ADDENDA

ASHRAE

ANSI/ASHRAE Addendum a to
ANSI/ASHRAE Standard 140-2017

Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs

Approved by ASHRAE and the American National Standards Institute on September 1, 2020.

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- ***[Note: READ THIS.Edits to existing sections apply tracked changes (underline/strikethrough text) to indicate proposed changes to Standard 140-2017.***
  - ***Double underline/strikethrough indicates moved text (appears only pp. 50, 65).***
- ***Where material is all new, a "Note" is provided to indicate that, and that material is shown with no marked edits.]***

BSR/ASHRAE Addendum *a* to ANSI/ASHRAE Standard 140-2017, *Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs*

[Note: This addendum indicates proposed updates to the building thermal fabric model test cases of Sections 5.2.1, 5.2.2, 5.2.3, and related sections of Standard 140. The following informative Foreword is new material for the addendum; underline text not applied.]

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

Foreword to Addendum *a*

Purpose of the Addendum

The purpose of this addendum is to update the test cases of Sections 5.2.1, 5.2.2, and 5.2.3 of Standard 140, for testing the ability of whole-building energy simulation programs to model the building thermal fabric. These are software-to-software comparative tests, where simulation results are compared to each other. The tested modeling physics includes conduction, convection, and radiative (solar and infrared) heat transfer associated with various building surfaces (and their related thermal mass), windows, outside-air infiltration/ventilation, internal heat gains, external shading devices, a sunspace, and variations in thermostat control (deadband and setback). The updated test cases are from *Update of ASHRAE Standard 140 Section 5.2 and Related Sections (BESTEST Building Thermal Fabric Test Cases)*, [A-15] by Argonne National Laboratory (Argonne) and National Renewable Energy Laboratory (NREL) in collaboration with the ASHRAE Standing Standard Project Committee 140 (SSPC 140) and other international software developers and simulation-trial participants. Related project funding for Argonne and NREL was provided by the U.S. Department of Energy.

The test cases of Section 5.2.4 (Ground-Coupled Slab-on-Grade Analytical Verification Tests) are not affected by this addendum and remain as is.

Background

The Building Energy Simulation Test and Diagnostic Method (BESTEST) procedure for testing the ability of whole building energy simulation software to model the building thermal fabric was originally published in 1995[B-29]. This test suite was adapted for the initial version of ASHRAE Standard 140, *Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs* as ANSI/ASHRAE Standard 140-2001 and has remained in all revisions of the standard through the current version (ANSI/ASHRAE Standard 140-2017). The state of the art in building energy simulation modeling has advanced since 1995. Additionally, comments on the test specification over the years identified ambiguities, further necessitating the update to the original work.

The update work built on the initial version of the building thermal fabric BESTEST suite as published in ASHRAE Standard 140-2001 through 140-2017. From this starting point, there was substantial effort to improve and field-test an updated test specification intended for continuing use by most state-of-the-art whole building energy modeling software and suitable for Standard 140. The specification improvements addressed ambiguities discovered since the original field-trials before 1995 and included additional test cases and diagnostic outputs. J. Neymark & Associates, under contracts with Argonne and NREL, led the collaborative effort to a) extensively revise and update the test specifications such that they would be unambiguous for the input structures of most whole-building energy simulation programs with time steps of one hour or less, and b) field-test the specifications with a variety of different simulation programs and associated software development groups around the world to ensure their suitability as a standard method of test that can be integrated into ASHRAE Standard 140. The collaboration included a number of software developer members of SSPC 140 along with other international software developers and participants; see Informative Annex B11, Table B11-1.

The resulting updated building thermal fabric modeling test suite includes a set of 52 diagnostic test cases. The test cases are summarized in Section 5.2.1, Table 5-1 with parametric variations summarized in Tables B1-2 and B1-3 of Informative Annex B1. These include a number of substantive revisions to the original test suite along with development of new test cases. A major enhancement to the initial test specification was to improve equivalent inputs for surface heat transfer. Another substantial improvement was replacing the Denver, Colorado TMY data set applied for the original test cases with Denver TMY3 weather data for the new test cases. There were also a number of other specification revisions, including to window construction properties, super-insulated floor details, site altitude and terrain details, infiltration airflow rate adjustment for site altitude, internal mass, simulation initialization and pre-conditioning requirements, thermostat control, etc. Development of new test cases includes basic cases for low-emissivity windows, single-pane windows, and increased insulation, along with in-depth cases applying constant surface heat-transfer coefficients. Details are discussed in Part III, Section 3 of the originating test-suite-update final report[A-15]; also see the informative file ChangesSummary-140-2017-A.PDF included with the accompanying electronic media. For the convenience to users of previous versions of Standard 140 (editions 140-2017, 2014, 2011, 2007, 2004, and 2001), all revisions to Standard 140-2017 for this addendum are provided in the informative accompanying file “140-2017-A-Informative-EditTracked.pdf”, indicated by edit tracking.

The addendum also includes updated informative example simulation results, which replace the example results of Standard 140-2017. The new results were vetted in simulation trials documented in the originating test-suite-update final report[A-15] and are indicated in Informative Annex B8.

Summary of changes in this addendum:

The file ChangesSummary-140-2017-A.PDF (see the accompanying electronic media) gives a detailed listing of the substantive changes to Sections 5.2.1, 5.2.2, and 5.2.3, and related sections, annexes, and accompanying electronic media. An abbreviated listing of those changes follows (listed Sections are normative unless otherwise indicated):

- Update Section 5.2 “Input Specification for Building Thermal Envelope and Fabric Load Tests.” This is the major substantive portion of the addendum affecting Sections 5.2.1, 5.2.2, and 5.2.3. The test cases of Section 5.2.4 (Ground-Coupled Slab-on-Grade Analytical Verification Tests) are not affected by this addendum and remain as is. Changes to Sections 5.2.1, 5.2.2, and 5.2.3 include:
    - Substantive revisions to existing test cases as described in “Background” above
    - Development of additional test cases as described in “Background” above
- Update Section 6, “Class I Output Requirements,” includes output requirements related to Section 5.2 update
- Update Section 3.2 “Abbreviations and Acronyms” for language of the Section 5.2 update
- Update Informative Section 4.3, “Organization of Test Cases” (overall Standard 140 roadmap), for consistency with extension of the Section 5.2 test cases
- Update Section 5.1, “Modeling Approach,” to include requirements related to the Section 5.2 update

- Update Annex A1, “Weather Data,” to include weather data used for the Section 5.2 update
- Update Annex A2, “Standard Output Reports,” includes updates to the results template Sec5-2Aout.XLSX and to the modeler report template S140outNotes.TXT
- Update the following informative annexes to include new information relevant for the update of Section 5.2:
    - B1 Tabular Summary of Test Cases
    - B2 About Typical Meteorological Year (TMY) Weather Data [no longer referenced by Section 5.2]
    - B3 Infiltration and Fan Adjustments for Altitude
    - B4 Alternative Constant Convective-Only and Combined Radiative and Convective Surface Heat Transfer Coefficients
    - B5 Infrared Portion of Film Coefficients [no longer referenced by Section 5.2]
    - B6 Window Thermal and Optical Property Calculations
    - B7 Detailed Calculation of Alternative Constant Interior Solar Distribution Fractions
    - B8 Example Results for Building Thermal Envelope and Fabric Load and Ground-Coupled Slab-On-Grade Tests of Section 5.2
    - B9 Diagnosing the Results Using the Flow Diagrams
    - B10 Instructions for Working with Results Spreadsheets Provided with the Standard
    - B11 Production of Example Results for Building Thermal Envelope and Fabric Load and Ground-Coupled Slab-On-Grade Tests of Section 5.2
    - B12 Temperature Bin Conversion Program [annex deleted]
    - B24 Informative References
- Update accompanying electronic files as called out in this addendum (see Readme 140-2017-A.DOCX with the accompanying electronic media).

[Note: Contents included here for convenience. Changes in text are indicated with underline/strikethrough. Page numbers are shown for material included in this addendum.]

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Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs

SECTION **PAGE**

[Note: Revisions proposed for this addendum begin with Section 3.2.]

[Note: Section 3.2 is revised to include new items and revisions to existing items. Selected abbreviations and acronyms included here that have not been edited appear elsewhere in this addendum material and are provided for convenience.]

3.2 Abbreviations and Acronyms

α	solar absorptance
ε	infrared emittance
20,20 Tstat	a single-temperature thermostat control strategy (heat ON below 20°C, cooling ON above 20°C)
20,27 Tstat	a deadband thermostat control strategy (heat ON below 20°C, cooling ON above 27°C)
Abs.	absorptance
ach	air changes per hour
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BESTEST	Building Energy Simulation Test and Diagnostic Method
Coef.	coefficient
cp	specific heat, J/(kg·K) (Btu/[lb·°F])
DOE	United States Department of Energy
E,W,N,S	east, west, north, south
Ext.	exterior
FF	free-floating thermostat control strategy (no heating or cooling)
h	convective surface coefficient, W/(m^2·K) (Btu/[h·ft^2·°F])
h,comb,ext	exterior combined convective and radiative surface heat transfer coefficient, W/(m^2·K)
h,comb,int	interior combined convective and radiative surface heat transfer coefficient, W/(m^2·K)
h,conv,ext	exterior convective surface heat transfer coefficient, W/(m^2·K)
h,conv,int	interior convective surface heat transfer coefficient, W/(m^2·K)
hi	window interior combined convective and radiative surface heat transfer coefficient, W/(m^2·K)
ho	window exterior combined convective and radiative surface heat transfer coefficient, W/(m^2·K)
hs	effective window airgap conductance, including radiative and convective heat transfer, W/(m^2·K)
HC Wall El.	high-conductance wall element
High-mass	heavy mass
HVAC	heating, ventilating, and air conditioning
Int	interior
k	thermal conductivity, W/(m·K) (Btu/[h·ft·°F])
Keff	total effective conductivity of all components of a glazing system except for the exterior and interior surface combined (convective and radiative) heat transfer coefficients (W/(m·K)).
Low-E	low emissivity
Low mass	light mass
NREL	National Renewable Energy Laboratory
NSRDB	National Solar Radiation Database
Ohang	overhang shading device
R	unit thermal resistance, m^2·K/W (h·ft^2·°F/Btu)
Refl.	reflectance
Refl.,b	overall solar reflectance for radiation incident from the front of a window (i.e., from outside the zone)
Refl.,f	overall solar reflectance for radiation incident from the back of a window (i.e., from inside the zone)
SC	shading coefficient
SHGC	solar heat gain coefficient
SI	Système Internationale
SSPC 140	ASHRAE Standing Standard Project Committee responsible for ANSI/ASHRAE Standard 140, *Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs*
Surf.	surface
TMY	Typical Meteorological Year
TMY2	Typical Meteorological Year, version 2
TMY3	Typical Meteorological Year, version 3
Trans.	solar transmittance
Tsky	sky temperature
U	unit thermal conductance or overall heat transfer coefficient, W/(m^2·K) (Btu/[h·ft^2·°F])
UA	thermal conductance, W/K

WYEC2 Weather Year for Energy Calculations 2

4. METHODS OF TESTING

Informative Note: Sections 4.2, 4.3, and 4.4 and their subsections are informative material.

[Note: Sections 4.1 and 4.2 are not shown here; that material is unchanged.]

***[Note: Introductory portion of Section 4.3 is shown for context of edits to 4.3.1. All of Section 4.3 is informative material.*]**

4.3 Organization of Test Cases. The specifications for determining test case configurations and input values are provided on a case-by-case basis in Section 5 and Section 7. The test cases are divided into two separate test classes to satisfy various levels of software modeling detail. Such classification allows more convenient citation of specific sections of Standard 140 by other codes and standards and by certifying and accrediting agencies, as appropriate. The Class I test cases (Section 5) are detailed diagnostic tests intended for simulation software capable of hourly or subhourly simulation time steps. The Class II test cases (Section 7) may be used for all types of building load calculation methods, regardless of time-step granularity. The Class I (Section 5) test cases are designed for more detailed diagnosis of simulation models than the Class II (Section 7) test cases.

Weather information required for use with the test cases is provided as described in Normative Annex A1. Informative Annex B1 provides an overview for all the test cases and contains information on those building parameters that change from case to case; Annex B1 is recommended for preliminary review of the tests, but do not use it for defining the cases. Additional information regarding the meaning of the cases is shown in Informative Annex B9 on diagnostic logic. In some instances (e.g., Case 620, Section 5.2.2.1.2), a case developed from modifications to a given base case (e.g., Case 600 in Section 5.2.1) will also serve as the base case for other cases. The cases are grouped as follows:

a. Class I Test Procedures
   1. Building Thermal Envelope and Fabric Load Tests (see Section 4.3.1.1)
      - Building Thermal Envelope and Fabric Load Base Case (see Section 4.3.1.1.1)
      - Building Thermal Envelope and Fabric Load Basic Tests (see Section 4.3.1.1.2)
         - Low mass (see Section 4.3.1.1.2.1)
         - High mass (see Section 4.3.1.1.2.2)
         - Free float (see Section 4.3.1.1.2.3)
      - Building Thermal Envelope and Fabric Load In-Depth Tests (see Section 4.3.1.1.3)
      - Ground-Coupled Slab-on-Grade Analytical Verification Tests (see Section 4.3.1.1.4)

[Note: The remainder of introductory Section 4.3(a) and all of introductory 4.3(b) are not shown; that material is unchanged.]

4.3.1 Class I Test Procedures

4.3.1.1 Building Thermal Envelope and Fabric Load Tests

4.3.1.1.1 Building Thermal Envelope and Fabric Load Base Case. The base-building plan is a low-mass, rectangular single zone with no interior partitions. It is presented in detail in Section 5.2.1. Supplementary to the material of Informative Annex B1, Informative Table 5-1 (see Section 5.2.1) provides a summary listing of the test cases of Sections 5.2.1, 5.2.2, and 5.2.3, including the primary tested modeling features addressed by each test case. Additional summary discussion of these cases follows here in Sections 4.3.1.1.2 and 4.3.1.1.3.

4.3.1.1.2 Building Thermal Envelope and Fabric Load Basic Tests. The basic tests analyze the ability of software to model building envelope loads in a low-mass configuration with the following variations: window orientation, shading devices, setback thermostat, and night ventilation.

4.3.1.1.2.1 The low-mass basic tests (Cases 600 through 695~~50~~) utilize lightweight walls, floor, and roof. They are presented in detail in Section 5.2.2.1.

4.3.1.1.2.2 The high-mass basic tests (Cases 900 through 995~~60~~) utilize masonry walls and concrete slab floor and include an additional configuration with a sunspace. They are presented in detail in Section 5.2.2.2.

4.3.1.1.2.3 Free-float basic tests (Cases 600FF, 650FF, 680FF, 900FF, and 950FF, and 980FF) have no heating or cooling system. They analyze the ability of software to model zone temperature in both low-mass and high-mass configurations with and without night ventilation, and with and without added insulation. The tests are presented in detail in Section 5.2.2.3.

4.3.1.1.3 Building Thermal Envelope and Fabric Load In-Depth Tests. The in-depth cases are presented in detail in Section 5.2.3.
4.3.1.1.3.1 In-depth Cases 195 through 320 analyze the ability of software to model building envelope loads for a nondeadband ON/OFF thermostat control configuration with the following variations among the cases: no windows, opaque windows, exterior infrared emittance, interior infrared emittance, infiltration, internal gains, exterior shortwave absorptance, south solar gains, interior shortwave absorptance, window orientation, shading devices, and thermostat set points. These are a detailed set of tests designed to isolate the effects of specific algorithms. However, some of the cases may be incompatible with some building energy simulation programs.

4.3.1.1.3.2 In-depth Cases 395 through 470440, 800, and 810 analyze the ability of software to model building envelope loads in a deadband thermostat control configuration with the following variations: no windows, opaque windows, infiltration, internal gains, exterior shortwave absorptance, south solar gains, interior shortwave absorptance, and thermal mass, and constant combined interior and exterior surface heat transfer coefficients. This series of in-depth tests is designed to be compatible with more building energy simulation programs. However, the diagnosis of software using this test series is not as precise as for Cases 195 through 320.

[Note: The remainder of Section 4 is not shown; that material is unchanged.]

5. CLASS I TEST PROCEDURES

[Note: Section 5 introductory language not shown; this addendum has no changes to that material.]

[Note: The following sections are revised as shown; the entire text of Sections 5.1 and 5.2 are included, except Section 5.2.4. This addendum has no changes to Section 5.2.4.

5.1 Modeling Approach. This modeling approach shall apply to all of the test cases presented in Section 5.
5.1.1 Time Convention. All references to “time” in this specification are to local standard time and assume that hour 1 = the interval from midnight to 1 A.M. Daylight savings time or holidays shall not be used for scheduling.
Informative Note: TMY weather data are in hourly bins corresponding to solar time as specified in Annex A1, Section A1.5. TMY2, TMY3, and WYEC2 data are in hourly bins corresponding to local standard time.
5.1.2 Geometry Convention. If the program being tested includes the thickness of walls in a three-dimensional (3D) definition of the building geometry, then wall, roof, and floor thicknesses shall be defined such that the interior air volume of the building model remains as specified. The thicknesses shall extend exterior to the currently defined internal volume.
Informative Notes: For example, for the building thermal envelope and fabric load test cases of Sections 5.2.1, 5.2.2, and 5.2.3, interior air volume would be calculated as 6 × 8 × 2.7 m = 129.6 m^3 (19.7 × 26.2 × 8.9 ft = 4576.8 ft^3).
5.1.3 Nonapplicable Inputs. If the specification includes input values that do not apply to the input structure of the program being tested, disregard the nonapplicable inputs and continue.
Informative Note: Selected equivalent inputs are included in the test specification for those programs that may need them.
5.1.4 Consistent Modeling Methods. Where options exist within a simulation program for modeling a specific thermal behavior, consistent modeling methods shall be used for all cases. The option that is used shall be documented in the Standard Output Report (as specified in Annex A2).
Informative Note: For example, if a program gives a choice of methods for modeling windows, the same window modeling method is to be applied for all cases.
5.1.5 Equivalent Modeling Methods. Where a program or specific model within a program does not allow direct input of specified values, or where input of specified values causes instabilities in a program’s calculations, modelers shall develop equivalent inputs that match the intent of the test specification as nearly as the software being tested allows. Such equivalent inputs shall be developed based on the data provided in the test specification, and such equivalent inputs shall have a mathematical, physical, or logical basis and shall be applied consistently throughout the test cases. The modeler shall document the equivalent modeling method in the Standard Output Report (see Normative Annex A2).

5.1.6 Use of Nonspecified Inputs. Use of nonspecified inputs shall be permitted only for the following specified sections relating to the following topics:

• Alternative constant exterior convective or combined (radiative and convective) surface coefficients in Sections 5.2.1.9.3, 5.2.3.1.4.3, 5.2.3.3.2, and 5.3.1.8

• Alternative constant Iinterior convective or combined (radiative and convective) surface coefficients in Sections 5.2.1.10.3, 5.2.3.1.4.4, 5.2.3.2.2, and 5.3.1.9

• Alternative constant Iinterior solar distribution fractions in Sections 5.2.1.12, 5.2.2.1.2.2, 5.2.2.1.6.2, 5.2.2.1.7.2, 5.2.2.2.7.4, 5.2.3.9.3, 5.2.3.10.2, and 5.2.3.12.2

• Air density given at specific altitudes for the space cooling and space heating equipment cases in Sections 5.3.1.4.3, 5.3.3.4.3, and 5.4.1.4.3.

Use of nonspecified inputs shall be permitted only if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. Use of nonspecified inputs shall be documented in the Standard Output Report specified in Normative Annex A2.

5.1.7 Simulation Initialization and Preconditioning.

5.1.7.1 For the test cases of Section 5.2.4 (ground-coupled slab-on-grade analytical verification tests), see Section 5.1.8.2 and skip Section 5.1.7.2.

5.1.7.2 For test cases other than those of Section 5.2.4, Iif the program being tested allows for preconditioning (iterative (simulation of an initial time period before recording annual simulation results beginning January 1 hour 1), until temperatures, fluxes, loads, or all of these, stabilize at initial values), that capability shall be applied.used. If the program being tested allows, and if applicable to the model, the simulation initialization process shall begin with zone air conditions that equal the outdoor air conditions.

Informative Note: For the test cases of Sections 5.2.1, 5.2.2, and 5.2.3, initialization may most affect annual peak heating load results and January monthly heating and peak heating load results.

5.1.8 Simulation Duration

5.1.8.1 Results for the tests of Sections 5.2.1, 5.2.2, 5.2.3, 5.3.3, and 5.3.4 shall be taken from full annual simulations.

5.1.8.2 For the tests of Section 5.2.4, if the program being tested allows multiyear simulations, models shall run for a number of years to satisfy the requirements of specific test cases. If the software being tested is not capable of simulation duration sufficient to satisfy the requirements of specific test cases, the simulation shall be run for the maximum duration allowed by the software being tested.

Informative Note: The duration to achieve requirements of specific test cases may vary among the test cases.

5.1.8.3 For the tests of Sections 5.3.1 and 5.3.2, the simulation shall be run for at least the first two months for which the weather data are provided. Provide output for the second month of the simulation (February) in accordance with Section 6.3.1.

Informative Note: The first month of the simulation period (January) serves as an initialization period.

5.1.8.4 For the tests of Section 5.4, the simulation shall be run for at least the first three months for which the weather data are provided. Provide output for the first three months of the year (January 1 through March 31) in accordance with Section 6.4.

5.1.8.5 For the tests of Section 5.5, the simulation shall be run until the final hour output agrees with the previous hour output. Provide output in accordance with Section 6.5.

5.1.9 Rules for Modifying Simulation Programs or Simulation Inputs. Modifications to simulation programs or simulation inputs shall have a mathematical, physical, or logical basis and shall be applied consistently across tests. Arbitrary modification of a simulation program's input or internal code solely for the purpose of more closely matching a given set of results shall be prohibited.

If changes are made to the source code of the software for the purpose of performing tests, and these changes are not available in publicly released versions of the software, then the changes shall be documented in sufficient detail, using the modeler report template provided in Normative Annex A2, so that the implications of the changes are assessable.

5.2 Input Specifications for Building Thermal Envelope and Fabric Load Tests

5.2.1 Case 600: Base Case. Begin with Case 600. Case 600 shall be modeled as specified in this section and its subsections.

Informative Note: Informative Table 5-1 provides a summary listing of the test cases of Sections 5.2.1, 5.2.2, and 5.2.3, including the primary tested modeling features addressed by each test case. Further summary description regarding parameters that vary among these test cases is provided in Annex B1, Tables B1-2 and B1-3. Full input specification details are provided beginning in Section 5.2.1.1.

Informative Note: The bulk of the work for implementing the tests is assembling an accurate base-building model. It is recommended that base-building inputs be double checked and results disagreements be diagnosed before going on to the other cases.

Informative Note: For the convenience to users of previous versions of Standard 140 (editions 140-2017, 2014, 2011, 2007, 2004, and 2001), all revisions to the test cases of Sections 5.2.1, 5.2.2, and 5.2.3 of Standard 140-2017, Addendum *a* are provided in the informative accompanying file "140-2017-A-Informative-EditTracked.pdf", indicated by edit tracking.

Informative Table 5-1 Summary of Test Cases and Tested Features for Sections 5.2.1, 5.2.2, and 5.2.3

	Low Mass Building		High Mass Building	
Primary Tested Feature	**Test**	**Section**	**Test**	**Section**
Basic Tests with Windows (South unless East/West is Indicated)				
Base Case (South clear double-pane windows and "20,27" Deadband thermostat)	600	5.2.1	900	5.2.2.2.1
South Shading (overhang)	610	5.2.2.1.1	910	5.2.2.2.2
East/West Windows	620	5.2.2.1.2	920	5.2.2.2.3
East/West Windows with Shading (overhang + fins)	630	5.2.2.1.3	930	5.2.2.2.4
Thermostat Setback	640	5.2.2.1.4	940	5.2.2.2.5
Night Ventilation	650	5.2.2.1.5	950	5.2.2.2.6
Low-Emissivity Windows	660	5.2.2.1.6		
Single-Pane Windows	670	5.2.2.1.7		
Sunspace			960	5.2.2.2.7
Increased Wall and Roof Insulation	680	5.2.2.1.8	980	5.2.2.2.8
"20,20" Thermostat (Tstat)	685	5.2.2.1.9	985	5.2.2.2.9
Increased Wall and Roof Insulation with "20,20" Tstat	695	5.2.2.1.10	995	5.2.2.2.10
Basic Tests without Mechanical Heating and Cooling (Free-Float [FF] Temperatures)				
Base Case	600FF	5.2.2.3.1	900FF	5.2.2.3.4
Night Ventilation	650FF	5.2.2.3.2	950FF	5.2.2.3.5
Increased Wall and Roof Insulation	680FF	5.2.2.3.3	980FF	5.2.2.3.6
In-Depth Tests with "20,20" Tstat, and High-Conductance Wall Elements or Solid Conduction				
Base Case (0 internal heat gains, 0 infiltration)	220	5.2.3.1		
Interior Infrared Radiation Exchange	210	5.2.3.2		
Exterior Infrared Radiation Exchange	215	5.2.3.3		
Interior and Exterior Infrared Radiation Exchange	200	5.2.3.4		
Solid Conduction (no windows or high-cond. wall elements)	195	5.2.3.5		
Infiltration	230	5.2.3.6		
Internal Gains	240	5.2.3.7		
Exterior Solar Absorptance	250	5.2.3.8		
In-Depth Tests with "20,20" Tstat and Windows (South unless East/West is indicated)				
South Solar Gains	270	5.2.3.9		
Cavity Albedo (interior solar absorptance)	280	5.2.3.10		
South Shading (overhang)	290	5.2.3.11		
East/West Windows	300	5.2.3.12		
East/West Windows with Shading (overhang + fins)	310	5.2.3.13		
"20,27" Deadband Thermostat	320	5.2.3.14		
In-Depth Tests with "20,27" Deadband Tstat, and High-Conductance Wall Elements or Solid Conduction				
Base Case (0 internal heat gains, 0 infiltration)	400	5.2.3.15		
Solid Conduction	395	5.2.3.16		
Infiltration	410	5.2.3.17		
Internal Gains	420	5.2.3.18		
Exterior Solar Absorptance	430	5.2.3.19		
Thermal Mass Without Solar Gains			800	5.2.3.24
In-Depth Tests with "20,27" Deadband Tstat and South Windows				
Cavity Albedo	440	5.2.3.20	810	5.2.3.25
Constant Combined Interior and Exterior Surface Coefficients	450	5.2.3.21		
Constant Combined Interior Surface Coefficients	460	5.2.3.22		
Constant Combined Exterior Surface Coefficients	470	5.2.3.23		

5.2.1.1 Weather and Site Data
5.2.1.1.1 Weather Data.
5.2.1.1.1.1 Normative Weather Data. The ~~DRYCOLD.TMY~~725650TY.CSV weather data provided with the electronic files accompanying this standard shall be used for all cases in Sections 5.2.1, 5.2.2, and 5.2.3. These data are described in Normative Annex A1, Section A1.1.1.
5.2.1.1.1.2 Informative Sky Temperature Data. ***Informative Note:*** The specified weather data file does not include data for sky temperature (T_{sky}). For programs that do not automatically calculate T_{sky}, and use T_{sky} as an input from the weather data file, calculated T_{sky} values are provided as informative material in the file "Tsky-Informative.xlsx", included with the electronic files accompanying this standard. That file and calculation of T_{sky} data are further described in the informative note with Annex A1, Informative Section A1.1.1.2.
5.2.1.1.2 Site Data.
5.2.1.1.2.1. The site ~~parameters~~ latitude, longitude, altitude, and time zone provided in Normative Annex A1, Table A1-1 shall be used.
5.2.1.1.2.2. The site shall be located at the weather station, in open terrain with scattered obstructions having heights generally less than 9m, including flat open country typical of meteorological station surroundings. There is no additional shielding of the building at the site.
Informative Note: The site location corresponds with Terrain Category 3, documented in *2017 ASHRAE Handbook of Fundamentals*, p. 24.4, Table 1 [B-101].
5.2.1.1.2.3. The height of the weather station tower (location of sensors) shall be assumed as 10 m.
5.2.1.1.2.4. The interior surface of the building floor shall be assumed to be 10 m below the top of the weather station.
5.2.1.1.2.5. The solar reflectance of the site ground surface = 0.2. ***Informative Note:*** Ground reflectance (albedo) included with the weather data is recommended to be ignored if the software being tested does not require use of that data. Ground reflectance in the provided weather data ranges from 0.19 to 0.22 with an average of 0.203; it is provided as hourly data, but only varies monthly.

5.2.1.2 Output Requirements. Case 600 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. Case- 600 ~~only~~ output in accordance with Section 6.2.1.2
c. Daily hourly output as specified for Case 600 in Section 6.2.1.8
d. General reporting requirements of Section 6.1.
Informative Note: In this description the term "free-float cases" refers to cases designated with "FF" in the case description (i.e., 600FF, 650FF, 900FF, 950FF); non-free-float cases are all the other cases described in Sections 5.2.1, 5.2.2, and 5.2.3 (Informative Annex B1, Tables B1-2 and B1-3, include a summary listing of the cases of Sections 5.2.1, 5.2.2, and 5.2.3.).

5.2.1.3 Building Geometry. The base building plan shall be a 48 m^2 floor area, single story, low mass building with rectangular-prism geometry and 12 m^2 of south-facing windows as shown in Figure 5-1.

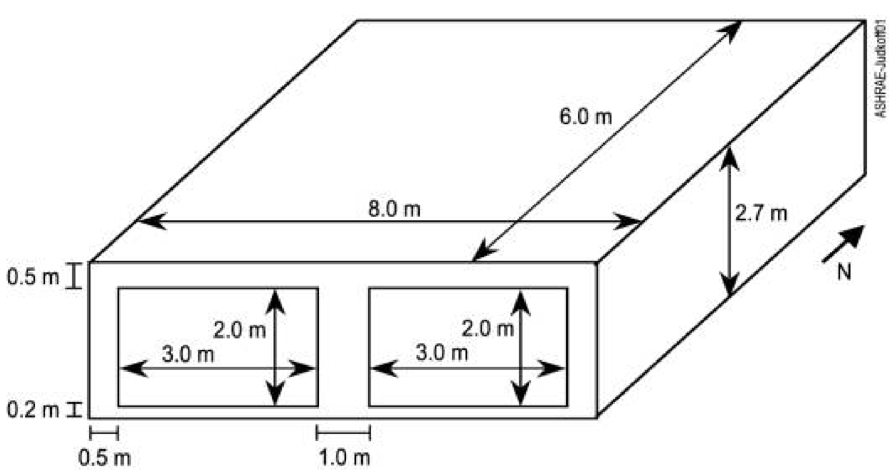


Figure 5-1 Isometric south windows—unshaded (Case 600).

5.2.1.4 Material Properties. For the walls, floor, and roof, the fundamental thermal and material properties provided in Table 5-2~~1~~ shall be applied. ~~used.~~ ***Informative Note:*** Informative Table 5-3 includes summary calculated values derived from fundamental properties of normative Table 5-2 and alternative constant surface coefficients of Sections 5.2.1.9.3 and 5.2.1.10.3, for programs that may need this information. For programs that automatically calculate ~~interior~~ surface radiation ~~and~~ or convection or both, or that ~~treat interior~~ allow more detailed constant surface coefficient~~s~~ inputs (e.g., for scheduling), ~~as specified in Section 5.2.1.10,~~ variation of individual interior surface coefficient U-values, ~~and~~ total U- and total UA-values, and heat capacities from ~~those specified in~~ Table 5-3~~1~~ may be expected. ~~shall be permitted.~~

[Note: Table 5-1 of 140-2017 rearranged to separate normative basic material properties (see Table 5-2) from informative calculated values (Informative Table 5-3). Tracked changes indicate deletion of extraneous zeroes in Table 5-2 and changes to values in Informative Table 5-3, but are not applied for the rearrangement of existing material.]

Table 5-2~~1~~ Material Specifications ~~Lightweight~~ Low Mass Case

Element	k, W/(m·K)	Thickness, m	U, W/(m²·K)	R, ~~(~~m²·K~~)~~/W	Density, kg/m³	c_p, J/(kg·K)
Fundamental Material Thermal Properties						
~~Lightweight~~ Low Mass Case: Exterior Wall (inside to outside~~doors~~)						
Plasterboard	0.16~~0~~	0.012	13.333	0.075	950~~.000~~	840~~.000~~
Fiberglass quilt	0.04~~0~~	0.066	0.606	1.650	12~~.000~~	840~~.000~~
Wood Siding	0.14~~0~~	0.009	15.556	0.064	530~~.000~~	900~~.000~~
~~Lightweight~~ Low Mass Case: Raised Floor (inside to outside~~doors~~)						
Timber flooring	0.14~~0~~	0.025	5.600	0.179	650~~.000~~	1200~~.000~~
Insulation	0.04~~0~~	1.003	0.040	25.075	0~~b~~[a]	0~~b~~[a]
~~Lightweight~~ Low Mass Case: Roof (inside to outside~~doors~~)						
Plasterboard	0.16~~0~~	0.010	16.000	0.063	950~~.000~~	840~~.000~~
Fiberglass quilt	0.04~~0~~	0.1118	0.358	2.794	12~~.000~~	840~~.000~~
Roofdeck	0.14~~0~~	0.019	7.368	0.136	530~~.000~~	900~~.000~~

a~~b~~. Underfloor insulation has the minimum density and specific heat the program being tested will allow, but not < 0.

5.2.1.4.1 Internal Mass. There shall be no additional internal mass within the zone corresponding to furniture or other non-specified elements. ***Informative Note:*** Programs should consider thermal capacitance of the zone based on the given zone construction details, zone air volume, and their determination of density of air within the zone.

Informative Table 5-3 Calculated Summary Thermal Conductances and Heat Capacities, Low Mass Case[a]

Element	U, W/(m²·K)	R, m²·K/W
Low Mass Case: Exterior Wall (inside to outside)		
Interior Surface Coefficient	**1.8** ~~8.290~~	**0.556** ~~0.121~~
Total surface-to-~~-~~surface[b]	0.559	1.789
Exterior Surface Coefficient	**21.6** ~~29.300~~	**0.046** ~~0.034~~
Total air-to-~~-~~air[c]	**0.418** ~~0.514~~	**2.391** ~~1.944~~
Low Mass Case: Raised Floor (inside to outside)		
Interior Surface Coefficient~~a~~	**3.7** ~~8.290~~	**0.270** ~~0.121~~
Total surface-to-~~-~~surface[b]	0.040	25.254
Exterior Surface Coefficient	**5.2**	**0.192**
Total air-to-~~-~~air[c]	0.039	**25.716** ~~25.374~~
Low Mass Case: Roof (inside to outside)		
Interior Surface Coefficient~~a~~	**1.700** ~~8.290~~	**0.588** ~~0.121~~
Total surface-to-~~-~~surface[b]	0.334	2.992
Exterior Surface Coefficient	**21.8** ~~29.300~~	**0.046** ~~0.034~~
Total air-to-~~-~~air[c]	**0.276** ~~0.318~~	**3.626** ~~3.147~~

Summary: ~~Lightweight~~ Low Mass Case Component	Area, m²	UA, W/K	Heat Capacity[d], kJ/K Internal[e]	Total
Wall	63.6~~00~~	**26.598** ~~32.715~~	**651**	**924**
Floor	48.0~~00~~	**1.867** ~~1.892~~	**936**	**936**
Roof	48.0~~00~~	**13.237** ~~15.253~~	**437**	**872**
S Window	12.0~~00~~	**25.184** ~~36.000~~		
Infiltration[f]		**18.555** ~~18.440~~~~[e]~~		
Total ~~UA (with S Glass)~~		**85.440** ~~104.300~~	**2024**	**2732**
~~**Total UA (without S Glass)**~~		~~**68.300**~~		

Values and Air Properties for UA infiltration~~i~~[f]	ach	Volume, m³	~~Altitude, m~~	Density, kg/m³	c_p, J/(kg·K)
	0.5~~00~~	129.6~~00~~	~~1609.000~~	**1.0156**	**1015**

a. Values that were added or changed from Standard 140-2017 are highlighted with bold font.
b. "Total surface-to-surface" values are based on the sum of the R-values for the basic material properties for the given construction element.
c. "Total air-to-air" values are based on the sum of the listed surface coefficients and "Total surf – surf" R-value for the given construction element.
~~a. *Informative Note:* The interior film coefficient for floors and ceilings is a compromise between upward and downward heat flow for summer and winter.~~
d. Heat Capacity = density × cp × thickness × surface area, summed for each component of the given element.
e. Internal heat capacity includes building mass within the thermal envelope (i.e., plasterboard, timber flooring, and insulation included; wood siding and roofdeck excluded).
f~~e.~~. ~~*Informative Note:*~~ UA corresponding to infiltration based on average values calculated from the weather data: ach × volume × (1 hr/3600 s) × (specific heat of moist air [cp]) × (density of moist air ~~at specified altitude~~); where specific heat of moist air = cpa + W·cpv, where specific heat of dry air (cpa) = 1006 J/(kg·K) and specific heat of water vapor (cpv) = 1860 J/(kg·K)[A-1]. For average humidity ratio (W) = 0.0049 kgv/kgda, implies cp = 1015 J/(kg·K), and density of moist air is as calculated in informative Annex B3, Section B3.1.

5.2.1.5 Raised Floor Exposed to Air. ~~**Ground Coupling.** The exterior surface of the floor contacts the ground.~~ ***Informative Note:*** To reduce uncertainty regarding testing the other aspects of simulating the building envelope, the floor insulation described in Table 5-2~~1~~ has been made very thick to effectively decouple the floor thermally from the ground~~.~~, while not decoupling the floor mass from the zone. Application of a raised floor eliminates the need for modeling ground-coupled heat transfer.

5.2.1.5.1 The floor shall be modeled as follows:

• The air temperature below the raised floor shall be equal to the outdoor air temperature.

• The floor exterior surface (surface facing downward) shall receive no solar radiation.

• The underside of the conditioned-zone floor shall have zero wind speed. ***Informative Note:*** Instructions for modeling exterior surface heat transfer for all surfaces are provided in Section 5.2.1.9.

Informative Note: The assumption that the air temperature below the raised floor is equal to ambient temperature may be approximated either by modeling a building that hovers above the ground (raised floor on stilts for example), or by modeling a highly ventilated crawl space. The zero wind speed approximation is applicable because the interior floor surface location relative to the weather tower sensors is as described in Sections 5.2.1.1.2.3 and 5.2.1.1.2.4. The zero solar-radiation-to-exterior-floor assumption can be modeled by assigning the highest solar reflectance allowed by the software being tested to the underside of the floor and/or defining shading planes where walls would be if the raised floor were modeled as a crawl space. For programs that do not apply constant combined

film coefficients, infrared radiative exchange between the floor exterior surface and the ground surface may be modeled as typical for the program being tested.
5.2.1.5.21 The underfloor insulation shall have the minimum density and specific heat that the program being tested allows.
~~**5.2.1.5.2** For software that requires input of ground thermal properties, the ground in the vicinity of the building shall be dry packed soil with the following characteristics:~~
~~• Soil thermal conductivity *k* = 1.3 W/(m·K)~~
~~• Soil density = 1500 kg/m^3~~
~~• Soil specific heat = 800 J/(kg·K)~~
~~• Deep ground temperature = 10°C~~

5.2.1.6 Infiltration. The infiltration rate shall be 0.5 ach, continuously (24 hours per day for the full year). The infiltration rate shall be independent of wind speed, indoor/outdoor temperature difference, and other variables.
5.2.1.6.1 The weather data file represents a high-altitude site with an elevation of 16509 m above sea level. If the program being tested does not use barometric pressure from the weather data or otherwise automatically correct for the change in air density due to altitude, then the specified infiltration rates shall be adjusted to yield mass flows equivalent to those occurring at 16509 m altitude as shown in Table 5-42.
Informative Note: Air density at 16509 m altitude is roughly 80% of that at sea level. The calculation technique used to develop Table 5-42 is provided as background information in Informative Annex B3, Section B3.1.
Informative Note: Alternatively, the given infiltration rate may be input as a constant ventilation rate.

Table 5-42 Infiltration Rates Depending on the Presence of Automatic Altitude Adjustment[a]

Altitude Adjustment Algorithm	Input Air Changes per Hour, ach	Adjustment Factor
Programs with automatic altitude adjustment; set altitude to 16509 m above sea level	0.5	1.0
Programs with fixed assumption that site is at sea level (no automatic adjustment)	**0.414[b]**	**0.829**[b] ~~0.822~~[a]

a. ***Informative Note:*** **Changes to Standard 140-2017 highlighted with bold font.**
~~a.~~b. (Specified Rate) × **(1.0156/1.2255)** ~~0.822~~ = (altitude adjusted rate)

5.2.1.7 Internally Generated Sensible Heat. The following internal heat gains shall be used:
• Internal gains shall be 200 W, continuously (24 hours per day for the full year).
• Internal gains shall be 100% sensible, 0% latent.
• Sensible ~~I~~internal gains shall be 60% radiative, 40% convective.
Informative Note: These are internally generated sources of heat (from equipment, lights, people, etc.), that are not related to heating, ventilating, and air conditioning (HVAC). The convective portion of ~~Internally generated sensible and latent~~ internal gains ~~are~~ may be reasonably assumed to be distributed evenly throughout the zone air. The radiative portion may be reasonably assumed to be distributed uniformly among the zone interior surfaces (area weighted distribution), assuming an effective infrared transmittance of approximately one for air within the zone. ~~These are internally generated sources of heat (from equipment, lights, people, animals, etc.) that are not related to heating, ventilating, and air conditioning (HVAC).~~

5.2.1.8 Opaque Surface Radiative Properties.
5.2.1.8.1 Absorptances and Emittances.
a. The interior and exterior opaque surfaces solar (visible and ultraviolet wavelengths) absorptances and infrared emittances shall be applied to all opaque surfaces, except for the raised floor, as specified in Table 5-53.
b. For the raised floor:
- Interior surface solar absorptance and infrared emittance, and exterior surface infrared emittance, shall be applied as specified in Table 5-5.
- The exterior surface shall be modeled as receiving no solar radiation (see Section 5.2.1.5.1).

Table 5-53 Opaque Surface Radiative Properties, Case 600

	Interior Surface	Exterior Surface
Solar absorptance	0.6	0.6
Infrared emittance	0.9	0.9

5.2.1.8.2 Surrounding Ground Surface Temperature for Exterior Infrared Radiation Exchange. If the program being tested does not automatically calculate a separate component of exterior surface infrared radiation exchange with the surrounding ground, skip the remaining instructions and proceed to Section 5.2.1.9.
5.2.1.8.2.1 If the program being tested calculates this exchange component and the program automatically calculates surrounding ground surface temperature, then the program's calculated surrounding ground surface temperature shall be applied. If this instruction is applied, skip the remaining instructions and proceed to Section 5.2.1.9.
5.2.1.8.2.2 If the program being tested calculates this exchange component and does not automatically calculate surrounding ground surface temperature, the instructions of Section 5.2.1.8.2.2.1 or 5.2.1.8.2.2.2 shall be applied.
5.2.1.8.2.2.1 The surrounding ground surface temperature shall be equal to, and shall vary with, the ambient air temperature from the provided weather data (see Section 5.2.1.1.1) for each hour of the simulation.
5.2.1.8.2.2.2 If the program being tested calculates an ambient air temperature for each time step of the simulation based on the given weather data, the surrounding ground surface temperature for each time step shall be equal to, and shall vary with, the calculated ambient air temperature for each time step.

5.2.1.9 Exterior Surface Heat Transfer.
5.2.1.9.1 Terrain Category. For programs that allow variation of wind speed with height above ground, local site terrain data provided in Section 5.2.1.1.2 shall be applied.
5.2.1.9.2 Exterior Surface Texture. For programs that allow variation of exterior surface convection with surface texture, exterior surface texture shall be as indicated in Table 5-6.

Table 5-6 Exterior Surface Texture, Case 600

Surface Type	Surface Texture[a]
Walls	**Rough[b]**
Roof	**Rough[b]**
Raised Floor	**Rough[b]**
Windows (glass)	**Very Smooth**

a. ***Informative Note:*** Surface texture designations correspond with: *2009 ASHRAE Handbook – Fundamentals*, p. 26.2[B-10]; Walton (1983), Section III.I.1[B-20]; and DOE (2018), Section 3.5.5.1[A-2]. Also see Part IV, Appendix A, Section 4A.2.1 of the originating test-suite-update final report[A-15].
b. ***Informative Note:*** The "Rough" surface corresponds to brick or rough plaster exterior. Uniform exterior surface texture is specified for the Case 600 opaque exterior surfaces to simplify input.

5.2.1.9.3 Alternative Constant Convective and Combined (Radiative and Convective) Surface Coefficients.
a. If the program being tested automatically calculates exterior surface convective coefficients and infrared radiativeon exchange and convection varying with time step:,
- those calculations shall be applied
- skip the remaining instructions in this section and proceed to Section 5.2.1.10.

b. If the program being tested does not calculate this effect time-step varying exterior surface convective coefficients or infrared radiative exchange, then the information provided in Table 5-74 shall be applied. used. In applying Table 5-7:
- Programs that calculate time-step varying exterior surface infrared radiative exchange, but not convective coefficients, shall apply the listed exterior *convective* surface coefficients (h,conv,ext) for each surface type.
- Programs that do not calculate time-step varying exterior surface convective coefficients and infrared radiative exchange shall apply the listed exterior *combined* surface coefficients (h,comb,ext) for each surface type.
- Use of different (nonspecified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test

cases. Use of nonspecified values shall be documented in the Standard Output Report specified in Normative Annex A2.

Informative Note: The exterior combined radiative and convective surface coefficient for the glass and very smooth opaque surfaces (used only in some of the in-depth cases of Section 5.2.3) is specified as equivalent (applying infrared emittance of 0.9) for convenience of input, even though the infrared emittance for common window glass is usually 0.84.

Informative Note: The constant values of Table 5-7 are provided for programs that require this input, i.e., that have no time-step varying exterior surface convective coefficient or infrared radiative heat transfer calculation method, or no other constant exterior surface heat transfer coefficients explicit to their internal coding. Programs (or models within those programs, where a program allows a variety of modeling methods) that calculate time-step varying surface convective coefficients and infrared radiative heat transfer should not be adjusted to match the constant values provided here.

Informative Note: Example constant surface coefficients presented here apply only to the test cases and were calculated using a verified simulation process (see Part IV, Appendix A, Section 4A.3 of the originating test-suite-update final report[A-15]) only for test cases with south facing windows or south facing high-conductance wall elements. They should not be assumed to apply beyond this test suite. Supporting information about Tthe calculation technique used to development of Table 5-74 is provided as background information in Informative Annex B4. A calculation technique that may be used for comparing combined surface coefficients as of infrared radiative exchange as a function of infrared emittance is provided as background information in Informative Annex B5.

Table 5-74 Alternative Constant Exterior Convective and Combined Surface Coefficients for Each Versus Surface Type, Texture, Case 600[a,b]

Surface Texture	Exterior Combined Surface Coefficient
Brick or rough plaster (all walls and roofs)	29.3 W/(m²·K)
Glass (window)	21.0 W/(m²·K)

Note: All values in table based on a mean annual wind speed of 4.02 m/s.

Surface Type	Exterior *Convective* Surface Coefficient (h,conv,ext) W/(m²·K)	Exterior *Combined* Surface Coefficient (h,comb,ext) W/(m²·K)
Walls	**11.9**	**21.6**
Roof	**14.4**	**21.8**
Raised Floor	**0.8**	**5.2**
Windows	**8.0**	**17.8**

a. ***Informative Note:*** **Changes to Standard 140-2017 highlighted with bold font.**
b. ***Informative Note:*** Informative Annex B4 includes supporting information.
c. ***Informative Note:*** Calculated for wind speed = 0 as described in Section 5.2.1.9; also see Part IV, Appendix A, Section 4A.2.1.1 of the originating test-suite-update final report[A-15].

5.2.1.10 Interior Surface Heat Transfer.

5.2.1.10.1 Zone Air Flow Regime. For programs that allow variation of zone air flow regime, buoyancy (non-mechanically) driven airflow shall be applied. Operation of the specified ideal mechanical system (see Section 5.2.1.13) shall have no effect on the interior surface convective heat transfer flow regime.

5.2.1.10.2 Interior Surface Texture. For programs that allow variation of interior surface convection with surface texture, interior surface texture shall be as indicated in Table 5-8.

Table 5-8 Interior Surface Texture, Case 600

Surface Type	Surface Texture[a]
Walls	Smooth[b]
Roof	Smooth[b]
Raised Floor	Smooth[b]
Windows (glass)	Very Smooth

a. ***Informative Note:*** Surface texture designations correspond with: *2009 ASHRAE Handbook – Fundamentals*, p. 26.2[B-10]; Walton (1983), Section III.I.1[B-20]; and DOE (2018), Section 3.5.5.1[A-2]. Also see Part IV, Appendix A, Section 4A.2.1 of the originating test-suite-update final report[A-15].
b. ***Informative Note:*** The "Smooth" surface corresponds to smooth plaster. Uniform interior surface texture is specified for the Case 600 opaque interior surfaces to simplify input.

5.2.1.10.3 Alternative Constant Convective and Combined (Radiative and Convective) Surface Coefficients.

a. If the program being tested ~~automatically~~ calculates interior surface convective coefficients and infrared radiativ~~e~~on exchange ~~and convection,~~ varying with time step:
- those calculations shall be applied ~~then~~
- skip the remaining instructions in this section and proceed to Section 5.2.1.11.

b. If the program being tested does not calculate ~~these effects~~ time-step varying interior surface convective coefficients or infrared radiative exchange, ~~the constant combined radiative and convective surface coefficients~~ then the information provided in Table 5-9~~5~~ shall be applied. ~~used.~~ In applying Table 5-9:
- Programs that calculate time-step varying interior surface infrared radiative exchange, but not convective coefficients, shall apply the listed interior *convective* surface coefficients (h,conv,int) for each surface type.
- Programs that do not calculate time-step varying interior surface convective coefficients and infrared radiative exchange shall apply the listed interior *combined* surface coefficients (h,comb,int) for each surface type. ~~If the program being tested does not allow assignment of values based on the direction of heat flow or other scheduling of these coefficients, 8.29 W/(m²·K) shall be used for all horizontal surfaces. For cases with an interior infrared emittance of 0.9, a radiative portion of 5.13 W/(m²·K) shall be permitted for these combined coefficients.~~
- Use of different (nonspecified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. Use of nonspecified values shall be documented in the Standard Output Report specified in Normative Annex A2.

Informative Note: The constant values of Table 5-9 are provided for programs that require this input, i.e., that have no time-step varying interior surface convective coefficient or infrared radiative heat transfer calculation method or no other constant interior surface heat transfer coefficients explicit to their internal coding. Programs (or models within those programs, where a program allows a variety of modeling methods) that calculate time-step varying surface convective coefficients and infrared radiative heat transfer should not be adjusted to match the constant values provided here.

Informative Note: ~~The interior combined radiative and convective surface coefficient for the glass is specified as equivalent to that for other vertical surfaces (assuming infrared emittance of 0.9) for convenience of input, even though the infrared emittance for common window glass is usually 0.84. Background information regarding values provided in Table 5-5 is available in the *2009 ASHRAE Handbook – Fundamentals*[B-10], Chapter 26.~~ Example constant surface coefficients presented here apply only to the test cases and were calculated using a verified simulation process (see Part IV, Appendix A, Section 4A.3 of the originating test-suite-update final report[A-15]) only for test cases with south facing windows or south facing high-conductance wall elements. They should not be assumed to apply beyond this test suite. Example constant interior surface coefficients assume buoyancy regime heat transfer only (see Part IV, Appendix A, Section 4A.2.2 of the originating test-suite-update final report[A-15]). Supporting information about the development of Table 5-9 is provided as in Informative Annex B4. ~~Informative Annex B5 includes background information about combined radiative and convective film coefficients.~~

Table 5-95 Alternative Constant Interior Convective and Combined Surface Coefficients Versus for Each Surface Type, Orientation Case 600[a,b]

Orientation of Surface and Heat Flow	Interior Combined Surface Coefficient
Horizontal heat transfer on vertical surfaces	8.29 W/(m²·K)
Upward heat transfer on horizontal surfaces	9.26 W/(m²·K)
Downward heat transfer on horizontal surfaces	6.13 W/(m²·K)

Surface Type	Interior *Convective* Surface Coefficient (h,conv,int) W/(m²·K)	Interior *Combined* Surface Coefficient (h,comb,int) W/(m²·K)
Walls	2.2	1.8[c]
Ceiling	1.8	1.7[c]
Raised Floor	2.2	3.7
Windows	2.4	4.5

a. ***Informative Note:*** **Changes to Standard 140-2017 highlighted with bold font.**
b. ***Informative Note:*** Informative Annex B4 includes supporting information.
c. ***Informative Note:*** h,comb,int < h,conv,int is possible here because convective and infrared radiative heat flows may be in opposite directions for a given surface for a sufficient number of time steps.

5.2.1.11 Transparent Window

Informative Note: Use of different algorithms to calculate window thermal and optical performance requires different inputs. Extensive information about the window properties has therefore been provided so that equivalent input for the window will be possible for many programs. Recall from Section 5.1.3 (Nonapplicable Inputs) to use only the information that is relevant to the program being tested.

5.2.1.11.1 Geometry. The windows shall have no sash area. The rough openings shown in Figure 5-1 shall contain only the double-pane glass specified in Tables 5-106. and 5-7.

5.2.1.11.2 Window Properties. The basic properties of the window provided in Table 5-106 shall be applied. used. All glass pane surfaces are clean; there is no dirt or fouling.

Informative Note, Calculated Properties of Informative Table 5-11: Informative Table 5-11 includes calculated values derived from fundamental properties of normative Table 5-10 and alternative constant surface coefficients of Sections 5.2.1.9.3 and 5.2.1.10.3, for programs that may need this information.

Informative Note, Variation of Listed Surface Coefficients and Overall U-Values from Values of Informative Table 5-11: For programs that calculate time-step varying surface infrared radiative exchange or convective coefficients or both, or that allow more detailed constant surface coefficient inputs (e.g., for scheduling), variation of the following from the values given in Table 5-11 may be expected: individual surface coefficient U-values, air gap effective conductance, and overall U-value.

Informative Note, Variation of Air Gap Conductance from Values of Informative Table 5-11: For programs that automatically calculate heat transfer within an air space or empty cavity, variation of the following from the values given in Table 5-11 may be expected: effective air gap conductance and overall U-value.

5.2.1.11.3 Alternative Incidence-Angle Dependent Optical Properties.

a. If the program being tested automatically calculates incidence-angle-dependent optical properties based on inputs from Table 5-10, or if the program does not allow direct user input of angle-dependent optical properties, then skip the instructions in this section and proceed to Section 5.2.1.12.

b. For programs that apply incidence-angle-dependent optical properties as direct inputs, the values given in Table 5-127 shall be applied. used.
   - For programs that need transmittance or reflectance at other angles of incidence, the user shall be permitted to interpolate between the values in Table 5-12 7 using the cosine of the incident angle as the basis for interpolation.
   - Where unspecified equivalent inputs are needed, values that are consistent with those specified shall be applied according to the instructions of Section 5.1.5 "Equivalent Modeling Methods."

Informative Note: Many programs use different algorithms to calculate window transmittance and therefore require different inputs. For example, SERIRES[B-11] calculates transmittance, absorptance, and reflectance for each hourly incidence angle given the index of refraction, extinction coefficient, glazing thickness, and number of panes in the window assembly. BLAST[B-12] calculates extinction coefficient, absorptance, reflectance, and angle-dependent transmittance given the direct normal transmittance of a single pane in air, glass thickness, index of refraction, and number of panes. Extensive information about the window properties has therefore been provided so that equivalent input for the window will be possible for many programs. Use only the information that is relevant to the program being tested.

Informative Note: For further informative discussion related to calculating angle-dependent glazing optical properties, refer to Informative Annex B6.

Informative Note: Supporting information regarding window thermal and optical properties is provided in Informative Annex B6. This includes the output report from the WINDOW 7 software[A-3] that was applied to generate values in Table 5-12, and selected values in informative Table 5-11, as described in the notes with those tables. This informative data file is included with the accompanying electronic media and may be used by simulation programs that can read it directly.

[Note: Regarding changes to Table 5-6 of 140-2017, normative material is provided in Table 5-10 and informative material is provided in Informative Table 5-11. In Tables 5-10 and 5-11, some properties are presented in different order versus 140-2017, Table 5-6. Tracked changes are applied for further clarifications, but not applied for reordering of items (for clarity of intended revisions), and not applied for reordering of table notes.]

Table 5-106 Window Clear Double-Pane Glazing System Fundamental Properties[a]

Property	Value
Fundamental Construction Properties	
Height, individual rough opening	2 m
Width, individual rough opening	3 m
Area, individual gross window (also center of glass area)	6 m^2
Number of panes	2
Pane thickness[b] (standard 1/8 in. glass under the inch-pound [I-P] system)	**3.048**175 mm
Air gap t**Thickness of space between panes[c]**	**12.0**3 mm
Fill gas (in space between panes)	Air
Curtains, blinds, frames, spacers, mullions, obstructions inside the window	None
Basic Material Properties	
Thermal conductivity of glass[b]	**1.00**6 W/(m·K)
Density of glass[d]	2500**2470** kg/m^3
Specific heat of glass[d]	750 J/(kg·K)
Air: conductivity (k)[e,f]	**0.024069 W/(m·K), shall be allowed to vary with temperature and pressure**
Air: specific heat (c_p)[e,f]	**1006.103271 J/(kg·K), shall be allowed to vary with temperature and pressure**
Air: density (ρ)[e,f]	**1.292498 kg/m^3, shall be allowed to vary with temperature and pressure**
Air: viscosity (μ)[e,f]	**0.000017 kg/(m·s), shall be allowed to vary with temperature and pressure**
Air:Prandtl number (Pr)[e,f]	**0.7197 (dimensionless), shall be allowed to vary with temperature and pressure**
Air: molecular weight[e]	**28.970 g/mol**
Hemispherical infrared emittance of ordinary uncoated glass[b]	0.840 (Use 0.9 for simplicity of input. If the program being tested must use 0.84 this is acceptable because the effect on outputs will be less than 0.5%)
Infrared transmittance of glass[b]	0.000
Normal d**Direct-beam transmittance through** one **each pane** in air[b]	**0.834**6156, at normal incidence
Direct-beam reflectance for each pane[b]	**0.075**, at normal incidence

a. ***Informative Note:*** **Updates to Standard 140-2017 highlighted with bold font.**
b. ***Informative Note:*** Value from WINDOW 7 glass library, "CLEAR_3.DAT".
c. ***Informative Note:*** Value from WINDOW 7 glazing system library "Double Clear Air" (ID #2).
d. ***Informative Note:*** Value for soda-lime glass from *2017 ASHRAE Fundamentals* (SI version)[B-101], p. 33.3.
e. ***Informative Note:*** Value from WINDOW 7 gas library, "Air".
f. ***Informative Note:*** In WINDOW 7 this value is reported at 0°C, 101.325 kPa.

Informative Table 5-11 Calculated Clear Double-Pane Glazing System Properties[a]

Effective conductance of air gap, ~~Combined~~ including radiative and convective heat transfer ~~coef of air gap~~ (h_s)[b]	**5.208** ~~6.297~~W/(m^2·K)	[**R-0.19200** ~~0.1588~~ m^2·K/W]
Conductance of each glass pane[c]	**328** ~~333~~ W/(m^2·K)	[**R-0.00305** m^2·K/W]
Exterior combined surface coefficient (h_o)[d]	**17.8** ~~21.00~~W/(m^2·K)	[**R-0.05618** ~~0.0476~~ m^2·K/W]
Interior combined surface coefficient (h_i)[d]	**4.5** ~~8.29~~ W/(m^2·K)	[**R-0.22222** ~~0.1206~~ m^2·K/W]
U-Value from interior air to ambient air[e]	**2.10** ~~3.0~~ W/(m^2·K)	[**R-0.47650** ~~0.3333~~ m^2·K/W]
Double-pane solar heat gain coefficient (SHGC)[f] ~~(at normal incidence)~~	**0.769**~~89~~, at normal incidence[g]	
Double-pane shading coefficient (SC)[h] ~~(at normal incidence)~~	**0.883**~~907~~, at normal incidence	
Index of refraction[i]	**1.493**~~526~~	
Extinction coefficient[i]	**0.0337**~~196~~/mm	

a. **Updates to Standard 140-2017 highlighted with bold font.**
b. Calculated: (air gap conductance) = (Keff) / (air gap thickness), where Keff = 0.0625 W/(m·K) from Window 7 on-screen output; R-Value = 1 / (conductance).
c. Calculated: (pane conductance) = (pane conductivity) / (pane thickness); R-Value = 1 / (conductance).
d. Value from Annex B4, Section B4.1.
e. Calculated: (R value, total) = $1/(h_s) + 2 *$ (pane R value) + $1/h_i + 1/h_o$; (U Value) = 1 / (R value). This value agrees with WINDOW 7 output of U = 2.10 W/(m·K) applying constant combined coefficients in the environmental conditions.
f. Calculated by WINDOW 7, see Informative Annex B6, Section B6.1. This matches within rounding tolerance SHGC from Equations 13, 14, and 16 (pp. 15. 19-20) of *ASHRAE 2017 Fundamentals*[B-101].
g. Table 5-12 includes angle-dependent optical properties calculated by WINDOW 7.
h. WINDOW 7 on-screen value. This matches within rounding tolerance SC = SHGC/0.87 per Eqn. 91 (p. 31.39) of ASHRAE 2005 Fundamentals[B-32].
i. Calculated, based on Informative Annex B6, Section B6.2.

Table 5-12~~7~~ Alternative Angular Dependen~~ce of~~t Optical Properties for the Double-Pane Window~~*~~a,b,c

Angle of Incidence	Trans.	Refl.,f	Refl.,b	Abs. Outer Pane	Abs. Inner Pane	SHGC[d]
0	~~0.747~~**0.703**	~~0.136~~**0.128**	**0.128**	~~0.064~~**0.096**	~~0.052~~**0.072**	~~0.789~~**0.769**
10	~~0.747~~**0.702**	~~0.136~~**0.128**	**0.128**	~~0.065~~**0.097**	~~0.053~~**0.073**	~~0.789~~**0.768**
20	~~0.745~~**0.699**	~~0.136~~**0.128**	**0.128**	~~0.066~~**0.099**	~~0.053~~**0.074**	~~0.787~~**0.766**
30	~~0.740~~**0.692**	~~0.137~~**0.130**	**0.130**	~~0.068~~**0.102**	~~0.055~~**0.075**	~~0.784~~**0.761**
40	~~0.730~~**0.678**	~~0.143~~**0.139**	**0.139**	~~0.071~~**0.106**	~~0.057~~**0.077**	~~0.775~~**0.748**
50	~~0.707~~**0.646**	~~0.160~~**0.164**	**0.164**	~~0.075~~**0.112**	~~0.058~~**0.078**	~~0.754~~**0.718**
60	~~0.652~~**0.577**	~~0.210~~**0.227**	**0.227**	~~0.080~~**0.119**	~~0.059~~**0.077**	~~0.700~~**0.651**
70	~~0.517~~**0.438**	~~0.343~~**0.365**	**0.365**	~~0.086~~**0.127**	~~0.054~~**0.070**	~~0.563~~**0.509**
80	~~0.263~~**0.208**	~~0.602~~**0.612**	**0.612**	~~0.094~~**0.130**	~~0.041~~**0.050**	~~0.302~~**0.267**
90	0.000	1.000	1.000	0.000	0.000	0.000
Hemis.	**0.601**	**0.206**	**0.206**	**0.110**	**0.073**	**0.670**

~~*~~a. "Trans." = transmittance;~~,~~ "Refl.,f" = overall solar reflectance for radiation incident from the front (i.e., from the outside);~~,~~ "Refl.,b" = overall solar reflectance for radiation incident from the back (i.e., from inside the zone); "Abs." = absorptance;~~,~~ SHGC = solar heat gain coefficient; "Hemis." = hemispherically integrated. "Refl.,f" = "Refl.,b", for this glazing system.

b. ***Informative Note:*** **Changes to Standard 140-2017 are highlighted with bold font.**

c. ***Informative Note:*** **Properties evaluated using WINDOW 7[A-3]; see Annex B6, Section B6.1.**

d. ***Informative Note:*** This matches within rounding tolerance SHGC from Equations 13, 14, and 16 (pp. 15.19-20) of *ASHRAE 2017 Fundamentals*[B-101].

5.2.1.12 Interior Solar Distribution.

5.2.1.12.1 This is the fractional distribution among interior surfaces of solar radiation transmitted through the windows that is absorbed by each given surface after all reflections off of interior surfaces and accounting for solar lost (transmitted solar radiation reflected by interior opaque surfaces and retransmitted back out the windows). For programs that calculate interior solar distribution internally (via ray tracing or other means based on interior solar absorptance given in Table 5-5), and do not require a separate input for interior solar distribution fraction, ignore Section 5.2.1.12.2 and skip to Section 5.2.1.13.

5.2.1.12.2 If the program being tested does not calculate ~~this effect~~ interior solar distribution internally but requires distribution fractions from the user, then the use of Table 5-13~~8~~ shall be permitted. Use of different (nonspecified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. The use of nonspecified values shall be documented in the Standard Output Report (Normative Annex A2).

Informative Note: Table 5-13~~8~~ presents an approximate calculation of solar distribution fractions by assuming that 100% of the incoming radiation strikes the floor first and that all reflections are diffuse. Fractional values for the walls with windows (i.e., the south wall) include the portion of the solar radiation absorbed by the glass (as it passes back out the window) and conducted back into the zone. Solar radiation absorbed by the glass (and conducted inward) as it initially passes into the building is not included in the values in Table 5-13~~8~~. Informative Annex B7 gives background information regarding the calculation technique used for developing these solar fractions.

Table 5-138 Alternative Constant Interior Solar Distribution Fractions by Surface, Case 600[a]

Surface	Floor	Ceiling	East Wall	West Wall	North Wall	South Wall	Solar Lost through Windows
Solar Fraction	0.642	**0.167 8**	0.038	0.038	0.053	**0.027 6**	0.035

a. ***Informative Note:*** **Changes to Standard 140-2017 are highlighted with bold font.**

5.2.1.13 Mechanical System. All equipment shall be 100% efficient with no duct losses and no capacity limitations. The mechanical system shall be modeled with the following features as noted specified below and in Sections 5.2.1.13.1 and 5.2.1.13.2:

a. 100% convective air system
b. The thermostat senses only the air temperature
c. Nonproportional-type thermostat (as specified in Section 5.2.1.13.1)
d. No latent heat extraction.

Informative Note: The intent of the mechanical system is to produce only pure heating load and sensible cooling load outputs.

5.2.1.13.1 Thermostat Control Strategy

5.2.1.13.1.1 The following thermostat control strategy shall be used:

• Heat = ON if temperature < 20°C; otherwise, Heat = OFF
• Cool = ON if temperature > 27°C; otherwise, Cool = OFF.

Informative Note: "Temperature" refers to conditioned-zone air temperature.

5.2.1.13.1.2 The thermostat is nonproportional.

Informative Note: A nonproportional thermostat operates such that when the conditioned-zone air temperature exceeds the thermostat cooling set point, the heat extraction rate is adjusted to maintain the zone air temperature exactly at the cooling set point. assumed to equal the maximum capacity of the cooling equipment. Likewise, when the conditioned-zone air temperature drops below the thermostat heating set point, the heat addition rate is adjusted to maintain the zone air temperature exactly at the heating set point. equals the maximum capacity of the heating equipment. A proportional thermostat throttles the heat addition rate (or extraction rate) in proportion to the difference between the zone set point temperature and the actual zone temperature. A proportional thermostat model can be made to approximate a nonproportional thermostat model by setting a very small throttling range (the minimum allowed by the program being tested).

5.2.1.13.2 Equipment Characteristics. The following inputs shall be used:

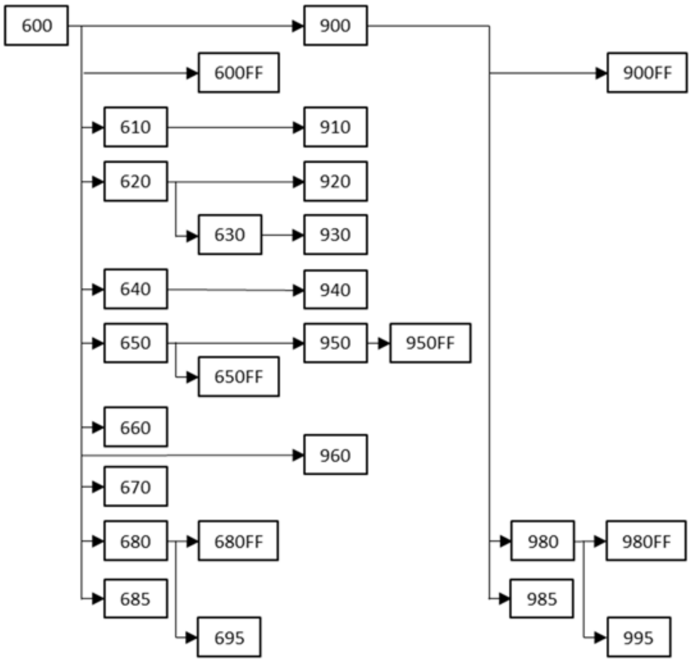
• Heating capacity = 1000 kW (effectively infinite)
• Effective efficiency = 100%
• Cooling capacity = 1000 kW (effectively infinite)
• Effective efficiency = 100%
• Sensible cooling only; no latent heat load calculation
• Waste heat from fan = 0.

Equipment efficiency shall be always 100% independent of part loading, indoor dry-bulb temperature and humidity ratio, outdoor dry-bulb temperature and humidity ratio, and/or other conditions.

5.2.2 Basic Tests. The basic tests shall be modeled as specified in this section and its subsections. The basic tests include Cases 610 through 995 and 600FF through 980FF.
Informative Note: For convenience to users, the base cases for developing the various basic tests are as shown in Informative Table 5-14 and Informative Figure 5-2. In Informative Table 5-14 "Secondary Base Case" indicates additional cases from where selected input specifications for the given test case are applied.
Informative Note: It is recommended to double check the Case 600 base building inputs and to diagnose Case 600 results disagreements before going on to the other cases.

Informative Table 5-14 Base Cases for Basic Tests of Section 5.2.2

	Low Mass Building			High Mass Building		
Primary Tested Feature	**Case**	**Primary Base Case**	**Secondary Base Case**	**Case**	**Primary Base Case**	**Secondary Base Case**
South Windows Base Case	600	---	---	900	600	---
South Shade (overhang)	610	600	---	910	610	900
East/West Windows	620	600	---	920	620	900
East/West Shade (ohang + fins)	630	620	610	930	630	900
Thermostat Setback	640	600	---	940	640	900
Night Ventilation	650	600	---	950	650	900
Low-Emissivity Windows	660	600	---			
Single-Pane Windows	670	600	---			
Sunspace				960	600	900
Increased Insulation	680	600	---	980	900	---
"20,20" Thermostat (Tstat)	685	600	---	985	900	685
Increased Insulation + "20,20" Tstat	695	680	685	995	980	685
Free Float, Base Case (S. windows)	600FF	600	---	900FF	900	600FF
Free Float, Night Ventilation	650FF	650	600FF	950FF	950	650FF
Free Float, Increased Insulation	680FF	680	600FF	980FF	980	600FF



Informative Figure 5-2 Primary base cases for basic cases of Section 5.2.2.

5.2.2.1 Low Mass Tests. The low-mass basic tests shall be modeled as ~~detailed~~ specified in this section and its subsections. The low-mass basic tests include cases 600 through 695~~50~~. Once an accurate input description for Case 600 has been developed, the remaining low mass basic cases~~, except Case 630,~~ shall be input by modifying Case 600, except for the following cases:~~.~~

- Case 630 shall be input by modifying Case 620
- Case 695 shall be input by modifying Case 680.

5.2.2.1.1 Case 610: South Shading. Case 610 shall be modeled exactly the same as Case 600 except for changes ~~noted~~ specified in the subsections below.
5.2.2.1.1.1 South Overhang Geometry. The overhang ~~detailed~~ specified in Figure 5-3~~2~~ shall be added. The horizontal overhang for south-facing windows shall extend across the entire length of the south wall.
5.2.2.1.1.2 Overhang Construction.
5.2.2.1.1.2.1 Properties. The following properties shall be applied to both sides of the shading device as nearly as the program being tested allows:
a. Solar absorptance = 1 (reflectance = 0, transmittance = 0) independent of incidence angle
b. Infrared emittance = 0
c. All heat from solar radiation absorbed by the shading device is dissipated to the ambient environment via convection
d. Both sides of the shading device actively shade the building.

Informative Note: For properties with values of 0, apply the lowest value allowed by the program being tested for stable simulation (e.g., 0.0001).
5.2.2.1.1.2.2 Thickness. If the program requires an input for thickness of shading devices, the smallest allowable value shall be applied (e.g., 0.001 m).
5.2.2.1.1.3~~2~~ Output Requirements. Case 610 requires the following output:
a. All non-free-float-case output in accordance with Section 6.2.1.1
b. Additional output in accordance with Section 6.2.1.3
c. General reporting requirements of Section 6.1.

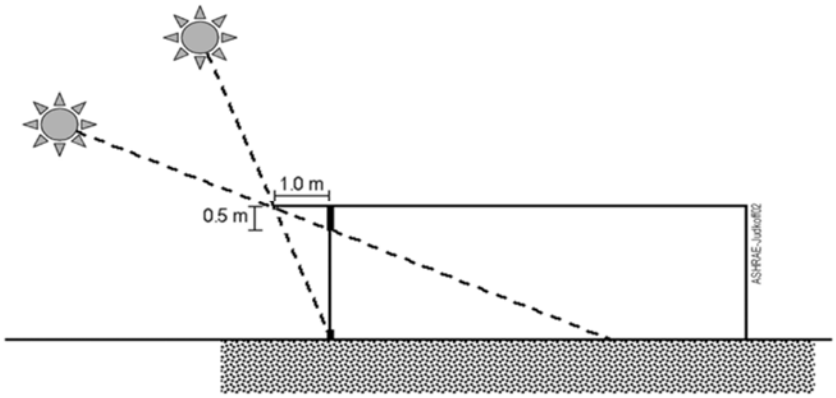


Figure 5-3~~2~~ Section of south window overhang (Case 610).

5.2.2.1.2 Case 620: East/West Window Orientation.
Case 620 shall be modeled exactly the same as Case 600 except for changes ~~noted~~ specified in the subsections below.

5.2.2.1.2.1 Window Orientation. The window orientation shall be modified, as ~~detailed~~ specified in Figure 5-4~~3~~, such that there shall be 6 m^2 of window area facing east, 6 m^2 of window area facing west, and no other windows. Other than the change in orientation, the windows shall be exactly as in Case 600.

5.2.2.1.2.2 Interior Solar Distribution.

5.2.2.1.2.2.1 This is the fractional distribution among interior surfaces of solar radiation transmitted through the windows that is absorbed by each given surface after all reflections off of interior surfaces and accounting for solar lost (transmitted solar radiation reflected by interior opaque surfaces and retransmitted back out the windows). For programs that calculate interior solar distribution internally (via ray tracing or other means based on interior solar absorptance given in Table 5-5), and do not require a separate input for interior solar distribution fraction, ignore the following Section 5.2.2.1.2.2.2 and skip to Section 5.2.2.1.2.3.

5.2.2.1.2.2.2 If the program being tested does not calculate interior solar distribution internally but requires distribution fractions from the user, then the use of Table 5-15~~9~~ shall be permitted. Use of different (nonspecified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. The use of nonspecified values shall be documented in the Standard Output Report (see Normative Annex A2).

Informative Note: Table 5-15~~9~~ presents an approximate calculation of solar distribution fractions adjusted for the geometry of Case 620 by assuming that 100% of the incoming radiation strikes the floor first and that all reflections are diffuse. Fractional values for the walls with windows (i.e., the east and west walls) include the portion of the solar radiation absorbed by the glass (as it passes back out the window) and conducted back into the zone. Solar radiation absorbed by the glass (and conducted inward) as it initially passes into the building is not included in the values in Table 5-15~~9~~. Informative Annex B7 gives background information regarding the calculation technique used for developing these solar fractions.

5.2.2.1.2.3 Output Requirements. Case 620 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. Additional output in accordance with Section 6.2.1.4
c. General reporting requirements of Section 6.1.

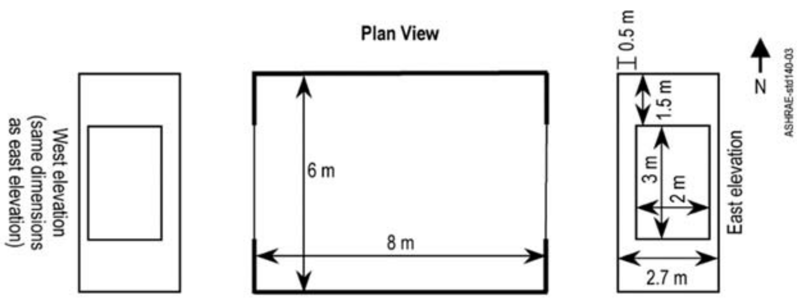


Figure 5-4~~3~~ East and west window (Case 620).

~~Informative~~ Table 5-15~~9~~ Alternative Constant Interior Solar Distribution Fractions by Surface, Case 620[a]

Surface	Floor	Ceiling	East Wall	West Wall	North Wall	South Wall	Solar Lost Through Windows
Solar Fraction	0.642	0.167~~8~~	0.025	0.025	**0.053~~25~~**	**0.053~~25~~**	0.035

a. ***Informative Note:*** **Changes to Standard 140-2017 are highlighted with bold font.**

5.2.2.1.3 Case 630: East/West Shading. Case 630 shall be modeled exactly the same as Case 620 except for changes ~~noted~~ specified in the subsections below.

5.2.2.1.3.1 East/West Overhang and Fin Geometry.
Shading devices shall be added to the east and west windows as ~~detailed~~ specified in Figures 5-5~~4~~ and 5-6~~5~~.

5.2.2.1.3.2 Overhang and Fin Construction. Shading device construction shall be applied as specified in Sections 5.2.2.1.1.2.1 and 5.2.2.1.1.2.2 (Case 610).

5.2.2.1.3.3~~2~~ Output Requirements. Case 630 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. Additional output in accordance with Section 6.2.1.5
c. General reporting requirements of Section 6.1.

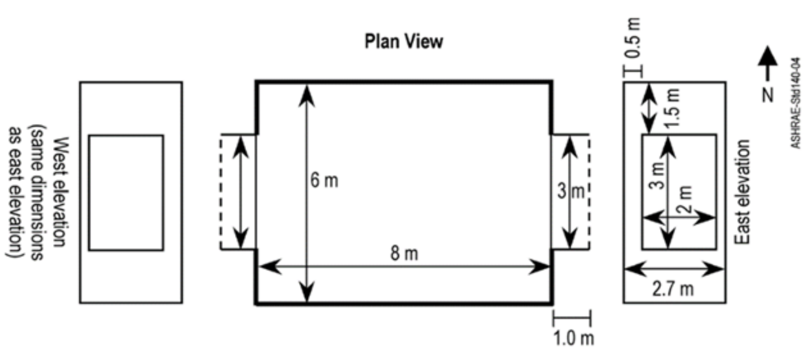


Figure 5-5~~4~~ East and west window shading (Case 630).

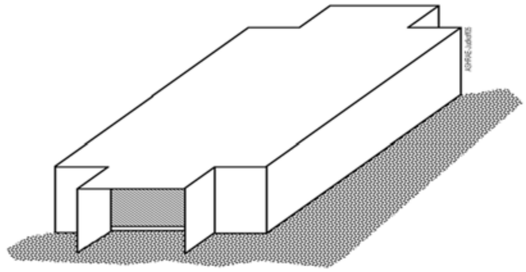


Figure 5-6~~5~~ Isometric east and west window shading (Case 630).

5.2.2.1.4 Case 640: Thermostat Setback. Case 640 shall be modeled exactly the same as Case 600 except for changes ~~noted~~ specified in the subsections below.

5.2.2.1.4.1 Thermostat Control Strategy

5.2.2.1.4.1.1 The thermostat set point control shall be scheduled as follows:

a. From 0800 hours to 2300 hours, Heat = ON IF Temperature < 20°C

b. From 2300 hours to 0700 hours, Heat = ON IF Temperature < 10°C

- The 10°C setting beginning immediately after 2300 hours shall be an instantaneous step-down from the 20°C setting ending at 2300 hours, as shown in Figure 5-7.

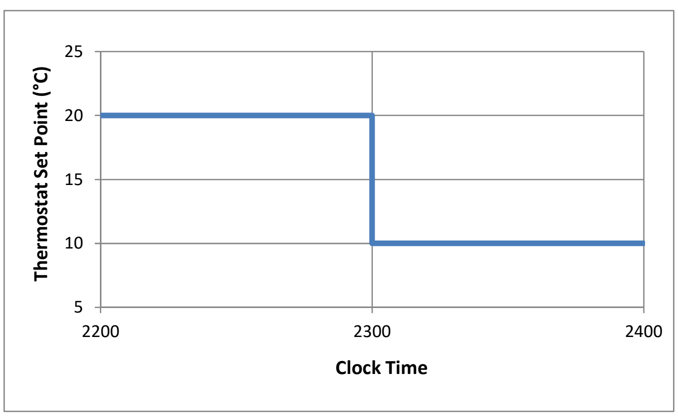


Figure 5-7 Thermostat instantaneous step down at clock time = 2300 from 20°C to 10°C (Case 640).

c. From 0700 hours to ~~2300~~ 0800 hours, ~~Heat = ON IF Temperature < 20°C~~ the thermostat set point shall vary linearly with time from 10°C to 20°C as shown in Figure 5-8. If the program runs with sub-hourly time steps, the instructions of the following Section 5.2.2.1.4.1(c.1) shall be applied and then skip Section 5.2.2.1.4.1(c.2) and continue with Section 5.2.2.1.4.1(d); if the program runs with hourly time steps, the instructions of Section 5.2.2.1.4.1(c.2) (below) shall be applied.

c.1 For programs with sub-hourly time steps, during the hour 0700 – 0800, if the zone temperature is less than the thermostat set point for a sub-hourly time step, heat shall be added to the zone such that the zone temperature at the end of each sub-hourly time step shall correspond to the thermostat set point that occurs at the end of each sub-hourly time step (see Figure 5-8), and such that zone temperature = 20°C at 0800. ***Informative Note:*** For example, incremental linear ramp-up implies that for a 15-minute time step, the set point ramps up as 12.5°C, 15°C, 17.5°C, and 20°C within the hour (0700 – 0800).

c.2 For programs with hourly time steps, during the hour 0700 – 0800, if zone temperature < 20°C at 0700, heat shall be added to the zone during the hour such that zone temperature = 20°C at 0800.

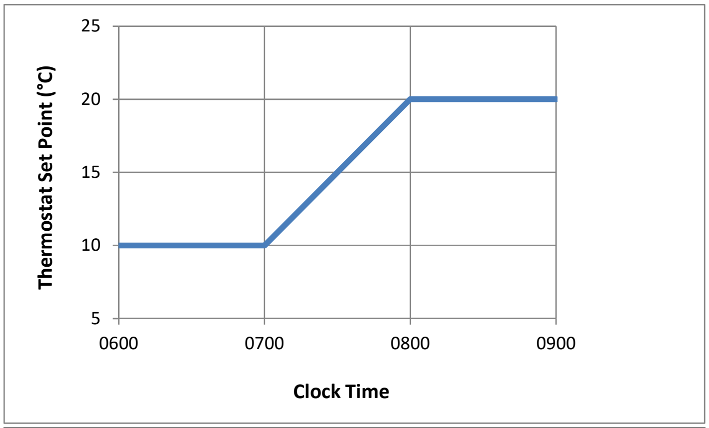


Figure 5-8 Thermostat linear variation from 10°C to 20°C for clock time = 0700 to 0800 (Case 640).

d.• All hours, Cool = ON IF Temperature > 27°C
e.• Otherwise, mechanical equipment is OFF.
Informative Note: "Temperature" refers to the conditioned-zone air temperature.
5.2.2.1.4.1.2 A nonproportional thermostat as specified in Section 5.2.1.13.1.2 (Case 600) shall be used.
5.2.2.1.4.2 Output Requirements. Case 640 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. Daily hourly output as specified for Case 640 in Section 6.2.1.8
cb. General reporting requirements of Section 6.1.

5.2.2.1.5 Case 650: Night Ventilation. Case 650 shall be modeled exactly the same as Case 600 except for changes noted specified in the subsections below.
5.2.2.1.5.1 Thermostat and Ventilation Fan Control Strategy.
5.2.2.1.5.1.1 The following configuration schedule shall be applied:
• From 1800 hours to 0700 hours, Vent fan = ON
(1800 to 0700 is the same as Hour 19 *through* Hour 7 per the time convention of Section 5.1.1.)
• From 0700 hours to 1800 hours, Vent fan = OFF
(0700 to 1800 is the same as Hour 8 *through* Hour 18 per the time convention of Section 5.1.1.)
• Heating = always OFF
• From 1800 hours to 0700 hours, Cool = OFF
• From 0700 hours to 1800 hours, Cool = ON IF Temperature > 27°C; otherwise, Cool = OFF
Informative Note: "Temperature" refers to the conditioned-zone air temperature.
5.2.2.1.5.1.2 A nonproportional thermostat as specified in Section 5.2.1.13.1.2 (Case 600) shall be used.
5.2.2.1.5.2 Ventilation Fan Characteristics
a. Vent fan capacity = 17003.16 standard m^3/h (in addition to specified infiltration rate of Section 5.2.1.6 [Case 600])
b. Waste heat from fan = 0.
c. If the program being tested does not automatically correct for the reduced density of air at altitude, inputs for the fan capacity shall be adjusted as shown in Table 5-160.
Informative Note: The calculation technique used to develop Table 5-160 is provided as background information in Informative Annex B3, Section B3.1.

Table 5-160 Vent Fan Capacity Airflow Rate Depending on the Presence of Automatic Altitude Adjustment[a]

Vent Fan Volumetric Airflow Rate Capacity Specification (in Addition to Specified Infiltration Rate)	m³/h	Air Changes per Hour, ach
Input for programs that automatically correct vent fan mass flow for altitude; set altitude to 16509 m above sea level.	1700 1703.16	13.12 13.14
Input for programs with fixed assumption that site is at sea level (no automatic correction of fan mass flow).	1409 [b] 1400	10.87 10.8

a. *Informative Note:* **Changes to Standard 140-2017 are highlighted with bold font.**
b. (Specified Rate) × (1.0156/1.2255) = (altitude adjusted rate)

5.2.2.1.5.3 Output Requirements. Case 650 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. General reporting requirements of Section 6.1.

[Note: Following are new Cases 660, 670, 680, 685, and 695 (Sections 5.2.2.1.6 through 5.2.2.1.10); edit tracking not applied.]

5.2.2.1.6 Case 660: Low-Emissivity Windows with Argon Gas.
Case 660 shall be modeled exactly the same as Case 600 except for changes specified in the subsections below.

5.2.2.1.6.1 Transparent Window.
Informative Note: Use of different algorithms to calculate window thermal and optical performance requires different inputs. Extensive information about the window properties has therefore been provided so that equivalent input for the window will be possible for many programs. Recall from Section 5.1.3 (Nonapplicable Inputs) to use only the information that is relevant to the program being tested.
5.2.2.1.6.1.1 Geometry. The windows shall have no sash area; the rough openings shown in Figure 5-1 (see Section 5.2.1.11.1 [Case 600]) shall contain only the low-e argon-filled window specified in Table 5-17.
5.2.2.1.6.1.2 Window Properties. The properties of the window provided in Table 5-17 shall be applied. All glass pane surfaces are clean; there is no dirt or fouling.
Informative Note, Calculated Properties of Informative Table 5-18: Informative Table 5-18 includes calculated values derived from fundamental properties of normative Table 5-17 and alternative constant surface coefficients of Sections 5.2.1.9.3 and 5.2.1.10.3 (Case 600), for programs that may need this information.
Informative Note, Corresponding Overall UA Values: For programs that may need this information, corresponding calculated values for south window UA and total building UA are:

- South Window UA = 14.239 W/K
- Total Building UA = 74.495 W/K

These values for Case 660 (low-e window) are analogous to those UA values listed in Informative Table 5-3 (see informative note with Section 5.2.1.4 [Case 600]) for the clear double-pane window of Case 600.
Informative Note, Variation of Listed Surface Coefficients and Overall U-Values from Values of Informative Table 5-18. For programs that calculate time-step varying surface infrared radiative exchange or convective coefficients or both, or that allow more detailed constant surface coefficient inputs (e.g., for scheduling), variation of the following from values given in Table 5-18 may be expected: individual surface coefficient U-values, effective conductance of the space between window panes, and overall U-value.
Informative Note, Variation of Conductance of the Space Between Window Panes from Values of Informative Table 5-18: For programs that automatically calculate heat transfer within a space between window panes or empty cavity, variation of the following from values given in Table 5-18 may be expected: effective conductance of the space between window panes and overall U-value.

Table 5-17 Low-Emissivity Argon-Filled Glazing System Fundamental Properties

Property	Value
Fundamental Construction Properties	
Height, individual rough opening	2 m
Width, individual rough opening	3 m
Area, individual gross window (also center of glass area)	6 m^2
Number of panes	2
Outer (low-e) pane thickness[a]	3.180 mm
Inner (clear) pane thickness[b]	3.048 mm
Thickness of space between panes[c]	12.0 mm
Fill gas (in space between panes)	Argon
Curtains, blinds, frames, spacers, mullions, obstructions inside the window	None
Basic Material Properties	
Thermal conductivity of glass[a,b]	1.00 W/(m·K)
Density of glass[d]	2470 kg/m^3
Specific heat of glass[d]	750 J/(kg·K)
Argon: conductivity (k)[e,f]	0.016349 W/(m·K), shall be allowed to vary with temperature and pressure
Argon: specific heat (c_p)[e,f]	521.928528 J/(kg·K), shall be allowed to vary with temperature and pressure
Argon: density (ρ)[e,f]	1.782282 kg/m^3, shall be allowed to vary with temperature and pressure
Argon: viscosity (μ)[e,f]	0.000021 kg/(m·s), shall be allowed to vary with temperature and pressure
Argon: Prandtl number (Pr)[e,f]	0.6704 (dimensionless), shall be allowed to vary with temperature and pressure
Argon: molecular weight[e]	39.948 g/mol
Hemispherical infrared emittance of glass[a,b]	0.840, except outer pane inside facing surface
Outer-pane inside facing surface infrared emittance[a]	0.047
Infrared transmittance of glass[a,b]	0.000
Outer-pane direct-beam transmittance[a]	0.452, at normal incidence
Outer-pane direct-beam refl., outside facing surface[a]	0.359, at normal incidence
Outer-pane direct-beam reflectance, inside facing surface[a]	0.397, at normal incidence
Inner-pane direct-beam transmittance[b]	0.834, at normal incidence
Inner-pane direct-beam reflectance (same value both sides)[b]	0.075, at normal incidence

a. ***Informative Note:*** Value from WINDOW 7 glass library, “CSR42_3.afg”; this pane is the same as the outer pane of the double-pane low-e window for WINDOW 7 glazing system ID 3 (basic low-e example).
b. ***Informative Note:*** Value from WINDOW 7 glass library, “CLEAR_3.DAT”; this is the same as the Case 600 pane.
c. ***Informative Note:*** Value same as the Case 600 glazing system.
d. ***Informative Note:*** Value for soda-lime glass from *2017 ASHRAE Fundamentals* (SI version)[B-101], p. 33.3.
e. ***Informative Note:*** Value from WINDOW 7 gas library, “Argon”.
f. ***Informative Note:*** In WINDOW 7 this value is reported at 0°C, 101.325 kPa.

Informative Table 5-18 Calculated Low-Emissivity Argon-Filled Glazing System Properties

Effective conductance of argon gap, including radiative and convective heat transfer (h_s)[a]	1.792 W/(m^2·K) [R-0.55814 m^2·K/W]
Conductance of outer pane[b]	314 W/(m^2·K) [R-0.00318 m^2·K/W]
Conductance of inner pane[b]	328 W/(m^2·K) [R-0.00305 m^2·K/W]
Exterior combined surface coefficient (h_o)[c]	17.8 W/(m^2·K) [R-0.05618 m^2·K/W]
Interior combined surface coefficient (h_i)[c]	4.5 W/(m^2·K) [R-0.22222 m^2·K/W]
U-Value from interior air to ambient air[d]	1.19 W/(m^2·K) [R-0.84277 m^2·K/W]
Double-pane solar heat gain coefficient (SHGC)[e]	0.440, at normal incidence[f]
Double-pane shading coefficient (SC)[g]	0.506, at normal incidence
Index of refraction, inner pane[h]	1.493
Extinction coefficient, inner pane[h]	0.0337/mm
Index of refraction, outer pane	Not calculated[i]
Extinction coefficient, outer pane	Not calculated[i]

a. Calculated: (argon gap conductance) = (Keff) / (thickness of space between panes), where Keff = 0.0215 W/(m·K) from Window 7 on-screen output; R-Value = 1 / (conductance).
b. Calculated: (pane conductance) = (pane conductivity) / (pane thickness); R-Value = 1 / (conductance).
c. Value from Annex B4, Section B4.1.
d. Calculated: (R value, total) = $1/(h_s)$ + (outer pane R value) + (inner pane R value) + $1/h_i$ + $1/h_o$; (U Value) = 1 / (R value). This value agrees with WINDOW 7 output of U = 1.19 W/(m·K) applying constant combined coefficients in the environmental conditions.
e. Calculated by WINDOW 7, see Informative Annex B6, Section B6.1. This matches within rounding tolerance SHGC from Equations 13, 14, and 16 (pp. 15.19-20) of *ASHRAE 2017 Fundamentals*[B-101].
f. Table 5-19 includes angle-dependent optical properties calculated by WINDOW 7.
g. WINDOW 7 on-screen value. This matches within rounding tolerance SC = SHGC/0.87 per Eqn. 91 (p. 31.39) of ASHRAE 2005 Fundamentals[B-32].
h. Calculated, based on Informative Annex B6, Section B6.2.
i. Single values of index of refraction and extinction coefficient do not adequately describe the optical properties of coated glass.

5.2.2.1.6.1.3 Alternative Incidence-Angle Dependent Optical Properties.

a. If the program being tested automatically calculates incidence-angle-dependent optical properties based on inputs from Table 5-17, or if the program does not allow direct user input of angle-dependent optical properties, then skip the instructions in this section and proceed to Section 5.2.2.1.6.2.
b. For programs that apply incidence-angle-dependent optical properties as direct inputs, the values given in Table 5-19 shall be applied.
   - For programs that need transmittance or reflectance at other angles of incidence, the user shall be permitted to interpolate between the values in Table 5-19 using the cosine of the incident angle as the basis for interpolation.
   - Where unspecified equivalent inputs are needed, values that are consistent with those specified shall be applied according to the instructions of Section 5.1.5 “Equivalent Modeling Methods.”

Informative Note: Supporting information regarding window thermal and optical properties is provided in Informative Annex B6. This includes the output report from the WINDOW 7 software[A-3] that was applied to generate values in Table 5-19 and selected values in informative Table 5-18, as described in the notes with those tables. This informative data file is included with the accompanying electronic media and may be used by simulation programs that can read it directly.

Table 5-19 Alternative Angular Dependent Optical Properties for the Low-Emissivity Window[a,b]

Angle of Incidence	Trans.	Refl.,f	Refl.,b	Abs. Outer Pane	Abs. Inner Pane	SHGC[c]
0	0.394	0.380	0.349	0.195	0.031	0.440
10	0.397	0.375	0.344	0.197	0.031	0.443
20	0.391	0.374	0.342	0.204	0.031	0.438
30	0.383	0.376	0.342	0.209	0.032	0.432
40	0.373	0.384	0.347	0.211	0.032	0.422
50	0.353	0.398	0.360	0.215	0.033	0.403
60	0.310	0.427	0.393	0.230	0.032	0.361
70	0.228	0.496	0.476	0.247	0.029	0.278
80	0.108	0.658	0.652	0.213	0.021	0.148
90	0.000	0.999	1.000	0.001	0.000	0.000
Hemis.	0.329	0.415	0.384	0.215	0.031	0.377

a. "Trans." = transmittance; "Refl.,f" = overall solar reflectance for radiation incident from the front (i.e., from the outside); "Refl.,b" = overall solar reflectance for radiation incident from the back (i.e., from inside the zone); "Abs." = absorptance; SHGC = solar heat gain coefficient; "Hemis." = hemispherically integrated.

b. ***Informative Note:*** Properties evaluated using WINDOW 7[A-3]; see Annex B6, Section B6.1.

c. ***Informative Note:*** This matches within rounding tolerance SHGC from Equations 13, 14, and 16 (pp. 15.19-20) of *ASHRAE 2017 Fundamentals*[B-101].

5.2.2.1.6.2 Interior Solar Distribution.

5.2.2.1.6.2.1 This is the fractional distribution among interior surfaces of solar radiation transmitted through the windows that is absorbed by each given surface after all reflections off of interior surfaces and accounting for solar lost (transmitted solar radiation reflected by interior opaque surfaces and retransmitted back out the windows). For programs that calculate interior solar distribution internally (via ray tracing or other means based on interior solar absorptance given in Table 5-5), and do not require a separate input for interior solar distribution fraction, ignore the following Section 5.2.2.1.6.2.2 and skip to Section 5.2.2.1.6.3.

5.2.2.1.6.2.2 If the program being tested does not calculate interior solar distribution internally but requires distribution fractions from the user, then the use of Table 5-20 shall be permitted. Use of different (nonspecified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. The use of nonspecified values shall be documented in the Standard Output Report (Normative Annex A2).

Informative Note: Table 5-20 presents an approximate calculation of solar distribution fractions by assuming that 100% of the incoming radiation strikes the floor first and that all reflections are diffuse. Fractional values for the walls with windows (i.e., the south wall) include the portion of the solar radiation absorbed by the glass (as it passes back out the window) and conducted back into the zone. Solar radiation absorbed by the glass (and conducted inward) as it initially passes into the building is not included in the values in Table 5-20. Informative Annex B7 gives background information regarding the calculation technique used for developing these solar fractions.

Table 5-20 Alternative Constant Interior Solar Distribution Fractions by Surface, Case 660

Surface	Floor	Ceiling	East Wall	West Wall	North Wall	South Wall	Solar Lost through Windows
Solar Fraction	0.645	0.170	0.039	0.039	0.054	0.026	0.027

5.2.2.1.6.3 Output Requirements. Case 660 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. Additional output in accordance with Section 6.2.1.2.2
c. Daily hourly output as specified for Case 660 in Section 6.2.1.8
d. General reporting requirements of Section 6.1.

5.2.2.1.7 Case 670: Single Pane Windows.
Case 670 shall be modeled exactly the same as Case 600 except for changes specified in the subsections below.

5.2.2.1.7.1 Transparent Window.
Informative Note: Use of different algorithms to calculate window thermal and optical performance requires different inputs. Extensive information about the window properties has therefore been provided so that equivalent input for the window will be possible for many programs. Recall from Section 5.1.3 (Nonapplicable Inputs) to use only the information that is relevant to the program being tested.
5.2.2.1.7.1.1 Geometry. The windows shall have no sash area; the rough openings shown in Figure 5-1 (see Section 5.2.1.11.1 [Case 600]) shall contain only the single-pane window specified in Table 5-21.
5.2.2.1.7.1.2 Window Properties. The properties of the window provided in Table 5-21 shall be applied. All glass pane surfaces are clean; there is no dirt or fouling.
Informative Note, Calculated Properties of Informative Table 5-22: Informative Table 5-22 includes calculated values derived from fundamental properties of normative Table 5-21 and alternative constant surface coefficients of Sections 5.2.1.9.3 and 5.2.1.10.3 (Case 600), for programs that may need this information.
Informative Note, Corresponding Overall UA Values: For programs that may need this information, corresponding calculated values for south window UA and total building UA are:
- South Window UA = 61.935 W/K
- Total Building UA = 122.191W/K

These values for Case 670 (single-pane window) are analogous to those UA values listed in Informative Table 5-3 (see informative note with Section 5.2.1.4 [Case 600]) for the clear double-pane window of Case 600.
Informative Note, Variation of Listed Surface Coefficients and Overall U-Values from Values of Informative Table 5-22. For programs that calculate time-step varying surface infrared radiative exchange or convective coefficients or both, or that allow more detailed constant surface coefficient inputs (e.g., for scheduling), variation of the following from values given in Table 5-22 may be expected: individual surface coefficient U-values, and overall U-value.
5.2.2.1.7.1.3 Alternative Incidence-Angle Dependent Optical Properties.
a. If the program being tested automatically calculates incidence-angle-dependent optical properties based on inputs from Table 5-21, or if the program does not allow direct user input of angle-dependent optical properties, then skip the instructions in this section and proceed to Section 5.2.2.1.7.2.
b. For programs that apply incidence-angle-dependent optical properties as direct inputs, the values given in Table 5-23 shall be applied.
   - For programs that need transmittance or reflectance at other angles of incidence, the user shall be permitted to interpolate between the values in Table 5-23 using the cosine of the incident angle as the basis for interpolation.
   - Where unspecified equivalent inputs are needed, values that are consistent with those specified shall be applied according to the instructions of Section 5.1.5 "Equivalent Modeling Methods."

Informative Note: Supporting information regarding window thermal and optical properties is provided in Informative Annex B6. This includes the output report from the WINDOW 7 software[A-4] that was applied to generate values in Table 5-23 and selected values in informative Table 5-22, as described in the notes with those tables. This informative data file is included with the accompanying electronic media and may be used by simulation programs that can read it directly.

Table 5-21 Clear Single-Pane Glazing System Fundamental Properties

Property	Value
Fundamental Construction Properties	
Height, individual rough opening	2 m
Width, individual rough opening	3 m
Area, individual gross window (also center of glass area)	6 m^2
Number of panes	1
Pane thickness[a]	3.048 mm
Curtains, blinds, frames, spacers, mullions, obstructions inside the window	None
Basic Material Properties	
Thermal conductivity of glass[a]	1.00 W/(m·K)
Density of glass[b]	2470 kg/m^3
Specific heat of glass[b]	750 J/(kg·K)
Hemispherical infrared emittance of glass[a]	0.840
Infrared transmittance of glass[a]	0.000
Pane direct-beam transmittance[a]	0.834, at normal incidence
Pane direct-beam reflectance (same value both sides)[a]	0.075, at normal incidence

a. ***Informative Note:*** Value from WINDOW 7 glass library, "CLEAR_3.DAT"; this is the same as the Case 600 pane.
b. ***Informative Note:*** Value for soda-lime glass from *2017 ASHRAE Fundamentals* (SI version)[B-101], p. 33.3.

Informative Table 5-22 Calculated Clear Single-Pane Glazing System Properties

Pane conductance[a]	328 W/(m^2·K) [R-0.00305 m^2·K/W]
Exterior combined surface coefficient (h_o)[b]	16.0 W/(m^2·K) [R-0.06250 m^2·K/W]
Interior combined surface coefficient (h_i)[b]	7.8 W/(m^2·K) [R-0.12821 m^2·K/W]
U-Value from interior air to ambient air[c]	5.16 W/(m^2·K) [R-0.19376 m^2·K/W]
Solar heat gain coefficient (SHGC)[d]	0.864, at normal incidence[e]
Shading coefficient (SC)[f]	0.993, at normal incidence
Index of refraction[g]	1.493
Extinction coefficient[g]	0.0337/mm

a. Calculated: (pane conductance) = (pane conductivity) / (pane thickness); R-Value = 1 / (conductance).
b. Value from Annex B4, Section B4.1.
c. Calculated: (R value, total) = (Pane R value) + $1/h_i$ + $1/h_o$; (U Value) = 1 / (R value). This value agrees with WINDOW 7 output of U = 5.16 W/(m·K) applying constant combined coefficients in the environmental conditions.
d. Calculated by WINDOW 7, see Informative Annex B6, Section B6.1. This matches within rounding tolerance SHGC from Equations 13, 14, and 16 (pp. 15.19-20) of *ASHRAE 2017 Fundamentals*[B-101].
e. Table 5-23 includes angle-dependent optical properties calculated by WINDOW 7.
f. WINDOW 7 on-screen value. This matches within rounding tolerance SC = SHGC/0.87 per Eqn. 91 (p. 31.39) of ASHRAE 2005 Fundamentals[B-32].
g. Calculated, based on Informative Annex B6, Section B6.2.

Table 5-23 Alternative Angular Dependent Optical Properties for the Single-Pane Window[a,b]

Angle of Incidence	Trans.	Refl.,f	Refl.,b	Abs.	SHGC[c]
0	0.834	0.075	0.075	0.091	0.864
10	0.833	0.075	0.075	0.092	0.864
20	0.831	0.075	0.075	0.094	0.862
30	0.827	0.077	0.077	0.096	0.859
40	0.818	0.082	0.082	0.100	0.851
50	0.797	0.099	0.099	0.104	0.831
60	0.749	0.143	0.143	0.108	0.785
70	0.637	0.253	0.253	0.110	0.673
80	0.389	0.506	0.506	0.105	0.424
90	0.000	1.000	1.000	0.000	0.000
Hemis.	0.753	0.136	0.136	0.101	0.787

a. "Trans." = transmittance; "Refl.,f" = overall solar reflectance for radiation incident from the front (i.e., from the outside); "Refl.,b" = overall solar reflectance for radiation incident from the back (i.e., from inside the zone); "Abs." = absorptance; SHGC = solar heat gain coefficient; "Hemis." = hemispherically integrated. "Refl.,f" = "Refl.,b", for this glazing system.

b. ***Informative Note:*** Properties evaluated using WINDOW 7[A-4]; see Annex B6, Section B6.1.

c. ***Informative Note:*** This matches within rounding tolerance SHGC from Equations 13, 14, and 16 (pp. 15.19-20) of *ASHRAE 2017 Fundamentals*[B-101].

5.2.2.1.7.2 Interior Solar Distribution.

5.2.2.1.7.2.1 This is the fractional distribution among interior surfaces of solar radiation transmitted through the windows that is absorbed by each given surface after all reflections off of interior surfaces and accounting for solar lost (transmitted solar radiation reflected by interior opaque surfaces and retransmitted back out the windows). For programs that calculate interior solar distribution internally (via ray tracing or other means based on interior solar absorptance given in Table 5-5), and do not require a separate input for interior solar distribution fraction, ignore the following Section 5.2.2.1.7.2.2 and skip to Section 5.2.2.1.7.3.

5.2.2.1.7.2.2 If the program being tested does not calculate interior solar distribution internally but requires distribution fractions from the user, then the use of Table 5-24 shall be permitted. Use of different (nonspecified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. The use of nonspecified values shall be documented in the Standard Output Report (Normative Annex A2).

Informative Note: Table 5-24 presents an approximate calculation of solar distribution fractions by assuming that 100% of the incoming radiation strikes the floor first and that all reflections are diffuse. Fractional values for the walls with windows (i.e., the south wall) include the portion of the solar radiation absorbed by the glass (as it passes back out the window) and conducted back into the zone. Solar radiation absorbed by the glass (and conducted inward) as it initially passes into the building is not included in the values in Table 5-24. Informative Annex B7 gives background information regarding the calculation technique used for developing these solar fractions.

Table 5-24 Alternative Constant Interior Solar Distribution Fractions by Surface, Case 670

Surface	Floor	Ceiling	East Wall	West Wall	North Wall	South Wall	Solar Lost through Windows
Solar Fraction	0.641	0.166	0.038	0.038	0.052	0.025	0.040

5.2.2.1.7.3 Output Requirements. Case 670 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. Additional output in accordance with Section 6.2.1.2.2
c. Daily hourly output as specified for Case 670 in Section 6.2.1.8
d. General reporting requirements of Section 6.1.

5.2.2.1.8 Case 680: Increased Exterior Wall and Roof Insulation. Case 680 shall be modeled exactly the same as Case 600, except for changes specified in the subsections below.

5.2.2.1.8.1 Material Properties. For the walls and floor, the fundamental materials specifications of Table 5-25 shall be applied in place of the materials specifications of Table 5-2 (see Section 5.2.1.4 [Case 600]). The following changes shall be applied as indicated with bold font in Table 5-25:

- Exterior wall insulation material is changed to foam insulation and thickness is increased; this change is applied to all four exterior walls.
- Roof fiberglass quilt thickness is increased.
- The floor is unchanged from Case 600.

Informative Note: Informative Table 5-26 includes summary calculated values derived from fundamental properties of normative Table 5-25 and alternative constant surface coefficients of Sections 5.2.1.9.3 and 5.2.1.10.3 (Case 600), for programs that may need this information. Changes indicated in Informative Table 5-26 versus Informative Table 5-3 (see Section 5.2.1.4 [Case 600]) are highlighted with bold font. For programs that automatically calculate surface radiation or convection or both, or that allow more detailed constant surface coefficient inputs (e.g., for scheduling), variation of individual interior surface coefficient U-values, total U and total UA values, and heat capacities from Table 5-26 may be expected.

5.2.2.1.8.2 Output Requirements. Case 680 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. Additional output specified for Case 680 in Section 6.2.1.8
c. General reporting requirements of Section 6.1.

Table 5-25 Material Specifications, Increased Exterior Wall and Roof Insulation, Low Mass Case[a]

Element	k, W/(m·K)	Thickness, m	U, W/(m²·K)	R, m²·K/W	Density, kg/m³	c_p, J/(kg·K)
Fundamental Material Thermal Properties						
Low Mass Case: Exterior Wall (inside to outside)						
Plasterboard	0.16	0.012	13.333	0.075	950	840
Foam Insulation	0.04	**0.250**	**0.160**	**6.250**	**10**	**1400**
Wood Siding	0.14	0.009	15.556	0.064	530	900
Low Mass Case: Raised Floor (inside to outside)[b]						
Timber flooring	0.14	0.025	5.600	0.179	650	1200
Insulation	0.04	1.003	0.040	25.075	0[c]	0[c]
Low Mass Case: Roof (inside to outside)						
Plasterboard	0.16	0.010	16.000	0.063	950	840
Fiberglass quilt	0.04	**0.400**	**0.100**	**10.000**	12	840
Roofdeck	0.14	0.019	7.368	0.136	530	900

a. **Changes to Case 600 are highlighted with bold font, except headers are always bold.** All other properties remain as in Case 600.
b. The Case 680 floor is the same as the Case 600 floor.
c. Underfloor insulation has the minimum density and specific heat the program being tested will allow, but not < 0.

Informative Table 5-26 Calculated Summary Thermal Conductances and Heat Capacities, Increased Exterior Wall and Roof Insulation, Low Mass Case[a]

Element	U, W/(m²·K)	R, m²·K/W
Low Mass Case: Exterior Wall (inside to outside)		
Interior Surface Coefficient	1.8	0.556
Total surface-to-surface[b]	**0.157**	**6.389**
Exterior Surface Coefficient	21.6	0.046
Total air-to-air[c]	**0.143**	**6.991**
Low Mass Case: Raised Floor (inside to outside)[d]		
Interior Surface Coefficient	3.7	0.270
Total surface-to-surface[b]	0.040	25.254
Exterior Surface Coefficient	5.2	0.192
Total air-to-air[c]	0.039	25.716
Low Mass Case: Roof (inside to outside)		
Interior Surface Coefficient	1.700	0.588
Total surface-to-surface[b]	**0.098**	**10.198**
Exterior Surface Coefficient	21.8	0.046
Total air-to-air[c]	**0.092**	**10.832**

Summary: Low Mass Case Component	Area, m²	UA, W/K	Heat Capacity[e], kJ/K Internal[f]	Heat Capacity[e], kJ/K Total
Wall	63.6	**9.097**	**832**	**1105**
Floor	48.0	1.867	936	936
Roof	48.0	**4.431**	**577**	**1012**
S Window	12.0	25.184		
Infiltration[g]		18.555		
Total		**59.134**	**2344**	**3052**

Values and Air Properties for UA infiltration[g]	ach	Volume, m³	Density, kg/m³	c_p, J/(kg·K)
	0.5	129.6	1.0156	1015

a. **Changes to Case 600 are highlighted with bold font, except headers are always bold.** All other calculated properties remain as in Case 600.
b. "Total surface-to-surface" values are based on the sum of the R-values for the basic material properties for the given construction element.
c. "Total air-to-air" values are based on the sum of the listed surface coefficients and "Total surf – surf" R-value for the given construction element.
d. The Case 680 floor is the same as the Case 600 floor.
e. Heat Capacity = density × cp × thickness × surface area, summed for each component of the given element.
f. Internal heat capacity includes building mass within the thermal envelope (i.e., plasterboard, timber flooring, and insulation included; wood siding and roofdeck excluded).
g. UA corresponding to infiltration based on average values calculated from the weather data, as described in Informative Table 5-3, note f.

5.2.2.1.9 Case 685: Base Case with "20,20" Thermostat. Case 685 shall be modeled exactly the same as Case 600, except for changes specified in the subsections below.

5.2.2.1.9.1 Thermostat Control

5.2.2.1.9.1.1 The following "20,20" thermostat control configuration shall be used:

- Heat = ON if temperature < 20ºC
- Cool = ON if temperature > 20ºC.

Informative Note: "Temperature" refers to the conditioned-zone air temperature.

5.2.2.1.9.1.2 The thermostat shall be nonproportional as specified in Section 5.2.1.13.1.2 (Case 600).

5.2.2.1.9.2 Output Requirements. Case 685 requires the following output:

a. All non-free-float case output in accordance with Section 6.2.1.1
b. Additional output specified for Case 685 in Section 6.2.1.8
c. General reporting requirements of Section 6.1.

5.2.2.1.10 Case 695: Increased Exterior Wall and Roof Insulation with "20,20" Thermostat. Case 695 shall be modeled exactly the same as Case 680 (increased exterior wall and roof insulation), except for changes specified in the subsections below.

5.2.2.1.10.1 Thermostat Control

5.2.2.1.10.1.1 The following "20,20" thermostat control configuration shall be used (as in Case 685):

- Heat = ON if temperature < 20ºC
- Cool = ON if temperature > 20ºC.

Informative Note: "Temperature" refers to the conditioned-zone air temperature.

5.2.2.1.10.1.2 The thermostat shall be nonproportional as specified in Section 5.2.1.13.1.2 (Case 600).

5.2.2.1.10.2 Output Requirements. Case 695 requires the following output:

a. All non-free-float case output in accordance with Section 6.2.1.1
b. Additional output specified for Case 695 in Section 6.2.1.8
c. General reporting requirements of Section 6.1.

[Note: Edits to existing material recommence here.]

5.2.2.2 High Mass Basic Tests. The high mass basic tests shall be modeled as ~~detailed~~ specified in this section and its subsections. These tests include cases 900 through 995. ~~960.~~ The first case shall be Case 900. Once an accurate input description for Case 900 has been developed, the remaining high mass cases~~, except for Case 960,~~ shall be input by modifying each corresponding 600-series case as indicated case-by-case below, except for the following cases:~~.~~

- Case 960 (sunspace) shall be based on Case 600 and shall integrate aspects of Case 900 as specified in Section 5.2.2.2.7.
- Case 995 shall be input by modifying Case 980 as specified in Section 5.2.2.2.10.

Informative Note: For Cases 900 through 950 and 985, ~~T~~the high mass cases are the same as the corresponding low mass 600-series cases except that material properties are taken from Table 5-27~~11~~ rather than Table 5-2~~1.~~ so that ~~T~~the wall and floor properties are more massive;~~, and~~ the roof properties and all surface textures are unchanged. For Cases 980 and 995, where wall and roof insulation properties are varied, the high mass cases are the same as the corresponding low mass 600-series cases (Cases 680 and 695) except that material properties are taken from Table 5-31 rather than Table 5-25.

5.2.2.2.1 Case 900: High Mass Base Building. Case 900 shall be modeled exactly the same as Case 600, except for changes ~~noted~~ specified in the subsections below.

5.2.2.2.1.1 Material Properties. For the~~ exterior~~ walls and floor, the fundamental materials specifications of Table 5-27~~11~~ shall be ~~used~~ applied in place of the materials specifications of Table 5-2~~1~~ (see Section 5.2.1.4 [Case 600]). The roof materials shall not change for any of the 900-series cases. The surface textures of Sections 5.2.1.9.2 and 5.2.1.10.2 (Case 600) shall continue to apply. ***Informative Note:*** Informative Table 5-28 includes summary calculated values derived from fundamental properties of normative Table 5-27 and alternative constant surface coefficients of Sections 5.2.1.9.3 and 5.2.1.10.3 (Case 600), for programs that may need this information. For programs that automatically calculate surface radiation or convection or both, or that allow more detailed constant surface coefficient inputs (e.g., for scheduling), variation of individual interior surface coefficient U-values, total U and total UA values, and heat capacities from Table 5-28 may be expected.

[Note: Table 5-11 of 140-2017 revised with normative material designated as Table 5-27 and informative material designated as Informative Table 5-28, similar change as for Case 600 (Tables 5-2 and 5-3).]

Table 5-27~~11~~ Material Specification ~~Heavyweight~~ High Mass Case

Element	k, W/(m·K)	Thickness, m	U, W/(m^2·K)	R, m^2·K/W	Density, kg/m^3	c_p, J/(kg·K)
Fundamental Material Thermal Properties						
~~Heavyweight~~ High Mass Case: Exterior Wall (inside to outside)						
Concrete Block	0.51~~0~~	0.100	5.100	0.196	1400	1000
Foam Insulation	0.04~~0~~	0.0615	0.651	1.537	10	1400
Wood Siding	0.14~~0~~	0.009	15.556	0.064	530	900
~~Heavyweight~~ High Mass Case: Raised Floor (inside to outside)						
Concrete Slab	1.13~~0~~	0.080	14.125	0.071	1400	1000
Insulation	0.04~~0~~	1.007[a]	0.040	25.175	0[b]	0[b]
~~Heavyweight~~ High Mass Case: Roof (inside to outside)[c]						
Plasterboard	0.16~~0~~	0.010	16.000	0.063	950	840
Fiberglass quilt	0.04~~0~~	0.1118	0.358	2.794	12	840
Roofdeck	0.14~~0~~	0.019	7.368	0.136	530	900

a. ***Informative Note:*** Because the R-value of the concrete slab material layer in Case 900 varies slightly from the R-value of the timber floor layer in Case 600, the floor insulation thickness varies slightly from Case 600 so that the total floor R-values match better for both cases.
[Note: Previous Note a is with Table 5-28, shown as deleted.]

b. Underfloor insulation has the minimum density and specific heat the program being tested will allow, but not < 0.
c. ***Informative Note:*** The ~~heavyweight~~ high mass case roof is the same as the ~~lightweight~~ low mass case roof.

[Note: In Table 5-28, tracked changes indicate changes to values of 140-2017, but are not applied for the rearrangement of existing material.]

Informative Table 5-28 Calculated Summary Thermal Conductances and Heat Capacities, High Mass Case[a]

Element			U, W/(m²·K)	R, m²·K/W	
High Mass Case: Exterior Wall (inside to outside)					
Interior Surface Coefficient			**1.8** ~~8.290~~	**0.556** ~~0.121~~	
Total surface-to-surface[b]			0.556	1.797	
Exterior Surface Coefficient			**21.6** ~~29.300~~	**0.046** ~~0.034~~	
Total air-to-air[c]			**0.417** ~~**0.512**~~	**2.399** ~~**1.952**~~	
High Mass Case: Raised Floor (inside to outside)					
Interior Surface Coefficient[a]			**3.7** ~~8.290~~	**0.270** ~~0.121~~	
Total surface-to-surface[b]			0.040	25.246	
Exterior Surface Coefficient			**5.2**	**0.192**	
Total air-to-air[c]			0.039	**25.708** ~~**25.366**~~	
High Mass Case: Roof (inside to outside)[d]					
Interior Surface Coefficient[a]			**1.700** ~~8.290~~	**0.588** ~~0.121~~	
Total surface-to-surface[b]			0.334	2.992	
Exterior Surface Coefficient			**21.8** ~~29.300~~	**0.046** ~~0.034~~	
Total air-to-air[c]			**0.276** ~~**0.318**~~	**3.626** ~~**3.147**~~	
Summary: ~~Heavyweight~~ High Mass Case				**Heat Capacity[e], kJ/K**	
Component	**Area, m²**		**UA, W/K**	**Internal[f]**	**Total**
Wall	63.6~~00~~		**26.509** ~~32.580~~	**8959**	**9232**
Floor	48.0~~00~~		**1.867** ~~1.892~~	**5376**	**5376**
Roof	48.0~~00~~		**13.237** ~~15.253~~	**437**	**872**
S. Window	12.0~~00~~		**25.184** ~~36.000~~		
Infiltration[g]			**18.555** ~~18.440[d]~~		
Total ~~**UA (with S. Glass)**~~			**85.351** ~~**104.165**~~	**14772**	**15480**
~~**Total UA (without S. Glass)**~~			~~**68.165**~~		
Values and Air Properties for UA infiltration[g]	**ach**	**Volume, m³**	~~**Altitude, m**~~	**Density, kg/m³**	**c_p, J/(kg·K)**
	0.5~~00~~	129.6	~~1609.0~~	**1.0156**	**1015**

~~a. *Informative Note:* The interior film coefficient for floors and ceilings is a compromise between upward and downward heat flow for summer and winter.~~
a. Values that were added or changed from Standard 140-2017 are highlighted with bold font.
b. "Total surface-to-surface" values are based on the sum of the R-values for the basic material properties for the given construction element.
c. "Total air-to-air" values are based on the sum of the listed surface coefficients and "Total surf – surf" R-value for the given construction element.
d~~c~~. ~~***Informative Note:***~~ The ~~heavyweight~~ high mass case roof is the same as the ~~lightweight~~ low mass case roof.
e~~h~~. Heat Capacity = density × Cp × thickness × surface area, summed for each component of the given element.
f. Internal heat capacity includes building mass within the thermal envelope (i.e., concrete block, plasterboard, concrete slab, and insulation included; wood siding and roofdeck excluded).
g. ~~***Informative Note:***~~ UA corresponding to infiltration based on average values calculated from the weather data: ach × volume × (1 hr/3600 s) × (specific heat of moist air [cp]) × (density of moist air ~~at specified altitude~~); where specific heat of moist air = cpa + W·cpv, where specific heat of dry air (cpa) = 1006 J/(kg·K) and specific heat of water vapor (cpv) = 1860 J/(kg·K)$^{A-1}$. For average humidity ratio (W) = 0.0049 kgv/kgda, implies cp = 1015 J/(kg·K), and density of moist air is as calculated in informative Annex B3, Section B3.1.

5.2.2.2.1.2 Output Requirements. Case 900 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. Monthly conditioned zone load output specified in Section 6.2.1.2.4
c~~b~~. Additional output specified for Case 900 in Section 6.2.1.8
d~~c~~. General reporting requirements of Section 6.1.

5.2.2.2.2 Case 910: High Mass South Shading. Case 910 shall be modeled exactly the same as Case 610 except for changes ~~noted~~ specified in the subsections below.
5.2.2.2.2.1 Material Properties. See the requirements of Section 5.2.2.2.1.1 (Case 900).
5.2.2.2.2.2 Output Requirements. Case 910 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. General reporting requirements of Section 6.1.

5.2.2.2.3 Case 920: High Mass East/West Window Orientation. Case 920 shall be modeled exactly the same as Case 620 except for changes ~~noted~~ specified in the subsections below.
5.2.2.2.3.1 Material Properties. See the requirements of Section 5.2.2.2.1.1 (Case 900).
5.2.2.2.3.2 Output Requirements. Case 920 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. General reporting requirements of Section 6.1.
5.2.2.2.4 Case 930: High Mass East/West Shading. Case 930 shall be modeled exactly the same as Case 630 except for changes ~~noted~~ specified in the subsections below.
5.2.2.2.4.1 Material Properties. See the requirements of Section 5.2.2.2.1.1 (Case 900).
5.2.2.2.4.2 Output Requirements. Case 930 requires the following output:
a. All non-free float case output in accordance with Section 6.2.1.1
b. General reporting requirements of Section 6.1.
5.2.2.2.5 Case 940: High Mass Thermostat Setback.
Case 940 shall be modeled exactly the same as Case 640 except that the exterior wall and floor materials specifications of Table 5-27~~11~~ shall be~~ used~~ applied in place of the materials specifications of Table 5-2~~1~~.
5.2.2.2.6 Case 950: High Mass Night Ventilation.
Case 950 shall be modeled exactly the same as Case 650 except that the exterior walls and floor materials specifications of Table 5-27~~11~~ shall be~~ used~~ applied in place of the materials specifications of Table 5-2~~1~~.
5.2.2.2.7 Case 960: Sunspace. Case 960 shall consist of two zones (back zone and sun zone) separated by a common wall (as specified in Figure 5-9~~6~~). The back zone shall be of lightweight construction, and the sun zone shall be of heavyweight construction.

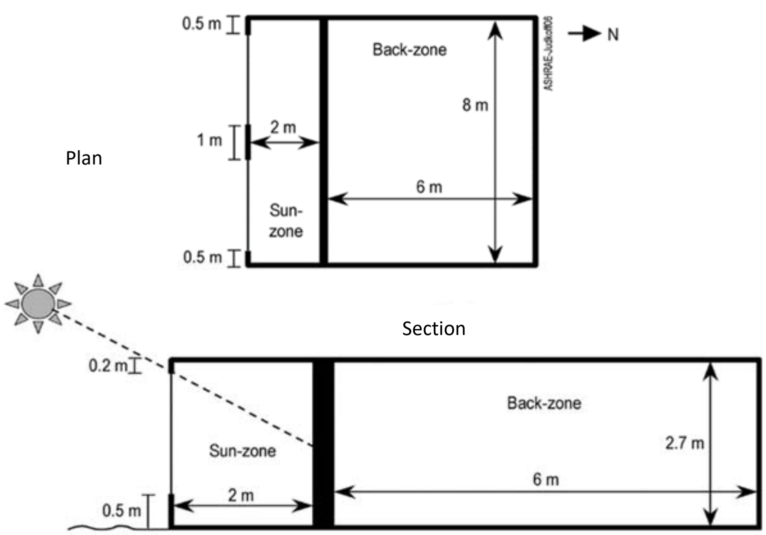


Figure 5-9~~6~~ Sunspace plan and section (Case 960).
Informative Note: In Figure 5-9, plan and section diagrams have different scales.

5.2.2.2.7.1 Back Zone
a. The geometric and thermal properties of the back zone shall be exactly the same as for Case 600 except that the south wall and windows are replaced with the common wall.
b. Infiltration in the back zone = 0.5 ach. This is exchange of back zone air and ambient air only; there is no inter-zonal air exchange between the sun zone and the back zone. If the program being tested does not use barometric pressure from weather data or otherwise automatically correct for the change in air density due to altitude, then follow the requirements of Section 5.2.1.6.1 (Case 600).
c. Internal heat generation in the back zone shall be as specified in Section 5.2.1.7 (Case 600).
5.2.2.2.7.2 Sun Zone/Back Zone Common Wall.
Material properties of the sun-zone/back-zone common wall specified in Table 5-29~~12~~ shall be used. In Table 5-29, U- and R-values are surface-to-surface conductance and resistance, excluding interior surface heat transfer coefficients. If the program being tested does not calculate interior surface convective coefficients and infrared radiative exchange varying with time step, then the instructions of Section 5.2.1.10 (Case 600) shall apply.

Table 5-29~~12~~ Thermal and Physical Properties of the Sun-Zone/Back-Zone Common Wall (Case 960)

k, W/(m·K)	Thickness, m	U, W/(m²·K)	R, m²·K/W	Density, kg/m³	~~Specific Heat~~ c_p, J/(kg·K)	Shortwave Absorptance	Infrared Emittance
0.510	0.20	2.55	0.392	1400	1000	0.6	0.9

5.2.2.2.7.3 Sun Zone. The sun zone shall be 2 m deep by 8 m wide by 2.7 m high. The back (north) wall of the sun zone shall be the common wall. The south wall of the sun zone shall contain two 6 m² windows that shall be the same as the windows in Case 900 except that they are raised 0.3 m higher on the south wall than in Case 900 (as specified in Figure 5-9~~6~~). The thermal and physical properties of the sun zone shall be the same as Case 900 with the following exceptions:

a. Zone depth shall be 2 m.
b. The north wall shall be replaced by the common wall.
c. The south wall shall have two 3×2 m windows raised 0.3 m higher on the south wall than in Case 900. These windows shall be double-pane and have the same properties as the windows in Case 900.
d. The east and west walls of the sun zone (end walls) shall be 5.4 m² each.
e. The air volume of the sun zone shall be 43.2 m².
f. Infiltration in the sun zone shall be 0.5 ach. This is exchange of sun zone air and ambient air only; there is no inter-zonal air exchange between the sun zone and the back zone. If the program being tested does not use barometric pressure from weather data or otherwise automatically correct for the change in air density due to altitude, then the infiltration rate shall be adjusted according to Section 5.2.1.6.1 (Case 600).
g. Internal heat gains in the sun zone = 0 W.
h. The exact geometric details shall be as shown in Figure 5-9~~6~~.

5.2.2.2.7.4 Interior Solar Distribution in Sun Zone.

5.2.2.2.7.4.1 This is the fractional distribution among interior surfaces of solar radiation transmitted through the windows that is absorbed by each given surface after all reflections off of interior surfaces and accounting for solar lost (transmitted solar radiation reflected by interior opaque surfaces and retransmitted back out the windows). For programs that calculate interior solar distribution internally (via ray tracing or other means based on interior solar absorptance given in Table 5-5), and do not require a separate input for interior solar distribution fraction, ignore the following Section 5.2.2.2.7.4.2 and skip to Section 5.2.2.2.7.5.

5.2.2.2.7.4.2 If the program being tested does not calculate ~~this effect~~ interior solar distribution internally but requires distribution fractions from the user, the use of Table 5-30~~13~~ shall be permitted. Use of different (nonspecified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. The use of nonspecified values shall be documented in the Standard Output Report (Normative Annex A2).

Table 5-30~~13~~ Alternative Constant Interior Solar Distribution Fractions by Surface, Case 960, Sun Zone[a]

Surface	Floor	Ceiling	East Wall	West Wall	North Wall	South Wall	Solar Lost Through Windows
Solar Fraction	0.6	**0.05~~6~~**	0.02	0.02	0.2	0.03	**0.08~~7~~**

a. Values that were changed from Standard 140-2017 are highlighted with bold font.

Informative Note: Table 5-30~~13~~ presents an approximate calculation of solar distribution fractions adjusted for the geometry of the Case 960 sun zone by assuming that 100% of the incoming radiation strikes the floor first and that all reflections are diffuse. Fractional values for the walls with windows (i.e., the sun zone south wall) include the portion of the solar radiation absorbed by the glass (as it passes back out the window) and conducted back into the zone. Solar radiation absorbed by the glass (and conducted inward) as it initially passes into the building is not included in the values in Table 5-30~~13~~. Informative Annex B7 gives background information regarding the calculation technique used for developing these solar fractions.

5.2.2.2.7.5 Heating and Cooling Control Strategies

a. The sun zone shall not have a space conditioning system, and the sun zone air temperature shall be allowed to free-float.

b. The back zone shall be controlled the same as for Case 600.
5.2.2.2.7.6 Interzone Mass Transfer. There shall be no mechanically-driven or natural interzone air exchange.
5.2.2.2.7.7 Output Requirements. Case 960 requires the following output:
a. Back zone only, all non-free-float case outputs in accordance with Section 6.2.1.1
b. Sun zone only, all free-float case outputs in accordance with Section 6.2.1.6
c. General reporting requirements of Section 6.1.

[Note: Following are new Cases 980, 985, and 995 (Sections 5.2.2.2.8, 5.2.2.2.9, and 5.2.2.2.10, respectively); edit tracking not applied.]

5.2.2.2.8 Case 980: High Mass Increased Exterior Wall and Roof Insulation. Case 980 shall be modeled exactly the same as Case 900, except for changes specified in the subsections below.

5.2.2.2.8.1 Material Properties. For the walls and floor, the fundamental materials specifications of Table 5-31 shall be applied in place of the materials specifications of Table 5-27 (see Section 5.2.2.2.1.1 [Case 900]). The following changes shall be applied as indicated with bold font in Table 5-31:

- Exterior wall insulation thickness is increased; this change is applied to all four exterior walls.
- Roof fiberglass quilt thickness is increased.
- The floor is unchanged from Case 900.

Informative Note: Informative Table 5-32 includes summary calculated values derived from fundamental properties of normative Table 5-31 and alternative constant surface coefficients of Sections 5.2.1.9.3 and 5.2.1.10.3 (Case 600, also applied for Case 900), for programs that may need this information. Changes indicated in Informative Table 5-32 versus Informative Table 5-28 (see Section 5.2.2.2.1.1 [Case 900]) are highlighted with bold font. For programs that automatically calculate surface radiation or convection or both, or that allow more detailed constant surface coefficient inputs (e.g., for scheduling), variation of individual interior surface coefficient U-values, total U and total UA values, and heat capacities from Table 5-32 may be expected.

5.2.2.2.8.2 Output Requirements. Case 980 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. Additional output specified for Case 980 in Section 6.2.1.8
c. General reporting requirements of Section 6.1.

Table 5-31 Material Specifications, Increased Exterior Wall and Roof Insulation, High Mass Case[a]

Element	k, W/(m·K)	Thickness, m	U, W/(m²·K)	R, m²·K/W	Density, kg/m³	c_p, J/(kg·K)
Fundamental Material Thermal Properties						
High Mass Case: Exterior Wall (inside to outside)						
Concrete Block	0.51	0.100	5.100	0.196	1400	1000
Foam Insulation	0.04	**0.2452**	**0.163**	**6.130**	10	1400
Wood Siding	0.14	0.009	15.556	0.064	530	900
High Mass Case: Raised Floor (inside to outside)[b]						
Concrete Slab	1.13	0.080	14.125	0.071	1400	1000
Insulation	0.04	1.007[c]	0.040	25.175	0[d]	0[d]
High Mass Case: Roof (inside to outside)[e]						
Plasterboard	0.16	0.010	16.000	0.063	950	840
Fiberglass quilt	0.04	**0.4**	**0.100**	**10.000**	12	840
Roofdeck	0.14	0.019	7.368	0.136	530	900

a. **Changes to Case 900 are highlighted with bold font, except headers are always bold.** All other calculated properties remain as in Case 900.
b. The Case 980 floor is the same as the Case 900 floor.
c. ***Informative Note:*** Because the R-value of the concrete slab material layer in Case 900 (and Case 980) varies slightly from the R-value of the timber floor layer in Case 600 (and Case 680), the floor insulation thickness varies slightly from Case 600 so that the total floor R-values match better for the cases.
d. Underfloor insulation has the minimum density and specific heat the program being tested will allow, but not < 0.
e. ***Informative Note:*** The Case 980 roof is the same as the low mass Case 680 roof.

Informative Table 5-32 Calculated Summary Thermal Conductances and Heat Capacities, Increased Exterior Wall and Roof Insulation, High Mass Case[a]

Element		U, W/(m²·K)	R, m²·K/W	
High Mass Case: Exterior Wall (inside to outside)				
Interior Surface Coefficient		1.8	0.556	
Total surface-to-surface[b]		**0.156**	**6.390**	
Exterior Surface Coefficient		21.6	0.046	
Total air-to-air[c]		**0.143**	**6.992**	
High Mass Case: Raised Floor (inside to outside)[d]				
Interior Surface Coefficient		3.7	0.270	
Total surface-to-surface[b]		0.040	25.246	
Exterior Surface Coefficient		5.2	0.192	
Total air-to-air[c]		0.039	25.708	
High Mass Case: Roof (inside to outside)[e]				
Interior Surface Coefficient		1.700	0.588	
Total surface-to-surface[b]		**0.098**	**10.198**	
Exterior Surface Coefficient		21.8	0.046	
Total air-to-air[c]		**0.092**	**10.832**	
Summary: High Mass Case			**Heat Capacity[f], kJ/K**	
Component	**Area, m²**	**UA, W/K**	**Internal[g]**	**Total**
Wall	63.6	**9.096**	**9122**	**9395**
Floor	48.0	1.867	5376	5376
Roof	48.0	**4.431**	**577**	**1012**
S. Window	12.0	25.184		
Infiltration[h]		18.555		
Total		**59.133**	**15075**	**15783**

Values and Air Properties for UA infiltration[h]	ach	Volume, m³	Density, kg/m³	c_p, J/(kg·K)
	0.5	129.6	1.0156	1015

a. **Changes to Case 900 are highlighted with bold font, except headers are always bold.** All other calculated properties remain as in Case 900.
b. "Total surface-to-surface" values are based on the sum of the R-values for the basic material properties for the given construction element.
c. "Total air-to-air" values are based on the sum of the listed surface coefficients and "Total surf – surf" R-value for the given construction element.
d. The Case 980 floor is the same as the Case 900 floor.
e. The Case 980 roof is the same as the low mass Case 680 roof.
f. Heat Capacity = density × Cp × thickness × surface area, summed for each component of the given element.
g. Internal heat capacity includes building mass within the thermal envelope (i.e., concrete block, plasterboard, concrete slab, and insulation included; wood siding and roofdeck excluded).
h. UA corresponding to infiltration based on average values calculated from the weather data, as described in Informative Table 5-3, note f.

5.2.2.2.9 Case 985: High Mass with "20,20" Thermostat. Case 985 shall be modeled exactly the same as Case 900, except for changes specified in the subsections below.

5.2.2.2.9.1 Thermostat Control
5.2.2.2.9.1.1 The following "20,20" thermostat control configuration shall be used (as in Case 685):
• Heat = ON IF Temperature < 20ºC
• Cool = ON IF Temperature > 20ºC.
Informative Note: "Temperature" refers to the conditioned-zone air temperature.
5.2.2.2.9.1.2 The thermostat shall be nonproportional as specified in Section 5.2.1.13.1.2 (Case 600, also applied in Case 685).

5.2.2.2.9.2 Output Requirements. Case 985 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. Additional output specified for Case 985 in Section 6.2.1.8
c. General reporting requirements of Section 6.1.

5.2.2.2.10 Case 995: High Mass Increased Exterior Wall and Roof Insulation with "20,20" Thermostat. Case 995 shall be modeled exactly the same as Case 980 (high mass increased exterior wall and roof insulation), except for changes specified in the subsections below.
5.2.2.2.10.1 Thermostat Control

5.2.2.2.10.1.1 The following "20,20" thermostat control configuration shall be used (as in Case 685):
• Heat = ON IF Temperature < 20ºC
• Cool = ON IF Temperature > 20ºC.
Informative Note: "Temperature" refers to the conditioned-zone air temperature.
5.2.2.2.10.1.2 The thermostat shall be nonproportional as specified in Section 5.2.1.13.1.2 (Case 600, also applied in Case 685).

5.2.2.2.10.2 Output Requirements. Case 995 requires the following output:
a. All non-free-float case output in accordance with Section 6.2.1.1
b. Additional output specified for Case 995 in Section 6.2.1.8
c. General reporting requirements of Section 6.1.

[Note: Edits to existing material recommence here.]

5.2.2.3 Free-Float Cases: Cases 600FF, 650FF, 680FF, 900FF, and 950FF, and 980FF. If the program being tested has the ability to calculate and output hourly zone air temperatures, the four six free-floating cases (600FF, 650FF, 900FF, and 950FF) shall be modeled as detailed specified in this section and its subsections.
Informative Note: The FF cases are based on their corresponding non-FF cases. For all cases where free-float zone air temperature output is required, the free-float zone air temperature is for the zone air only, assuming well-mixed air with no radiant effects (i.e., equivalent to what would be obtained from a hypothetical aspirated temperature sensor perfectly shielded from solar and infrared radiation).

5.2.2.3.1 Case 600FF: Free-Float Low Mass. Case 600FF shall be modeled exactly the same as Case 600 except for changes noted specified in the subsections below.
5.2.2.3.1.1 Mechanical System. There is no mechanical heating or cooling of the building.
5.2.2.3.1.2 Output Requirements. Case 600FF requires the following output:
a. All free-float case output in accordance with Section 6.2.1.6
b. Daily hourly output specified for Case 600FF in Section 6.2.1.8
c. General reporting requirements of Section 6.1.

5.2.2.3.2 Case 650FF: Free-Float Night Ventilation. Case 650FF shall be modeled exactly the same as Case 650 except for changes noted specified in the subsections below.
5.2.2.3.2.1 Mechanical System.
a. There is no mechanical heating or cooling of the building (as in Case 600FF).
b. The mechanical venting schedule shall remain as follows:
• From 1800 hours to 0700 hours, vent fan = ON
(1800 to 0700 is the same as Hour 19 *through* Hour 7 per the time convention of Section 5.1.1.)
• From 0700 hours to 1800 hours, vent fan = OFF
(0700 to 1800 is the same as Hour 8 *through* Hour 18 per the time convention of Section 5.1.1.).
c. Ventilation fan characteristics shall remain as follows:
a. • Vent fan capacity = 17003.16 standard m^3/h (in addition to specified infiltration rate of Section 5.2.1.6 [Case 600, also applied in Case 650])
b. • Waste heat from fan = 0.
d. If the program being tested does not automatically correct for the reduced density of air at altitude, then the inputs for the fan capacity shall be adjusted as specified in Table 5-160 (see Section 5.2.2.1.5.2 [Case 650]).
5.2.2.3.2.2 Output Requirements. Case 650FF requires the following output:
a. All free-float case output in accordance with Section 6.2.1.6
b. Daily hourly output specified for Case 650FF in accordance with Section 6.2.1.8
c. General reporting requirements of Section 6.1.

[Note: Insert new Case 680FF (Section 5.2.2.3.3), all new material; edit tracking not applied.]

5.2.2.3.3 Case 680FF: Free-Float Increased Exterior Wall and Roof Insulation. Case 680FF shall be modeled exactly the same as Case 680 except for changes specified in the subsections below.
5.2.2.3.3.1 Mechanical System. There is no mechanical heating or cooling of the building (as in Case 600FF).
5.2.2.3.3.2 Output Requirements. Case 680FF requires the following output:
a. All free-float case output in accordance with Section 6.2.1.6
b. Daily hourly output specified for Case 680FF in Section 6.2.1.8

c. General reporting requirements of Section 6.1.

[Note: Edits to existing material recommence here.]

5.2.2.3.4 3 Case 900FF: Free-Float High Mass. Case 900FF shall be modeled exactly the same as Case 900 except for changes noted specified in the subsections below.
5.2.2.3.4.1 3.1 Mechanical System. There is no mechanical heating or cooling of the building (as in Case 600FF).
5.2.2.3.4.2 3.2 Output Requirements. Case 900FF requires the following output:
a. All free-float case output in accordance with Section 6.2.1.6
b. Case 900FF only output in accordance with Section 6.2.1.7
c. Daily hourly output specified for Case 900FF in Section 6.2.1.8
d. General reporting requirements of Section 6.1.

5.2.2.3.5 4 Case 950FF: Free-Float High Mass Night Ventilation. Case 950FF shall be modeled exactly the same as Case 950 except for changes noted specified in the subsections below.
5.2.2.3.5.1 4.1 Mechanical System. See Section 5.2.2.3.2.1 (Case 650FF) for requirements.
5.2.2.3.5.2 4.2 Output Requirements. Case 950FF requires the following output:
a. All free-float case output in accordance with Section 6.2.1.6
b. Daily hourly output specified for Case 950FF in Section 6.2.1.8
c. General reporting requirements of Section 6.1.

[Note: Insert new Case 980FF (Section 5.2.2.3.6). This is all new material; edit tracking not applied.]

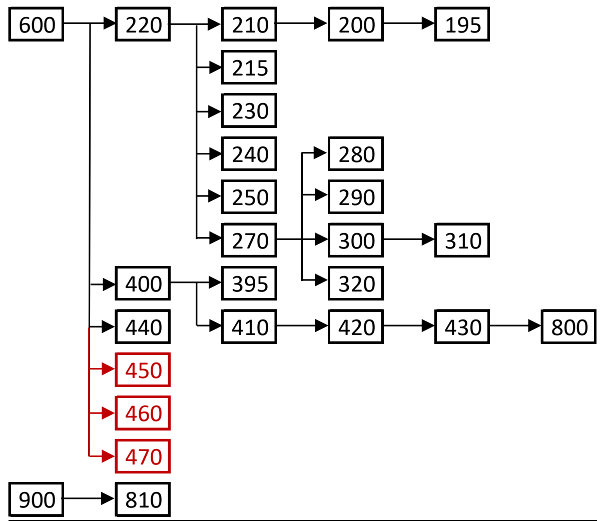
5.2.2.3.6 Case 980FF: Free-Float High Mass Increased Exterior Wall and Roof Insulation. Case 980FF shall be modeled exactly the same as Case 980 except for changes specified in the subsections below.
5.2.2.3.6.1 Mechanical System. There is no mechanical heating or cooling of the building (as in Case 600FF).
5.2.2.3.6.2 Output Requirements. Case 980FF requires the following output:
a. All free-float case output in accordance with Section 6.2.1.6
b. Daily hourly output specified for Case 980FF in Section 6.2.1.8
c. General reporting requirements of Section 6.1.

[Note: Edits to existing material recommence here.]

5.2.3 In-Depth Tests.
a. The in-depth tests shall be modeled as detailed specified in this section and the following subsections. The in-depth tests include Cases 195 through 320, 395 through 440 470, 800 and 810. ~~The proper base case for developing the various in-depth cases, as shown in Table 5-14 and Figure 5-7, shall be used.~~
b. The in-depth series tests require only non-free-float case output and general reporting requirements in accordance with Sections 6.2.1.1 and 6.1, respectively.
Informative Note: For convenience to users, the base cases for developing the various in-depth tests are as shown in Informative Table 5-33 and Informative Figure 5-10. In Informative Table 5-33, "Secondary Base Case" indicates additional cases from where selected input specifications for the given case are applied.

Informative Table 5-33~~1~~4 Base Cases for In-Depth Cases of Section 5.2.3

Primary Tested Feature	Cases with "20,20" Tstat			Cases with "20,27" Tstat		
~~Case~~ ~~Basis for that Case~~	Case	~~Basis for that~~ Primary Base Case	Secondary Base Case	Case	~~Basis for that~~ Primary Base Case	Secondary Base Case
Low Mass Cases with High Conductance Wall Elements or Solid Conduction						
High-Cond. Wall Elements Base Case	220	600	685			
Interior IR Radiation Exchange	210	220	---			
Exterior IR Radiation Exchange	215	220	---			
Int. & Ext. IR Radiation Exchange	200	210	215			
Surface Heat Transfer with "20,27" Tstat				400	600	220
Solid Conduction (no windows or high-cond. wall elements)	195	200	600	395	400	195
Infiltration	230	220	---	410	400	600
Internal Gains	240	220	---	420	410	600
Exterior Solar Absorptance	250	220	600	430	420	600
Low Mass Cases with Windows (South facing unless East/West is indicated)						
South Solar Gains (add South windows)	270	220	600			
Cavity Albedo (interior solar absorptance)	280	270	---	440	600	280
South Shading (overhang)	290	270	610			
East/West Windows	300	270	620			
East/West Shading (overhang + fins)	310	300	630			
"20,27" Thermostat with South Windows	320	270	600			
Constant Combined Int. & Ext. Surf. Coefs.				450	600	---
Constant Combined Interior Surf. Coefs.				460	600	450
Constant Combined Exterior Surf. Coefs.				470	600	450
High Mass Cases						
Thermal Mass Without Solar Gains				800	430	900
Cavity Albedo with South Windows				810	900	280



Informative Figure 5-10~~7~~ Primary ~~B~~base cases for in-depth cases of Section 5.2.3.

5.2.3.1 Case 220: In-Depth Series Base Case. Case 220 shall be modeled exactly the same as Case 600 except for the changes specified in the following subsections.

5.2.3.1.1 Infiltration. Infiltration rate = 0 ach, continuously (24 hours per day for the full year).

5.2.3.1.2 Internal Gains. Internal gains = 0 W, continuously (24 hours per day for the full year).

5.2.3.1.3 Opaque Surface Radiative Properties.

a. Interior and exterior opaque surface solar (visible and ultraviolet wavelengths) absorptances and infrared emittances shall be applied to all opaque surfaces, except for the raised floor, as specified in Table 5-34~~15~~.

b. For the raised floor:

- Interior surface solar absorptance and infrared emittance, and exterior surface infrared emittance, shall be applied as specified in Table 5-34.
- The exterior surface shall continue to be modeled as receiving no solar radiation (see Section 5.2.1.5.1 [Case 600]).

~~Where variations to opaque surface radiative properties are specified for other test cases of Section 5.2.3, these variations shall apply to all interior only, exterior only, or interior and exterior opaque surfaces, as specified for a given test case.~~

c. ~~Where a test case includes a high-conductance wall/opaque window, variation of the o~~Opaque surface radiative properties shall also be applied to the high-conductance wall elements as specified in Section 5.2.3.1.4.2 (below). ~~there as specified for a given test case.~~

Informative Note: Where variations to opaque surface radiative properties are specified for other test cases of Section 5.2.3, these variations ~~shall~~ apply to all interior only, exterior only, or interior and exterior opaque surfaces, as specified for a given test case.

Informative Note: Listed infrared emittances are unchanged from Case 600.

Table 5-34~~15~~ Opaque Surface Radiative Properties, Case 220

	Interior Surface	Exterior Surface
Solar absorptance	0.6[a] ~~N/A~~	0.1
Infrared emittance	0.9	0.9

~~N/A = Not Applicable.~~ [a]***Informative Note:*** As there are no solar gains to the zone in cases with high-conductance wall elements, the value input for interior solar absorptance should not affect the simulation results.

5.2.3.1.4 High~~-~~Conductance Wall Element.~~/Opaque Window.~~

5.2.3.1.4.1 ~~An element that is either a h~~High~~-ly~~ conduct~~ive~~ance wall elements ~~or an opaque window~~ shall replace the 12 m^2 of transparent windows on the south wall.

5.2.3.1.4.2 The properties of the high-conductance wall elements shall be as follows:

a. Shortwave transmittance = 0.

b. Infrared emittances and solar absorptances provided in Table 5-34~~15~~ shall be applied.~~used.~~

c. ~~The exterior surface coefficient is in accordance with Section 5.2.1.9 (Case 600); if combined coefficients are applied, then 21.0 W/(m²·K) shall be used.~~ The surface texture for the high-conductance wall elements shall be very smooth, the same as the window glass; see Tables 5-6 and 5-8 of Sections 5.2.1.9 and 5.2.1.10 (Case 600), respectively.

~~d. The interior surface coefficient shall be in accordance with Section 5.2.1.10 (Case 600).~~

d~~e~~. ~~Conductance, density, specific heat, and surface texture (very smooth)~~ Other construction geometry and material thermal properties shall be applied as specified in Tables 5-35 and 5-36, respectively. ~~the same as for the transparent window listed in Table 5-16.~~

Informative Note, Calculated Properties of Informative Table 5-37: Informative Table 5-37 includes calculated values derived from fundamental material thermal properties of normative Table 5-36 and alternative constant surface coefficients of Sections 5.2.3.1.4.3 and 5.2.3.1.4.4, for programs that may need this information.

***Informative Note, Variation of Listed Surface Coefficients and Overall U-Values from Values of Informative Table 5-37*:** For programs that calculate time-step varying surface infrared radiative exchange or convective coefficients or both, or that allow more detailed constant surface coefficient inputs (e.g., for scheduling), variation of the following from the values given in Table 5-37 may be expected: individual surface coefficient U-values and overall U-value.

Informative Note: Values listed in Tables 5-35, 5-36, and 5-37 are excerpted from those for the Case 600 transparent window listed in Tables 5-10 and 5-11.

[Note: Table 5-16 of 140-2017 revised as: normative material as Tables 5-35 and 5-36, informative material as Informative Table 5-37. In Tables 5-35, 5-36, and 5-37 some properties are presented in different order versus 140-2017, Table 5-16. Tracked changes are for further clarifications, but not applied for reordering of items (for clarity of intended revisions).]

Table 5-35~~16~~ High-Conductance Wall Element Geometry and Construction Properties

Property	Value
Height, individual unit	2 m
Width, individual unit	3 m
Area, individual unit	6 m²
Number of individual units ~~opaque panes~~	2
~~Opaque pane thickness~~	~~3.175 mm~~
~~Thermal conductivity of opaque pane~~	~~1.06 W/(m·K)~~
~~Density of opaque pane~~	~~2500 kg/m³~~
~~Specific heat of opaque pane~~	~~750 J/(kg·K)~~

Table 5-36 High-Conductance Wall Element Fundamental Material Thermal Properties [a,b]

Element	k, W/(m·K)	Thickness, mm	U, W/(m²·K)	R, m²·K/W	Density, kg/m³	c_p, J/(kg·K)
Opaque panel	**1.00~~6~~**	**3.048** ~~3.175~~	**328** ~~333~~	**0.00305**	**2470** ~~2500~~	750
Air gap[c]	**0.0625[d]**	**12.0** ~~13~~	**5.208** ~~6.297~~	**0.19200** ~~0.1588~~	**1.292498**	**1006.103271**
Opaque panel	**1.00~~6~~**	**3.048** ~~3.175~~	**328** ~~333~~	**0.00305**	**2470** ~~2500~~	750

a. ***Informative Note:*** **Updates to Standard 140-2017 highlighted with bold font.**
b. ***Informative Note:*** Values listed here are from Tables 5-10 and 5-11 (see Section 5.2.1.11 [Case 600]), except where noted.
c. For the high-conductance wall element, air gap properties are constant (not allowed to vary with temperature and pressure).
d. ***Informative Note:*** Air gap conductivity from k = U × (Thickness); this is the effective constant air gap conductivity including the effect of natural convection as calculated by WINDOW 7 for the Case 600 clear double pane window of Table 5-10.

Informative Table 5-37 Calculated High-Conductance Wall Element Properties[a]

~~Combined radiative and convective heat transfer coefficient of air gap between opaque panes~~	~~6.297 W/(m²·K) [R-0.1588 m²·K/W]~~	
~~Conductance of each opaque pane~~	~~333 W/(m²·K) [R-0.003 m²·K/W]~~	
Element	**U, W/(m²·K)**	**R, m²·K/W**
Interior combined surface coefficient (h_i)[b]	**4.5**	**0.22222**
Total surface-to-surface[c]	**5.048**	**0.19810**
Exterior combined surface coefficient (h_o)[b]	**17.8**	**0.05618**
Total air-to-air[d]	**2.10**	**0.47650**

a. **Updates to Standard 140-2017 highlighted with bold font.**
b. U-values listed here are combined surface coefficient values (h,comb) from Tables 5-38 and 5-39 (see Sections 5.2.3.1.4.3 and 5.2.3.1.4.4, respectively); (R Value) = 1 / (U value); these match values of Table 5-11 (see Section 5.2.1.11 [Case 600]).
c. Calculated from values of Table 5-36: (R value, total surface to surface) = (R air gap) + 2 × (opaque panel R value); (U Value) = 1 / (R value).
d. Calculated: (R value, total air to air) = (R value, total surface to surface) + $1/h_i$ + $1/h_o$; (U Value) = 1 / (R value); these match values of Table 5-11 (see Section 5.2.1.11 [Case 600]).

5.2.3.1.4.3 Alternative Constant Exterior Convective and Combined (Radiative and Convective) Surface Coefficients.

a. If the program being tested calculates exterior surface convective coefficients and infrared radiative exchange varying with time step:
- those calculations shall be applied
- skip the remaining instructions in this section and proceed to Section 5.2.3.1.4.4.

b. If the program being tested does not calculate time-step varying exterior surface convective coefficients or infrared radiative exchange, then the information provided in Table 5-38 shall be applied. In applying Table 5-38:
- Programs that calculate time-step varying exterior surface infrared radiative exchange, but not convective coefficients, shall apply the listed exterior *convective* surface coefficient (h,conv,ext) for the high-conductance wall elements.
- Programs that do not calculate time-step varying exterior surface convective coefficients and infrared radiative exchange shall apply the listed exterior *combined* surface coefficient (h,comb,ext) for the high-conductance wall elements.
- Use of different (non-specified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. Use of non-specified values shall be documented in the Standard Output Report specified in Normative Annex A2.

Informative Note: The constant values of Table 5-38 are provided for programs that require this input, i.e., that have no time-step varying exterior surface convective coefficient or infrared radiative heat transfer calculation method or no other constant exterior surface heat transfer coefficients explicit to their internal coding. Programs (or models within those programs, where a program allows a variety of modeling methods) that calculate time-step varying surface convective coefficients and infrared radiative heat transfer should not be adjusted to match the constant values provided here.

Informative Note: Supporting information about development of alternative constant surface coefficients is provided in Informative Annex B4.

Table 5-38 Alternative Constant Exterior Convective and Combined Surface Coefficients for High-Conductance Wall Elements, Case 220[a,b]

Surface Type	Exterior *Convective* Surface Coefficient (h,conv,ext) W/(m²·K)	Exterior *Combined* Surface Coefficient (h,comb,ext) W/(m²·K)
High-Conductance Wall Element	**8.0**	**17.8**

a. ***Informative Note:*** **Changes to Standard 140-2017 highlighted with bold font.**
b. ***Informative Note:*** Informative Annex B4 includes supporting information.

5.2.3.1.4.4 Alternative Constant Interior Convective and Combined (Radiative and Convective) Surface Coefficients.

a. If the program being tested calculates interior surface convective coefficients and infrared radiative exchange varying with time step:
- those calculations shall be applied
- skip the remaining instructions in this section and proceed to Section 5.2.3.1.5.

b. If the program being tested does not calculate time-step varying interior surface convective coefficients or infrared radiative exchange, then the information provided in Table 5-39 shall be applied. In applying Table 5-39:
- Programs that calculate time-step varying interior surface infrared radiative exchange, but not convective coefficients, shall apply the listed interior *convective* surface coefficient (h,conv,int) for the high-conductance wall elements.
- Programs that do not calculate time-step varying interior surface convective coefficients and infrared radiative exchange shall apply the listed interior *combined* surface coefficient (h,comb,int) for the high-conductance wall elements.
- Use of different (non-specified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. Use of non-specified values shall be documented in the Standard Output Report specified in Normative Annex A2.

Informative Note: The constant values of Table 5-39 are provided for programs that require this input, i.e., that have no time-step varying interior surface convective coefficient or infrared radiative heat transfer calculation method or no other constant interior surface heat transfer coefficients explicit to their internal coding. Programs (or models within those programs, where a program allows a variety of modeling methods) that calculate time-step varying surface convective coefficients and infrared radiative heat transfer should not be adjusted to match the constant value provided here.

Informative Note: Supporting information about development of alternative constant surface coefficients is provided in Informative Annex B4.

Table 5-39 Alternative Constant Interior Convective and Combined Surface Coefficients for High-Conductance Wall Elements, Case 220[a,b]

Surface Type	Interior *Convective* Surface Coefficient (h,conv,int) W/(m²·K)	Interior *Combined* Surface Coefficient (h,comb,int) W/(m²·K)
High-Conductance Wall Element	**2.4**	**4.5**

a. ***Informative Note:*** **Changes to Standard 140-2017 highlighted with bold font.**
b. ***Informative Note:*** Informative Annex B4 includes supporting information.

5.2.3.1.5 Thermostat Control
5.2.3.1.5.1 The following "20,20" thermostat control configuration shall be used (as in Case 685):
• Heat = ON IF Temperature < 20ºC
• Cool = ON IF Temperature > 20ºC.
Informative Note: "Temperature" refers to the conditioned-zone air temperature.
5.2.3.1.5.2 The thermostat shall be nonproportional as specified in Section 5.2.1.13.1.2 (Case 600).
5.2.3.1.6 Output Requirements. Case 220 requires the following output:
a. Non-free-float case output in accordance with Section 6.2.1.1
b. General reporting requirements of Section 6.1.

5.2.3.2 Case 210: Interior Infrared Radiation. Case 210 shall be modeled exactly the same as Case 220 except for changes specified in the following subsections.
5.2.3.2.1 Opaque Surface Radiative Properties. Interior infrared emittance = 0.1. This value shall be applied to only the interior side of all opaque surfaces, including the high-conductance wall elements (see Section 5.2.3.1.4 [Case 220]).
5.2.3.2.2 Alternative Constant Interior Convective and Combined (Radiative and Convective) Surface Coefficients.
a. If the program being tested calculates interior surface convective coefficients and infrared radiativeon exchange and convection, varying with time step:
- those calculations shall be applied
- skip the remaining instructions in this section and proceed to Section 5.2.3.3 (Case 215).

b. If the program being tested does not calculate these effects time-step varying interior convective surface coefficients or infrared radiative exchange, the constant combined radiative and convective surface coefficients given information provided in Table 5-4017 shall be applied. used.In applying Table 5-40:
- Programs that calculate time-step varying interior surface infrared radiative exchange, but not convective coefficients, shall apply the listed interior *convective* surface coefficients (h,conv,int) for each surface type.
- Programs that do not calculate time-step varying interior surface convective coefficients and infrared radiative exchange shall apply the listed interior *combined* surface coefficients (h,comb,int) for each surface type.
- If the program being tested does not allow scheduling of these coefficients, 3.73 W/(m^2·K) shall be used for horizontal surfaces. Use of different (nonspecified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. Use of nonspecified values shall be documented in the Standard Output Report specified in Normative Annex A2. For cases with an infrared emittance of 0.1, a radiative portion of 0.57 W/(m^2·K) shall be permitted for these combined coefficients.

Informative Note: The constant values of Table 5-40 are provided for programs that require this input, i.e., that have no time-step varying interior surface convective coefficient or infrared radiative heat transfer calculation method or no other constant interior surface heat transfer coefficients explicit to their internal coding. Programs (or models within those programs, where a program allows a variety of modeling methods) that calculate time-step varying surface convective coefficients and infrared radiative heat transfer should not be adjusted to match the constant values provided here.
Informative Note: Supporting information about development of Table 5-40 is provided in Informative Annex B4.Informative Annex B5 includes background information about combined radiative and convective film coefficients.

Table 5-4017 Alternative Constant Interior Convective and Combined Surface Coefficient Versus for Each Surface Type, Orientation, Case 210[a,b]

Orientation of Surface and Heat Flow	Interior Combined Surface Coefficient
Horizontal heat transfer on vertical surfaces	3.73 W/(m²·K)
Upward heat transfer on horizontal surfaces	4.70 W/(m²·K)
Downward heat transfer on horizontal surfaces	1.57 W/(m²·K)

Surface Type	Interior *Convective* Surface Coefficient (h,conv,int) W/(m²·K)	Interior *Combined* Surface Coefficient (h,comb,int) W/(m²·K)
Walls	**1.9**	**2.1**
Ceiling	**1.9**	**1.9**[c]
Raised Floor	**1.0**	**0.4**[c]
High-Conductance Wall Elements	**2.6**	**3.1**

a. ***Informative Note:*** **Changes to Standard 140-2017 highlighted with bold font.**
b. ***Informative Note:*** Informative Annex B4 includes supporting information.
c. ***Informative Note:*** h,comb,int ≤ h,conv,int is possible here because convective and radiative heat flows may be in opposite directions for a given surface for a sufficient number of time steps.

5.2.3.3 Case 215: Exterior Infrared Radiation. Case 215 shall be modeled exactly the same as Case 220 except for changes specified in the following subsections.
5.2.3.3.1 Opaque Surface Radiative Properties. Exterior infrared emittance = 0.1. This value shall be applied to only the exterior side of all opaque surfaces, including the high-conductance wall elements (see Section 5.2.3.1.4 [Case 220]).
5.2.3.3.2 Alternative Constant Exterior Convective and Combined (Radiative and Convective) Surface Coefficients.

a. If the program being tested calculates exterior surface convective coefficients and infrared radiativeon exchange and convection automatically, varying with time step:
   - those calculations shall be applied
   - skip the remaining instructions in this section and proceed to Section 5.2.3.4 (Case 200).

b. If the program being tested does not calculate this effect, time-step varying exterior surface coefficients or infrared radiative exchange, the coefficients given information provided in Table 5-4118 shall be applied.used. In applying Table 5-41:
   - Programs that calculate time-step varying exterior surface infrared radiative exchange, but not convective coefficients, shall apply the listed exterior *convective* surface coefficients (h,conv,ext) for each surface type.
   - Programs that do not calculate time-step varying exterior surface convective coefficients and infrared radiative exchange shall apply the listed exterior *combined* surface coefficients (h,comb,ext) for each surface type.
   - Use of different (non-specified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. Use of non-specified values shall be documented in the Standard Output Report specified in Normative Annex A2.

Informative Note: The constant values of Table 5-41 are provided for programs that require this input, i.e., that have no time-step varying exterior surface convective coefficient or infrared radiative heat transfer calculation method or no other constant exterior surface heat transfer coefficients explicit to their internal coding. Programs (or models within those programs, where a program allows a variety of modeling methods) that calculate surface convective coefficients and infrared radiative heat transfer should not be adjusted to match the constant values provided here.
Informative Note: Supporting information about The calculation technique used to development of Table 5-4118 is provided as background information in Informative Annex B4. A calculation technique that may be used for comparing combined surface coefficients as a function of infrared emittance is provided as background information in Informative Annex B5.

Table 5-4118 Alternative Constant Exterior Convective and Combined Surface Coefficients Versus for Each Surface Type, Texture, Case 215 a,b

Surface Texture	Exterior Combined Surface Coefficient
Brick or rough plaster (all walls and roofs)	25.2 W/(m²·K)
High conductance wall	16.9 W/(m²·K)

Informative Note: All values in table based on a mean annual wind speed of 4.02 m/s.

Surface Type	Exterior *Convective* Surface Coefficient (h,conv,ext) W/(m²·K)	Exterior *Combined* Surface Coefficient (h,comb,ext) W/(m²·K)
Walls	**11.8**	**12.8**
Roof	**14.4**	**17.4**
Raised Floor	**0.9**	**1.3**
High-Conductance Wall Elements	**7.9**	**8.1**

a. ***Informative Note:*** **Changes to Standard 140-2017 highlighted with bold font.**
b. ***Informative Note:*** Informative Annex B4 includes supporting information.

5.2.3.4 Case 200 Surface Convection/Infrared Radiation.
Case 200 shall be modeled exactly the same as Case 210 except for changes specified in the following subsections.
5.2.3.4.1 Opaque Surface Radiative Properties. Exterior infrared emittance = 0.1. This value shall be applied to only the exterior side of all opaque surfaces, including the high-conductance wall elements.
5.2.3.4.2 Alternative Constant Exterior Convective and Combined (Radiative and Convective) Surface Coefficients. See Section 5.2.3.3.2 (Case 215) for requirements.
5.2.3.5 Case 195: Solid Conduction Test. Case 195 shall be modeled exactly the same as Case 200, except the 12 m² of high-conductance windows wall elements shall be replaced with the lightweight exterior walls with thermal and material properties as specified in Table 5-21 (see Section 5.2.1.4 [Case 600]). These walls shall have:

- a rough exterior surface and smooth interior surface; see Tables 5-6 and 5-8 of Sections 5.2.1.9 and 5.2.1.10 (Case 600), respectively.
- and shall have surface radiative properties and associated surface coefficients heat transfer characteristics as specified for the lightweight exterior walls of Case 200.

5.2.3.6 Case 230: Infiltration. Case 230 shall be modeled exactly the same as Case 220 except that the infiltration rate shall be 1.0 ach, continuously (24 hours per day for the full year). The infiltration rate shall be independent of wind speed, indoor/outdoor temperature difference, or other variables.
The weather data file represents a high-altitude site with an elevation of 16509 m above sea level. If the program being tested does not use barometric pressure from the weather data or otherwise automatically correct for the change in air density due to altitude, then the specified infiltration rates shall be adjusted to yield mass flows equivalent to those occurring at the specified altitude as shown in Table 5-4219.
Informative Note: Air density at 16509 m altitude is roughly 80% of that at sea level. The calculation technique used to develop Table 5-4219 is provided as background information in Informative Annex B3, Section B3.1.
Informative Note: Alternatively, the given infiltration rate may be input as a constant ventilation rate.

Table 5-42~~19~~ Infiltration Rates Depending on the Presence of Automatic Altitude Adjustment, Case 230[a]

Altitude Adjustment Algorithm	Input Air Changes per Hour (ach)	Adjustment Factor
Programs with automatic altitude adjustment; set altitude to 165~~0~~9 m above sea level	1.0	1.0
Programs with fixed assumption that site is at sea level (no automatic adjustment)	**0.829** ~~0.822~~	**0.829**[b] ~~0.822[a]~~

a. ***Informative Note:* Changes to Standard 140-2017 highlighted with bold font.**

b.~~a.~~ (Specified Rate) × (1.0156/1.2255) ~~0.822~~ = (Altitude adjusted rate)

5.2.3.7 Case 240: Internal Gains. Case 240 shall be modeled exactly the same as Case 220 except for the following changes to internal gains:

• Internal gains = 200 W, continuously (24 hours per day for the full year)
• Internal gains are 100% sensible, 0% latent
• Sensible ~~I~~internal gains are 60% radiative, 40% convective.

Informative Note: ~~Internally generated sensible and latent internal gains are assumed to be distributed evenly throughout the zone air.~~ These are internally generated sources of heat (from equipment, lights, people, ~~animals,~~ etc.) that are not related to heating, ventilating, and air conditioning (HVAC). The convective portion of internal gains may be reasonably assumed to be distributed evenly throughout the zone air. The radiative portion may be reasonably assumed to be distributed uniformly among the zone interior surfaces (area weighted distribution), assuming an effective infrared transmittance of approximately one for air within the zone.

5.2.3.8 Case 250: Exterior Shortwave Absorptance.

a. Case 250 shall be modeled exactly the same as Case 220~~,~~ except that exterior shortwave (solar) absorptance = 0.9.

b. Except for the raised floor, this value shall be applied to only the exterior side of all opaque surfaces, including the high-conductance wall elements (see Section 5.2.3.1.4 [Case 220]).

c. For the raised floor, the exterior surface shall continue to be modeled as receiving no solar radiation (see Section 5.2.1.5.1 [Case 600]).

5.2.3.9 Case 270: South Solar Gains. Case 270 shall be modeled exactly the same as Case 220 except for the changes specified in the following subsections.

5.2.3.9.1 Opaque Surface Radiative Properties. Interior shortwave absorptance = 0.9. This value shall be applied to only the interior side of all opaque surfaces.

5.2.3.9.2 Transparent Window. The 12 m^2 of high-conductance wall~~s~~ elements on the south walls shall be replaced by transparent windows as in Case 600. Window geometry shall be as shown in Figure 5-1 (Section 5.2.1.3 [Case 600]), and window thermal and optical properties shall be as shown in Section 5.2.1.11 (Case 600). Exterior and interior surface radiation and convection for windows are as specified in Sections 5.2.1.9 and 5.2.1.10 (Case 600), respectively.

5.2.3.9.3 Interior Solar Distribution.

5.2.3.9.3.1 This is the fractional distribution among interior surfaces of solar radiation transmitted through windows that is absorbed by each given surface after all reflections off of interior surfaces and accounting for solar lost (transmitted solar radiation reflected by interior opaque surfaces and retransmitted back out the windows). For programs that calculate interior solar distribution internally (via ray tracing or other means based on interior solar absorptance given in Section 5.2.3.9.1 [above]), and do not require a separate input for interior solar distribution fraction, ignore the following Section 5.2.3.9.3.2 and skip to Section 5.2.3.10 (Case 280).

5.2.3.9.3.2 If the program being tested does not calculate interior solar distribution internally but requires distribution fractions from the user, the use of Table 5-43~~20~~ shall be permitted. Use of different (nonspecified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. The use of nonspecified values shall be documented in the Standard Output Report (Normative Annex A2).

Informative Note: Table 5-43~~20~~ presents an approximate calculation of solar distribution fractions corresponding to the interior solar absorptance for Case 270 by assuming that 100% of the incoming radiation strikes the floor first and that all reflections are diffuse. Fractional values for the walls with windows (i.e., the south wall) include the portion of the solar radiation absorbed by the glass (as it passes back out the window) and conducted back into the zone. Solar radiation absorbed by the glass (and conducted inward) as it initially passes into the building is not included in the values in Table 5-43~~20~~. Informative Annex B7 gives background information regarding the calculation technique used for developing these solar fractions.

Table 5-43~~20~~ Alternative Constant Interior Solar Distribution Fractions by Surface, Case 270[a]

Surface	Floor	Ceiling	East Wall	West Wall	North Wall	South Wall	Solar Lost through Windows
Solar Fraction	0.903	**0.050~~39~~**	**0.010~~3~~**	**0.010~~3~~**	**0.014~~8~~**	**0.007~~8~~**	0.006

a. ***Informative Note:*** **Changes to Standard 140-2017 are highlighted with bold font.**

5.2.3.10 Case 280: Cavity Albedo. Case 280 shall be modeled exactly the same as Case 270 except for changes specified in the following subsections.
5.2.3.10.1 Opaque Surface Radiative Properties. Interior shortwave absorptance = 0.1. This value shall be applied to only the interior side of all opaque surfaces.
5.2.3.10.2 Interior Solar Distribution.
5.2.3.10.2.1 This is the fractional distribution among interior surfaces of solar radiation transmitted through windows that is absorbed by each given surface after all reflections off of interior surfaces and accounting for solar lost (transmitted solar radiation reflected by interior opaque surfaces and retransmitted back out the windows). For programs that calculate interior solar distribution internally (via ray tracing or other means based on interior solar absorptance given in Section 5.2.3.10.1 [above]), and do not require a separate input for interior solar distribution fraction, ignore the following Section 5.2.3.10.2.2 and skip to Section 5.2.3.11 (Case 290).
5.2.3.10.2.2 If the program being tested does not calculate interior solar distribution internally but requires distribution fractions from the user, then the use of Table 5-44~~21~~ shall be permitted. Use of different (nonspecified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. The use of nonspecified values shall be documented in the Standard Output Report (Normative Annex A2).
Informative Note: Table 5-44~~21~~ presents an approximate calculation of solar distribution fractions corresponding to the interior solar absorptance of Case 280 by assuming that 100% of the incoming radiation strikes the floor first and that all reflections are diffuse. Fractional values for the walls with windows (i.e., the south wall) include the portion of the solar radiation absorbed by the glass (as it passes back out the window) and conducted back into the zone. Solar radiation absorbed by the glass (and conducted inward) as it initially passes into the building is not included in the values in Table 5-44~~21~~. Informative Annex B7 gives background information regarding the calculation technique used for developing these solar fractions.

Table 5-44~~21~~ Alternative Constant Interior Solar Distribution Fractions by Surface, Case 280[a]

Surface	Floor	Ceiling	East Wall	West Wall	North Wall	South Wall	Solar Lost through Windows
Solar Fraction	**0.243** ~~0.244~~	0.191	0.057	0.057	**0.077** ~~0.082~~	**0.063** ~~0.065~~	**0.312** ~~0.304~~

a. ***Informative Note:*** **Changes to Standard 140-2017 are highlighted with bold font.**

5.2.3.11 Case 290: South Shading. Case 290 shall be modeled exactly the same as Case 270 except that the overhang ~~detailed~~ specified in ~~Figure 5-2 (~~Sections 5.2.2.1.1.1 and 5.2.2.1.1.2 (Case 610) is added. The horizontal overhang for south-facing windows shall extend across the entire length of the south wall.
5.2.3.12 Case 300: East/West Window Orientation. Case 300 shall be modeled exactly the same as Case 270 except for changes specified in the following subsections.
5.2.3.12.1 Window Orientation. The window orientation shall be modified as detailed in Figure 5-4~~3~~ (Section 5.2.2.1.2.1 [Case 620]) such that 6 m^2 of window area face east and 6 m^2 of window area face west and there are no other windows. Other than the change in orientation, the windows shall be exactly as in Case 270.
5.2.3.12.2 Interior Solar Distribution.
5.2.3.12.2.1 This is the fractional distribution among interior surfaces of solar radiation transmitted through windows that is absorbed by each given surface after all reflections off of interior surfaces and accounting for solar lost (transmitted solar radiation reflected by interior opaque surfaces and retransmitted back out the windows). For programs that calculate interior solar distribution internally (via ray tracing or other means based on interior solar absorptance given in Section 5.2.3.9.1 [Case 270]), and do not require a separate input for interior solar distribution fraction, ignore the following Section 5.2.3.12.2.2 and skip to Section 5.2.3.13 (Case 310).

5.2.3.12.2.2 If the program being tested does not calculate ~~this effect~~ interior solar distribution internally but requires distribution fractions from the user, the use of Table 5-45~~22~~ shall be permitted. Use of different (nonspecified) values shall not be prohibited if there is a mathematical, physical, or logical basis for applying them. Where different values are used, they shall be applied consistently throughout the test cases. The use of nonspecified values shall be documented in the Standard Output Report (Normative Annex A2).
Informative Note: Table 5-45~~22~~ presents an approximate calculation of solar distribution fractions adjusted for the geometry of Case 300 by assuming that 100% of the incoming radiation strikes the floor first and that all reflections are diffuse. Fractional values for the walls with windows (i.e., the east and west walls) include the portion of the solar radiation absorbed by the glass (as it passes back out the window) and conducted back into the zone. Solar radiation absorbed by the glass (and conducted inward) as it initially passes into the building is not included in the values in Table 5-45~~22~~. Informative Annex B7 gives background information regarding the calculation technique used for developing these solar fractions.

Table 5-45~~22~~ Alternative Constant Interior Solar Distribution Fractions by Surface, Case 300[a]

Surface	Floor	Ceiling	East Wall	West Wall	North Wall	South Wall	Solar Lost through Windows
Solar Fraction	0.903	**0.050~~39~~**	**0.0065~~8~~**	**0.0065~~8~~**	**0.014~~8~~**	**0.014~~8~~**	0.006

a. ***Informative Note:*** **Changes to Standard 140-2017 are highlighted with bold font.**

5.2.3.13 Case 310: East/West Shading. Case 310 shall be modeled exactly the same as Case 300 except that shading devices are added to the east and west windows as ~~detailed~~ specified in ~~Figures 5-4 and 5-5 (~~Sections 5.2.2.1.3.1 and 5.2.2.1.3.2 (Case 630).
5.2.3.14 Case 320: Thermostat. Case 320 shall be modeled exactly the same as Case 270 except for the changes specified in the following subsections.
5.2.3.14.1 The thermostat shall have the following 20,27 deadband configuration (as in Case 600):
• Heat = ON IF Temperature < 20°C; otherwise, Heat = OFF
• Cool = ON IF Temperature > 27°C; otherwise, Cool = OFF.
Informative Note: "Temperature" refers to the conditioned-zone air temperature.
5.2.3.14.2 The thermostat shall be nonproportional as specified in Section 5.2.1.13.1.2 (Case 600).
5.2.3.15 Case 400: ~~Opaque Windows~~ High-Conductance Wall Elements with Deadband Thermostat. Case 400 shall be modeled exactly the same as Case 600 except for the changes specified in the following subsections.
5.2.3.15.1 Infiltration. Infiltration rate = 0 ach, continuously (24 hours per day for the entire year).
5.2.3.15.2 Internal Gains. Internal gains = 0 W, continuously (24 hours per day for the entire year).
5.2.3.15.3 Opaque Surface Radiative Properties.
a. Exterior solar absorptance = 0.1.
b. Except for the raised floor, this value shall be applied to only the exterior side of all opaque surfaces, including the high-conductance wall elements of Section 5.2.3.15.4 (below).
c. For the raised floor, the exterior surface shall continue to be modeled as receiving no solar radiation (see Section 5.2.1.5.1 [Case 600]).
5.2.3.15.4 High-Conductance Wall Element.~~/Opaque Window.~~ ~~An element that is either a highly conductive wall or an opaque window~~ High-conductance wall elements shall replace the 12 m^2 of transparent windows on the south wall~~.~~, as follows:
a. The properties of the high-conductance wall elements shall be as ~~follows:~~ specified in Section 5.2.3.1.4 (Case 220) and its subsections.
~~a. Shortwave transmittance = 0.~~
~~b. Interior and exterior infrared emittances = 0.9.~~
~~c.~~b. Exterior solar absorptance = 0.1.~~; interior solar absorptance is not applicable.~~
~~d. The exterior surface coefficient shall be in accordance with Section 5.2.1.9 (Case 600); if combined coefficients are applied, 21.0 W/(m²·K) shall be used. The surface texture for the high-conductance wall shall be very smooth, the same as glass.~~
~~e. The interior surface coefficient shall be in accordance with Section 5.2.1.10 (Case 600).~~
~~f. Conductance, density, specific heat, and surface texture (very smooth) shall be the same as for Case 220 as listed~~

in Table 5-16 (Section 5.2.3.1.4).
5.2.3.15.5 Output Requirements. Case 400 requires the following output:
a. Non-free-float case output in accordance with Section 6.2.1.1
b. General reporting requirements of Section 6.1.
5.2.3.16 Case 395: Solid Conduction Test. Case 395 shall be modeled exactly the same as Case 400 except that the 12 m^2 of high-conductance wall elements windows shall be replaced with the lightweight exterior walls that shall have thermal and material properties specified in Table 5-21 (see Section 5.2.1.4 [Case 600]), as in Case 195. These walls shall have:

- a rough exterior surface and smooth interior surface; see Tables 5-6 and 5-8 of Sections 5.2.1.9 and 5.2.1.10 (Case 600), respectively.
- and shall have surface radiative properties and associated surface coefficients heat transfer characteristics as specified for the lightweight exterior walls of Case 400.

5.2.3.17 Case 410: Infiltration. Case 410 shall be modeled exactly the same as Case 400 except that infiltration rate = 0.5 ach, continuously (24 hours per day for the full year). If the program being tested does not use barometric pressure from weather data or otherwise automatically correct for the change in air density due to altitude, the infiltration rate shall be adjusted as specified in Section 5.2.1.6.1 (Case 600).
5.2.3.18 Case 420: Internal Gains. Case 420 shall be modeled exactly the same as Case 410 except for the following changes to internal gains (as in Case 600):

- Internal gains = 200 W, continuously (24 hours per day for the full year)
- Internal gains are 100% sensible, 0% latent
- Sensible Iinternal gains are 60% radiative, 40% convective.

Informative Note: Internally generated sensible and latent internal gains are assumed to be distributed evenly throughout the zone air. These are internally generated sources of heat (from equipment, lights, people, animals, etc.) that are not related to heating, ventilating, and air conditioning (HVAC). The convective portion of internal gains may be reasonably assumed to be distributed evenly throughout the zone air. The radiative portion may be reasonably assumed to be distributed uniformly among the zone interior surfaces (area weighted distribution), assuming an effective infrared transmittance of approximately one for air within the zone.
5.2.3.19 Case 430: Exterior Shortwave Absorptance.
a. Case 430 shall be modeled exactly the same as Case 420 except that exterior shortwave (solar) absorptance = 0.6 (as in Case 600).
b. Except for the raised floor, this value shall be applied to only the exterior side of all opaque surfaces, including the high-conductance wall elements.
c. For the raised floor, the exterior surface shall continue to be modeled as receiving no solar radiation (see Section 5.2.1.5.1 [Case 600]).
5.2.3.20 Case 440: Cavity Albedo. Case 440 shall be modeled exactly the same as Case 600 except for changes specified in the following subsections.
5.2.3.20.1 Opaque Surface Radiative Properties. Interior shortwave absorptance = 0.1 (as in Case 280). This value shall be applied to only the interior side of all opaque surfaces.
5.2.3.20.2 Interior Solar Distribution. Interior solar distribution shall be as specified in Section 5.2.3.10.2 (Case 280).
5.2.3.20.3 Output Requirements. Case 440 requires the following output:
a. Non-free-float case output in accordance with Section 6.2.1.1.
b. General reporting requirements of Section 6.1.

[Note: Following are new Cases 450, 460, and 470 (Sections 5.2.3.21 through 5.2.3.23); edit tracking not applied.]

5.2.3.21 Case 450: Constant Combined Interior and Exterior Surface Coefficients. Case 450 shall be modeled exactly the same as Case 600 except for changes specified in the following subsections.
Informative Note: The purpose of Case 450 is to isolate differences associated with varying surface interior and exterior surface convective heat transfer and radiative exchange models by comparing results of this case to Cases 600, 460, and 470.
5.2.3.21.1 Interior Combined Radiative and Convective Surface Coefficients. The constant interior combined surface coefficients (h,comb,int) provided in Table 5-46 shall be applied. Time-step varying calculation of interior surface heat transfer coefficients is prohibited. Use of constant values other than those of Table 5-46 is prohibited.
Informative Note: For programs that allow direct input of constant convective surface coefficients, but not direct input of constant combined (radiative and convective) surface coefficients, input may be entered as follows: enter the appropriate values given for interior surfaces in Table 5-46 as convective coefficients, and set respective interior

surface emittances to 0 (or as low as the program being tested allows). ***Informative Note:*** These are the same values as for h,comb,int in Table 5-9 (Section 5.2.1.10 [Case 600]). Constant surface coefficients presented here apply only to the test cases and were calculated only for test cases with south facing windows or south facing high-conductance wall elements; they should not be assumed to apply beyond this test suite. Supporting information about development of Table 5-46 is provided in Informative Annex B4.

5.2.3.21.2 Exterior Combined Radiative and Convective Surface Coefficients. The constant exterior combined surface coefficients (h,comb,ext) provided in Table 5-46 shall be applied. Time-step varying calculation of exterior surface heat transfer coefficients is prohibited. Use of constant values other than those of Table 5-46 is prohibited. ***Informative Note:*** For programs that allow direct input of constant convective surface coefficients, but not direct input of constant combined (radiative and convective) surface coefficients, input may be entered as follows: enter the appropriate values given for exterior surfaces in Table 5-46 as convective coefficients, and set respective exterior surface emittances to 0 (or as low as the program being tested allows). ***Informative Note:*** These are the same values as for h,comb,ext in Table 5-7 (Section 5.2.1.9 [Case 600]). Constant surface coefficients presented here apply only to the test cases and were calculated only for test cases with south facing windows or south facing high-conductance wall elements; they should not be assumed to apply beyond this test suite. Supporting information about development of Table 5-46 is provided in Informative Annex B4.

5.2.3.21.3 Output Requirements. Case 450 requires the following output:

a. Non-free-float case output in accordance with Section 6.2.1.1

b. General reporting requirements of Section 6.1.

Table 5-46 Interior and Exterior Combined Surface Coefficients for Each Surface Type, Case 450[a]

Surface Type	*Interior* Combined Surface Coefficient (h,comb,int) W/(m²·K)	*Exterior* Combined Surface Coefficient (h,comb,ext) W/(m²·K)
Walls	1.8	21.6
Roof	1.7	21.8
Raised Floor	3.7	5.2
Windows	4.5	17.8

a. ***Informative Note:*** Informative Annex B4 includes supporting information.

5.2.3.22 Case 460: Constant Combined Interior Surface Coefficients. Case 460 shall be modeled exactly the same as Case 600 except for changes specified in the following subsections.

Informative Note: The purpose of Case 460 is to isolate differences associated with varying surface interior surface convective heat transfer and radiative exchange models by comparing results of this case to Cases 600 and 450.

5.2.3.22.1 Interior Combined Radiative and Convective Surface Coefficients. The constant interior combined surface coefficients (h,comb,int) provided in Table 5-46 (see Section 5.2.3.21 [Case 450]) shall be applied. Time-step varying calculation of interior surface heat transfer coefficients is prohibited. Use of constant values other than those of Table 5-46 is prohibited. ***Informative Note:*** For programs that allow direct input of constant convective surface coefficients, but not direct input of constant combined (radiative and convective) surface coefficients, input may be entered as follows: enter the appropriate values given for interior surfaces in Table 5-46 as convective coefficients, and set respective interior surface emittances to 0 (or as low as the program being tested allows). ***Informative Note:*** These are the same values as for h,comb,int in Table 5-9 (Section 5.2.1.10 [Case 600]). Constant surface coefficients presented here apply only to the test cases and were calculated only for test cases with south facing windows or south facing high-conductance wall elements; they should not be assumed to apply beyond this test suite. Supporting information about development of Table 5-46 is provided in Informative Annex B4.

Informative Note: Exterior surface heat transfer remains as in Section 5.2.1.9 (Case 600).

5.2.3.22.2 Output Requirements. Case 460 requires the following output:

a. Non-free-float case output in accordance with Section 6.2.1.1

b. General reporting requirements of Section 6.1.

5.2.3.23 Case 470: Constant Combined Exterior Surface Coefficients. Case 470 shall be modeled exactly the same as Case 600 except for changes specified in the following subsections.

Informative Note: The purpose of Case 470 is to isolate differences associated with varying surface exterior surface convective heat transfer and radiative exchange models by comparing results of this case to Cases 600 and 450.
5.2.3.23.1 Exterior Combined Radiative and Convective Surface Coefficients. The constant exterior combined surface coefficients (h,comb,ext) provided in Table 5-46 (see Section 5.2.3.21 [Case 450]) shall be applied. Time-step varying calculation of exterior surface heat transfer coefficients is prohibited. Use of constant values other than those of Table 5-46 is prohibited. ***Informative Note:*** For programs that allow direct input of constant convective surface coefficients, but not direct input of constant combined (radiative and convective) surface coefficients, input may be entered as follows: enter the appropriate values given for exterior surfaces in Table 5-46 as convective coefficients, and set respective exterior surface emittances to 0 (or as low as the program being tested allows).
Informative Note: These are the same values as for h,comb,ext in Table 5-7 (Section 5.2.1.9 [Case 600]). Constant surface coefficients presented here apply only to the test cases, and were calculated only for test cases with south facing windows or south facing high-conductance wall elements; they should not be assumed to apply beyond this test suite. Supporting information about development of Table 5-46 is provided in Informative Annex B4.
Informative Note: Interior surface heat transfer remains as in Section 5.2.1.10 (Case 600).
5.2.3.23.2 Output Requirements. Case 470 requires the following output:
a. Non-free-float case output in accordance with Section 6.2.1.1
b. General reporting requirements of Section 6.1.

[Note: Edits to existing material recommence here.]

5.2.3.24~~1~~ Case 800: High Mass without Solar Gains. Case 800 shall be modeled exactly the same as Case 430 except as follows. The exterior wall and floor materials specifications of Table 5-27~~11~~ (Section 5.2.2.2.1.1 [Case 900]) shall be ~~used~~ applied in place of the materials specifications of Table 5-2~~1~~ (Section 5.2.1.4 [Case 600]). The roof materials shall not change, and the high-conductance wall~~s~~ elements shall also remain as in Case 430.
Informative Note: Informative Table 5-28 (Section 5.2.2.2.1.1 [Case 900]) includes summary calculated values derived from fundamental properties of normative Table 5-27 and alternative constant surface coefficients of Sections 5.2.1.9.3 and 5.2.1.10.3 (Case 600), for programs that may need this information. For programs that automatically calculate surface radiation or convection or both, or that allow more detailed constant surface coefficient inputs (e.g., for scheduling), variation of individual interior surface coefficient U-values, total U and total UA values, and heat capacities from Table 5-28 may be expected.

5.2.3.25~~2~~ Case 810: High Mass Cavity Albedo. Case 810 shall be modeled exactly the same as Case 900 except for changes specified in the following subsections.
5.2.3.25~~2~~.1 Opaque Surface Radiative Properties. Interior shortwave absorptance = 0.1 (as in Case 280). This value shall be applied to only the interior side of all opaque surfaces.
5.2.3.25~~2~~.2 Interior Solar Distribution. Interior solar distribution ~~is in accordance with~~ shall be as specified in Section 5.2.3.10.2 (Case 280).
5.2.3.25~~2~~.3 Output Requirements. Case 810 requires the following output:
a. Non-free-float case output in accordance with Section 6.2.1.1.
b. General reporting requirements of Section 6.1.

[Note: Sections 5.2.4 through 5.5.4 not shown; this material is not affected by the addendum.]

6. CLASS I OUTPUT REQUIREMENTS

Class I output requirements listed in Section 6 shall be applied as specified in Section 5.

6.1 Reporting Results

6.1.1 Standard Output Reports. The standard output reports included on the accompanying electronic media shall be used. Instructions regarding these reports are included in Normative Annex A2. Information required for this report includes the following:

a. Software name and version number

b. Modeling documentation using "S140outNotes.TXT" on the accompanying electronic media for the following:
   1. Software identifying information and operating requirements
   2. Modeling methods used when alternative methods are available in the software (as specified in Section 5.1.4)
   3. Equivalent modeling methods used when the software does not allow direct input of specified values (as specified in Section 5.1.5)
   4. Nonspecified inputs (as specified in Section 5.1.6)
   5. Changes to source code for the purpose of running the tests, where such changes are not available in publicly released versions of the software (as specified in Section 5.1.9)
   6. Omitted test cases and results (as specified in Section 6.1.3)
   7. Anomalous results (as specified in Section 6.1.4)

c. Results for simulated cases using the following files on the accompanying electronic media:
   1. Sec5-2Aout.XLSX for the building thermal envelope and fabric load tests of Sections 5.2.1, 5.2.2, and 5.2.3

[Note: Remainder of Section 6.1.1 not shown; that material has no revisions.]

6.1.2 Simulation Input Files. All supporting data required for generating results with the tested software shall be saved, including the following:

- Input files
- Processed weather data
- Intermediate files containing calculations used for developing inputs
- A "Readme-softwarename-yymmdd.pdf" file that briefly describes the contents of the above files according to their file type (i.e., their ".xyz" file extension).

6.1.3 Omitted Test Cases. If a program being tested omits a test case, the modeler shall provide an explanation of the omission using the modeler report template provided in Normative Annex A2.

6.1.4 Discussion of Anomalous Results. Explanation of anomalous test results using the modeler report template provided in Normative Annex A2 shall be permitted but is not required.

6.2 Output Requirements for Building Thermal Envelope and Fabric Load and Ground-Coupled Slab-on-Grade Tests of Section 5.2. Required output shall be as specified in the sections below.

6.2.1 Output Requirements for Building Thermal Envelope and Fabric Load Tests of Sections 5.2.1, 5.2.2, and 5.2.3

6.2.1.1 All Non-Free-Float Cases. Required outputs for the non-free-float cases shall be as designated in Sections 6.2.1.1.1 through 6.2.1.1.5.

Informative Note: In this description the term "free-float cases" refers to cases designated with "FF" in the case description (i.e., 600FF, 650FF, 680FF, 900FF, 950FF, 980FF); non-free-float cases are all the other cases described in Sections 5.2.1, 5.2.2, and 5.2.3 (Tables B1-2 and B1-3 of Informative Annex B1 include an informative summary listing of the cases of Sections 5.2.1, 5.2.2, and 5.2.3).

6.2.1.1.1 Annual heating load (MWh).

6.2.1.1.2 Annual sensible cooling loads (MWh).

6.2.1.1.3 Annual hourly integrated peak heating load (kW) with ~~date~~ month, day, and hour of occurrence, applying month abbreviations specified in Sec5-2Aout.xlsx, tab 'A', cells C17 to C30.

6.2.1.1.4 Annual hourly integrated peak sensible cooling load (kW) with ~~date~~ month, day, and hour of occurrence, applying month abbreviations specified in Sec5-2Aout.xlsx, tab 'A', cells C17 to C30.

6.2.1.1.5 All heating and cooling loads listed in Sections 6.2.1.1.1 through 6.2.1.1.4 shall be entered into the appropriate standard output report (as specified in Normative Annex A2) as positive values (≥ 0).

6.2.1.2 Case 600 ~~Only~~(and other cases where indicated)

[Note: Items of 6.2.1.2.1 reordered for consistency with new Sec5-2Aout.xlsx format, no substantive change to requirements.]

6.2.1.2.1 Annual incident unshaded total solar radiation (diffuse and direct-beam) on horizontal, north, east, south, and west, south, and horizontal surfaces (kWh/m^2).
6.2.1.2.2 (also for Cases 660 and 670) Unshaded annual transmitted total solar radiation (diffuse and direct-beam) through south windows (kWh/m^2). 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.

6.2.1.2.3 If the program applies sky temperature, report sky temperature output as follows. ***Informative Note:*** This is the temperature that the program applies for the portion of infrared radiation exchange between an exterior surface and the deep sky, including adjustment for the presence of clouds.
6.2.1.2.3.1 Annual mean sky temperature (°C).
6.2.1.2.3.2 Annual hourly integrated minimum sky temperature (°C) with month, day, and hour of occurrence, applying month abbreviations specified in Sec5-2Aout.xlsx, tab 'A', cells C17 to C30.
6.2.1.2.3.3 Annual hourly integrated maximum sky temperature (°C) with month, day, and hour of occurrence, applying month abbreviations specified in Sec5-2Aout.xlsx, tab 'A', cells C17 to C30.

6.2.1.2.4 (also for Case 900) Monthly conditioned zone loads shall be as designated in Sections 6.2.1.2.4.1 through 6.2.1.2.4.5.
6.2.1.2.4.1 Monthly heating load for each month of the year (kWh).
6.2.1.2.4.2 Monthly cooling load for each month of the year (kWh).
6.2.1.2.4.3 Monthly hourly integrated peak heating load (kW) for each month of the year, with day and hour of occurrence.
6.2.1.2.4.4 Monthly hourly integrated peak sensible cooling load (kW) for each month of the year, with day and hour of occurrence.
6.2.1.2.4.5 All heating and cooling loads listed in Sections 6.2.1.2.4.1 through 6.2.1.2.4.4 shall be entered into the appropriate standard output report (as specified in Normative Annex A2) as positive values (≥ 0).

6.2.1.3 Case 610 Only
6.2.1.3.1 Annual transmitted solar radiation (diffuse and direct-beam) through the shaded south window with a horizontal overhang (kWh/m^2). 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.

6.2.1.4 Case 620 Only
6.2.1.4.1 Unshaded annual transmitted solar radiation (diffuse and direct-beam) through the west window (kWh/m^2). 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.

6.2.1.5 Case 630 Only
6.2.1.5.1 Annual transmitted solar radiation (diffuse and direct-beam) through the shaded west window with horizontal overhang and vertical fins (kWh/m^2). 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.

6.2.1.6 All Free-Float Cases. Required outputs for the free-float cases shall be as designated in Sections 6.2.1.6.1 through 6.2.1.6.3.
Informative Note: In this description the term "free-float cases" refers to cases designated with "FF" in the case description (i.e., 600FF, 650FF, 680FF, 900FF, 950FF, 980FF, and for just the sun zone in Case 960).

[Note: Subsections of 6.2.1.6 reordered for consistency with new Sec5-2Aout.xlsx format, no substantive change to requirements.]

6.2.1.6.13 Annual mean zone air temperature (°C).
6.2.1.6.1 Annual hourly integrated maximum zone air temperature (°C) with date and hour of occurrence.
6.2.1.6.2 Annual hourly integrated minimum zone air temperature (°C) with date month, day, and hour of occurrence, applying month abbreviations specified in Sec5-2Aout.xlsx, tab 'A', cells C17 to C30.
6.2.1.6.3 Annual hourly integrated maximum zone air temperature (°C) with date month, day, and hour of occurrence, applying month abbreviations specified in Sec5-2Aout.xlsx, tab 'A', cells C17 to C30.
6.2.1.6.3 Annual mean zone air temperature (°C).

Informative Note: For all cases where free-float zone air temperature output is required, the free-float zone air temperature is for the zone air only, assuming well-mixed air with no radiant effects (i.e., equivalent to what would be obtained from an aspirated temperature sensor perfectly shielded from solar and infrared radiation).

6.2.1.7 Case 900FF Only
6.2.1.7.1 Annual hourly integrated 1°C zone air temperature bin frequencies from –20°C to 70°C –50°C to 98°C, where "bin frequency" is the number of hours a given zone air temperature has values within given bins (1°C bin width) during the annual simulation.
6.2.1.7.1.1 Zone air temperature bins are defined by an integer value of temperature as the lower bound (inclusive) of the range, the upper bound of the range being less than the next highest integer value.
Informative Note: For example, the zone air temperature T bin defined by 20°C is 20°C ≤ T < 21°C; similarly, the bin defined by –2°C is –2°C ≤ T < –1°C.
Output Example: Output from an annual simulation (8760 hours) might indicate 400 hours when the zone air temperature (T) is 25°C (25°C ≤ T < 26°C), and 430 hours when the zone air temperature is 28°C (28°C ≤ T < 29°C), with temperatures for remaining hours distributed among other bins as appropriate. ~~Additional information regarding this calculation is provided in Informative Annex B12.~~
6.2.1.7.1.2 To process bin frequencies, the post-processor included with sheet tab 'TMPBIN' with the normative output file (Sec5-2Aout.xls) shall be used. To apply the post-processor, the 8760 hours of annual hourly zone temperature data shall be sequential hourly values compatible with entry into an xls or xlsx file, and shall be entered into a single data column. ***Informative Note:*** Post-processor data entry instructions and data flow description are included with Sec5-2Aout.xls, sheet tab 'TMPBIN', beginning in cell C1.

6.2.1.8 Daily Hourly Output for Building Thermal Envelope and Fabric Load Tests of Sections 5.2.1 and 5.2.2. If the program being tested is capable of producing hourly outputs, the following hourly values for the specified days shall be provided. To produce this output, the simulation period shall be a typical annual run, as specified in Sections 5.1.7 and 5.1.8.1. Running the simulation for only the required days specified in the output requirements shall be prohibited, because the results could contain temperature history errors. Required outputs shall be as listed for specific cases in Table 6-1.

[Note: Table 6-1 reorganized to indicate multiple cases and days for each output type, where appropriate, in place of relisting each item for each case and day. Tracked changes indicate substantive revisions, and also applied for some of the non-substantive reorganization.]

Table 6-1 Daily Hourly Output Requirements for Building Thermal Envelope and Fabric Load Tests of Sections 5.2.1 and 5.2.2

Case(s)	Hourly Outputs Type~~*~~[a]	Day(s)[b]
600	Hourly integrated incident unshaded total solar radiation (direct and diffuse) on horizontal, south, and west surfaces (Wh/m^2)	May 4, Jul 14 ~~March 5~~
~~600~~	~~Hourly incident unshaded solar radiation (direct and diffuse) on south and west surfaces (Wh/m^2)~~	~~July 27~~
600	Hourly integrated sky temperature (°C)[c]	Feb 1, May 4, Jul 14
600, 660, 670	Hourly integrated transmitted total solar radiation (direct and diffuse) through south windows (Wh/m^2)[d]	Feb 1, May 4, Jul 14
600, 660, 670, 680, 685, 695, 900, 980, 985, 995	Hourly integrated heating (+) and sensible cooling (–) loads (kWh, designate cooling with a [–] sign)	Feb 1, Jul 14 ~~January 4~~
	~~Hourly heating (+) and sensible cooling (–) loads (kWh, designate cooling with a [–] sign)~~	~~January 4~~
640, 940	Hourly integrated heating (+) and sensible cooling (–) loads (kWh, designate cooling with a [–] sign)	Feb 1
640, 940	Hourly integrated conditioned zone air temperature (ºC)	Feb 1
600FF, 680FF, 900FF, 980FF	Hourly integrated free-float zone air temperature (ºC)	Feb 1 ~~January 4~~
650FF, 950FF	Hourly integrated free-float zone air temperature (ºC)	Jul 14 ~~July 27~~
	~~Hourly free-float zone air temperature (ºC)~~	~~January 4~~
	~~Hourly free-float zone air temperature (ºC)~~	~~July 27~~

~~*~~[a] Hourly data to consist of 24 hourly integrated values for each day. The first hour (hour 1) is defined to run from 0000 to 0100 hours.

[b] Month abbreviations: "Feb" = "February", "May" = May, "Jul" = July.

[c] ***Informative Note:*** This is the temperature that the program applies for the portion of infrared radiation exchange between an exterior surface and the deep sky, including adjustment for the presence of clouds.

[d] ***Informative Note:*** These outputs may be taken as the hourly integrated total transmitted solar radiation, divided by the total window area.

[Note: Remainder of Section 6.2 has no proposed revisions.]

[Note: Sections 6.3 through 8.2 have no proposed revisions.]

[Note: Only edits to selected portions of Annex A1 relevant to the test cases of Sections 5.2.1, 5.2.2, and 5.2.3 are included here. All other Annex A1 material is unchanged.]

(This is a normative annex and is part of the standard.)

NORMATIVE ANNEX A1
WEATHER DATA

A1.1 Weather Data

A1.1.1 Weather Data for Building Thermal Envelope and Fabric Load Tests of Sections 5.2.1, 5.2.2, and 5.2.3.
A1.1.1.1 Normative Weather Data. The full-year weather data ~~(DRYCOLD.TMY)~~725650TY.CSV (Denver International Airport TMY3 data) provided with the accompanying electronic media shall be used for performing the tests called out in Sections 5.2.1, 5.2.2, and 5.2.3. Site and weather characteristics are summarized in Table A1-1. See Section A1.8~~5~~ for details about TMY3 weather data file format.

A1.1.1.2 Informative Sky Temperature Data*. Informative Note:* The specified weather data file does not include data for sky temperature (T_{sky}). For programs that do not automatically calculate T_{sky}, and use T_{sky} as an input from the weather data file, calculated T_{sky} values are provided as informative material in the file "Tsky-Informative.xlsx" (see tab "Informative-Tsky"), included with the electronic files accompanying this standard. Calculation of T_{sky} is provided in Part IV, Appendix B (Section 4B) of the originating test-suite-update final report[A-15].

[Note: Informative text of 140-2017, Annex B11, Section B11.1.3 is deleted by this addendum. The reference to that text in the second informative note of Section A1.5 is deleted as shown below. The remainder of Section A1.5 and its informative notes are unchanged.]

A1.5 TMY Weather Data Format.

Informative Note [excerpted portion]: …. ~~Additional background regarding the difference between solar time and standard time is included in Informative Annex B11 (Section B11.1.3).~~

Table A1-1 Site and Weather Summary for ~~DRYCOLD.TMY~~ 725650TY.CSV Weather Data Used with Building Thermal Envelope and Fabric Load Tests[a]

Weather type	Cold~~,~~ clear winters/hot~~,~~ dry summers
Weather format	**Typical Meteorological Year 3 (TMY3)**
Latitude	**39.833**° North
Longitude	**104.650**~~9~~° West
Altitude	**1650**~~09~~ m
Time zone	7
Ground reflectance	0.2[b]
Site	Open terrain with scattered obstructions having heights generally less than 9m.[c] ~~Flat, unobstructed, located exactly at weather station~~
Anemometer height	**10 m**[d]
Mean annual wind speed	~~4.02~~ **3.9** m/s
Maximum annual wind speed	**20.6** m/s
~~Deep ground temperature~~	~~10°C~~
Mean annual ambient dry-bulb temperature	~~9.71~~ **10.9**°C
Minimum annual dry-bulb temperature	~~-24.39~~ **-19.4**°C
Maximum annual dry-bulb temperature	~~35.0~~ **40.0**°C
~~Maximum annual wind speed~~	~~14.89 m/s~~
Heating degree-days (base 18~~.3~~°C)	~~3636.2~~ **3129**°C-days
Cooling degree-days (base 18~~.3~~°C)	~~487.1~~ **529**°C-days
Mean annual dew-point temperature	~~-1.44~~ **-1.1**°C
Mean annual relative humidity	**50%**
Mean annual humidity ratio	**0.0049**[e] ~~0.0047~~
Mean annual opaque cloud cover	**0.44, fraction of covered sky**
Global horizontal solar radiation annual total	~~1831.82~~ **1670** kwh/(m^2·y)
Direct normal solar radiation annual total	~~2353.58~~ **1978** kWh/(m^2·y)
~~Direct horizontal solar radiation~~	~~1339.48 kWh/(m^2·y)~~
Diffuse horizontal solar radiation	~~492.34~~ **556** kWh/(m^2·y)

a. ***Informative Note:*** **Updates to Standard 140-2017 highlighted with bold font.**

b. ***Informative Note:*** See informative note with Section 5.2.1.1.2.5 regarding use of ground reflectance data.

c. ***Informative Note:*** The site location corresponds with Terrain Category 3, documented in *2017 ASHRAE Handbook of Fundamentals*, p. 24.4, Table 1 [B-101].

d. ***Informative Note:*** Assumed typical anemometer location height.

e. ***Informative Note:*** Approximation calculated from ODB, RH, and Patm based on ideal gas equations.

[Note: Add new Section A1.8 as shown.]

A1.8 TMY3 Weather Data Format. TMY3 weather data are provided in comma separated value (CSV) file format. The TMY3 data format has two file headers followed by 8,760 lines of data, each with 68 data fields, as described below.

Informative Note: This information is provided for those programs that do not have Typical Meteorological Year 3 (TMY3) weather processors. If this summary is insufficient, the complete documentation on TMY3 weather data[A-5] can be obtained at http://www.nrel.gov/docs/fy08osti/43156.pdf.

A1.8.1 File Headers. The first row of each file is the file header that describes the station. This row contains the WBAN number, city/location, state, time zone, latitude, longitude, and elevation. The field positions and definitions of these header elements are given in Table A1-19. The second row of data includes the data field name and its units for each data field, see Table A1-20.

A1.8.2 Hourly Records. Following the file headers, 8,760 rows of hourly data records provide one year of solar radiation, illuminance, and meteorological data, along with their source and uncertainty flags, as described in Table A1-21. Tables A1-22 through A1-24 include source and uncertainty flag definitions as called out in Table A1-21.

Informative Note: For solar radiation and illuminance elements, the data values represent the energy received during the 60 minutes *preceding the hour indicated* (60-minute period ending at the time stamp) as described in Table A1-21. For meteorological elements (with some exceptions), observations or measurements were made *at the hour indicated* as described in Table A1-21. Some of the meteorological elements had observations, measurements, or estimates made at other intervals.

Table A1-19. TMY3 data header (line 1)

Field	Element	Unit or Description
1	Site identifier code	USAF number
2	Station name	Quote delimited
3	Station state	Two-letter U.S. Postal abbreviation
4	Site time zone	Hours from Greenwich, negative west
5	Site latitude	Decimal degree
6	Site longitude	Decimal degree
7	Site elevation	Meter

Table A1-20. TMY3 data header (line 2)

Field	Element
1-68	Data field name and units (abbreviation or mnemonic)

Table A1-21. TMY3 data fields (lines 3-8762)

Field	Element	Unit or Range	Resolution	Description
1	Date	MM/DD/YYYY	--	Date of data record
2	Time	HH:MM	--	Time of data record (local standard time)
3	Hourly extraterrestrial radiation on a horizontal surface	Watt-hour per square meter	1 Wh/m^2	Amount of solar radiation received on a horizontal surface at the top of the atmosphere during the 60-minute period ending at the timestamp
4	Hourly extraterrestrial radiation normal to the sun	Watt-hour per square meter	1 Wh/m^2	Amount of solar radiation received on a surface normal to the sun at the top of the atmosphere during the 60-minute period ending at the timestamp
5	Global horizontal irradiance	Watt-hour per square meter	1 Wh/m^2	Total amount of direct and diffuse solar radiation received on a horizontal surface during the 60-minute period ending at the timestamp
6	Global horizontal irradiance source flag	1-2	--	See Table A1-22
7	Global horizontal irradiance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates. ***Informative Note:*** For more information see *NSRDB User's Manual*[A-6].
8	Direct normal irradiance	Watt-hour per square meter	1 Wh/m^2	Amount of solar radiation (modeled) received in a collimated beam on a surface normal to the sun during the 60-minute period ending at the timestamp
9	Direct normal irradiance source flag	1-2	--	See Table A1-22
10	Direct normal irradiance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates. ***Informative Note:*** For more information see *NSRDB User's Manual*[A-6].
11	Diffuse horizontal irradiance	Watt-hour per square meter	1 Wh/m^2	Amount of solar radiation received from the sky (excluding the solar disk) on a horizontal surface during the 60-minute period ending at the timestamp
12	Diffuse horizontal irradiance source flag	1-2	--	See Table A1-22
13	Diffuse horizontal irradiance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates. ***Informative Note:*** For more information see *NSRDB User's Manual*[A-6].
14	Global horizontal illuminance	Lux	100 lx	Average total amount of direct and diffuse illuminance received on a horizontal surface during the 60-minute period ending at the timestamp
15	Global horizontal illuminance source flag	1-2	--	See Table A1-22
16	Global horizontal illuminance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates. ***Informative Note:*** For more information see *Users Manual for TMY3 Data Sets*[A-5], section 2.10.
17	Direct normal illuminance	Lux	100 lx	Average amount of direct normal illuminance received within a 5.7° field of view centered on

				the sun during 60-minute period ending at the timestamp
18	Direct normal illuminance source flag	1-2	--	See Table A1-22
19	Direct normal illuminance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates. ***Informative Note:*** For more information see *Users Manual for TMY3 Data Sets*[A-5], section 2.10.
20	Diffuse horizontal illuminance	Lux	100 lx	Average amount of illuminance received from the sky (excluding the solar disk) on a horizontal surface during the 60-minute period ending at the timestamp
21	Diffuse horizontal illuminance source flag	1-2	--	See Table A1-22
22	Diffuse horizontal illuminance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates. ***Informative Note:*** For more information see *Users Manual for TMY3 Data Sets*[A-5], section 2.10.
23	Zenith luminance	Candela per square meter	10 cd/m^2	Average amount of luminance at the sky's zenith during the 60-minute period ending at the timestamp
24	Zenith luminance source flag	1-2	--	See Table A1-22
25	Zenith luminance uncertainty	Percent	1%	Uncertainty based on random and bias error estimates. ***Informative Note:*** For more information see *Users Manual for TMY3 Data Sets*[A-5], section 2.10.
26	Total sky cover	Tenths of sky	1 tenth	Amount of sky dome covered by clouds or obscuring phenomena at the time indicated
27	Total sky cover flag (source)			See Table A1-23
28	Total sky cover flag (uncertainty)			See Table A1-24
29	Opaque sky cover	Tenths of sky	1 tenth	Amount of sky dome covered by clouds or obscuring phenomena that prevent observing the sky or higher cloud layers at the time indicated
30	Opaque sky cover flag (source)			See Table A1-23
31	Opaque sky cover flag (uncertainty)			See Table A1-24
32	Dry-bulb temperature	Degree C	0.1°	Dry-bulb temperature at the time indicated
33	Dry-bulb temperature flag (source)			See Table A1-23
34	Dry-bulb temperature flag (uncertainty)			See Table A1-24
35	Dew-point temperature	Degree C	0.1°	Dew-point temperature at the time indicated
36	Dew-point temperature flag (source)			See Table A1-23
37	Dew-point temperature flag (uncertainty)			See Table A1-24
38	Relative humidity	Percent	1%	Relative humidity at the time indicated
39	Relative humidity flag (source)			See Table A1-23
40	Relative humidity flag (uncertainty)			See Table A1-24
41	Station pressure	Millibar	1 mbar	Station pressure at the time indicated
42	Station pressure flag (source)			See Table A1-23
43	Station pressure flag (uncertainty)			See Table A1-24

44	Wind direction	Degrees from north (360° = north; 0° = undefined, calm)	10°	Wind direction at the time indicated
45	Wind direction flag (source)			See Table A1-23
46	Wind direction flag (uncertainty)			See Table A1-24
47	Wind speed	Meter/second	0.1 m/s	Wind speed at the time indicated
48	Wind speed flag (source)			See Table A1-23
49	Wind speed flag (uncertainty)			See Table A1-24
50	Horizontal visibility	Meter*	1 m	Distance to discernable remote objects at the time indicated (7777 = unlimited)
51	Horizontal visibility flag (source)			See Table A1-23
52	Horizontal visibility flag (uncertainty)			See Table A1-24
53	Ceiling height	Meter*	1 m	Height of the cloud base above local terrain (77777 = unlimited)
54	Ceiling height flag (source)			See Table A1-23
55	Ceiling height flag (uncertainty)			See Table A1-24
56	Precipitable water	Centimeter	0.1 cm	The total precipitable water contained in a column of unit cross section extending from the earth's surface to the top of the atmosphere
57	Precipitable water flag (source)			See Table A1-23
58	Precipitable water flag (uncertainty)			See Table A1-24
59	Aerosol optical depth, broadband	[unitless]	0.001	The broadband aerosol optical depth per unit of air mass due to extinction by the aerosol component of the atmosphere
60	Aerosol optical depth, broadband flag (source)			See Table A1-23
61	Aerosol optical depth, broadband flag (uncertainty)			See Table A1-24
62	Albedo	[unitless]	0.01	The ratio of reflected solar irradiance to global horizontal irradiance
63	Albedo flag (source)			See Table A1-23
64	Albedo flag (uncertainty)			See Table A1-24
65	Liquid precipitation depth	Millimeter*	1 mm	The amount of liquid precipitation observed at the indicated time for the period indicated in the liquid precipitation quantity field
66	Liquid precipitation quantity	Hour*	1 hr	The period of accumulation for the liquid precipitation depth field
67	Liquid precipitation depth flag (source)			See Table A1-23
68	Liquid precipitation depth flag (uncertainty)			See Table A1-24

* Value of -9900 indicates the measurement is missing.

Table A1-22. Solar radiation and illuminance source flags

Flag	Definition
1	Data modeled using METSTAT or from 1961-1990 NSRDB solar fields
2	Data modeled using SUNY Satellite model (time shifted)

Table A1-23. Meteorological source flags

Flag	Definition
A	Data as received from NCDC, converted to SI units
B	Linearly interpolated
C	Non-linearly interpolated to fill data gaps from 6 to 47 hours in length
D	Not used
E	Modeled or estimated, except: precipitable water, calculated from radiosonde data; dew point temperature calculated from dry bulb temperature and relative humidity; and relative humidity calculated from dry bulb temperature and dew point temperature
F	Precipitable water, calculated from surface vapor pressure; aerosol optical depth, estimated from geographic correlation
?	Source does not fit any of the above. Used mostly for missing data

Table A1-24. Meteorological uncertainty flags

Flag	Definition
1 – 6	Not used
7	Uncertainty consistent with NWS practices and the instrument or observation used to obtain the data
8	Greater uncertainty than 7 because values were interpolated or estimated
9	Greater uncertainty than 8 or unknown
0	Not definable

[Note: Selected portions of Annex A2 are revised as shown. Only material relevant to edits is provided here; all other Annex A2 material is unchanged. The indicated revisions are consistent with revisions to Sec5-2Aout.xlsx, S140outNotes.txt, and S140outNotesExamples.txt, provided in the accompanying electronic media. With respect to the S140outNotes files, these edits are shown in accompanying pdf versions of the .txt files and are also shown here.]

(This is a normative annex and is part of the standard.)

NORMATIVE ANNEX A2
STANDARD OUTPUT REPORTS

The standard output reports, consisting of the following seven forms provided with the electronic media accompanying this standard, shall be used:

a. Output results for cases of Sections 5.2.1, 5.2.2, and 5.2.3 (Sec5-2Aout.XLSX, spreadsheet file)

[….]

h. Modeling notes (S140outNotes.TXT, text file reprinted as Attachment A2.7)

[….]

Informative Note: For entering modeling notes into S140outNotes.TXT, the format of the examples applying S140outNotes_Examples.TXT given in Informative Attachment A2.8 within this section is recommended. Changes to S140outNotes.TXT and S140outNotes_Examples.TXT since 140-2017 are indicated, respectively, in “Informative-S140outNotes-txt-edits-140-2017-A.PDF” and “S140outNotes_Examples-txt-edits-140-2017-A.PDF”.

Attachment A2.1—Instructions for Entering Results into Sec5-2Aout.XLSX

STANDARD 140 OUTPUT FORM—RESULTS
Sec5-2Aout.XLSX, Sheet ‘A’

INSTRUCTIONS:

1. Use specified units.

2. All radiation data are for sum of direct and diffuse solar radiation.

3. Output terminology is defined in Section 6.2.1.

4.~~3.~~ Format dates using the appropriate ~~two-digit date followed by a~~ three-character~~digit~~ month code, one- or two-digit day, and two-digit hour code (24-hour clock) as shown below:

MONTH	CODE
January	Jan
February	Feb
March	Mar
April	Apr
May	May
June	Jun
July	Jul
August	Aug
September	Sep
October	Oct
November	Nov
December	Dec

For example, a peak occurring on Jan 4 during the 158th hour interval (0700-08002 to 3 p.m.), shall be input as follows:

DATEMONTH	**DAY**	**HOUR**
04 Jan	4	8 15

5.4. Data entry is restricted to the following ranges: Column B or Columns B, C, D. Enter appropriate output in the proper columns for the case or hour listed in Column A. This worksheet extends down to Row 901. The protection option has been used in this worksheet to help ensure that data are input to the correct cells.

C61…C63:	Software Name, Version, and Date of Results
C70…L115:	Conditioned Zone Loads (Non-Free-Float Test Cases)
C130…K136:	Free-Float Case Zone Temperatures
C155…C171:	Solar Radiation, as specified
C178…K178:	Sky Temperature
C190…R201:	Monthly Conditioned Zone Loads (Cases 600 and 900)
C230…T253:	Specific-Day Hourly Output: incident and transmitted solar radiation and sky temperatures
C262…Z285:	Specific-Day Hourly Output: zone loads (selected cases) and conditioned-zone temperatures (Cases 640 and 940)
C294…H317:	Specific-Day Hourly Output: free float temperatures
C330…C478:	Case 900FF Zone Temperature Bin Data, enter 8760 hours of zone temperature data in Sheet 'TMPBIN' (of Sec5-2Aout.xlsx), as described in Cell E1 there. Bin data will flow to C330 – C478 on Sheet 'A' (of Sec5-2Aout.xlsx).

Attachment A2.7—Standard 140 Output Form—Modeling Notes (S140outNotes.TXT)

[Note: See S140outNotes.TXT in accompanying electronic media for the full form; accompanying file Informative-S140outNotes-txt-edits-140-2017-A.PDF shows the proposed changes to the S140outNotes.TXT for this addendum. Only Report Block D is shown here as that is the only report block that has changes; all other S140outNotes.TXT material is unchanged.]

[Note: This updated version of S140outNotes.TXT will also replace the existing file for the other Standard-140 test suites, included in accompanying electronic media subfolders Sec5-2BFiles, Sec5-3AFiles, Sec5-3BFiles, Sec5-4Files, Sec5-5Files, and Sec7-2Files.]

D. REPORT BLOCK FOR USE OF NONSPECIFIED INPUTS

CONTENT: This section shall describe nonspecified inputs used to perform the tests. Use of nonspecified inputs shall be permitted only for the following specified sections relating to the following topics:

- Alternative constant exterior surface coefficients in Sections 5.2.1.9.3, 5.2.3.1.4.3, 5.2.3.3.2, and 5.3.1.8
- Alternative constant Iinterior combined radiative and convective surface coefficients in Sections 5.2.1.10.3, 5.2.3.1.4.4, 5.2.3.2.2, and 5.3.1.9
- Alternative constant Iinterior solar distribution fractions in Sections 5.2.1.12, 5.2.2.1.2.2, 5.2.2.1.6.2, 5.2.2.1.7.2, 5.2.2.2.7.4, 5.2.3.9.3, 5.2.3.10.2, and 5.2.3.12.2
- Air density given at specific altitudes for the space-cooling and space-heating equipment cases in Sections 5.3.1.4.3, 5.3.3.4.3, and 5.4.1.4.3.

INSTRUCTIONS: If nonspecified inputs are applied, a separate note for each use of nonspecified inputs shall be provided. The standard format shown below and a separate number and title for each note shall be applied. If nonspecified inputs are not applied, specify "NONE" in place of the information below.

NOTE 1—<Title>

1.1 Describe the Effect Being Simulated:

1.2 Section(s) of the Standard where Relevant Inputs are Specified:

1.3 Nonspecified Input(s) Used:

1.4 Physical, Mathematical, or Logical Justification for Use of the Nonspecified Input(s)—provide supporting calculations if relevant:

INFORMATIVE ATTACHMENT A2.8—EXAMPLES OF MODELING NOTES (~~S140OUTNOTES_EXAMPLES~~S140outNotes_Examples.TXT)

Informative Note: **Attachment A2.8 is all informative material and is not part of the Standard.**

MODELING NOTES FOR ASHRAE STANDARD 140—EXAMPLES

See S140outNotes_Examples.TXT provided with the accompanying electronic media within the “Informative Materials” subfolder included within any of the “Sec…Files” subfolders.

[Note: See S140outNotes_Examples.TXT in accompanying electronic media for the full form; accompanying file Informative-S140outNotes_Examples-txt-edits-140-2017-A.PDF shows the proposed changes to the S140outNotes_Examples.TXT for this addendum. Only Report Block D is changed within the file (similar changes as to S140outNotes.TXT); all other S140outNotes_Examples.TXT material is unchanged.]

[Note: This updated version of S140outNotes_Examples.TXT will also replace the existing file for the other Standard-140 test suites, included in accompanying electronic media subfolders Sec5-2BFiles, Sec5-3AFiles, Sec5-3BFiles, Sec5-4Files, Sec5-5Files, and Sec7-2Files.]

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX B1 TABULAR SUMMARY OF TEST CASES

[Note: Selected portions of Annex B1 are revised as shown. Only material relevant to edits is provided here; all other Annex B1 material is unchanged.]

Table B1-1 summarizes the content of the test-case tabular summary tables, including relevant sections of the standard for each suite of tests.

Nomenclature

Abbreviations and symbols used in Tables B1-2, B1-3, and B1-6 through B1-17 are listed below. Abbreviations used for Tables B1-4, B1-5, and B1-18 are listed with those tables.

1.0mH	horizontal overhang projecting 1 m perpendicular to window surface as in Figure 5-3~~2~~ (Section 5.2.2.1.1.1)
1.0mHV	horizontal overhang and vertical fins projecting 1 meter perpendicular to window surface as in Figures 5-54 and 5-6~~5~~ (Section 5.2.2.1.3.1)
1-pane	single-pane window
20,20	a single-temperature thermostat control strategy (heat ON below 20ºC, cooling ON above 20ºC)
20,27	a deadband thermostat control strategy (heat ON below 20ºC, cooling ON above 27ºC)
27,V	a thermostat and ventilation control strategy with cooling (ON above 27ºC, daytime only) and nighttime-only ventilation; no heating anytime
Absorpt.	absorptance
ach	air changes per hour
Apr.	April
AHRI	Air-Conditioning, Heating and Refrigeration Institute
COP	coefficient of performance
DB	dry-bulb temperature
DBT	dry-bulb temperature
DP	dew-point temperature
E,W	east and west
EDB	entering dry-bulb temperature
Emit.	emittance
Ext.	exterior
FF	free-floating thermostat control strategy (no heating or cooling)
H	heavy mass
H,C,V	heating, cooling, ventilation
high	greater loads relative to “mid”
high2	greater loads relative to “mid2”
Infil.	infiltration (natural ventilation)
Int.	interior
Intgen.	internally generated sensible heat gains
IR	infrared radiation
L	light mass
Low-e	low emissivity window
mid	internal gains schedules are relatively high daytime and low nighttime periodically/seasonally adjusted values
mid2	similar to “mid” but with cooler-month internal gains = 0 for 0 cooling at ODB < 55°F for 0 OA
NA	not applicable
Num.	zone number (1 or 2)
OA	outdoor air
Oct.	October
ODB	outdoor dry-bulb temperature

Orient.	orientation
PLR	part-load ratio for cooling
PLR*f*	part-load ratio for furnace
S	south
Shade	window shading device: horizontal overhang and/or vertical fins
SHR	sensible heat ratio
SS	sunspace
SW	shortwave (solar spectrum) radiation
Temp.	temperature
tstat	thermostat
V	forced ventilation cooling

Table B1-2 Section 5.2.3 Case Descriptions, Low Mass In-Depth

Case #	Setpoints H, C, V, °C	Mass	Intgen., W	Infil., ach	Opaque Surface Int. IR Emit.	Opaque Surface Ext. IR Emit.	Opaque Surface Int. SW Absorpt.	Opaque Surface Ext. SW Absorpt.	Glass, m^2	Orient.	Shade	Comments
195	20, 20	L	0	0	0.1	0.1	NA see Note 1	0.1	See Note 2	S	No	Case 195 tests solid conduction.
200	20, 20	L	0	0	0.1	0.1	NA	0.1	0 (See Note 3)	S	No	~~Do~~Run cases 200 through 215 only if you can explicitly adjust infrared emittance in your code. Cases 200, 195 test film convection algorithms. The major portion of the change in results between Cases 200 and 195 will be from the ~~opaque window~~ high-conductance wall elements. Increased differences between codes will be from the different film algorithms.
210	20, 20	L	0	0	0.1	0.9	NA	0.1	0	S	No	Cases 220, 210 test Int. IR with Ext. IR ON. Cases 210, 200 test Ext. IR with Int. IR OFF.
215	20, 20	L	0	0	0.9	0.1	NA	0.1	0	S	No	Cases 220, 215 test Ext. IR with Int. IR ON. Cases 215, 200 test Int. IR with Ext. IR OFF.
220	20, 20	L	0	0	0.9	0.9	NA	0.1	0	S	No	Cases 220, 210 test Int. IR with Ext. IR ON. Case 220 is the base for Cases 230 through 270.
230	20, 20	L	0	1	0.9	0.9	NA	0.1	0	S	No	Cases 230, 220 test infiltration.
240	20, 20	L	200	0	0.9	0.9	NA	0.1	0	S	No	Cases 240, 220 test internal gains.
250	20, 20	L	0	0	0.9	0.9	NA	0.9	0	S	No	Cases 250, 220 test exterior solar absorptance/incident solar.
270	20, 20	L	0	0	0.9	0.9	0.9	0.1	12	S	No	Cases 270, 220 test south solar transmittance/incident solar.
280	20, 20	L	0	0	0.9	0.9	0.1	0.1	12	S	No	Cases 280, 270 test cavity albedo.
290	20, 20	L	0	0	0.9	0.9	0.9	0.1	12	S	1.0 mH	Cases 290, 270 test south horizontal overhang.
300	20, 20	L	0	0	0.9	0.9	0.9	0.1	6, 6	E, W	No	Cases 300, 270 test east and west solar transmittance and incidence.
310	20, 20	L	0	0	0.9	0.9	0.9	0.1	6, 6	E, W	1.0 m HV	Cases 310, 300 test east and west overhang and fins.
320	20, 27	L	0	0	0.9	0.9	0.9	0.1	12	S	No	Cases 320, 270 test thermostat deadband.

Note 1: Interior shortwave absorptance doesn't matter when glass area is zero.

Note 2: Case 195 has neither a windows nor a "high--conductance wall elements," but consists of 100% normally insulated wall as specified for the lightweight case.

Note 3: Cases with zero glass area (except cases 195 and 395) have a "high-conductance wall elements" in place of the windows and with the same area as the windows. The "high-conductance wall elements" haves the same exterior and interior IR emittance and the same solar absorptance as specified for the normal wall in each case. The "high--conductance wall" element surface texture is very smooth (like glass.).

Table B1-3 Sections 5.2.1, 5.2.2 and 5.2.3 Case Descriptions, Basic and In-Depth Cases

Case #	Setpoints H, C, V, °C	Mass	Intgen., W	Infil., ach	Opaque Surface Int. IR Emit.	Opaque Surface Ext. IR Emit.	Opaque Surface Int. SW Absorpt.	Opaque Surface Ext. SW Absorpt.	Glass, m^2	Orient.	Shade	Comments
395	20, 27	L	0	0	0.9	0.9	NA	0.1	see Note 1	S	No	Case 395 tests solid conduction.
400	20, 27	L	0	0	0.9	0.9	NA	0.1	0	S	No	Cases 400, 395 test surface convection and IR. (See Note 2.)
410	20, 27	L	0	0.5	0.9	0.9	NA	0.1	0	S	No	Cases 410, 400 test infiltration.
420	20, 27	L	200	0.5	0.9	0.9	NA	0.1	0	S	No	Cases 420, 410 test internal heat generation.
430	20, 27	L	200	0.5	0.9	0.9	NA	0.6	0	S	No	Cases 430, 420 test exterior solar absorptance and incident solar.
440	20, 27	L	200	0.5	0.9	0.9	0.1	0.6	12	S	No	Cases 440, 600 test interior solar absorptance and cavity albedo.
450	This case is the same as Case 600 except constant combined interior and exterior suface coefficients are applied.											Cases 450, 460, 470, 600 test interior and exterior surface convective and IR heat transfer.
460	This case is the same as Case 600 except constant combined *interior* suface coefficients are applied.											Cases 460, 450, 600 test interior convective and IR heat transfer.
470	This case is the same as Case 600 except constant combined *exterior* suface coefficients are applied.											Cases 470, 450, 600 test exterior surface convective and IR heat transfer.
600	20, 27	L	200	0.5	0.9	0.9	0.6	0.6	12	S	No	Cases 600, 430 test south solar transmission.
610	20, 27	L	200	0.5	0.9	0.9	0.6	0.6	12	S	1.0 mH	Case 610, 600 test south overhang.
620	20, 27	L	200	0.5	0.9	0.9	0.6	0.6	6, 6	E, W	No	Cases 620, 600 test east and west solar transmittance/incidence.
630	20, 27	L	200	0.5	0.9	0.9	0.6	0.6	6, 6	E, W	1.0 m HV	Cases 630, 620 test east and west overhangs and fins.
640	SETBACK	L	200	0.5	0.9	0.9	0.6	0.6	12	S	No	Cases 640, 600 test night setback.
650	27, V	L	200	0.5	0.9	0.9	0.6	0.6	12	S	No	Cases 650, 600 test venting.
660	20, 27	L	200	0.5	0.9	0.9	0.6	0.6	12, Low-e	S	No	Cases 660, 600 test low-emissivity window
670	20, 27	L	200	0.5	0.9	0.9	0.6	0.6	12, 1-pane	S	No	Cases 670, 600 test single-pane window
680	20, 27	L	This case is the same as Case 600 except increased wall and roof insulation are applied.									Cases 680, 600 test increased insulation; 20,27 tstat.
685	20, 20	L	200	0.5	0.9	0.9	0.6	0.6	12	S	No	Cases 685, 600 test thermostat deadband.
695	20, 20	L	This case is the same as Case 685 except increased wall and roof insulation are applied.									Cases 695, 685 test increased insulation; 20,20 tstat.

Note 1: Case 395 has neither a window nor high-conductance wall elements.~~an "opaque window."~~ It consists of 100% normally insulated wall as specified for the lightweight case.

Note 2: Cases 400, 395 test surface convection and IR radiation. The major portion of the change in results will be from high-conductance wall elements~~the opaque window~~. Increased differences between codes will be from the different film convection and IR algorithms.

Table B1-3 Sections 5.2.1, 5.2.2 and 5.2.3 Case Descriptions, Basic and In-Depth Cases (Continued)

Case #	Setpoints H, C, V, °C	Mass	Intgen., W	Infil., ach	Opaque Surface Int. IR Emit.	Opaque Surface Ext. IR Emit.	Opaque Surface Int. SW Absorpt.	Opaque Surface Ext. SW Absorpt.	Glass, m²	Orient.	Shade	Comments
800	20, 27	H	200	0.5	0.9	0.9	NA	0.6	0	S	No	Cases 800, 430 test thermal mass with no transmitted solar.
810	20, 27	H	200	0.5	0.9	0.9	0.1	0.6	12	S	No	Cases 810, 900 test interior solar absorptance and mass interaction.
900	20, 27	H	200	0.5	0.9	0.9	0.6	0.6	12	S	No	Cases 900, 600 test thermal mass and solar interaction.
910	20, 27	H	200	0.5	0.9	0.9	0.6	0.6	12	S	1.0 mH	Cases 910, 900 test south overhang/mass interaction.
920	20, 27	H	200	0.5	0.9	0.9	0.6	0.6	6, 6	E, W	No	Cases 920, 900 test east and west transmittance/mass interaction.
930	20, 27	H	200	0.5	0.9	0.9	0.6	0.6	6, 6	E, W	1.0 m HV	Cases 930, 920 test east and west shading/mass interaction.
940	SETBACK	H	200	0.5	0.9	0.9	0.6	0.6	12	S	No	Cases 940, 900 test setback/mass interaction.
950	27, V	H	200	0.5	0.9	0.9	0.6	0.6	12	S	No	Cases 950, 900 test venting/mass interaction.
960	2ZONE, SS		See specification in Test Procedures									960 tests passive solar/interzonal heat transfer.
980	20, 27	H	This case is the same as Case 900 except increased wall and roof insulation are applied.									Cases 980, 900 test increased insulation/mass interaction; 20,27 tstat.
985	20, 20	H	200	0.5	0.9	0.9	0.6	0.6	12	S	No	Cases 985, 900 test tstat deadband/mass interaction.
995	20, 20	H	This case is the same as Case 985 except increased wall and roof insulation are applied.									Cases 995, 985 test increased insulation/mass interaction; 20,20 tstat.
600FF	NONE	These cases, labeled FF (interior temperatures free-float), are exactly the same as the corresponding non-FF cases, except there are no mechanical heating or cooling systems.										
900FF	NONE											
650FF	NONE, V											
950FF	NONE, V											
680FF	NONE, Increased insulation											
980FF	NONE, Increased insulation											

[Note: Annex B2 is no longer referenced by the Section 5.2 test cases; edits here document revisions needed for consistency with that.]

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX B2 ABOUT TYPICAL METEOROLOGICAL YEAR (TMY) WEATHER DATA

~~TMY data are used in Standard 140, Sections 5.2.1, 5.2.2, and 5.2.3 for the following reasons:~~

~~a. The original research that is the foundation of Standard 140, *IEA BESTEST*, was performed by the National Renewable Energy Laboratory in collaboration with the International Energy Agency[B-29]. The underlying research used in this standard began in 1990 and was completed in 1993. At that time TMY data represented the state-of-the-art for hourly weather data.~~

~~b. During the process of converting the original NREL/IEA work into a Standard Method of Test, SPC 140 considered changing the weather data file and format. The problems with this were as follows:~~

~~1. Some parts of the test specification are based on the specific TMY data file provided with Standard 140. For example, the convective portion of annual average exterior combined surface coefficients—provided for those programs that do not calculate exterior convection hourly—are related to the average annual wind speed from the original weather data file. This means that some inputs in the test specification would need to be changed.~~

~~2. The example results of Informative Annex B8 would not be consistent with user-generated results if new weather data were used, unless the test cases were rerun for all the programs shown. For many users of Standard 140, the evaluation of results will be facilitated by being able to compare the results for their program with the example results presented in Informative Annex B8, which requires using consistent testing methods and weather data.~~

The original research for Section 7.2, *HERS BESTEST*, was performed by NREL in collaboration with the U.S. HERS Council Technical Committee [B-38,B-39]. The underlying research began in 1993 and was completed in 1995. At that time TMY data represented the state-of-the-art for hourly weather data. ~~(~~TMY2 data were just becoming available toward the end of the project, but the work was too far along to switch weather data files, which would have required adjusting test specifications.~~)~~ For example, the specified equivalent convective portion of annual average exterior combined surface coefficients—provided for those programs that do not calculate exterior convection hourly—are related to the average annual wind speed from the original weather data file. Such changes to the test specification would also require rerunning the programs that provided example results.

For Sections 5.3.1 and 5.3.2, either TMY-format data or TMY2-format data may be used as described in Normative Annex A1, Section A1.2.1.

For convenience, we have reprinted the following discussion from the documentation for DOE2.1A *Reference Manual* (p. VIII-31) [B-40].

Solar radiation and surface meteorological data recorded on an hourly basis are maintained at the National Climatic Data Center (NCDC). These data cover recording periods from January 1953 through December 1975 for 26 data rehabilitation stations, although the recording periods for some stations may differ. The data are available in blocked (compressed) form on magnetic tape (SOLMET) for the entire recording period for the station of interest. ***Note:*** Hourly readings for meteorological data are available through 1964; subsequent readings are on a three-hour basis.

Contractors desiring to use a database for simulation or system studies for a particular geographic area require a database that is more tractable than these and also one that is representative of the area. Sandia National Laboratory has used statistical techniques to develop a method for producing a typical meteorological year for each of the 26 rehabilitation stations. This section describes the use of these magnetic tapes.

The TMY tapes comprise specific calendar months selected from the entire recorded span for a given station as the most representative, or typical, for that station and month. For example, a single January is chosen from the 23 Januaries for which data are recorded from 1953 through 1975 on the basis of its being most nearly like the composite of all 23 Januaries. Thus, for a given station, January of 1967 might be selected as the typical meteorological month (TMM) after a statistical comparison with all of the other 22 Januaries. This process is pursued for each of the other calendar months, and the twelve months chosen then constitute the TMY.

Although the data have been rehabilitated by NCDC, some recording gaps do occur in the SOLMET tapes. Moreover, there are data gaps because of the change from one-hour to three-hour meteorological data recording in 1965. Consequently, as TMY tapes were being constituted from the SOLMET data, the variables data for barometric pressure, temperature, and wind velocity and direction were scanned on a month-by-month basis, and missing data were replaced by linear interpolation. Missing data in the leading and trailing positions of each monthly segment are replaced with the earliest/latest legitimate observation.

Also, since the TMMs were selected from different calendar years, discontinuities occurred at the month interfaces for the above continuous variables. Hence, after the monthly segments were rearranged in calendar order, the discontinuities at the month interfaces were ameliorated by cubic spline smoothing covering the six-hourly points on either side of the interface.

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INFORMATIVE ANNEX B3 INFILTRATION AND FAN ADJUSTMENTS FOR ALTITUDE

Air density correction for altitude was required in the development of the analytical solutions and by modelers generating example results with programs that did not automatically adjust for altitude. This Annex details the altitude correction used in the development of the analytical solutions of Standard 140. These corrections differ slightly from the *2009 ASHRAE Handbook—Fundamentals*, Chapter 1[B-10]. Section B3.3 below discusses this in more detail.

B3.1 Adjustments for Test Cases of Sections 5.2.1, 5.2.2, and 5.2.3. The decline in air density with altitude may be expressed according to the following exponential curve fit:

$$\rho_{air,u} = \rho_{air,0} \times e^{(a)(elev)} \quad \text{(B3-1)}$$

where

$\rho_{air,u}$ = air density at specified elevation

$\rho_{air,0}$ = air density at sea level

e = inverse Ln

a = −1.219755 × 10^{-4}/m

$elev$ = elevation, m

For sea level standard temperature and pressure conditions of 15°C and 101.325 kPa (ASHRAE 2017[B-101], p. 1.1), Aair density at sea level = 1.2255 01385 kg/m^3 (ASHRAE 2012)[A-7]. this example value is the SI conversion from 0.075 lb/ft^3, which is the approximate value for air at 70°F, 14.696 psia; this value was used in *IEA BESTEST*[B-29] [Appendix B] and is also cited for "standard air [I-P]" in *ASHRAE Terminology of HVAC&R*[B-41]).

Air density at 1609 m = 0.987298 kg/m^3

For the current weather data file, located at an altitude of 1650 m, annual average air density of 1.0156 kg/m^3 was calculated. This was based on an hourly air density calculation, applying ASHRAE (2017)[B-101], Chapter 1, Equation 26 – where atmospheric pressure and dry-bulb temperatures are taken directly from the weather file (with simple unit conversions as needed), and humidity ratio is calculated from weather file hourly dry-bulb temperature, relative humidity, and atmospheric pressure based on ASHRAE (2017)[B-101], Chapter 1, Equation 20 and related equations. The resulting annual average humidity ratio using this calculation was 0.0049 kgw/kgda. For programs that do not allow variation of air density, corrections to the infiltration and ventilation rates specified for various test cases are calculated as follows.

For programs assuming standard air density, Tthe corrected infiltration rate for 1609 m altitude = (specified rate) × (1.0156/1.2255). (0.987298/1.201385). (For example, 0.5 ach becomes 0.414 ach, and 1 ach becomes 0.8292 ach.)

Similarly for cases with vent fan (650, 950, 650FF, 950FF), Tthe corrected vent-fan capacity for 1609 m altitude = (specified capacity) × (1.0156/1.2255). using converted I-P conditions at sea level) × (0.987298/1.201385). (For example, 17003.16 m^3/h becomes 1409 1399.7m^3/h.) ***Note:*** U.S. Standard Atmosphere conditions with dry air behaving as a perfect gas at 15°C and 101.325 kPa (*2005 ASHRAE Handbook—Fundamentals*, p. 6.1 [B-32]), implies air density = 1.225 kg/m^3.

B3.2 Adjustments for Section 7.2 Test Cases. The decline in air density with altitude may be expressed according to the following exponential curve fit:

$$\rho_{air,u} = \rho_{air,0} \times e^{(a)(elev)} \quad \text{(B3-1)}$$

For *HERS BESTEST*[B-38], parameters of Equation B3-1 are as follows:

$\rho_{air,u}$ = air density at specified elevation

$\rho_{air,0}$ = air density at sea level = 0.075 lb/ft^3 (approximate value)

e = inverse Ln
a = $-3.71781196 \times 10^{-5}$/ft
elev = elevation, ft

This results in the following:
Air density at 6145 ft = 0.05968 lb/ft^3
Air density at 2178 ft = 0.06917 lb/ft^3

If the software being tested does not allow variation of air density, the specified infiltration rate is adjusted as follows:

Corrected infiltration rate for 6145 ft altitude = (Specified rate) x (0.05968/0.075)

Corrected infiltration rate for 2178 ft altitude = (Specified rate) x (0.06917/0.075)

[Note: The remainder of Section B3.2 is not shown; there are no changes to that material.]

B3.3 Comparison of Section B3.2 with *ASHRAE Handbook—Fundamentals*. The altitude correction in Sections B3.1 and B3.2 was created by fitting an exponential curve to data in the *1993 ASHRAE Handbook—Fundamentals*, chapter 6, Table 1[B-26]. Beginning in 2001, *ASHRAE Handbook—Fundamentals*[B-30] included an equation for calculating altitude corrections in addition to the tabular data. (see Equation B3-2 below). This equation is gives results slightly different from that described in Section B3.2, this annex, with a maximum difference of 0.2%.

The decline in atmospheric pressure with altitude is presented in the *201709 ASHRAE Handbook—Fundamentals*, p. 1.1, Equation 3[B-101], as follows:

$$p = 101.325(1 - 2.25577 \times 10^{-5}Z)^{5.2559}$$

where
p = atmospheric pressure at elevation, bar
Z = elevation, m

A dimensionless altitude correction factor for pressure or density (these are directly proportional assuming air is an ideal gas) can be expressed as follows:

$$cf = (1 - 2.25577 \times 10^{-5}Z)^{5.2559} \qquad \text{(B3-2)}$$

In the Annex B3, Section B3.1For example, infiltration of 1 ach at an elevation of 6145 ft (1873 m)1609 m is equivalent to 0.7957 8218 ach at sea level using the Annex B3 eEquation B3-1 versus 0.7970 8234 ach at sea level using the *ASHRAE Handbook—Fundamentals* eEquation B3-2.

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX B4 ALTERNATIVE CONSTANT CONVECTIVE-ONLY AND ~~EXTERIOR~~ COMBINED RADIATIVE-~~-~~AND-~~-~~CONVECTIVE SURFACE COEFFICIENTS

~~**B4.1 General Equation.** ASHRAE and some simulation programs (e.g., BLAST 3.0 Level 193, using its option for simple outside surface conductance) calculate the exterior combined radiative and convective surface coefficient as a second order polynomial in wind speed of the following form:~~

~~$h = a_1 + a_2V + a_3V^2$, (B4-1)~~

~~where the units of h are W/(m^2·K), and the a coefficients are dependent on the surface texture.~~

~~**B4.2 Exterior Surface Coefficients for Test Cases of Sections 5.2.1, 5.2.2, and 5.2.3.** Assuming a surface texture of brick or rough plaster and a mean annual wind speed of 4.02 m/s, then the information in Table B4-1 is applicable.[B-33]~~

~~For cases where the exterior infrared emittance = 0.9, the exterior combined surface coefficient for all walls and roofs will be 29.3 W/(m^2·K) and the exterior combined surface coefficient for glass and high-conductance walls/opaque windows will be 21.0 W/(m^2·K).~~

~~For cases where the exterior infrared emittance = 0.1, the exterior combined surface coefficient for all walls and roofs will be 25.2 W/(m^2·K), and the exterior combined surface coefficient for high-conductance walls/opaque windows will be 16.9 W/(m^{2}K).~~

~~For convenience of input, the exterior combined radiative and convective surface coefficient for the transparent window and the opaque window are assumed to be the same, even though the hemispherical infrared emittance of ordinary uncoated window glass is usually 0.84. This is equivalent to assuming that the emittance of the glass is 0.9.~~

~~Convective and radiative portions of these coefficients are disaggregated in Informative Annex B5.~~

~~**Table B4-1 Polynomial Coefficients for Describing Exterior Surface Coefficient as a Function of Wind Speed (SI Units)**~~

~~Material~~	~~a_1~~	~~a_2~~	~~a_3~~
~~Stucco~~	~~11.58~~	~~5.894~~	~~0.0~~
~~Brick/rough plaster~~	~~12.49~~	~~4.065~~	~~0.028~~
~~Concrete~~	~~10.79~~	~~4.192~~	~~0.0~~
~~Clear pine~~	~~8.23~~	~~4.0~~	~~-0.057~~
~~Smooth plaster~~	~~10.22~~	~~3.1~~	~~0.0~~
~~Glass~~	~~8.23~~	~~3.33~~	~~-0.036~~

[Note: Following material is new; edit tracking not applied.]

Alternative constant values for exterior and interior surface coefficients are provided for programs that require these inputs, i.e., that have no automated (time-step varying) exterior or interior surface convective coefficient or infrared radiative heat transfer calculation method, or no other constant exterior or interior surface heat transfer coefficients explicit to their internal coding. Programs (or models within those programs, where a program allows a variety of modeling methods) that calculate time-step varying surface convective coefficients and infrared radiative heat transfer should not be adjusted to match the constant values provided here. Additionally, the calculation methods provided here should be perceived as examples only. Other methods may also be reasonably applied.

Further information on alternative constant surface coefficients derived for the test cases of Sections 5.2.1, 5.2.2, and 5.2.3 is included in Section B4.1. Further information on alternative surface coefficients for the test cases of Section 7.2 is included in Section B4.3 and Informative Annex B5. (Section B4.2 is intentionally blank.)

B4.1 Alternative Constant Convective and Combined (Convective and Radiative) Surface Heat Transfer Coefficients for Test Cases of Sections 5.2.1, 5.2.2, and 5.2.3.

Alternative constant convective and combined (convective and radiative) surface heat transfer coefficients are provided in Tables B4-1 and B4-2, respectively. Each table provides coefficients for interior and exterior surfaces, disaggregated for surfaces with ε = 0.9 and ε = 0.1, where ε is surface infrared emittance. Values for high-conductance wall elements with ε = 0.9, where they occur (e.g., Case 220), are the same as for the transparent windows. Table B4-2 further includes alternative combined surface coefficients for the Case 670 single-pane windows; these have a significant impact on results versus applying the Case 600 double-pane window combined coefficients (see Part IV, Appendix A, Section 4A.3.3.2 of the originating test-suite-update final report[A-15] for more details). For the walls, ceiling, and floor, Case 670 applies the same alternative coefficients as Case 600. The following abbreviations are applied in the tables:

- h,conv,int: interior convective surface coefficient
- h,conv,ext: exterior convective surface coefficient
- h,comb,int: interior combined surface coefficient
- h,comb,ext: exterior combined surface coefficient

Table B4-1. Interior and Exterior Surface Convective Heat Transfer Coefficients for Test Cases of Sections 5.2.1, 5.2.2, and 5.2.3

Surface Type	Windows or High-Conductance Wall Elements	Walls	Ceiling	Floor
ε = 0.9, Interior				
h,conv,int (W/(m²·K))	2.4	2.2	1.8	2.2
ε = 0.9, Exterior				
h,conv,ext (W/(m²·K))	8.0	11.9	14.4	0.8
ε = 0.1, Interior				
h,conv,int (W/(m²·K))	2.6	1.9	1.9	1.0
ε = 0.1, Exterior				
h,conv,ext (W/(m²·K))	7.9	11.8	14.4	0.9

SurfCoeffAnalysis…032718.xlsx; AllCoeffs600+…!P81+

Table B4-2. Interior and Exterior Surface Combined (Convective and Radiative) Heat Transfer Coefficients for Test Cases of Sections 5.2.1, 5.2.2, and 5.2.3

Surface Type	Windows or High-Conductance Wall Elements	Walls	Ceiling	Floor	Case 670 Single-Pane Windows
ε = 0.9, Interior					
h,comb,int (W/(m²·K))	4.5	1.8	1.7	3.7	7.8
ε = 0.9, Exterior					
h,comb,ext (W/(m²·K))	17.8	21.6	21.8	5.2	16.0
ε = 0.1, Interior					
h,comb,int (W/(m²·K))	3.1	2.1	1.9	0.4	
ε = 0.1, Exterior					
h,comb,ext (W/(m²·K))	8.1	12.8	17.4	1.3	

SurfCoeffAnalysis…080318.xlsx; AllCoeffs600+…!P94+

Example constant surface coefficients presented here apply only to the test cases and were calculated using a verified simulation process (see Part IV, Appendix A, Section 4A.3 of the originating test-suite-update final report[A-15]) **only for test cases with south facing windows or south facing high-conductance wall elements.** They should not be assumed to apply beyond this test suite.

Example constant interior surface coefficients assume buoyancy regime heat transfer only (see Part IV, Appendix A, Section 4A.2.2 of the originating test-suite-update final report[A-15])**.**

$h_{comb} < h_{conv}$ is possible here because convective and radiative heat flows may be in opposite directions for a given surface for a sufficient number of time steps.

Equations underlying the provided derived constant convective coefficients (h_{conv}) for various surface configurations are described in Part IV, Appendix A, Section 4A.2 of the originating test-suite-update final report[A-15]. Application of these equations for development of equivalent constant h_{conv} values, along with development of example constant combined coefficients, (h_{comb}) are described in Part IV, Appendix A, Section 4A.3 of the originating test-suite-update final report[A-15]. The content of Part IV of the originating test-suite-update final report[A-15] is summarized in Neymark et al. (2019).[A-8]

[Note: Edits to existing material recommence here.]

B4.2 Intentionally Blank.

B4.3 Alternative Constant Exterior Surface Coefficients for Section 7.2 Test Cases. Some simulation programs (e.g., EnergyPlus, using its option for simple outside surface conductance[A-2,B-20]) allow calculation of the exterior combined radiative and convective surface coefficient as a second order polynomial in wind speed of the form:

$$h = a_1 + a_2 V + a_3 V^2, \qquad \text{(B4-1)}$$

where the units of *h* are W/(m²·K), and the *a* coefficients are dependent on the surface texture. ~~For~~ From HERS BESTEST[B-38], the *a* coefficients that apply for Equation B4-1 (using I-P units) are listed in Table B4-3~~2~~.

Assuming a surface texture of brick or rough plaster, and a mean annual wind speed of 10.7 mph (9.304 knots), then

Exterior combined surface coefficient for all walls and roofs = 5.748 Btu/(h·ft²·°F).

For programs requiring a method for disaggregation of infrared and convective surface coefficients from combined surface coefficients, see Informative Annex B5.

Table B4-3~~2~~ Polynomial Coefficients for Describing Exterior Surface Coefficient as a Function of Wind Speed (I-P Units)

Material	a_1	a_2	a_3
Stucco	2.04	0.535	0.0
Brick/rough plaster	2.20	0.369	0.001329
Concrete	1.90	0.380	0.0
Clear pine	1.45	0.363	-0.002658
Smooth plaster	1.80	0.281	0.0
Glass	1.45	0.302	-0.001661

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INFORMATIVE ANNEX B5 INFRARED PORTION OF FILM COEFFICIENTS

[Note: Annex B5 is no longer referenced by the Section 5 test cases; it is referenced by the Section 7 tests. Edits here are for consistency with related Annex B4 revisions.]

B5.1 General Equation. The infrared portion of film coefficients is based on the linearized gray-body radiation equation[B-97]:

$h_i = 4\varepsilon\sigma T^3$, (B5-1)

B5.2 Intentionally blank.Tabulation for Test Cases of Sections 5.2.1, 5.2.2, and 5.2.3. For the test cases of Sections 5.2.1, 5.2.2 and 5.2.3, the parameters of Equation B5-1 are as follows:

ε = infrared emittance
σ = 5.67×10^{-8} W/(m^2·K^4) (Stefan-Boltzmann constant)
T = average temperature of surrounding surfaces (assumed 10°C [283 K] for outside, 20°C [293 K] for inside)
K = Kelvin (absolute 0 = –273.16°C)
h_i = infrared radiation portion of surface coefficient
h_c = convective portion of surface coefficient
h_s = total combined interior surface coefficient
h_o = total combined outside surface coefficient

For convenience of input, the interior combined radiative and convective surface coefficient for the opaque window and the transparent window are assumed the same, even though the hemispherical infrared emittance of ordinary uncoated window glass is usually 0.84. This is equivalent to assuming that the emittance of the glass is 0.9. Table B5-1 shows convective and infrared radiative portion of film coefficients for various surface types of *IEA BESTEST*[B-29].

Table B5-1 Disaggregation of Film Coefficients Versus Surface Infrared Emittance for Various Surface Types related to Tests of Sections 5.2.1, 5.2.2, and 5.2.3 (SI Units)

	$\varepsilon = 0.9$	$\varepsilon = 0.84$	$\varepsilon = 0.1$
Very Smooth Surface Outside[a] (T = 10°C) (283 K)			
h_i (W/[m^2·K])	4.63	4.32	0.51
h_o (W/[m^2·K])	21	20.69	16.88
h_c (W/[m^2·K]) = $h_o - h_i$	16.37	16.37	16.37
Inside Surface (T = 20°C) (293 K)			
h_i (W/[m^2·K])	5.13	4.79	0.57
h_s (W/[m^2·K])	8.29	7.95	3.73
h_c (W/[m^2·K]) = $h_s - h_i$	3.16	3.16	3.16
Brick/Rough Plaster Outside[a] (T = 10°C) (283 K)			
h_i (W/[m^2·K])	4.63		0.51
h_o (W/[m^2·K])	29.3		25.18
h_c (W/[m^2·K])	24.67		24.67

a. Based on a mean annual wind speed of 4.02 m/s for outside surfaces.

B5.3 Tabulation for Section 7.2 Test Cases

For the test cases of Section 7.2, the parameters of Equation B5-1 are as follows:

ε = infrared emittance
σ = 0.1718×10^{-8} Btu/(h·ft²·°R⁴) (Stefan/Boltzmann constant)
T = average temperature of surrounding surfaces (assumed 50 °F [510 °R] for outside, 68 °F [528 °R] for inside)
R = ~~r~~Rankine (absolute zero = 0 °R = –459.67 °F)
h_i = infrared radiation portion of surface coefficient.

Other nomenclature used for Tables B5-1~~2~~ and B5-2~~3~~ ~~are~~ is as follows:

h_c = convective portion of surface coefficient
h_s = total combined interior surface coefficient
h_o = total combined outside surface coefficient.

Tables B5-1~~2~~ and B5-2~~3~~ show convective and infrared radiative portions of film coefficients for the various orientations and surfaces of *HERS BESTEST*[B-38]. In Table B5-1~~2~~, combined exterior surface coefficients are evaluated using the algorithm of Informative Annex B4, Section B4.3; combined interior surface coefficients are based on ASHRAE data (see 1993 *ASHRAE Handbook— Fundamentals,* p. 22.1[B-26]). In Table B5-2~~3~~, combined interior and exterior surface coefficients are based on the output of WINDOW 4.1[B-25].

[Note: Tables B5-1 and B5-2 not shown; they are for the Section 7.2 tests and only have changes to their Table numbers as shown.]

Table B5-1~~2~~ Disaggregated Film Coefficients for Opaque Surfaces for Section 7.2 Tests (I-P Units)

Table B5-2~~3~~ Disaggregated Film Coefficients for Windows and Window Frames for Section 7.2 Tests (I-P Units)

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INFORMATIVE ANNEX B6 ~~INCIDENT ANGLE-DEPENDENT~~ WINDOW THERMAL AND OPTICAL PROPERTY CALCULATIONS

B6.1 Window Modeling with WINDOW 7

[Note: Section B6.1 is all new material; edit tracking not applied.]

WINDOW 7.4.8[A-3,A-9] was applied for calculating thermal and optical properties shown in the following tables:

- Tables 5-11 and 5-12 for the clear double-pane window (Case 600 and most other cases)
- Tables 5-18 and 5-19 for the low-e window (Case 660)

WINDOW 7.6.4[A-4] was applied for calculating thermal and optical properties shown in Tables 5-22 and 5-23 for the single-pane window (Case 670), as this work was done after new combined surface coefficients were developed for Case 670.

The calculations in WINDOW 7 are based on ISO 15099[A-10]. For the windows of Cases 600 and 660, there were no differences in results for version 7.6.04 (the latest version as of this writing) versus version 7.4.8, so the version 7.4.8 results remain here for those windows.

Tables B6-1, B6-2, and B6-3 include the WINDOW 7 listing of outputs and inputs for the updated BESTEST Case 600 (base case) double-pane window, Case 660 low-e argon window, and Case 670 single-pane window, respectively. Abbreviations used in these tables are described in Section B6.1.1. The following inputs applied in the analysis are not listed in the tables:

- "NFRC" calculation mode is applied
- Environmental conditions match "NFRC 100-2014"[A-11], except:
  - For Cases 600 and 660:
    - Fixed combined interior surface coefficient = 4.5 W/(m^2K)
    - Fixed combined exterior surface coefficient = 17.8 W/(m^2K).
  - For Case 670:
    - Fixed combined interior surface coefficient = 7.8 W/(m^2K)
    - Fixed combined exterior surface coefficient = 16.0 W/(m^2K).

The tables only include the WINDOW 7 Glazing System report; no frames, spacers, mullions, etc., are included for these idealized windows, so the full Window report is not applied. The Glazing System report does not include the constant surface coefficient values provided above. Presumably, the listed wind speeds are not applied when constant surface coefficients are specified; in any case, the reported "Uvalue" matches the manually calculated total U-values (see Table 5-11, note "e"; Table 5-18, note "d"; and Table 5-22, note "c").

The low-e (outer) window pane for Case 660 was selected from the WINDOW 7 glazing system library, ID 3 (basic low-e example); this pane – along with the clear pane applied for the low-e, clear double-pane, and clear single-pane windows – are taken from the International Glazing Database[A-12]. The selected low-e glazing pane happens to be somewhat similar to that applied in Case L130A of Section 7.2.2.3 (also see *HERS BESTEST*[B-38] and *BESTEST-EX*[A-13]), but also includes spectral data embedded in the WINDOW 7 library.

For programs that may read WINDOW 7 output directly, the following "Glazing System Thermal and Optical Properties" report output is included with the accompanying electronic media as informative material (see README-*.DOCX with the accompanying electronic media):

- Case600-W7-DblPaneClr-ID23.txt
- Case660-W7-DblPaneLowE-ID36.txt
- Case670-W7-SglPaneClr-ID15.txt.

Table B6-1 WINDOW 7 Input/Output Tabulation, Clear Double-Pane Window

```
BERKELEY LAB WINDOW v7.4.8.0 Glazing System Thermal and Optical Properties 12/13/16
15:11:49

ID      : 23
Name    : BESTEST Double Clear, EnvCond=7
Tilt    : 90.0
Glazings: 2
KEFF    : 0.0914
Width   : 18.096
Uvalue  : 2.10
SHGCc   : 0.77
SCc     : 0.88
Vtc     : 0.81
RHG     : 577.51

Layer Data for Glazing System '23 Double Clear, EnvCond=7'

ID     Name            D(mm) Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2 Keff
------ --------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
Outside
   102 CLEAR_3.DAT    #  3.0 .834 .075 .075 .899 .083 .083 .000 .840 .840 1.00
       1 Air            12.0                                              .063
   102 CLEAR_3.DAT    #  3.0 .834 .075 .075 .899 .083 .083 .000 .840 .840 1.00
Inside

Environmental Conditions: 7 hi=4.5; he=17.8

          Tout   Tin  WndSpd   Wnd Dir   Solar  Tsky  Esky
          (C)    (C)   (m/s)            (W/m2)  (C)
         -----  ----  ------  --------  ------  ----  ----
Uvalue   -18.0  21.0    5.50  Windward     0.0 -18.0  1.00
Solar     32.0  24.0    2.75  Windward   783.0  32.0  1.00

Optical Properties for Glazing System '23 Double Clear, EnvCond=7'

Angle      0    10    20    30    40    50    60    70    80    90 Hemis

Vtc  : 0.814 0.814 0.813 0.809 0.797 0.766 0.693 0.537 0.273 0.000 0.712
Rf   : 0.150 0.150 0.150 0.153 0.164 0.193 0.264 0.418 0.682 1.000 0.238
Rb   : 0.150 0.150 0.150 0.153 0.164 0.193 0.264 0.418 0.682 1.000 0.238

Tsol : 0.703 0.702 0.699 0.692 0.678 0.646 0.577 0.438 0.208 0.000 0.601
Rf   : 0.128 0.128 0.128 0.130 0.139 0.164 0.227 0.365 0.612 1.000 0.206
Rb   : 0.128 0.128 0.128 0.130 0.139 0.164 0.227 0.365 0.612 1.000 0.206

Abs1 : 0.096 0.097 0.099 0.102 0.106 0.112 0.119 0.127 0.130 0.000 0.110
Abs2 : 0.072 0.073 0.074 0.075 0.077 0.078 0.077 0.070 0.050 0.000 0.073

SHGCc: 0.769 0.768 0.766 0.761 0.748 0.718 0.651 0.509 0.267 0.000 0.670

Tdw-K  :  0.598
Tdw-ISO:  0.738
Tuv    :  0.564

      Temperature Distribution (degrees C)
        Winter         Summer
       Out   In       Out   In
      ----  ----      ----  ----
Lay1 -13.4 -13.2      36.9  37.0
Lay2   2.6   2.8      34.9  34.7
```

Gas Data (from Window 7 gas data library)

ID	Name	Type	Conductivity W/m-K	Viscosity kg/m-s	Cp J/kg-K	Density kg/m3	Prandtl
1	Air	Pure	0.024069	0.000017	1006.103271	1.292498	0.7197

Note: Window 7 does not tabulate constant surface coefficients in an output report.

Table B6-2 WINDOW 7 Input/Output Tabulation, Double-Pane Low-E Window

```
BERKELEY LAB WINDOW v7.4.8.0 Glazing System Thermal and Optical Properties 12/13/16
15:51:13

ID      : 36
Name    : BESTEST Double Low-e Argon, EnvCond=7
Tilt    : 90.0
Glazings: 2
KEFF    : 0.0323
Width   : 18.228
Uvalue  : 1.19
SHGCc   : 0.44
SCc     : 0.51
Vtc     : 0.65
RHG     : 329.02

Layer Data for Glazing System '36 BESTEST Double Low-e Argon, EnvCond=7'

ID     Name            D(mm) Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2 Keff
------ --------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
Outside
  1042 CSR42_3.afg    #  3.2 .452 .359 .397 .714 .207 .148 .000 .840 .047 1.00
       2 Argon          12.0                                              .021
   102 CLEAR_3.DAT    #  3.0 .834 .075 .075 .899 .083 .083 .000 .840 .840 1.00
Inside

Environmental Conditions: 7 hi=4.5; he=17.8

          Tout   Tin  WndSpd   Wnd Dir   Solar  Tsky  Esky
          (C)    (C)   (m/s)            (W/m2)  (C)
          -----  ----  ------  --------  ------  ----  ----
Uvalue   -18.0  21.0    5.50  Windward     0.0 -18.0  1.00
Solar     32.0  24.0    2.75  Windward   783.0  32.0  1.00

Optical Properties for Glazing System '36 BESTEST Double Low-e Argon, EnvCond=7'

Angle      0    10    20    30    40    50    60    70    80    90 Hemis

Vtc  : 0.650 0.654 0.645 0.633 0.618 0.586 0.515 0.377 0.179 0.000 0.545
Rf   : 0.250 0.244 0.242 0.244 0.254 0.275 0.314 0.404 0.601 0.999 0.298
Rb   : 0.204 0.198 0.197 0.201 0.213 0.239 0.295 0.424 0.669 1.000 0.274

Tsol : 0.394 0.397 0.391 0.383 0.373 0.353 0.310 0.228 0.108 0.000 0.329
Rf   : 0.380 0.375 0.374 0.376 0.384 0.398 0.427 0.496 0.658 0.999 0.415
Rb   : 0.349 0.344 0.342 0.342 0.347 0.360 0.393 0.476 0.652 1.000 0.384

Abs1 : 0.195 0.197 0.204 0.209 0.211 0.215 0.230 0.247 0.213 0.001 0.215
Abs2 : 0.031 0.031 0.031 0.032 0.032 0.033 0.032 0.029 0.021 0.000 0.031

SHGCc: 0.440 0.443 0.438 0.432 0.422 0.403 0.361 0.278 0.148 0.000 0.377

Tdw-K  :  0.335
Tdw-ISO:  0.500
Tuv    :  0.242

      Temperature Distribution (degrees C)
        Winter         Summer
       Out   In       Out   In
      ----  ----      ----  ----
Lay1 -15.4 -15.2      42.7  42.9
Lay2  10.8  10.9      31.0  30.9
```

Gas Data (from Window 7 gas data library)

ID	Name	Type	Conductivity W/m-K	Viscosity kg/m-s	Cp J/kg-K	Density kg/m3	Prandtl
2	Argon	Pure	0.016349	0.000021	521.928528	1.782282	0.6704

Note: Window 7 does not tabulate constant surface coefficients in an output report.

Table B6-3 WINDOW 7 Input/Output Tabulation, Clear Single-Pane Window

```
BERKELEY LAB WINDOW v7.6.4.0 Glazing System Thermal and Optical Properties 03/23/18
16:45:16

ID      : 15
Name    : BESTEST Single Clear, EnvCond=8
Tilt    : 90.0
Glazings: 1
KEFF    : 1.0000
Width   : 3.048
Uvalue  : 5.16
SHGCc   : 0.86
SCc     : 0.99
Vtc     : 0.90
RHG     : 666.74

Layer Data for Glazing System '14 BESTEST Single Clear, EnvCond=7'

ID     Name            D(mm) Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2 Keff
------ --------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
Outside
   102 CLEAR_3.DAT    #  3.0 .834 .075 .075 .899 .083 .083 .000 .840 .840 1.00
Inside


Environmental Conditions: 8 hi=7.8; he=16.0

          Tout   Tin  WndSpd   Wnd Dir   Solar  Tsky  Esky
          (C)    (C)   (m/s)            (W/m2)  (C)
          -----  ----  ------  --------  ------  ----  ----
Uvalue   -18.0  21.0    5.50  Windward     0.0 -18.0  1.00
Solar     32.0  24.0    2.75  Windward   783.0  32.0  1.00

Optical Properties for Glazing System '15 BESTEST Single Clear, EnvCond=8'

Angle      0    10    20    30    40    50    60    70    80    90 Hemis

Vtc  : 0.899 0.899 0.898 0.896 0.889 0.870 0.822 0.705 0.441 0.000 0.822
Rf   : 0.083 0.083 0.083 0.085 0.091 0.109 0.156 0.272 0.536 1.000 0.148
Rb   : 0.083 0.083 0.083 0.085 0.091 0.109 0.156 0.272 0.536 1.000 0.148

Tsol : 0.834 0.833 0.831 0.827 0.818 0.797 0.749 0.637 0.389 0.000 0.753
Rf   : 0.075 0.075 0.075 0.077 0.082 0.099 0.143 0.253 0.506 1.000 0.136
Rb   : 0.075 0.075 0.075 0.077 0.082 0.099 0.143 0.253 0.506 1.000 0.136

Abs1 : 0.091 0.092 0.094 0.096 0.100 0.104 0.108 0.110 0.105 0.000 0.101

SHGCc: 0.864 0.864 0.862 0.859 0.851 0.831 0.785 0.673 0.424 0.000 0.787


Tdw-K  :  0.728
Tdw-ISO:  0.842
Tuv    :  0.715

      Temperature Distribution (degrees C)
        Winter         Summer
       Out   In       Out   In
      ----  ----      ----  ----
Lay1  -5.4  -4.8      32.4  32.3
```

Note: Window 7 does not tabulate constant surface coefficients in an output report.

B6.1.1 Abbreviations for Tables B6-1, B6-2, and B6-3

Abbreviations used in Tables B6-1, B6-2, and B6-3 are primarily excerpted from the WINDOW 4.1 user's manual[B-25]. The definition documentation does not appear to be updated for WINDOW 6[A-9], or WINDOW 7[A-4] (which references the WINDOW 6 documentation). Further detail may be obtained in Finlayson et al[A-14].

- Abs: solar absorptance for a pane of a glazing system (exterior facing surface is 1, and interior-facing surface is 2)
- Angle: solar incidence angle with respect to vertical surface, "0" is normal to vertical
- D: glazing layer thickness (mm), input from glass library.
- Emis: infrared emittance of a glazing layer, (exterior-facing surface is 1, and interior-facing surface is 2), input from the glass library.
- Esky: effective sky emittance for calculating radiation exchange between the exterior glazing surface and the sky, input from environmental conditions.
- Glazings: number of glazing panes
- Hemis: hemispherically integrated property.
- ID: Window 7 library identification number for given system or component
- Keff: a conductivity or effective conductivity of a window component (glass, gap, etc.), input from the glass library or as calculated for the gap between panes (W/(mK))
- KEFF: total effective conductivity of all components of a glazing system except for the exterior and interior surface combined (convective and radiative) heat transfer coefficients (W/(mK)).
- Lay: glass layer (exterior layer is 1, interior layer is 2)
- Rb: the back (exterior) surface reflectance of a glazing system
- Rf: the front (interior) surface reflectance of a glazing system
- RHG: relative heat gain through the glazing system equal to Uc*(Ti-To)+SC*(Incident Solar Radiation); see WINDOW 4.1[B-25] and Finlayson et al[A-14] for more detail.
- Rsol: solar reflectance of the glazing layer (exterior-facing surface is 1, and interior-facing surface is 2), input from the glass library.
- Rvis: visible reflectance of the glazing layer (exterior-facing surface is 1, and interior-facing surface is 2), input from the glass library.
- SCc: the shading coefficient of the glazing system (center-of-glass).
- SHGCc: the solar heat gain coefficient of the glazing system (center-of-glass) only.
- Solar: incident solar radiation from environmental conditions for which SC and SHGC are calculated, input from environmental conditions
- Tdw: the damage weighted transmittance, which includes the effects of damage from the ultraviolet and visible portions of the solar spectrum
- Tin: inside surface temperature, input from environmental conditions (°C)
- Tir: thermal infrared transmittance of a glazing layer, input from the glass library.
- Tilt: tilt angle of the window, 90° is vertical
- Tsky: effective sky temperature for calculating infrared radiation heat transfer between the exterior glass surface and the sky, input from environmental conditions.
- Tout: outside temperature, input from environmental conditions (°C)
- Tsol: solar transmittance of the glazing layer input from the glass library, or as calculated for the glazing system.
- Tuv: the unweighted transmittance between 0.30 and 0.38 microns wave length.
- Tvis: visible transmittance of the glazing layer input from the glass library, or as calculated for the glazing system.
- Uvalue: the total air-to-air heat transfer coefficient for the window system, including exterior and interior surface combined (convective and radiative) heat transfer coefficients (W/(m^2K)).
- Vtc: visible transmittance of the glazing system (center-of-glass) only.
- Width: total thickness of the glazing system (mm).
- Wnd Dir: wind direction, input from environmental conditions (windward or leeward)
- WndSpd: wind speed, input from environmental conditions (m/s)

[Note: Edits to existing material recommence here.]

B6.21 Alternate Calculation of Optical Properties Based on Index of Refraction and Extinction Coefficient. Listed in Table 5-7.

In Table 5-7 (Section 5.2.1.11) window transmittance and inner and outer pane absorptances are based on data from, and the calculation methods associated with, Table B6-1. In Table 5-7, the absorptance values for incidence angles of 10 and 50 degrees are from cosine-of-incident-angle interpolations of values listed in Table B6-1. Reflectances listed in Table 5-7 are based on the formula:

Reflectance = 1 – (transmittance) – (outer pane absorptance) – (inner pane absorptance)

Solar heat gain coefficients (SHGC) are calculated based on the equations of the 1993 *ASHRAE Handbook—Fundamentals*, p. 27.18[B-26], using the optical properties listed in Table 5-7 and the thermal properties listed in Table 5-6 (Section 5.2.1.11).

Table B6-4 provides clear glazing optical property calculations applying calculated transmittances due to reflectance and absorptance losses (Tr and Tabs respectively, see nomenclature below). These calculations were applied for developing optical properties in the original BESTEST suite[B-29] and are also useful for comparing with WINDOW 7 output (see Section B6.3).

For developing Table B6-4, values of index of refraction and extinction coefficient were adjusted for single-pane glass to match the normal-incident reflectance and transmittance indicated by WINDOW 7 for the layer of clear glass from the WINDOW 7 glass library that was selected for developing glazing system properties described in Section B6.1. Resulting normal-incident absorptance has greater disagreement versus that of Table B6-1 than the resulting transmittance and reflectance, but is less of a concern because some absorbed solar radiation is conducted back out to ambient conditions. The resulting clear single-pane glazing index of refraction and extinction coefficient were then applied to the double-pane glazing system calculation, yielding the values shown in Table B6-4.

Index of refraction and extinction coefficient were not calculated for the low-e glazing system (Case 660) because single values for each of these parameters do not adequately describe the optical properties of coated glass.

Nomenclature and associated equations for calculating the angle-dependent solar transmittance of glass in air listed in Table B6-41 are listed provided below. Inner and outer pane solar absorptances listed in Table B6-1 were calculated using the program ESP-WIN[B-42].

Nomenclature

ABSi	inner window pane solar absorptance
ABSo	outer window pane solar absorptance
AOI	angle of incidence
AOR	angle of refraction
INDRA	index of refraction for air = 1.0
INDRG	index of refraction for glass = 1.526 (for this case)
RPERP	perpendicular reflectance (component of polarization)
RPAR	parallel reflectance (component of polarization)
R	reflectance: (RPERP + RPAR)/2
n	number of panes of glass = 2 (for this case)
Tr	transmittance due to reflectance losses (transmittance if there were just reflectance losses and no absorptance losses)
$Tabs$	transmittance due to absorptance losses (transmittance if there were just absorptance losses and no reflectance losses)
T	total transmittance $\cong Tr \times Tabs$
K	extinction coefficient = 0.0196/mm (for this case)
TH	thickness of glass = 3.175 mm (for this case)
L	path length = TH/(cos AOR)
ARCSIN	INVSIN
e	INV_Ln = EXP (value)

Snell's Law

INDRA/INDRG = sin AOR/sin AOI

AOR = ARCSIN [(sin AOI)/INDRG]

Fresnel Equations (Reflectance at ~~1~~an individual air to glass interface)

$\text{RPERP} = [\sin^2(\text{AOR} - \text{AOI})]/[\sin^2(\text{AOR} + \text{AOI})]$

$\text{RPAR} = [\tan^2(\text{AOR} - \text{AOI})]/[\tan^2(\text{AOR} + \text{AOI})]$

R = (RPERP + RPAR)/2

Fresnel Equations (Transmittance due to reflectance with several panes)

$Tr,n = 0.5\ \{[(1 - \text{RPERP})/(1 + (2n - 1)\text{RPERP})] +$
$[(1 - \text{RPAR})/(1 + (2n - 1)\text{RPAR})]\}$

Bouguer’s Law (Transmittance due to absorptance)

$Tabs = e^{[n(-\text{KL})]}$

$T \cong Tr \times Tabs$

[Note: Table B6-4 replaces 140-2017 Table B6-1.]

Table B6-4~~1~~ Glazing Properties as a Function of Incidence Angle

INPUTS — DOUBLE GLAZING — (deg=degrees rad=radians)

AOI(deg)	INDRA	INDRG	n	K(/mm)	TH(mm)	AOI(rad)	AOR(rad)
0	1	1.493	2	0.0337	3.048	0.0000	0.0000
10	1	1.493	2	0.0337	3.048	0.1745	0.1166
20	1	1.493	2	0.0337	3.048	0.3491	0.2311
30	1	1.493	2	0.0337	3.048	0.5236	0.3415
40	1	1.493	2	0.0337	3.048	0.6981	0.4451
45	1	1.493	2	0.0337	3.048	0.7854	0.4934
50	1	1.493	2	0.0337	3.048	0.8727	0.5388
60	1	1.493	2	0.0337	3.048	1.0472	0.6188
70	1	1.493	2	0.0337	3.048	1.2217	0.6808
80	1	1.493	2	0.0337	3.048	1.3963	0.7203

OUTPUTS — DOUBLE GLAZING

AOI(deg)	AOR(deg)	RPERP	RPAR	R	Tr	Tabs	T
0	0.0000	0.0391	0.0391	0.0391	0.8600	0.8143	0.7003
10	6.6791	0.0407	0.0375	0.0391	0.8600	0.8132	0.6993
20	13.2431	0.0461	0.0327	0.0394	0.8595	0.8097	0.6960
30	19.5662	0.0566	0.0246	0.0406	0.8574	0.8041	0.6894
40	25.5015	0.0757	0.0139	0.0448	0.8500	0.7964	0.6769
45	28.2692	0.0904	0.0082	0.0493	0.8419	0.7920	0.6667
50	30.8699	0.1102	0.0031	0.0566	0.8282	0.7871	0.6519
60	35.4546	0.1741	0.0019	0.0880	0.7674	0.7771	0.5964
70	39.0058	0.2966	0.0428	0.1697	0.6102	0.7677	0.4684
80	41.2706	0.5358	0.2372	0.3865	0.3118	0.7608	0.2373

INPUTS — SINGLE GLAZING

AOI	INDRA	INDRG	n	K	TH	AOI RAD	AOR RAD
0	1	1.493	1	0.0337	3.048	0.0000	0.0000
10	1	1.493	1	0.0337	3.048	0.1745	0.1166
20	1	1.493	1	0.0337	3.048	0.3491	0.2311
30	1	1.493	1	0.0337	3.048	0.5236	0.3415
40	1	1.493	1	0.0337	3.048	0.6981	0.4451
45	1	1.493	1	0.0337	3.048	0.7854	0.4934
50	1	1.493	1	0.0337	3.048	0.8727	0.5388
60	1	1.493	1	0.0337	3.048	1.0472	0.6188
70	1	1.493	1	0.0337	3.048	1.2217	0.6808
80	1	1.493	1	0.0337	3.048	1.3963	0.7203

OUTPUTS — SINGLE GLAZING

AOI	AOR	RPERP	RPAR	R	Tr	Tabs	T
0	0.0000	0.0391	0.0391	0.0391	0.92473	0.90238	0.83446
10	6.6791	0.0407	0.0375	0.0391	0.92471	0.90175	0.83385
20	13.2431	0.0461	0.0327	0.0394	0.92432	0.89985	0.83175
30	19.5662	0.0566	0.0246	0.0406	0.92240	0.89672	0.82713
40	25.5015	0.0757	0.0139	0.0448	0.91594	0.89243	0.81741
45	28.2692	0.0904	0.0082	0.0493	0.90903	0.88992	0.80896
50	30.8699	0.1102	0.0031	0.0566	0.89766	0.88721	0.79642
60	35.4546	0.1741	0.0019	0.0880	0.84979	0.88153	0.74911
70	39.0058	0.2966	0.0428	0.1697	0.73017	0.87618	0.63976
80	41.2706	0.5358	0.2372	0.3865	0.45939	0.87226	0.40071

B6.3~~2~~ Comparison of Two Algorithms for Calculating Window Transmittance.
~~The angle-dependent optical properties used in developing some of the example results (where simulation software allowed input or where intermediate simulation output could be compared to such properties) are those listed in Table 5-7.~~ Table B6-5~~2~~ compares angle-dependent solar transmittance ~~and SHGCs~~ calculated using the equations of Section B6.2~~1~~ to the same properties calculated by WINDOW 7 (see Section B6.1) for the clear double-pane window of Case 600. ~~4.0~~[B-43]~~; the WINDOW 4.0 calculation is also based on the general optical properties listed in Table 5-6. While the WINDOW 4.0 algorithm is more detailed than the algorithm presented in Section B6.1, neither method for calculating optical properties has been perfectly validated.~~

Table B6-5~~2~~ shows that at higher incidence angles there is an increasing difference between the transmittance calculated by the two algorithms. This difference occurs because of a simplification associated with the algorithm of Section B6.2~~1~~. The error caused by the simplification is magnified at the higher incidence angles but is still small in the context of solar heat gains. The resulting difference in solar heat gains to the building is minimalized for two reasons:

a. As incidence angle increases, the intensity of solar radiation incident on a given surface decreases with the cosine of the incidence angle.
b. As incidence angle increases, the solar transmittance of glass decreases as a cosine-like function of the incidence angle.

~~The direct normal shading coefficient (SC) of 0.907 shown in Table 5-6 (Section 5.2.1.11) was calculated assuming SHGC for reference glass is 0.87 as in the 1993 *ASHRAE Handbook—Fundamentals* (p. 27.19)~~[B-26]~~. WINDOW 4.0 calculates direct normal SC = 0.916 and uses a reference glass value of SHGC slightly lower than ASHRAE.~~

~~Inner and outer pane solar absorptances calculated by ESP-WIN~~[B-42] ~~are within 1% of those calculated by WINDOW 4.0 at most incidence angles and are within 3% at the worst point of disagreement (inner pane absorptance at 60 degree incidence angle).~~

~~Table B6-2 Angular Dependence of SHGC~~

~~Incidence Angle~~	~~Table 5-7~~		~~WINDOW 4.0~~	
	~~Trans~~*	~~SHGC~~*	~~Trans~~*	~~SHGC~~*
~~0~~	~~0.747~~	~~0.789~~	~~0.748~~	~~0.787~~
~~10~~	~~0.747~~	~~0.789~~	~~0.747~~	~~0.786~~
~~20~~	~~0.745~~	~~0.787~~	~~0.745~~	~~0.785~~
~~30~~	~~0.740~~	~~0.784~~	~~0.739~~	~~0.780~~
~~40~~	~~0.730~~	~~0.775~~	~~0.725~~	~~0.767~~
~~50~~	~~0.707~~	~~0.754~~	~~0.693~~	~~0.737~~
~~60~~	~~0.652~~	~~0.700~~	~~0.622~~	~~0.666~~
~~70~~	~~0.517~~	~~0.563~~	~~0.475~~	~~0.518~~
~~80~~	~~0.263~~	~~0.302~~	~~0.229~~	~~0.266~~

~~*Note: Trans = Transmittance, SHGC = Solar Heat Gain Coefficient.~~

Table B6-5 Angular Dependence of Transmittance of Clear Double-Pane Glazing System

Incidence Angle	Section B6.1 (Window 7)[A-3] Solar Transmittance	Section B6.2 (BESTEST 1995)[B-29] Solar Transmittance
0	0.703	0.700
10	0.702	0.699
20	0.699	0.696
30	0.692	0.689
40	0.678	0.677
50	0.646	0.652
60	0.577	0.596
70	0.438	0.468
80	0.208	0.237

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INFORMATIVE ANNEX B7 DETAILED CALCULATION OF ALTERNATIVE CONSTANT INTERIOR SOLAR DISTRIBUTION FRACTIONS

[Note: Content revised so that cases of Sections 5.2.1, 5.2.2, and 5.2.3 now apply same algorithm for developing alternative constant solar distribution fractions as Section 7.]

~~**B7.1 Solar Fraction Approximation Algorithm for Test Cases of Sections 5.2.1, 5.2.2, and 5.2.3.**~~
For double-pane glazing, ~~S~~solar fraction approximations are calculated from the following:

$$SF_n = B1_n + B2_n + B3_n + BR_n$$

where

n = a particular surface
SF = total solar fraction

B1 describes the first bounce of incident shortwave radiation, assuming all of it initially hits the floor.
$B1_{floor}$ = α
$B1_{all\ other}$ = 0
α = interior shortwave absorptance of opaque surfaces (all interior surfaces have the same absorptance except for the transparent window absorptance, which is ~~denoted~~ indicated as α_w).

B2 describes the second bounce such that shortwave radiation diffusely reflected by the floor is distributed over other surfaces in proportion to their view factor-absorptance product.
$B2_{floor\text{-}floor}$ = 0
$B2_{floor\text{-}other\ opaque}$ = $(1 - \alpha)(FF_i)(\alpha)$
$B2_{floor\text{-}window\ lost}$ = $(1 - \alpha)(FF_i)[1 - (\rho_w + N_i\alpha_i + N_o\alpha_o)]$
$B2_{floor\text{-}window\ absorbed}$ = $(1 - \alpha)(FF_i)(N_i\alpha_i + N_o\alpha_o)$
~~$B2_{floor\text{-}window\ lost}$ = $(1 - \alpha)(FF_i)\{1 - [\rho_w + (\alpha_w/2)]\}$~~
~~$B2_{floor\text{-}window\ absorbed}$ = $(1 - \alpha)(FF_i)(\alpha_w/2)$,~~

where

i = particular surface the floor "sees" according to the view factor (see "FF" below). View factors for windows are based on the view factor for the wall where the windows are located, multiplied by the fraction of the area of that wall occupied by the windows. View factors for the opaque portion of walls with windows are adjusted similarly. To simplify calculation of solar lost, all windows are assumed located on the south wall as in Case 600 (Section 5.2.1) and Case L150A (Section 7.2).
ρ_w = reflectance for specific glazing, hemispherically integrated (diffuse radiation)
α_i = inner pane absorptance for specific glazing, hemispherically integrated (diffuse radiation)
α_o = outer pane absorptance for specific glazing, hemispherically integrated (diffuse radiation)
N_i = inward conducted fraction of cavity reflected absorbed solar radiation for inner pane
N_o = inward conducted fraction of cavity reflected absorbed solar radiation for outer pane.

For double-pane glazing, N_i and N_o are the ratio of total R-value of the components on the exterior side of the inner and outer pane, respectively, to the total air-air center-of-glass R-value of the double-pane unit including gap between panes, window panes, and interior and exterior surface combined (convective and radiative) heat transfer coefficients.

~~ρ_w = $1 - \tau_r$, τ_r = 0.76 from Table B6-1 (Section B6.1) for double glazing, where τ_r is taken at a 60 degree incidence angle to approximate properties of diffuse radiation~~

~~α_w = 1 − τ_{abs} , τ_{abs} = 0.86 from Table B6-1 (Section B6.1) for double glazing, where τ_{abs} is taken at a 60 degree incidence angle to approximate properties of diffuse radiation~~

~~Use of (α_w/2) assumes half of the interior reflected radiation absorbed by the double-pane window is conducted back out to ambient; the other half remains as heat in the zone.~~

FF = view factor from Figures B7-1 and B7-2, which are equivalent to the equations below.

Equation for Figure B7-1:

$$F_{1-2} = \frac{1}{\pi Y}\left(\begin{array}{l} Y\tan^{-1}\left(\frac{1}{Y}\right) + Z\tan^{-1}\left(\frac{1}{Z}\right) - \sqrt{Z^2+Y^2}\,\tan^{-1}\left(\frac{1}{\sqrt{Z^2+Y^2}}\right) \\ + \frac{1}{4}\ln\left\{ \frac{(1+Y^2)(1+Z^2)}{(1+Y^2+Z^2)} \left[\frac{Y^2(1+Y^2+Z^2)}{(1+Y^2)(Y^2+Z^2)}\right]^{Y^2} \left[\frac{Z^2(1+Z^2+Y^2)}{(1+Z^2)(Z^2+Y^2)}\right]^{Z^2} \right\} \end{array} \right)$$

where

$Y = y/x$, $Z = z/x$ for x, y, and z as defined in Figure B7-1.

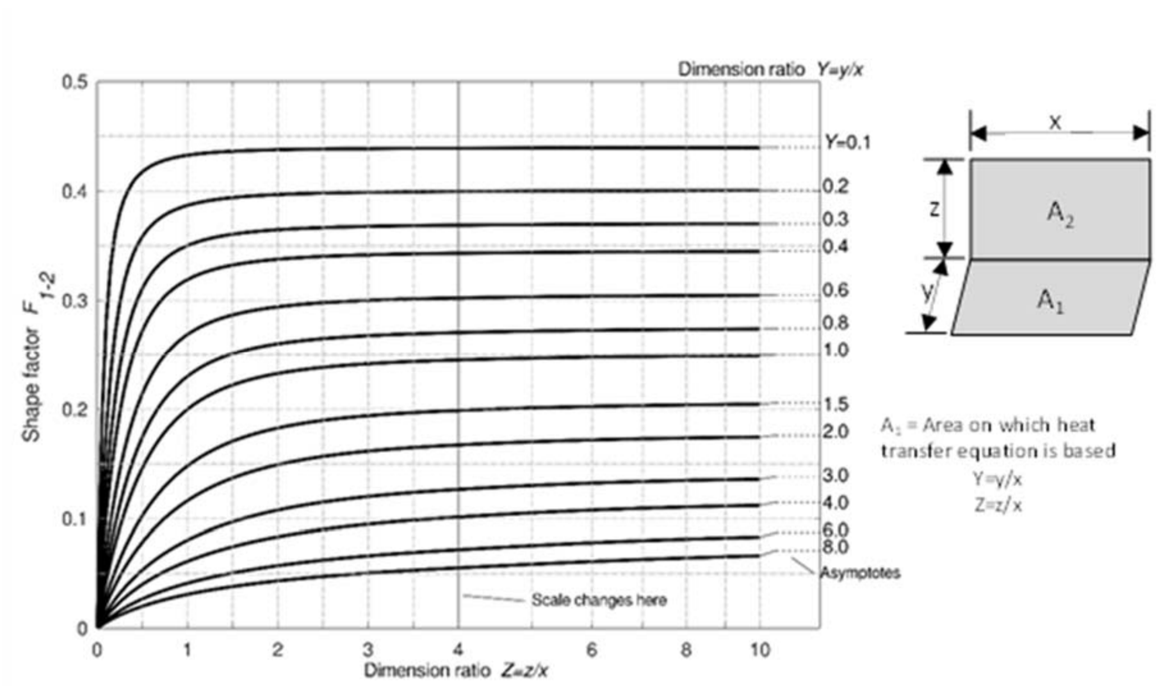


Figure B7-1 Shape factor for adjacent rectangles in perpendicular planes sharing a common edge[B-44].

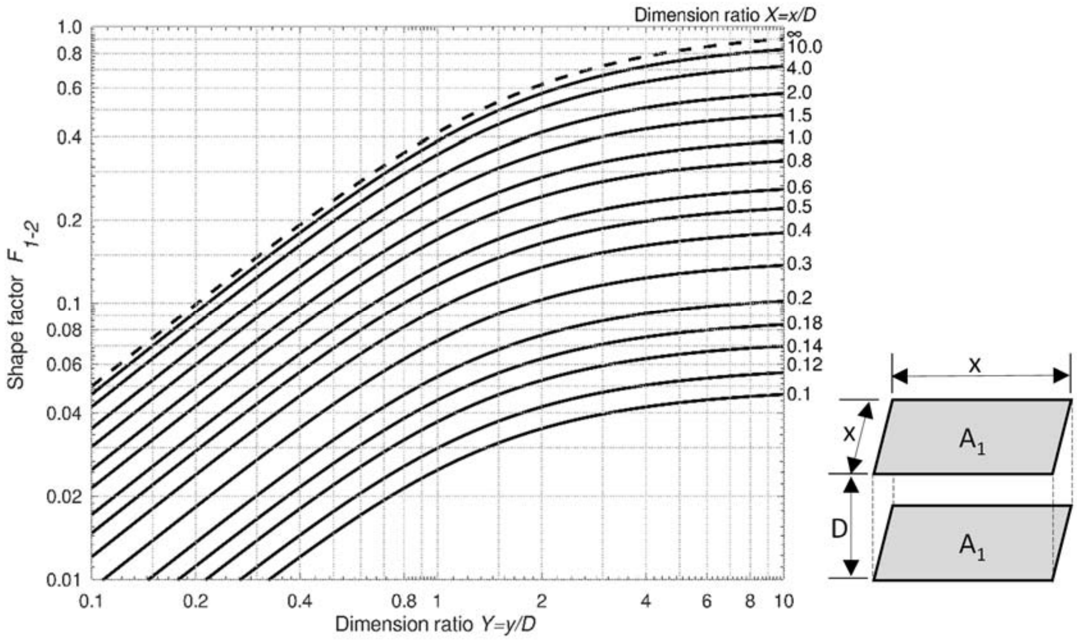


Figure B7-2 Shape factor for directly opposed rectangles[B-44].
~~(Reprinted by permission from *Principles of Heat Transfer,* Fifth Edition by Frank Kreith and Mark S. Bohn, Copyright 1993 by West Publishing Company. All Rights Reserved.)~~

The equation for Figure B7-2 is as follows:

$$F_{1-2} = \frac{2}{\pi XY}\left(\begin{array}{l} \ln\left[\frac{(1+X^2)(1+Y^2)}{(1+X^2+Y^2)}\right]^{1/2} + X\sqrt{1+Y^2}\tan^{-1}\left(\frac{X}{\sqrt{1+Y^2}}\right) \\ + Y\sqrt{1+X^2}\tan^{-1}\left(\frac{Y}{\sqrt{1+X^2}}\right) - X\tan^{-1}X - Y\tan^{-1}Y \end{array} \right)$$

where $X = x/D$, $Y = y/D$ for x, y, and D as defined in Figure B7-2.

B3 describes the third bounce such that the remaining nonabsorbed shortwave radiation is distributed over each surface in proportion to its area-absorptance product.

$B3_{opaque\text{-}opaque}$ = $[1 - \alpha - \sum(B2_n)](A_n/A_{total})(\alpha)$
$B3_{opaque\text{-}window\ lost}$ = $[1 - \alpha - \sum(B2_n)](A_n/A_{total})[1 - (\rho_w + N_i\alpha_i + N_o\alpha_o)]$
$B3_{opaque\text{-}window\ absorbed}$ = $[1 - \alpha - \sum(B2_n)](A_n/A_{total})(N_i\alpha_i + N_o\alpha_o)$
~~$B3_{opaque\text{-}window\ lost}$ = $[1 - \alpha - \sum(B2_n)](A_n/A_{total})\{1 - [\rho_w + (\alpha_w/2)]\}$~~
~~$B3_{opaque\text{-}window\ absorbed}$ = $[1 - \alpha - \sum(B2_n)](A_n/A_{total})(\alpha_w/2)$~~

where

A_n = area of surface n
A_{total} = total area of all surfaces

BR describes the distribution of all remaining bounces based on distribution fractions from calculations for $B3_n$ above.

$BR_n = [1 - \alpha - \sum(B2_n) - \sum(B3_n)][B3_n/\sum(B3_n)]$

For single-pane glazing, the solar lost calculation is the same as for double-pane glazing, except for the following differences.

$B2_{floor\text{-}window\ lost} = (1 - \alpha)(FF_i)\{1 - [\rho_w + (N)(\alpha_w)]\}$
$B2_{floor\text{-}window\ absorbed} = (1 - \alpha)(FF_i)(N)(\alpha_w)$
$B3_{opaque\text{-}window\ lost} = [1 - \alpha - \sum(B2_n)](A_n/A_{total})\{1 - [\rho_w + (N)(\alpha_w)]\}$
$B3_{opaque\text{-}window\ absorbed} = [1 - \alpha - \sum(B2_n)](A_n/A_{total})(N)(\alpha_w)$

where

α_w = absorptance for specific glazing, hemispherically integrated (diffuse radiation)
N = inward conducted fraction of cavity reflected absorbed solar radiation. For single-pane glass, N is the ratio of the exterior combined (convective and radiative) surface heat transfer coefficient R-value to the total air-air center of glass R-value.

No transmitted solar radiation is assumed to be directly absorbed by the zone air at any time during this analysis.

B7.1 Resulting Alternative Constant Solar Distribution Fractions for the Cases of Sections 5.2.1, 5.2.2, and 5.2.3.

Table B7-1 summarizes the interior solar distribution fractions, using the above formulation, for the various window configurations and interior surface absorptances that arise in the test cases of Sections 5.2.1, 5.2.2, and 5.2.3. the standard. Where needed, minor rounding adjustments were made to the values for the ceiling or east/west walls as indicated in the table, so that the sum of listed rounded values in Table B7-1 for all cases is 1.000.

Fractional values for the walls with windows include the portion of the internally reflected solar radiation absorbed by the glass (as it passes back out the window) that is conducted back into the zone. Solar radiation absorbed by the glass (and conducted inward) as it initially passes into the building is treated separately by most programs in their window optical algorithms, so it is therefore not included in the values in Table B7-1.

In the cases with windows oriented east and west, solar fractions are assumed to be the same as for the south-oriented cases with similar interior solar absorptance, except that the fractions are adjusted in proportion to the change in the opaque areas of the east, west, and south walls caused by moving the windows.

For Case 960 (sunspace) solar losts was calculated using the same assumptions as for the south window orientation cases, with some adjustments because the sun zone south wall (containing the windows) and common wall are only 2 m apart. The tabulated values assume a solar fraction of 0.6 for the floor and 0.2 for the common wall. The solar-lost fraction was adjusted based on increased ratio of window area to opaque surface area for the sunspace versus Case 600, and rounded to 0.07. The remaining solar fractions were distributed in proportion to the area-absorptance products of the remaining surfaces. The solar-lost fraction was rounded to 0.07.

Calculations applying the preceding algorithm are documented in Part IV, Appendix C (Section 4C) of the originating test-suite-update final report[A-15].

Table B7-1 Alternative Constant Interior Solar Distribution Fractions Versus Window Orientation and Interior ~~Shortwave~~ Solar Absorptance for Tests of Sections 5.2.1, 5.2.2, and 5.2.3[a,b]

Surface	South Window Cases, α = 0.6	East/West Window Cases, α = 0.6	Low-E S. Win. Case, α = 0.6[c]	1-Pane S. Win. Case, α = 0.6[c]	South Window Cases, α = 0.9	East/West Window Cases, α = 0.9	South Window Cases, α = 0.1	Sunspace Case
Floor	0.642	0.642	**0.645**	**0.641**	0.903	0.903	**0.243~~4~~**	0.6
Ceiling	**0.167~~8~~**	**0.167~~8~~**	**0.170**	**0.166**	**0.050~~39~~**	**0.050~~39~~**	0.191[e]	**0.05~~6~~**
East wall	0.038	0.025[d]	**0.039**	**0.038**	**0.010~~3~~**	**0.0065[f]~~8~~**	0.057	0.02
West wall	0.038	0.025[d]	**0.039**	**0.038**	**0.010~~3~~**	**0.0065[f]~~8~~**	0.057	0.02
North wall	0.053	**0.053~~25~~**	**0.054**	**0.052**	**0.014~~8~~**	**0.014~~8~~**	**0.077~~82~~**	0.2
South wall	**0.027~~6~~**	**0.053~~25~~**	**0.026**	**0.025**	**0.007~~8~~**	**0.014~~8~~**	**0.063~~5~~**	0.03
Solar lost through windows	0.035	0.035	**0.027**	**0.040**	0.006	0.006	**0.312~~304~~**	**0.08~~7~~**

~~Note:~~ a. Interior solar absorptance ~~denoted~~ indicated as α.
b. **Changes to Standard 140-2017 are highlighted with bold font.**
c. The Low-E south-window and the Single (1)-Pane south-window columns are new since 140-2017.
d. Value rounded down (by 0.0002) so that sum of all indicated values is 1.000.
e. Value rounded up (by 0.0004) so that sum of all indicated values is 1.000.
f. Value rounded up (by 0.0001) so that sum of all indicated values is 1.000.

~~**B7.1.1 A Note about Selected Results for Interior Solar Absorptance (α) = 0.9.** The example results of Informative Annex B8 are drawn from *IEA BESTEST*[B-29]. The *IEA BESTEST* test specification contained a minor error in its approximate solar fractions table for interior α = 0.9. In the affected cases (270, 290, 300, 310, and 320), two of the sets of example results used the approximate solar fractions for inputs: SERIRES/SUNCODE 5.7[B-24] and SERIRES 1.2[B-45]. Results from the other programs are not affected because they use various methods for automatically calculating interior solar distribution as discussed in *IEA BESTEST*, and DOE- 2.1D[B-46] was not able to vary interior solar absorptance on exterior walls. We were able to correct the inputs for SERIRES/SUNCODE 5.7 and provide new example results for the standard; however, we were not able to adjust the SERIRES 1.2 results. Table B7-2 compares the current standard method of test (revised) and prior *IEA BESTEST* (erroneous) solar fractions; the value for solar lost did not change. The effect of changing the solar fractions is shown using SERIRES/SUNCODE 5.7 in Table B7-3; there is only a minor effect on heating and sensible cooling annual total loads and annual peak hourly loads.~~

~~**Table B7-2 Revision to Solar Fractions for Interior Solar Absorptance = 0.9**~~

	~~Current (Revised) Values~~		~~Previous IEA BESTEST (Erroneous Values)~~	
~~Surface~~	~~South Window Cases~~	~~East/West Window Cases~~	~~South Window Cases~~	~~East/West Window Cases~~
~~Floor~~	~~0.903~~	~~0.903~~	~~0.651~~	~~0.651~~
~~Ceiling~~	~~0.039~~	~~0.039~~	~~0.177~~	~~0.177~~
~~East wall~~	~~0.013~~	~~0.008~~	~~0.041~~	~~0.027~~
~~West wall~~	~~0.013~~	~~0.008~~	~~0.041~~	~~0.027~~
~~North wall~~	~~0.018~~	~~0.018~~	~~0.056~~	~~0.056~~
~~South wall~~	~~0.008~~	~~0.018~~	~~0.028~~	~~0.056~~
~~Solar lost~~	~~0.006~~	~~0.006~~	~~0.006~~	~~0.006~~

Table B7-3 Sensitivity Test Results of Varying Solar Fractions Using SERIRES/SUNCODE 5.7

Case	Annual Heating, MWh/y	Annual Cooling, MWh/y	Peak Heating, kW	Peak Cooling, kW
270, using IEA BESTEST solar fractions	5.482	9.631	3.670	7.163
270A, using revised solar fractions	5.341	9.828	3.661	7.234
Delta	-0.141	0.197	-0.009	0.071
Delta %	-2.57%	2.05%	-0.25%	0.99%
270-220	-2.620	8.804	-0.025	5.823
270A-220	-2.761	9.001	-0.034	5.894
Delta	-0.141	0.197	-0.009	0.071
Delta %	5.38%	2.24%	36.00%	1.22%
300, using IEA BESTEST solar fractions	5.689	6.525	3.685	4.642
300A, using revised solar fractions	5.587	6.665	3.681	4.657
Delta	-0.102	0.14	-0.004	0.015
Delta %	-1.79%	2.15%	-0.11%	0.32%

B7.2 Solar Fraction Approximation Algorithm for Section 7.2 Test Cases. This section describes tThe method used to determine solar lost for the Section 7.2 tests is described with the introductory text of this Annex. The assumptions there are useful for the calculation of solar lost, but would result in different inside solar fractions for various opaque surfaces than the area weighting shown in Section 7.2 tables that contain solar fractions (e.g., Table 7-3). A spreadsheet tabulation of the calculation process for the Section 7.2 tests is provided in Table B7-2.4. Note that iInterior walls have been excluded to simplify the calculation of solar lost. Also, as shown in Table B7-2, solar radiative exchange between opaque surfaces for the third bounce and the remaining bounces (B3 and BR, respectively) can be aggregated.

Some equations described below differ from those of Section B7.1. For single-pane glazing, the solar lost approximations are calculated from the following:

$$SF_n = B1_n + B2_n + B3_n + BR_n$$

where

n = a particular surface
SF = total solar fraction

B1 describes the first bounce of incident shortwave radiation assuming all of it initially hits the floor.
$B1_{floor} = \alpha$
$B1_{all\ other} = 0$
α = interior shortwave absorptance of opaque surfaces (all interior surfaces have the same absorptance except for the window which is denoted as α_w)

B2 describes the second "bounce" such that shortwave radiation diffusely reflected by the floor is distributed over other surfaces in proportion to their view-factor-absorptance product.
$B2_{floor\text{-}floor} = 0$
$B2_{floor\text{-}other\ opaque} = (1 - \alpha)(FF_i)(\alpha)$
$B2_{floor\text{-}window\ lost} = (1 - \alpha)(FF_i)\{1 - [\rho_w + (N)(\alpha_w)]\}$
$B2_{floor\text{-}window\ absorbed} = (1 - \alpha)(FF_i)(N)(\alpha_w)$

where FF are view factors from Figures B7-1 and B7-2 and accompanying equations for those figures given in Section B7.1.

i = particular surface which the floor "sees." View factors for windows are based on the view factor for the wall where the windows are located, multiplied by the fraction of the area of that wall occupied by the windows. View factors for walls with windows are adjusted similarly. To simplify calculation of solar lost, all windows are assumed located on the south wall (as in Case L150A).
ρ_w = reflectance for specific glazing, hemispherically integrated (diffuse radiation)
α_w = absorptance for specific glazing, hemispherically integrated (diffuse radiation)
N = inward conducted fraction of cavity reflected absorbed solar radiation. For single-pane glass, N is the ratio of the exterior film coefficient R-value to the total air-air center of glass R-value (for single-pane windows, this is the sum of the interior and exterior film coefficient R-values).

B3 describes the third bounce such that the remaining nonabsorbed shortwave radiation is distributed over each surface in proportion to its area-absorptance product. In this part and the final part of the calculation below, solar radiative exchange between opaque surfaces can be aggregated as shown in Table B7-4.

$B3_{opaque\text{-}opaque} = [1 - \alpha - \Sigma(B2_n)](A_n/A_{total})(\alpha)$
$B3_{opaque\text{-}window\ lost} = [1 - \alpha - \Sigma(B2_n)](A_n/A_{total})\{1 - [\rho_w + (N)(\alpha_w)]\}$
$B3_{opaque\text{-}window\ absorbed} = [1 - \alpha - \Sigma(B2_n)](A_n/A_{total})(N)(\alpha_w)$

where

A_n = area of surface n
A_{total} = total area of all surfaces

BR describes the distribution of all remaining bounces based on distribution fractions from calculations for $B3_n$ above.

$BR_n = [1 - \alpha - \Sigma(B2_n) - \Sigma(B3_n)][B3_n/\Sigma(B3_n)]$

For double-pane glazing, the solar lost calculation is the same as for single-pane glazing, except for the following differences.

$B2_{floor\text{-}window\ lost} = (1 - \alpha)(FF_i)[1 - (\rho_w + N_i\alpha_i + N_o\alpha_o)]$
$B2_{floor\text{-}window\ absorbed} = (1 - \alpha)(FF_i)(N_i\alpha_i + N_o\alpha_o)$
$B3_{opaque\text{-}window\ lost} = [1 - \alpha - \Sigma(B2_n)](A_n/A_{total})[1 - (\rho_w + N_i\alpha_i + N_o\alpha_o)]$
$B3_{opaque\text{-}window\ absorbed} = [1 - \alpha - \Sigma(B2_n)](A_n/A_{total})(N_i\alpha_i + N_o\alpha_o)$

where

α_i = inner pane absorptance for specific glazing, hemispherically integrated (diffuse radiation)
N_i = inward conducted fraction of cavity reflected absorbed solar radiation for inner pane
α_o = outer pane absorptance for specific glazing, hemispherically integrated (diffuse radiation)
N_o = inward conducted fraction of cavity reflected absorbed solar radiation for outer pane

For double-pane glazing, N_i and N_o are the ratio of total R-value of the components on the exterior side of the pane in question to the total air-air center-of-glass R-value of the double-pane unit (including air gap between panes and interior and exterior film coefficients).

[Note: Table B7-2 not shown; it is for the Section 7.2 tests and only has changes to Table number as shown.]

Table B7-2 4 Calculations of Solar Lost (Cavity Albedo) for Section 7.2 Tests

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX B8 EXAMPLE RESULTS FOR BUILDING THERMAL ENVELOPE AND FABRIC LOAD AND GROUND-COUPLED SLAB-ON-GRADE TESTS OF SECTION 5.2

Example results from various detailed building energy simulation programs that applied the tests of Section 5.2 are presented in tabular and graphic form in the electronic media provided with this standard; these also include the analytical solution and verified numerical model results for the ground-coupled slab-on-grade cases of Section 5.2.4. These results can be used for comparison with the software being tested. Alternatively, a user can run a number of different programs through this standard method of test or generate their own detailed numerical model results and, where applicable, draw comparisons from those results independently or in conjunction with the results listed here. In either case, when making comparisons, the user should employ the diagnostic logic presented in Informative Annex B9, Section B9.4.

For generating example simulation results presented in this annex, along with using consistent modeling methods, simulationists were requested to use the most detailed modeling methods their software allows, consistent with the level of detail provided in the test specifications. The building energy simulation computer programs used to generate example results are described in Informative Annex B11. These computer programs have been subjected to a number of analytical verification, empirical validation, and comparative testing studies. However, there is no such thing as a completely validated building energy simulation computer program. All building models are simplifications of reality. The philosophy here is to generate a range of results from several programs that are generally accepted as representing the state of the art in whole-building energy simulation programs. In the presented results, to the extent possible, input errors or differences have been eliminated. Thus, for a given case, the range of differences between results presented in Informative Annex B8 represents algorithmic differences among these computer programs for comparative envelope tests. For any given case, a tested program may fall outside of this range without necessarily being incorrect. However, it is worthwhile to investigate the source of substantial differences, as the collective experience of the authors of this standard is that such differences often indicate problems with the software or its use, including, but not limited to the following:

a. User input error, where the user misinterpreted or misentered one or more program inputs
b. Inadequate or faulty documentation
c. A problem with a particular algorithm in the program
d. One or more program algorithm used outside its intended range.

Also, for any given case, a program that yields values in the middle of the range established by the example results should not be perceived as better or worse than a program that yields values at the borders of the range.

[Note: RESULTS5-2A.XLSX and RESULTS5-2A.PDF are updated for this addendum; see accompanying electronic media.]

B8.1 Building Thermal Envelope and Fabric Load Tests of Sections 5.2.1, 5.2.2, and 5.2.3. Example results are included in the file RESULTS5-2A.PDF in the electronic media accompanying this standard. Nomenclature used in the tables and figures are defined in Section B8.1.1, and listings of the tables and figures are provided in Section B8.1.2. For the convenience of users who wish to plot or tabulate their results along with the example results, the example results have been included with the file RESULTS5-2A.XLSX in the electronic media provided with this standard. Sections B8.1.1 and B8.1.2, nomenclature and formatted table and figure listings, respectively, apply to this file as well. Further documentation regarding RESULTS5-2A.XLSX has been included with the file and is printed in Informative Annex B10, Section B10.1, for convenience. For a summary of how example results were developed, see Informative Annex B11, Section B11.1. For more detailed information about the example results, see ~~*IEA BESTEST*~~the originating test-suite-update final report[~~B-29~~A-15].

B8.1.1 Nomenclature for RESULTS5-2A.PDF and RESULTS5-2A.XLSX. Abbreviations and acronyms used in the results tables and figures are defined below. Results are grouped by case numbers; e.g., "395" is Case 395 (Section 5.2.3.16). Sensitivity results are listed using two case numbers separated by a minus sign; e.g., "610 – 600" is the difference between Case 610 (Section 5.2.2.1.1) and Case 600 (Section 5.2.1).

Abs.	absorptance
~~ABS~~	~~absolute value~~
Apr.	April
Ann.	annual
Aug.	August
~~BEL-BRE~~	~~Belgium, Vrije Universiteit/United Kingdom, Building Research Establishment; modeler~~
BESTEST	Building Energy Simulation Test and Diagnostic Method
~~BLAST~~	~~BLAST 3.0 level 193 v. 1 (see Table B11-1); simulation model~~
~~BRE~~	~~Building Research Establishment (see Table B11-1); modeler~~
BSIMAC	BSIMAC, Version 9.0.74 (see Table B11-1); simulation model
Coefs	coefficients
Cond	conductance
Const	constant
Conv.	convection
CSE	California Simulation Engine, Version 0.861.1 (see Table B11-1); simulation model
Dec	December
Delta~~ELTA~~	difference between listed cases (sensitivity)
DeST	DeST, Version 20190401 (see Table B11-1); simulation model
~~DOE21D~~	~~DOE2.1D 14 (see Table B11-1); simulation model~~
~~DMU~~	~~De Montfort University, U.K. (see Table B11-1); modeler~~
E.	east
El.	element
EnergyPlus	EnergyPlus, Version 9.0.1 (see Table B11-1); simulation model
Ext~~.~~	exterior
ESP-r	ESP-r~~RV8~~, Version 13.3 (see Table B11-1); simulation model
E&W	east and west windows
Feb	February
H~~/~~C Wall	high-conductance wall element ~~heating and cooling~~
Himass	high mass
Hr	hour
Htg~~.~~	heating
Int~~.~~	interior
IR	infrared radiation
Jan	January
Jul	July
Jun	June
kW	kilowatt
kWh/m^2	kilowatt-hours per square meter~~e~~
Low E	low emissivity (window)
Mar	March
Max~~.~~	maximum
May	May
Min~~.~~	minimum
Mo.	month
MWh	megawatt-hour
N.	north
Nov	November
~~NREL~~	~~National Renewable Energy Laboratory; modeler~~
Oct	October
~~Op.~~	~~operable~~
~~Op.Win.~~	~~opaque window/high conductance wall~~

Or.	orientation
Orient.	orientation
S.	south
Sep	September
Shd.	shading
~~S.SHADE~~	~~south overhang~~
~~S.WINDOW~~	~~south window~~
~~SERIRES~~	~~SERIRES 1.2 (see Table B11-1); simulation model~~
~~SETBACK~~	~~setback thermostat control strategy~~
Sol.	solar
~~SRES~~	~~SERIRES 1.2 (see Table B11-1); simulation model~~
~~SRES-SUN~~	~~SERIRES/SUNCODE 5.7 (see Table B11-1); simulation model~~
~~S3PAS~~	~~S3PAS (see Table B11-1); simulation model~~
Surf.	surface
~~TASE~~	~~TASE (see Table B11-1); simulation model~~
T	temperature
Temp.	temperature
Transf	transfer
TRNSYS	TRNSYS ~~13.1~~, Version 18.01.0001 (see Table B11-1); simulation model
Tstat	thermostat
~~US-IT~~	~~USA, National Renewable Energy Laboratory/Italy, Politecnico Torino; modeler~~
Vent~~ENT~~	~~night~~ ventilation ~~control strategy~~
w/	with
W.	west
~~WALL~~	~~no windows or opaque windows/high conductance walls~~
Win.	window
~~Y~~	~~year~~
20/20	thermostat setpoint 20°C heating/20°C cooling
20/27	thermostat setpoint 20°C heating/27°C cooling
> Ins.	greater insulation

B8.1.2 Listing of Tables and Figures. Tables B8-1 and B8-2 list example results tables and figures, respectively, included in the RESULTS5-2A.PDF and RESULTS5-2A.XLSX files. The RESULTS5-2A.PDF file presents these tables and figures sequentially. The “Sheet” and “Cell Range” columns are only applicable to the RESULTS5-2A.XLSX file.

Table B8-1 B8.1.2 RESULTS5-2A.XLSX Tables

Table	Description	Sheet	Cell Range
Table B8-1	Annual Heating Loads	Tables 1	B7–N57~~P47~~
Table B8-2	Annual Sensible Cooling Loads		B7–N109~~B48–P89~~
Table B8-3	Annual Hourly Integrated Peak Heating Loads	Tables 2	B7–AI57~~AH47~~
Table B8-4	Annual Hourly Integrated Peak Sensible Cooling Loads		B59–AI109~~B48–AH88~~
Table B8-5	Free-Float Temperature Output		B111–AI145~~B89–AH118~~
Table B8-6	Low-Mass Basic Sensitivity Tests	Tables 3	B7–N58~~P39~~
Table B8-7	High-Mass Basic Sensitivity Tests		B61-N112~~B41–P81~~
Table B8-8	Low-Mass In-Depth (Cases 195 through 320) Sensitivity Tests	Tables 4	B7–N76~~P78~~
Table B8-9	Low-Mass In-Depth (Cases 395 through 470~~440~~) Sensitivity Tests	Tables 5	B7–N64~~P45~~
Table B8-10	High-Mass Basic and In-Depth Sensitivity Tests		B67–N122~~B47–P91~~
Table B8-11	Annual Transmissivity Coefficient of Windows	Tables 6	B7–N16~~O14~~
Table B8-12	Annual Shading Coefficient of Window Shading Devices: Overhangs ~~and~~ & Fins		B18–N25~~B16–O23~~
Table B8-13	Case 600 Annual Incident Solar Radiation (kWh/m^2)		B27–N36~~B25–O34~~
Table B8-14	Case 600 Annual Transmitted Solar Radiation—Unshaded (kWh/m^2)		B38–N46~~B36–O42~~
Table B8-15	Case 600 Annual Transmitted Solar Radiation—Shaded (kWh/m^2)		B48–N54~~B44–O50~~
Table B8-16	Sky Temperature Output, Case 600	Tables 7	B7–AM15
Table B8-M1	Monthly Heating Loads	Tables M1	B7–N36
Table B8-M2	Monthly Sensible Cooling Loads		B38–N67
Table B8-M3	Monthly Hourly Integrated Peak Heating Loads	Tables M2	B7–AB36
Table B8-M4	Monthly Hourly Integrated Peak Sensible Cooling Loads		B38–AB67
Table B8-M5	Monthly Load 600-900 Sensitivity Tests	Tables M3	B7–N68

Table B8-2 B8.1.2 RESULTS5-2A.XLSX Figures

Figure	Title	Sheet Tab
B8-1	~~BESTEST BASIC~~ Annual Incident Solar Radiation	Fig~~.~~ B8-1 Ann Incident Solar
B8-2	~~BESTEST BASIC~~ Annual Transmitted Solar Radiation Unshaded	Fig~~.~~ B8-2 Ann SolRad Unshaded
B8-3	~~BESTEST BASIC~~ Annual Transmitted Solar Radiation Shaded	Fig~~.~~ B8-3 Ann SolRad Shaded
B8-4	~~BESTEST BASIC~~ Annual Transmissivity Coefficient of Windows (Unshaded Transmitted)/(Incident Solar Radiation)	Fig~~.~~ B8-4 Trans Coeff
B8-5	~~BESTEST BASIC~~ Annual Overhang and Fin Shading Coefficients (1-(Shaded)/(Unshaded)) Transmitted Solar Radiation	Fig~~.~~ B8-5 OH&Fin Shade Coeff
B8-6	Average, Minimum and Maximum Sky Temperature, Case 600	Fig B8-6 Sky Temp
B8-7~~6~~	~~BESTEST BASIC~~Basic: Low Mass Annual Heating	Fig~~.~~ B8-7~~6~~ Lomass Ann Heat
B8-8~~7~~	~~BESTEST BASIC~~Basic: Low Mass Annual Sensible Cooling	Fig~~.~~ B8-8~~7~~ Lomass Ann Cool
B8-9~~8~~	~~BESTEST BASIC~~Basic: Low Mass Peak Heating	Fig~~.~~ B8-9~~8~~ Lomass Peak Heat
B8-10~~9~~	~~BESTEST BASIC~~Basic: Low Mass Peak Sensible Cooling	Fig~~.~~ B8-10~~9~~ Lomass Peak Cool
B8-11~~0~~	~~BESTEST BASIC~~Basic: High Mass Annual Heating	Fig~~.~~ B8-11~~0~~ Himass Ann Heat
B8-12~~1~~	~~BESTEST BASIC~~Basic: High Mass Annual Sensible Cooling	Fig~~.~~ B8-12~~1~~ Himass Ann Cool
B8-13~~2~~	~~BESTEST BASIC~~Basic: High Mass Peak Heating	Fig~~.~~ B8-13~~2~~ Himass~~s~~ Peak Heat
B8-14~~3~~	~~BESTEST BASIC~~Basic: High Mass Peak Sensible Cooling	Fig~~.~~ B8-14~~3~~ Himass Peak Cool
B8-15~~7~~	~~BESTEST BASIC~~Basic and In-Depth: South Window ~~Shading~~ (Delta) Annual Heating and Sensible Cooling	Fig~~.~~ B8-15~~7~~ Delta-S Win-Ann~~Shade-Load~~
B8-16~~8~~	~~BESTEST BASIC~~Basic and In-Depth: South Window ~~Shading~~ (Delta) Peak Heating and Sensible Cooling	Fig~~.~~ B8-16~~8~~ Delta-S ~~Shade~~Win-Peak
B8-17~~9~~	~~BESTEST BASIC~~Basic: ~~East & West~~ Window Shading and Orientation (Delta) Annual Heating and Sensible Cooling	Fig~~.~~ B8-17~~9~~ Delta-~~E&W~~ShadeOrient-Load
B8-18~~20~~	~~BESTEST BASIC~~Basic: ~~East & West~~ Window Shading and Orientation (Delta) Peak Heating and Sensible Cooling	Fig~~.~~ B8-18~~20~~ Delta-~~E&W~~ShadeOrient-Peak
~~B8-21~~	~~BESTEST BASIC East & West Shaded Window (Delta) Annual Heating and Sensible Cooling~~	~~Fig. B8-21 Delta-E&WShade-Load~~
~~B8-22~~	~~BESTEST BASIC East & West Shaded Window (Delta) Peak Heating and Sensible Cooling~~	~~Fig. B8-22 Delta-E&WShade-Peak~~
B8-19~~23~~	~~BESTEST BASIC~~Basic: Thermostat Setback, Vent Cooling, and Sunspace (Delta) Annual Heating and Sensible Cooling	Fig~~.~~ B8-19~~23~~ Delta-640650960-Load~~TSetback-Heat~~
B8-20~~24~~	~~BESTEST BASIC~~Basic: Thermostat Setback, Vent Cooling, and Sunspace (Delta) Peak Heating and Sensible Cooling	Fig~~.~~ B8-20~~24~~ Delta-640650960~~TSetback-~~Peak
~~B8-25~~	~~BESTEST BASIC Vent Cooling (Delta) Annual Sensible Cooling~~	~~Fig. B8-25 Delta-VentCool-Load~~
~~B8-26~~	~~BESTEST BASIC Vent Cooling (Delta) Peak Sensible Cooling~~	~~Fig. B8-26 Delta-VentCool-Peak~~

Table B8-2 B8.1.2 RESULTS5-2A.XLSX Figures *(Continued)*

Figure	Title	Sheet Tab
~~B8-27~~	~~BESTEST BASIC Sunspace (Delta) Annual Heating and Sensible Cooling~~	~~Fig. B8-27 Delta-Sunspace-Load~~
~~B8-28~~	~~BESTEST BASIC Sunspace (Delta) Peak Heating and Sensible Cooling~~	~~Fig. B8-28 Delta-Sunspace-Peak~~
B8-21~~9~~	~~BESTEST BASIC AND IN-DEPTH~~Basic and In-Depth: Mass Effect (Delta) Annual Heating and Sensible Cooling	Fig~~.~~ B8-21~~9~~ Delta-Mass Effect-Ann
B8-22~~30~~	~~BESTEST BASIC AND IN-DEPTH~~Basic and In-Depth: Mass Effect (Delta) Peak Heating and Sensible Cooling	Fig~~.~~ B8-22~~30~~ Delta-Mass Effect-Pk
B8-23	Basic: Cases 660 to 695 and 980 to 995 Annual Heating	Fig B8-23 660+ Ann Heat
B8-24	Basic: Cases 660 to 695 and 980 to 995 Annual Cooling	Fig B8-24 660+ Ann Cool
B8-25	Basic: Cases 660 to 695 and 980 to 995 Peak Heating	Fig B8-25 660+ Peak Heat
B8-26	Basic: Cases 660 to 695 and 980 to 995 Peak Cooling	Fig B8-26 660+ Peak Cool
B8-27	Basic: Window Types (Delta), Annual Heating and Sensible Cooling	Fig B8-27 Delta-Windows-Load
B8-28	Basic: Window Types (Delta), Peak Heating and Sensible Cooling	Fig B8-28 Delta-Windows-Peak
B8-29	Basic: Insulation (Delta), Annual Heating and Sensible Cooling	Fig B8-29 Delta-Insul-Load
B8-30	Basic: Insulation (Delta), Peak Heating and Sensible Cooling	Fig B8-30 Delta-Insul-Peak
B8-31	Basic: Insulation, Mass Effect (Delta), Annual Heating and Sensible Cooling	Fig B8-31 Del-Mass-Ins-Load
B8-32	Basic: Insulation, Mass Effect (Delta), Peak Heating and Sensible Cooling	Fig B8-32 Del-Mass-Ins-Peak
B8-33~~16~~	~~BESTEST BASIC~~Basic: Average Hourly Annual Temperature Free-Float Cases	Fig B8-33~~16~~ FF Average Temp
B8-34~~14~~	~~BESTEST BASIC~~Basic: Maximum Hourly Annual Temperature Free-Float Cases	Fig~~.~~ B8-34~~14~~ FF Maximum Temp
B8-35~~15~~	~~BESTEST BASIC~~Basic: Minimum Hourly Annual Temperature Free-Float Cases	Fig~~.~~ B8-35~~15~~ FF Minimum Temp
~~B8-31~~	~~BESTEST IN-DEPTH South Window (Delta) Annual Heating and Sensible Cooling~~	~~Fig. B8-31 Delta-S Win-Ann~~
~~B8-32~~	~~BESTEST IN-DEPTH South Window (Delta) Peak Heating and Sensible Cooling~~	~~Fig. B8-32 Delta-S Win-Peak~~
B8-36~~3~~	~~BESTEST IN-DEPTH~~In-Depth: Low Mass Cases 195 to 250 Annual Heating ~~Cases 195 to 250~~	Fig~~.~~ B8-36~~3~~ 195to250 Ann Heat~~Indepth 1~~
B8-37~~4~~	~~BESTEST IN-DEPTH~~In-Depth: Low Mass Cases 195 to 250 Annual Sensible Cooling ~~Cases 195 to 250~~	Fig~~.~~ B8-37~~4~~ 195to250 Ann Cool~~Indepth 2~~
B8-38~~5~~	~~BESTEST IN-DEPTH~~In-Depth: Low Mass Cases 195 to 250 Peak Heating ~~Cases 195 to 250~~	Fig~~.~~ B8-38~~5~~ 195to250 Peak Heat~~Indepth 3~~
B8-39~~6~~	~~BESTEST IN-DEPTH~~In-Depth: Low Mass Cases 195 to 250 Peak Sensible Cooling ~~Cases 195 to 250~~	Fig~~.~~ B8-39~~6~~ 195to250 Peak Cool~~Indepth 4~~
B8-40~~37~~	~~BESTEST IN-DEPTH~~In-Depth: Low Mass Cases 270 to 320 Annual Heating ~~Cases 270 to 320~~	Fig~~.~~ B8-40~~37~~ 270to320 Ann Heat~~Indepth 5~~
B8-41~~38~~	~~BESTEST IN-DEPTH~~In-Depth: Low Mass Cases 270 to 320 Annual Sensible Cooling ~~Cases 270 to 320~~	Fig~~.~~ B8-41~~38~~ 270to320 Ann Cool~~Indepth 6~~
B8-42~~39~~	~~BESTEST IN-DEPTH~~In-Depth: Low Mass Cases 270 to 320 Peak Heating ~~Cases 270 to 320~~	Fig~~.~~ B8-42~~39~~ 270to320 Peak Heat~~Indepth 7~~
B8-43~~0~~	~~BESTEST IN-DEPTH~~In-Depth: Low Mass Cases 270 to 320 Peak Sensible Cooling ~~Cases 270 to 320~~	Fig~~.~~ B8-43~~0~~ 270to320 Peak Cool~~Indepth 8~~
B8-44~~1~~	~~BESTEST IN-DEPTH~~In-Depth: Cases 195 to 220 (Delta) Annual Heating and Sensible Cooling	Fig~~.~~ B8-44~~1 Indepth~~ Delta 195to220 Load
B8-45~~2~~	~~BESTEST IN-DEPTH~~In-Depth: Cases 195 to 220 (Delta) Peak Heating and Sensible Cooling	Fig~~.~~ B8-45~~2 Indepth~~ Delta ~~2~~195to220 Peak
B8-46~~3~~	~~BESTEST IN-DEPTH~~In-Depth: Cases 220 to 270 (Delta) Annual Heating and Sensible Cooling	Fig~~.~~ B8-46~~3 Indepth~~ Delta ~~3~~220to270 Load
B8-47~~4~~	~~BESTEST IN-DEPTH~~In-Depth: Cases 220 to 270 (Delta) Peak Heating and Sensible Cooling	Fig~~.~~ B8-47~~4 Indepth~~ Delta ~~4~~220to270 Peak
B8-48~~5~~	~~BESTEST IN-DEPTH~~In-Depth: Cases 270 to 320 (Delta) Annual Heating and Sensible Cooling	Fig~~.~~ B8-48~~5 Indepth~~ Delta ~~5~~270to320 Load
B8-49~~6~~	~~BESTEST IN-DEPTH~~In-Depth: Cases 270 to 320 (Delta) Peak Sensible Cooling	Fig~~.~~ B8-49~~6 Indepth~~ Delta ~~6~~270to320 Peak
B8-50~~47~~	~~BESTEST IN-DEPTH~~In-Depth: Cases 395 to 440, 800, 810 Annual Heating ~~Cases 395 to 440, 800, 810~~	Fig~~.~~ B8-50~~47~~ 395to440,8n0 Ann Heat~~Indepth 9~~
B8-51~~48~~	~~BESTEST IN-DEPTH~~In-Depth: Cases 395 to 440, 800, 810 Annual Sensible Cooling ~~Cases 395 to 440, 800, 810~~	Fig~~.~~ B8-51~~48~~ 395to440,8n0 Ann Cool~~Indepth 10~~
B8-52~~49~~	~~BESTEST IN-DEPTH~~In-Depth: Cases 395 to 440, 800, 810 Peak Heating ~~Cases 395 to 440, 800, 810~~	Fig~~.~~ B8-52~~49~~ 395to440,8n0 Pk Heat~~Indepth 11~~
B8-53~~0~~	~~BESTEST IN-DEPTH~~In-Depth: Cases 395 to 440, 800, 810 Peak Sensible Cooling ~~Cases 395 to 440, 800, 810~~	Fig~~.~~ B8-53~~0~~ 395to440,8n0 Pk Cool~~Indepth 12~~

Table B8-2 B8.1.2 RESULTS5-2A.XLSX Figures *(Continued)*

Figure	Title	Sheet Tab
B8-54~~1~~	~~BESTEST IN-DEPTH~~In-Depth: Cases 395 to 600, 810 to 900	Fig~~.~~ B8-54~~1~~ Del 395-600,810,900 Ld~~Indepth Delta 7~~

Table B8-2 B8.1.2 RESULTS5-2A.XLSX Figures *(Continued)*

Figure	Title	Sheet Tab
B8-H17	Hourly Loads: Clear Cold Day, Case 640 (Low Mass, Night Setback) Heating (+), Sensible Cooling (–)	Fig B8-H17 Hrly-640Loads-Cold
B8-H18	Hourly Conditioned Zone Temperatures, Clear Cold Day, Case 640 Heating (+), Sensible Cooling (-)	Fig B8-H18 Hrly-640Tzone-Cold
B8-H19	Hourly Loads: Clear Cold Day, Case 940 (High Mass, Night Setback) Heating (+), Sensible Cooling (-)	Fig B8-H19 Hrly-940Loads-Cold
B8-H20	Hourly Conditioned Zone Temperatures, Clear Cold Day, Case 940 Heating (+), Sensible Cooling (-)	Fig B8-H20 Hrly-940Tzone-Cold
B8-H21	Hourly Loads: Clear Cold Day, Case 660 (Low-E Window) Heating (+), Sensible Cooling (-)	Fig B8-H21 Hrly-660Loads-Cold
B8-H22	Hourly Loads: Clear Hot Day, Case 660 (Low-E Window) Heating (+), Sensible Cooling (-)	Fig B8-H22 Hrly-660Loads-Hot
B8-H23	Hourly Loads: Clear Cold Day, Case 670 (Single-Pane Window) Heating (+), Sensible Cooling (-)	Fig B8-H23 Hrly-670Loads-Cold
B8-H24	Hourly Loads: Clear Hot Day, Case 670 (Single-Pane Window) Heating (+), Sensible Cooling (-)	Fig B8-H24 Hrly-670Loads-Hot
B8-H25	Hourly Loads: Clear Cold Day, Case 680 (Insulation) Heating (+), Sensible Cooling (-)	Fig B8-H25 Hrly-680Loads-Cold
B8-H26	Hourly Loads: Clear Hot Day, Case 680 (Insulation) Heating (+), Sensible Cooling (-)	Fig B8-H26 Hrly-680Loads-Hot
B8-H27	Hourly Loads: Clear Cold Day, Case 685 (20/20 Tstat) Heating (+), Sensible Cooling (-)	Fig B8-H27 Hrly-685Loads-Cold
B8-H28	Hourly Loads: Clear Hot Day, Case 685 (20/20 Tstat) Heating (+), Sensible Cooling (-)	Fig B8-H28 Hrly-685Loads-Hot
B8-H29	Hourly Loads: Clear Cold Day, Case 695 (20/20, Insulation) Heating (+), Sensible Cooling (-)	Fig B8-H29 Hrly-695Loads-Cold
B8-H30	Hourly Loads: Clear Hot Day, Case 695 (20/20, Insulation) Heating (+), Sensible Cooling (-)	Fig B8-H30 Hrly-695Loads-Hot
B8-H31~~59~~	~~BESTEST HOURLY LOADS~~ Hourly Loads: Clear Cold Day, Case 900 (High Mass) Heating (+), Sensible Cooling (–)	Fig~~.~~ B8-H31~~59~~ Hrly-900Loads-Cold~~Case900~~
B8-H32	Hourly Loads: Clear Hot Day, Case 900 (High Mass) Heating (+), Sensible Cooling (-)	Fig B8-H32 Hrly-900Loads-Hot
B8-H33	Hourly Loads: Clear Cold Day, Case 980 (High Mass, Insulation) Heating (+), Sensible Cooling (-)	Fig B8-H33 Hrly-980Loads-Cold
B8-H34	Hourly Loads: Clear Hot Day, Case 980 (High Mass, Insulation) Heating (+), Sensible Cooling (-)	Fig B8-H34 Hrly-980Loads-Hot
B8-H35	Hourly Loads: Clear Cold Day, Case 985 (High Mass, 20/20 Tstat) Heating (+), Sensible Cooling (-)	Fig B8-H35 Hrly-985Loads-Cold
B8-H36	Hourly Loads: Clear Hot Day, Case 985 (High Mass, 20/20 Tstat) Heating (+), Sensible Cooling (-)	Fig B8-H36 Hrly-985Loads-Hot
B8-H37	Hourly Loads: Clear Cold Day, Case 995 (High Mass, 20/20, Insulation) Heating (+), Sensible Cooling (-)	Fig B8-H37 Hrly-995Loads-Cold
B8-H38	Hourly Loads: Clear Hot Day, Case 995 (High Mass, 20/20, Insulation) Heating (+), Sensible Cooling (-)	Fig B8-H38 Hrly-995Loads-Hot

[Note: Section B8.2 is not shown for this addendum. There are no changes to B8.2, which relates to the test cases of Section 5.2.4 that are also not affected by this addendum.]

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX B9 DIAGNOSING THE RESULTS USING THE FLOW DIAGRAMS

B9.1 General Description. Figures B9-1 through B9-10 contain a set of flow diagrams that serve as a guide for diagnosing the cause of disagreeing results that may arise from using this method of test. These flow diagrams list the features being tested, thus indicating potential sources of algorithmic differences.

B9.2 Comparing Tested Software Results to Other Example Results

B9.2.1 Example results are either results presented in Informative Annexes B8 and B16 or other results that were generated using this standard method of test.

B9.2.2 In this annex we provide no formal criteria for when results agree or disagree. Determination of when results agree or disagree is left to the user. In making this determination, the user should consider the following:

a. Magnitude of results for individual cases.
b. Magnitude of difference in results between certain cases (e.g., “Case 610 – Case 600”).
c. Same direction of sensitivity (positive or negative) for difference in results between certain cases (e.g., “Case 610 – Case 600”).
d. ~~If~~ Whether results are logically counterintuitive with respect to known or expected physical behavior.
e. Availability of analytical solution, quasi-analytical solution, or verified numerical model results (i.e., mathematical or secondary mathematical truth standards as described in Informative Annex B16, Section B16.2, and Informative Annex B8, Section B8.2.1).
f. For the analytical verification test cases, the degree of disagreement that occurred for other simulation results versus the analytical solution, quasi-analytical solution, or verified numerical model results.
g. Example simulation results do not represent a truth standard.

B9.2.3 Check the program being tested for agreement (see Section B9.2.2) with example results for both the absolute outputs and the sensitivity (or delta) outputs. For example, when comparing to the example results shown in Informative Annex B8 for Case “610 – 600” in the “low mass basic” flow diagram (Figure B9-1), the program results are compared with both the Case 610 example results and the Case 610 – 600 example sensitivity results.

B9.2.4 Compare all available output types specified for each case that can be produced by the program being tested, as described in Section 6. A disagreement with any one of the output types may be cause for concern.

B9.2.5 There are some cases where it is possible to proceed even if disagreements were uncovered in the previous case. For example, using Figure B9-1, in Case 610, inability to model a shading overhang would not affect the usefulness of the program for modeling buildings with unshaded windows. Thus, the flow diagram has an extra arrow connecting Cases 610 and 620, which denotes that you may proceed regardless of the results for Case 610. Where cases are connected by a single arrow, a satisfactory result is required in order to proceed to the next case. For example, in Case 620, the inability to model transmitted radiation through an unshaded east window makes it difficult to proceed with these tests until the disagreement is reconciled.

B9.3 If Tested Software Results Disagree with Example Results. If the tested program shows disagreement (as defined above in Section B9.2.2) with the example results, then recheck the inputs against the specified values. Use the diagnostic logic flow diagrams to help isolate the source of the difference. If no input error can be found, then look for an error in the software. If an error is found, then fix it and rerun the tests. If, in the engineering judgment of the user, the disagreement is caused by a reasonable difference in algorithms between the tested software and the example results or other tested software, then continue with the next test case.

B9.4 Diagnostic Logic Flow Diagrams for Building Thermal Envelope and Fabric Load and Ground-Coupled Slab-on-Grade Tests (Section 5.2)

[Note: For this addendum, additions to the flow diagrams (Figures B9-1 through B9-4) are shown in red within the figures.]

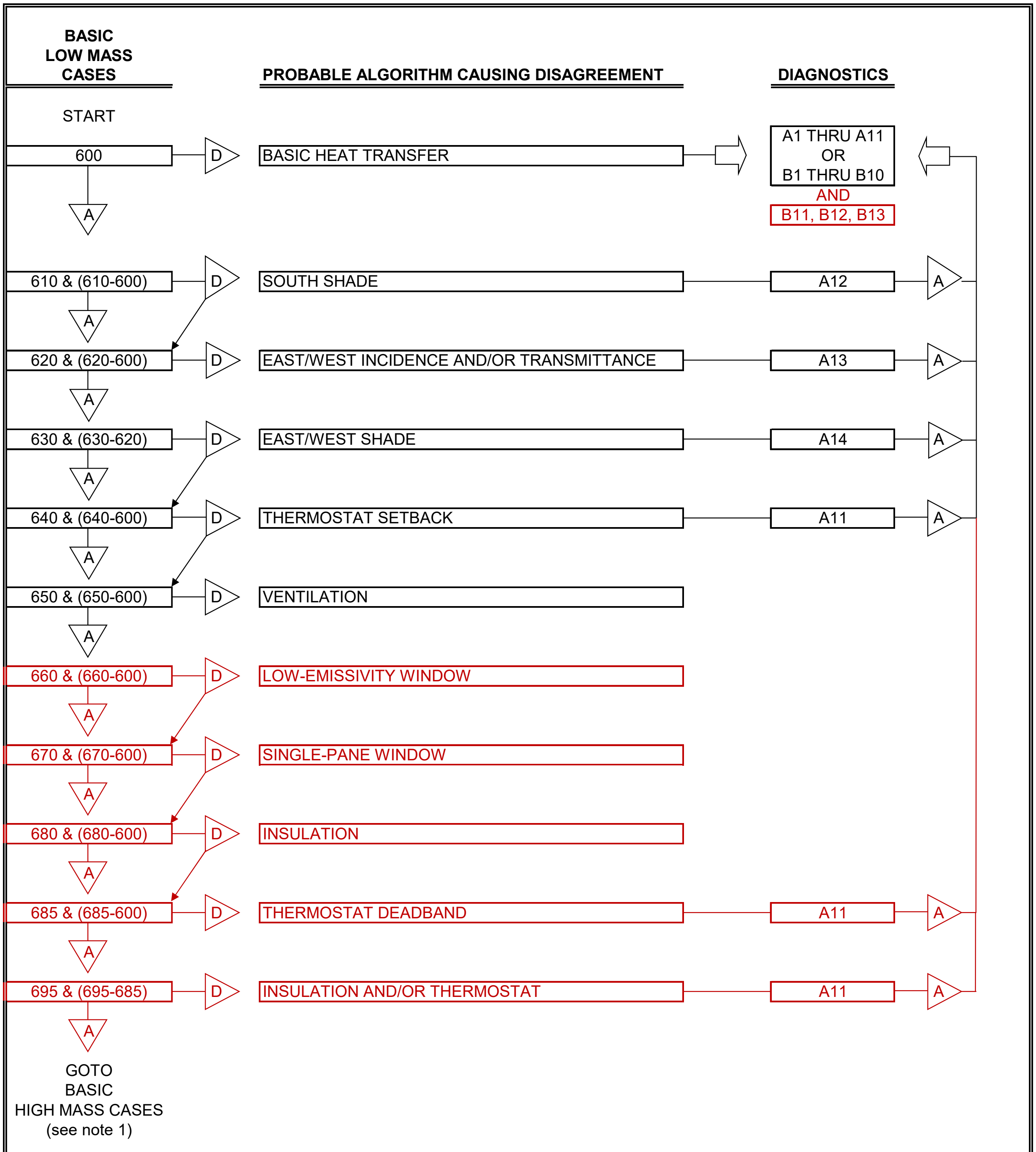
B9.4.1 Low-Mass and High-Mass Basic Tests. The first flow diagram (Figure B9-1) begins with the base building (Case 600). It is very important to have confidence in your Case 600 results before proceeding to the other cases. If output from the tested program agrees satisfactorily with other example results for Case 600, check other output according to the flow diagram. Once the low-mass basic cases have been checked, proceed with the high-mass basic (900 series) cases (Figure B9-3).

B9.4.2 In-Depth Tests. These tests provide detailed diagnostic capability. The "in-depth test" flow diagram (Figure B9-2) indicates two possible diagnostic paths, A1 through A11 or B1 through B10; also run B11, B12, and B13 in addition to A1 – A11 or B1 – B10. Selecting Path A versus Path B depends on the capabilities of the program being tested. Path A is the preferable diagnostic path. Use Path A if the software being tested is literal enough in its treatment of building physics to allow input of those cases. Otherwise, Path B will still help to identify algorithmic sources of differences but less definitively because of interacting effects.

B9.4.3 Mass Interaction Tests. Further diagnostic information can be obtained regarding thermal mass interactions using the diagnostic logic flow diagram of Figure B9-4. When disagreement among results occurs, this diagram sometimes returns to the low-mass, in-depth diagnostics (Figure B9-2) even though the program may have already showed agreement in the low-mass basic tests. The reason for this is that the high-mass cases may reveal disagreements that the low-mass cases did not expose because of the following:

a. The disagreement is more readily detectable when mass is present.
b. The disagreement was not previously detectable because of compensating differences.
c. The disagreement was not previously detectable because of other unknown interactions.

[Note: The remainder of Annex B9 is not shown for this addendum. There are no changes to that material, which relates to other test suites that are also not affected by this addendum.]

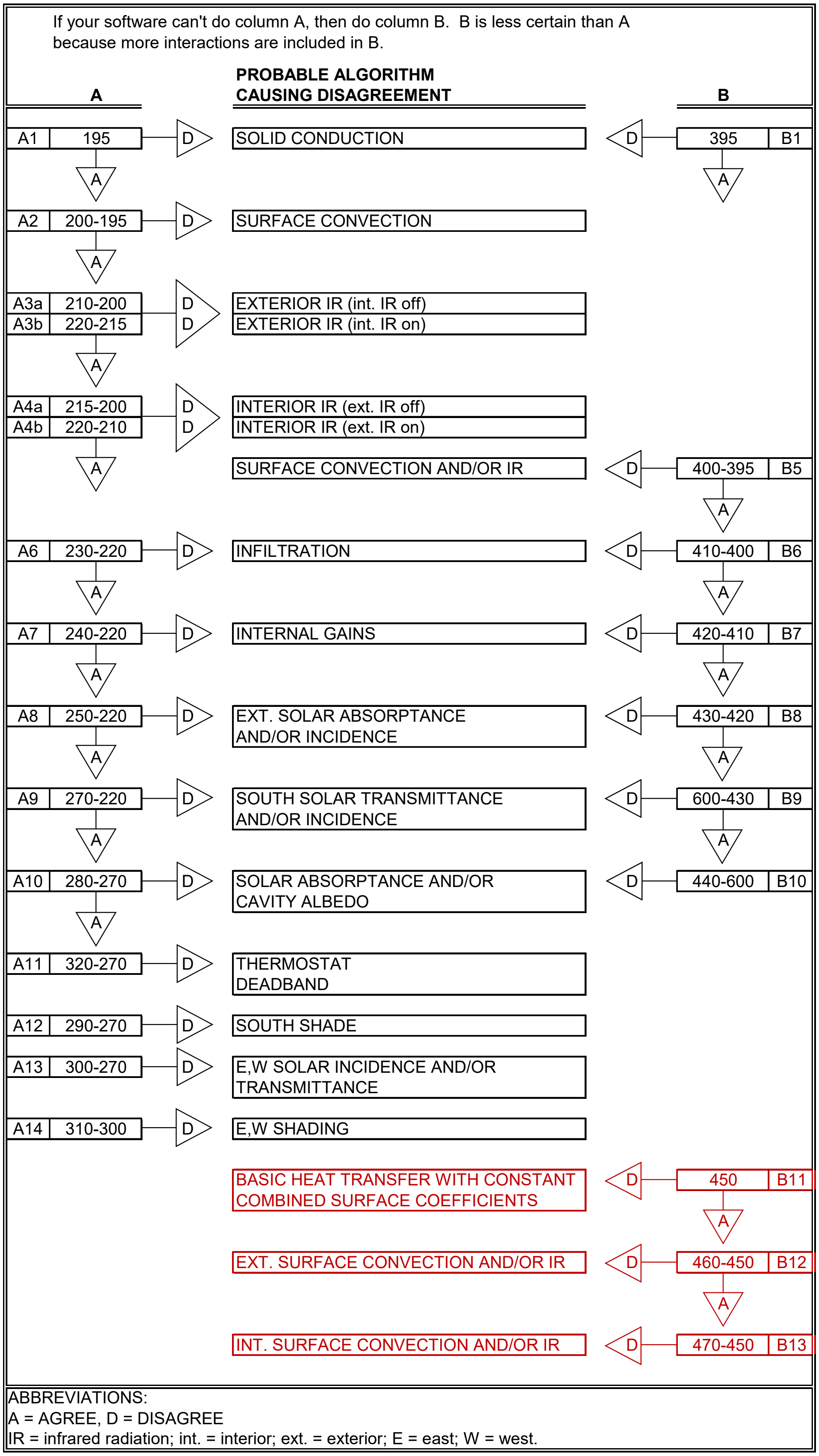


ABBREVIATIONS:
A = AGREE which means to show agreement with the example results or other user provided results for the case itself and the sensitivity case.
For example, to check for agreement regarding Case 610, example results for Case 610 and Case 610-600 sensitivity are compared.
D = DISAGREE which means to show disagreement with the example results or other user provided results.

Note 1: Do not run those high-mass cases for which the analogous low-mass cases disagreed until the given low-mass case disagreement is resolved. For example if Case 610 results disagreed, don't run Case 910 until the Case 610 (and/or 610-600) south shading disagreement is resolved.

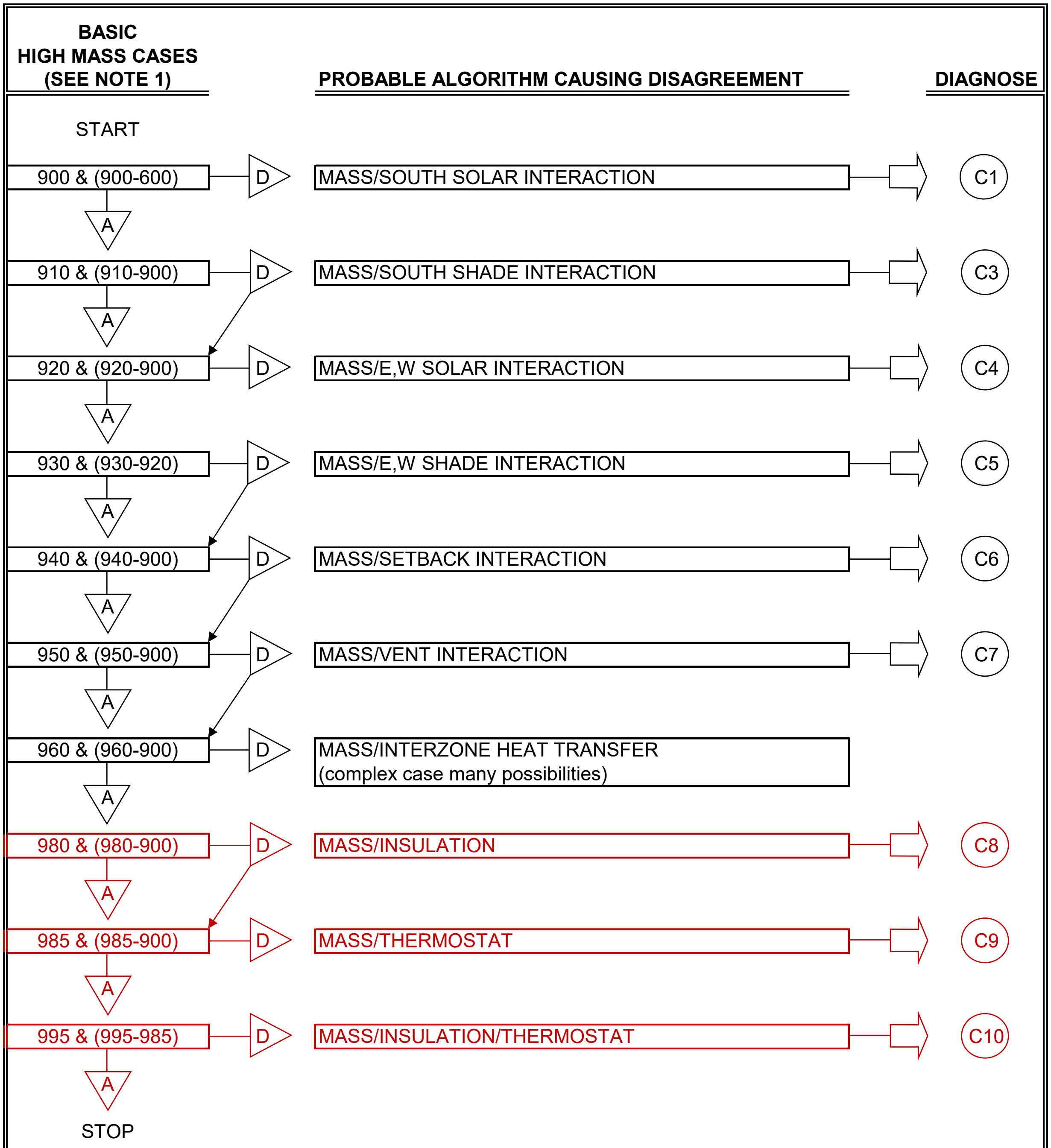
FigB9-1.xlsx; 01/07/20

Figure B9-1 BESTEST: Low-mass basic flow diagram.



FigB9-2.xlsx; 010720

Figure B9-2 BESTEST: Low-mass in-depth flow diagram.



ABBREVIATIONS:
A = AGREE, D = DISAGREE
A slash "/" = "and/or"; E = east; W = west;

Note 1: Only run those high mass cases for which the analoguous low mass cases show agreement. For example, don't run Case 910 if there was disagreement with Case 610; first resolve the Case 600 (and/or 610-600) disagreement.

FigB-3.xlsx; 010720

Figure B9-3 BESTEST: High-mass basic flow diagram.

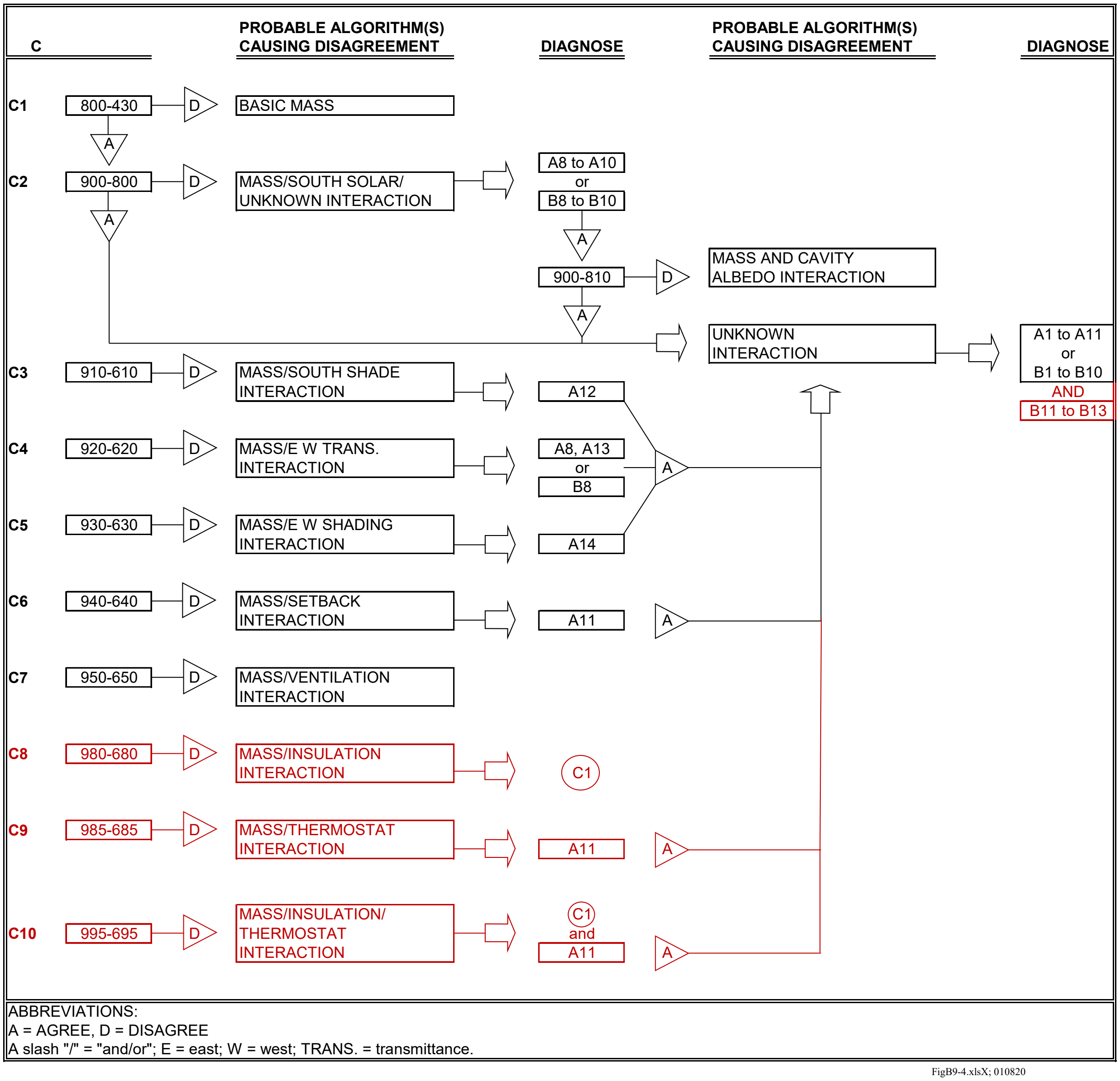


Figure B9-4 BESTEST: High-mass basic and in-depth flow diagram.

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX B10 INSTRUCTIONS FOR WORKING WITH RESULTS SPREADSHEETS PROVIDED WITH THE STANDARD

For the convenience of users, a printout of documentation for navigating the example results files is included below.

B10.1 Documentation for RESULTS5-2A.XLSX (given in RESULTS5-2A.DOCX). This spreadsheet workbook contains the ASHRAE SSPC 140 international software developer working group IEA 12B/21C participant results that are presented as informative example results for the Section 5.2.1, 5.2.2, and 5.2.3 building thermal envelope and fabric load tests as described in Informative Annex B8, Section B8.1. Table B10-1 presents an index of all sheets contained in the RESULTS5-2A.XLSX file. The "ReadMe" sheet within the file provides a general overview of the file. Example results tables and figures are listed with location (sheet tab and cell range) in Informative Annex B8, Section B8.1.2, and also on the "Table List" and "Figure List" sheets in the XLSX file. New results can be imported to the "YourData" sheet and will automatically appear in all tables and also in the graphic figures. The "YourData" sheet has been designed with the same data structure (data units, format, and position) as the Standard Output Report spreadsheet Sec5-2Aout.XLSX file so that new results can be copied directly. Import data so that Cell B661 of Sec5-2Aout.XLSX is in B661 of sheet "YourData." Check that the first value (Annual Heating Load for Case 600) is in YourData!C70B65. The "Adding Results" sheet has instructions for accomplishing this. and also has a full tabulation of results locations. New results data will appear in the rightmost column of each table and in all figures. To print example results, or example results with new user-generated results, go to the "Title Page" sheet and follow the instructions starting in Cell B5.

Table B10-1. Index of Sheets in RESULTS5-2A.XLSX

Sheet	Description
Read Me	General directions to using this workbook.
Adding Results	Instructions for adding new results. Also has cell map to individual data items in example results and "YourData" sheets.
YourData	For inputting new simulation test results; see sheet "Adding Results" for instructions. Data input to this sheet will pass through into all tables and charts.
Title Page	Title Page for printed informative example or new comparison results. Sets headers for tables and charts. See instructions on page.
Program List	List of simulation programs and organizations producing Informative Annex B8, Section B8.1 example results.
Table List	Listing of Informative Annex B8, Section B8.1 tables with sheet tab locations.
Figure List	Listing of Informative Annex B8, Section B8.1 figures with sheet tab labels.locations.
Tables 1 through Tables 6 7; Tables M1 through Tables M3 (6 10 sheets)	Formatted summary results tables, including example simulation results and statistics. See Annex B8, Section B8.1.2 or the "Table List" sheet in RESULTS5-2A.XLSX for a list of all tables with sheet tab and cell range locations. New results (entered in sheet "YourData") automatically appear on the right side of each table.
Fig B8-1 "Ann Incident Solar" through Fig B8-59 "Hrly Loads Case900" ; Fig B8-M1 through B8-M12; Fig B8-H1 through B8-H38 (59109 sheets)	FiftyOne-hundred-nine summary charts (one per sheet). See Informative Annex B8, Section B8.1.2 or the "Figure List" sheet in RESULTS5-2A.XLSX for a list of all figures with sheet tab location.
DataDATA for charts	Unformatted data for use by the 59 109 charts. New results (entered in sheet "YourData") automatically appear on the right side of each data table.
ESP-DMU through TASE BSIMAC through TRNSYS (86 sheets)	Results sheets from each simulation program used to produce example results.
TestSpecAlt	Tsky alternative values from the test specification (see Section 5.2.1.1.1.2 and Annex A1, Section A1.1.1.2); data apply only to Table B8-16 and Figures B8-6, B8-H10, and B8-H11.
K	Spare data entry sheet.

[Note: Remainder of Annex B10 is not shown for this addendum; that material has no revisions.]

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX B11 PRODUCTION OF EXAMPLE RESULTS FOR BUILDING THERMAL ENVELOPE AND FABRIC LOAD AND GROUND-COUPLED SLAB-ON-GRADE TESTS OF SECTION 5.2

This section describes the criteria used to select programs to produce the example results, provides details of the program versions used, and provides details of the analytical solutions.

Example results were created as part of the original research projects that developed the test cases in Section 5.2. Each project used different programs and/or program versions. Simulation programs used to develop the results were the current versions at the time of the original research; programs may have been updated since the example results were produced. For some test cases, analytical solutions or verified numerical-model results have been developed and serve as mathematical truth standards and secondary mathematical truth standards, respectively.

B11.1 Results for Building Thermal Envelope and Fabric Load Cases of Sections 5.2.1, 5.2.2, and 5.2.3. The full discussion of example results is included in the originating test-suite-update final report[A-15]. ~~*IEA BESTEST*[B-29].~~ Portions of that discussion have been included here.

The programs used to generate the example results for Sections 5.2.1, 5.2.2, and 5.2.3 are described in Table B11-1. Under the "computer program" column, the first entry in each cell is the proper program name and version number. The entries in parentheses are the abbreviations for the programs used in Informative Annex B8, Section B8.1, and occasionally elsewhere in the informational annexes.

The second column of Table B11-1 indicates the university, ~~or~~ national research facility, or industry organization with expertise in building science that wrote the simulation software. The third column indicates the university, ~~or~~ national research facility, or industry organization with expertise in building science that performed the simulations. The majority of participating organizations that performed simulations ~~either~~ ran software written by their organization. ~~or otherwise ran other building energy simulation software in addition to that written by their organization.~~

To minimize the potential for user error, ~~when feasible~~ more than one modeler developed input files for each program when feasible. This was done for ~~BLAST, SERIRES,~~ DeST, ESP-r, EnergyPlus, and TRNSYS. Where disagreement in the inputs or results was found, the modelers were requested to resolve the differences. Where only a single modeler was involved, it was strongly recommended that inputs be carefully checked by another modeler familiar with the program.

Where improvements to simulation programs or simulation inputs were made as a result of running the tests, such improvements must have mathematical and physical bases and must be applied consistently across tests. Also, all improvements were required to be documented in modeler reports. Arbitrary modification of a simulation program's input or internal code just for the purpose of more closely matching a given set of results was not allowed.

Input files used to generate the results are provided with the electronic files accompanying this standard; see the README*.DOCX file. **The accompanying files can be downloaded online at http://www.ashrae.org/140_2017**. ~~The IEA participants that ran SERIRES 1.2 only provided two input files with their results. IEA participants that ran simulations for ESP, S3PAS, and TASE did not supply input files with their results.~~

Table B11-1 Computer Programs, Program Authors, and Producers of Example Results

[Note: 140-2017 Table B11-1 is deleted and replaced in its entirety by the following new content; edit tracking is not applied.]

Simulation Program	Authoring Organization	Implemented by	Abbreviation
BSIMAC, Version 9.0.74	Alec Johannsen Consulting Engineers, South Africa	Alec Johannsen Consulting Engineers, South Africa	BSIMAC
California Simulation Engine, Version 0.861.1	J.R. Barnaby/C.S. Barnaby/Big Ladder Software LLC/Wrightsoft Corp., United States	Big Ladder Software LLC, United States	CSE
DeST 2.0, Version 20190401	Tsinghua University, China	Southeast University, China Tsinghua University, China	DeST
EnergyPlus, Version 9.0.1	U.S. Department of Energy, Building Technologies Office, United States	GARD Analytics, Inc., United States	EnergyPlus
ESP-r, Version 13.3	University of Strathclyde, United Kingdom	University of Strathclyde, United Kingdom	ESP-r
TRNSYS, Version 18.01.0001	Transsolar Energietechnik GmbH, Germany; Thermal Energy System Specialists, United States	Transsolar Energietechnik GmbH, Germany	TRNSYS
TRNSYS, Versions 17.02.0005 and 18.00.0017	Transsolar Energietechnik GmbH, Germany; Thermal Energy System Specialists, United States	Ecole Polytechnique Montréal, Canada[a,b]	[n/a]

[a] Ecole Polytechnique and GARD also worked on simulations for developing alternative constant interior and exterior surface coefficients, applying TRNSYS and EnergyPlus, respectively.
[b] Also checking input files versus the Transsolar participant's files and vice versa.

[Note: Edits to existing material recommence here.]

B11.1.1 Selection of Programs for Producing Example Results. The criteria for selection of programs used for producing example results required that

~~a. a program be public domain, in the sense that a large portion of its development was government sponsored, and that its source code be available for scrutiny and~~
~~b~~a. the program be a true simulation based on hourly weather data and calculational time increments of one hour or less.
b. the program was currently maintained at the time of publication of the originating test-suite-update final report[A-15]
c. a program be representative of the state of the art in whole-building energy simulation as defined by the working group participants making the selection.

The programs used to generate example results have been subjected to extensive prior validation testing. Such testing includes the preliminary trials of ~~*IEA BESTEST* [B-29]~~ the originating test-suite-update final report[A-15] that ran from 2014 through 2019. ~~1991 through 1993.~~ The programs (to various extents) were also subjected to other comparative, empirical validation and/or analytical verification tests, such as those referenced in Informative Annex B23 and the 2017 *ASHRAE Handbook—Fundamentals*[B-101], Chapter 19, Section 8. ~~*IEA BESTEST* and in International Building Performance Simulation Association (IBPSA) proceedings[B-47,B-48].~~

B11.1.2 Non-Application of Interior Surface Texture. For the example results of Informative Annex B8, Section B8.1, none of the models apply interior surface texture to evaluate interior surface heat transfer, so that inputs from Table 5-8 (see Section 5.2.1.10.2) do not affect results for any of the programs that provided example results for Informative Annex B8, Section B8.1. However, many of these models apply direct input of exterior surface texture (see Table 5-6 of Section 5.2.1.9.2) to evaluate exterior surface heat transfer and are sensitive to that input.

B11.1.3~~2~~ Exclusion of Specific Results. Specific results from the originating test-suite-update final report[A-15] ~~*IEA BESTEST* [B-29]~~ used to develop example results were excluded according to a specific set of rules.

a. Where there is known to be a specific, identifiable, documented deficiency in a program, which impacts the results for specific cases and not for any other cases, the results for those cases were excluded.
b. If a fundamental bug or algorithmic error is suspected that affects many of the results from a particular program, then all the results from that program were excluded.
c. A significantly outlying result for a particular case must be explained/justified by the modeler, or corrected by the modeler with an explanation of the physical basis for the correction, or it was excluded.

[Note: The following is proposed new material, appended to Section B11.1.3 (previously B11.1.2 of 140-2017). This material pertains to the new results set (see Results 5-2A-140-2017-A.XLSX provided with the accompanying electronic media for this addendum).]

Application of these rules resulted in the elimination of BSIMAC results for cases with interior solar absorptance (α,int) = 0.9; i.e., Cases 270, 290, 300, 310, 320. BSIMAC does not allow variation of interior solar absorptance (α,int), because it applies the Radiant Time Series method as described in the modeler report for this program included with the test-suite-update final report[A-15]. Based on this issue, the code author/modeler had excluded results for the test-suite-update final report for cases with α,int = 0.1 that specifically test cavity albedo. However, the code author included results there for cases with α,int = 0.9 (Cases 270, 290, 300, 310, 320) because those cases include in-depth thermostat, orientation, and shading sensitivity diagnostics where the 20/20 thermostat, 0 internal gains, and 0 ACH infiltration are applied throughout – these cases were of value to the code author.

[Note: The remainder of this section (140-2017, Section B11.1.2) is deleted as shown, including Table B11-2. That material related to the previous results set of 140-2017, Results5-2A.XLSX, which is superseded by the new results of this addendum (see Results 5-2A-140-2017-A.XLSX provided with the accompanying electronic media for this addendum). B11.1.2 is not specifically cross-referenced elsewhere in the Standard.]

~~Application of these rules resulted in the elimination of the following:~~

~~a. SERIRES 1.2 (SERIRES-BRE) [B-45] for output related to peak loads~~
~~b. TASE [B-49] results related to east and west shading devices (Cases 630 and 930)~~
~~c. Various in-depth results as noted in Table B11-2~~

~~SERIRES-BRE peak load results were excluded because the implementation of SERIRES 1.2 for producing example results did not explicitly model a pure convective thermostat as called for in Section 5.2.1.13. A convective thermostat is one that responds to pure interior air temperature (does not respond directly to infrared radiation from interior surfaces). The mathematical representation of the thermostat control temperature in the SERIRES-BRE results is closer to a radiant temperature than an air temperature. This can have a significant effect on peak load prediction in certain cases. In the SERIRES/SUNCODE 5.7 (SRES/SUN)[B-24] results, the pure convective thermostat is modeled by reducing the combined radiative/convective interior film coefficient from 8.29 W/(m²·K) to a convection-only film coefficient of 3.16 W/(m²·K). The modelers then slightly increased the thermal conductivity of the wall and roof insulation materials and increased the resistance of the floor insulation materials so that the building air-to-air heat transmission coefficient remained equivalent to that specified in Tables 5-1 and 5-11. For more discussion about this, see Section 2.5.3.3 of *IEA BESTEST* [B-29].~~

~~TASE results related to east and west shading devices (Cases 630 and 930) were also eliminated based on communications with the modeler.~~

For in-depth Cases 195 to 440 and 800 to 810, results are presented in Informative Annex B8 only from those simulation programs capable of explicitly modeling the effect in question. The most difficult cases were those that required variation of exterior and/or interior infrared emittance ε and those that required variation of interior shortwave absorptance α. Thus, for cases that specified interior ε = 0.1, exterior ε = 0.1, or interior α = 0.1 (Cases 195, 200, 210, 220, 280, 440, and 810), the decision to include a program's results was based on the modeling approach described by each modeler (see *IEA BESTEST* [B-29]). Where explicit modeling of the effect was internal to the program, or where the modeler documented a credible method equivalent to explicit modeling of the effect, the results were included. Table B11-2 shows those effects responsible for eliminating some of the programs ("No" = eliminated).

For Case 210, to present results required at least some sort of interior radiosity network and the ability to explicitly vary interior emittance. ESP,[B-42], BLAST[B-12], TRNSYS[B-51], and TASE[B-49] were the only programs able to meet these requirements. The TRNSYS modelers were able to do Case 210 (interior ε = 0.1) by varying the Stefan-Boltzmann constant within the context of a simplified radiosity network. The SERIRES[B-24,B-45] modelers were able to do Cases 280, 440, and 810 (cavity albedo) by externally calculating the fraction of shortwave radiation absorbed by interior surfaces based on shape factors and absorptances (SERIRES/SUNCODE 5.7) or area weighting and absorptances (SERIRES 1.2). Most of the programs were capable of explicitly modeling the remainder of the in-depth cases.

Table B11-2 Ability of Participating Computer Programs to Explicitly Model In-Depth Cases That Vary Selected Radiative Properties

Computer Program	Exterior ε = 0.1	Interior ε = 0.1	Interior α = 0.1
BLAST 3.0 level 193 v.1	No[a]	Yes	Yes
DOE-2.1D14	No	No	No
SERIRES/SUNCODE 5.7	No	No	Yes
SERIRES 1.2	No	No	Yes
ESP-RV8	Yes	Yes	Yes
S3PAS	No	No	No
TRNSYS 13.1	No	Yes	Yes
TASE	No	Yes	Yes

a. Just prior to final publication of *IEA BESTEST*, the BLAST Support Office notified the BLAST modelers of the undocumented commands for invoking BLAST's most detailed algorithm for handling of exterior surface infrared radiation exchange. This information was not available in time to revise the example results.

[Note: All of 140-2017, Section B11.1.3 is deleted as shown, including Table B11-3. That material related to the previous results set of 140-2017, Results5-2A.XLSX, which is superseded by the new results of this addendum (see Results 5-2A-140-2017-A.XLSX provided with the accompanying electronic media for this addendum).]

B11.1.3 Hourly Time Convention. Details of differences in modeling methods utilized by various software are given in Part II of *IEA BESTEST* [B-29]. That reference does not discuss how the specified time convention is modeled by various simulation software. For Standard 140, the time convention for the input specification and hourly outputs is standard time, while the time convention for Typical Meteorological Year (TMY) weather data is solar time (see Informative Annex A1, Section A1.5, for discussion of the difference between solar time and standard time). The time convention is therefore most correctly modeled by software that rebins TMY data into hourly data based on local standard time. A tabulation of how the time convention was modeled by some of the software used to generate the example results given in Informative Annex B8 is noted in Table B11-3.

Because software being tested by Standard 140 may not rebin TMY data, it is important to understand the potential differences in Standard 140 results that can be generated by applying a time convention different from that specified in Section 5.1.1. In Standard 140, such differences are minimized and are primarily related to the equation of time (see Normative Annex A1, Section A1.5) because the building site has been located within 0.1 degree longitude of the standard meridian. For this reason, Standard 140 does not provide a good test for the ability to calculate solar incidence angles for longitudes far away from the standard meridian.

To estimate the potential difference caused by deviating from the time convention in Section 5.1.1, a series of sensitivity tests were performed using DOE-2.1D [B-46]. In these tests, solar incidence angle calculations were intentionally distorted by specifying the longitude of the site in the input file as different from the longitude used in the TMY weather data processor. Such a site longitude shift is based on one degree of planetary rotation per four minutes and was limited to 4.3 degrees corresponding to the maximum shift that would be caused by the equation of time. The effect of distorting the calculations was negligible (≤1%) for most outputs. The most significant potential differences identified are as follows:

a. Three percent for annual peak sensible cooling load in the east/west window cases (with or without shading present).
b. Eight percent for hourly sensible cooling loads without window shading (9% with shading present) and 8% for hourly solar transmission (with or without shading present) during hours when the equation of time causes the maximum difference between solar time and standard time occurring in February, October, and November. However, the differences for these worst-case hours cancel out on an annual basis and are not coincident with occurrence of annual peak loads so that the effect on results required to be entered in the standard output report is negligible.

Since the worst potential difference for results required to be entered in the standard output report is 3%, and that for just peak sensible cooling loads in the cases with east/west windows, it is reasonable to conclude that the potential difference in results generated for Standard 140 due to deviating from the solar time convention of the TMY weather data is negligible.

Table B11-3 Time Convention Models for Selected Simulation Programs

Simulation Program	Weather Data Rebinned to Local Standard Time	Solar Angle Calculations Assume Processed Weather Data Is in Standard Time
BLAST 3.0	No	Yes
DOE-2.1D	Yes	Yes
ESP-RV8	No	Yes
SERIRES/SUNCODE 5.7	No	No
TASE	No	Yes

[Note: This addendum adds new Section B11.1.4.]

B11.1.4 Legitimate Modeling Differences. We define legitimate modeling differences or disagreement as where:

1. the program's test case inputs conform to the test specification
2. reviewers have not identified a disqualifying algorithmic deficiency as the cause of disagreement.

Criterion 1 is directly determinable from the simulation-trial participant modeler reports (see Part III, Section 3.9 of the test-suite-update final report[A-15]). Regarding criterion 2, the determination of "legitimate" or "disqualifying" is a judgement decision on the part of the simulation-trial modeler-report author, the Standard 140 Committee, and/or other reviewer(s).

Some points on the topic of the second criterion initially articulated at the January 2019 Building Thermal Fabric Working Group meeting (SSPC 140 BTF WG minutes, 2019)[A-16] and further developed here, include:

- Some algorithms are difficult to measure empirically (e.g., sky temperature, surface heat transfer) and some may depend on correlations for which there is no overall agreement on which correlation is best. Differences among such algorithms are generally legitimate modeling differences.
- A program is a set of many algorithms, where some individual aspects of a given model may be stronger than those of other models. For example, varying surface heat-transfer coefficients are clearly better than annual-constant coefficients. However, where a program may have some better or weaker individual aspects, but is not obviously better or weaker overall, then use of simplifications in programs can be legitimate.

Based on these two points, and where Criterion 1 is satisfied, we should conclude that characterization of a difference would default to "legitimate" when 1) there is not a clear set of measurements to show which individual algorithm (as applied in a program with many algorithms) is better OR 2) when it is not clear that a more detailed composite model is obviously better.

For the current results set, the six programs have good agreement for most outputs with legitimate modeling differences noted in their modeler reports (see Part III, Section 3.9 of the test-suite-update final report[A-15]), where previous disagreements were corrected with logical justifications (also discussed in the modeler reports). The remaining disagreements, especially for annual and monthly peaks and hourly results, are attributed to legitimate modeling differences; these differences were identified for each program in the modeler reports and are summarized in Part II, Section 2.2.2 of the test-suite-update final report[A-15].

[Note: The remainder of Annex B11 (Section B11.2) is not shown here. Section B11.2 has no changes; it relates to test cases of Section 5.2.4, which are not affected by this addendum.]

[Note: Informative Annex B12 is deleted entirely. TMPBIN.EXE replaced with post-processor with Sec5-2Aout.xls; see Section 6.2.1.7.1.]

~~**(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)**~~

~~INFORMATIVE ANNEX B12 TEMPERATURE BIN CONVERSION PROGRAM~~

~~To reduce calculation time in Section 6.2.1.7.1, a computer program or spreadsheet binning function may be used. An example of such a computer program is described below.~~

~~Included with the downloadable electronic files that accompany this standard is an executable program (TMPBIN.EXE) that may be used for sorting annual hourly temperature output into bins of 1°C. The bins range from −50°C to 99°C. The program will abort if temperatures outside this range are encountered. The annual hourly temperature file must be sequential, and each line must not contain more than one occurrence of the temperature of interest. The program reads either free-format or formatted data. In free-format mode, the number of the column in which the data resides is needed (the program interactively explains this input). No alpha characters are allowed in the data columns in free-format mode. A line with alpha characters in the data column will be escaped.~~

~~It is advisable to use the formatted option in which alphanumeric characters prior to the data of interest are skipped over, using X format. The limitation is that the format has to be in either "F" or "E" FORTRAN formats. Even if the temperature data in the file were integers, the format has to be for a "REAL" type number. In such cases integers must be read in "F" format with 0 digits (F3.0).~~

~~Output from the bin program is written into a file with the same name as the temperature data file but with the extension ".BND."~~

~~The program will prompt the user for input with some explanatory remarks. It displays dots after each ten lines processed to show it is running. When finished it will show the number of lines processed and the number of lines that contained errors or unreadable characters. If the number of errors is substantial, the input file and format should be corrected. Run and error information is stored in a file with the same name as the input data file but with the extension ".INF."~~

[Note: Material of Informative Annexes B13 through B22 are not affected by this addendum. These annexes may be renumbered, or Annex B12 may be marked as intentionally blank.]

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX B24 INFORMATIVE REFERENCES

[Note: References new to Standard 140 begin with "A-" and are listed below sequentially in the order they are first referenced in the preceding text. References beginning with "B-" are already cited elsewhere in Standard 140-2017; where those references apply in the preceding text, they are cited as listed further below using the reference numbering of Standard 140-2017.]

[A-1]McQuiston, F., and J. Parker. 1994. *HVAC Analysis and Design*, Fourth Edition, pp. 66, 707, 709. New York: John Wiley & Sons.

[A-2]U.S. DOE. (2018). *EnergyPlus Engineering Reference, Version 8.9.0.* Washington, DC: United States Department of Energy; Urbana, IL: University of Illinois; Berkeley, CA: University of California and Lawrence Berkeley National Laboratory. March 2018. https://energyplus.net/sites/all/modules/custom/nrel_custom/pdfs/pdfs_v8.9.0/EngineeringReference.pdf. Last accessed Feb 27, 2019.

[A-3]WINDOW 7. (2016). Berkeley Lab WINDOW 7.4. Berkeley, CA: LBNL. https://windows.lbl.gov/software/window/7/index_7_4_8.html. Last accessed October 25, 2016. Note: WINDOW 6 is the relevant user's manual[A-9].

[A-4]WINDOW 7. (2017). Berkeley Lab WINDOW 7.6. Berkeley, CA: LBNL. https://windows.lbl.gov/tools/window/software-download. Last accessed Mar 23, 2018. Note: WINDOW 6 is the relevant user's manual[A-9].

[A-5]Wilcox, S., W. Marion. (2008). *Users Manual for TMY3 Data Sets.* NREL/TP-581-43156. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy08osti/43156.pdf

[A-6]Wilcox, S. (2007*). National Solar Radiation Database 1991–2005 Update: User's Manual*. 472 pp.; NREL Report No. TP-581-41364. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy07osti/41364.pdf

[A-7]ASHRAE (2012). *Psychrometric Analysis, Version 7.* Atlanta: ASHRAE.

[A-8]Neymark, J., Kummert, M., and Judkoff, R. (2019). "Developing Equivalent Surface Heat Transfer Input Parameters for Updated Standard 140/BESTEST Thermal Fabric Test Cases." *Proceedings of Building Simulation 2019.* Rome, Italy. Sep 2-4, 2019. International Building Performance Simulation Association.

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[A-11]NFRC 100-2014. (2014). Procedure for Determining Fenestration Product U-Factors. Greenbelt, MD: National Fenestration Rating Council.

[A-12]IGDB (2016). *International Glazing Database.* Berkeley, CA: LBNL. http://windowoptics.lbl.gov/data/igdb. Last accessed Oct. 21, 2016.

[A-13]Judkoff, R., Polly, B., Bianchi, M., and J. Neymark. (2010). *Building Energy Simulation Test for Existing Homes (BESTEST-EX) Phase 1 Test Procedure: Building Thermal Fabric Cases*. NREL/TP-550-47427. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy10osti/47427.pdf.

[A-14]Finlayson, E.; Arasteh, D.; Huizenga, C.; Rubin, M.; Reilly, M. (1993). WINDOW 4.0: Documentation of Calculation Procedures. LBL-33943. Berkeley, CA: LBNL.

[A-15]Neymark, J.; Judkoff, R.; Kummert, M.; Muehleisen, R.; Allison, J.; An, J.; Glazer, J.; Henninger, R.; Hiller, M.; Jiang, Y.; Johannsen, A.; Kruis, N.; McDowell, T.; Ono, E.; Strachan, P.; Witte, M.; Yan, D.; Yoshida, H.; Zhou, X. (2020). *Update of ASHRAE Standard 140 Section 5.2 and Related Sections (BESTEST Building Thermal Fabric Test Cases).* ANL-20/26. Lemont, Illinois, U.S.A.: Argonne National Laboratory. https://publications.anl.gov/anlpubs/2020/05/158451.pdf.

[A-16]ASHRAE SSPC 140. (2019). ASHRAE SSPC 140 Building Thermal Fabric Working Group Minutes, January 14, 2019, Atlanta, GA.

[Note: The following references are cited in this addendum material and are included here for convenience and to indicate deletions to existing references where shown. All other existing references remain unchanged.]

[B-10]*ASHRAE Handbook—2009 Fundamentals.* Atlanta, GA: ASHRAE.

[B-20]Walton, G. (1983). Thermal Analysis Research Program Reference Manual (TARP). NBSIR 83-2655. Washington, D.C.: National Bureau of Standards (now called National Institute of Standards and Technology).

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[B-26]1993 *ASHRAE Handbook—Fundamentals,* pp. 25.10–25.12 (and elsewhere, as ~~noted~~ described in the text). Atlanta: ASHRAE.

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[B-30]2001 *ASHRAE Handbook—Fundamentals*. Atlanta: ASHRAE.

[B-32]2005 *ASHRAE Handbook—Fundamentals*. Atlanta: ASHRAE.

[B-38]Judkoff, R., and J. Neymark. 1995. *Home Energy Rating System Building Energy Simulation Test (HERS BESTEST), Volume 1: Tier 1 and Tier 2 Tests User's Manual.* NREL/TP-472-7332a. Golden, CO: National Renewable Energy Laboratory. www.nrel.gov/docs/legosti/fy96/7332a.pdf

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~~[B-41]*ASHRAE Terminology of Heating, Ventilation, Air Conditioning, and Refrigeration*. 1991. Atlanta: ASHRAE. (Also see www.ashrae.org/resources--publications/free-resources/ashrae-terminology.)~~

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~~[B-43]WINDOW 4.0 1992. LBL-32091, UC-350. Berkeley, CA: Lawrence Berkeley National Laboratory~~

~~[B-44]Kreith, F., and M. Bohn. 1993. *Principles of Heat Transfer*, Fifth edition. St. Paul, MN: West Publishing Company.~~

~~[B-45]Haves, P. n.d. *SERI-RES/PC SERI-RES, Version 1.2, for IBM-PC and MS-DOS Microcomputers User's Guide*. London, UK: Polytechnic of Central London, Energy Technology Support Unit.~~

~~[B-46]*DOE-2 Supplement (Version 2.1D)*. 1989. Berkeley, CA: Lawrence Berkeley Laboratory.~~

~~[B-49]Aittomäki, A., and T. Kalema. 1976. *TASE—A Computer Program for Energy Analysis of Buildings*. Technical Research Centre of Finland, Espoo, Finland.~~

~~[B-50]*S3PAS User's Manual*, Escuela Superior Ingenieros Industriales, Sevilla, Spain.~~

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[B-101]ASHRAE. 2017. *ASHRAE Handbook—Fundamentals*. Atlanta: ASHRAE.

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