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REDLINE VERSION

INTERNATIONAL STANDARD

Classification of environmental conditions –
Part 2-4: Environmental conditions appearing in nature – Solar radiation and temperature

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CLASSIFICATION OF ENVIRONMENTAL CONDITIONS –

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FOREWORD

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International Standard IEC 60721-2-4 has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test.

This second edition cancels and replaces the first edition published in 1987 and Amendment 1:1988. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Figures updated including the addition of global irradiation information,

b) Format updated.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
104/800/FDIS	104/803/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60721 series, published under the general title *Classification of environmental conditions*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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CLASSIFICATION OF ENVIRONMENTAL CONDITIONS –

Part 2-4: Environmental conditions appearing in nature – Solar radiation and temperature

1 Scope

This part of IEC 60721 presents a broad division into types of solar radiation areas. It is intended to be used as part of the background material when selecting appropriate severities of solar radiation for product applications.

All types of geographical areas are covered, except areas with altitudes above 5 000 m.

~~When selecting severities of solar radiation for product applications, the values which are given in IEC 60721-1 should be applied.~~

~~2 Object~~

This document also serves to define limiting severities of solar radiation to which products are liable to be exposed during transportation, storage and use.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 General

Solar radiation can affect products primarily by the heating of material and their environment or by photochemical degradation of material.

~~The~~ Solar radiation, especially its ultraviolet content ~~of solar radiation~~, causes photochemical degradation of most organic materials. Elasticity and plasticity of certain rubber compounds and plastic materials are affected. Optical glass may become opaque.

Solar radiation bleaches out colours in paints, textiles, paper, etc. This can be of importance, for example for the colour-coding of components.

The heating of material is ~~the most important effect~~ a consequence of exposure to solar radiation. The presentation of severities of solar radiation is therefore related to the power density radiated towards a surface, or irradiance, expressed in W/m^2.

An object subjected to solar radiation will attain a temperature that depends primarily on the surrounding air temperature, the energy radiated from the Sun, and the incidence angle of the radiation on the object. Other factors, for example wind and heat conduction to mountings, can be of importance. In addition, the absorptance α_s of the surface for the solar spectrum is of importance.

An artificial air temperature t_s may be defined, which, under steady-state conditions, results in the same surface temperature of an object as the combination of the actual air temperature t_u and the solar radiation of the irradiance E.

An approximate value can be obtained from the following equation:

$$t_s = t_u + \frac{\alpha_s \cdot E}{h_y}$$

The coefficient h_y is the heat transfer coefficient for the surface, in W/(m^2 · °C). It includes thermal radiation to the surroundings, heat conduction of the surface material and convection due to wind.

The absorptance α_s, depends on the thermal colour, the reflectance and the transmittance of the surface.

Typical clear sky values for common materials are:

α_s = 0,7
h_y = 20 W/(m^2 · °C)
E = 900 W/m^2

resulting in an "over temperature" due to solar radiation of about 30 °C. It can then be seen that an error of 10 % in the estimation of the intensity of the solar radiation will influence the temperature involved by less than 5 °C. Therefore, there is no need in this classification for extremely accurate severities of solar radiation and minor factors affecting the heat radiated have therefore been disregarded here.

The heating effect is caused mainly by short-term radiation of high intensity, i.e. the solar radiation around noon on cloudless days. Such values are presented in Table 1.

It may also be of interest to identify the lowest possible value of atmospheric radiation during clear nights in order to determine the “under temperature” of products exposed to the night sky.

~~Such values are given in figure 1.~~

5 Solar radiation physics

The electromagnetic radiation from the Sun to the Earth covers ~~a rather broad~~ the spectrum from the ultraviolet to the near infra-red. Most of the energy reaching the surface of the Earth is in the wavelength range of 0,3 µm to 4 µm with a maximum in the visible range around 0,5 µm. Typical spectra are shown in Figure 1.

The amount of radiant energy from the Sun which falls upon the unit area of a plane normal to the Sun's rays just outside the atmosphere at the mean distance from the Earth to the Sun is called the solar constant. Its value is ~~approximately 1,37 kW/m^2~~ 1 367 W/m^2 .

The distance from the Earth to the Sun varies during the year, and consequently the radiation varies ~~from approximately 1,41 kW/m^2 in January to approximately 1,32 kW/m^2 in July~~.

Approximately 99 % of the energy of the Sun is emitted at wavelengths below 4 µm. Most of the energy below 0,3 µm is absorbed by the atmosphere and does not reach the surface of the Earth. Further absorption and scattering of the radiation takes place, due to particles and gases, during passage through the atmosphere. The scattering of the direct solar radiation in the atmosphere results in diffuse radiation from the sky. Thus, the energy received at a certain place on Earth is the sum of the direct solar radiation and the diffuse solar radiation, which is referred to as "global radiation". From the point of view of heating effects, this sum is of interest and the levels given in this document are therefore related to global radiation.

6 Levels of global radiation

6.1 Maximum levels

The maximum level of global radiation on a clear day occurs at noon. The highest value of the power achieved on a cloudless day at noon at a surface perpendicular to the direction of the Sun depends on the content of aerosol particles, ozone and water vapour in the air. It varies considerably with geographical latitude and type of climate.

The global radiation on a surface perpendicular to the direction of the Sun ~~may~~ can reach a value of 1 120 W/m^2 in a range of 280 nm to 3 000 nm at noon on a cloudless day with approximately 1 cm of water vapour content, 2 mm of ozone and aerosols of β = 0,05, where β is the Ångström turbidity coefficient. The value 1 120 W/m^2 is typical for flat land far away from industrial areas and from large cities at solar elevations exceeding 60°.

NOTE 1 The water vapour content of a vertical column of the atmosphere is measured as the height, in centimetres, of the corresponding precipitated water. Analogously, the ozone content of a vertical column of the atmosphere is measured as the height of the corresponding ozone column at normal temperature and pressure. The scattering and absorption by aerosol particles is expressed by the Ångström turbidity coefficient, which is the optical depth of the atmosphere with respect to extinction of monochromatic radiation of wavelength λ = 1 µm.

NOTE 2 During partly clouded days the global solar irradiation can increase up to 1 300 W/m^2 for a few minutes. This short-term phenomenon occurs when the Sun comes out behind the clouds and the radiation is reflected from the edges of the clouds.

The direct solar radiation decreases with increasing turbidity. Turbidity is high in subtropical climates and in deserts where the concentration of particles in the air is high. It is also high in large cities and low in mountainous areas.

The levels in Table 1 are recommended for application as peak values of global irradiance at noon, experienced by a surface perpendicular to the direction of the Sun in a cloudless sky. The level varies only by a few per cent within the hours nearest to noon and can therefore be assumed to be representative for a few hours at a time.

Table 1 – Typical peak values of global irradiance (in W/m^2 from a cloudless sky)

Area	Large cities	Flat land	Mountainous areas
Subtropical climates and deserts	700	750	1 180
Other areas	1 050	1 120	1 180

6.2 Mean monthly and annual global solar radiation

Whilst the maximum heating effect of solar radiation on a surface is normally dependent on short-term irradiance around noon, the photochemical effects are related to radiation, integrated over time, i.e. irradiation. For the purpose of comparison, daily global irradiation is the most convenient and commonly used value.

In December, the monthly mean average of daily irradiation reaches approximately 10,8 kWh/m^2 close to the South Pole, because of the duration of daylight. Outside the Antarctic area, daily levels reach approximately 8,4 kWh/m^2.

The highest annual mean averages of daily global irradiation, up to 6,6 kWh/m^2, are found mainly in desert areas.

6.3 Simultaneous values of maximum air temperatures and solar radiation

The lowest values of the turbidity coefficient β are found in cold air masses. Therefore, the levels in Table 1 do not occur at the highest values of air temperature.

~~It may be assumed that global irradiance does not reach more than 80 % of the values given in table 1 at the maximum air temperatures given in IEC 60721-2-1.~~

6.4 World distribution of daily global irradiation

For the distribution of daily global irradiation, see Annex A.

7 Minimum levels of atmospheric radiation at night

In cloudless nights when the atmospheric radiation is very low, objects exposed to the night sky will attain surface temperatures below the surrounding air temperature.

The theoretical temperature T_0, in kelvins, of an object in equilibrium with the atmospheric radiation is given by Boltzmann's law:

$$T_0 = \left(\frac{A}{\sigma}\right)^{1/4}$$

where

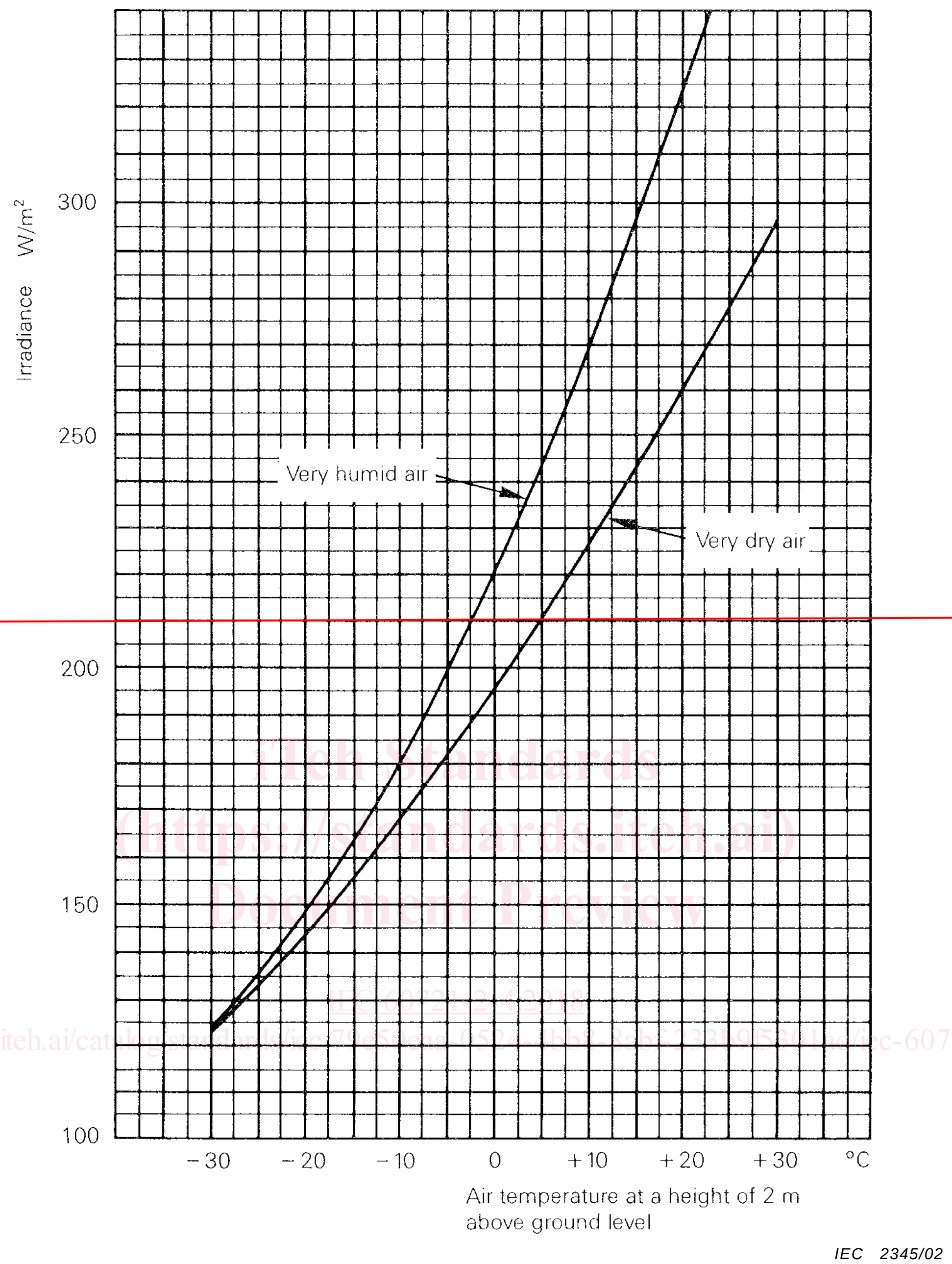
σ is Stefan-Boltzmann's constant, 5,67 · 10^{-8} W/(m^2 · K^4);

A is the atmospheric radiation in W/m^2 ~~(see figure 1)~~.

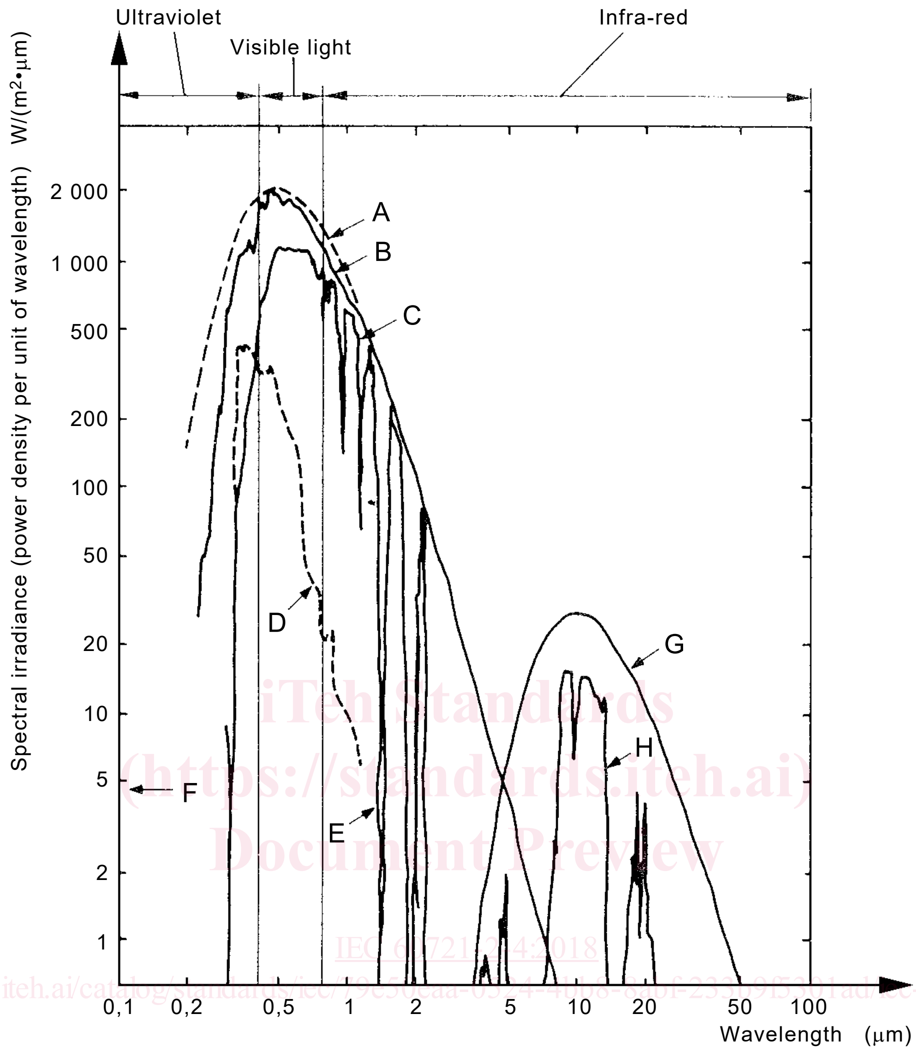
In practice, temperatures will be higher due to heat conduction, convection and water condensation.

As an example, it has been found that the surface of a horizontal disk thermally isolated from the ground and exposed to the night sky during a clear night can attain a temperature of −14 °C when the air temperature is 0 °C and the relative humidity is close to 100 %.

~~Figure 1 shows the atmospheric radiation from the night sky in clear air as a function of air temperature at a height of 2 m above the ground level.~~ The relative humidity is normally very high on clear nights.



~~**Figure 1 – Atmospheric radiation from a clear night sky**~~



A Radiation outside the atmosphere from the Sun represented as a black body at temperature 6 000 K (1,60 kW/m^2)

B Solar radiation outside the atmosphere (1,37 kW/m^2)

C Direct solar radiation at the surface of the Earth perpendicular to the direction of radiation (e.g. 0,9 kW/m^2)

D Diffuse solar radiation at the surface of the Earth (e.g. 0,10 kW/m^2)

E Absorption bands of water vapour and carbon dioxide

F Absorption by oxygen and ozone

G Radiation of a black body at 300 K (0,47 kW/m^2)

H Thermal radiation from the Earth (e.g. 0,07 kW/m^2)

Figure ~~2~~1 – Spectra of electromagnetic radiation from the Sun and the surface of the Earth

Annex A
(informative)

World distribution of daily global irradiation

Figures A.1, A.2 and A.3 are world maps showing isohels of relative global irradiation (June, December and annual mean values), derived from satellite measurements (see [1][1]). Relative global irradiation is defined as the ratio of global irradiation measured at the Earth's surface, divided by the extra-terrestrial global irradiation, which is the solar radiation on a plane perpendicular to the direction of the Sun just outside the atmosphere.

In order to obtain the mean daily value of global irradiation at the Earth's surface, the percentage value shown on the maps should be multiplied by the appropriate mean daily value of extra-terrestrial global irradiation, which is given as a function of geographical latitude in Table A.1.

NOTE The basis for determining the daily irradiation values in kWh/m^2 is the values of monthly and annual irradiation in MJ/m^2 divided by the number of days in June (30), in December (31), and in the year (365).

EXAMPLE:

Determination of the mean daily global irradiation to be expected in June at the southern point of the Californian peninsula.

From Figure A.1, the point (at an approximate geographical latitude of 23° N) is surrounded by an isohel of 60 %, and the percentage value for the point is estimated to be 62 %.

In Table A.1, interpolation for 23° N in the June column gives 11,16 kWh/m^2, which is multiplied by the percentage value above.

The mean daily global irradiation will thus be approximately 6,9 kWh/m^2.

1 Numbers in square brackets refer to the Bibliography.

Table A.1 – Mean daily extra-terrestrial global irradiation (kWh/m²)

Latitude	June	December	Annual
90 N	12,47	0,0	4,17
85 N	12,42	0,0	4,20
80 N	12,28	0,0	4,30
75 N	12,05	0,0	4,49
70 N	11,72	0,0	4,76
65 N	11,40	0,11	5,16
60 N	11,40	0,65	5,71
55 N	11,48	1,36	6,29
50 N	11,56	2,16	6,87
45 N	11,61	3,00	7,42
40 N	11,61	3,85	7,93
35 N	11,56	4,72	8,40
30 N	11,44	5,57	8,82
25 N	11,26	6,40	9,19
20 N	11,00	7,20	9,49
15 N	10,68	7,96	9,73
10 N	10,30	8,68	9,90
5 N	9,84	9,34	10,01
0	9,33	9,95	10,04
5 S	8,76	10,50	10,01
10 S	8,13	10,98	9,90
15 S	7,46	11,39	9,73
20 S	6,74	11,73	9,49
25 S	5,99	12,00	9,19
30 S	5,21	12,19	8,82
35 S	4,41	12,32	8,40
40 S	3,60	12,37	7,93
45 S	2,79	12,37	7,41
50 S	2,01	12,31	6,86
55 S	1,27	12,22	6,29
60 S	0,60	12,13	5,71
65 S	0,10	12,12	5,16
70 S	0,0	12,45	4,75
75 S	0,0	12,80	4,48
80 S	0,0	13,05	4,30
85 S	0,0	13,20	4,20
90 S	0,0	13,25	4,16