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RECOMMENDATIONS FOR PHOTOMETRIC INTEGRATORS

B.S. 354 : 1961

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The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

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This standard makes reference to the following British Standards:

B.S. 232 Vitreous-enamelled steel reflectors for use with tungsten filament lamps.
B.S. 233 Glossary of terms used in illumination and photometry.
B.S. 324 Translucent (diffusing) glassware illumination fittings for interior lighting
B.S. 1950 Vitreous-enamelled steel reflectors for use with mercury electric discharge lamps.
B.S. .... Lighting fittings (in course of preparation).

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The following B.S.I. references relate to the work on this standard:
Committee reference LGE/7 Draft for comment A(LGE) 7892

CO-OPERATING ORGANIZATIONS

The Illumination Industry Standards Committee under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Admiralty
Air Ministry
Association of Public Lighting Engineers
British Electrical & Allied Manufacturers' Association
British Electrical Development Association
British Railways, The British Transport Commission
D.S.I.R.—Building Research Station
*Electric Lamp Industry Council
*Electric Light Fittings Association
Electricity Council, the Generating Board and the Area Boards in England and Wales
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The 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 this standard:
British Lighting Council
Research Association of British Paint Colour and Varnish Manufacturers

BRITISH STANDARD RECOMMENDATIONS FOR

PHOTOMETRIC INTEGRATORS

FOREWORD

This standard has been revised at the request of the Illumination Industry Standards Committee to take account of developments which have taken place since the publication of the 1945 edition.

The text has been amended to cover the testing of tubular lamps, and recommendations relating to accuracy of measurement have been included. The Appendix, which gave formulae for suitable paints for the internal surface of an integrator, has also been revised.

In view of the wider scope of this revised edition, it is issued in the form of recommendations, whereas the previous edition was issued as a specification.

Opportunity has also been taken to amend the definitions to agree with those given in B.S. 233*.

NOTE. Since it is not possible in this publication to cover completely the subject of Photometric Integrators, it is suggested that the text book 'Photometry' by J. W. T. Walsh (Constable, 3rd edition, 1958) would be of assistance in investigating the subject in greater detail.

RECOMMENDATIONS

SCOPE

1. These recommendations apply to photometric integrators suitable for the measurement of all normal light sources, including for example tungsten filament electric lamps, tubular fluorescent and other gaseous discharge lamps.

They are also suitable for measurements on lighting fittings such as those specified in B.S. 324†, B.S. 232‡, B.S. 1950§ and B.S. ....¶, but additional recommendations, with regard to integrator dimensions and measuring techniques, are included in the appropriate sections of these standards.

DEFINITIONS

2. For the purpose of this British Standard the following definitions apply:

Reflection factor. The ratio of the reflected luminous flux to the incident luminous flux. Where mixed reflection occurs, the total reflection factor can be divided into two parts, the direct reflection factor and the diffuse reflection factor.

Absorption factor. The ratio of the absorbed luminous flux to the incident luminous flux.

* B.S. 233, 'Glossary of terms used in illumination and photometry'.

† B.S. 324, 'Translucent glassware illumination fittings for interior lighting'.

‡ B.S. 232, 'Vitreous-enamelled steel reflectors for use with tungsten filament lamps'.

§ B.S. 1950, 'Vitreous-enamelled steel reflectors for use with mercury electric discharge lamps'.

¶ B.S. ...., 'Lighting fittings' (in course of preparation).

Working standard lamp. A lamp in regular use which is calibrated from time to time by reference to a secondary standard lamp.

Secondary standard lamp. A lamp the photometric characteristics of which are accurately known.

PHOTOMETRIC PERFORMANCE OR ACCURACY

3. The recommendations set out in this standard are intended to ensure that the total uncorrected photometric error due to the integrator system itself will not exceed ±2 per cent for the intercomparison of the various types of tungsten filament lamp, and also for the intercomparison of other types of lamp by proper substitutional procedures. Where tubular lamps are measured by comparison with tungsten filament secondary standard lamps in an integrator of the minimum size allowed by Clause 6, the error may be somewhat greater. This figure for performance of course takes no account of any additional uncertainty which may in some cases arise from unsteady behaviour of the light source or sources, while it is open to the user to assess the integrator errors in any particular case and to improve the accuracy by applying the corresponding corrections.

CONSTRUCTION AND USE

4. *Form of integrator*. The interior of the integrator should be spherical.

NOTE. It is sometimes convenient to use a less perfect integrator. A cube may be used for the comparison of lamps not differing too much in shape or light-distribution. For tubular lamps a rectangular box of square section, or a cylindrical box with hemispherical ends, may be used. Provided that such partial integrators are large enough, that their other known limitations are respected particularly by the use of strictly substitutional methods of calibration, and that in appropriate cases the provisions of this standard in respect of Internal Surface Coating and Selectivity or Colour of Integrator are observed, the performance may be held within the limits stated in Clause 3.

DESIGNATION OF SIZE

5. The basic dimension of a spherical integrator is the internal diameter.

If a cubical integrator is used as suggested in the note to Clause 4, its basic dimension is the internal distance between opposite sides.

SIZE OF INTEGRATOR

6. The size of the integrator for tungsten filament general service lamps should be at least six times the overall length of the lamp, exclusive of the cap. The size of the integrator for tubular fluorescent and other tubular lamps should be at least one and a half times the length of the lamp. For translucent glassware fittings and dispersive reflector fittings, the dimensions of the integrator to be used will be found in B.S. 324, 232 and 1950 respectively, together with the lower levels of accuracy associated with these specifications.

When measurements of luminous flux are required to be made to the highest accuracy, larger integrators of spherical form may be necessary and the spherical form is essential.

WINDOWS

7. In the most generally favoured arrangement, a translucent window is employed. In this case the edges of it and its frame should be not more than 1 mm above or below the general internal surface of the integrator. If a cubical integrator is used (see Clause 4) the distance between the centre of the window and the centre of the side in which it is situated should not exceed one fifth of the size of the cube as defined in Clause 4.

The window material should be such that, for a given value of incident illumination, the luminance by transmission should be as far as possible independant of the angle of incidence of the light. It should also have a neutral spectral transmission characteristic and be non-fluorescent.

The diameter of a circular window should be not more than one-tenth of the size of the integrator diameter as defined in Clause 5.

In another arrangement a portion of the internal surface of the integrator is used for the photometric measurement, the light from it being received directly by the observing instrument, or else re-directed on to it by means of a mirror. When a mirror is used, this should be substantially non-selective over the visible spectrum as, for instance, a front-aluminized mirror.

When no translucent window is used, the size and position of that portion of the internal surface which is used for the photometric measurement should be as prescribed for a window.

INTERNAL SURFACE COATING

8. The coating of the internal surface of the integrator should be matt, durable and non-fluorescent. It should not deteriorate to an extent greater than that indicated in Clause 9 and its reflection factor for white light should be between 75 and 85 per cent. It may be measured by a method in which a flat sample is illuminated normally and viewed at 45°, or by one in which the sample is illuminated approximately normally and the reflected light is integrated. The spectral reflection factor should be as nearly uniform as possible over the visible spectrum.

Recommendations regarding paints which have been found satisfactory are given in the Appendix together with details of methods of preparation and use.

SELECTIVITY OR COLOUR OF INTEGRATOR

9. The recommendations contained in Clauses 7 and 8 regarding the spectral properties of the window and the coating are directed to ensuring that the spectral quality of the light emerging from the window should differ as little as possible from that of the direct light from the source, and particularly that such modification as inevitably remains should be equivalent to the action of a

filter whose spectral transmission curve is of a simple, smooth type. When a physical photometer is used in conjunction with the integrator, it is usually easy to compensate for this residual selectivity of the integrator by a suitable adjustment of the overall spectral response of the photometric equipment. If, however, the compensation must be external to the photometer, as may be the case for visual methods of photometry, a filter of suitable thickness, whose spectral transmission is complementary to that of the integrator, should be placed over the window or observing aperture. Glass filters of the kind specifically designed for colour-temperature conversion will often be found suitable. The exactness of the compensation obtained by this means may be checked spectrophotometrically if suitable apparatus is available.

Alternatively, the following visual method may be used. Two gas-filled tungsten filament lamps of the same type are adjusted in voltage until they give light of the same colour at approximately rated voltage. One lamp is then placed inside the integrator and its voltage readjusted until the light emitted from the window or observing aperture of the integrator matches that of the other lamp. Compensation may be considered satisfactory for most purposes if the amount of this readjustment in voltage is not greater than 10 per cent of the original colour-match voltage of the lamp.

Compensation by the addition of coloured media to the material of the integrator coating is specifically not recommended. The colourmatch which may be so obtained is not usually accompanied by a sufficiently close energy match in the spectral qualities of the light from the source and that which emerges from the integrator. This may result in significant errors in certain cases, for instance in the comparison of sodium or mercury vapour discharge lamps with tungsten filament standard lamps.

NOTE. In the visual method of checking mentioned above, using a gas-filled lamp running at a colour temperature of about 2800°K, the criterion of a 10 per cent adjustment in the voltage of the lamp in the integrator corresponds to a change of about 100°K in its apparent colour-temperature, resulting from coloration of the integrator. If the coloration is assumed to be of the same simple spectral type as that of an ideal colour-temperature conversion filter, the corresponding errors in the comparison of tungsten filament lamps at various temperatures in the usual working range will usually not exceed a small fraction of 1 per cent, dependent on the differences in temperature between the lamps being compared. For sodium and mercury vapour discharge lamps, compared with tungsten filament standard lamps at about 2800°K, the error will not exceed about 1 per cent. The magnitude of the error will in all cases be closely proportional to the voltage adjustment found to be required, while its sign will depend on the particular type of source in question (see Walsh and Barnett, *Trans.Opt.Soc.*, 1926-7, **28**, 21, and Buckley, *Phil.Mag.*, 1935, **20**, 745).

The barium sulphate integrator paint formulated in the Appendix should, when freshly applied, be found to conform to this criterion. Although its spectral characteristic is not exactly of the type just considered, it is smooth and errors will not exceed those just quoted.

The possibility must be stressed that a less satisfactory paint might be found to conform to the above visual criterion and yet to give rise to larger errors on account of an unsuitable spectral characteristic; or the combined effect of paint and window may lead to a similar situation for the integrator as a whole. In such cases, errors can be safely predicted only on the basis of spectrophotometric measurements.

SCREENS

10. A screen should be provided, the position of which can be adjusted to prevent the window, or portion of the internal surface used for the photometric measurement, from receiving any direct light from the luminous source. The screen should be coated with the same material as that used for the internal surface of the integrator (see Clause 7). It should be placed between the luminous source and the window (or portion of the internal surface used for the photometric measurement), at a distance from the luminous source of not less than one-third, nor more than one-half, of the distance between the luminous source and the window (or portion of the internal surface used for the photometric measurement). The size of the screen should be as small as possible consistent with the condition that no direct light from the source, bulb, or fitting reaches the window or portion of the internal surface used for the photometric measurement.

For any one series of comparisons, a screen suitable for the largest light source in the series should be chosen in accordance with this last condition and it must remain in position throughout the series of tests.

POSITION OF TEST LAMP OR LUMINOUS SOURCE

11. The lamp or luminous source under test and the working standard lamp should be placed either in the same position or symmetrically with respect to the window of the integrator, or the screened area of the integrator wall on which observations are made.

For fluorescent lamps the preferred position for test is with the lamp mounted centrally in the integrator and operated in the horizontal position. The axis of the lamp should be parallel to the planes of the window and of the screen.

An alternative arrangement which has been suggested is to operate the lamp horizontally, but inclined at an angle of between 45 and 60° with a line joining the window to the centre of the integrator. (See ' Photometry ' by Walsh, 3rd edition, p. 497). Any light source having marked directional light characteristics shall be mounted so that the peak intensity is not projected towards the screen, but towards a part of the integrator clearly visible from, but not near to, the window.

INTERNAL FITTINGS

12. All internal fittings, such as lampholders, should be whitened to have at least as high a reflection factor as the surface of the integrator and should be so small and so positioned that they receive either no direct light, or a minimum of direct light from the source.

APPENDIX

INTERNAL SURFACE COATING

Integrating spheres may be constructed of various materials, including copper, steel, zinc, aluminium, plywood or plaster. Whatever the material used it should be suitably prepared and primed so as to give a smooth surface suitable to receive coating compositions of the type described in this Appendix.

A1. Pretreatment and priming. Pretreatment and priming will not in general affect the optical properties of the finished system, but should be such as to ensure good adhesion to the base material and freedom from subsequent corrosion, flaking etc.

Further information on pretreatment and priming will be obtained from the British Standard Code of Practice CP 231, 'Painting'.

A2. Internal surface coating. The internal surface coating recommended consists of the following:

a. a white base coat*, and

b. a water-removable white matt coat* which when soiled can be removed, fresh layers being then applied.

In general it will be necessary to renew only the water-removable coat, but in cases where the base coat has become discoloured, it may be necessary to remove this completely by rubbing or scraping and to apply a new base coat. In cases where breakdown of the underlying layers has occurred it may be necessary to remove both the base coat and priming down to the metal or wood, and then to proceed as for new work.

A3. White base coat. It is desirable that the base coat should give a white matt surface and should show no yellowing with age. The composition used to produce the coat should therefore contain an adequate proportion of a good white pigment of high hiding power (e.g. titanium dioxide) dispersed in a binding medium known to be substantially non-yellowing.

Two full coats of white composition of the polyvinyl acetate emulsion type can be recommended as giving a suitable base coat.

A4. Water-removable white matt coat. The properties required in this coating (described in Clause 7) may be achieved by a composition based on a good white grade of fine precipitated barium sulphate (blanc-fixe) dispersed in a water-soluble, substantially non-yellowing medium, such as a fine grade of

* Information regarding suitable paints which are commercially available may be obtained on application to the Director, British Standards Institution, 2, Park Street, London, W.1.

sodium carboxymethyl cellulose as free from fibres as possible. Other colloids with similar properties are also available.

The white composition may be tinted to the required reflection factor by addition of a small quantity of a well-dispersed aqueous paste of a carbon black pigment with a bluish undertone, i.e. of a grade commercially known as ivory, drop, vegetable or lamp black.

NOTE. Artists' water-colour ivory black is one example of a suitable ready-prepared paste.

To produce a composition which will give the necessary smooth matt coat requires some care, not only in the selection of materials, but also in compounding them. One method which has been found suitable is described below and details of recommended quantities are also given.

a. Quantities.

1000 parts by wt. blanc-fixe.
25 „ „ „ sodium carboxymethyl cellulose (SCMC) (low viscosity type).
1000 „ „ „ distilled water.

b. Preparation. The blanc-fixe is dispersed in distilled water, assisted by a dispersing agent, e.g. 0·2 per cent by weight of the pigment of sodium hexametaphosphate, using a mixer or mill such as is used in paint making. It is tinted to the required reflection factor (by the user).

It is important to ensure that a uniform smooth paste is obtained*.

The amount of water used at this stage should be kept as small as possible and should only just be sufficient to give a paste of consistency suitable for the particular conditions of mixing or milling used.

The colloid is dissolved in sufficient distilled water to give a 5 per cent solution by either:

(i) leaving the mixture overnight to swell, or

(ii) heating the mixture to 90°C on a water-bath for about 1 hour, with stirring.

The resulting solution should be clear and fibre-free.

The colloid solution and the blanc-fixe dispersion with the small quantity of black paste added are intimately mixed† and the remaining quantity of water is then added, the mixture being stirred during the process.

Two to four full coats of the white matt composition may be applied by brush, spray or roller, as convenient.

* For quantities up to 2 litres, milling in a laboratory ball mill for 4 hours has been found suitable. To avoid the risk of contamination a steel mill should not be used.

† In the circumstances referred to above this could be achieved by ball milling for a further 2 hours.

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BS 89. Electrical indicating instruments.
BS 233. Glossary of terms used in illumination and photometry.
BS 1853. Tubular fluorescent lamps for general lighting service.
BS 3693. Recommendations for the design of scales and indexes. Part 1. Instruments of bold presentation and for rapid reading.

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