BRITISH STANDARD

BS 4995:1973

Recommendations for

Measurement of the veiling glare index of lenses and optical systems

Confirmed December 2011

UDC 535.818.7

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
Electrical Research Association
Electricity Council, The Central Electricity Generating Board and the Area Boards in England and Wales
Electronic Engineering Association
Engineering Equipment Users' Association*
Gauge and Tool Makers' Association
HEVAC Association
Institute of Measurement and Control*
Institution of Chemical Engineers
Institution of Electrical Engineers
Institution of Mechanical Engineers
Institution of Production Engineers
Meteorological Office
Ministry of Defence, Air Force Department
Ministry of Defence, Army Department*
Ministry of Defence, Navy Department
National Coal Board
National Physical Laboratory (Department of Trade and Industry)*
Oil Companies Materials Association
Scientific Instrument Manufacturers' Association*

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 Broadcasting Corporation
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)
Ministry of Defence, Procurement Executive
Royal Microscopical Society
Sira Institute
Individual experts

This British Standard, having been approved by the Instrument Industry Standards Committee, was published under the authority of the Executive Board on 27 November 1973

The following BSI references relate to the work on this standard:
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Amendments issued since publication

Amd. No.	Date of issue	Comments

Contents

Foreword

This British Standard has been prepared under the authority of the Instrument Industry Standards Committee. It is based on work carried out by an Image Quality group administered by Sira Institute.

The aim is to establish an objective procedure for use when measuring the veiling glare characteristics of an optical system. The measure of veiling glare adopted in this British Standard is the ratio of the minimum illumination in the image of a black area at the centre of an extended uniformly illuminated field to the illumination of the same area of the field when the black area is removed.

The number resulting from such a measurement is referred to as the veiling glare index. This is not an absolute quantity, in the sense that the result of such a measurement depends on the exact conditions of the test, (e.g. size of the extended field and that of the black area etc.) and the results obtained under one set of conditions cannot necessarily be used to predict those obtained under a different set of conditions. Equally the veiling glare index defined in this way cannot in general be used to predict specifically the effect of veiling glare on the imaging characteristics of the optical system. Attention is also drawn to Appendix B.

The main advantage of this technique is that it gives a single figure of merit and requires relatively simple and inexpensive equipment for its measurement.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 9 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

This British Standard adopts veiling glare index (bright field) (VGI) as a measure of the veiling glare characteristics of an optical system. Laboratory techniques for measuring VGI are described in general terms and recommendations are made regarding the performance of the main sub-units of the equipment.

Standard methods of specifying conditions of test and of expressing the results are given, while to assist in the intercomparison of VGI figures, four standard test conditions are specified. It is also the purpose of this standard to give guide lines for the operation of VGI measuring equipment such that accurate results may be achieved.

2 Definitions

For the purposes of this British Standard, the following definitions apply:

2.1
veiling glare

unwanted light in the image plane, resulting from scatter and/or unwanted reflections

2.2
veiling glare index (VGI)

the ratio of the minimum illumination scattered into the image of the black area to the illumination of the same area of the field when the black area is removed. The number obtained will depend upon the position of the black area in the field. For the purposes of this British Standard, VGI is taken to be with the black area in the centre of the field

NOTE 1 The measurement is made under specified conditions of the illuminated field size, black area size, and the proportion of black area image area used for measurement.

NOTE 2 If an integrating sphere is used to represent the extended illuminated field and the black area is not easily removed, the equivalent result may be obtained by turning the lens through a small angle so as to include an equivalent illuminated area not containing the black area.

3 Preferred conditions

In general, the VGI will depend on the dimensions of the black area and the illuminated field, the area over which the illumination in the image of the black area is measured, and the conjugates at which measurements are made. These must therefore be specified when giving a figure for the VGI. To help in specifying test conditions, four different test conditions are defined in Clause 4.

In view of the wide range of optical systems and the wide range of conditions of their use, it is necessary to try to limit the number of possible combinations of instruments and conditions of test for veiling glare. In addition, practical problems of feasibility can arise, for instance that of arranging for an extended field of illumination for a system working at longer distances.

4 Test conditions for the measurement of veiling glare index

4.1 Test condition A (see Figure 1)

This is defined as:

Extended uniformly illuminated field subtending 180° at the entrance pupil of the optical system under test.

Circular black area producing an image of diameter equal to 1/10th ± 20 % (actual figure is to be stated) of the image format diagonal.

Measuring aperture with the diameter not greater than 1/5th the diameter of the image of the black area. If too small a diameter is used, this could give rise to instrumental difficulties.

Object conjugate greater than × 5 the focal length of the optical system under test.

4.2 Test condition B (see Figure 1)

This is defined as:

Extended uniformly illuminated field of such shape and size as to fill the image format of the system under test.

Circular black area producing an image of diameter equal to 1/10th ± 20 % of the image format diagonal.

Measuring aperture with the diameter not greater than 1/5th the diameter of the image of the black area. If too small a diameter is used this could give rise to instrumental difficulties.

Object conjugate greater than × 5 the focal length of optical systems designed for infinite conjugate applications, and at the relative design value for optical systems designed for object conjugates less than × 5 focal length.

4.3 Test condition C1 (see Figure 2)

This is defined as:

Extended uniformly illuminated field effectively located at infinity by the use of a collimator, the field being circular in shape and of size slightly larger than the field of the instrument or optical system under test.

A diffuse, back illuminated screen to be placed perpendicular to the optical axis of the test system at the focal point of the collimating lens. A black area of diameter such as to subtend 1/6th of the field of view of the instrument under test is to be placed against the screen on the axis of the test system.

In the case of a telescope etc., a stop would be required at the exit pupil of the eyepiece to ensure that the apparatus does not receive more veiling glare than normally accepted by the dark adapted eye. This is achieved for the worst case condition by using a stop which should be of 7 mm diameter. This stop is placed in the exit pupil of the instrument under test.

A collimator lens is to be placed at a distance $\leqslant 5F$ from the first optical surface of the instrument under test (where F is the focal length of the objective). The collimator lens is to be of such diameter as to subtend the field of view of the instrument under test when viewed from the entrance pupil. The collimator lens is to have an appropriate anti-reflection coating to minimize secondary reflections of light possibly reflected from the instrument under test (in practice this has been found to be very important).

Measuring aperture with a diameter not greater than 1/5th the diameter of the image of the black area. If too small a diameter is used, this could give rise to instrumental difficulties.

When testing an instrument which cannot be adjusted to form an image, a +4 dioptre plano-convex lens with an anti-reflection coating should be used to focus the black area.

4.4 Test condition C2 (see Figure 3)

This is defined as:

Extended illuminated field subtending 90° at the entrance pupil of the instrument under test.

A diffuse, back illuminated screen to be placed perpendicular to the optical axis of the test system and at a distance such that it passes through the focal point of the collimating lens. A black area of the diameter such as to subtend 1/6th of the field of view of the instrument under test is to be placed against the screen on the axis of the test system.

In the case of a telescope etc., a stop would be required at the exit pupil of the eyepiece to ensure that the apparatus does not receive more veiling glare than normally accepted by the dark adapted eye. This is achieved for the worst case condition by using a stop which should be of 7 mm diameter. This stop is placed in the exit pupil of the instrument under test.

A collimator lens is to be placed at a distance $\geqslant 5F$ from the first optical surface of the instrument under test (where F is the focal length of the objective). The collimator lens is to be of such diameter as to subtend the field of view of the instrument under test when viewed from the entrance pupil. The collimator lens is to have an appropriate anti-reflection coating to minimize secondary reflections of light possibly reflected from the instrument under test (in practice this has been found to be very important).

Measuring aperture with a diameter not greater than 1/5th the diameter of the image of the black area. If too small a diameter is used this could give rise to instrumental difficulties.

When testing an instrument which cannot be adjusted to form an image, a +4 dioptre plano-convex lens with an anti-reflection coating should be used to focus the black area.

4.5 Application

Test conditions A, B, C1 and C2 are regarded as preferred conditions of test for the following type of instrument but, since there is a very wide spectrum of application within the areas cited, other tests may often be needed.

Test condition A. For photographic objectives. TV lenses without hoods.

Test condition B. For use where there are limitations of field e.g. process lenses, enlarging lenses and copying lenses. TV lenses with hoods.

Test condition C1. For telescopes, binoculars and director sights.

Test condition C2. For telescopes, binoculars and director sights; an alternative method for assessing veiling glare of instruments when used in an environment where the illumination covers an extended field, e.g. outdoor situations for equipment not provided with a lens hood. Under such conditions the VGI measured under Test Condition C1 may be a very inadequate predictor of system performance. This is particularly true for high power telescopic systems.

The test conditions employed should be stated and whether it is the preferred condition A, B, C1, C2 or any other.

5 General requirements

5.1 Laboratory environment

The level and type of ambient light should be such as not to affect the accuracy of the measurement. A clean environment is recommended, since dust, grease etc. on optical surfaces will adversely affect the veiling glare index of a system.

5.2 Equipment

The equipment for measuring veiling glare index is illustrated diagrammatically in Figure 1. It consists of four main items:

1) *Extended source*. This is of uniform brightness with a facility for introducing a well defined circular black area at its centre.

2) *Detector unit*. Measures the intensity of illumination in the image plane of the system under test and normally comprises a small aperture, filters for adjusting the spectral content of the source and a photoelectric detector.

Such a detector should be mounted so that it can be moved in a direction perpendicular to the image plane of the system under test, so as to position the aperture accurately in the image plane of the system as well as in a plane parallel to the image plane, so that the aperture can be moved to the position where the intensity in the image of the black area is a minimum.

A photographic material offers an alternative detector for the measurement of the intensity of illumination in the image plane of the system under test. It is positioned accurately in the image plane of the system corresponding to the position of the small aperture in the detector unit.

3) *Auxiliary optical systems*. For testing certain systems and in particular a focal systems such as telescopic sights, it will be necessary to use at least one auxiliary lens in order to obtain a real image.

4) *Optical bench*. The purpose of this is to support the optical system under test, any auxiliary optical systems, the extended source and the detector unit, as required in performing the measurements.

6 Detailed equipment requirements

To ensure that accurate values of veiling glare index are obtained, the measurements described in this standard should be made under controlled conditions. In particular, wherever instrumental parameters may influence the results they should either be offset by the application of correction factors (see Clause **8**) or, if this is not practicable, they should be taken into account when estimating the accuracy of the measured index. The purpose of this section is to indicate those instrumental parameters which require particular attention. Clause **10** suggests procedures for checking whether some of these requirements are met.

6.1 Extended source

6.1.1 *Luminance characteristic*. The extended source should behave as a Lambertian emitter (i.e. the luminance as viewed from the entrance pupil of the system under test should remain constant for all field angles) over angles at least as large as the maximum angle subtended by the source at the entrance pupil of the optical system under test. A luminance which drops off with the angle to the normal no faster than the cosine of that angle is acceptable. A central area whose diameter is equal to half the equivalent image format diagonal of the system under test should have a luminance level constant to ± 5 %. The luminance of the whole area of the source should be constant to ± 8 %.

6.1.2 *Stability*. The source should be monitored for variations in intensity with time which could significantly affect measurements. Such variations are significant if they occur over periods of time comparable in length to that involved in making a complete measurement of veiling glare index.

6.1.3 *Spectral characteristics*. The spectral power distribution of the extended source should be known for the spectral range over which the detector is sensitive.

6.1.4 *Central "black area"*. The central "black area" should have a luminance which is less than $\times 10^{-4}$ that of the luminance at any point of the bright surround (see **10.1**).

6.2 Detector unit

6.2.1 *Stability of sensitivity*. The detector unit should be monitored for variation in sensitivity which could significantly affect measurement. Such variations are significant if they occur over periods of time comparable in length to that involved in making a complete measurement of veiling glare index.

6.2.2 *Angular responsivity*. The angular responsivity of the detector unit in the vertical and horizontal planes should be measured, and it should be able to accept all rays from the aperture of the optical system under test without significant reduction of sensitivity to marginal rays.

6.2.3 *Spectral sensitivity of photo-detector*. The individual spectral sensitivity of each photo-detector in use should be known. Such measurements should also be made of combinations of filters and photo-detectors used to simulate particular spectral responses.

If interference filters are used, particular care should be taken to ensure that transmission and/or apparent spectral changes with obliquity do not produce significant errors.

6.2.4 *Linearity*. The linearity of the detector system plus any amplifiers, meters etc., should be measured over the range of light intensities used e.g. 40 dB and should be consistent with the accuracy quoted for any measurements of veiling glare index.

6.2.5 *Reflectance of detector unit surface*. The external surfaces of the detector unit, from which light may be reflected including e.g. that of the aperture plate, should be coated to have a suitable reflectance. When the veiling glare of a lens or mirror system alone is being measured the preferred maximum value is 3 %. When the veiling glare measurement is to include a detector such as a photographic material, the reflectance shall be representative of the conditions of use.

7 Specification of measurement conditions

In order that the results of a measurement of veiling glare index should be unambiguous, it is necessary that the system under test should be fully specified and the conditions under which the test is made should be indicated clearly. In determining how much of a complete system should be tested it may be necessary to take account of such items as surfaces of photographic material, camera bodies etc.

The test conditions to be specified are given below.

1) The description of the system under test shall be stated.

2) The dimensions and format of the extended source should be specified.

3) The subtended angle(s) of the illuminated source should be specified.

4) The diameter of the central black area or its image should be specified.

5) The nature and dimensions of the detector unit surface should be stated if the reflectance exceeds a preferred value of 3 %.

6) The diameter of the aperture in the detector unit should be specified as a fraction of the diameter of the image of the central black area.

7) Where relevant, the distance between object and image should be specified, together with the magnification and which end of the optical system faces the object (i.e. extended source).

8) The spectral characteristics of the complete combination of light source, detector and any colour filters used should be stated or preferably should be plotted in the form of a graph.

9) The lens apertures for the tests should be stated.

10) If the measurements are made with a hood on the optical system which is detachable and not an integral part of the optical system, the lens hood used should be specified.

11) If it is necessary to make use of auxiliary apparatus, e.g. auxiliary lenses, to improve the feasibility or convenience of making a measurement, such extras are to be fully specified.

8 Points requiring special attention during veiling glare measurements

8.1 Detector dark current

When a d.c. measuring system is used there will normally be a dark current signal from the measuring system even when no light is falling on the detector. This dark current may be significant in comparison with the signals which result from the light levels occurring inside the image of the central black area. The dark current signal should therefore be measured and where significant should be subtracted from the instrument reading.

It is important to note that the dark current signal will tend to vary with time and should therefore be determined for each VGI measurement made.

8.2 Stray light

Unless great care is taken in the design of equipment for measuring VGI and in the environment in which it is used, some light might fall on the aperture of the detector unit which does not arise from veiling glare in the optical system under test and may therefore give rise to false readings. This stray light may come from the extended source, for instance by reflection from laboratory walls, bench surfaces, clothing, or from other sources such as instrument indicator lamps etc.

The contribution to the output signal of the instrument which arises from stray light should be measured. This can be done by taking readings with the aperture of the optical system under test masked off. Efforts should be made to minimize the contribution from stray light by screening, but the residual signal should nevertheless be subtracted from the instrument reading.

8.3 Dirt and dust on optical surfaces

Any dust, dirt or grease (in particular finger prints) on the optical surfaces of the system under test will affect the results of the veiling glare index measurement. Unless otherwise specified, it is normally assumed that the veiling glare index quoted for a particular optical system applies to the system as submitted for test. If it is required that the surfaces of the system are to be cleaned immediately prior to testing, an appropriate cleaning procedure should be specified by the agency submitting the system for test.

8.4 Auxiliary optical systems

The use of auxiliary optical systems should be avoided if at all possible. Where this cannot be done, as for instance when testing afocal systems, steps are to be taken to ensure that these do not contribute significantly to the veiling glare of the overall system.

9 Presentation of results

A preferred format is illustrated in Appendix A.

In presenting the results of veiling glare index measurements, complete information about the conditions of test (see Section 7) should be given. Comment should be made on the surface condition and with regard to "cosmetic defects" (including bubbles etc.) of the optical system as received for test.

The veiling glare index, which is the ratio of the intensity inside the image of the central black area to that in the image of the extended source in the absence of the black area, should be expressed as a percentage.

10 Practical experimental techniques

10.1 Extended source

The extended source may be one of two main types:

1) A diffusely transmitting plate such as a suitable ground glass or opal glass screen, uniformly illuminated from the rear by a bank of lamps (see **6.1.1**). The central black area in this case is usually an opaque disc covered with "flock paper", black velvet or a very low reflectance matt black paint (see **6.1.4**), which is either fixed to the centre of the screen or is held close to the screen on a narrow metal arm. Normally a number of black areas of different diameters will be required to cover a variety of test conditions.

The preferred method of measurement of screen luminance is to remove the black area and determine the illuminance of the image of the screen which the black area previously obstructed.

2) A diffusely reflecting screen. This can be metallic and coated with one of the special photometric integrator paints available commercially.

The screen is illuminated from the front by a bank of lamps which must be suitably masked so that light from the lamps does not fall directly on the optical system under test.

When a reflecting screen is used it is not normally sufficient to use a blackened disc as the black area, since the reflection cannot usually be made low enough. Instead some form of aperture with an absorbing cavity behind it must be used.

For VGI measurements using a 180° extended field, this form of source is normally used. The screen is then usually a sphere or hemisphere.

The aperture and absorbing cavity is usually constructed so that it can be removed from the screen and replaced by a section with the same reflecting characteristics as the rest of the screen, when measuring the illuminance of the image of the extended source.

10.2 Detector unit

It will frequently be convenient to use a photo-multiplier as the detector. In many situations it may be sufficient to place this behind the measuring aperture without the use of any additional components, but it is usually preferable to have a diffusing screen between it and the aperture.

The photomultiplier is usually used in a d.c. mode and the anode current measured directly on a sensitive galvanometer, or amplified electronically and measured on a d.c. voltmeter. However, the photomultiplier can be used in an a.c. mode by arranging a suitable mechanical chopper close to the aperture to chop the light. The photomultiplier output can then be amplified using an a.c. amplifier and measured on an a.c. voltmeter.

If a photographic technique is used, the normal care and precautions should be taken with regard to sensitometric procedures.

In addition, it should be noted that the reflectance of the detector is likely to exceed the preferred maximum value in **6.2.5**.

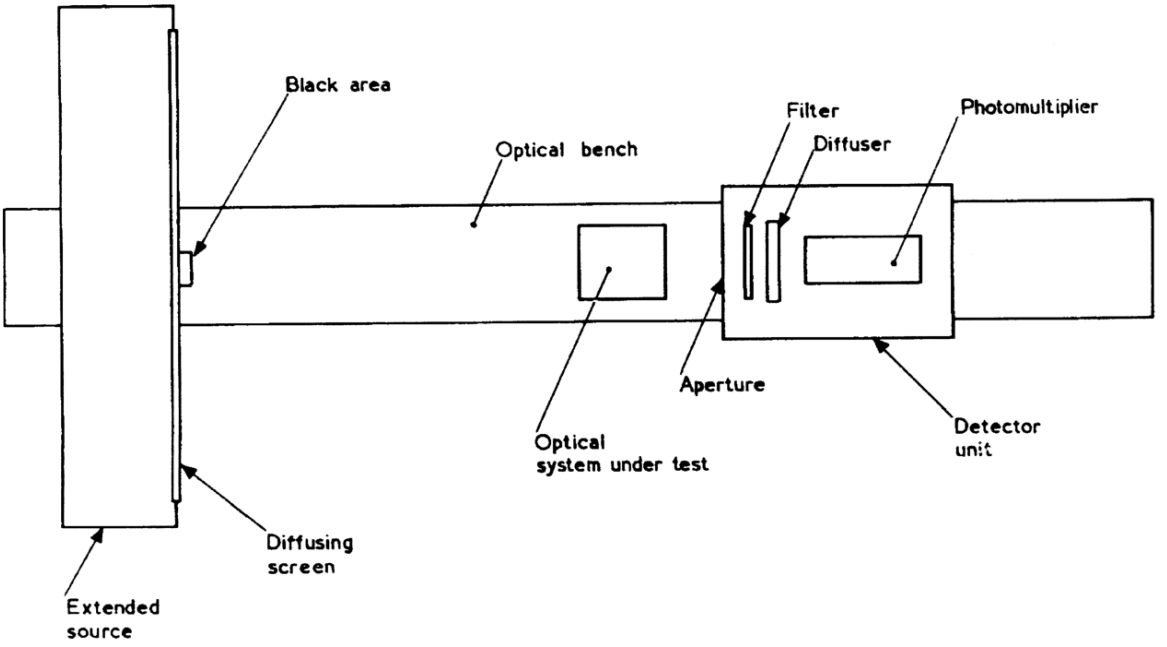

Figure 1 — Equipment for test conditions A and B

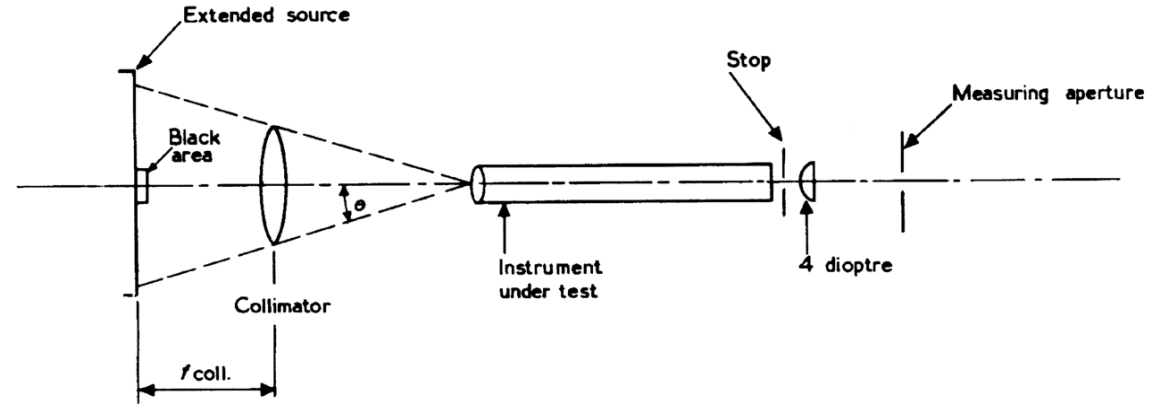

Figure 2 — Equipment for test condition C1

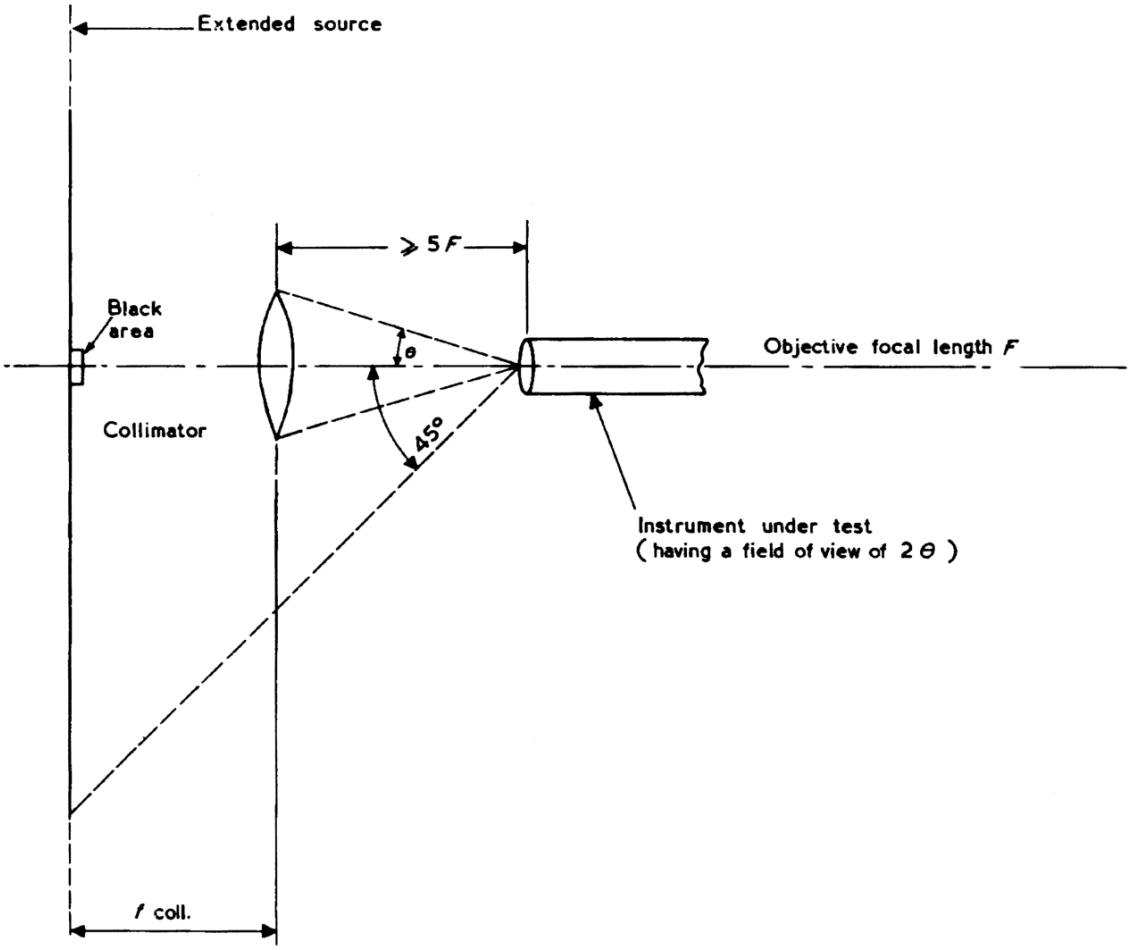

Figure 3 — Equipment for test condition C2

Appendix A Preferred format for veiling glare test

Test details

Schedule numbers

Instrument/Equipment under test

1) Description
2) Serial number

Manufacturer

Firm or establishment undertaking test

Instrument/Equipment used for test

1) Description
2) Serial number

Test centre/laboratory certification identification

Date

Test parameters

Test condition to BE 4995 A B C1 C2 (delete as appropriate)

Dimensions and format of extended source

Object size and shape

Distance of object or collimating lens to entrance pupil of test instrument

Distance of exit pupil to image plane

Spectral characteristics

1) Light source
2) Filter
3) Detector

Marked numerical or relative aperture(s)

Lens hoods

Auxiliary lens used (dioptre)

Distance of exit pupil of test instrument to auxiliary lens

Image diameter at detector/diffuser

Type and serial number of detector

Measuring aperture size of detector

Value of neutral density (ND) filter if used

Results

(These should include a statement of marked numerical and relative apertures and focal lengths/magnifications for each quoted performance figure).

A correction of . . . . . has/has not been applied for the use of the auxiliary lens.

Authentication signatures

Appendix B Other methods of measuring veiling glare index

The veiling glare characteristics of an optical system may be completely specified by a set of curves, each of which shows the distribution of energy in the image plane of the system when a small source of light is present in the object plane. A number of curves is required, corresponding to different positions of the source both inside and outside the normal field of the system.

A particular feature of the curves defining the energy distribution in the image plane ("glare spread functions") is that they must cover a wide range of intensities (typically $1 : 10^6$ to 10^9) if they are to prove useful in predicting levels of veiling glare.

To obtain a comprehensive set of "glare spread functions" is very time-consuming and this technique (usually referred to as the analytical method) has not therefore normally been used as the basis of a test specification. However, in some situations, a limited number of measurements using the analytical method or some modification of it, may form a more useful basis for a specification than the black area method described in this BSI specification. For instance, in applications where the veiling glare arises mainly from a small source with a high relative intensity it may be better to specify limits to the shape and magnitude of the glare spread function for a source at one or two selected points in object space, rather than use the black area criterion.

Another analytical function which is a useful measure of veiling glare is a plot of the glare illuminance at a given point in the image plane as a function of the position of a small source in object space. In a circularly symmetrical system, the function need only be plotted for positions of a source along a semi-diagonal of the object field. Moreover, plots of this function for (say) three positions in the image plane would give a fairly complete description of the veiling glare characteristics of the system.

Simple figures of merit including the veiling glare index may be derived from analytical functions by calculating the integrated area under the curve between certain specified object or image positions, weighted, if necessary, according to the object or image position and suitably normalized.

It is anticipated that a future standard will deal with the specification and measurement of veiling glare by some of these alternatives to the black area technique.

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