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application notes

Field Measurements Using Precision Photometer Type 1105



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Introduction

Precision Photometer Type 1105 is a versatile photometer offering high accuracy and precision together with ease and flexibility of operation. This application note illustrates the wide range of field measurements which can be performed with the Type 1105 and briefly describes how they are conducted.

In addition to the full range of illuminance measurements, other useful

parameters such as luminance, hemispherical illuminance and semicylindrical illuminance can also be measured with the Type 1105. This greatly extends the applications of this instrument, particularly in outdoor measurements where use of spatial adaptors is rapidly growing in popularity. Furthermore, the photometer possesses considerable processing power which facilitates data collection and manipulation.

A feature of the Precision Photometer is that there is no need to zero the instrument between measurements as this is done automatically before each measurement. This is extremely convenient in field measurements and is especially important at low lighting levels. The illuminated digital display of the 1105 makes it easy to read the results in low lighting conditions.

Section 1—Measurements with Illuminance Transducer

As with all measurements, the quality of the results depends to a large extent on the quality of the transducer. Brüel & Kjær enjoy a world-wide reputation for the design and craftsmanship of their microphones, accelerometers and other transducers. The Illuminance Transducer Type 8600 is no exception. Its sensing device is a silicon photodiode of high thermal stability. The geometry of the transducer is carefully designed for a cosine response to incident light and the excellent spectral match of less than 2% is provided by a multilayer absorbance filter.

The spectral match is defined according to the method described in CIE Publication (1). With this calculation, all deviations from the $V(\lambda)$ curve are integrated and therefore a value as low as 2% means that there is an excellent spectral match across the entire visible spectrum. This is a more stringent definition than another common definition which is based on the difference in areas of the transducers spectral response and $V(\lambda)$ and which allows negative deviations to cancel positive deviations. According to this definition, the spectral match error is in the order of 0,5%.

Illuminance in a room

The illuminance in a room (also termed average illuminance or mean illuminance) is defined as the sum of all measurements divided by the num-

ber of measurements. It is usually measured to check whether the lighting levels are satisfactory. A general rule is that no interior workspace which is continuously occupied should

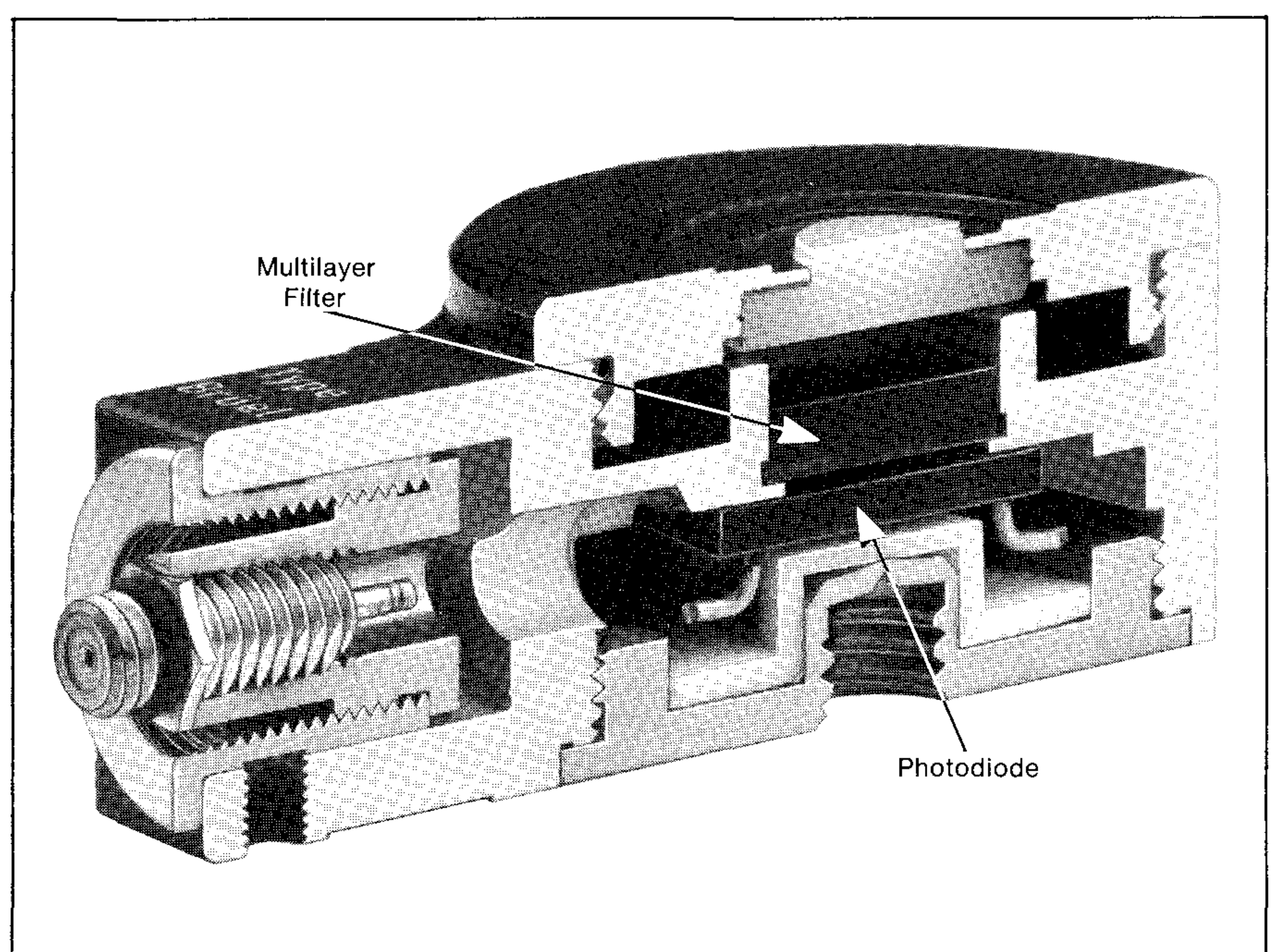


Fig. 1. Cross section of Illuminance Transducer Type 8600

have an illuminance of less than 200 lux on the work plane but recommended values for specific applications should be consulted. (See for example references 2, 3 and 4). Measurement of the illuminance in a room using the Precision Photometer is extremely fast and convenient as the mean of up to 1999 measurements can be displayed directly.

The density of measuring points in an area depends on the accuracy required; sixteen measurement points in a room $20 \times 20 \text{ m}^2$ will give an error of less than 10%. It is important that all measurements be taken at the same height. To facilitate this, Illuminance Transducer Type 8600 screws directly onto tripod UA 0587.

A special feature of the 1105, which is of particular importance with flickering light sources, is that the averaging time of the measurement can be selected as required. For light sources of flicker frequency greater than 50 Hz, 0,1 or 1 s is suitable. A simple rule of thumb is that if repeated measurements are reproducible, the averaging time is sufficiently long.

If you are concerned that the illuminance falls within certain limits, this can be quickly checked by defining those limits on the Type 1105 and scanning the room. The audible alarm sounds if the illuminance is outside the desired limits.

Point Illuminance

Point illuminance is measured when the illuminance at a specific workplace is of interest. Typical examples are office desks and component assembly areas. Again, the recommended values for specific tasks should be

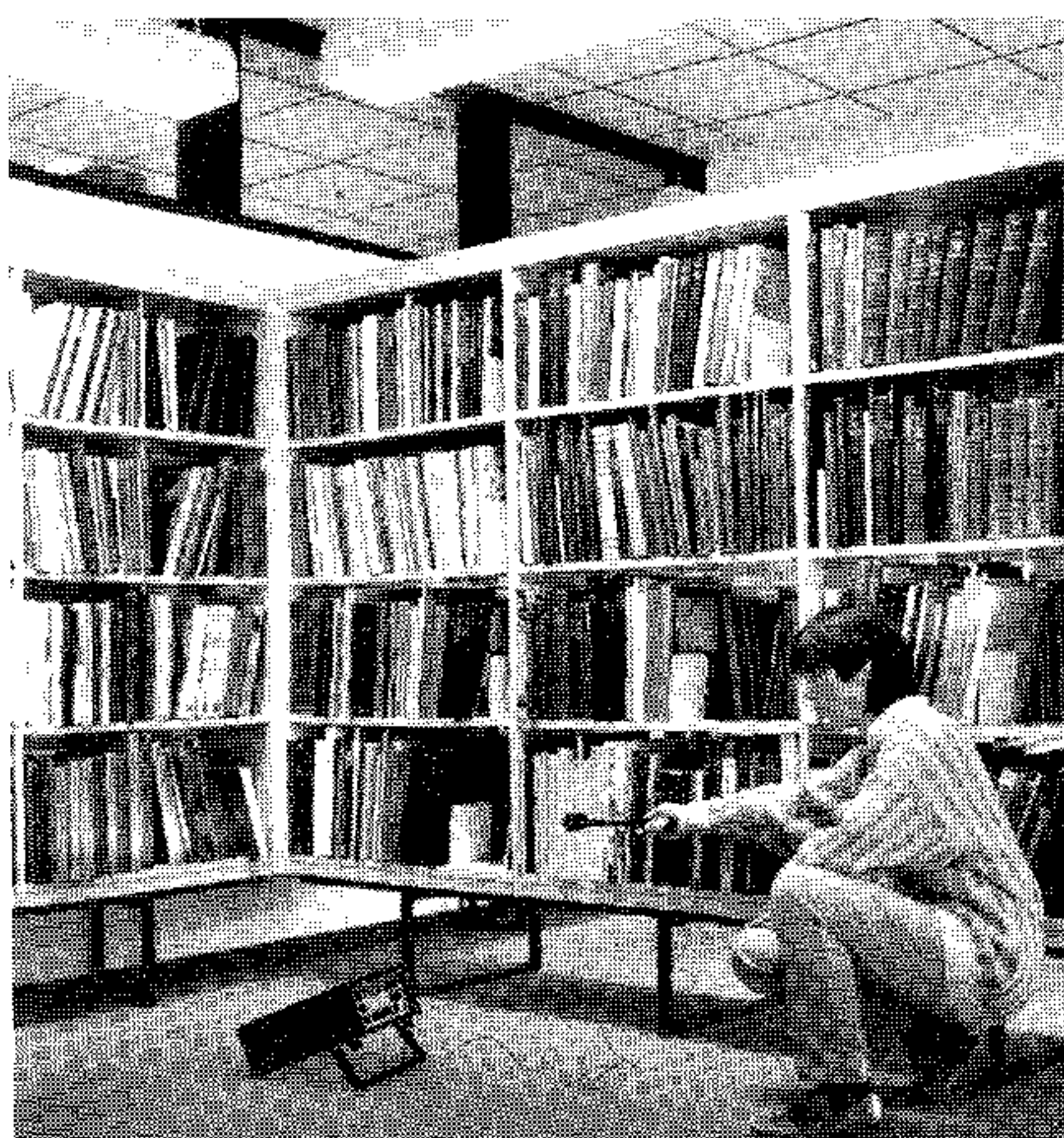


Fig. 2. Applications such as libraries and stores require illuminance measurements on the vertical plane

found in the national standards. Point illuminance measurements are generally taken with the worker in his usual position. Attention should be paid to the plane of the task, which is not always the same as the work plane, particularly in industrial situations.

Peak Illuminance

Flashing light sources are measured using the peak measurement mode of the Precision Photometer and flashes as short as $100 \mu\text{s}$ can be measured.

For flickering light sources, the crest factor (the ratio of the peak illuminance to the average illuminance) is a measure of the flicker. This ratio can be conveniently obtained using the quotient pushkeys on the 1105 and the result displayed directly.

Instantaneous Illuminance

The instantaneous value of the illuminance is obtainable from the analogue output of the 1105 for graphic recording or oscilloscope display. This enables a detailed investigation of the light signal to be performed.

Intensity Measurements

The intensity of a light source can be measured and displayed directly on the Precision Photometer. The relationship between the intensity, I , and the illuminance, E , for normal incidence is

$$E = I/d^2$$

where d is the distance from the light source, Fig.3. This relationship is strictly applicable only for point sources but holds true within one-half per cent when d is at least five times the maximum dimension of the source or the acceptance area, whichever is greater.

To display the intensity instead of the illuminance, a conversion factor, $1/d^2$, is keyed in before commencing the measurements.

Isolux Mapping

An isolux diagram is usually constructed by taking measurements at regular spacings and then drawing equal illuminance contours.

An alternative method is also possible with the Type 1105 which takes advantage of the continuous measurement facility and which is generally found to be faster and more accurate.

It involves scanning the area for each isolux value in turn, and marking a number of these points on a sheet placed over the surface. By simply joining the dots, the isolux contours are drawn (Fig.4).

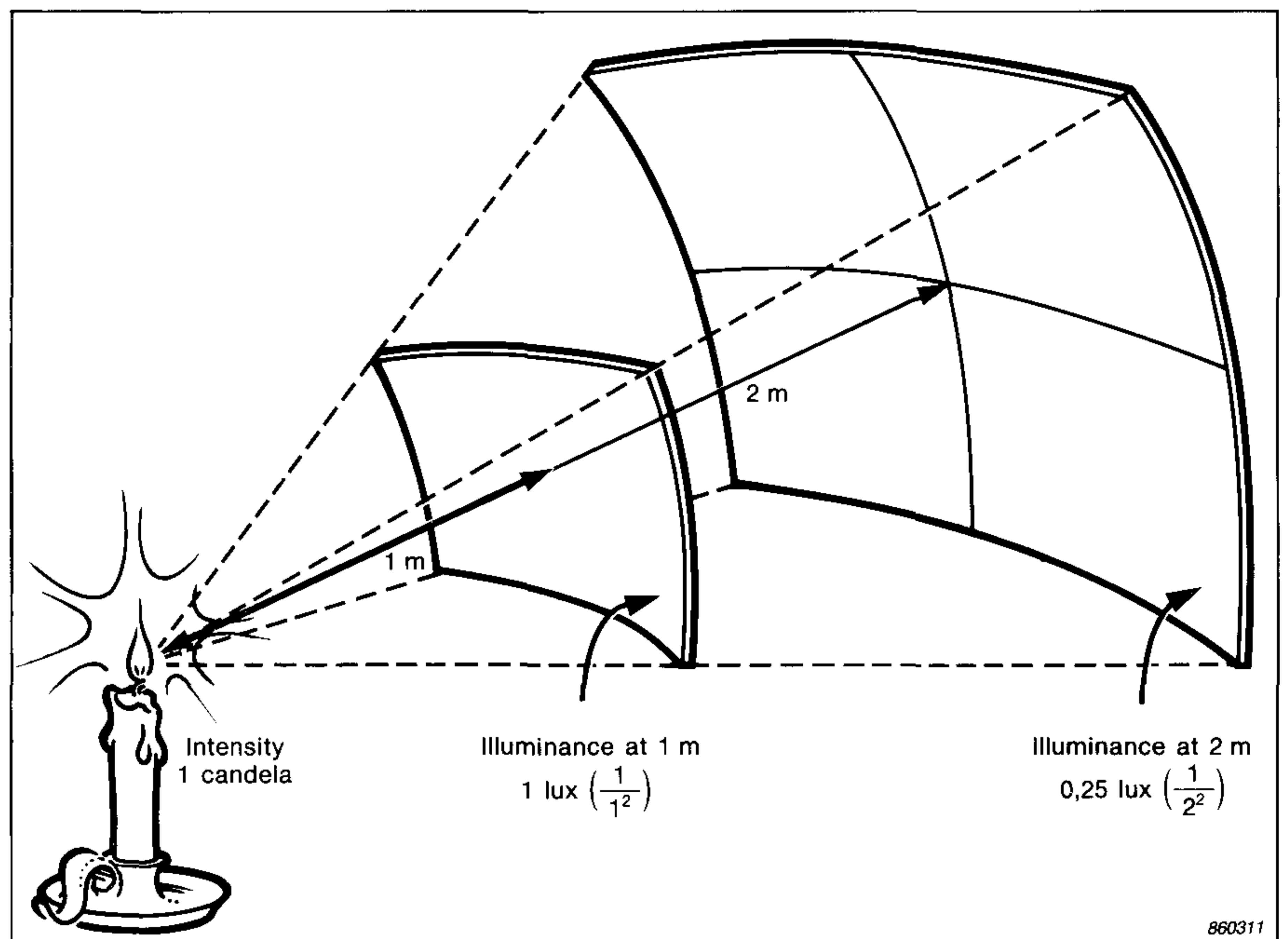


Fig. 3. Relationship between intensity and illuminance. To display the intensity of a source 2 m from the transducer, a conversion factor of 0,25 is keyed into the Type 1105

Illuminance Ratios

In order to reduce eye-strain, the illuminance on the workplace should not vary too much. The uniformity is generally expressed as the ratio of the minimum illuminance to the mean illuminance, $E_{\min}/E_{\text{mean}}$, and sometimes as $E_{\min}/E_{\max}$. Uniformity quotients are particularly easy to obtain with the Precision Photometer Type 1105. The mean, maximum and minimum illuminances are stored in the memory and, using the calculating facility of the 1105, the desired illuminance ratio can be displayed directly.

Suitable illuminance ratios are given in Fig.5. In general, the mean illuminance of the surroundings should be of slightly lower illuminance than the task area so that glare is reduced but not so low that the eye has to adapt a lot when looking up from the task.

Illumination Vector

The illumination vector at a point in space gives a measure of the flow of light — it has both magnitude and direction. It is obtained by measuring the illuminance in the two exactly opposite planes in the vector direction and calculating the difference (Fig.13). A convenient method of finding the direction of the vector is to use the hemispherical adaptor attached to the transducer with the Extension Arm affixed. By rotating the adaptor in the likely directions of the vector, a position is found where the illuminance is constant on rotation. The illumination vector is in the direction of the handle.

The direction of lighting has a considerable influence on the quality of the lighting. For the favourable illumination of faces, an angle of between 10° and 45° from the horizontal is generally suitable. Larger angles, as obtained with ceiling-mounted lights, tend to give a harsh, unnatural look and smaller angles give a flat effect.

In industrial situations there are many examples where strongly directional lighting is desirable in order to highlight visibility of an object, both in production and in quality control. This effect is illustrated in Fig. 6.

The illumination vector is also used to obtain the vector/scalar ratio. This is a modelling descriptor which is discussed further in section 3.

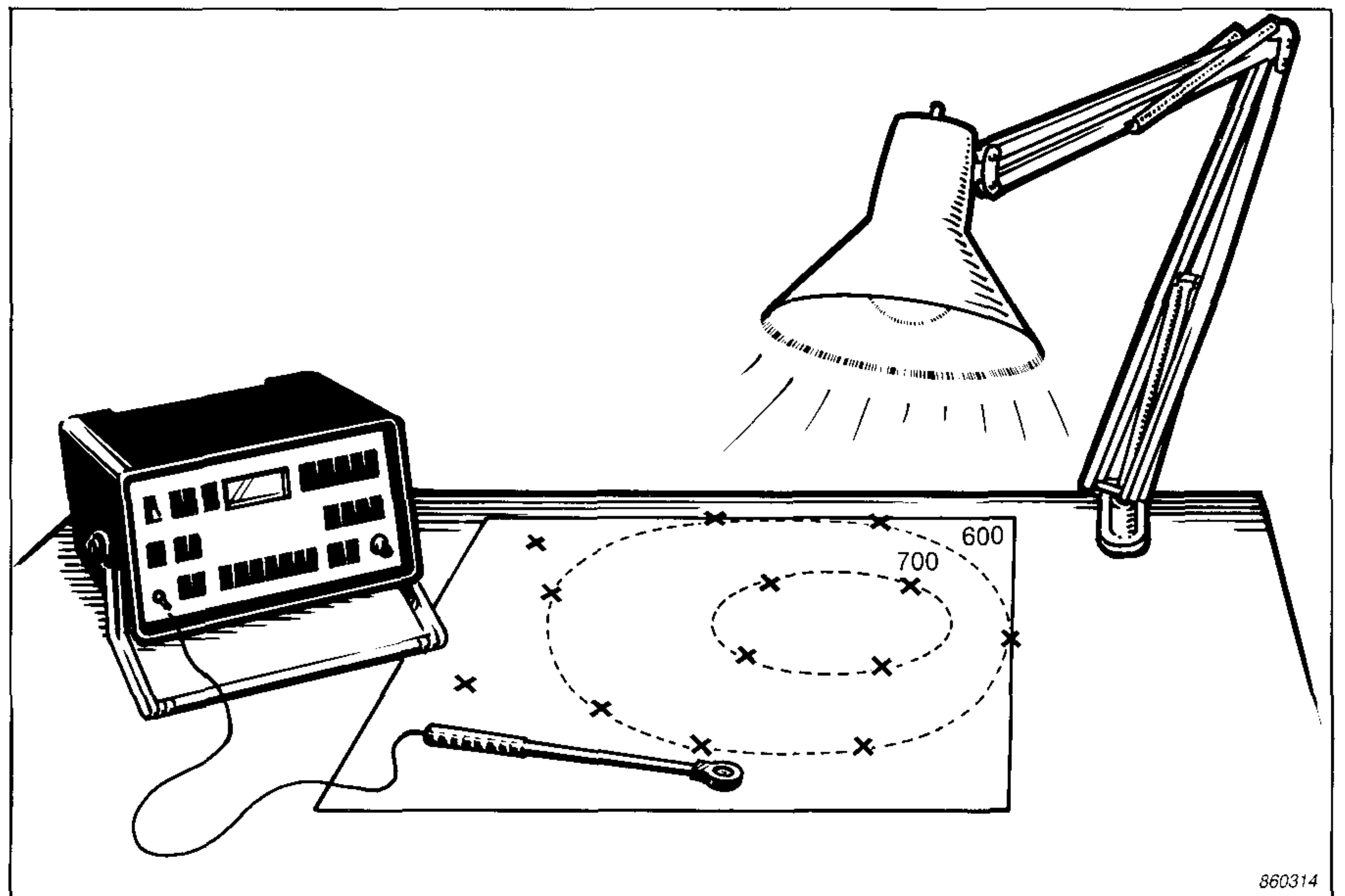


Fig. 4. Constructing an Isolux Diagram with the Precision Photometer Type 1105. For small areas, this is more convenient than the traditional grid method

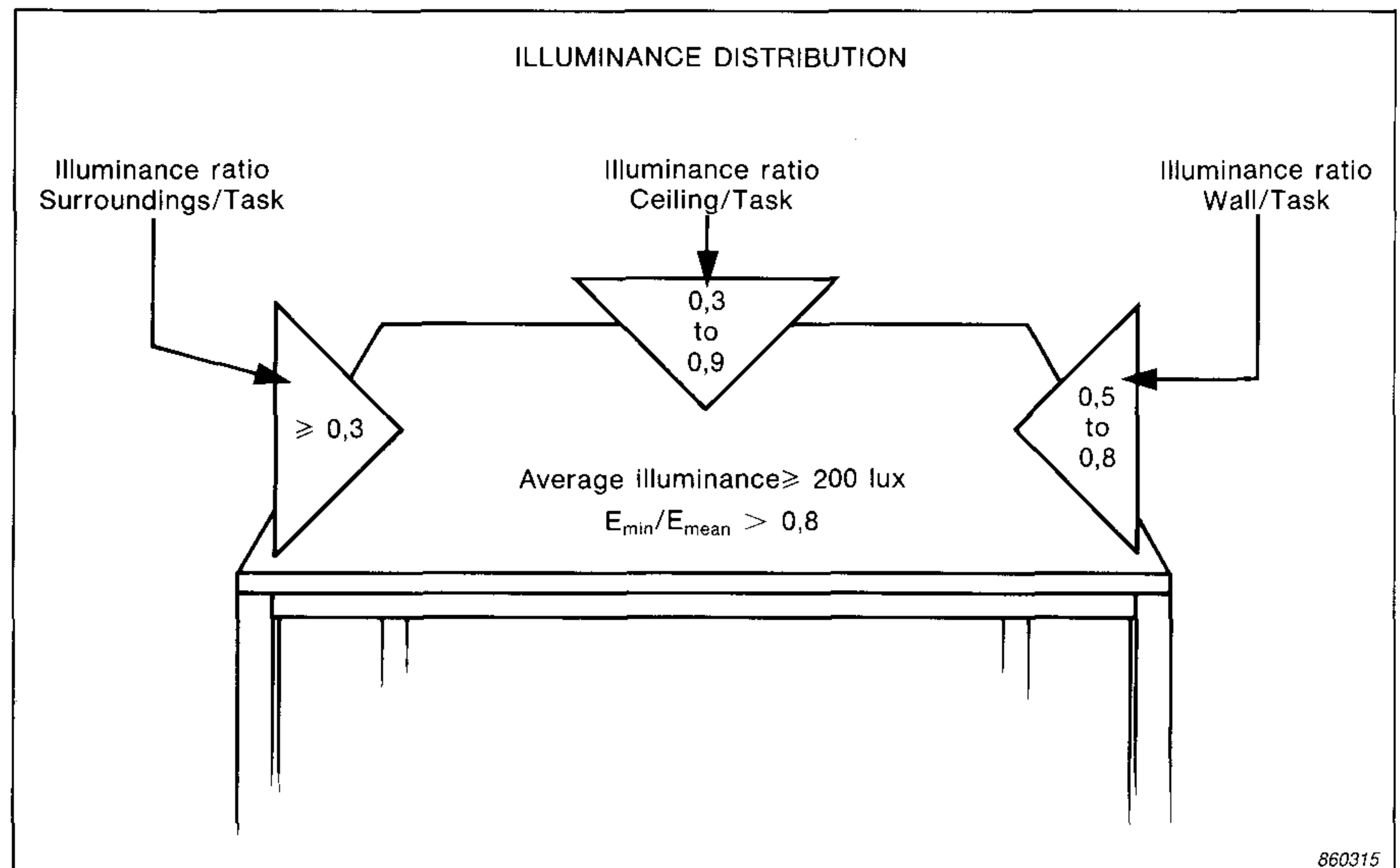


Fig. 5. Recommended illuminance ratios for interior lighting (2)

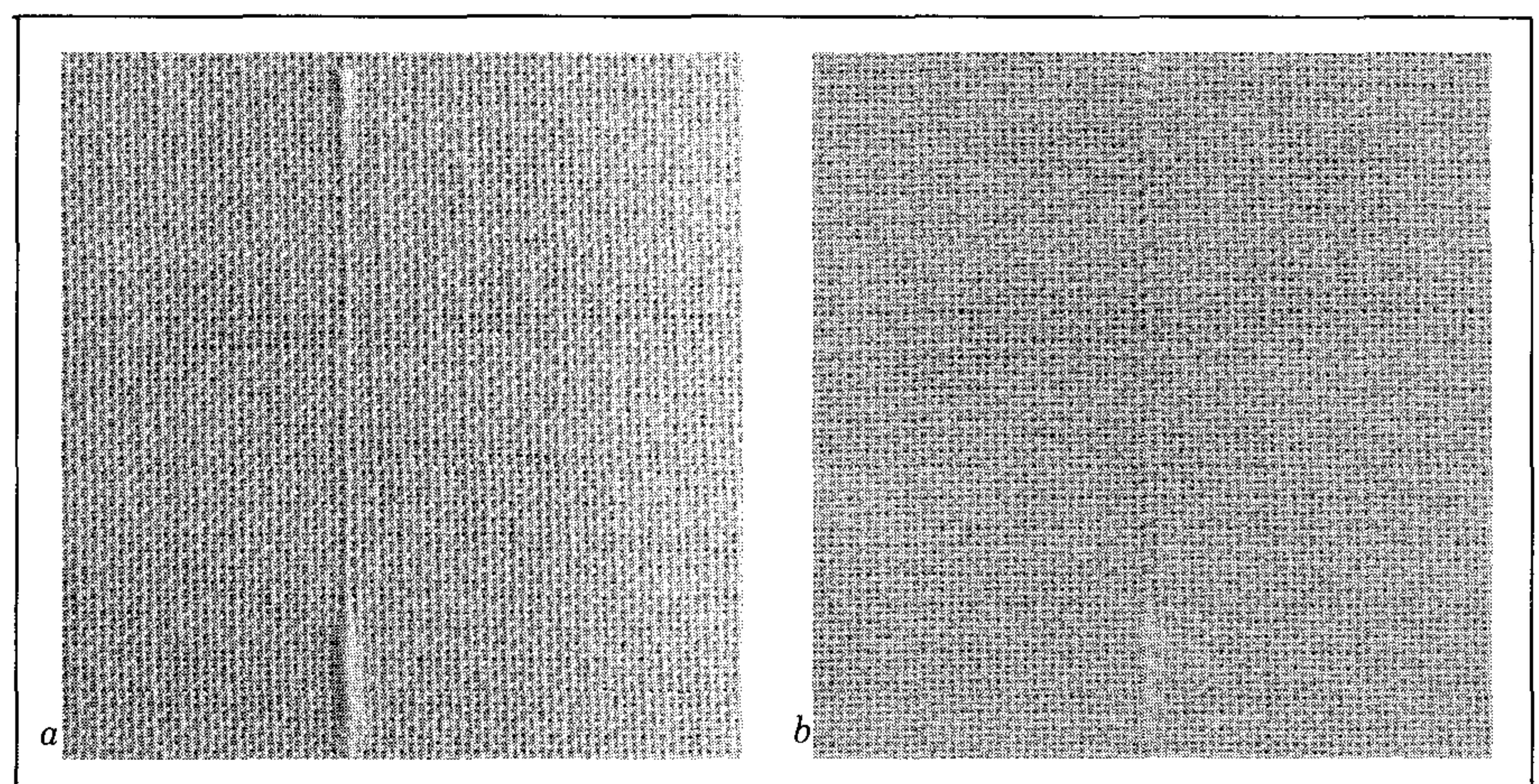


Fig. 6. The direction and strength of the illumination vector can be important in quality control. The flaw is much more visible in 6(a) which is illuminated from the side, than in 6(b), illuminated from above

Section 2—Measurements with Luminance Adaptor

The inclusion of a luminance adaptor is of great benefit to users performing indoor surveys since complaints of over-brightness and glare can usually be quantified in terms of luminance and reflectance.

Luminance Measurements

The luminance adaptor, with a measurement field angle of 10° , is particularly suited to the measurement of large surfaces. At a distance of 1m from the source, a circle of diameter approximately 18cm is covered.

There are a large number of applications for luminance measurements in the working environment. Floor, wall, window and ceiling luminances contribute both to the overall illuminance level and to glare. Modern offices often have a VDU terminal which, because of the very different luminances of the screen, keyboard and documentation, is a frequent source of problems. Eye strain can be significantly reduced by altering the lighting to give compatible luminances. Suitable ratios are given in Fig. 7. On the other hand, large changes in luminances can sometimes be desirable in order to draw attention to objects as for example, in the case of shop displays.

Luminance uniformity is also an important consideration in road lighting and the luminance adaptor can be used to get an approximate measure of this. The 1105 is convenient for this purpose as it computes the uniformity and displays it directly.

Reflectance

The reflectance of a surface influences its apparent brightness and is an important consideration with respect to both glare and overall illuminance levels. Specular reflectance is a partic-

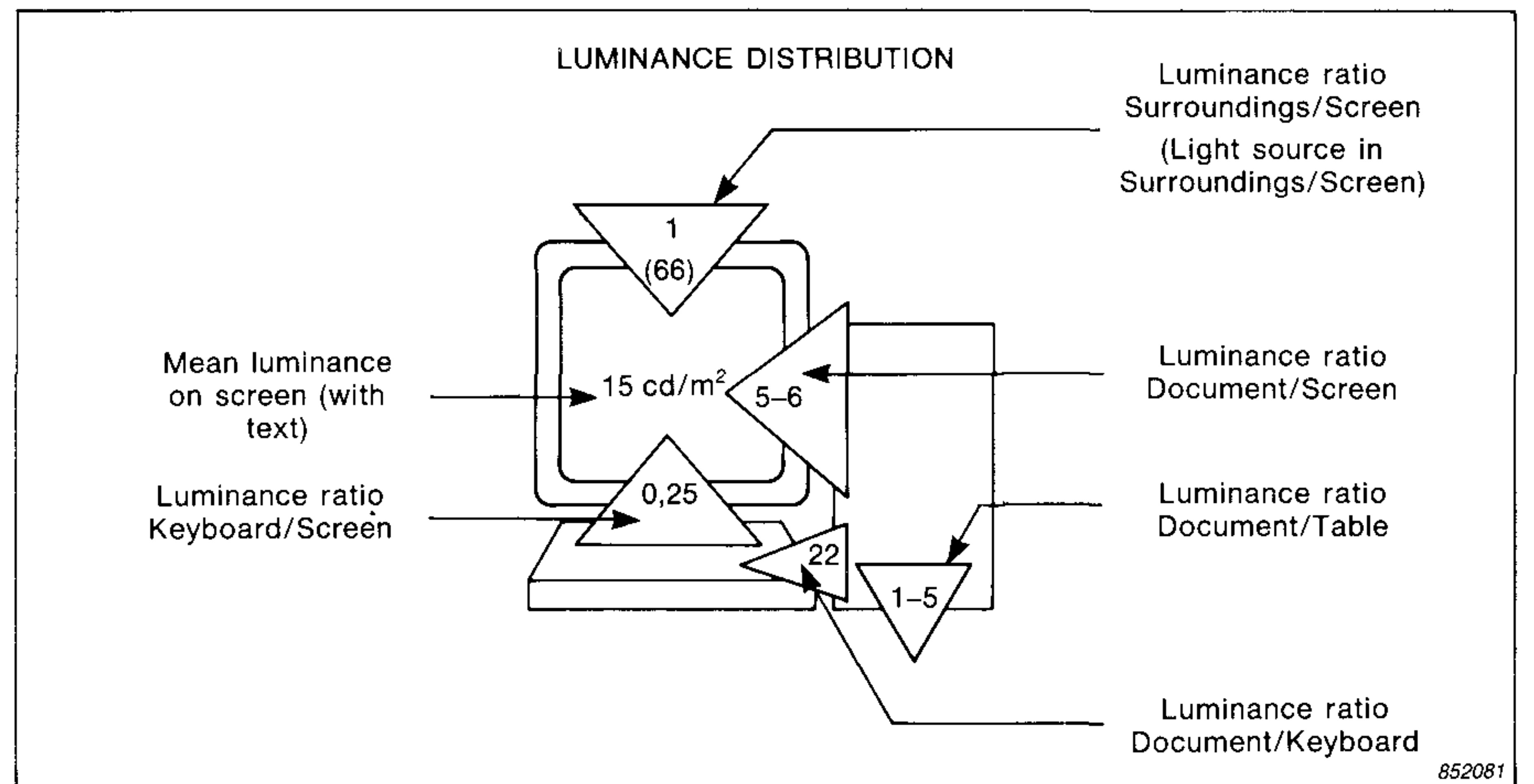


Fig. 7. Suitable luminance ratios at a VDU workplace

ular problem with smooth and glossy surfaces.

There are several methods for measuring the reflectance of matt surfaces. One approach is to employ a standard surface of known reflectance, $\rho_{std.}$, and measure both its luminance and the luminance of the actual surface under the same lighting conditions. Since

$$\frac{\rho_{surface}}{L_{surface}} \approx \frac{\rho_{std.}}{L_{std.}}$$

the reflectance of the actual surface is the only unknown.

Another approach is to use the following definition of reflectance

$$\rho = \pi \frac{L}{E}$$

where L and E are the luminance and illuminance respectively.

A third method is to measure the illuminance both on the surface and at a distance of 30 cm from it, pointing to

the surface. The ratio gives the reflectance.

Of these three methods, the first is the most accurate as it ignores the effect of stray light from bright sources such as windows.

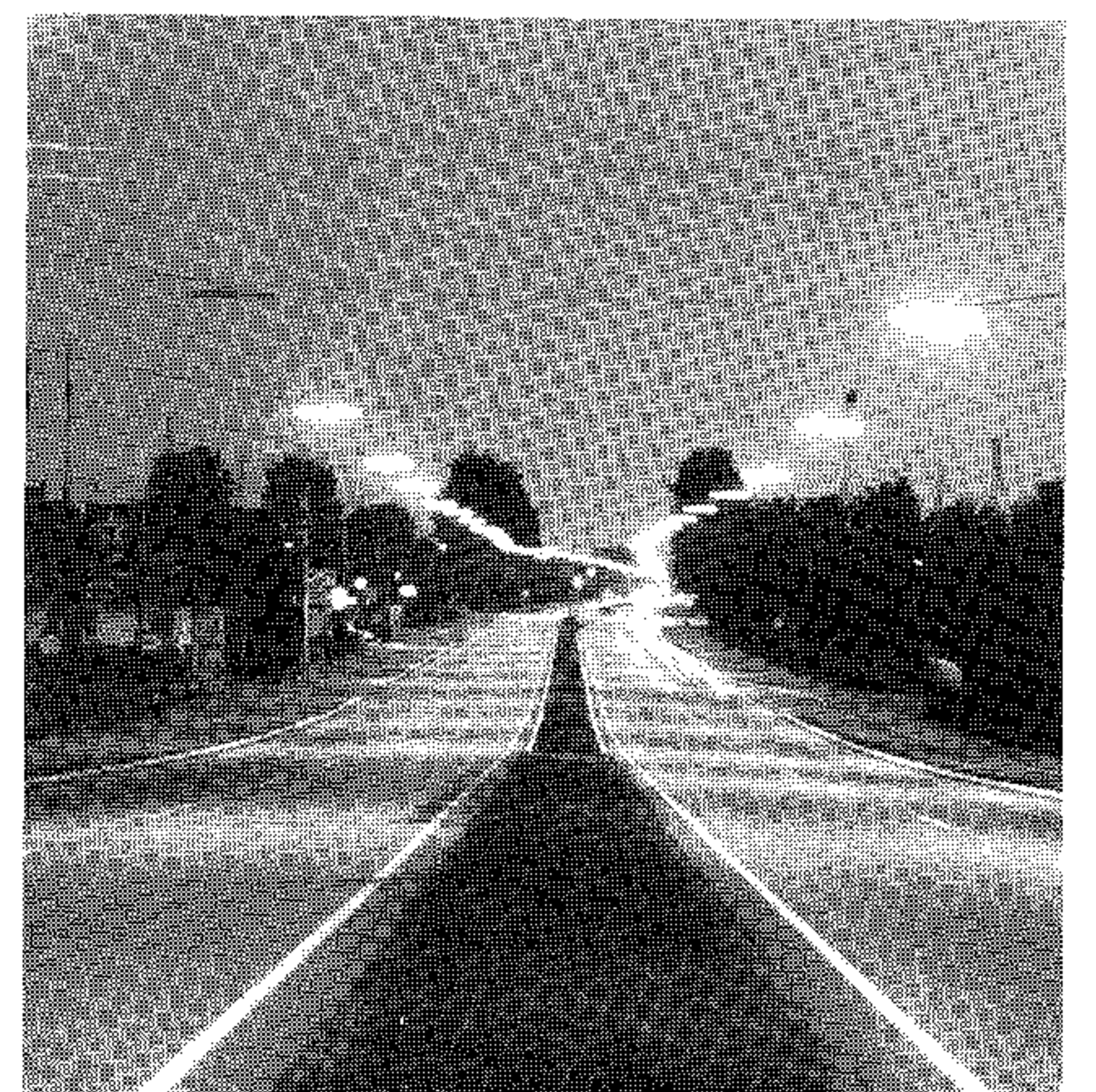


Fig. 8. Non-uniform lighting on roadways can affect safety. L_{min}/L_{max} measured in the longitudinal direction should be greater than 0.5

Section 3—Measurements with Spatial Adaptors

Spatial adaptors are being used increasingly in field measurements because they are found to more accurately describe the illuminance of 3-dimensional objects. Fig. 9 illustrates how the illuminance on a hemisphere and semicylinder correlates better with the illuminance on a three di-

mensional object than a flat surface does. The directional response of the planar transducer and the spatial adaptors are compared in Fig.10.

Hemispherical Illuminance

The hemispherical illuminance is the most suitable parameter for three

dimensional objects on the horizontal plane, particularly where these objects are below eye-level.

A frequent application of hemispherical illuminance is in road lighting, where it is a good measure of the illuminance of kerbs, speed ramps,

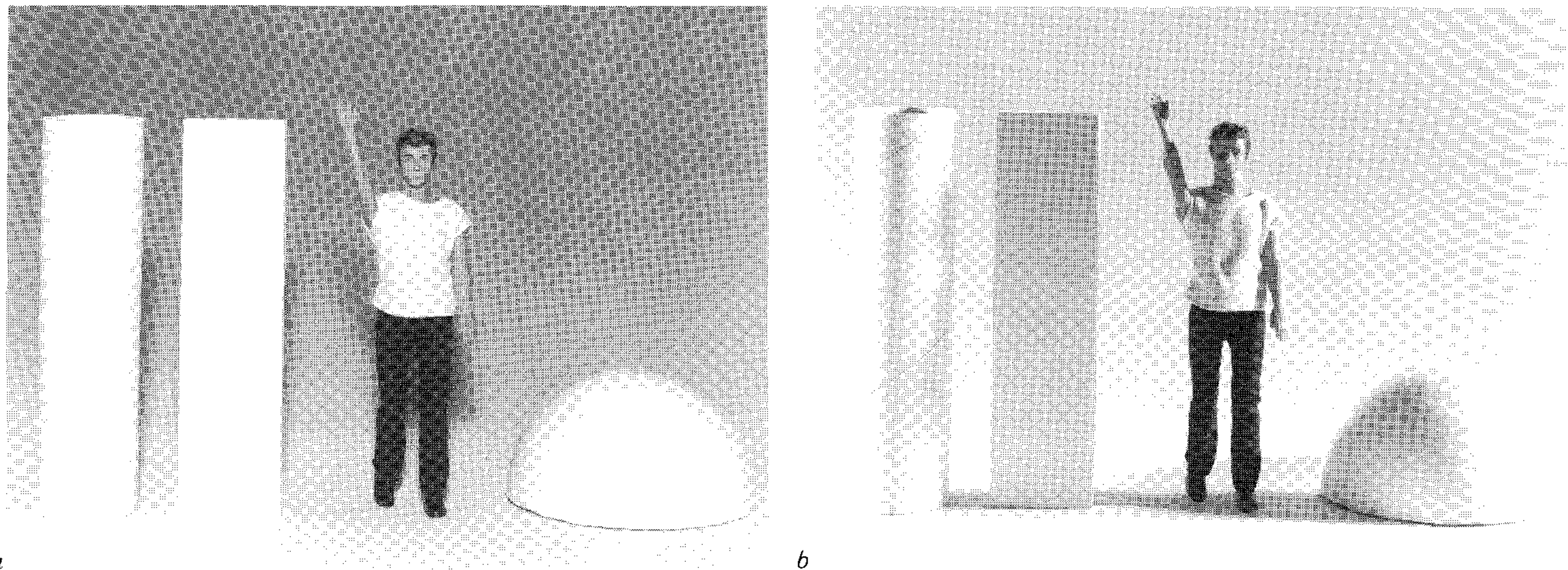
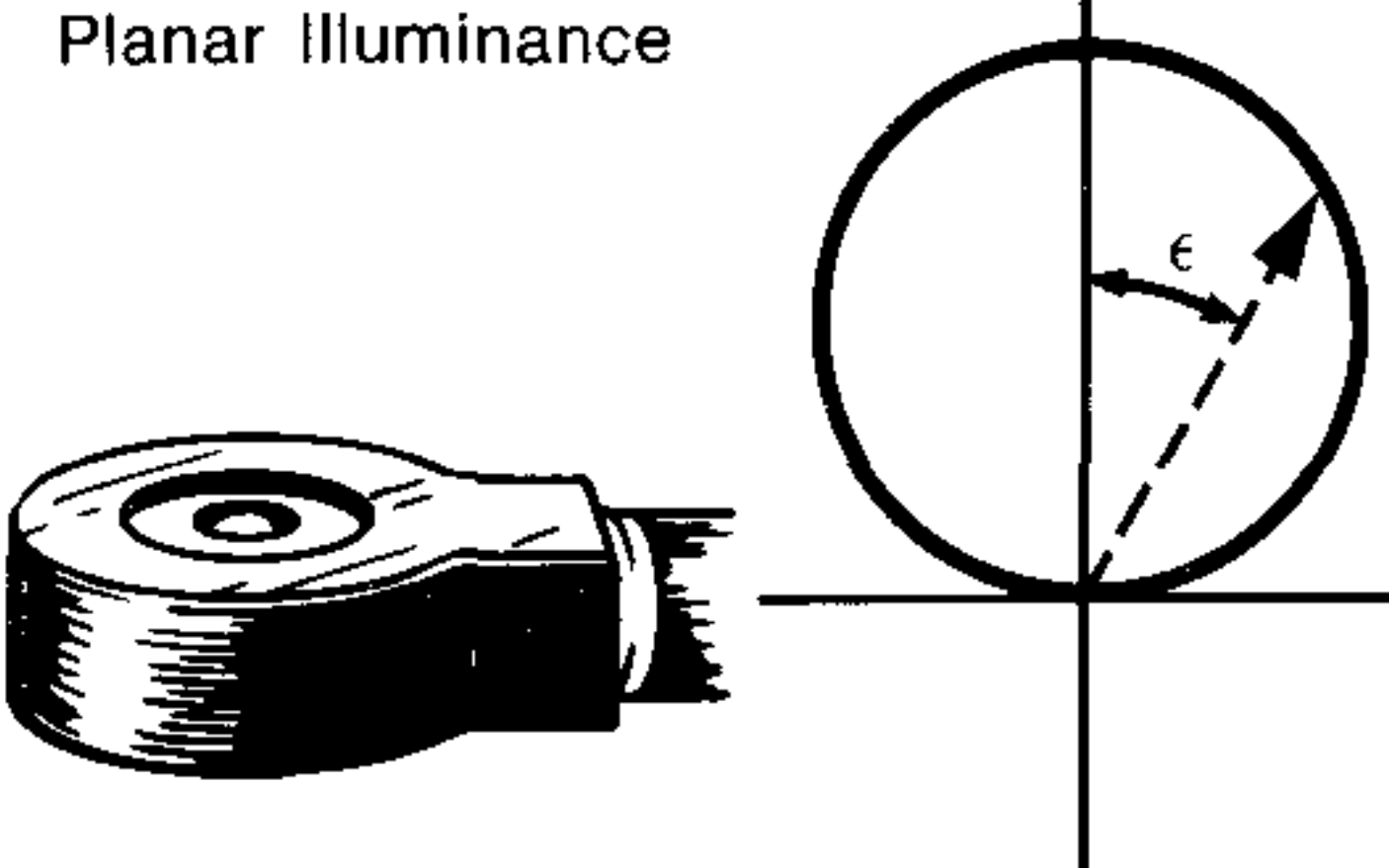
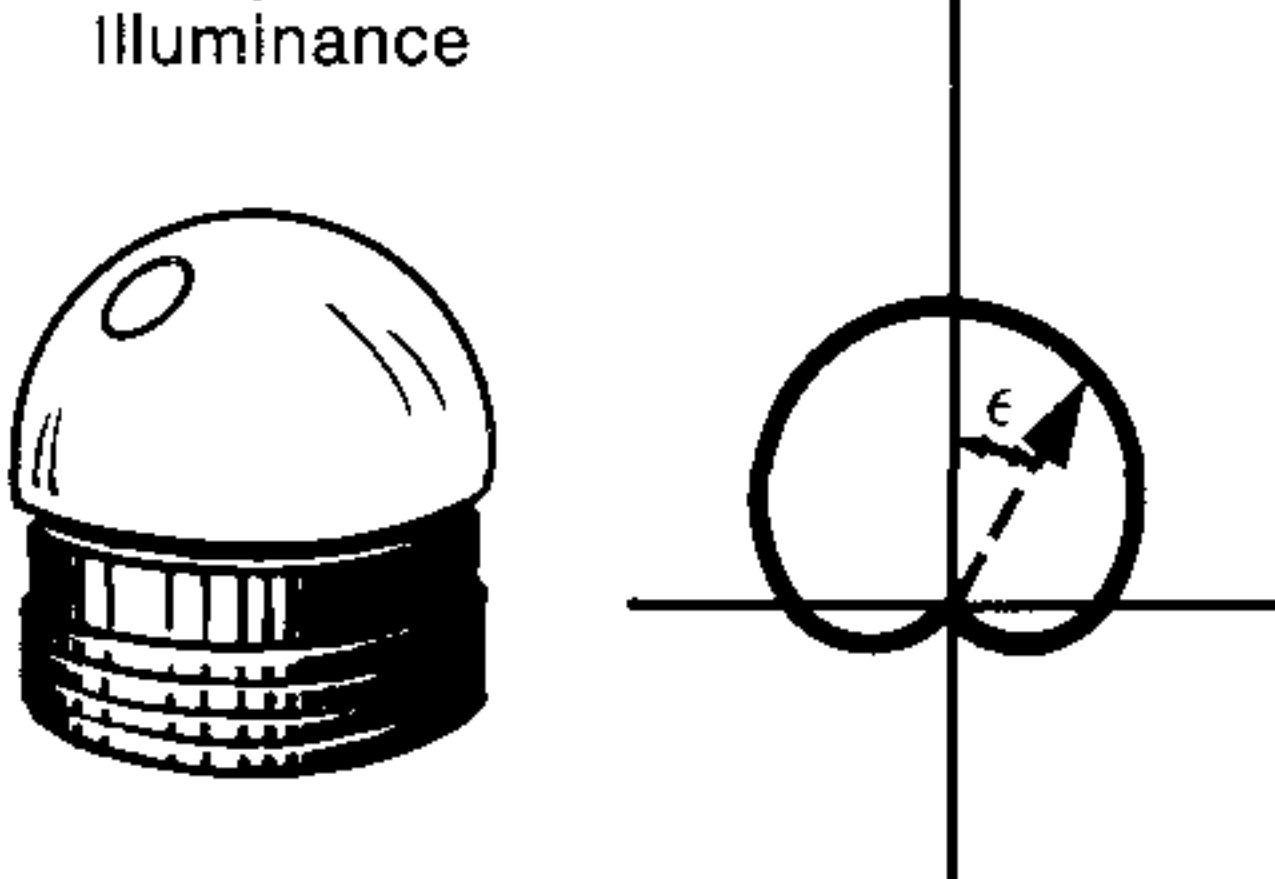
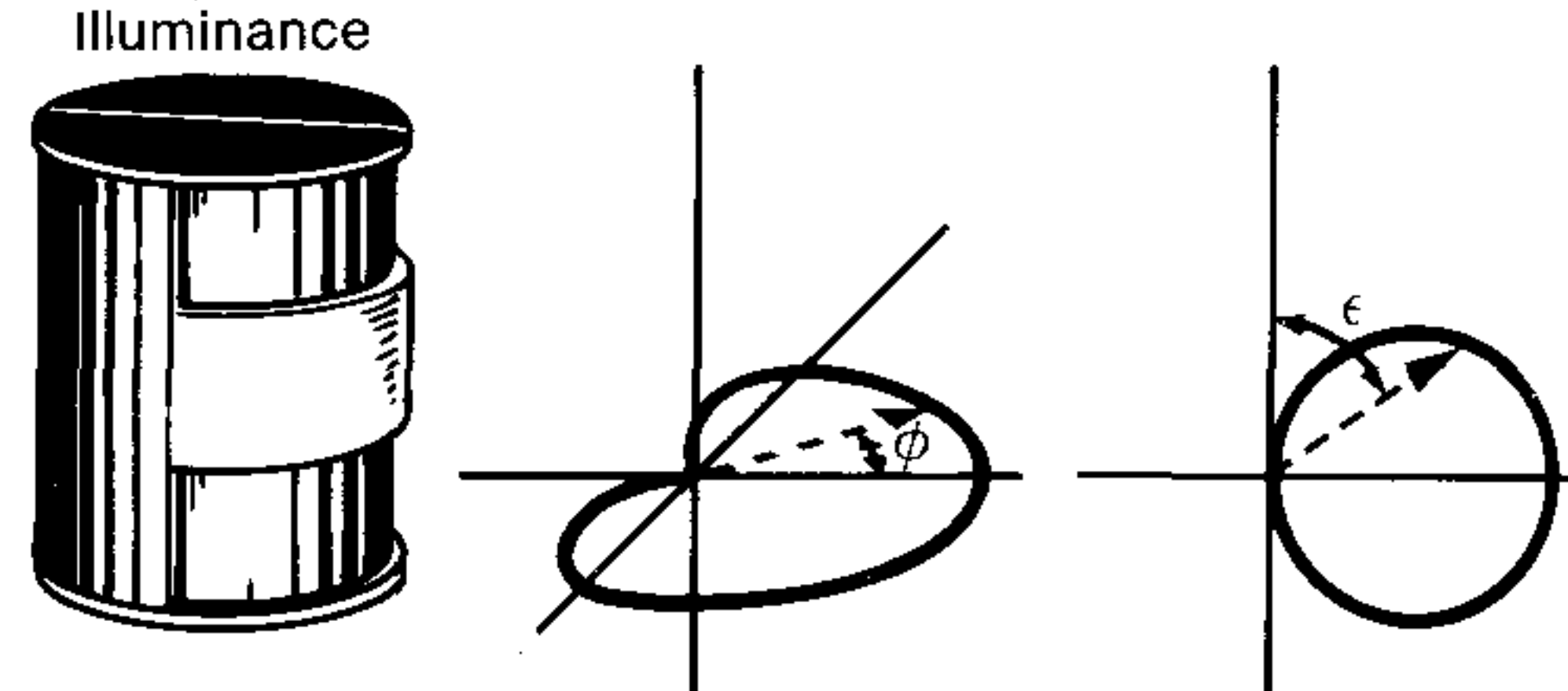


Fig. 9. The illuminance on hemispherical and semicylindrical surfaces correlates well with that on the model;
(a) front lighting, (b) side lighting

	Planar Illuminance	Hemispherical Illuminance	Semicylindrical Illuminance
Directional Responsivity			
Application:	Horizontal + vertical surfaces	3-dimensional objects, on horizontal plane	3-dimensional vertical objects
Examples:	Desks, assembly lines, libraries, stores, paintings	Road surfaces, kerbs, emergency lighting	Stage and sport lighting, pavement lighting
Definition:	$E = I \cos \epsilon / d^2$	$E_{HS} = I(1 + \cos \epsilon) / 4d^2$	$E_{SC} = I(1 + \cos \phi) \sin \epsilon / \pi d^2$

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Fig. 10. Comparison between Planar Illuminance, Hemispherical Illuminance and Semicylindrical Illuminance

hazardous objects on the road, etc. Some recommended values for road lighting are given in Table 1. Another application is in emergency lighting, where the visibility of objects along the escape route is of importance. For angles of incidence less than 70° , the hemispherical illuminance is lower than the horizontal illuminance but more uniform over an area. This is illustrated in the road measurement results presented in Fig. 11.

The hemispherical illuminance is easily calculated. For an angle of incidence ϵ from a single lamp source of height h , the hemispherical illuminance is given by

$$E_{HS} = I(\cos^2 \epsilon + \cos^3 \epsilon) / 4h^2.$$

Hemispherical illuminance measurements are made with the adaptor in the horizontal plane. Recommendations differ for the suggested mounting height but are either ground level or at 0,2 m above ground level.

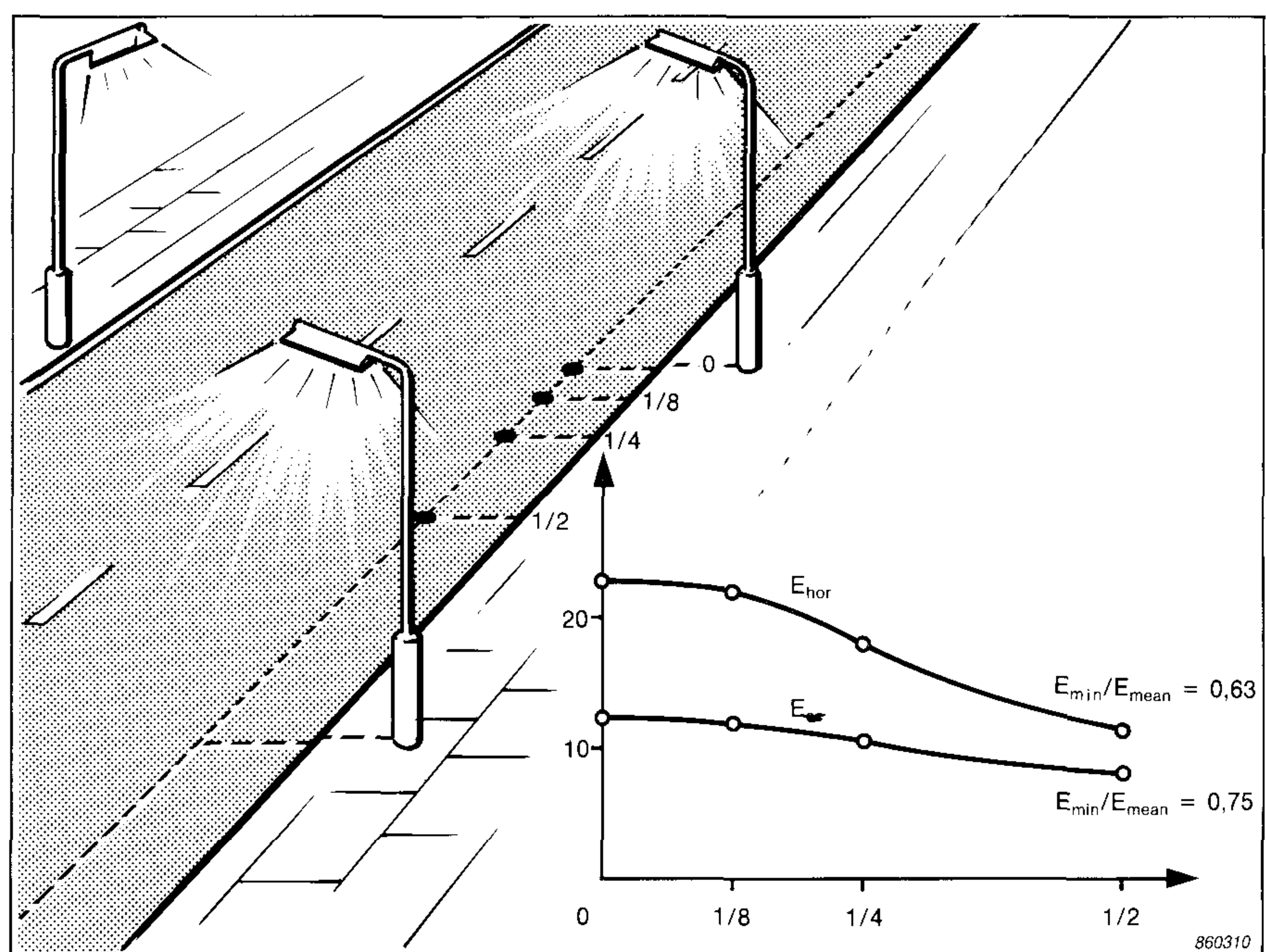


Fig. 11. Horizontal and hemispherical illuminance measurements were made at each of the four measurement points at a height of 0,2 m above ground level. The hemispherical illuminance is seen to be a lower value and more uniform as is typically the case. Because hemispherical illuminance measurements include the effect of side lighting, they are found to be a truer measure of the visibility of objects on the road

Semicylindrical Illuminance

The semicylindrical illuminance is a suitable measure for 3-dimensional objects on the vertical plane. Consequently it is most often used to measure the illuminance of people.

The superior correlation has been illustrated in experiments by Caminada and van Bommel (6). They also found that to recognise a person at 10 m, a semicylindrical illuminance level of 2,7 lux is required; at 0,8 lux, the recognition distance is 4 m.

One application of semicylindrical illuminance measurements which has benefits with regard to safety is in roadway measurements. Some CIE recommendations are given in Table 1. Danish standards also include recommended values for semicylindrical illuminances (7). Guidelines are also available for sports lighting situations (8, 9). Other applications for semicylindrical illuminance are in stage and television lighting.

Measurements should be made with the adaptor in the vertical plane at a height of 1,5 m above ground level. For sport/stage lighting, the acceptance area is pointed in the direction of the

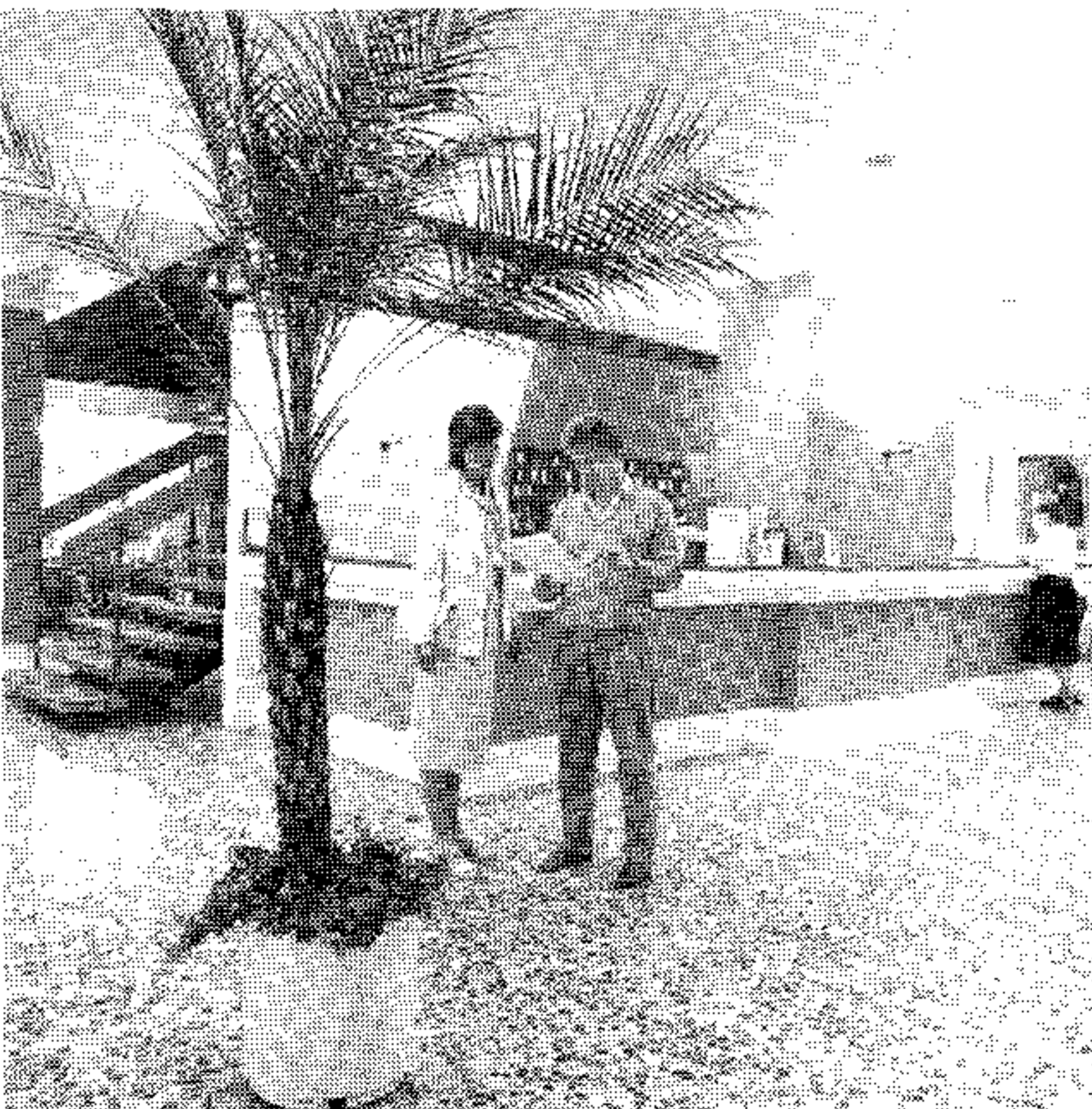


Fig. 12. The scalar illuminance is measured when there is no obvious working plane

		E _{sc} min	E _{HS} ave	E _H ave
Collector Roads	footpath	0,8 lux	2,5 lux	4 lux
	roadway	–	5 lux	7 lux
Local Roads	footpath	0,8 lux	2,5 lux	4 lux
	roadway	1 lux	5 lux	7 lux
Residential Complex	high usage area	–	7–10 lux	10–15 lux
	med. usage area	1 lux	3 lux	5 lux
	low usage area	0,5 lux	2 lux	3 lux
City/Town Centre	mixed vehicle/pedestrian	2 lux	15 lux	20 lux
	primarily pedestrian	2 lux	10 lux	15 lux
	wholly pedestrian	2 lux	7 lux	10 lux
Walkways	in parks etc.	0,8 lux	1,5 lux	2 lux
	in city centre	1 lux	3 lux	5 lux
	in arcades, passages	5 lux	10 lux	15 lux

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Table 1 A selection of the recommendations in the CIE guide (5)

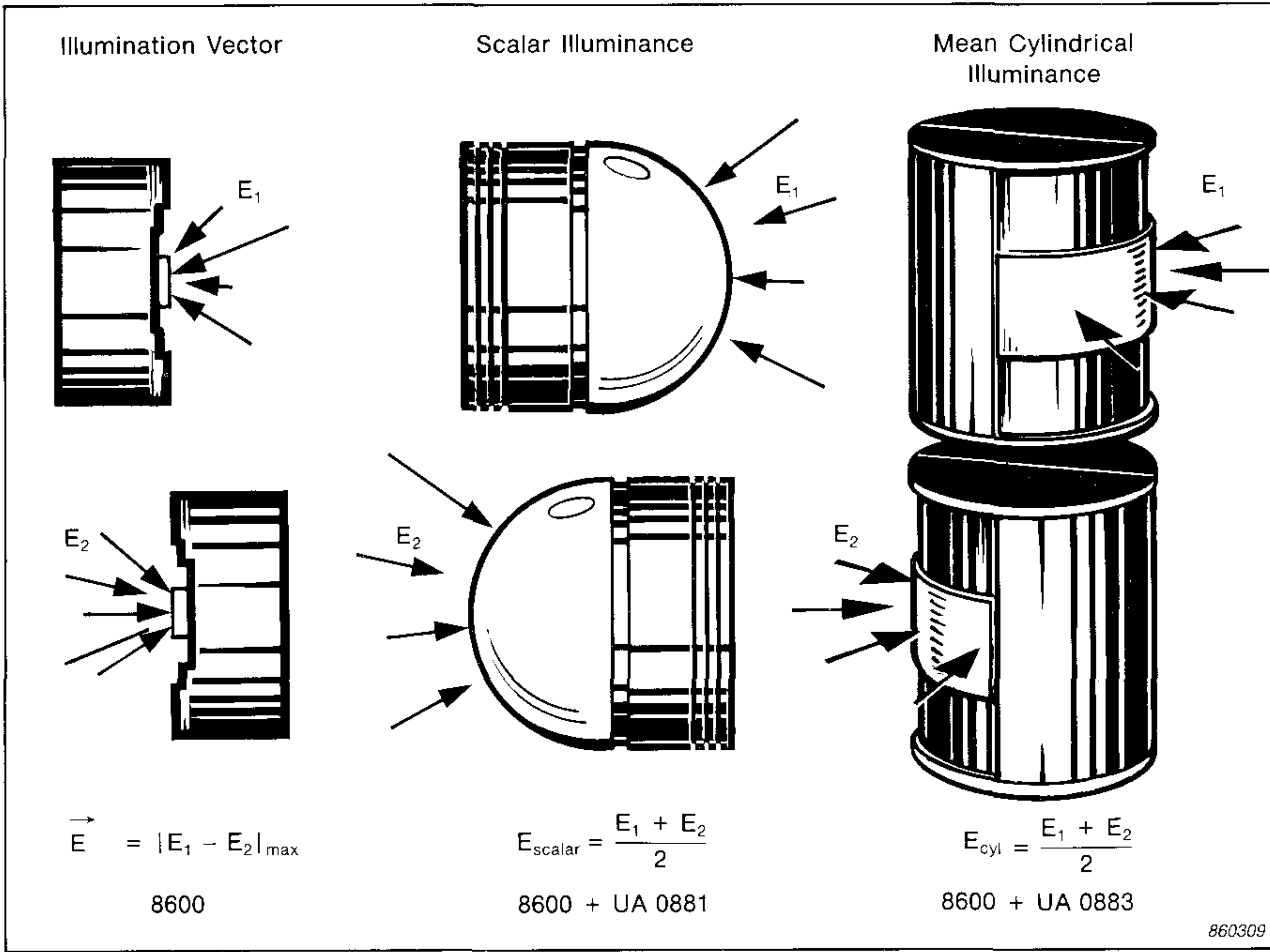


Fig. 13. The illumination vector, scalar illuminance and mean cylindrical illuminance are easily obtained from two measurements

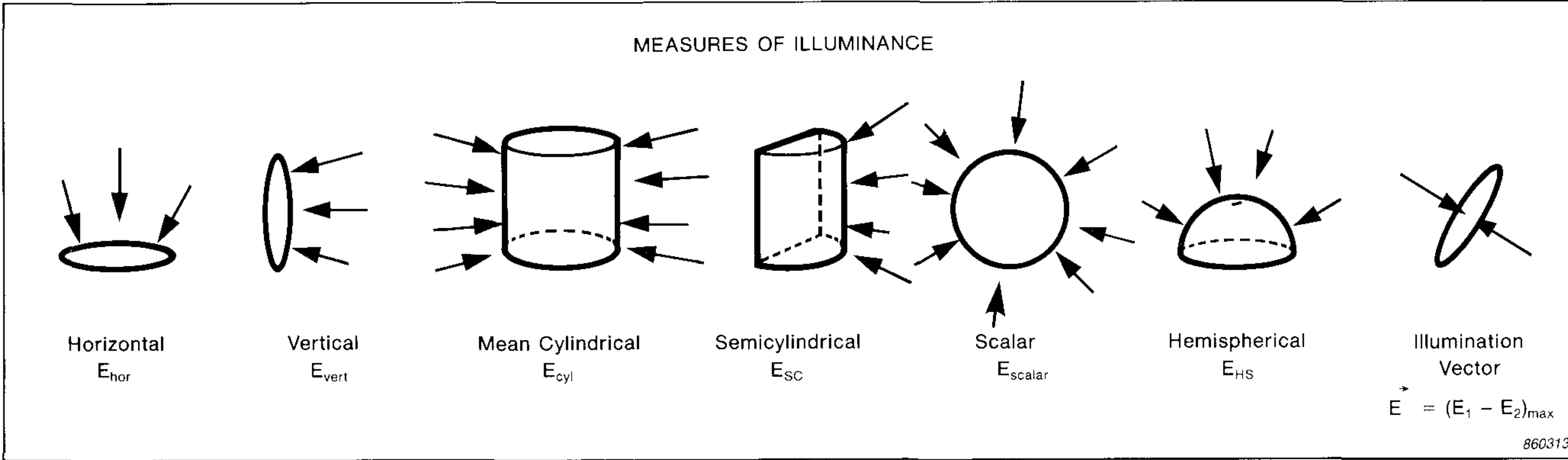


Fig. 14. Summary of the measures of illuminance used to describe lighting conditions

observer. For road lighting measurements are made both parallel and perpendicular to the run of the road.

Scalar Illuminance

Another measure of illuminance which can be obtained with the hemispherical adaptor is the scalar illuminance. This is the average illuminance over the surface of a small sphere at a point in space. It is a useful measure of the lighting conditions where there is no obvious working plane — in a reception area for example.

To date, use of the scalar illuminance has been limited due to the inconvenience of measuring it, but this problem is overcome with the 1105. Scalar illuminance is obtained by simply measuring the hemispherical illuminance in exactly opposing directions at a given point and averaging the two values (Fig.13). The recommended value is at least 40% of the illuminance on the horizontal plane.

Mean Cylindrical Illuminance

The mean cylindrical illuminance is used for 3-dimensional objects when the vertical or near vertical plane is of

major importance and is the preferred measure when there is no well-defined observer direction. It is obtained by taking semicylindrical illuminance measurements in two exactly opposite directions and averaging them (Fig.13). For a satisfactory installation, the mean cylindrical illuminance should be at least 40% of the horizontal illuminance.

Modelling

Modelling is the term most often used to refer to the amount of shadow and contrast in a lighting arrangement and it is an important consideration in interior lighting. There are a number of descriptors of modelling, all of which can be conveniently measured with the 1105. They are summarised in Table 2 together with the recommended values for pleasant definition of human features.

The ratio of the vertical to the semicylindrical illuminance is a suitable descriptor of modelling for human features. A ratio of 1 gives a well-balanced effect. A high ratio, greater than 1,3, results in too much "straight on" lighting, giving a flat effect. When the

Modelling definition	Recommended value
E_{cyl}/E_{hor}	> 0,3 (DIN) > 0,4 (CIBS)
E_{vert}/E_{SC}	0,8 – 1,3
E_{scalar}/E_{hor}	> 0,4
E_{vert}/E_{hor}	> 0,25
$\vec{E}/E_{scalar}$	scale 0 – 4

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Table 2 The terms used to describe the modelling together with the values generally recommended for flattering illumination of faces

ratio is low, less than 0,8, there is too much lighting from the sides resulting in overly strong contrast. A well-balanced lighting situation is compared with very low and very high contrast in Fig. 15.

The ratio of the illumination vector to the scalar illuminance is particularly well suited for applications such as warehouse lighting where readability on vertical planes is generally required and where the lighting is usually highly directional. As low a ratio as achievable is desirable.



Fig. 15. Illustration of the effect of different modelling conditions on human features. Strong contrast gives a harsh look while low contrast appears flat and shows insufficient detail

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