BRITISH STANDARD

BS 4793:1972

Recommendations for

Specifying the optical performance of lenses for television cameras

Confirmed December 2011

Co-operating organizations

The Instrument Industry Standards Committee, under whose supervision these recommendations were prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

British Calibration Service
British Electrical and Allied Manufacturers' Association
British Industrial Measuring and Control Apparatus Manufacturers' Association
British Mechanical Engineering Confederation
British Nautical Instrument Trade Association
British Railways Board
British Steel Industry
Council of British Manufacturers of Petroleum Equipment
Department of the Environment
Electrical Research Association
Electricity Council, The Central Electricity Generating Board and the Area Boards in England and Wales
Electronic Engineering Association
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Gauge and Tool Makers' Association
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National Coal Board
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Oil Companies Materials Association*
Scientific Instrument Manufacturers' Association*
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The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following were directly represented on the committee entrusted with the preparation of these recommendations:

British Photographic Manufacturers' Association Ltd
Department of Trade and Industry
Federation of Manufacturing Opticians
Flat Glass Manufacturers' Association
Illuminating Engineering Society
Institute of Physics and the Physical Society
Ministry of Defence, Inspectorate of Armaments
Royal Microscopical Society
Individual experts

These recommendations, having been approved by the Instrument Industry Standards Committee, were published under the authority of the Executive Board on 24 May 1972

The following BSI references relate to the work on these recommendations:
Committee reference INE/9/6
Draft for comment 70/35730

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Amendments issued since publication

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Contents

Foreword

These recommendations make reference to the following British Standards:

BS 4779, *Recommendations for measurement of the optical transfer function of optical devices.*

BS . . . . ., *Recommendations for veiling glare measurements.*

These recommendations have been prepared under the authority of the Instrument Industry Standards Committee.

Their principal aim is to recommend objective procedures for use when specifying the performance of television lenses. One of the measures of performance adopted in these recommendations is the optical transfer function (OTF). Techniques for the accurate measurement of this function have been established in recent years, and these not only form the basis of a reliable test method but also serve as a means of expressing performance in design specifications.

In addition to OTF, the complete assessment of television lenses demands the measurement of other parameters such as vignetting, veiling glare, distortion, etc.

It is envisaged that at some future date a generic standard for each given category of lens or optical instrument will be published, giving all those characteristics that are considered to be mandatory together with a preferred format for their presentation. The present document is to be considered as one for interim use, and its material will be incorporated in the full scheme as this develops.

No previous national or international recommendations exist that use OTF in connection with the performance of lenses for television.

Other standards in this series dealing with environmental, mechanical and test requirements are being prepared.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

These recommendations are for the specification and assessment of the optical performance of lenses for use with television cameras. These may be either zoom lenses, variable focal length lenses, or single focal length lenses, and they may be required to operate in either black-and-white or colour reproduction systems.

A special feature of these recommendations is that they adopt the optical transfer function (OTF), or more specifically its modulus, the modulation transfer function (MTF), as a method of assessing and specifying image quality.

These recommendations cover the performance of the lens as a complete optical unit but do not deal with the performance of individual component parts. The condition of test must however include any additional glass paths between the lens and the image plane that are required by the optical design, such as may be introduced by colour filters, beam splitting blocks, the face plate of the camera tube, etc.

2 Definitions

For the purposes of these recommendations the following definitions apply:

2.1
equivalent focal length

this is the ratio of the size of a focused image of a distant object to the angle subtended by that object, when the object is near the axis and the angle subtended by it has its apex on the front nodal point of the lens and is so small that its tangent is equal to its magnitude, in radians, within the limits of the required accuracy

2.2
back focal length

the back focal length is the distance from the point of intersection of the optical axis with the back surface of the lens to the rear focal point

2.3
flange focal distance

the flange focal distance is the minimum (perpendicular) distance between the plane of the flange mounting surface and the rear focal point

2.4
relative aperture

the relative aperture of a lens is also its "*f* number" and is the ratio of the equivalent focal length of the lens to the diameter or equivalent diameter (same area) of its entrance pupil. The relative aperture is normally written as f/N, where N is the above ratio the entrance pupil is specified as that for the infinite object distance

2.5
image format

the image format is the shape and size of the area within which the specified image must be formed. For a rectangular image format the shape is specified by the aspect ratio of breadth to height, whereas the size is determined by the length of the diagonal

2.6
zoom ratio

the zoom ratio is the ratio of the extreme values of equivalent focal length. It is expressed as n, where $n > 1$

2.7
lens hood

the lens hood is a shield, extending beyond the lens on the object side, to exclude light from bright sources outside the object field without obstructing light from the latter

2.8
near focusing distance

the near focusing distance is the distance from the point of intersection of the optical axis with the front surface of the lens to the nearest object point that can be brought to a focus in the image plane, defined in terms of the specified flange focal distance

NOTE Although this definition can apply to fixed focal length lenses, it is of prime importance for zoom lenses. It should also be borne in mind that, at the expense of image quality, a lens may be used at much shorter distances than those for which it is designed.

2.9
variable focal length lens

a variable focal length lens is a lens whose equivalent focal length can be varied. Such a lens will normally require to be refocused when this is done

2.10
zoom lens

a zoom lens is a lens whose equivalent focal length can be varied but whose image plane, for a given object plane, remains at a fixed distance from the mounting flange without the need for refocusing

2.11
line spread function

the line spread function of an optical system or device is the distribution of intensity across the image of a sufficiently narrow self-luminous line object as formed by that optical system or device

NOTE In general the line spread function of an optical system or device will vary with choice of image plane, wavelength, aperture, position in the image field, azimuth of the line object, etc.

2.12
optical transfer function (OTF)

this is a complex function of which the modulus is the modulation transfer function and the argument is the phase transfer function

an alternative and mathematically rigorous definition is that the optical transfer function is the Fourier transform of the line spread function. The modulus of this function is normalized to be unity at zero spatial frequency and the argument is zero at zero spatial frequency

2.13
modulation transfer factor

the modulation transfer factor, at a particular spatial frequency, is defined to be the ratio of image modulation to object modulation

2.14
modulation transfer function (MTF)

the variation of the modulation transfer factor with spatial frequency is defined to be the modulation transfer function. This function is normalized to unity at zero spatial frequency

2.15
axial transmission factor

the axial transmission factor is the ratio (normally expressed as a percentage) of the transmitted flux to the incident flux in an axial beam of monochromatic light that passes through the lens without being obstructed by any aperture stop

2.16
relative illumination

relative illumination is the ratio of the illuminance at the image plane for extra-axial field positions, to the illuminance at the centre of the field, for an object of uniform luminance

2.17
veiling glare index (bright field)

the veiling glare index (bright field) is the ratio of the minimum illumination in the image of a suitable "black" patch (of specified size and shape) at the centre of the field, to the illumination in a uniformly illuminated surrounding field filling, but not exceeding, the picture area

2.18
stray image

a distribution of light in the image plane, other than the primary image, which is an identifiable image of some object

2.19
image ghost

a stray image that is an identifiable image of the primary object

2.20
diaphragm ghost

a stray image that is an identifiable image of the diaphragm

NOTE Anti-reflection coatings greatly reduce the effects described in **2.17**, **2.18**, **2.19** and **2.20** and increase the axial transmission factor **2.15**.

2.21
radial distortion

an object point at distance R from the optical axis should be imaged in the image plane at a distance $k\ R$ from the optical axis, where k is a constant. Any departure from this simple proportionality is referred to as radial distortion

If R′ is the distance from the optical axis of the image of an object point at distance R, then the radial distortion is defined as

$$\Delta R' = R' - kR.$$

the value of the radial distortion so defined will depend on the particular choice of value for k

NOTE For zoom lenses, k will, of course, change with focal length.

2.22
radial distortion factor

this is the value of the radial distortion at a specified image distance from the optical axis, expressed as a fraction of that distance

the choice of distance to be employed varies with the condition of use but should at least include the maximum radial distortion factor obtained within the useful field of the lens

2.23
radial tracking error

this is the transverse displacement of a central image point produced when the focal length is altered

NOTE The maximum value is to be quoted as a percentage of the format diagonal.

2.24
standard image plane

the plane in which the modulation transfer factor of a zoom lens, at the centre of the field and for a chosen spatial frequency, aperture and spectral power distribution is a maximum at each of the two extremes of the focal length range

NOTE This plane exists for only one setting of the focusing adjustment and its position is normally established by an iterative process in which the modulation transfer factor is made a maximum at the short focal length by a choice of image plane, and at the long focal length end of the range by means of focusing adjustment provided on the lens.

2.25
axial spectral transmission characteristic

this is the curve that shows the variation of the axial transmission factor as a function of wavelength

2.26
focusing range

this is the range of object distances that can be brought into focus in the image plane of the camera by adjustment of the focusing control only

NOTE This range is not always from infinity to the near focusing distance, especially when certain attachments are used in conjunction with the basis lens.

3 Specification of parameters relevant to optical performance

3.1 Parameters relevant to optical performance

3.1.1 ***Equivalent focal lengths.*** The equivalent focal length should be within ± 3 % of the length specified by the manufacturer, but see **3.1.5**. In the case of zoom lenses and variable focal length lenses the minimum and maximum focal lengths should be specified and should be within this tolerance.

3.1.2 ***Relative aperture.*** Relative aperture should be within 5 % of that specified by the manufacturer. For zoom lenses a constant relative aperture should normally be held to within this tolerance over the whole zoom range for all aperture settings. In lenses with a very wide zoom range a gradual relaxation of maximum aperture may be permitted (in the interest of limiting the physical size of the lens) as the narrow angle extremity of the zoom is approached. In this case the manufacturer should specify the zoom ratio at which maximum relative aperture cannot be maintained and should also specify the maximum aperture at the narrow angle extremity of the zoom range.

3.1.3 ***Image format.*** Television images have an aspect ratio of 4 : 3. The image size is determined by, but not identical with, the diagonal of the camera tube.

Unless otherwise specified, the diagonal for the following common types of camera tube should be taken to be:

1) Image orthicon	40.6 mm
2) Plumbicon	21.4 mm
3) Vidicon	15.8 mm

Figure 1 illustrates this image format for television lenses and identifies three zones of the image field for the purpose of specifying image quality.

3.1.4 ***Additional optical components.*** The influence of additional glass components (e.g. the faceplate of the camera tube, colour filters, glass splitting block, etc.) between the lens and the image plane is to be compensated for in the lens design and test procedure, and the parameters so compensated should be fully specified as to thickness, refractive index and dispersive power.

3.1.5 ***Zoom ratio.*** This should be specified to an accuracy of ± 4 %.

3.1.6 ***Near-focusing distance.*** The near-focusing distance should be specified to an accuracy of ± 5 %.

For zoom lenses the zoom capability should be maintained at the specified near-focusing distance unless otherwise specified.

3.1.7 ***Aperture stop markings.*** These should be specified.

Stop markings, where provided, should be accurate to ± 5 %, i.e. the light flux is to be indicated to within ± 10 %.

3.2 Parameters directly describing optical performance

3.2.1 ***Modulation transfer factor.*** The minimum of the average values of the radial and tangential MTF at a spatial frequency corresponding to the chosen cut-off frequency of the television system[1] in which the lens is to be used, should be specified for each of the zones depicted in Figure 1 (MTF is to be measured in accordance with BS 4779).

The modulation transfer factor values quoted for each zone should be those corresponding to a common image plane and unless otherwise specified should be for an infinite object distance.

NOTE If either the radial or tangential value of the modulation transfer factor is low, e.g. 20 % or less, then a statement of the modulation transfer factor at the cut-off frequency may be misleading and should be supplemented by a measurement of the modulation transfer factor at half cut-off frequency.

[1] Unless otherwise specified, the cut-off frequency of the television system should be taken as 5.5 MHz System I — CCIR (International Radio Consultative Committee) and the corresponding spatial frequencies should be assumed to be:

Image orthicon format	9 c/mm.
Plumbicon	17 c/mm.
Vidicon	21 c/mm.

For monochrome applications the spectral characteristics to which these MTF values refer should be those resulting from the use of a tungsten source at 3 000 K and a detector having the following effective spectral sensitivity[2].

1) Image orthicon	Curve A	See Figure 2.
2) Plumbicon	Curve B	
3) Vidicon	Curve C	

For colour applications, spectral characteristics should be stated and the methods of measurement should be in accordance with BS 4779 or as otherwise stated.

In the case of zoom lenses and variable focal length lenses these values should be quoted for a comprehensive range of focal lengths that should include at least the two extremes and the geometric midpoint of the range.

Unless otherwise specified, all the values quoted for zoom lenses are to be for a common image plane and for a fixed setting of the focusing adjustment. If this common plane differs from the standard plane, the difference including distance and direction between the two planes should be stated.

3.2.2 ***Veiling glare index (bright field)*** (see BS . . . .[3]). The maximum veiling glare index should be stated for conditions specified in BS . . . .[3]. In the case of zoom lenses and variable focal length lenses these values should be quoted for a comprehensive range of focal lengths that should include at least the two extremes and the geometric midpoint of the range.

3.2.3 ***Axial transmission factor.*** For monochrome applications the minimum value of the axial transmission factor should be adequately specified for the relevant spectral characteristic(s) as defined in **3.2.1** and Figure 2. As an alternative to this, and when lenses are intended for colour transmission, the minimum axial transmission factor may be specified for a range of wavelengths from 440–450 nm, 520–530 nm or 600–610 nm and may conveniently be presented as a curve of axial transmission plotted against wavelength.

3.2.4 ***Relative illumination.*** For each aperture setting the minimum value of the relative illumination is to be specified at the edge of Zone 1, Zone 2 and Zone 3 (see Figure 1) along a diagonal of the format. In the case of zoom and variable focal length lenses these should be stated for a range of focal lengths that should include at least the two extremes and the geometric midpoint of the range.

3.2.5 ***Radial distortion factor.*** The radial distortion factor $\frac{\Delta R'}{R'}$ at the periphery of the field (image height, $R' = \frac{1}{2} \times$ format diagonal) is to be specified. For the purposes of these recommendations the constant k in the equation

$$\Delta R' = R' - kR$$

is to be chosen to make

$$\Delta R = 0, \text{ for } R' = \tfrac{1}{2} \times \text{format height}$$

$$= \frac{3}{10} \times \text{format diagonal.}$$

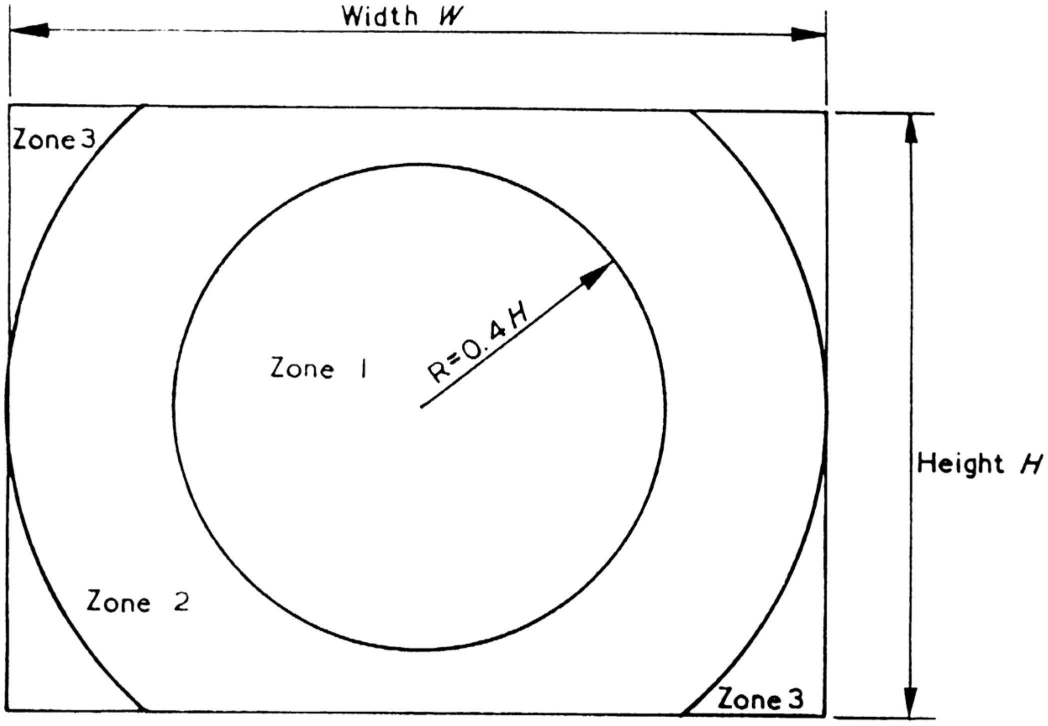
In the case of zoom lenses and variable focal length lenses, the radial distortion as defined here should be specified for a variety of focal lengths including at least the extremes and one point at about the geometric midpoint of the range.

3.2.6 ***Radial tracking error.*** The maximum values should be stated.

3.2.7 ***Miscellaneous***

3.2.7.1 *Lens hood.* The internal finish of the lens should be such as to minimize reflections as much as possible. However, for difficult lighting conditions it may be necessary to supply a shield type of lens hood for use with the lens. This should be designed to eliminate stray images caused by high-lights outside the field of view, without causing any restriction in the maximum field of view of the lens or any change in the relative illumination over the field.

[2] The curves given in Figure 2 are typical of present day manufacture and have been selected for the purposes of standardization in this present recommendation as representing the most commonly used characteristics.
[3] In course of preparation.

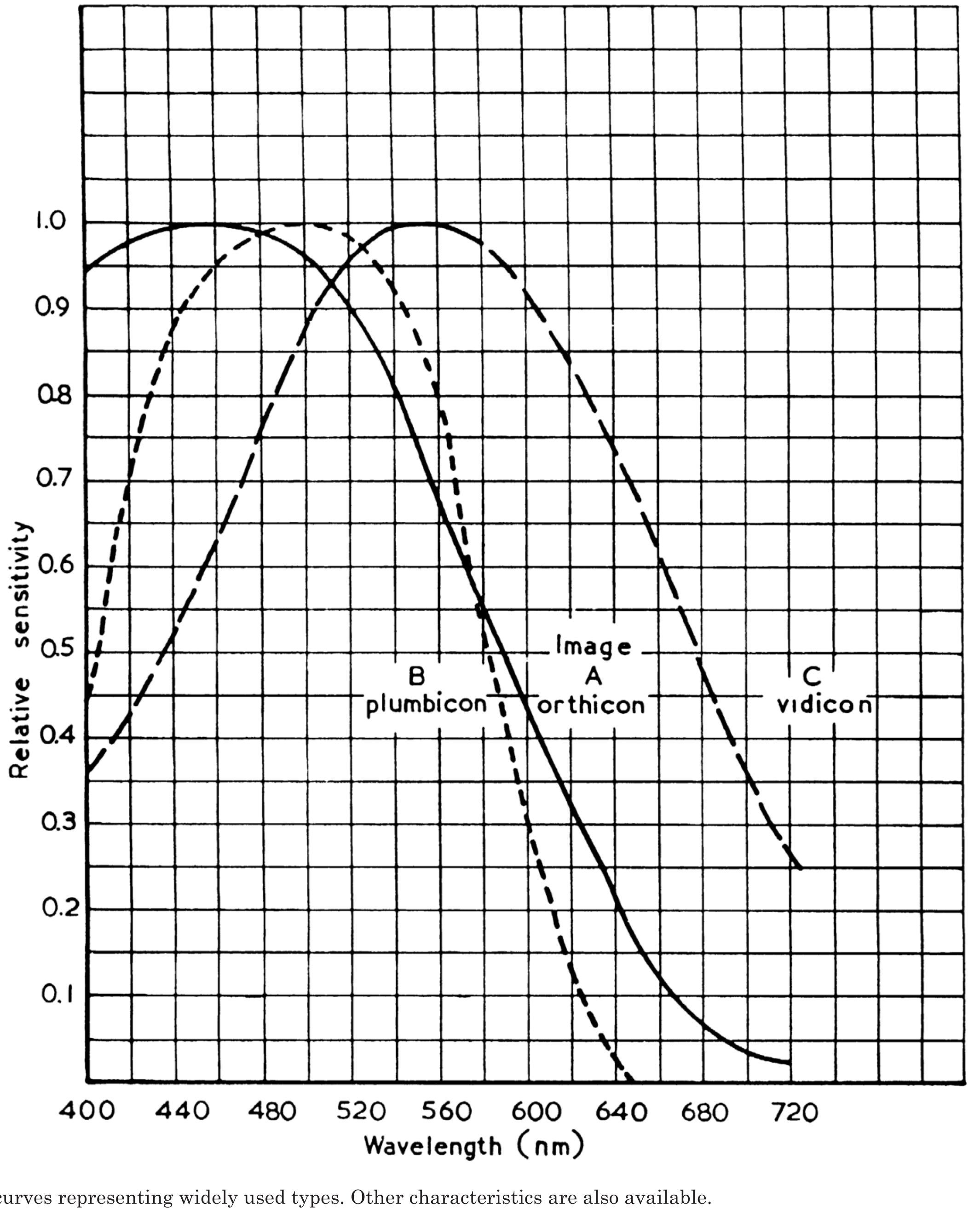


Aspect ratio = $\frac{\text{Width}}{\text{Height}} = \frac{W}{H} = \frac{4}{3}$

Zone 1 Circle with radius $0.4H$

Zone 2 Partial circle with radius $0.5W$

Figure 1 — Relative illumination zone



These are curves representing widely used types. Other characteristics are also available.

NOTE 1 nm = 10 Å.

Figure 2 — Typical spectral sensitivities

British Standards

The following are available on application:

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Including subject index and numerical list of British Standards

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