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# Optics and optical instruments — Veiling glare of image-forming systems — Definitions and methods of measurement

*Optique et instruments d'optique — Lumière parasite diffuse des systèmes d'imagerie — Définitions et méthodes de mesure*



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## Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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# Introduction

The image plane of an optical or electrooptical imaging system normally receives not only the image forming radiation, but also stray (unwanted) radiation which can reduce image contrast.

This unwanted radiation is referred to as "veiling glare". In lens systems it usually arises from one or more of the following causes:

a) internal multiple reflections between the lens surfaces;

b) scatter from the surfaces of the lens elements due to scratches and other imperfections in the polish, dirt and dust, fingerprints, grease, poor antireflection coatings and faulty reflective coatings on mirrors;

c) bulk scatter from the interior of the glass and from bubbles and striae;

d) scatter from optical cements;

e) scatter and reflections from ground edges of the lens elements, from internal lens mounts and from the internal surfaces of the lens barrel;

f) reflections from the surfaces of diaphragms and shutter blades;

g) fluorescence of the glass optical cements.

The veiling glare of lens on its own can be considerably different from the veiling glare of a lens system and camera body combination. In the latter case, reflection of part of the image-forming radiation from the photosensitive material in combination with further reflections and scatter from the lens system and camera body contribute significantly to the veiling glare.

In electrooptical devices, veiling glare arises from similar causes. For instance, in an image intensifier tube glare can arise from:

a) radiation transmitted through the photocathode being scattered and reflected by internal structures back onto the photocathode;

b) radiation emitted from the phosphor going back to the photocathode;

c) in tubes with microchannel plates some electrons incident on the input face can be back-scattered from this face before returning to it with the primary electrons.

For the purposes of this International Standard, it is important to differentiate between veiling glare which originates from radiation incident on the entrance pupil or input face of an optical or electrooptical system and other factors which may cause a reduction in contrast and which may therefore influence a measurement of veiling glare.

Examples of these are:

a) radiation entering a system through leaks in the casing or body of the system;

b) radiation from internal sources in a system such as LEDs;

c) reflection of ambient radiation from projection screens or CRT displays;

d) dark current in electrooptical devices;

e) fog in photographic emulsions.

There are two principle methods of measuring veiling glare, namely the integral (or black patch) and the analytical (or glare spread function).

In the integral method, the target object is a small black area surrounded by an extended uniform source. The veiling glare index (VGI) is specified as the ratio of the irradiance in the image of the black area to the irradiance in the image of the extended source. For definitions of this and other radiometric and photometric terms, see ISO 31-6.

In the analytical method, the object is a small source with a dark surround. The distribution of irradiance in the image plane normalised in a particular way, is defined as the glare spread function (GSF).

Each of these two methods of measuring veiling glare has its own particular areas of usefulness. In general, the integral method is applicable to systems where the scene will normally be of roughly uniform radiance (e.g. a landscape photographed in overcast conditions or with the sun behind the camera) whilst the analytical method is relevant to applications where intense isolated sources may be present in the scene (e.g. a star sensor system on a space vehicle, designed to operate with the sun just outside its field of view).

The analytical method has the further advantage that in principle it can be used to calculate glare levels in a specified real situation and in fact the VGI can be predicted from the GSF (e.g. by convolution and integration of the GSF with the radiance distribution in the scene) whilst the reverse is not possible.

# Optics and optical instruments — Veiling glare of image-forming systems — Definitions and methods of measurement



## 1 Scope

This International Standard adopts both the veiling glare index (VGI) and the glare spread function (GSF) as measures of the veiling glare characteristics of optical and electrooptical imaging systems. Laboratory measurement techniques are described in general terms and recommendations are made regarding the performance of the main subunits of the equipment.

The measurement techniques described in this International Standard are chiefly valid for the visual spectral range. For adjacent spectral ranges, modifications of these techniques will possibly be necessary.

Standard methods of specifying conditions of test and of expressing the results are given, while to assist in the intercomparison of VGI figures, standard test conditions are specified.

This International Standard also gives guidelines for the operation of measuring equipment such that accurate results can be achieved.

Results of veiling glare index measurements made using equipment which does not conform in detail to the configurations described in this International Standard are accepted as valid, provided the method of measurement is substantially similar (i.e. measures the ratio of the radiance in the image of the black area to the radiance in a surrounding bright field) and provided the test results can be correlated to the required accuracy with results obtained on equipment which conforms strictly to this International Standard.

## 2 Definitions

For the purposes of this International Standard, the following definitions apply.

**2.1 veiling glare:** Unwanted irradiation in the image plane of an optical or electrooptical system, caused by a proportion of the radiation which enters the system through its normal entrance aperture. The radiation may be from inside or outside the field of view of the system.

**2.2 veiling glare index (VGI):** Ratio of the irradiance at the centre of the image of a small, circular, perfectly black area superimposed on an extended field of uniform radiance, to the irradiance at the same point of the image plane when the black area is removed. VGI is expressed as a percentage unless otherwise specified.

NOTE 1 The size of the black area and of the surrounding field, as well as the proportion of the black area used for measurement, shall be specified.

**2.3 veiling glare index — band target (VGIB):** Ratio of the irradiance at a specified position along the centreline of the image of a narrow, perfectly black band superimposed on an extended field of uniform radiance, to the irradiance at the same point of the image plane when the black band is removed. VGIB is expressed as a percentage unless otherwise specified.

NOTE 2 The black band, or strip, shall extend across a diagonal of the image format. Its width and length, as well as the size of the surrounding field and the proportion of the black area used for measurement shall be specified.

**2.4 glare spread function (GSF):** Irradiance distribution in the image plane, produced by a small source object, normalised to unit total flux in the on-axis image of the small source.

i.e. $\text{GSF} = \dfrac{\text{irradiance due to veiling glare}}{\text{total flux in image of source}}$

GSF is expressed in units of reciprocal square metres ($m^{-2}$).

The GSF only has meaning outside the primary image of the source.

**2.5 glare spread function — radiant intensity (GSFR):** Radiant intensity in image space of an equivalent veiling glare source at the exit pupil of the test system which gives rise to the measured veiling glare irradiance in the image plane. This intensity is normalised to unit total flux in the on-axis image of the actual illuminating source.

i.e. $\text{GSFR} = \dfrac{\text{radiant intensity of equivalent veiling glare source}}{\text{total flux in image of actual source}}$

GSFR is expressed in units of reciprocal steradians ($sr^{-1}$).

GSFR is normally used in preference to GSF when dealing with afocal systems. GSFR only has meaning outside the primary image of the source.

## 3 Classification of test specimen

The arrangement of test equipment used in measuring veiling glare will depend on the test specimen and shall be representative of the conditions under which it will normally be used.

Table 1 illustrates how these conditions are classified for the purpose of this International Standard and gives examples of classifications for typical specimens.

The classification given in table 1 is based on object distance and area and image distance and as shown in table 2.

## 4 Measurement methods

### 4.1 Veiling glare index

#### 4.1.1 General technique

A typical arrangement for measuring the VGI of a lens is illustrated diagrammatically in figure 1.

The extended bright field (subtending $2\pi$ sr in this case) is produced by illuminating an integrating sphere with several lamps through suitable portholes.

The "black area" is an absorbing cavity in the wall of the integrating sphere which can be interchanged with a section having the same reflecting characteristics as the remainder of the internal surface of the integrating sphere. The lens under test is placed with its front end protruding into an exit port which is diametrically opposite the "black area" in the integrating sphere. The front of the lens should protrude into the sphere at least as far as the line of the integrating surface.

The irradiance in the image of the black area is measured with a suitable photoelectric detector in front of which is a small aperture (with, if necessary a small integrating sphere, or condenser lens system, and/or diffuser between the two).

**Table 1**

| Object distance | Image distance: Infinity or greater than 10 × focal length | Image distance: Finite | Image distance: Finite but inaccessible |
|---|---|---|---|
| **A** Object at infinity or greater than 10 × focal length (unlimited object area) | Telescopes, also image intensifier telescopes | Photographic lenses | TV systems, cameras, cine cameras |
| **B** Finite (limited object area) | Projection lenses, magnifiers, microscopes | Enlarging lenses, process lenses, photographic lenses, image converter tubes with fibre plates | TV microscopes |
| **C** Finite but not directly accessible/(limited object area) | (Microscopes) | — | Image converter tubes with glass discs (TV microscopes) |

**Table 2**

| | | |
|---|---|---|
| **Object space** | **A** | The object is at infinity or nominally at infinity. In this case, radiation from the total semiinfinite space (unlimited object area) falls on the test specimen. |
| | **B** | The object distance and area are finite. The radiating source corresponds, with exceptions, only to the maximum object area used (limited object area). |
| | **C** | The object distance and area are finite; the object is not, however, directly accessible as it is, for example, covered by a glass disc. |
| **Image space** | **a** | The image plane is at infinity or nominally at infinity. |
| | **b** | The image plane is at a finite distance and is of finite area. |
| | **c** | The image plane is at a finite distance but is inaccessible because, for example, it is covered by a glass disc. |

The ratio of the detector signal in the above situation to the detector signal when the black area is replaced by a section of normal integrating sphere surface, gives the veiling glare index.

For the situation where the black area cannot be replaced with a normal section of the surface; the second measurement can be obtained by moving the aperture and detector to a position clear of, but adjacent to the image of the black area.

The exact form taken by the measuring equipment will depend on the classification of the test specimen (see clause 3). For measurements of veiling glare using a black area in the form of a band across a diagonal of the image format (i.e. VGIB), suitable adaptations of the general technique are used. An important consideration in this case is that the black band or strip needs to be in focus over its whole length and will normally therefore be on a flat surface. Suitable configurations for the extended source and for the detector system are discussed in the following subclause.

### 4.1.2 Extended source and black area

#### 4.1.2.1 Object at infinity (Classification A)

For this case, the extended source ideally subtends $2\pi$ sr. It is obviously impossible to have such a source and black area actually at infinity and it is therefore acceptable that the equipment simulates a situation where the black area and bright surround are at a sufficiently great object distance to give a measurement of VGI which is the same as that which would result if the distances were infinite. For the purposes of this International Standard, it is assumed that the object distance shall be greater than ten times the focal length of a lens tested in its own, or of the objective, if the test piece is an electrooptical system (such as a night vision sight) or afocal system. When a lens is tested in conjunction with the remainder of the system it forms part of (e.g. a lens tested with a camera body), a further stipulation is made that the object distance is also greater than the minimum focusing distance of the system.

Several different arrangements of equipment can be used for making measurements under these conditions and four of these are described in 4.1.2.1.1 to 4.1.2.1.4. Specifications for the performance of each part of a test system will be found in clause 5.

##### 4.1.2.1.1 Single integrating sphere method

For lenses of relatively short focal length, the single integrating sphere arrangement illustrated in figure 1 and described briefly earlier in this clause may be used. The equipment can be used for testing optical systems with the black area in different parts of the field of view of the system. To do this, provision shall be made for interchanging sections of the sphere wall by the absorbing cavity, at the appropriate field angles.

##### 4.1.2.1.2 Two hemisphere method

Where the object distance required are so large that the use of a single integrating sphere would be inappropriate, the arrangement illustrated in figure 2 may be used.

This method employs a uniformly irradiated hemisphere close to the test specimen to provide most of the $2\pi$ sr of irradiation, with a second hemisphere at the required object distance containing the black area (absorbing cavity) and providing the remaining part of the $2\pi$ sr extended source. The second hemisphere is seen through an aperture in the first hemisphere, whose diameter shall be such that it does not vignette the aperture of the test specimen, as far as imaging of the black area is concerned, and at the same time limits the object field to something less than the area subtended by the second hemisphere.

For off-axis measurements, the first hemisphere and the test specimen shall be tiltable and the aperture in this hemisphere shall be movable.

The effective radiances of the hemispheres shall be identical.

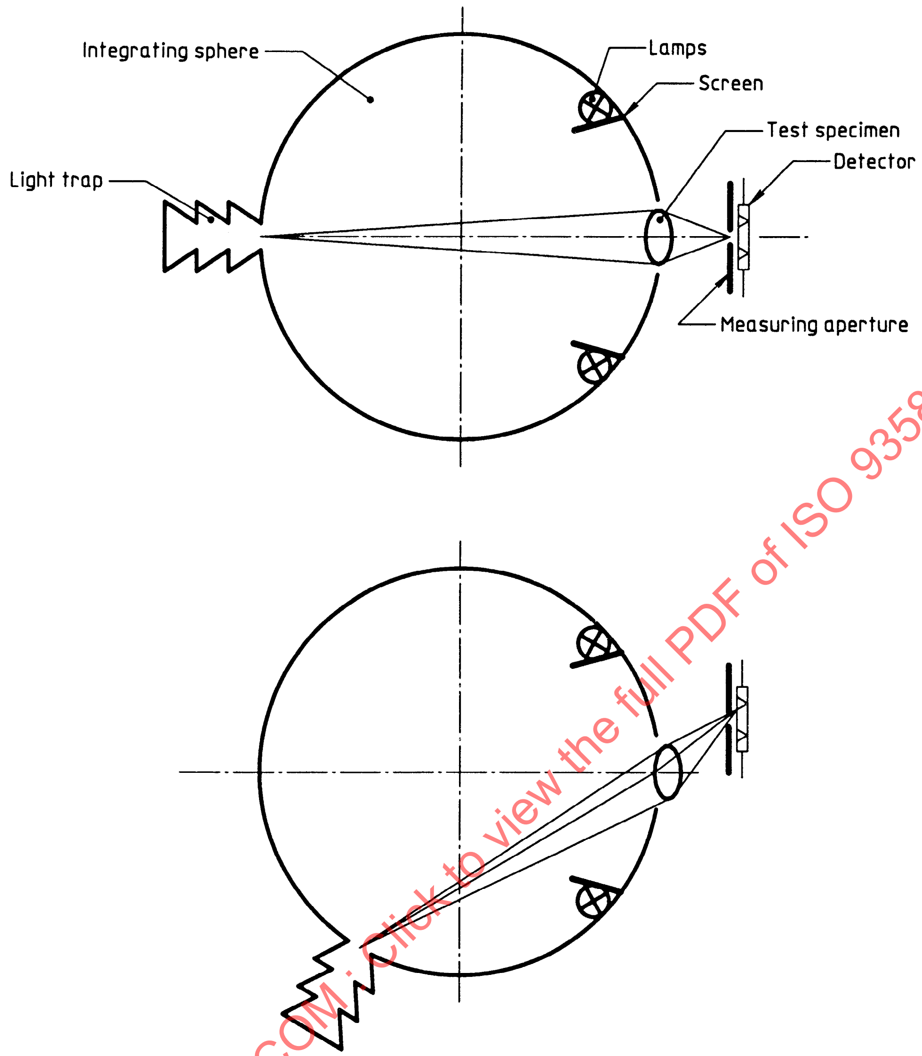





Figure 1 — Veiling glare measurement in the case of an unlimited object field

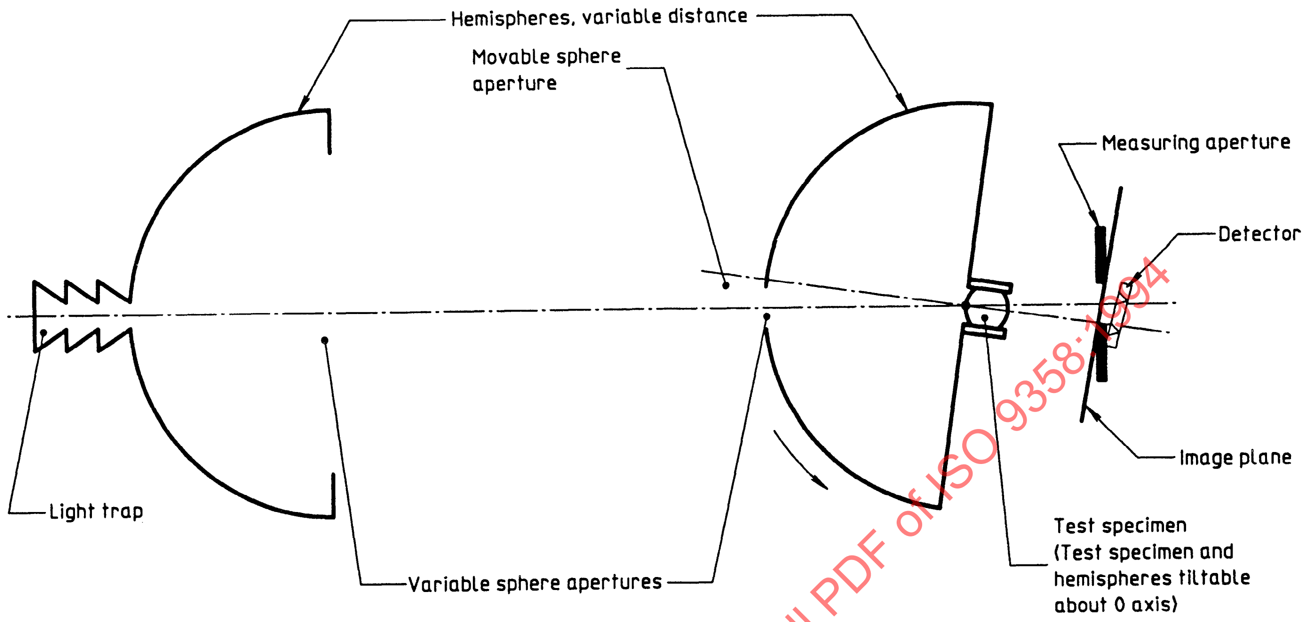
#### 4.1.2.1.3 Integrating sphere and collimator method

When long object distances are required, an alternative to the two hemisphere method is to use a single integrating sphere with a collimator, as illustrated in figure 3. For off-axis measurements, the test specimen is tilted about the centre of its entrance pupil.

Great care is required in any technique using auxiliary optics, such as a collimator, to ensure that they do not themselves introduce significant levels of veiling glare which would affect the accuracy of measurements (see clause 5 for recommendations regarding collimators).

#### 4.1.2.1.4 Irradiated rectangular box method

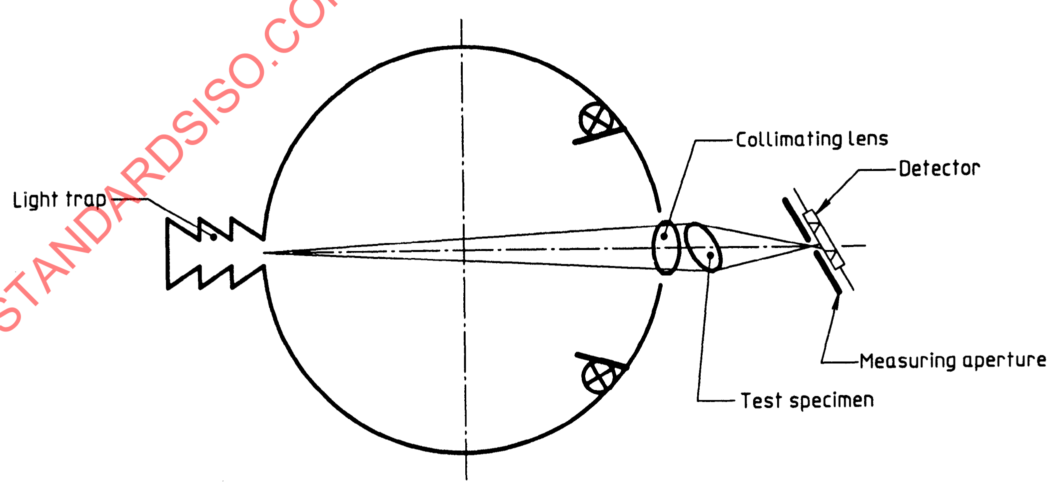
A rectangular box integrating cavity may be used instead of a single integrating sphere, provided its design is such that it meets the radiance specification in clause 5.




NOTE — The infinite object distance is obtained using a second hemisphere.

**Figure 2 — Veiling glare measurement with unlimited object field and infinite object distance**






NOTE — The image field is off-axis.

**Figure 3 — Veiling glare measurement with unlimited object field using an auxiliary lens**

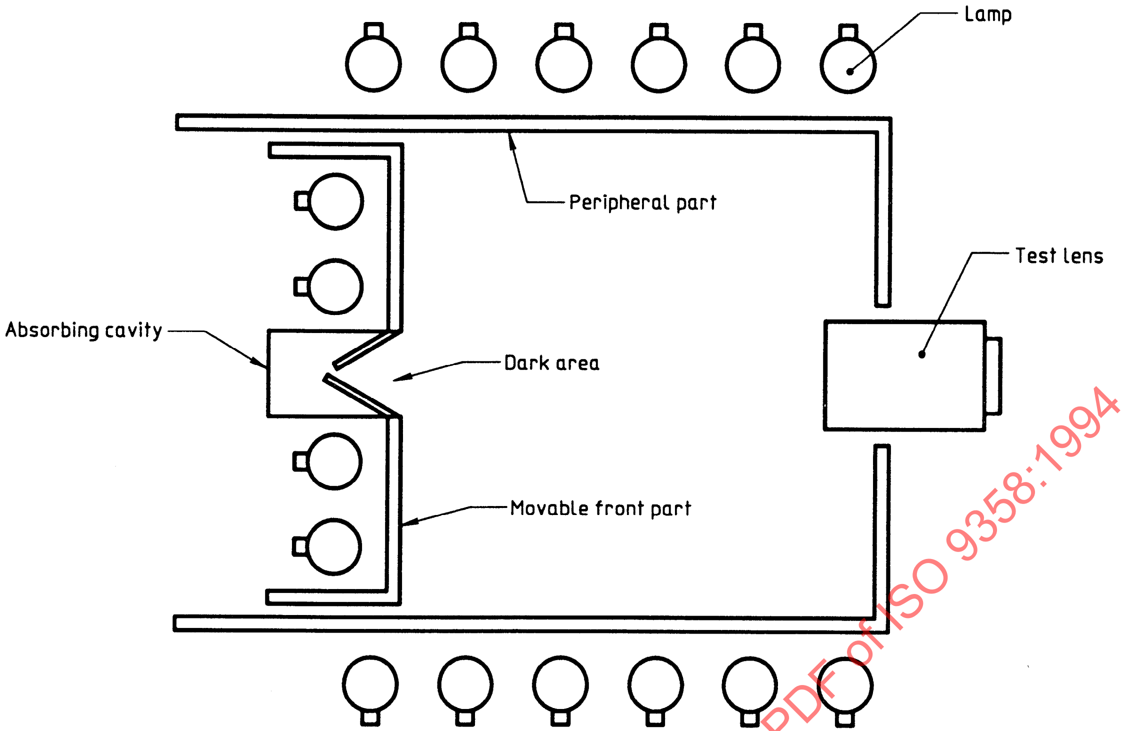



**Figure 4 — Schematic diagram of square box type radiation source**



Such an arrangement is illustrated in figure 4. It has the advantage that it can be built with a movable front or rear end in order to accomodate objectives of various focal lengths.

This form of integrating cavity may be used in VGI measurements where the black area is circular in shape. It is particularly suited however to VGIB measurements where a black area in the form of an absorbing strip extended diagonally across the full field of view of a system is used. Such an arrangement has, in particular, been used with the rectangular cavity as a convenient means of rapidly scanning through several different field positions. The absorbing strip is mounted on a pivot at the centre of the field of view so that it can be rotated to cover the full field. This arrangement may be used in conjuction with an array of detectors in the image plane to measure the VGI at different image positions.

#### 4.1.2.2 Object at a finite distance with limited object area (Classification B)

For this type of measurement, the size and shape of the extended source is strictly limited to being that of the size and shape of the object format of the test specimen.

Figure 5 illustrates the normal arrangement used for measuring VGI under these conditions.

The extended field is a uniformly irradiated diffusely transmitting screen with size and shape equal to the object format of the test piece. For VGI measurements, the black area is a circular opaque patch, usually arranged so that it can be moved to different parts of the field of view. A black opaque diagonal band is used for VGIB measurements.

#### 4.1.2.3 Inaccessible object plane (Classification C)

Where the object plane is inaccessible (and the object area is of limited size), it usually becomes necessary to project the extended source and black area into the object plane by means of auxiliary optics. The arrangement of equipment can be similar to that described in 4.1.2.2 for classification B systems with the addition of a projection lens system.

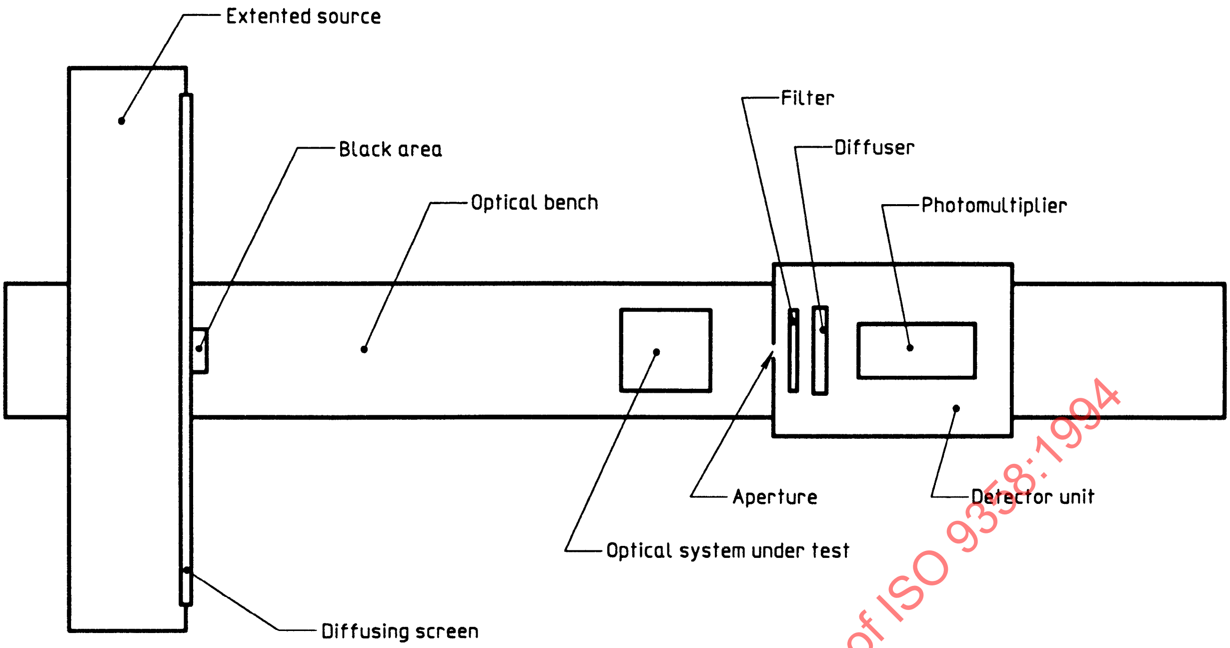



**Figure 5 — Equipment for measurement of veiling glare at finite object distance**



The veiling glare introduced by the auxiliary optics shall be kept as small as possible. It will in any case be necessary to correct for any residual veiling glare by subtracting its measured value from the total veiling glare measurement.

### 4.1.3 Detector system

The detector system normally consists of a circular measuring aperture, a filter holder and the detector. The polar responsivity of the detector system shall be uniform for the angular range over which it will receive radiation. To achieve this it may be necessary to incorporate additional components between the aperture and the detector such as a diffuser and/or condensing optics.

In some applications, reflections from the surface normally in the image plane of the test specimen (e.g. the film in the case of photographic objectives) can have a substantial effect on the veiling glare of the system. To simulate this effect, it may be necessary to arrange that the external surface of the detector system (i.e. the area surrounding the measuring aperture) has the same area and reflectivity characteristics as the surface normally present in the image plane of the test specimen. Similar considerations apply to any mechanical structures in this area (e.g. the camera body in the case of a photographic objective). It may be necessary to simulate these or use the actual structures in order to get a true veiling glare measurement for a complete system.

Where the image plane of the test specimen is at infinity a collimator may be used to image the radiation from the test specimen to a finite distance. The aperture of the collimator shall not vignette any radiation from the test specimen. Moreover the collimator shall be selected so as to introduce negligible veiling glare of its own (see clause 5 ).

When the image plane is inaccessible, a relay lens can be used to transfer the image plane to a plane where measurements can be made. Again the relay lens should introduce negligible veiling glare of its own, but if this is not possible it may be necessary to measure its veiling glare and apply a correction.

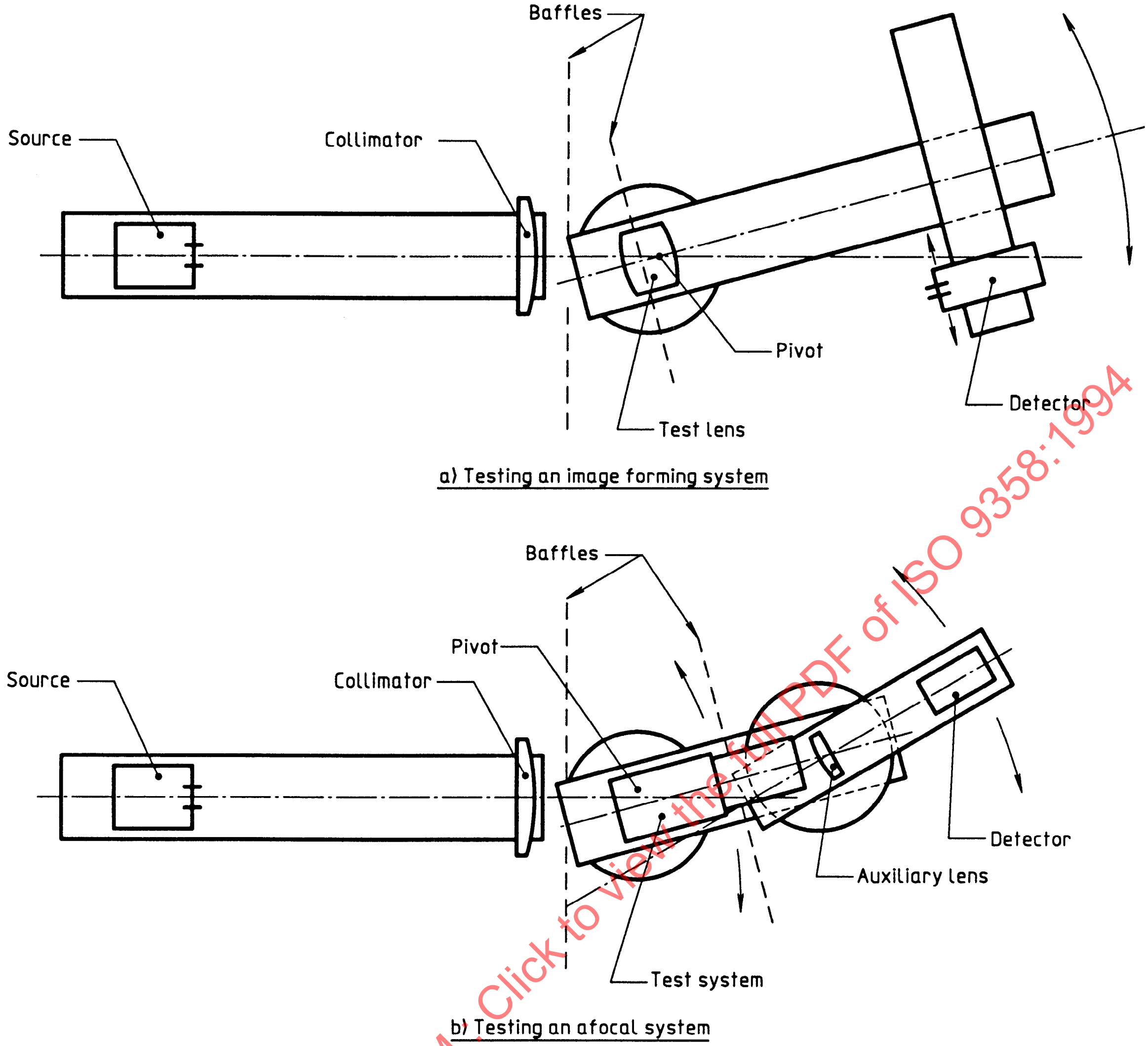



**Figure 6 — Equipment for measuring glare spread function**



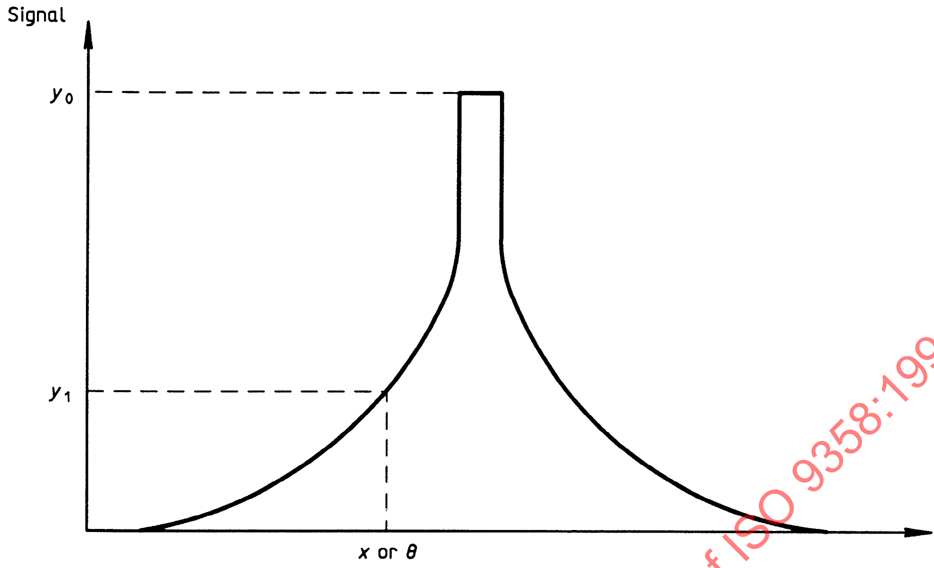
## 4.2 Glare spread function

### 4.2.1 General technique

A typical arrangement for measuring GSF or GSFR of a lens working with an infinite object conjugate is illustrated diagrammatically in figure 6.

A small circular source of uniform radiance is positioned at the focus of a collimator whose aperture it irradiates uniformly. The test specimen is mounted in the beam from the collimator in such a way that it can be rotated to vary the angular position of the source in its field of view whilst at the same time the test specimen's entrance aperture remains completely filled. Suitable means (e.g. baffles etc.) are required to prevent any radiation by passing the system under test and being measured by the detector. The irradiance distribution in the image plane of the lens is measured by the detector unit which normally consists of a small aperture, filters for adjusting the spectral content of the source and a photoelectric detector. The detector unit is mounted so that it can be positioned anywhere in the image field of the test specimen.

A particular requirement of GSF measurements is that the detector system must cover a very large dynamic range of irradiances. Typically this may be $10^4$ to $10^6$ or greater, depending on the type of lens or system being tested. To accommodate such a large dynamic range the detector system is usually designed to have a logarithmic response. The use of calibrated neutral density filters, inserted either in the source or the detector unit at appropriate stages of measurement, can help considerably to reduce the dynamic range required.




$A$ area of source image

$a$ area of detector

$k$ flux/signal

$x$ distance in image plane (linear measurement)

$\theta$ distance in image plane (angular measurement)

1 Detector < image

Irradiance is $ky_1/a$

Flux in image is $ky_0\,A/a$

Irradiance per unit is $y_1/y_0A$

2 Detector > image

Irradiance is $ky_1/a$

Flux in image is $ky_0$

Irradiance per unit flux is $y_1/y_0a$

**Figure 7 — GSF plot and method of normalisation**



For normalising the irradiance distribution to obtain the GSF, the former is divided by the total flux in the on-axis image of the source. If the detector aperture is smaller than the image of the source the total flux is usually taken as the product of the average irradiance over the source image and the area of the source image. This is obviously easier to determine if the source is of uniform irradiance.

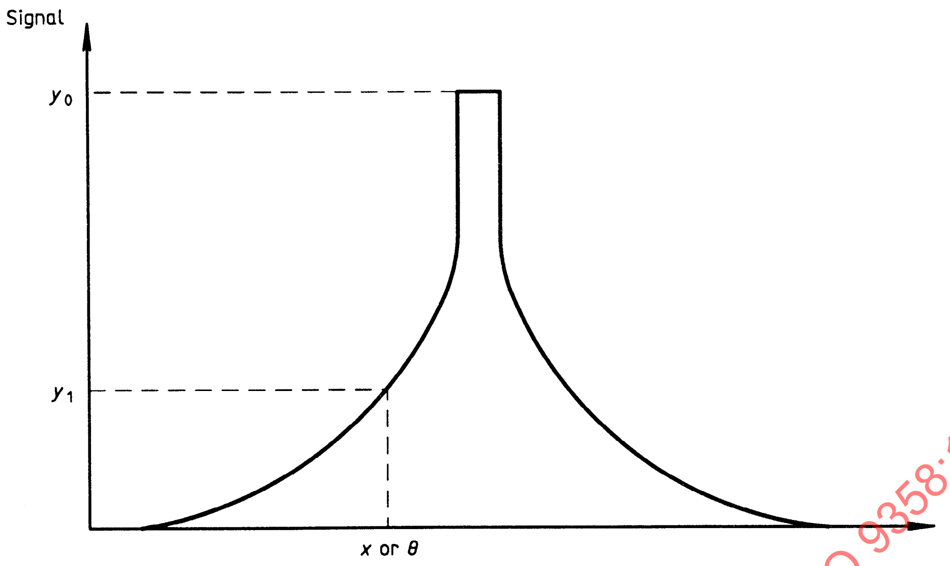
If the detector aperture is larger than the image of the source then the detector signal obtained when the source image is centred on the detector aperture is a direct measure of the total flux. The uniformity of irradiance over the image of the source is not of importance in this case.

The actual process of normalisation in both these situations is illustrated in figure 7. Similar considerations apply to the measurement of GSFR and the actual normalisation process is illustrated in figure 8.

### 4.2.2 Source

#### 4.2.2.1 Object at infinity (Classification A)

The arrangement of equipment illustrated in figure 6 and described in 4.2.1 is suitable for measurements where the object distance is infinite.




*k* flux/signal

*A* area of source image source

*a* area of detector

*d* detector to exit-pupil distance

*x* distance in image plane (linear measurement)

*θ* distance in image plane (angular measurement)

1 Detector < image

Pupil intensity is $ky_1d^2/a$

Flux in image is $ky_0\ A/a$

Intensity per unit flux is $y_1/d^2/y_0a$

2 Detector > image

Intensity is $ky_1/d^2a$

Flux in image is $ky_0$

Intensity per unit flux is $y_1d^2/y_0a$

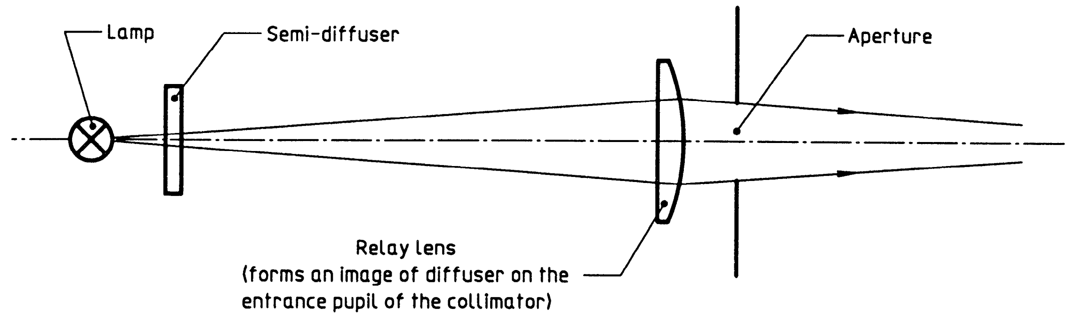
**Figure 8 — GSFR plot and method of normalisation**



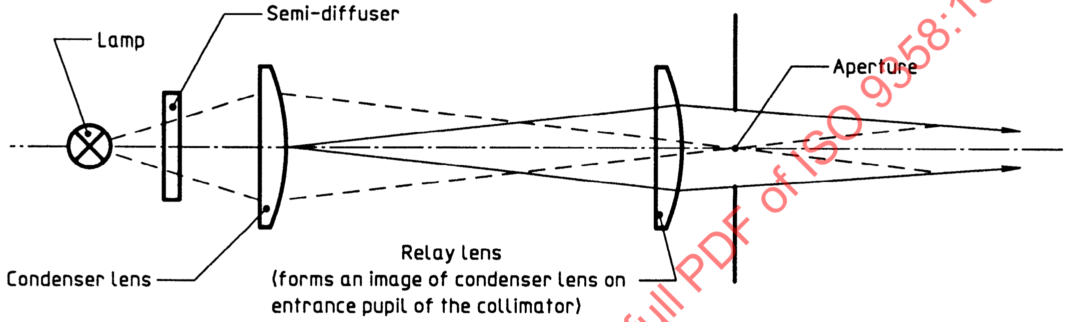
The choice of collimator should meet the criteria set out in clause 5 in order to reduce its effect on the measurement. The source itself is an irradiated aperture which could take the form shown in figure 9 a) or figure 9 b), particularly if uniform irradiance is required.

#### 4.2.2.2 Object at finite distance with limited object area (Classification B)

The equipment used for such measurements is illustrated diagrammatically in figure 10. The source unit is mounted so that it can be moved to any position within the object plane and format of the test specimen. The source once again consists of an irradiated aperture, however, in order to uniformly irradiate the entrance aperture of the test specimen at all field positions it becomes necessary either to use a source which comprises a transmitting diffuser irradiated by a lamp (which can lead to problems with signal levels), or if one of the arrangements illustrated in figure 9 is used either the cone of irradiation from the source unit shall be sufficiently large, or a mechanical facility shall be provided so that the source system can be tilted to always point to the centre of the entrance aperture of the test specimen.




a)




b)



**Figure 9 — Source systems**

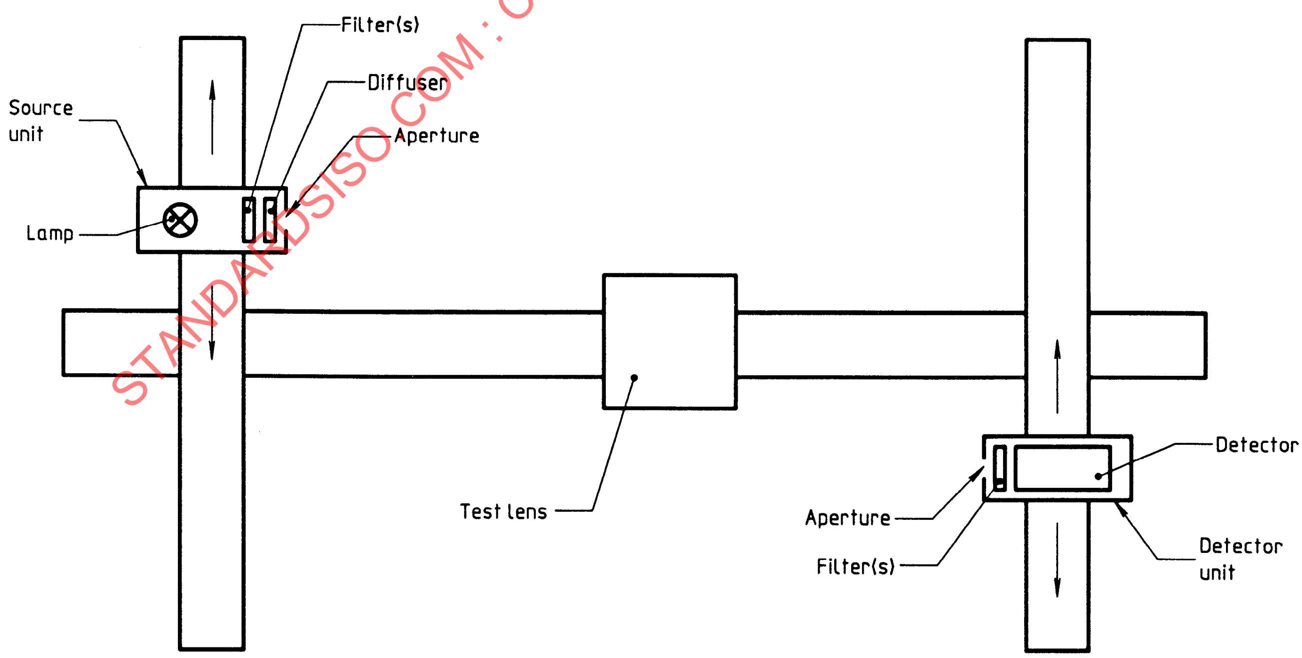



**Figure 10 — Equipment for measurement of GSF or GSFR of a lens with finite object distance**

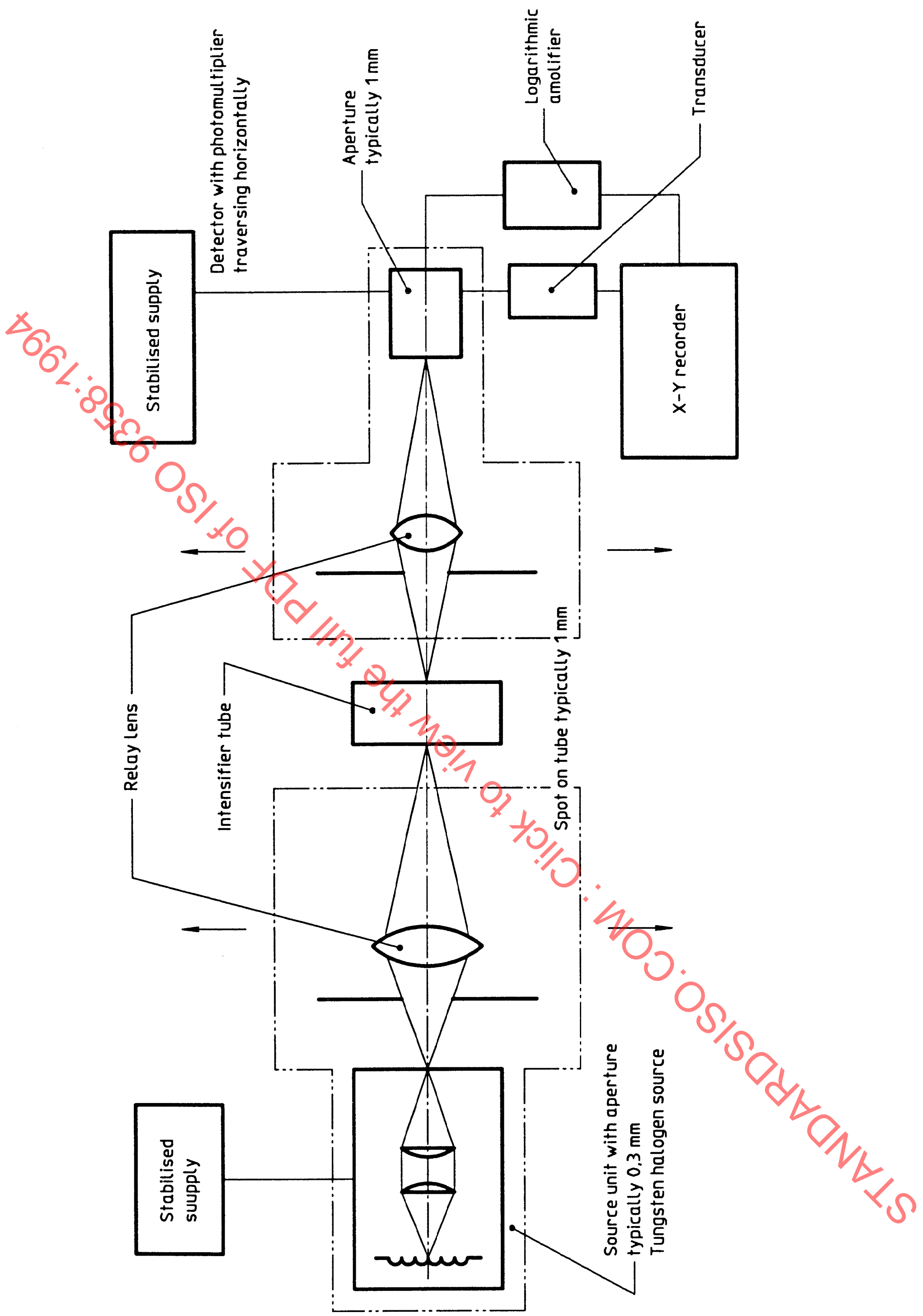



Figure 11 — Equipment for measuring GSF of an image intensifier tube

#### 4.2.2.3 Inaccessible object plane (Classification C)

An arrangement similar to that described in 4.2.2.2 is suitable for this type of measurement, with the addition of an auxiliary lens system to project the image of the source into the object plane of the test specimen.

An arrangement for measuring the GSF of image intensifier tubes is illustrated in figure 11.

Veiling glare from the auxiliary lens shall be negligible compared to that from the test specimen.

### 4.2.3 Detector system

The description and comments made in 4.1.3 for measurement of VGI also apply to the measurement of GSF and GSFR.

# 5 Test conditions

## 5.1 Measurement of VGI and VGIB

### 5.1.1 Extended source

#### 5.1.1.1 Size

For classification A systems, the source will subtend as near as possible an angle of $2\pi$ sr at the entrance pupil of the test piece. For classification B and classification C systems, the source will be equal in size and shape to the specified object field of the test piece.

#### 5.1.1.2 Radiance characteristics

The extended source shall behave as a Lambertian emitter, that is it shall have a radiance, as viewed from the entrance pupil of the system under test, which remains constant for all field angles. The accuracy with which the radiance level remains constant shall be better than ± 5 % over a central area whose diameter is equal to half the equivalent image format diagonal and ± 8 % over the whole area of the source.

#### 5.1.1.3 Stability

Variations of radiance with time should be less than 5 % over periods of time comparable to that involved in making a complete measurement of veiling glare index.

#### 5.1.1.4 Spectral characteristics

The spectral power distribution of the extended source shall be known for the spectral range over which the detector is sensitive and shall be compatible with the overall spectral characteristics required for the measurements.

#### 5.1.1.5 Black area

The black area shall be circular in shape with a diameter such that it produces an image equal to (0,1 ± 0,02) of the diameter of the image format diagonal. As an alternative, the black area may be a square of sides equal to (0,1 ± 0,02) of the image format diagonal. For VGIB measurement, a black strip of (0,1 ± 0,02) of the image format diagonal shall extend across the full image format.

The black area shall have a radiance which is less than $10^{-3}$ of the radiance of the surrounding bright field.

#### 5.1.1.6 Use of collimator and other auxiliary optics

In order to overcome the need to use an inconveniently large extended source when testing long focal length objectives (e.g. 1 000 mm telephoto lenses), it is permissible to use a collimating lens with the extended source (see figure 3).

The collimating lens should be a single element planoconvex lens with good quality antireflection coatings on both surfaces (reflectance less than 1 % per surface over the whole wavelength range used). It shall have a clear aperture of sufficiently large diameter that it does not vignette the test lens aperture over any part of the object format.

The collimator mount produce a minimum of obscuration of the extended source.

Similar considerations apply to a collimator used in image space, or to any auxiliary optics used to relay the source to an accessible object plane.

### 5.1.2 Detector unit

#### 5.1.2.1 Measuring aperture

The measuring aperture shall preferably be circular with a diameter of 0,2 times the diameter of the image of the black area.

#### 5.1.2.2 Angular responsivity

The output of the detector unit shall be linearly proportional to the irradiance at the measuring aperture with a constant of proportionality which varies by no more than 5 % over angles of incidence up to ± 45° and 10 % up to ± 80°.

#### 5.1.2.3 Reflectance if detector unit surfaces

Where the effect on veiling glare of the surface normally present in the image plane of the test specimen is required, the external surface if the detector unit from which light will be reflected shall have an area equal in size to the image format and shall either be covered by a suitable sample of the material normally present in this plane or have spectral and angular reflectance characteristics which are substantially similar to it. Any area outside this which could produce reflections back towards the lens shall have a reflectance of less than 3 %.

When the effect of veiling glare of the test specimen is required without the effect of a material surface in the image plane, the detector unit should be coated with a diffusely reflecting surface with a reflectance of less than 3 %.

#### 5.1.2.4 Linearity

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

#### 5.1.2.5 Stability of sensitivity

Variations in sensitivity of the complete detector/amplifier system shall be less than 2 % over periods of time comparable in length to that involved in making a complete measurement of veiling glare index.

#### 5.1.2.6 Spectral sensitivity of photodetector and filters

The spectral sensitivity of the photodetector as well as the spectral transmission characteristics of any filters used to simulate any particular spectral response shall be known. The filter or filters should preferably be located between measuring aperture and detector. The spectral response of the photodetector/filter system shall be chosen to measure veiling glare radiation in the spectrum range consistent with the actual use of the system.

Particular care should be taken to ensure that any filter transmission characteristics which change with obliquity do not produce significant errors.

### 5.1.3 Test conjugates

For a test specimen designed to work with an infinite object conjugate, the object conjugate shall be a minimum of ten times its focal length if it is a lens on its own, or ten times the focal length of the objective if it is an electrooptical or afocal system. If the test specimen is a complete system (e.g. camera lens plus camera body) then the object conjugate shall in addition be greater than the near focus distance of the system.

Where a test piece is designed to work at a finite object distance then the object conjugate used for veiling glare measurements shall be equal to that distance or shall be within the range of distances for which the test piece has been designed.

### 5.1.4 Field positions

Measurements of veiling glare index shall be made on the optical axis of the test specimen and at specified positions up to the full-field of the lens. It is recommended that if a single position is used, this should be chosen at 0,9 of the maximum field. For additional field positions, the following are recommended: 0,3, 0,5 and 0,7 of maximum field. When testing a lens plus camera body combination (or similar system) with asymmetrical features, the camera should be rotated about the optical axis to the orientation of maximum VGI.

### 5.1.5 Aperture settings

Measurements of VGI or VGIB of lens systems shall be made at full aperture as well as at the aperture setting giving a maximum value for VGI or VGIB for the on-axis field position. Measurements may also be made at other specified aperture settings especially to assess the veiling glare contribution of the aperture blades.

### 5.1.6 Tests on lens plus camera body (or similar complete systems)

In testing a lens/camera body combination, measurements should be made with the measuring aperture of the detector unit close to the film plane of the camera. To do this, it can be necessary to remove the camera back.

The measuring aperture shall be surrounded by fresh film or by a suitable simulation (i.e. one having the same reflectance characteristics) to completely cover the camera format.

## 5.2 Measurement of GSF and GSFR

### 5.2.1 Source

#### 5.2.1.1 Radiance characteristics

If measurements are made with a detector aperture smaller than the image of the source, then the source should have uniform radiance over its diameter, to within ± 5 %. The total flux in the image of the source is given by the product of the irradiance within the image and its area.

#### 5.2.1.2 Radiant emission from source

The polar distribution of the radiation leaving the source should be such that the entrance pupil of the collimator is evenly irradiated (any variation of intensity being preferably less than ± 10 %).

#### 5.2.1.3 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 duration to that involved in making a complete measurement of GSF.

#### 5.2.1.4 Spectral characteristics

The spectral power distribution of the source should be known for the spectral range over which the detector is sensitive.

#### 5.2.1.5 Diameter of source

The diameter of the source should be sufficiently small that any reduction in its size does not affect the value of the GSF in the region of interest (measurements of GSF within the image of the source are meaningless).

Normally, the source may safely subtend an angle of approximately 1/20th the total field of view of the system.

### 5.2.2 Collimator and other auxiliary optics

The collimator does not need to be highly corrected as far as aberrations are concerned (i.e. angular aberrations of the order of $5 \times 10^{-3}$ or less of the total angular field of view of the system under test are acceptable) and in most cases a single planoconvex element is adequate and even preferable as the collimator shall be effectively free from veiling glare (see 5.1.1.6).

### 5.2.3 Detector unit

#### 5.2.3.1 Aperture diameter

The diameter of the collecting aperture of the detector unit shall be sufficiently small that any reduction in its size does not affect the value of the GSF in the region of interest.

#### 5.2.3.2 Stability of sensitivity

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

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.

#### 5.2.3.3 Accuracy of response

The accuracy with which the detector system, including any variable density optical filters, amplifiers, meters, etc., follows the ideal response characteristics should be measured over the range of radiant intensities used and should be consistent with the accuracy quoted for any measurement of veiling glare. Normally, a logarithmic response characteristic will be used and light intensities can vary over a range of $10^4$ to $10^6$ or greater, depending on the type of lens or device being tested.

#### 5.2.3.4 Reflectance of detector unit

The external surfaces of the detector unit, from which radiation can be reflected including for example 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 the effect of a detector such as a photographic material, the reflectance shall be representative of the conditions of use (see 5.1.2.3 ).

## 6 Specification of measurement conditions

In order that the results of a measurement of veiling glare are unambiguous, 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