INTERNATIONAL STANDARD

ISO 9845-1

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Solar energy — Reference solar spectral irradiance at the ground at different receiving conditions —

Part 1:
Direct normal and hemispherical solar irradiance for air mass 1,5

Énergie solaire — Rayonnement solaire spectral de référence au sol sous différentes conditions de réception —

Partie 1: Rayonnement solaire direct normal et hémisphérique pour une masse d'air de 1,5

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Contents

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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.

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.

International Standard ISO 9845-1 was prepared by Technical Committee ISO/TC 180, *Solar energy*, Sub-Committee SC 1, *Climate -- Measurement and data*.

ISO 9845 consists of the following parts, under the general title *Solar energy — Reference solar spectral irradiance at the ground at different receiving conditions*:

— *Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5*

Annexes A, B, C and D of this part of ISO 9845 are for information only.

Introduction

Absorbance, reflectance and transmittance of terrestrial solar energy are important factors in solar thermal system performance, photovoltaic system performance, materials studies, biomass studies and solar simulation activities. These optical properties are normally functions of wavelength, which requires that the spectral distribution of the solar flux be known before the solar weighted property can be calculated. In order to compare the performance of competitive products, a reference standard solar spectral irradiance distribution is desirable.

The tables in this part of ISO 9845 provide spectral irradiance data. These modelled data, based on conditions selected in ASTM E 891-87, *Terrestrial direct normal solar spectral irradiance for air mass 1,5*, and ASTM E 892-87, *Terrestrial direct normal solar spectral irradiance at air mass 1,5 for a 37° tilted surface*, form the subject of the first of a series of standards dealing with spectral irradiance at different receiving conditions such as different albedos, tilt angles, etc.

The tables in this part of ISO 9845 are modelled data that were generated using a zero air mass solar spectrum based on the revised extraterrestrial spectrum of Neckel and Labs[1], the BRITE [3][4] Monte Carlo radiative transfer code, and the 1962 US Standard Atmosphere[5] with a rural aerosol [6] [7][8]. Further details are presented in annex A.

The extraterrestrial spectrum that was used to generate the terrestrial spectrum was provided by Fröhlich and Wehrli[1] and is a revised and extended Neckel and Labs[2] spectrum. Neckel and Labs revised their spectrum by employing newer solar limb-darkening data to convert from radiance to irradiance, as reported by Fröhlich[9], citing the study by Hardorp[10]. Comparisons by Fröhlich with calibrated sunphotometer data from Manua Loa, Hawaii[11], indicate that this new extraterrestrial spectrum is one of the best currently available.

The development of the terrestrial solar spectrum data is based on work reported by Bird *et al.* [12][13]. In computing the terrestrial values using the BRITE Monte Carlo radiation transfer code, the authors cited took the iterations to 2,450 0 µm only. The spectrum is extended to 4, 045 0 µm using sixteen E_{λ_i} values from ASTM E 891-87 and ASTM E 892-87. Irradiance values in ASTM E 891-87 were computed from the extraterrestrial spectrum. The additional data points were added to account for the solar irradiance in this region which accounts for approximately 1,5 % of the total irradiance between 0,305 0 µm and 4,045 0 µm.

Further parts of ISO 9845 will consider recent improvements in the basic data and modelling techniques leading to better accuracy.

Solar energy — Reference solar spectral irradiance at the ground at different receiving conditions —

Part 1:

Direct normal and hemispherical solar irradiance for air mass 1,5

1 Scope

This part of ISO 9845 provides an appropriate standard spectral irradiance distribution to be used in determining relative performance of solar thermal, photovoltaic, and other systems, components and materials where the direct and hemispherical irradiance component is desired. Possible shortcomings caused by modelling of the ground component at a constant albedo of 0,2 are explicitly noted.

The tables presented in this part of ISO 9845 define an air mass 1,5 solar spectral irradiance, for use in all solar applications where a standard spectral irradiance is required, for the direct normal radiation — 5,8° field-of-view angle — and hemispherical radiation on an equator-facing, 37° tilted plane for an albedo of 0,2. These tables are intended to represent ideal clear sky conditions.

2 Definitions

For the purposes of this part of ISO 9845, the following definitions apply.

2.1 air mass zero (AM0): Solar radiation quantities outside the earth's atmosphere at the mean earth-sun distance.

2.2 air mass (AM): Ratio of the mass of atmosphere in the actual observer—sun path to the mass that would exist if the observer were at sea level, at standard barometric pressure, and the sun were directly overhead.

NOTE 1 Air mass varies with the elevation of the sun and the local barometric pressure, which changes with altitude. For a sun zenith angle, Z, of 62° or less, and local atmospheric pressure, P, where P_0 is standard atmospheric pressure, $\mathrm{AM} = P/(P_0 \cos Z)$.

2.3 direct solar irradiance: On a given plane receiver surface, the ratio of the radiant fluxes received from a small solid angle centred on the sun's disk to the area of that surface (unit: watts per square metre, $\mathrm{W \cdot m^{-2}}$).

NOTE 2 If the plane is perpendicular to the axis of the solid angle, the direct normal solar irradiance is received. For appropriate radiometers of modern design, the applied solid angles correspond to field-of-view angles of less than 6°.

2.4 hemispherical solar irradiance: On a given plane, the ratio of the solar radiant flux received from the sky hemisphere above — including the direct solar radiant flux — to the area of the plane (unit: watts per square metre, $\mathrm{W \cdot m^{-2}}$).

2.5 spectral solar irradiance (E_λ): Solar irradiance E per unit wavelength interval at a given wavelength λ (unit: watts per square metre per micrometre, $\mathrm{W \cdot m^{-2} \cdot \mu m^{-1}}$).

$$E_\lambda = \mathrm{d}E/\mathrm{d}\lambda$$

NOTE 3 The reference spectra are evaluated in the range of 0,305 μm to 4,045 μm. The relevant spectral range of the measurement of the solar radiation is confined to the range from 0,3 μm to 3 μm. This accounts for 98,5 % of the spectra (further details are given in ISO 9060:1990, *Solar energy — Specification and classification of instruments for measuring hemispherical solar and direct solar radiation*). However, the spectra in this part of ISO 9845 are confined to the range from 0,305 μm to 4,045 μm.