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MODERN DEVELOPMENTS IN LENSES FOR TELEVISION

DURING THE PAST 15 years the process of television, in both its technological and production aspects, has experienced many significant but gradual changes. Not the least among these has been the process of producing the image on the television camera tube.

In this period we have seen the development of lenses designed specially for the television process instead of using standard film camera lenses. This in turn led to the formulation of standards of performance best suited to the limitations of the television process. The consequence of this development has been to stimulate a general programme of work directed at the assessment of lens performance by frequency response methods.

On the production side of television, the provision of a turret of lenses on a camera, yielding a comprehensive range of angular view points, has led to a flexibility of programme presentation. However, as production techniques have developed so have the demands on lens flexibility, which have culminated in the rapidly increasing replacement of fixed-focus lenses by zoom lenses having large focal ranges. In the beginnings of television, quite naturally, the techniques used were simply extensions of well-tried ciné techniques; however, with the somewhat different conditions of live and low budget operation, an entirely new technique has emerged which has in turn encouraged the development of new methods of camera and lens operation, which have not yet been exploited in the film-making industry.

Digressing a little on the progress that has been made in the establishing of standards of performance for television lenses, due credit must be given to the lead, and endeavour, of the BBC and their Research Establishment at Kingswood Warren. At a time in the mid-1950's when there was much activity regarding the theoretical aspects of frequency-response methods of assessing the performance of lenses, the BBC were engaged in developing equipment to measure firstly spread function and eventually direct frequency response values (Fig. 1).

The use of frequency-response methods have an immediate advantage in the television field in that the language problem is more easily overcome. However, it is really the very low inherent frequency limitations of television (of the order of 8 lines per millimetre maximum for Image Orthicon channels) that dictates that normal photographic resolving power methods are inadequate and that new means had to be adopted.

The principles of frequency-response methods have been well covered in recent years,[1,2,3] but in one respect the field of television is still ahead of some of the other means of photographic imagery. That is, that an attempt has been made to correlate the whole of the image chain, including receptor and observer, into a single unit of merit. This unit is termed the liminal unit and a very full explanation is given in a paper by Sproson of the BBC.[4]

In brief, the factors of sharpness and variations of illumination across the field of imagery are correlated to the ability of a number of observers to detect known changes in performance. Thus, for example, it was found that a reduction in sharpness of 11% can be detected by 50% of the observers whilst the remaining 50% are unaware that a change has been made. A

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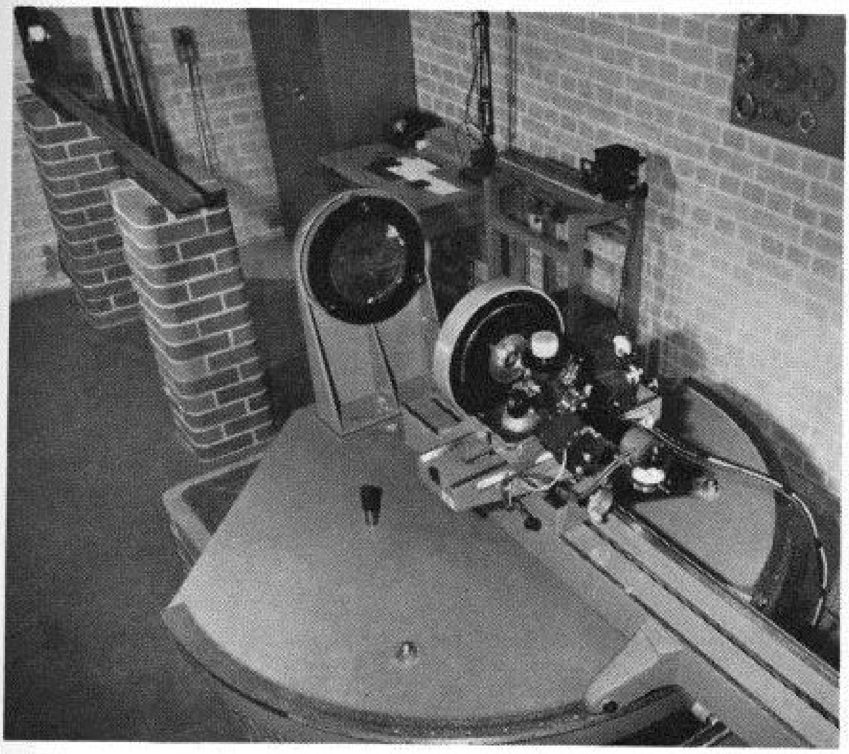

Fig. 1. The latest frequency response bench developed by the BBC at Kingswood Warren. The arrangement shows a slit source, a collimator, the lens under test and a sine wave analyser which is coupled (not shown) to a paper trace recorder.

difference in sharpness factor of 11% is said to be one liminal unit, the zero liminal unit rating being the performance of the theoretical perfect lens. Thus the greater the liminal unit rating the lower the level of performance. Table 1 shows the performance of a range of fixed-focus lenses which have gained high repute in recent years.

Having briefly examined the methods of assessing the performance of any lens for use with television, it is sufficient to say that the high standards of performance achieved by the ranges of fixed-focal-length lenses made the introduction of zoom lenses a somewhat difficult task.

In the first instance the novelty of the zooming effect made the task easier, but in the final count the quality of the presentation was held to be the most important thing. The demand for a high optical performance determined that the bulk of the effort, in the design of zoom lenses for television, be spent on the more expensive mechanically compensated zoom lens as opposed to the optically compensated type. The difference between the two types was that the former requires somewhat precise cam mechanisms to maintain a constant focal plane during change of focal

TABLE 1

IMAGE ORTHICON
OVERALL ASSESSMENT IN LIMINAL UNITS

Lens	*Relative Aperture*	*Sharpness*	*Vignetting*	*Total*
1– in. *f*/2·8	*f*/2·8	0·4	0·7	1·1
Ortal	*f*/4·0	0·1	0·0	0·1
2 in. *f*/2·0	*f*/2·0	0·7	1·3	2·0
Ortal	*f*/2·8	0·5	0·9	1·4
3 in. *f*/2·0	*f*/2·0	0·7	0·1	0·8
Ortal	*f*/2·8	0·5	0·1	0·6
5 in. *f*/2·8	*f*/2·8	0·3	0·1	0·4
Ortal	*f*/4·0	0·2	0·0	0·2
8 in. *f*/4·0	*f*/4·0	0·7	0·0	0·7
Ortal	*f*/5·6	0·8	0·0	0·8
12½ in. *f*/4·0	*f*/4·0	1·2	0·0	1·2
Ortal	*f*/5·6		No result available	
16 in. *f*/4·0	*f*/4·0	1·2	0·0	1·2
Ortal	*f*/5·6	0·8	0·0	0·8

Performance figures of a range of fixed-focal-length lenses. (Published by kind permission of the BBC.)

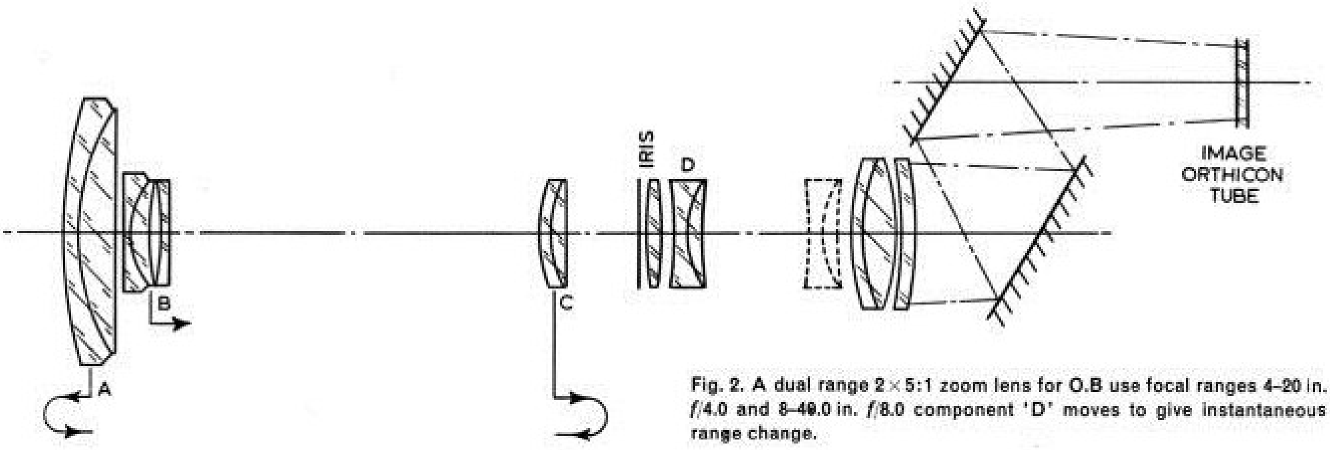

Fig. 2. A dual range 2 × 5:1 zoom lens for O.B use focal ranges 4–20 in. f/4.0 and 8–40.0 in. f/8.0 component 'D' moves to give instantaneous range change.

length, whereas the latter relies generally on linear movements of coupled optical members to provide an approximately constant focal plane.

The earlier zoom lenses had restricted focal ratios not exceeding 5:1 and covered medium angular fields of view. Their standards of performance were not significantly below those of the longer fixed-focal-length lenses and they did much to encourage the wider use of zoom lenses and the development of new operating techniques. Such lenses were used generally on outside broadcast presentations where the flexibility of the zoom lens was immediately appreciated.

In the mid-1950's zoom lenses having wider fields of view, but only having focal ratios of about 3½:1, were introduced in the television studio. (Having a focal range covering roughly the normal turret complement of 2 in., 3 in., 5 in. and 8 in. focal-length lenses on Image Orthicon channels and 2 cm, 3 cm, 5 cm and 8 cm on Vidicon channels.)

These lenses, whilst having a somewhat reduced full aperture compared with the range of fixed-focus lenses, when operated at apertures for normal studio levels of illumination, gave a very comparable level of performance to fixed-focal-length lenses. The acceptance of a zoom lens having an adequate standard of performance in turn meant an even wider usage and further developments of studio techniques, which has stimulated a demand for even wider focal ratios.

In 1960 these needs were satisfied to some degree by the introduction of a dual range 5:1 system for outside broadcast use (Fig. 2). The system had the novelty of using a variable focal length construction for its rear optical component. It thus provided further intensive research into methods of achieving lenses having continuous focal ratios of 10:1 covering wide angular fields of studio use.

In 1962 these efforts were realized by the introduction of the Angenieux 10×35A *f*/4·5 and the Rank Taylor Hobson 1·6 to 16 in. *f*/4·0 zoom lenses, and the full significance of the 10:1 zoom lens is perhaps only now being fully appreciated. Additional to the flexibility of providing all the facilities of a turret of fixed-focal-length lenses, they provide the ability to vary on an infinite scale the choice of focal length combinations, and in some instances make available the use of a particular focal length which would otherwise be denied, due to limited camera-tube movement or the limited number of turret positions available.

Allied to the extensive optical design research that has taken place, there have been similar strides forward in both the mechanical operation of the zoom lens and in the means of controlling it (Fig. 3). The development of sensitive, but rugged, cam mechanisms with low torque and wear characteristics have played a great part in attaining a level of performance comparable with the range of fixed-focal-length lenses the 10:1 zoom lens is intended to replace (Table 2).

Experience over a number of years has led to satisfactory mechanical means of manually controlling

TABLE 2

OVERALL ASSESSMENT (LIMINAL UNITS)

Focal Length (mm)	40	59	86	126	186	272	400	
(in.)	1·6	2·3	3·4	5·0	7·3	10·7	16·0	*Aperture*
Sharpness (liminal impairment units)	0·8	0·8	1·0	1·0	1·0	1·8	1·5	*f*/4·0
Vignetting units	0·6	1·2	0·2	0·2	0·0	0·2	0·3	(*T*/4·5)
Total	1·4	2·0	1·2	1·2	1·0	2·0	1·8	
Sharpness (liminal impairment units)	0·5	0·5	0·5	0·6	0·7	0·8	1·1	*f*/5·6
Vignetting units	0·2	0	0	0	0	0	0	(*T*/6·2)
Total	0·7	0·5	0·5	0·6	0·7	0·8	1·1	

Performance figures for the Varotal V 10:1 zoom lens for Image Orthicon. (Published by kind permission of the BBC.)

zoom lenses. However, the greater range and flexibility of the 10:1 zoom lens presents a challenge and additional advantage with the use of servo-operated controls. For example, in the control of focal length either of two modes are attainable from a single control. In the one, one may vary the rate of change of focal length in an infinitely variable range of speeds, or by providing a number of push-buttons incorporated in the demand unit, which may be pre-set to nominated focal positions, one can reproduce the action of a turret of fixed-focal-length lenses. With this arrangement it is possible to change focal length more smoothly than a normal turret change and at any desired speed. Additionally, a wider choice of field angles may be made available by the provision of a greater number of buttons than the normal number of turret positions. The speed and sensitivity of the first-mentioned rate control can be demonstrated by saying that a full end-to-end zoom may be accomplished in under 1 second, or as long as 20 minutes with negligible effort by the operator. The product of these developments is a smoothness and flexibility of operation almost impractical to achieve by mechanical means of control. A similar conclusion could be drawn when considering the servo control of focus.

In any zoom lens the sensitivity of focusing varies with the focal-length setting. This is due to the combined effects of depth of field considerations and change in scale of the image detail. The effect is in proportion to the square of the focal ratio and is thus 100:1 in the new 10:1 zoom lenses compared with a maximum of 25:1 previously experienced. In a servo form of control, signals from the zoom control, indicating a particular focal length, can be linked to a focus control to change the sensitivity of focus accordingly and thus provide compensation for the effect.

The essence of combining servo operation with a zoom lens of extensive focal ratio is fully to exploit the flexibility that the combination offers, with a degree of smoothness and control not attained by manual methods of operation. Attempts to combine the zoom lens with the camera as an integral unit, however, have met with a limited success.

The Image Orthicon camera presents particularly severe difficulties in this respect due to the size of tube and yoke assemblies, and, unless the optical path can be folded to allow the lens and yoke to be side by side, the straight 'in-line' arrangement of camera and lens offers little scope for change. There is, however, now the opportunity to dispense with the long-familiar turret on the camera and consider future cameras equipped for zoom lenses only. This then raises the question of a single zoom lens to cover all applications of studio and outside broadcast presentation.

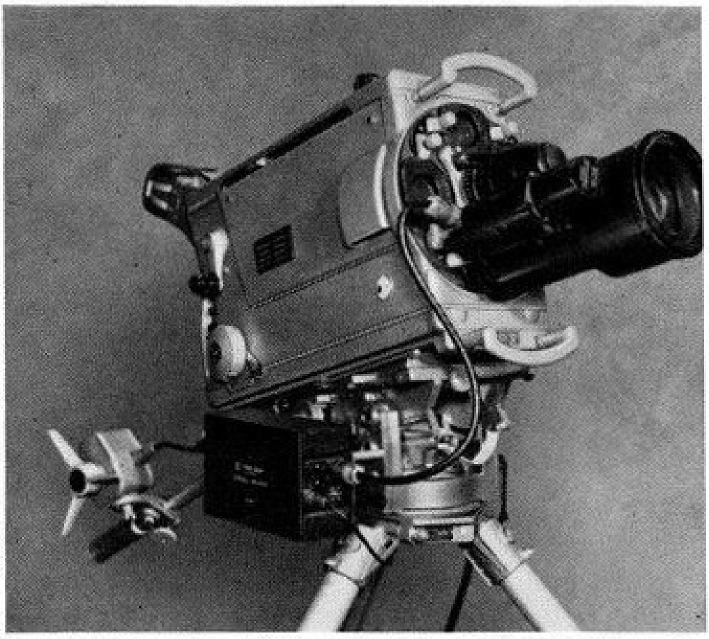

Fig. 3(a). A servo-controlled Varotal V Zoom Lens showing the servo amplifier and focus control.

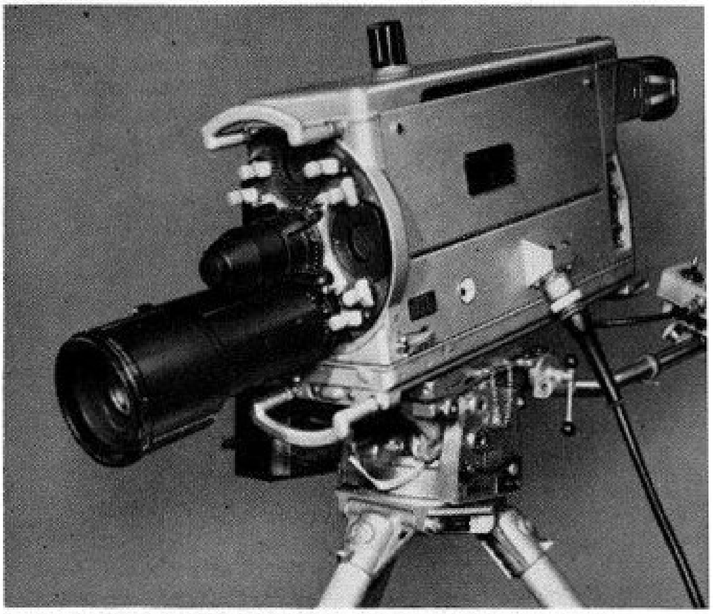

Fig. 3(b). The view from the other side showing the push-button 'shot box' controlling focal length.

Ideally the lens would require a specification of about 35 mm to 1,000 mm e.fil (30:1 zoom range) at a full aperture of *f*/2·0 for Image Orthicon channels. Such a lens is certainly impractical at this stage of the art and would certainly be unnecessary for many studios or outside broadcast applications. What is

Fig. 4. A Mark IV Image Orthicon Camera with a Varotal V Zoom Lens at the 1964 Winter Olympic Games at Innsbruck.

more realistic, is a continuance of the present situation of overlapping specifications of zoom lenses for both types of presentation, with the effort being made to provide greater compatibility with an easy interchange. Should, however, the television camera tube alter by way of either speed or size then this position could be materially altered in the future.

Remote control of Vidicon cameras incorporating zoom lenses is already in operation on a very small scale. This involves the additional servo controls of the pan and tilt functions of the camera, thus today perhaps we are seeing the beginnings of the 'Automated Studio' age in which all cameras will be operated from the production control room.

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