BRITISH STANDARD

BS ISO 15469:2004

Spatial distribution of daylight — CIE standard general sky

ICS 17.180.20

British Standards

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INTERNATIONAL STANDARD

ISO 15469
CIE S 011/E

Second edition
2004-02-15

Spatial distribution of daylight — CIE standard general sky

Répartition spatiale de la lumière du jour — Ciel général normalisé CIE

Reference number
ISO 15469:2004(E)
CIE S 011/E:2003

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

ISO 15469 was prepared as Standard CIE S 011/E by the International Commission on Illumination, which has been recognized by the ISO Council as an international standardizing body. It was adopted by ISO under a special procedure which requires approval by at least 75 % of the member bodes casting a vote, and is published as a joint ISO/CIE edition.

The International Commission on Illumination (abbreviated as CIE from its French title) is an organization devoted to international cooperation and exchange of information among its member countries on all matters relating to the science and art of lighting.

ISO 15469 was prepared by Division 3 (Interior Environment and Lighting Design) of the CIE.

This second edition cancels and replaces the first edition (ISO 15469:1997), of which it constitutes a technical revision. ii

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SPATIAL DISTRIBUTION OF DAYLIGHT - CIE STANDARD GENERAL SKY

INTRODUCTION

The luminance distribution of the sky depends on weather and climate, and it changes during the course of a day with the position of the sun. This standard lists a set of luminance distributions, which model the sky under a wide range of conditions, from the heavily overcast sky to cloudless weather. It is intended for two purposes:

i. to be a universal basis for the classification of measured sky luminance distributions

ii. to give a method for calculating sky luminance in daylighting design procedures.

The Standard defines relative luminance distributions: the luminance of the sky at any point is given as a function of the zenith luminance. For daylighting calculation purposes it may be used with values of zenith luminance or of horizontal illuminance to obtain absolute luminance distributions.

The Standard incorporates both the CIE Standard Clear Sky and the CIE Standard Overcast Sky, which are treated as particular cases of the General Sky. The Overcast Sky is retained as a separate formula because there are many calculation procedures that embody the mathematical formulation of this particular distribution.

1. SCOPE

This Standard defines a set of outdoor daylight conditions linking sunlight and skylight for theoretical and practical purposes.

The luminance distributions given have the following characteristics:

i. They are symmetrical about the solar meridian and are functions of the angular distance, Z_s, between the sun and the zenith.

ii. They are defined by smooth continuous functions. Such distributions are typical of cloudless skies and of those where the cloud cover is homogeneous. They provide an approximation to skies of broken cloud that is sufficiently accurate for many practical daylight calculation purposes.

iii. The relative luminance at any point in the sky depends on the angle, , between that sky element and the sun, and on the angle, Z, between the sky element and the zenith. It is given in terms of two functions: the relative scattering indicatrix, $f()$, and the luminance gradation between horizon and zenith, (Z).

2. NORMATIVE REFERENCES

The following standards contain provisions, which through reference in the text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on the Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of the CIE, IEC and ISO maintain registers of currently valid international standards.

1. CIE 17.4-1987 *International Lighting Vocabulary*, ILV (joint publication IEC/CIE).
2. ISO 31:1992 *Quantities and Units, Part 6: Light and Related Electromagnetic Radiations*.

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3. LIST OF SYMBOLS

For the purposes of this Standard, the following symbols apply:

a, b luminance gradation parameters

azimuth of a sky element (clockwise from north) [rad]

s azimuth of the sun (clockwise from north) [rad]

c, d, e scattering indicatrix parameters

shortest angular distance between a sky element and the sun [rad]

f() scattering indicatrix function

(*Z*) luminance gradation function

angle of elevation of a sky element above the horizon [rad]

s angle of elevation of the sun above the horizon [rad]

L_a luminance of a sky element [cd/m^2]

L_z zenith luminance [cd/m^2]

Z angular distance between a sky element and the zenith [rad]

Z_s angular distance between the sun and zenith [rad]

For quantities and units see Normative References 1 & 2.

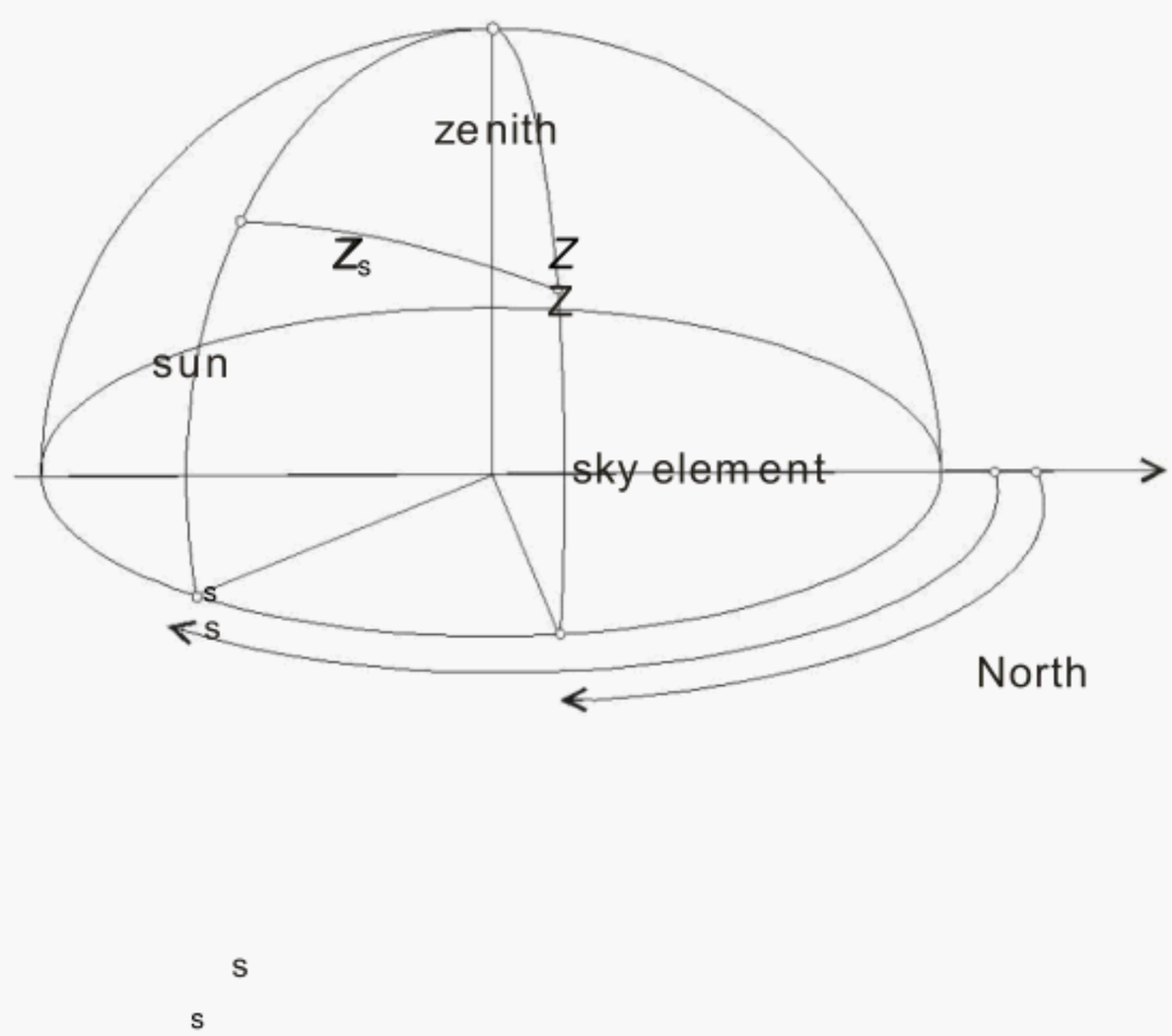

Figure 1. Angles defining the position of the sun and a sky element.

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4. SPECIFICATION: THE RELATIVE SKY LUMINANCE DISTRIBUTION

The position of an arbitrary sky element is defined by its zenith angle, Z, and by the azimuth difference between the element and the sun, $_s$. If Z_s is the zenith angle of the sun, the angular distance between the element and the sun is

$$\arccos\cos Z_s \cos Z \sin Z_s \sin Z \cos \quad _s \qquad (1)$$

Alternatively, the angle of elevation, , may be used instead of the zenith angle, Z, to define the position of an element. Then

$$Z \qquad (2)$$

$$_2$$

Similarly the zenith angle of the sun may be obtained from the solar elevation by

$$Z \tag{3}$$

s 2

s

The ratio of the luminance, L_a, of an arbitrary sky element to the zenith luminance, L_z, is

$$\frac{L_a}{L_z} = \frac{f(Z_s)}{f(0)} \tag{4}$$

The luminance gradation function, , relates the luminance of a sky element to its zenith angle:

$$f(Z) = 1 - a\exp\left(\frac{b}{\cos Z}\right), \quad \text{when } 0 \le Z \le \frac{\pi}{2} \tag{5}$$

$$f(0) = 1, \quad \text{at the horizon}$$

The parameters *a* and *b* are given in Table 1 for standard sky types.

Equation 4 requires the value at the zenith. This is

$$f(0) = 1 - a\exp b \tag{6}$$

The function *f* is a scattering indicatrix which relates the relative luminance of a sky element to its angular distance from the sun:

$$f(\ ) \quad 1 \quad c \quad \exp d \quad \exp d \quad \frac{0}{\ } \quad e \ \cos^{2} \qquad (7)$$

$$\left[\frac{1}{\ } \right]^{/2}_{0}$$

$$\left[\frac{1}{\ } \right]^{2}_{3}$$

Its value at the zenith is

$$!$$

$$f(Z_s)\ 1\quad c\quad \frac{1}{\exp dZ_s\ \exp d\ \left(\frac{1}{2}\right)\ e\ \cos^2 Z_s} \tag{8}$$

5. SPECIFICATION: STANDARD PARAMETERS

For purposes of classification and description, the parameters *a* to *e* in equations 5 - 8 shall be selected from Table 1. This lists fifteen standard relative luminance distributions which are based on six groups of *a* and *b* values for the gradation function and six groups of *c*, *d* and *e* values for the indicatrix function. The resulting curves are illustrated in Figs. 2 and 3.

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Table 1. Standard parameters.

Type	*Gradation group*	*Indicatrix group*	*a*	*b*	*c*	*d*	*e*	*Description of luminance distribution*
1	I	1	4,0	-0,70	0	-1,0	0	**CIE Standard Overcast Sky,** Steep luminance gradation towards zenith, azimuthal uniformity
2	I	2	4,0	-0,70	2	-1,5	0,15	Overcast, with steep luminance gradation and slight brightening towards the sun
3	II	1	1,1	-0,8	0	-1,0	0	Overcast, moderately graded with azimuthal uniformity
4	II	2	1,1	-0,8	2	-1,5	0,15	Overcast, moderately graded and slight brightening towards the sun
5	III	1	0	-1,0	0	-1,0	0	**Sky of uniform luminance**
6	III	2	0	-1,0	2	-1,5	0,15	Partly cloudy sky, no gradation towards zenith, slight brightening towards the sun
7	III	3	0	-1,0	5	-2,5	0,30	Partly cloudy sky, no gradation towards zenith, brighter circumsolar region
8	III	4	0	-1,0	10	-3,0	0,45	Partly cloudy sky, no gradation towards zenith, distinct solar corona
9	IV	2	-1,0	-0,55	2	-1,5	0,15	Partly cloudy, with the obscured sun
10	IV	3	-1,0	-0,55	5	-2,5	0,30	Partly cloudy, with brighter circumsolar region
11	IV	4	-1,0	-0,55	10	-3,0	0,45	White-blue sky with distinct solar corona
12	V	4	-1,0	-0,32	10	-3,0	0,45	**CIE Standard Clear Sky, low luminance turbidity**
13	V	5	-1,0	-0,32	16	-3,0	0,30	**CIE Standard Clear Sky, polluted atmosphere**
14	VI	5	-1,0	-0,15	16	-3,0	0,30	Cloudless turbid sky with broad solar corona
15	VI	6	-1,0	-0,15	24	-2,8	0,15	White-blue turbid sky with broad solar corona

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6. SPECIFICATION: THE TRADITIONAL OVERCAST SKY

The Standard General Sky integrates the traditional overcast sky formula as the 16th sky* that may be used as an alternate to Sky Type 1 when only overcast skies are to be modelled. This luminance distribution should be expressed by the ratio of the luminance of a sky element, $L_{oc}()$, to the zenith luminance, L_{zoc}:

$$\frac{L_{oc}}{L_{zoc}} \quad \frac{1 \quad 2 \sin}{3} \qquad (9)$$

where is the angle of elevation of the sky element above the horizon.

The difference between Sky Types 1 and 16 is shown on Fig. 4.

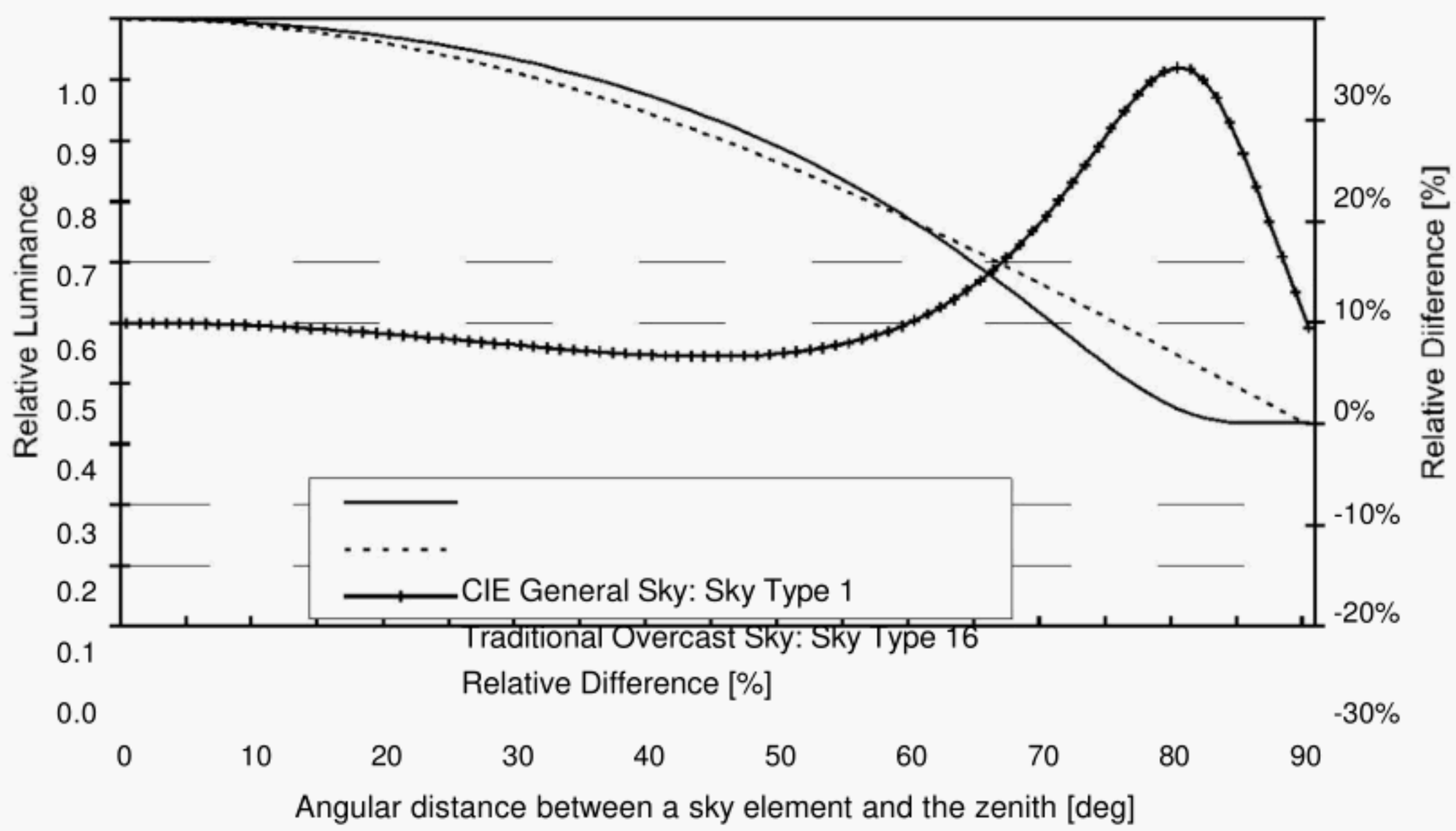

Figure 4. Difference between Sky Types 1 and 16.

7. DERIVATION OF THE STANDARD SKY

The CIE Standard Overcast Sky and the CIE Standard Clear Sky were developed in a series of publications between 1955 and 1994 [1-4].

The CIE Standard General Sky is a generalisation of the CIE Clear Sky formula [5]. It has been shown to be a good model of skies with smoothly varying luminous distributions occurring in various climatic conditions [7,8]. Formulae of this type have also been shown to provide a good approximation to skies of broken cloud in maritime climates [9,11]. It has also been shown that approximately four types of the General Sky can give a good characterisation of the exterior daylight conditions, although the particular sky types may differ between climates [11].

Absolute values of sky luminance vary with solar elevation, and therefore with latitude. Empirical equations for zenith luminance and horizontal illuminance have been published for various climates [6,10,12,13].

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* Same as CIE Standard Overcast Sky of CIE S003/E-1996.

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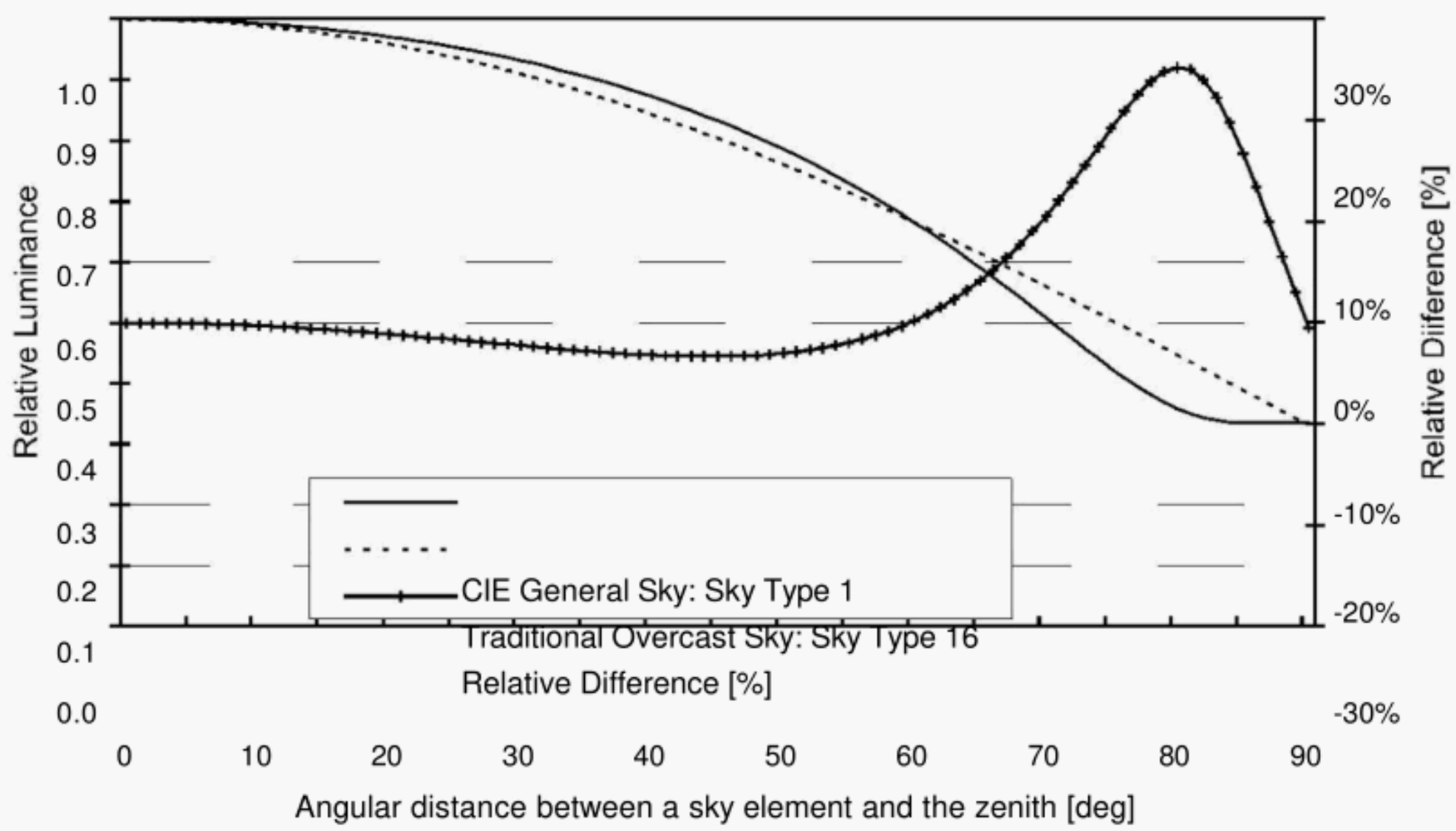

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ANNEX A (INFORMATIVE): REFERENCES

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