1	1	1	1	1	1
	Saturated colours	3	4	3	3·3	1	1	1	1	1	1	1	1
	Flesh tones, etc.	3·2	1	2·5	2·2	1	1	1	1	1	1	1	1
	Grey areas	1	1	1	1	1	1	1	1	1	1	1	1
	Male live subject with sun-burnt face	-	4	-	4	-	1	-	1	-	1	-	1

It should be stated that the response of the circuits and monitor was such as to offer no more attenuation at the high video frequencies than that offered to low-frequency video signals. Notwithstanding this we had expected the visibility of the dot pattern, due to the chrominance signal, to be significantly less than would be encountered in 625-line television due to the higher field frequency used in the U.S.A. It is to be expected that the cancellation effects on the dot structure due to the odd half line-frequency relationship would be more effective at 15 c/s (half the U.S. picture frequency) than at 12·5 c/s (half the European picture frequency). On the other hand, the relatively lower frequency of the American colour subcarrier would tend to offset the expected improvement due to the higher field frequency. It is believed that the relatively poor dot structure compatibility is due to the raising of the ratio of chrominance to luminance signals which forms part of the technique of coding Livingston-type signals from four-tube cameras.

2.8. Shading

Very slight blue shading in the dark tones was visible at times.

2.9. Specular reflexions

Intense specular reflexions were introduced into the scene before the camera. The effect was very similar to that seen on a black-and-white image orthicon camera, the halo area around the specular reflexion, however, being coloured but at a low intensity. The performance in this respect was outstandingly good.

3. MECHANICAL FEATURES

All the controls for setting up the camera are located within the camera itself where there are no less than 44, not including pre-set adjustments. The controls for the camera control unit are divided into two groups, some on the camera control unit itself, and those controls normally required during operation on a separate operating control panel. The controls on this engineering control panel consist of iris, black level, fine video-gain (the so-called 'paint box' controls) and lens capping.

It will be appreciated that the practicability of the above arrangements depends upon a high degree of stability of performance of the camera. If, for example, the registration had to be looked at as much as once a day, this would inevitably consume valuable studio time. As already indicated, during the visit the camera was remarkably stable but it must be remembered it was operating essentially in laboratory conditions, with little or no movement such as is encountered in practical studio conditions. Moreover the small studio in which it was located was extremely well cooled and the camera was not operating under any intense studio lighting.

It was clear that some of the engineers concerned with the design of this camera were not in agreement with the philosophy of placing all the camera adjustments within the camera itself.

A single camera cable was provided with its outlet located at the rear of the camera facing forward so that the camera cable passed through the panning head. This would not be suitable for use with the standard Vinten mark III panning heads.

The size and weight have been reported previously; they are 22½ inches wide, 16¼ inches high, 53 inches long (with wide-angle adaptor and viewfinder as required for studio use) and 340 lb with wide-angle adaptor.

This is, of course, a very large and heavy camera which would severely restrict movement of the type which is now common practice in black-and-white operation. The penalties and difficulties of using such a camera on outside broadcasts are only too obvious.

4. CONCLUSIONS

From the assessments described in the preceding pages we may deduce the following opinions:

(i) Sensitivity

The sensitivity of the four-tube camera as set up at Camden is disappointing, but significantly greater sensitivity could be obtained by reducing the exposure of the camera by a half stop or more, by an optical network having higher overall transmission, and possibly by the use of a tri-alkali photo cathode in the luminance tube.

(ii) Picture sharpness

The picture sharpness was that to be expected from a 3-inch image orthicon. R.C.A. have confidence in the claims made by the Fernseh Co. for their 3-inch image orthicon, and they say that an improved scanning yoke would give better resolution. The employment of a 4½-inch image orthicon, instead of the 3-inch variety would be certain to improve the picture sharpness, if this could be done.

(iii) Noise

The performance of the R.C.A. type TK 42 camera as regards noise was good, and the increase of noise level consequent upon the reduction in studio illumination suggested in the preceding paragraph would still give rise to acceptable pictures.

(iv) Colour reproduction

The colour reproduction of the R.C.A. camera leaves room for improvement, but it is comparable with three-tube cameras, which are the only other type available. It is felt that the relatively poor performance in green, cyan and orange could possibly be improved by the use of better colour analysis. In order to obtain the good assessment allocated to red, the four-tube camera apparently has to be operated at a non-standard ratio of chrominance to luminance.

(v) Registration

The registration of the present R.C.A. camera is unsatisfactory when it is tilted upwards by 30°. This is not a test which the R.C.A. engineers had undertaken before our visit, and they stated that the specification to which they had to work would entail curing this trouble.

(vi) Lag

The lag of the TK 42 camera is quite acceptable.

(vii) Compatibility

The compatibility of the R.C.A. colour camera is acceptable as viewed on a wide-band laboratory monitor. It will, therefore, be satisfactory when viewed on domestic black-and-white receivers. This applies to U.S. 60-field television. It is slightly less certain whether it would apply equally to European 50-field television. If, as has been stated above, it is essential to operate the four-tube camera with a higher than normal chrominance to luminance ratio, then the possibility of using this camera on either the SECAM or PAL systems requires serious consideration.

Finally, it may be said that the R.C.A. four-tube camera must be included as a serious contender for use in colour studios, provided that the mis-registration arising from camera tilting is eliminated.

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CHS

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