1. PURPOSE

This standard specifies test procedures for evaluating the technical capabilities and ranges of applicability of computer programs that calculate the thermal performance of buildings and their HVAC systems.

2. SCOPE

These standard test procedures apply to building energy computer programs that calculate the thermal performance of a building and its mechanical systems. While these standard test procedures cannot test all algorithms within a building energy computer program, they can be used to indicate major flaws or limitations in capabilities.

3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

3.1 Terms Defined for this Standard

***adiabatic*:** without loss or gain of heat (e.g., an adiabatic boundary does not allow heat to flow through it).

adjusted net sensible capacity: the gross sensible capacity less the actual fan power. (Also see *gross sensible capacity.*)

adjusted net total capacity: the gross total capacity less the actual fan power. (Also see *gross total capacity.*)

altitude: vertical elevation above sea level.

analytical solution: a mathematical solution of a model of reality that has an exact result for a given set of parameters and simplifying assumptions.

***analytical verification*:** where outputs from a program, subroutine, algorithm, or software object are compared to results from a known analytical solution or to results from a set of closely agreeing quasi-analytical solutions or verified numerical models. (Also see *analytical solution*, *quasi-analytical solution*, and *verified numerical model*.)

annual heating load: the heating load for the entire one-year simulation period; e.g., for hourly simulation programs this is the sum of the hourly heating loads for the one-year simulation period.

annual hourly integrated maximum zone air temperature: the hourly zone temperature that represents the maximum for the one-year simulation period.

annual hourly integrated minimum zone air temperature: the hourly zone temperature that represents the minimum for the one-year simulation period.

***annual hourly integrated peak floor conduction*:** the hourly floor conduction that represents the maximum for the final year of the simulation period, used for tests of Section 5.2.4.

annual hourly integrated peak heating load: the hourly heating load that represents the maximum for the one-year simulation period.

annual hourly integrated peak sensible cooling load: the hourly sensible cooling load that represents the maximum for the one-year simulation period.

***annual hourly integrated peak zone load*:** the hourly zone load that represents the maximum for the final year of the simulation period, used for tests of Section 5.2.4.

annual hourly 1°C zone air temperature bin frequency: the number of hours that the zone air temperature has values within a given bin (1°C bin width) for the one-year simulation period.

annual incident unshaded total solar radiation (diffuse and direct): the sum of direct solar radiation and diffuse solar radiation that strikes a given surface for the entire one-year simulation period when no shading is present. ***Informative Note:*** For example, for hourly simulation programs this is the sum of the hourly total incident solar radiation for the one-year simulation period.

annual mean zone air temperature: the average zone air temperature for the one-year simulation period. ***Informative Note:*** For example, for hourly simulation programs this is the average of the hourly zone air temperatures for the one-year simulation period.

annual sensible cooling load: the sensible cooling load for the entire one-year simulation period. ***Informative Note:*** For example, for hourly simulation programs this is the sum of the hourly sensible cooling loads for the one-year simulation period.

annual transmitted solar radiation (diffuse and direct): the sum of direct solar radiation and diffuse solar radiation that passes through a given window for the entire one-year simulation period. This quantity does not include radiation that is absorbed in the glass and conducted inward as heat. ***Informative Note:*** This quantity may be taken as the optically transmitted solar radiation through a window that is backed by a perfectly absorbing black cavity.

apparatus dew point (ADP): the effective coil surface temperature when there is dehumidification. On the psychrometric chart, this is the intersection of the condition line and the saturation curve, where the condition line is the line going through entering air conditions with slope defined by the sensible heat ratio ([gross sensible capacity]/[gross total capacity]). (Also see *gross sensible capacity* and *gross total capacity.*) ***Informative Note:*** The ADP is the temperature to which all the supply air would be cooled if 100% of the supply air contacted the coil.

aspect ratio (AR): the ratio of the floor slab length to the floor slab width.

building thermal envelope and fabric: elements of a building that enclose spaces and that control or regulate heat and mass transfer between the interior spaces and the building exterior, the internal thermal capacitance, and heat and mass transfer between internal zones.

bypass factor (BF): the percentage of the distribution air that does not come into contact with the cooling coil; the remaining air is assumed to exit the coil at the average coil temperature (apparatus dew point). (See also *apparatus dew point*.)

cavity albedo: see *solar lost through window.*

coefficient of performance (COP): for a cooling (refrigeration) system, the ratio, using the same units in the numerator as in the denominator, of the net refrigeration effect to the corresponding energy input. For the purpose of calculating COP, corresponding energy input is the related cooling energy consumption, except for Cases CE300 through CE440 (see Sections 5.3.3, 5.3.4.1, and 5.3.4.2) where the indoor air distribution fan energy is included only during times when heat is being extracted by the evaporator coil. (Also see *net refrigeration effect* and *cooling energy consumption*.)

combined radiative and convective surface coefficient: a constant of proportionality relating the rate of combined convective and radiative heat transfer at a surface to the temperature difference across the air film on that surface.

combined surface coefficient: see *combined radiative and convective surface coefficient*.

conductance: thermal conductance.

***convective surface coefficient*:** a constant of proportionality relating the rate of convective heat transfer at a surface to the temperature difference across the air film on that surface.

***convergence tolerance*:** for an iterative solution process, the maximum acceptable magnitude of a selected error estimate; when the error criterion is satisfied, the process is deemed to have converged on a sufficiently accurate approximate solution.

cooling energy consumption: the site electric energy consumption of the mechanical cooling equipment, including the compressor, air distribution fan (regardless of whether the compressor is ON or OFF), condenser fan, and related auxiliaries.

COP2: the ratio, using the same units, of the gross total evaporator coil load to the sum of the compressor and outdoor condenser fan energy consumptions. (Also see *gross total evaporator coil load*.)

COP_{SEER}: the seasonal energy efficiency ratio (dimensionless).

COP degradation factor (CDF): a multiplier (≤1) applied to the full-load system COP or COP2. CDF is a function of part-load ratio. (Also see *part-load ratio*.)

deep ground temperature: the ground temperature at or below a soil depth of 2 m (6.56 ft), except for Section 5.2.4 ground coupling tests where the ground boundary depth varies as specified in the test cases.

degradation coefficient: a measure of efficiency loss due to cycling of equipment.

***detailed ground heat transfer model*:** employs transient three-dimensional (3D) numerical-methods (finite-element or finite-difference) heat transfer modeling throughout the modeled domain.

dew-point temperature: the temperature of saturated air at a given humidity ratio and pressure. As moist air is cooled at constant pressure, the dew point is the temperature at which condensation begins. (Also see *humidity ratio*.)

diffuse solar radiation: the solar radiation received from the sun after its direction has been changed by scattering by the atmosphere or other objects such as the ground.

direct solar radiation: the solar radiation received from the sun without having been scattered by the atmosphere or other objects such as the ground; this is also called *beam* or *direct beam radiation*.

economizer: a control system that conserves energy, usually by using outdoor air and control logic to maintain a fixed minimum of outdoor air when increased outdoor airflow rates are not called for.

energy efficiency ratio (EER): the ratio of net refrigeration effect (in Btu per hour) to cooling energy consumption (in watts) so that EER is stated in units of (Btu/h)/W. (Also see *net refrigeration effect* and *cooling energy consumption*.)

entering dry-bulb temperature (EDB): the temperature indicated by an ordinary thermometer for air entering the evaporator coil. ***Informative Note:*** For a draw-through fan configuration with no heat gains or losses in the ductwork and no outdoor air mixed with return air, EDB equals the indoor dry-bulb temperature. For a similar configuration but when outdoor air is mixed with return air, EDB equals the mixed-air dry-bulb temperature.

entering wet-bulb temperature (EWB): the temperature indicated by the wet-bulb portion of a psychrometer when exposed to air entering the evaporator coil. ***Informative Note:*** For a draw-through fan with no heat gains or losses in the ductwork and no outdoor air mixed with return air, this would also be the zone air wet-bulb temperature. For a similar configuration but when outdoor air is mixed with return air, EWB equals the mixed-air wet-bulb temperature. For mixtures of water vapor and dry air at atmospheric temperatures and pressures, the wet-bulb temperature is approximately equal to the adiabatic saturation temperature (temperature of the air after undergoing a theoretical adiabatic saturation process). The wet-bulb temperature given in psychrometric charts is really the adiabatic saturation temperature.

evaporator coil loads: the actual sensible heat and latent heat removed from the distribution air by the evaporator coil. ***Informative Note:*** These loads include indoor air distribution fan heat for times when the compressor is operating, and they are limited by the system capacity (where system capacity is a function of operating conditions). Sensible evaporator coil load applies only to sensible heat removal. Latent evaporator coil load applies only to latent heat removal. (Also see *sensible hea*t and *latent heat*.)

exterior film: as used in Section 7, see *combined radiative and convective surface coefficient*.

extinction coefficient: the proportionality constant K in Bouguer's Law ($[dI] = [I\ K\ dx]$) where I is the local intensity of solar radiation within a medium and x is the distance the radiation travels through the medium.

film coefficient: see *combined radiative and convective surface coefficient*.

free float: a condition where mechanical heating and cooling equipment is OFF so that the space or zone temperature varies without constraint.

gross sensible capacity: the rate of sensible heat removal by the cooling coil for a given set of operating conditions. (Also

see *sensible heat*.) ***Informative Note:*** This value varies as a function of performance parameters such as EWB, ODB, EDB, and airflow rate.

gross total capacity: the total rate of both sensible heat and latent heat removal by the cooling coil for a given set of operating conditions. (Also see *sensible heat* and *latent heat*.) ***Informative Note:*** This value varies as a function of performance parameters such as EWB, ODB, EDB, and airflow rate.

gross total coil load (or gross total evaporator coil load): the sum of the sensible heat and latent heat removed from the distribution air by the evaporator coil.

heat input ratio (HIR): a ratio that is the inverse of the efficiency.

hemispherical infrared emittance: the average directional infrared emittance over a hemispherical envelope over the surface. Also see *infrared emittance*.

hourly free-floating zone air temperature: zone air temperature for a given hour during which heating and cooling equipment is OFF or for an unconditioned zone.

hourly heating load: the heating load for a given hour.

hourly incident unshaded solar radiation (direct and diffuse): the sum of direct solar radiation and diffuse solar radiation that strikes a given surface for a given hour.

hourly sensible cooling load: the sensible cooling load for a given hour.

humidity ratio: the ratio of the mass of water vapor to the mass of dry air in a moist air sample.

incidence angle: the angle defined by the intersection of a line normal to a surface and a ray that strikes that surface.

index of refraction: relates the angle of refraction (x_2) to the angle of incidence (x_1) at the surface interface of two media according to Snell's law ($n_1 \sin[x_1] = n_2 \sin[x_2]$), where n_1 and n_2 are indices of refraction for each medium.

indoor dry-bulb temperature (IDB): the temperature indicated by an ordinary thermometer when exposed to indoor air.

infiltration: the leakage of air through any building element (e.g., walls, windows, and doors).

infrared emittance: the ratio of the infrared spectrum radiant flux emitted by a body to that emitted by a blackbody at the same temperature and under the same conditions.

interior film: as used in Section 7, see *combined radiative and convective surface coefficient*.

interior solar distribution: the fraction of transmitted solar radiation incident on specific surfaces in a room. Also see *solar distribution fraction*.

internal gains: the heat gains generated inside the space or zone.

latent heat: the change in enthalpy associated with a change in humidity ratio, caused by the addition or removal of moisture. (Also see *humidity ratio*.)

mathematical truth standard: the standard of accuracy for predicting system behavior based on an analytical solution.

midlevel detailed ground heat transfer model: based on a transient two-dimensional (2D) or three-dimensional (3D) numerical-methods heat transfer model, applying some simplification(s) for adaptation to a whole-building energy simulation program; such models include correlation methods based on extensive 2D or 3D numerical analysis.

net refrigeration effect: the rate of heat removal (sensible + latent) by the evaporator coil, as regulated by the thermostat (not necessarily the full load capacity), after deducting internal and external heat transfers to air passing over the evaporator coil. ***Informative Note:*** For the tests of Section 5.3, the net refrigeration effect is the evaporator coil load less the actual air distribution fan heat for the time when the compressor is operating; at full load, this is also the adjusted net total capacity. (Also see *adjusted net total capacity*, *evaporator coil load*, *sensible heat*, and *latent heat*.)

net sensible capacity: the gross sensible capacity less the default rate of fan heat assumed by the manufacturer; this rate of fan heat is not necessarily the same as for the actual installed fan (see *adjusted net sensible capacity*). (Also see *gross sensible capacity.*)

net total capacity: the gross total capacity less the default rate of fan heat assumed by the manufacturer; this rate of fan heat is not necessarily the same as for the actual installed fan (see *adjusted net total capacity*). (Also see *gross total capacity.*)

nonproportional-type thermostat: a thermostat that provides two position (ON/OFF) control.

outdoor dry-bulb temperature (ODB): the temperature indicated by an ordinary thermometer when exposed to outdoor air. ***Informative Note:*** This is the temperature of air entering the condenser coil.

part-load factor (PLF): the ratio of the efficiency at part load to the steady-state efficiency. ***Informative Note:*** PLF represents the degradation in efficiency due to part-load operation.

part-load ratio for cooling (PLR): the ratio of the net refrigeration effect to the adjusted net total capacity for the cooling coil. (Also see *net refrigeration effect* and *adjusted net total capacity.*) ***Informative Note:*** As shown in Informative Annex B13, for the purpose of calculating the COP degradation factor (CDF), defining PLR as the ratio of gross total evaporator coil load to the gross total capacity produces an equivalent CDF. (Also see *COP degradation factor*, *gross total evaporator coil load*, and *gross total capacity.*)

part-load ratio for furnace (PLR_f): the ratio of the net heating effect to the adjusted net total capacity for the furnace.

quasi-analytical solution: the mathematical solution of a model for a given set of parameters and simplifying assumptions, which is allowed to include minor interpretation differences that cause minor results variations. ***Informative Note:*** Such a solution may be computed by generally accepted numerical methods or other means, provided that such calculations occur outside the environment of a whole-building energy simulation program and can be scrutinized.

raised floor exposed to air: a floor system where the air temperature below the floor is assumed to equal the outside air

temperature, the underside of the conditioned-zone floor has an exterior film coefficient consistent with a "rough" surface texture and zero wind speed, and the conditioned-zone floor exterior surface (surface facing the raised floor) receives no solar radiation. Also see Section 7.2.1.5.

relative humidity: the ratio of the mole fraction of water vapor in a given moist air sample to the mole fraction in an air sample that is saturated and at the same temperature and pressure. This is equivalent to the ratio of partial pressure of the water vapor in a sample to the saturation pressure at the same temperature.

seasonal energy efficiency ratio (SEER): the ratio of net refrigeration effect in Btu to the cooling energy consumption in watt-hours for a refrigerating device over its normal annual usage period. (Also see *net refrigeration effect* and *cooling energy consumption*.) ***Informative Note:*** This parameter is commonly used for simplified estimates of energy consumption based on a given load and is not generally useful for detailed simulations of mechanical systems. SEER is determined using ANSI/AHRI Standard 210/240-89.[B-1]

***secondary mathematical truth standard*:** the standard of accuracy for predicting system behavior based on the range of disagreement of a set of closely agreeing verified numerical models or other quasi-analytical solutions, to which other simulations are allowed to be compared. (Also see *verified numerical model* and *quasi-analytical solution*.)

sensible heat: the change in enthalpy associated with a change in dry-bulb temperature caused by the addition or removal of heat.

sensible heat ratio (SHR): the ratio of sensible heat transfer to total (sensible + latent) heat transfer for a process; also known as sensible heat factor (SHF). (Also see *sensible heat* and *latent heat*.)

shortwave: refers to the solar spectrum. ***Informative Note:*** For example, in this standard the terms *solar absorptance* and *shortwave absorptance* are used interchangeably.

simplified ground heat transfer model: a model based on a one-dimensional (1D) dynamic or steady-state heat transfer model; implementation of such a model usually requires no modification to a whole-building energy simulation program.

solar absorptance: the ratio of the solar spectrum radiant flux absorbed by a body to that incident on it.

solar distribution fraction: the fraction of total solar radiation transmitted through the window(s) that is absorbed by a given surface or retransmitted (lost) back out the window(s).

solar fraction: see *solar distribution fraction*.

solar heat gain coefficient (SHGC): a dimensionless ratio of solar heat gains to incident solar radiation, including transmittance plus inward flowing fraction of absorbed solar radiation. ***Informative Note:*** For windows, SHGC is dependent on incidence angle.

solar lost: see *solar lost through window.*

solar lost through window: the fraction of total solar radiation transmitted through the window(s) that is reflected by opaque surfaces and retransmitted back out the window(s).

standard temperature and pressure (STP) conditions: 0°C and 1 atm.

surface coefficient: see c*ombined radiative and convective surface coefficient*.

verified numerical model*:** a numerical model with solution accuracy verified by close agreement with an analytical solution and/or other quasi-analytical solution or numerical solutions, according to a process that demonstrates solution convergence in the space and time domains. (Also see *analytical solution* and *quasi-analytical solution*.) ***Informative Note: Such numerical models may be verified by applying an initial comparison with an analytical solution(s), followed by comparisons with other numerical models for incrementally more realistic cases where analytical solutions are not available.

zone air temperature: the temperature of just the zone air, not including infrared radiation from the interior surfaces. ***Informative Note:*** Such a temperature would be measured by a sensor housed in a well-aspirated containment shielded by a material with a solar and infrared reflectance of one; well-mixed air is assumed.

zone cooling loads: the sensible heat and latent heat loads associated with heat and moisture exchange between the building envelope and its surroundings as well as internal heat and moisture gains within the building. These loads do not include internal gains associated with operating the mechanical system. ***Informative Note:*** For example, these loads do not include air distribution fan heat.

3.2 Abbreviations and Acronyms Used in this Standard

α_{ext}	exterior solar absorptance
A	area
Abs.	absorptance
Abs. In	absorptance of inner pane
Abs. Out	absorptance of outer pane
ach	air changes per hour
ADP	apparatus dew point
AHRI	Air-Conditioning, Heating and Refrigeration Institute
ANSI	American National Standards Institute
Apr.	April
AR	aspect ratio
ARI	Air-Conditioning and Refrigeration Institute (now AHRI)
B	floor slab length in north/south direction, m (ft)
Base	base case
BESTEST	Building Energy Simulation Test and Diagnostic Method
BF	bypass factor
BHP	brake horsepower
Cd	degradation coefficient
CDF	coefficient of performance degradation factor
cfm	cubic feet per minute
COG	center of glass