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Standard Terminology of Solar Energy Conversion[1]

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1. Scope

1.1 This terminology pertains to the conversion of solar energy into other forms of energy by various means, including thermal absorption (i.e., solar thermal) and the photovoltaic effect (i.e., photovoltaics).

1.2 This terminology also pertains to instrumentation used to measure solar radiation.

1.3 This terminology also pertains to glass for solar energy applications.

1.4 Fundamental terms associated with electromagnetic radiation that are indicates as derived units in Standard IEEE/ASTM SI 10 are not repeated in this terminology.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C162 Terminology of Glass and Glass Products
C1048 Specification for Heat-Strengthened and Fully Tempered Flat Glass
C1651 Test Method for Measurement of Roll Wave Optical Distortion in Heat-Treated Flat Glass
D1003 Test Method for Haze and Luminous Transmittance of Transparent Plastics
D1245 Practice for Examination of Water-Formed Deposits by Chemical Microscopy
D4865 Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems
D5544 Test Method for On-Line Measurement of Residue After Evaporation of High-Purity Water
D7236 Test Method for Flash Point by Small Scale Closed Cup Tester (Ramp Method)
E349 Terminology Relating to Space Simulation
E490 Standard Solar Constant and Zero Air Mass Solar Spectral Irradiance Tables
E491 Practice for Solar Simulation for Thermal Balance Testing of Spacecraft
E927 Specification for Solar Simulation for Photovoltaic Testing
E948 Test Method for Electrical Performance of Photovoltaic Cells Using Reference Cells Under Simulated Sunlight
E816 Test Method for Calibration of Pyrheliometers by Comparison to Reference Pyrheliometers
E1021 Test Method for Spectral Responsivity Measurements of Photovoltaic Devices
E1036 Test Methods for Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells
E1125 Test Method for Calibration of Primary Non-Concentrator Terrestrial Photovoltaic Reference Cells Using a Tabular Spectrum
E1171 Test Methods for Photovoltaic Modules in Cyclic Temperature and Humidity Environments
E1362 Test Method for Calibration of Non-Concentrator Photovoltaic Secondary Reference Cells
E1462 Test Methods for Insulation Integrity and Ground Path Continuity of Photovoltaic Modules
E2236 Test Methods for Measurement of Electrical Performance and Spectral Response of Nonconcentrator Multijunction Photovoltaic Cells and Modules
E2527 Test Method for Electrical Performance of Concentrator Terrestrial Photovoltaic Modules and Systems Under Natural Sunlight
F1863 Test Method for Measuring the Night Vision Goggle-Weighted Transmissivity of Transparent Parts
G113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials
G130 Test Method for Calibration of Narrow- and Broad-Band Ultraviolet Radiometers Using a Spectroradiometer
G138 Test Method for Calibration of a Spectroradiometer Using a Standard Source of Irradiance
G167 Test Method for Calibration of a Pyranometer Using a Pyrheliometer
G173 Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 37° Tilted Surface

[1] This terminology is under the jurisdiction of ASTM Committee E44 on Solar, Geothermal and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.01 on Terminology and Editorial.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

G197 Table for Reference Solar Spectral Distributions: Direct and Diffuse on 20° Tilted and Vertical Surfaces
IEEE/ASTM SI 10 American National Standard for Metric Practice

2.2 *ISO Standard:*[3]

ISO 9060 Specification and Classification of Instruments for Measuring Hemispherical Solar and Direct Solar Radiaiton

2.3 *WMO Document:*[4]

WMO-No. 8 Guide to Meteorological Instruments and Methods of Observation, Seventh ed., 2008, World Meteorological Organization (WMO), Geneva

3. Adjectives for Electromagnetic Radiation

3.1 Properties and quantities associated with electromagnetic radiation vary with:

3.1.1 The direction and geometric extent (solid angle) over which the incident or exitant flux, or both, is evaluated, and

3.1.2 The relative spectral distribution of the incident flux and the spectral response of the detector for exitant flux.

3.2 Adjective modifiers can be used to indicate the geometric, spectral, and polarization conditions under which radiometric properties and quantities are evaluated. The adjectives defined in this Terminology are: **conical, diffuse, direct, directional, hemispherical, luminous, normal,** and **spectral**.

3.3 For reflectance and transmittance, the direction and geometric extent of both the incident beam and exitant beam must be specified.

3.4 For emittance, only the exitant beam need be specified, and for absorptance, only the incident beam need be specified.

3.5 Radiometric properties also vary with the polarization of the incident flux and the sensitivity to polarization of the collector-detector system for flux incident or exitant at angles greater than about 15° from normal.

3.6 An instrument used for solar energy measurements or a solar energy receiver will usually determine the directions and geometric extents, such as a pyranometer, a pyrheliometer, or a flat-plate solar thermal collector.

4. Terminology

ELECTROMAGNETIC RADIATION AND OPTICS

absorptance, *n*—ratio of the absorbed radiant or luminous flux to the incident flux. **E349**

absorption, *n*—transformation of radiant energy to a different form of energy by interaction with matter. **E349**

aerosol, *n*—any solid or liquid particles, with a nominal size range from 10 nm to 100 µm, suspended in a gas (usually air). **D5544**

aerosol optical depth, *AOD*, *n*—a measure of the **extinction** caused by **aerosols** in the atmosphere relative to the **zenith** and modeled with Ångstrom's **turbidity** formula.

DISCUSSION—Although it varies with wavelength, it is common to report aerosol optical depth at a single wavelength only, especially 0.5 µm.

air mass, *AM*, *n*—relative optical mass (see **optical mass, relative**) calculated using the density of air as a function of altitude.

$$AM \approx l_s / l_z = sec\theta_z, for\ \theta_z \leq 1\ \text{rad}\ (60°) \quad (1)$$

DISCUSSION—Eq 1 is a simple approximation of the **optical mass, relative** (see Eq 5) that uses the ratio of the path length along the sun vector (l_s) to the path length along the zenith (l_z) (see **sun vector, zenith**, and **zenith angle, solar**). Other solutions are more complicated and take factors such as refraction and local air pressure into account.

DISCUSSION—The abbreviation **AM** is also commonly used to refer to a particular standard solar spectral irradiance, such as those in Standard E490, Tables G173, and Table G197. Thus, **AM0** can indicate the extraterrestrial spectral irradiance table in Standard E490, and **AM1.5** the hemispherical spectral irradiance table in Tables G173. Using AM1.5 in this way is discouraged because air mass is but one of many variables that modify solar spectral irradiance such as clouds, aerosol scattering, and water vapor absorption; note that both Tables G173 and Table G197 use an air mass value of 1.5, but differ greatly. The distinction between a spectral irradiance and a path length ratio should be made clear whenever these abbreviations are used.

air mass one, *AM1*, *n*—a relative optical mass (see **optical mass, relative**) that is equal to one. Because of the way in which relative optical mass is defined, AM1 always denotes a vertical path at sea level.

air mass, optical—see **optical mass, relative**.

air mass, pressure corrected, AM_p, *n*—an approximation of **air mass** for locations above sea level that uses the ratio of the local barometric pressure *P*, to the standard sea level atmospheric pressure P_0 = 101.325 kPa (see Eq 2).

$$AMp \approx \frac{P}{P_0} AM \quad (2)$$

air mass ratio—see **optical mass, relative**.

air mass, relative optical—see **optical mass, relative**.

air mass zero, *AM0*, *n*—the absence of atmospheric attenuation of the solar irradiance at one astronomical unit from the sun. **E491**

albedo—discouraged in favor of the preferred term, **reflectance**.

angle of incidence, rad or °, *n*—the angle between a ray and the normal vector to the plane on which the ray is incident; especially the angle between the sun vector and the normal vector.

angle of reflection, rad or °, *n*—the angle between the direction of propagation of a reflected ray and the normal vector to the surface of interest at the point of reflection.

angle of refraction, rad or °, *n*—the angle between the direction of propagation of a refracted ray and the normal vector to the interface of interest at the point of refraction.

altitude angle, solar—see **elevation angle, solar**.

attenuation—see **extinction**.

[3] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

[4] Available from World Meteorological Organization, http://www.wmo.int.

azimuth angle, solar, ψ[rad or °], *n*—the angle between the line of longitude (or geographical meridian) at the location of interest and the horizontal component of the **sun vector**. By convention, the azimuth angle is positive when the sun is east of the line of longitude and negative when it is west of the line of longitude.

beam, *n—of radiant energy*, a collection of rays confined to a specific path.

blackbody, Planckian radiator, *n*—a thermal radiator which completely absorbs all incident radiation, whatever the wavelength, the direction of incidence, or the polarization. This radiator has, for any wavelength, the maximum spectral concentration of radiant exitance at a given temperature. **E491**

Bouguer's Law, *n*—an expression of the **extinction** of radiation in a medium that states the intensity exponentially decreases due to both scattering and absorption as it passes through the medium (see Eq 3), where τ_λ is the wavelength-dependent **extinction optical thickness**. The ratio of I to I_0 is equal to the atmospheric transmittance, T, and τ_λ is equal to the summation of the extinction optical thicknesses associated with each individual scattering or absorption process $\tau_{i\lambda}$.

$$I = I_0 exp(-\tau_\lambda) = I_0 exp\left(-\sum_{i=1}^{n} \tau_{i\lambda}\right) \quad (3)$$

DISCUSSION—Bouguer's Law is also known as Lambert's Law or Beer's Law.

*circumsolar diffuse radiation***—see radiant energy, circumsolar**.

conical, *adj*—describing a solid angle larger than an infinitesimal element and less than a hemisphere (2π sr); the geometry of the solid angle must be described in context.

diffuse, *adj—describing radiometric quantities*, indicates flux propagating in many directions, as opposed to a collimated beam.

diffuse, *adj—describing solar irradiance*, the global hemispherical irradiance minus the direct beam irradiance.

diffuse, *adj—describing reflectance*, the directional hemispherical reflectance minus the specular reflectance.

DISCUSSION—**Diffuse** has been used in the past to refer to hemispherical collection (including the specular component) or irradiation, with equal radiance for all directions over a hemisphere. This use is deprecated in favor of the more precise term **hemispherical**.

diffusion, *n*—change of the spatial distribution of a beam of radiation when it is deviated in many directions by a surface or a medium. **E349**

direct, *adj—describing solar radiation*, a collimated beam.

directional, *adj*—of or relating to a direction in space.

DISCUSSION—For optical properties, over an infinitesimal solid angle, the property is assumed constant. The variation in optical property with respect to changing azimuth (counter-clockwise) and incidence angle (from the surface normal), with respect to a reference mark on a sample, is the directional response.

elevation angle, solar, α [rad or °], *n*—the complement of the solar zenith angle, i.e. $\pi/2 - \theta_z$ radians. See **zenith angle, solar**.

emission, *n*—release of radiant energy. **E349**

*emissive power***—**discouraged in favor of the preferred term **radiant exitance**.

emittance, ε, *n*— for a sample at a given temperature, ratio of the radiant flux emitted by a sample to that emitted by a blackbody radiator at the same temperature, under the same spectral and geometric conditions of measurement.

extinction, *n*—the attenuation of radiant energy from an incident beam by the processes of molecular absorption and scattering caused by atmospheric constituents.

DISCUSSION—Scattering by air molecules can be modeled with **Rayleigh scattering**, and scattering by **aerosols** with Ångstrom's **turbidity** formula. Absorption processes are modeled with tables of measured absorption coefficients versus wavelength.

extinction coefficient, monochromatic, $k_{i\lambda}$[dimensionless], *n*—a measure of the **extinction** caused by a particular atmospheric constituent (see **Bouguer's Law** and **extinction optical thickness, monochromatic**).

extinction optical depth, monochromatic, [dimensionless], *n*—the product of the **extinction coefficient** $k_{i\lambda}$ for a particular atmospheric constituent times the path length to the top of the atmosphere, m_r, see **extinction optical thickness, monochromatic** and **optical mass, relative**.

DISCUSSION—Optical depth is sometimes used synonymously with optical thickness, but the preferred distinction between the two is that optical thickness refers to the extinction along the entire path through the atmosphere rather than the vertical path.

extinction optical thickness, monochromatic, $\tau_{i\lambda}$ [dimensionless], *n*—the product of the **extinction coefficient** $k_{i\lambda}$ for a particular atmospheric constituent times the path length through atmosphere, see **Bouguer's Law** and Eq 4, in which m_{act} is the **optical mass, actual**.

$$\tau_{i\lambda} = k_{i\lambda} \cdot m_{act} \quad (4)$$

hemispherical, *adj*—describing half of a sphere, i.e. a 2π sr solid angle.

*incident angle***—**see **angle of incidence.**

index of refraction, *n*—the numerical expression of the ratio of the velocity of light in a vacuum to the velocity of light in a substance. **D1245**

infrared radiation, *n*—radiation for which the wavelengths of the monochromatic components are greater than those for visible radiation, and less than about 1 mm. **E349**

irradiance, *E* [$W \cdot m^{-2}$], *n—at a point on a surface*, radiant flux incident per unit area of the surface; the derived unit **heat flux density, irradiance** in Standard IEEE/ASTM SI 10.

irradiance, spectral, E_λ *or* $E(\lambda)$[$W \cdot m^{-2} \cdot nm^{-1}$ or $W \cdot m^{-2} \cdot \mu m^{-1}$], *n*—the irradiation at a specific wavelength over a narrow bandwidth, or as a function of wavelength; also, the derivative with respect to wavelength of irradiance.

DISCUSSION—Spectral irradiance is commonly reported in tabular form as pairs of wavelength and irradiance values, as in Standard E490, Tables G173, and Table G197; see **spectral**.

DISCUSSION—Following the normal SI rules for compound units (see Standard IEEE/ASTM SI 10), the units for spectral irradiance, the derivative of irradiance with respect to wavelength *dE/dλ*, would be $W \cdot m^{-3}$. However, to avoid possible confusion with a volumetric power density unit and for convenience in numerical calculations, it is common practice to separate the wavelength with a compound unit. Compound units are used in Standard E490, Tables G173, and Table G197.

irradiance, total, E_T [$W \cdot m^{-2}$], *n*—the integration over all wavelengths of spectral irradiance, or the solar irradiance measured with a pyranometer or a pyrheliometer.

irradiation, *n*—application of radiation to an object. **E349**

irradiation—at a point on a surface, see **radiant exposure**.

isotropic radiant energy— see **radiant energy, isotropic**.

local zenith—see **zenith**.

luminous, *adj—referring to a radiometric quantity*, weighted according to the spectral luminous efficiency function V() of the CIE (1987). **D1003**

monochromatic radiation, *n*—radiation charcterized by a single frequency. By extension, radiation of a very small range of frequency or wavelenght that can be described by stating a single frequency or wavelength. **E349**

normal, *adj*—describing a direction that is perpendicular to a surface.

normal vector, *n*—the upward-pointing vector normal to the plane of a receiver.

optical depth—see **extinction optical depth, monochromatic**.

optical mass, actual, m_{act} [dimensionless], *n*—the line integral along the **sun vector** of the density (ρ) of a substance as a function of altitude between a point in the atmosphere (0) and the vacuum of space (∞); in atmospheric transmittance calculations, the densities are normalized with units of $(\text{length})^{-1}$ (see Eq 5).

$$m_{act} = \int_0^\infty \rho ds \tag{5}$$

DISCUSSION—The word "air" has been avoided in this definition because direct solar radiation is attenuated not only by air molecules but also by additional constituents such as aerosols and water vapor. Thus, it is possible to calculate water vapor mass as well as air mass using this equation. Optical masses are occasionally reported with units of km.

optical mass, relative, m_r [dimensionless], *n*—the ratio of the actual optical mass (see **optical mass, actual**, m_{act}) to the line integral along the **zenith** of the density of a substance as a function of altitude (ρ) between a point in the atmosphere (0) and the vacuum of space (∞) (see Eq 6).

$$m_r = m_{act} / \int_0^\infty \rho ds \tag{6}$$

optical thickness—see **extinction optical thickness, monochromatic**.

polarization, *n— with respect to optical radiation*, the restriction of the magnetic or electric field vector to a single plane. **G138**

polarization, parallel, *n*—a plane of polarization parallel to the plane of incidence, reflectance, or transmittance.

polarization, perpendicular, *n*—a plane of polarization perpendicular to the plane of incidence, reflectance, or transmittance.

polarization, plane of, *n*—by convention, the plane containing an electromagnetic wave's electric vector.

radiance, $W \cdot m^{-2} \cdot sr^{-1}$, *n*—the SI derived unit **radiance** in Standard IEEE/ASTM SI 10.

radiant emissive power—see **radiant exitance**.

radiant energy, *Q*[J], *n*—energy in the form of photons or electromagnetic waves.

radiant energy, atmospheric, *Q*[J], *n*—the portion of terrestrial radiation that is emitted by the atmosphere.

radiant energy, blackbody, J, *n*—radiant energy emitted by a (laboratory) blackbody, or radiant energy having that spectral distribution. See **Planck's law** in Practice E491.

radiant energy, circumsolar, J, *n*—radiation scattered by the atmosphere so that it appears to originate from an area of the sky immediately adjacent to the sun. Often referred to as the solar aureole, its angular extent is generally directly related to the aerosol optical depth.

radiant energy, effective nocturnal, J , *n*—energy transfer required to maintain a horizontal upward-facing blackbody surface at the ambient air temperature, in the absence of solar irradiance.

radiant energy, infrared—see **infrared radiation**.

radiant energy, isotropic, J, *n*—diffuse radiant energy that has the same radiance in all directions.

radiant energy, terrestrial, J, *n*—radiant energy emitted by the earth, including its atmosphere.

radiant exitance at a point on a surface, *M*[$W \cdot m^{-2}$], *n*—quotient of the radiant flux leaving an element of the surface containing the point, by the area of that element. **E349**

radiant exitance—see **radiant exitance at a point on a surface**.

radiant exitance, emitted—see **radiant exitance at a point on a surface**.

radiant exposure, *H*[$J \cdot m^{-2}$], *n—at a point on a surface*, time integral of irradiance.

radiant flux, Φ[J/s], *n*—the SI derived quantity **power, radiant flux** in Standard IEEE/ASTM SI 10.

radiant flux, net, W, *n*—difference between downward and upward (total solar and terrestrial) radiant flux; net flux of all radiant energy across an imaginary horizontal surface.

radiant flux, net terrestrial, W, *n*—difference between downward and upward terrestrial radiant fluxes; net flux of terrestrial radiant energy.

radiant power—see **radiant flux.**

radiation, *n—(1)* emission or transfer of energy in the form of electromagnetic waves or particles. *(2)* the electromagnetic waves or particles. **E349**

radiation coefficient, *n*—the quotient of the net radiant exitance of a blackbody (full radiator), by the temperature difference between the blackbody and the surroundings with which it is exchanging radiation. **E349**

Rayleigh scattering, *n*—a model of molecular scattering in the atmosphere in which the **monochromatic extinction coefficient** varies as the wavelength raised to the negative fourth power. Eq 7 is an approximation for dry air using wavelengths in µm.

$$k_{r\lambda} = 0.008735\lambda^{-4.08} \quad (7)$$

reflectance, *n*—ratio of the reflected radiant or luminous flux to the incident flux. **E349**

reflection, *n*—return of radiation by a surface without change of frequency of the monochromatic components of which the radiation is composed. **E349**

reflection angle—See **angle of reflection**.

reflectivity, *n*—reflectance of a layer of material of such a thickness that there is no change of reflectance with increased thickness. **E349**

Discussion—Reflectivity is a property of a material and reflectance is a property of a sample of the material, with no restriction on thickness or surface topography.

refraction, *n*—change in the direction of propagation of radiation determined by change in the velocity of propagation in passing from one medium to another medium with a different index of refraction.

refraction angle—see **angle of refraction.**

refraction index—see **index of refraction.**

reradiation, *n*—loss of energy by radiation from a surface previously heated by absorption.

spectral, *adj—referring to radiometric quantities*, for monochromatic radiation at a specified wavelength (or frequency), or, by extension, for radiation within a narrow wavelength band about a specified wavelength. **E349**

Discussion—When applied to a property, spectral is indicated by the subscript λ following the symbol for the quantity, as $L_\lambda = dL/d\lambda$; at a specific wavelength, it is indicated by the subscript λ with the wavelength in parentheses, as L_λ (500 nm).

sun vector, *n*—the vector pointing from the location of interest (usually a point on the Earth's surface in solar energy applications) to the center of the sun's disk.

Discussion—Because of the curvature of the Earth, and because of the refraction due to density variations with altitude, the sun vector varies along the path a beam of solar radiation follows from the top of atmosphere to the ground.

total irradiance—see **irradiance, total**.

transmission, *n*—passage of radiation through a medium without change of frequency of the monochromatic components of which the radiation is composed. **E349**

transmission coefficient—see **extinction coefficient**.

transmittance, *T* [dimensionless], *n*—ratio of the transmitted radiant or luminous flux to the incident flux. **E349**

turbidity, *n*—an empirical expression of **aerosol optical depth** that uses Ångstrom's wavelength-dependent formula (see Eq 8).

$$k_{\alpha\lambda} = \beta \cdot \lambda^{-\alpha} \quad (8)$$

Discussion—In Eq 8, α and β are called the Ångstrom turbidity parameters and λ is the wavelength. The units of α and β are such that the units of k_α are dimensionless. With wavelength units of µm, β is commonly called the "turbidity" because it varies more than α, which tends to stay fairly constant.

ultraviolet radiation, *n*—radiation for which the wavelengths of the monochromatic components are smaller than those for visible radiation and more than about 1 nm. **E349**

visible radiation, *n*—any radiation capable of causing a visual sensation. **E349**

zenith, *n*—the upward-pointing vector normal to the Earth's surface at the location of interest (usually a point on the Earth's surface in solar energy applications).

zenith angle, solar, θ_z[rad or °]**,** *n*—the angle between the **zenith** and the **sun vector**.

INSTRUMENTATION

absolute cavity pyrheliometer—see **self-calibrating absolute cavity pyrheliometer**.

absolute cavity radiometer—see **self-calibrating absolute cavity pyrheliometer**.

bolometer, *n*—instrument for measuring irradiance. Its principle is based on the variation of electrical resistance, with the incoming radiation of one or both of the resistance elements which comprise the instrument, as a result of temperature changes.

cavity radiometer—see **self-calibrating absolute cavity pyrheliometer**.

edge-stress meter—see **polarimeter, edge-stress**.

field pyrheliometer, *n*—pyrheliometers that are designed and used for long-term field measurements of direct solar radiation. These pyrheliometers are weatherproof and therefore possess windows, usually quartz, at the field aperture that pass all solar radiation in the range from 0.3 to 4-µm wavelength. **E816**

full width at half maximum, *FWHM*[nm or µm]**,** *n—in a bandpass filter*, FWHM is the interval between wavelengths at which transmittance is 50 % of the peak, frequently referred to as bandwidth. **G130**

grazing-angle surface polarimeter—see **polarimeter, grazing-angle surface**.

international pyrheliometric scale—see **World Radiometric Reference**.

net pyrgeometer—see **pyranometer, net.**

net pyrradiometer— see **pyranometer, net.**

photometer, *n*—a device that measures luminous intensity or brightness by converting (weighing) the radiant intensity of an object using the relative sensitivity of the human visual system as defined by the photopic curve. **F1863**

polarimeter, *n*—an instrument used to measure the rotation of the plane of polarization of polarized light passing through an optical structure or sample.

polarimeter, edge stress, *n*—a specialized **polarimeter** for measuring residual edge stress in annealed, heat-strengthened, or thermally tempered flat glass. Used as a non-destructive method of characterizing strength and relative frangibility of glass.

polarimeter, grazing-angle surface, *n*—a specialized **polarimeter** for measuring residual surface stress in annealed, heat-strengthened, or thermally tempered flat glass. Used as a non-destructive method of characterizing strength and relative frangibility of glass.

polarimeter, photoelastic, *n*—a **polariscope** adapted for quantitative measurement of optical retardation, birefringence, or stress and strain using photoelastic analysis techniques.

polariscope, *n*—an optical device consisting of a light source, mutually perpendicular polarizing elements, and generally equipped with one or more retardation plates for qualitative observations of relative optical retardation by color differentiation. **C162**

primary standard pyrheliometers, *n*—pyrheliometers, selected from the group of absolute pyrheliometers (see **self-calibrating absolute cavity pyrheliometer**). **E816**

pyranometer, *n*—a radiometer with a hemispherical field-of-view (i.e. a 2π sr solid angle) used to measure the total solar radiant energy incident upon a surface per unit time per unit area. This energy includes the direct radiant energy, diffuse radiant energy, and reflected radiant energy from the background.

pyranometer, field, *n*—a pyranometer meeting World Meteorological Organization (WMO) Second Class "moderate quality" or better (that is, "Good Quality" or "High Quality") First Class specifications, described in WMO-No. 8, appropriate to field use, and typically exposed continuously.

pyranometer, net, *n*—an instrument for measuring the difference between the irradiance falling on the top and bottom of a horizontal surface.

pyranometer, reference, *n*—a pyranometer (see also ISO 9060), used as a reference to calibrate other pyranometers, which is well-maintained and carefully selected to possess relatively high stability and has been calibrated using a pyrheliometer. **G167**

pyranometer, spherical, *n*—instrument for measuring the solar flux falling from a 4π sr solid angle onto a spherical surface.

pyrgeometer, *n*—an instrument for measuring infrared atmospheric irradiance at wavelengths greater than 3000 nm on a horizontal upward facing black surface at the ambient air temperature.

pyrheliometer, *n*—a radiometer used to measure the direct or beam solar irradiance incident on a surface normal to the sun's rays.

pyrheliometer, compensated, *n*—pyrheliometer based on the comparison of the heating of two identical metal strips, one exposed to a solar radiant energy, the other to a joule effect.

pyrheliometer, field—see **field pyrheliometer**.

pyrheliometer, primary standard—see **primary standard pyrheliomers**.

pyrheliometer, reference—see **reference pyrheliometer**.

pyrheliometer, secondary standard—see **secondary standard pyrheliometer**.

pyrheliometer, self-calibrating absolute cavity—see **self-calibrating absolute cavity pyrheliometer**

pyrheliometer, secondary reference, *n*—a pyrheliometer essentially meeting the World Meteorological Organization (WMO) "High Quality" specifications as described in WMO-No. 8, but not having self-calibrating capability.

pyrradiometer, spherical, *n*—instrument for measuring total flux incident from a 4π sr solid angle onto a spherical surface.

radiometer, *n*—a general class of instruments designed to detect and measure radiant energy. **G113**

radiometer, broad-band, *n*—a relative term generally applied to radiometers with interference filters or cut-on/cut-off filter pairs having a FWHM between 20 and 70 nm and with tolerances in center (peak) wavelength and FWHM no greater than ±2 nm. **G130**

radiometer, narrow-band, *n*—a relative term generally applied to radiometers with interference filters with FWHM ≤ 20 nm and with tolerances in center (peak) wavelength and FWHM no greater than ±2 nm. **G130**

radiometer, wide-band, *n*—a relative term generally applied to radiometers with combinations of cut-off and cut-on filters with FWHM greater than 70 nm. **G130**

radiometry, *n*—measurement of the quantities associated with radiation. **E349**

reference pyrheliometer, *n*—pyrheliometers of any category serving as a reference in calibration transfer procedures. They are selected and well-tested instruments (see Table 2 of ISO 9060), that have a low rate of yearly change in responsivity. The reference pyrheliometer may be of the same type, class, and manufacturer as the field radiometers in which case it is specially chosen for calibration transfer purposes and is termed a secondary standard pyrheliometer (see ISO 9060), or it may be of the self-calibrating cavity type (see **self-calibrating absolute cavity pyrheliometer**). **E816**

reflectometer, *n*—an instrument for the measurement of quantities pertaining to reflection. **E349**

refractometer, *n*—an optical instrument used to measure the index of refraction of an unknown sample.

roll-wave gauge, *n*—instrument used to monitor and quantify roller wave surface distortion, typically present in thermally tempered flat glass processed in a horizontal roller-hearth tempering furnace. **C1651**

secondary standard pyrheliometer, *n*—pyrheliometers of high precision and stability whose calibration factors are derived from primary standard pyrheliometers. This group comprises absolute cavity pyrheliometers that do not fulfill the requirements of a primary standard pyrheliometer. **E816**

self-calibrating absolute cavity pyrheliometer, *n*—a radiometer consisting of either a single- or dual-conical heated cavity that, during the self-calibration mode, displays the power required to produce a thermopile reference signal that is identical to the sampling signal obtained when viewing the sun with an open aperture. The reference signal is produced by the thermopile in response to the cavity irradiance resulting from heat supplied by a cavity heater with the aperture closed. **E816**

spectrophotometer, *n*—instrument for measuring the ratio of two spectral radiometric qualities. **E349**

spectroradiometer, *n*—an instrument for measuring the radiant energy of a light source at each wavelength throughout the spectrum. **G138**

strain viewer—see **polariscope**.

sunphotometer, *n*—a narrow-band radiometer (see **radiometer, narrow-band**) that measures relative direct solar intensity at a number of discrete wavelengths that are selected for determination of atmospheric optical depths due to constituents, especially aerosol scattering and molecular absorption by water vapor and ozone.

sun radiometer—see **sunphotometer**.

World Radiometric Reference, *WRR*, *n*—the mean of a selected group of at least four World Metrological Organization (WMO) self calibrating absolute cavity pyrheliometers maintained at the World Radiation Center, Physical Meteorological Organization, Davos (WRC/PMOD) at Davos, Switzerland. The WRR is accepted as representing the physical units of total solar irradiance with an uncertainty of 0.3 % and a confidence of 99 %.

Discussion—As of 1970 the WRR replaced the "International Pyrheliometric Scale of 1956, IPS56", the "Smithsonian Pyrheliometric Scale of 1913, SI13" and the "Angstrom Scale of 1905, A05", as follows: WRR/IPS56 = 1.026, WRR/SI13 = 0.977, and WRR/A05 = 1.026. See WMO-No. 8, Section 7.1.2.2.

SOLAR ENERGY – GENERAL

absorber, *n*—that part of a solar collector whose primary function is to absorb radiant energy and transform it into another form of energy.

Discussion—A thermal absorber usually possesses a solid surface through which energy is transmitted by thermal conduction to the transfer fluid; however, the transfer fluid itself can be the absorber in the case of an optically transparent container and a "black liquid". A photovoltaic absorber converts part of the incident solar flux into electrical energy, and part to thermal energy.

albedo—discouraged in favor of the preferred term, **reflectance**.

altazimuthal mount, *n*—a supporting device that facilitates tracking of the sun and allows rotation about horizontal and vertical axes. It can be used to aim equipment such as heliostats, concentrating collectors, exposure specimens, or radiometers.

apparent solar time, *apt*[h], *n*—the hours of the day (i.e. time) as computed from the position of the sun (see **solar noon**).

auxiliary energy subsystem, *n*—*in solar energy applications*, equipment using nonsolar energy sources to supplement or backup the output provided by a solar energy system.

cloud cover, *n*—that portion of the sky which is covered by clouds, usually expressed in tenths of sky covered.

collector cover (glazings)—see **cover plate, collector**.

collector, concentrating, *n*—a solar collector that uses reflectors, lenses, or other optical elements to redirect and concentrate the solar irradiance on the collector aperture onto an absorber of which the surface area is smaller than the collector aperture area.

collector, flat plate, *n*—a non-concentrating solar collector in which the absorbing surface is essentially planar.

collector, line-focus, *n*—a concentrating collector that focuses the solar flux in one dimension only.

collector, point focus, *n*—a concentrating collector that focuses the solar flux to a point, i.e. in two dimensions.

collector, tracking, *n*—a solar collector that moves so as to follow the apparent motion of the sun during the day, rotating about one axis or two orthogonal axes.

concentration ratio—see **concentration ratio, geometric** and **concentration ratio, photovoltaic**.

concentration ratio, geometric, *n*—*of a concentrating solar thermal collector*, the ratio of the collector aperture area to the absorber area.

concentration ratio, photovoltaic, *n*—the total irradiance at the front surface of a photovoltaic cell intended for use inside a concentrating collector, divided by 1000 $W \cdot m^{-2}$.

Discussion—The 1000 $W \cdot m^{-2}$ value of the denominator in this ratio is equal to the total irradiance from the **standard reporting conditons** defined for performance measurements made with respect to the Tables G173 **reference spectral irradiance distribution** (see Test Methods E948 and E1036). Because this value is defined as "one-sun", the normalization changes the total irradiance into a multiplicative factor corresponding to the magnitude of the concentration, which is sometimes referred to as the "number of suns".

concentrating collector—see **collector, concentrating**.

concentrator, *n*—an optical device (lenses or mirrors) that, as part of a solar collector, receives the unconcentrated solar irradiance over a large area aperture and redirects and focuses (concentrates) it to a smaller area (the receiver).

cover plate, collector, *n*—a sheet of transparent (or translucent) glazing placed above the absorber in a solar collector, to provide thermal and environmental protection.

design life, *n*—the period of time during which a system or component is expected to perform its intended function, without significant degradation of performance and without requiring major maintenance or replacement.

direct radiation, *n*—radiation received from a small solid angle centered on the sun's disk, on a given plane (see ISO 9060). That component of sunlight is the beam between an observer, or instrument, and the sun within a solid conical angle centered on the sun's disk and having a total included planar field angle of 5 to 6° (see also Test Method E816).

direct beam radiation—see **direct radiation**.

direct solar radiation—see **direct radiation**.

equatorial mount, *n*—a sun-tracking mount, usually clock-driven, whose axis of rotation is parallel to that of the earth's axis of rotation.

exposure racks, at-latitude, *n*—racks that hold specimens at an inclination angle equal to the latitude of the rack location, facing the equator.

flat plate collector—see **collector, flat plate**.

Fresnel lens, circular, *n*—a sheet of transparent material into which concentric grooves have been formed in such a pattern that light will be focused as with a lens. (Focusing mirrors of similar design are also available.)

Fresnel lens, linear, *n*—a sheet of transparent material into which parallel grooves have been formed in such a pattern that light will be focused as by a cylindrical lens. (Focusing mirrors of similar design are also available.)

Fresnel-reflector system, *n*—flat mirrors arranged in an array such that they reflect onto a target, the illuminated area of which simulates the shape and size of the flat mirror. (Such an array simulates the ray-tracing of a parabolic trough of the same aperture angle.)

heliostat, *n*—a reflector that is mechanically positioned so that solar flux is reflected onto a stationary receiver or target.

in-service conditions, *n*—the normal conditions to which a system and its components will be exposed during their operational lifetimes. This does not include stagnation conditions; see **stagnation conditions.**

insolation—discouraged in favor of the preferred term, **solar irradiance.**

DISCUSSION—Insolation is sometimes used as a synonym for **radiant exposure**, with units of $J \cdot m^{-2}$ or the non-SI equivlaent $kWh \cdot m^{-2}$. This usage is also discouraged.

isohel, $MJ \cdot m^{-2} \cdot year^{-1}$, *n*—a line on a map connecting points that receive equal amounts of solar radiation over a period of one year.

isopleth, *n*—a line on a chart or graph connecting points having a specified constant value of a single variable as a function of two other specified variables.

line-focus collector—see **collector, line-focus**.

natural-type environment, *n—in solar energy applications*, the natural aspects of the outdoor exposure elements (or simulation), including changes with time, that may affect the performance of a collector through degradation of collector materials or physical damage to the collector configuration. Typical aspects include radiant exposure, ambient temperature, and rain impingement.

natural weathering, *n*—outdoor exposure of materials to unconcentrated sunlight, the purpose of which is to assess the effects of environmental factors on various functional and decorative parameters of interest. **G113**

operating conditions, extreme, *n*—unusual physical conditions to which a component or system may be exposed and for which it is not designed or intended to withstand, nor is it required to withstand by a local regulatory agency.

operating conditions, normal, *n*—the usual range of physical conditions (for example, temperature, pressure, wear and tear, weather) for which the component or system was designed.

plant, solar, *n*—a generic term for any solar energy collection system, either photovoltaic or thermal; its usage is discouraged in favor of the specific terms **system, photovoltaic** or **system, solar thermal energy**.

point focus collector—see **collector, point focus**

receiver, *n—in solar energy systems*, that part of the solar collector to which the solar irradiance is finally directed or redirected, and includes the absorber and any associated glazings through which the redirected energy must pass.

shading—see **shadowing**.

shadowing, *v*—the act of casting a shadow across any surface.

solar, *adj—referring to radiometric quantities*, indicates that the radiant flux involved has the sun as its source, or has the relative spectral distribution of the sun's radiant flux.

solar, *adj—referring to optical properties*, indicates a weighted average of the spectral property, with a standard solar spectral irradiance distribution as the weighting function.

solar degradation, *n*—the process by which exposure to solar energy deteriorates the properties of materials and components; or, the deterioration of materials and components produced by exposure to solar energy.

solar energy, *n*—electromagnetic energy emitted by the sun. The solar radiation incident on the top of the terrestrial atmosphere is called extraterrestrial solar radiation; 97 percent of which is confined to the spectral range 290 to 3000 nm. **WMO-No. 8**

solar flux, Φ [J/s], *n*—**radiant flux** received from the sun.

solar irradiance, E_s[W·m^{-2}], *n*—**irradiance** received from the sun.

DISCUSSION—Solar irradiance is a function of distance between the sun and the place of measurement, falling off as the inverse of the square of the separation. Typically, the place of measurement is the surface of the earth, thus sometimes the term "terrestrial solar irradiance" is used. Note that the distance between the sun and the Earth changes because the Earth's orbit is elliptical; the resulting variation in solar irradiance at the top of the Earth's atmosphere is approximately ±3.0 %.

solar irradiance, diffuse, W·m^{-2}, *n*—the downward scattered solar flux as received on a horizontal surface from a 2π sr solid angle (hemisphere), with the exception of a conical solid angle with a 100 mrad included plane angle (approximately 6°) centered upon the sun's disk.

solar irradiance, direct, W·m^{-2}, *n*—solar flux from the solid angle of the sun's disk incident on a surface perpendicular to the axis of that solid angle. Conventional instruments have an acceptance cone with an included plane angle of about 6°. See also **pyrheliometer**.

solar irradiance duration, h, *n—bright sunshine*, time interval during which direct radiation casts distinct shadows; defined in WMO-No. 8 as a direct irradiance exceeding a threshold value of 120 W·m^{-2}.

solar irradiance duration, h, *n—geographically or topographically possible*, maximum interval during which solar energy can reach a given surface.

solar irradiance, global, W·m^{-2}, *n*—hemispherical solar irradiance incident on a horizontal surface; see discussion for **solar irradiance, hemispherical**.

solar irradiance, global horizontal—see **solar irradiance, global**.

solar irradiance, global normal—discouraged in favor of the preferred term **solar irradiance, hemispherical tracking**.

solar irradiance, global tilted—discouraged in favor of the preferred term **solar irradiance, hemispherical tilted**.

solar irradiance, hemispherical, E_H[W·m^{-2}], *n*—on a given plane, the solar radiant flux received from within the 2π steradian field of view of a tilted plane from the portion of the sky dome and the foreground included in the plane's field of view, including both diffuse and direct solar radiation. **G173**

DISCUSSION—For the special condition of a horizontal plane the hemispherical solar irradiance is properly termed global solar irradiance, E_G. Incorrectly, global tilted, or total global irradiance is often used to indicate hemispherical irradiance for a tilted plane. In case of a sun-tracking receiver, this hemispherical irradiance is commonly called global normal irradiance. The adjective global should refer only to hemispherical solar radiation on a horizontal, not a tilted, surface. **G173**

solar irradiance hemispherical tracking, W·m^{-2}, *n*—on a plane that always pointed normal to the sun with a tracking device, the solar radiant flux received from within the 2π sr field-of-view of a tilted plane from the portion of the sky dome and the foreground included in the plane's field of view, including both diffuse and direct solar radiation.

solar irradiance, hemispherical tilted, W·m^{-2}, *n*—hemispherical solar irradiance incident on a non-horizontal stationary surface; see discussion for **solar irradiance, hemispherical**.

solar irradiance, total global—discouraged in favor of the preferred term **solar irradiance, hemispherical tilted**.

solar irradiance, instantaneous, W·m^{-2}—see **solar irradiance**.

solar irradiance, spectral, E_λ or E(λ)[W·m^{-2}·nm^{-1} or W·m^{-2}·µm^{-1}, *n*—a spectral irradiance of the sun; see **irradiance, spectral**.

solar irradiation, terrestrial, W·m^{-2}, *n*—irradiance received from the sun within the Earth's atmosphere; see **solar irradiance**.

solar irradiation, time average, W·m^{-2}, *n*—the time integral of solar irradiance over a specified time period divided by the duration of that time period.

solar irradiation—discouraged in favor of the preferred term **radiant exposure**.

solar noon, h, *n*—that instant of any day when the sun reaches its greatest elevation above the local horizon, or crosses the local meridian.

solar panel—discouraged in favor of the more precise terms **collector, flat-plate** or **module, photovoltaic**. See also **panel, photovoltaic**.

solar plant, *n*—see **plant, solar**.

solar radiation—see **solar energy**.

solar rights, *n*—the legal right of a person who uses a solar energy device not to have his or her sunlight blocked by another person's new structure or foliage.

solar simulator, *n*—an artificial light source with associated optics intended to produce simulated solar radiation for indoor performance testing of photovoltaic devices or solar thermal collectors. Typical solar simulator designs use Xenon arc lamps with reflective and refractive optics to provide spatially uniform illumination. Solar simulators that produce pulses of light shorter than 100 ms are commonly used for photovoltaic performance testing, see Specification E927.

solar spectrum, *n*—see **solar irradiance, spectral**.

tilt angle, *n—in solar energy applications*, the angle between the horizontal and the plane of the detector (collector, photovoltaic device, instrument) surface.

tracking collector—see **collector, tracking**.

tracking error, *n—for a two-axis tracking collector*, the angular deviation between the collector-sun line and a line that is normal to the aperture plane.

tracking error, *n—for a single-axis tracking collector*, the angular deviation between two planes that intersect along the axis of rotation. One plane contains the optical axis of the collector and the other contains the center of the sun.

weather conditions, normal, *n*—the (actual or anticipated) range of environmental conditions (rain, snow, hail, wind, temperature, pollution) that will typically occur in a local climatic region over several years.

PHOTOVOLTAICS

area, photovoltaic cell, m^2**,** *n*—the total frontal area of a photovoltaic cell including all area covered by grid lines and fingers, and contacting pads for bonding to external metallic conductors.

area, photovoltaic concentrator cell, m^2, *n*—the total frontal area of a photovoltaic concentrator cell including the area covered by grid lines or fingers, but excluding the area covered by contacting pads for bonding to external metallic conductors. See also **area, photovoltaic cell**.

DISCUSSION—This definition for photovoltaic concentrator cell area is sometimes referred to as the "area designed to be illuminated."

area, photovoltaic module, m^2, *n*—the rectangular area that touches the extreme outside edges of a photovoltaic module.

array, photovoltaic, *n*—an assembly of photovoltaic panels or modules, together with a support structure and other components (if used), to form a complete dc power-producing unit.

calibration constant, $A \cdot m^2 \cdot W^{-1}$, *n—of a photovoltaic reference device*, a number that expresses the calibration in terms of short-circuit current per unit incident irradiance at a given temperature while illuminated with a particular **reference spectral irradiance distribution**.

DISCUSSION—For a calibrated reference cell, the calibration constant equals the short-circuit current of the photovoltaic reference cell when irradiated by a reference spectral irradiance distribution (such as Tables E490 or G173) divided by the total irradiance of that reference spectral irradiance distribution.

cell, photovoltaic, *n*—the basic semiconductor device that generates electricity by the photovoltaic effect when exposed to radiant energy such as sunlight.

cell area, *n*—see **area, photovoltaic cell**.

cell temperature, °C, *n—of a photovoltaic cell*, the temperature of the semiconductor junction.

component cell, *n—of a multifunction device*, one of the individual photovoltaic junctions in a multijunction device.

concentrator cell, photovoltaic, *n*—a photovoltaic cell designed to be operated at irradiance levels greater than 2000 – 3000 $W \cdot m^{-2}$. See also **concentrator**.

concentrator cell area, *n*—see **area, photovoltaic concentrator cell**.

concentrator reporting conditions, photovoltaic, *n*—the ambient temperature, wind speed, and direct normal solar irradiance to which concentrator photovoltaic module or system performance data are corrected. **E2527**

current balance, *Z*, *n—of a photovoltaic multijunction component cell*, the ratio of the component cell current when illuminated with a **reference spectral irradiance districation**, i.e. the sun or a solar simulator. See Appendix X1 of Test Methods E2236.

DISCUSSION—Calculating the current balance for each component cell gives a measure of the spectral irradiance matching for the overall multijunction device.

current-voltage characteristic, *n—of a photovoltaic device*, the current through a photovoltaic device, paired with the voltage across the device, as the voltage is varied.

DISCUSSION—Typically, current-voltage characteristics are measured at a series of discrete current and voltage points. If the photovoltaic device is illuminated while in forward bias, performance characteristics such as **open-circuit voltage**, **short-circuit current**, and **maximum power** may be determined.

current-voltage curve—see **current-voltage characteristic**.

device, photovoltaic, *n*—any photovoltaic cell, module, panel, or array under consideration.

efficiency, η, *n—of a photovoltaic device*, the ratio of the power produced by a photovoltaic device operated at its maximum power point to the incident irradiance multiplied by the area of the photovoltaic device.

fill factor, *FF*, *n—of a photovoltaic device*, the ratio of maximum power to the product of open-circuit voltage and shortcircuit current. Fill factor may be reported as a dimensionless ratio or multiplied by 100 for units of percent.

I-V curve—see **current-voltage characteristic**.

junction temperature—see **cell temperature**.

maximum power, P_{max}[W], *n—of a photovoltaic device*, the electrical output when operated at a point on the current voltage curve at which the product of current and voltage is greatest. The maximum power point is between the open-circuit voltage and the short-circuit current points.

maximum system voltage, V, *n—of a photovoltaic system*, the maximum electrical potential, referenced at the system grounding point, that can be generated by a photovoltaic power system as specified by the module manufacturer. **E1462**

module area, *n*—see **area, photovoltaic module**.

module ground point, *n—of a photovoltaic module*, the terminal or lead identified by the manufacturer as the grounding point of the module. **E1171**

module, photovoltaic, *n*—single package containing two or more electrically interconnected photovoltaic cells, including a frame or integral mounting points, and means for electrical connection; which make it suitable for field installation without additional modification.

multijunction device, *n*—a photovoltaic device composed of more than one photovoltaic junction stacked on top of each other and electrically connected in series. **E2236**

nominal operating cell temperature, NOCT[°C] **,** *n—of a photovoltaic cell*, the temperature of a solar cell inside a module operating at an ambient temperature of 20°C, an irradiance of 800 Wm^{-2} , and an average wind speed of 1 ms^{-1}. **E1036**

non-primary reference cell, photovoltaic, *n*—a photovoltaic reference cell calibrated against another reference cell in accordance with Test Method E1362.

DISCUSSION—A **secondary reference cell, photovoltaic** is a special case of a non-primary reference cell; see Test Method E1362.

one-sun—see **concentration ratio, photovoltaic**.

open-circuit voltage, V_{oc}[V]**,** *n—of a photovoltaic device*, the voltage potential across the positive and the negative terminals under irradiation when zero current flows into or out of these terminals, i.e. the load resistance is infinite.

panel, photovoltaic, *n*—a number of photovoltaic modules that are electrically connected and mechanically integrated, and designed to provide a field-installable unit.

photovoltaic plant, *n*—see **plant, photovoltaic**.

plant, photovoltaic, *n*—a common term for a photovoltaic solar energy system; its usage is discouraged in favor of the specific term **system, photovoltaic**.

primary reference cell, photovoltaic, *n*—a photovoltaic reference cell calibrated in sunlight in accordance with Test Method E1125.

quantum efficiency, *QE(λ)*, *n—of a photovoltaic cell*, number of collected electrons per incident photon at a specific wavelength.

DISCUSSION—Quantum efficiency is normally reported over the wavelength range to which a device responds; it may be reported as a dimensionless ratio or multiplied by 100 for units of percent. Quantum efficiency can be mathematically converted to **spectral responsivity**; see Test Method E1021.

quantum efficiency, relative, $QE_r(\lambda)$**,** *n——of a photovoltaic device*, the **quantum efficiency** at a given wavelength, measured in relative (dimensionless) units.

DISCUSSION—Relative quantum efficiency is used where the absolute magnitude of the quantum efficiency is unimportant, simplifying the measurement procedure; see Test Method E1021.

reference cell, photovoltaic—see **reference device, photovoltaic**.

reference device, photovoltaic—a photovoltaic cell or module whose short-circuit current is calibrated against the total irradiance of a reference spectral irradiance distribution. See also **calibration constant**.

reference module, photovoltaic—see **reference device, photovoltaic**.

reference spectral irradiance distribution, *n*—a solar spectral irradiance to which a photovoltaic reference device is calibrated, especially Tables G173 or E490; see **spectral irradiance, solar**.

secondary reference cell, photovoltaic, *n*—a photovoltaic reference cell calibrated against a primary reference cell in accordance with Test Method E1362.

short-circuit current, I_{sc}[A]**,** *n—of a photovoltaic device*, the current flowing between the positive and negative terminals under illumination when the voltage across these terminals is zero, i.e. when the device is shorted.

solar cell—see **cell, photovoltaic**.

spectral mismatch parameter, photovoltaic, *M***,** *n*—a dimensionless quantitative measure of the error, introduced in the testing of a photovoltaic device, caused by mismatch between the spectral responses of the photovoltaic device and the photovoltaic reference cell, as well as mismatch between the test light source and the reference spectral irradiance distribution to which the photovoltaic reference cell was calibrated; the spectral mismatch parameter may be used to correct measured photovoltaic device current values for this error.

spectral response—see **spectral responsivity**.

spectral responsivity, *R(λ)*, *n—of a photovoltaic device*, the short-circuit current per unit monochromatic irradiance or power at a given wavelength, measured in either relative (dimensionless) or absolute units ($A \cdot W^{-1}$or $A \cdot m^2 \cdot W^{-1}$). See Test Method E1021.

DISCUSSION—Spectral responsivity is normally reported over the wavelength range to which a device responds. Spectral responsivity can be mathematically converted to **quantum efficiency**; see Test Method E1021.

spectral responsivity, relative, $R_r(\lambda)$**,** *n—of a photovoltaic device*, the **spectral responsivity** at a given wavelength, measured in relative (dimensionless) units.

DISCUSSION—Relative spectral responsivity is used where the absolute magnitude of the spectral response is unimportant, simplifying the measurement procedure; see Test Method E1021.

standard reporting conditions, *SRC*, *n—for photovoltaic performance measurements*, a fixed set of conditions that constitute the device temperature, the total irradiance, and the reference spectral irradiance distribution to which electrical performance data are translated.

standard test conditions—see **standard reporting conditions**.

system, photovoltaic, *n*—a photovoltaic module, panel, or array electrically connected to a dc-ac inverter or other power conditioning device as appropriate, along with the support or mounting structures and any additional electrical equipment needed for operation.

SOLAR THERMAL

air handling unit, *n*—a device used for distributing conditioned air supply to a room, space, or area.

aperture area—see **area, aperture**.

area, absorber, m^2**,** *n—of a solar thermal collector*, the total uninsulated heat transfer surface area of the absorber, including unirradiated as well as irradiated portions.

area, aperture, m^2**,** *n—of a flat plate solar thermal collector*, the maximum projected area of a solar collector through which the unconcentrated solar radiant energy may be admitted to the absorber.

area, collector panel, m^2**,** *n—of a solar thermal collector*, the total area of the panel assembly (with its containing box, if present), projected on the aperture plane.

area, effective aperture, m^2**,** *n—of a solar thermal collector*, the aperture area projected normal to the sun's rays and corrected for any shading.

area, gross aperture, m^2**,** *n—of a concentrating solar thermal collector*, the maximum projected area through which the unconcentrated solar radiant energy is admitted, including any area of the reflector or refractor shaded by the receiver and its supports, and including gaps between reflector segments within a collector module.

area, gross collector, m^2**,** *n—of a solar thermal collector*, the maximum area of the complete collector module, including integral mounting means, projected on the aperture plane.

area, net aperture, m^2**,** *n—of a concentrating solar thermal collector*, the maximum projected area through which the unconcentrated solar radiant energy is admitted, excluding any area of the reflector or refractor shaded by the receiver and its supports, and excluding gaps between reflector segments within a collector module.

building heat loss factor, *n*—a measure of the heat loss rate of a building expressed in joules per degree day. This factor is multiplied by the number of degree days in a given period to estimate the energy required to heat the building during that period.

charge capacity—see **thermal capacity**.

collector efficiency—see **efficiency, collector**.

collector, evacuated tube, *n*—a solar collector made from transparent tubing (usually glass) with an evacuated space between the tube and the absorber. The absorber may consist of an inner tube or another shape, with means for removal of thermal energy and may be specially coated.

collector, solar thermal, *n*—a device designed to absorb solar irradiance and to transfer the thermal energy to a fluid passing through it.

collector subsystem, *n*—that portion of the solar system which includes the solar collectors and related piping or ducts.

collector, trickle, *n*—a flat plate solar collector in which unpressurized liquid flows or "trickles" over the absorber.

combustible liquid, *n*—a liquid having a flash point at or above 38°C. **D4865**

containment material, *n—in a solar energy system*, a material that encloses the heat-transfer fluid or is in contact with the heat transfer or heat storage material, or both.

convection, *n*—the transport of heat by fluid flow.

convection, forced, *n*—convection caused by mechanical forces such as fans and injectors.

convection, natural, *n*—convection within a fluid, due to density differences caused by temperature differences.

degree day—see **degree day, heating** and **degree day, cooling**.

degree-day, cooling, *n*—one cooling degree-day is counted for each degree of temperature that the daily mean temperature is higher than a base temperature; used to estimate energy requirements for air conditioning or refrigeration.

degree-day, heating, *n*—one heating degree-day is counted for each degree of temperature that the daily mean temperature is lower than a base temperature; used to estimate energy requirements for heating.

discharge capacity, thermal, *n*—the amount of heat that can be removed from a storage device during a period of time and for a specific set of values for the initial and final temperatures of the storage device, the temperature of the entering fluid, and the mass flow rate of fluid through the storage system.

discharge test time, *n*—the duration of a single transient test in which energy is removed from the storage device.

distribution subsystem, *n*—that portion of the solar system from the storage device to the point of ultimate use.

drainback solar energy system—see **solar energy system, drainback**.

*draindown solar energy system***,** *n*—see **solar energy system, draindown**.

efficiency, collector, *n—of a solar thermal collector*, the ratio of the amount of energy removed by the heat transfer fluid to the solar energy incident on the collector.

Discussion—For flat-plate collectors, the value of the incident solar energy used is usually based on gross collector area; for concentrating collectors the value is usually based on the aperture area.

efficiency, instantaneous collector, *n*—ratio of the amount of energy removed by the heat transfer fluid of a solar thermal collector over a specified time period (usually 5 or 15 min) to the solar energy incident on the collector area in the same period, under steady-state or quasi-steady state.

Discussion—For flat plate collectors, the area used is usually the gross collector area; for concentrating collectors the area used is usually the gross aperture area.

efficiency, period system, *n*—ratio of the useful energy supplied by the solar thermal energy system over a period of time to the solar energy incident on the collector area of the system in the same period.

Discussion—The period considered has to be of a suitable length for the type of system. For example, it would not be useful to define the efficiency of a solar space heating system over a month in the summer. For flat-plate collector systems, the value of incident solar energy used is usually based on the gross collector area; for concentrating collector systems, the value is usually based on the aperture area.

evacuated tube collector—see **collector, evacuated tube**.

flammable liquid, *n*—a liquid having a flash point below 38°C. **D4865**

flash point, *n*—lowest temperature corrected to a pressure of 101.3 kPa, at which application of a test flame causes the vapors of a test specimen of the sample to ignite momentarily under the specified conditions of the test. **D7236**

forced convection—see **convection, forced**.

free convection—see **convection, natural**.

gross collector area—see **area, gross collector**.

heat-actuated cooling, *n*—the use of thermal energy to initiate a thermodynamic cycle which results in a local decrease in temperature.

heat capacity, *n*—see **thermal capacity**.

heat loss rate, *n*—the rate at which heat is lost from a system or component of a system, per degree temperature difference between its average temperature and the average ambient air temperature.

heat transfer fluid, *n—in solar energy systems*, a liquid or gas that passes through the solar collector and carries the absorbed thermal energy away from the collector, or any fluid that is used to transfer thermal energy between subsystems in solar energy systems.

instantaneous collector efficiency—see **efficiency, instantaneous collector**.

natural convection—see **convection, natural**.

nonoperational mode, *n*—the condition that exists when a solar thermal collector has been filled, purged of heat transfer fluid (if a liquid), and capped (but not sealed) to prevent contamination by foreign substances prior to exposure.

nonselective surface, *n*—a surface for which the spectral optical properties reflectance, absorptance, transmittance, and emittance are essentially independent of wavelength over a particular wavelength range.

Discussion—For solar absorbers, the absorption of solar energy is largely confined to the wavelength range from 0.3 to 3.0 µm, but there is significant flux emitted at wavelengths out to about 30 µm.

period system efficiency—see **efficiency, period system**.

potable water, *n*—water that is satisfactory for drinking and culinary purposes, meeting the requirements of the health department having jurisdiction.

preheating, solar, *n*—the use of solar energy to partially heat a substance, such as domestic potable water, prior to heating it to a higher desired temperature with auxiliary fuel.

pressure relief device, *n*—a pressure-activated valve designed to automatically relieve excessive pressure.

quasi-steady state, *n—of a solar thermal collector*, state of the solar collector test when the flow rate and temperature of the fluid entering the collector are constant. The exit fluid temperature changes are small and due only to the normal change in irradiance that occurs with time for clear sky conditions.

selective surface, *n*—a surface for which the spectral optical properties reflectance, absorptance, emittance, or transmittance vary significantly with wavelength, which enhances the collection (or rejection) of radiant energy in a restricted portion of the spectrum.

Discussion—An example of a selective surface would be a collector cover glazing that has a high transmittance over the solar spectrum (300 to 2500 nm) and high reflectance over the spectral region of principal thermal infrared emission from the absorber.

solar cooling systems, *n*—the complete assembly of subsystems and components necessary to convert solar energy into other forms of energy for space cooling purposes.

solar energy system, active, *n*—a solar thermal energy system that uses mechanical equipment (pumps, fans) that is not an integral part of a structure to collect and transfer thermal energy, either to the point of use or to be stored for later use.

solar energy system, drainback, *n*—a solar thermal energy system in which the heat transfer fluid is drained out of the collector and exposed piping, and into a storage tank, a holding tank, or expansion tank in order to protect the collector and piping from damage due to freezing.

solar energy system, draindown, *n*—a solar thermal energy system in which the heat transfer fluid is drained out of the collector and exposed piping to an external drain in order to protect the collector and piping from damage due to freezing.

solar energy system, hybrid, *n*—any solar energy system that combines the characteristics of two separate systems. Particularly, a solar energy system supplemented by a conventional energy system may be termed a hybrid system.

solar energy system, open, *n*—a solar energy system that has its storage tank exposed (open) to atmospheric pressure.

solar energy system, passive, *n*—a solar thermal energy system that uses natural convection, conduction, or radiation to distribute thermal energy through a structure, or a portion of that structure within the limits of the indoor design temperature conditions. It can include movable components such as dampers, insulation, or blinds, which may be moved periodically, either by manual or automatic means.

solar energy system, thermosiphon, *n*—a solar thermal energy system in which the heat transfer fluid circulates by convection as the less dense, warm fluid rises and is displaced by the denser, cooler fluid.

solar fraction, *n*—ratio of the amount of input energy contributed by the solar energy system to the total input energy required for the application.

solar heating and cooling systems, *n*—the complete assembly of subsystems and components necessary to convert solar energy into thermal energy and use this energy in combination with auxiliary energy, where required, for combined heating and cooling purposes.

solar heating system, *n*—the complete assembly of subsystems and components necessary to convert solar energy into thermal energy and use this energy in combination with auxiliary energy, where required, for heating purposes.

solar thermal collector—see **collector, solar thermal**.

solar thermal energy system, *n*—see **system, solar thermal energy**.

solar water heating system, *n*—the complete assembly of subsystems and components necessary to convert energy into thermal energy and use this energy in combination with auxiliary energy, where required, to provide hot water.

solar water heating system, direct, *n*—a solar water heating system in which the potable water passes directly from the water supply, through the collectors and storage, to the residential hot water supply.

solar water heating system, indirect, *n*—a solar water heating system in which a closed circulation loop isolates one fluid from contact with others in the system. This closed loop may contain a nonpotable fluid.

stagnation conditions, *n—in solar energy systems*, the conditions (that is, temperature and pressure) existing when energy system has attained a quasi-steady state after the flow of heat-transfer fluid has stopped, but the absorber continues to receive significant solar irradiance.

storage component, thermal, *n*—a component of a building used for storing thermal energy. Includes all identifiable elements that serve an architectural as well as thermal function.

storage device, thermal, *n*—the container(s) plus all contents of the container(s) used for storing thermal energy. The transfer fluid and accessories such as heat exchangers, flow switching devices, valves, and baffles which are integral with the thermal storage container(s) are considered a part of the storage device.

storage medium, thermal, *n*—the material in the storage device, independent of the containing structure, in which the major portion of the thermal energy is stored.

system, solar thermal energy, *n*—the complete assembly of collectors, subsystems and components necessary to convert solar energy into thermal energy for either heating or cooling purposes, or both.

thermal capacity, *n*—the amount of thermal energy that can be stored in a storage device during a period of time and for a specific set of values (that is, initial temperature of the storage device, the temperature of the entering fluid, and the mass flow rate of fluid through the storage system).

thermal capacity, theoretical, *n*—the amount of energy that can be stored in the storage device if all its components undergo an increase in temperature from the original value to a final value.

thermal storage medium—see **storage medium, thermal**.

thermosiphon solar energy system—see **solar energy system, thermosiphon**.

time constant, *n—of a solar collector*, the time required for the fluid leaving a solar collector to attain 63.2 % of the resulting change in equilibrium outlet temperature following a step change in solar irradiance or inlet fluid temperature.

DISCUSSION—The step change involved should be specified in the procedure.

trickle collector—see **collector, trickle**.

GLASS FOR SOLAR APPLICATIONS

aluminum-boron-silicate glass, *n*—a glass composed mainly of SiO_2 with Al_2O_3 as the most abundant glass modifier and B_2O_3 as the next most abundant component, where composition is described in terms of weight percent of the metal oxide.

annealed glass, *n*—glass that has undergone a controlled heating and cooling process in order to relieve permanent residual stresses and/or reduce them to commercially acceptable levels.

barium-strontium-silicate glass, *n*—a glass composed mainly of SiO_2 with BaO as the most abundant glass modifier and SrO as the next most abundant component, where composition is described in terms of weight percent of the metal oxide.

boron-sodium-silicate glass, *n*—a glass composed mainly of SiO_2 with B_2O_3 as the most abundant glass modifier and Na_2O as the next most abundant component, where composition is described in terms of weight percent of the metal oxide

float glass, *n*—flat glass that has been formed on molten metal, commonly tin. **C162**

DISCUSSION—The surface of the glass in contact with the tin bath is known as the "tin" side due to the presence of tin molecules in that surface, in contrast to the "air" side.

fully tempered glass, *n*—flat glass that has been tempered to a high surface or edge compression to meet the requirements of Specification C1048. See **heat-strengthened glass**. **C162**

heat-strengthened glass, *n*—flat glass that has been tempered to a moderate surface or edge compression to meet the requirements of Specification C1048. (See **fully tempered glass**.) **C162**

low-iron glass, *n*—a glass composition that exhibits a higher degree of clarity and transmittance than conventional soda lime float glass. May also be classified as "mid-iron" or "ultra-low iron," depending on the percentage of Fe_2O_3 present.

pattern glass—see **patterned glass**.

patterned glass, *n*—glass that has been processed by passing it in a semi-molten state between two metal rollers to impart a pattern or design on the glass. Also called rolled glass or pattern glass.

rolled glass—see **patterned glass**.

roll-wave, *n—of a glass sheet*, the repetitive, wave-like departure from flatness that is characteristic in flat glass that has been heat-treated or processed in a horizontal roller hearth furnace. The waves occur across the glass at spaced intervals and are perpendicular to the direction of flow through the furnace.

Discussion—**Roll-wave** is not related to **warp**. The nature and extent of **roll-wave** deformation is determined by a number of factors, including roller condition, roller spacing, glass thickness, glass temperature, conveyor speed, and loading practices. **Warp** is caused by process-related issues, such as an imbalance in residual stresses resulting from non-uniform cooling or mechanical deformations due to excessively high oven temperatures.

roughness, *n—of a glass sheet*, the three-dimensional variations in surface topography characterized by wavelengths in the plane of the surface that are small compared to the sheet's X, Y and Z dimensions. Roughness may be considered as superimposed on a wavy surface.

sodium-calcium-silicate glass, *n*—a glass composed mainly of SiO_2 with Na_2O as the most abundant glass modifier and CaO as the next most abundant component, where composition is described in terms of weight percent of the metal oxide. This glass has traditionally been called soda-lime-silicate glass.

surface stress, *n—in glass*, a residual stress, typically compressive in nature, that is present in the parallel surfaces and edges of glass. In heat-treated glass, prescribed values of surface or edge compression may be used to characterize mechanical strength and impact resistance of the glass.

surface texture, *n—of a glass sheet*, the deviations from a reference plane which form the three dimensional topography of the surface. Surface texture includes **roughness, waviness**, and flaws.

tempered glass, *n*—a general term for glass that has been subjected to a thermal treatment characterized by rapid cooling to produce a compressively stressed surface layer. See **fully tempered glass** and **heat-strengthened glass**. **C162**

thickness, *n—of a glass sheet*, the perpendicular distance between one surface and the opposite surface.

total thickness variation, *TTV*, *n—of a glass sheet*, the difference between the maximum and minimum values of the thickness of the glass sheet.

warp, *n—of a glass sheet*, the out-of-plane deviation relative to a flat reference plane in a nominally flat glass sheet, which can extend over the entire sheet (overall bow), only at the edges (edge curl), or elsewhere on the surface (localized warp).

Discussion—Warp is to be differentiated from **roll-wave** (see **roll-wave** discussion).

waviness, *n—of a glass sheet*, the surface topographic variations characterized by wavelengths in the plane of the surface that are large compared to the roughness but smaller than the sheet's X, Y and Z dimensions.

5. Keywords

5.1 conversion; definitions; energy; glass; instrumentation; measurement; optics; photovoltaics; radiation; radiometry; solar; terminology; thermal