**BSR/ASHRAE Addendum *b* to**
**ANSI/ASHRAE Standard 140-2023**

## First Public Review Draft

# Proposed Addendum *b* to Standard 140-2023, Method of Test for Evaluating Building Performance Simulation Software

**First Public Review Draft (August 2025)**
**(Draft shows Proposed Changes to Current Standard)**

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).



*PDF includes hyperlinks for convenient navigation. Click on a reference to a section, table, figure, or equation to jump to its location. Return to the previous page via the bookmark menu.*

Includes Web-based access to normative and informative electronic supplemental files.

## FOREWORD

***[Note to Reviewers: see Section 3 for following defined terms used in the Foreword: analytical verification, analytical solution, mathematical truth standard, physical truth standard, quasi-analytical solution.]***

*Addendum b adds the test cases of Section 13 of Standard 140 for testing the ability of building performance simulation programs to model the building thermal fabric. These are Standard 140's first empirical validation tests, where simulation results are compared to measured data within the uncertainty of the measurements. The tested modeling physics includes steady-state conduction and interior surface heat transfer as a precursor to more dynamic test cases that are possible. The test cases were developed by a working group of ASHRAE Standing Standard Project Committee 140 (SSPC 140) and other international software developers and simulation-trial participants. Related project funding for development was provided by the U.S. Department of Energy via Argonne National Laboratory.*

***Background***

*The test cases of ASHRAE/IBPSA Standard 140-2023 apply analytical verification tests (where software results are compared to analytical and quasi-analytical solutions as defined in Section 3 of Standard 140) and comparative tests where software are compared with each other. This addendum introduces the first empirical validation test suite into Standard 140 in new Section 13. The importance of introducing empirical validation tests is summarized under "Empirical Validation Methodology and the Importance of a Physical Truth Standard".*

*Measurements for the new test cases apply data collected from an empirical validation test facility in France called "ETNA" for "Essais Thermique en climate Naturel et Artificiel", which translates as Thermal Tests in Natural and Artificial Climate. The ETNA facility is a building that has two similarly designed and oriented twin test cells (Cell A and Cell B), with each separated and enclosed by five fixed and separately controlled guard zones. The wall and window facing 30° West of South (nominally "South") can also be enclosed by a mobile thermal guard; this modular configuration of the south thermal guard zone provides the means for carrying out tests under natural or artificial climatic conditions. Separately controlled guard zones in the artificial-climate configuration allow for the ability to measure both overall facility UA-value (building loss coefficient, BLC) and individual UA values of the test cells' bounding surfaces (walls, floor, ceiling). Individual guard zone control also allows for driving heat through a single bounding surface such that, in combination with surface temperature measurements, measurement-based combined convective and radiative surface heat transfer coefficients are derived. The facility applies a custom heating system designed to emulate the mixed-air assumption of building performance simulation (BPS) software, while providing a gentle, measured airflow rate that is consistent with mechanically-driven HVAC system airflow rates. The heating system is also designed to be 100% efficient and to maximize convective (minimize radiative) output.*

*J. Neymark and Associates, under contract with Argonne National Laboratory (Argonne), led the collaborative effort to:*

- *Analyze and vet the measured data and the initial test case documentation [C-1, B-83] and select a subset of the data and documentation to develop for initial simulation trials that evaluate the feasibility of including empirical validation tests in Standard 140.*
- *Develop the test specifications such that they would be unambiguous for the input structures of most BPS software programs with time steps of one (1) hour or less.*
- *Field-test the specifications with a variety of different BPS software 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/IPBSA Standard 140. The collaboration included a number of software-developer members of SSPC 140 along with other international software developers and the Argonne project team; see Informative Annex B11, Table B11-4.*

*In the new test suite, only artificial-climate (fully guarded) conditions are applied. Temperatures are imposed on each side of the test cell boundary surfaces (walls, ceiling, floor, windows, door) via independent control of test-cell and* *guard-zone air temperatures, with no solar flux incident on the exterior of the test cell bounding surfaces. Six (6) test cases, three (3) in each test cell, are included. These cases test steady-state 1-D conduction models with and without window insulation (reduced and greater heat transfer, respectively), and test interior surface heat transfer models. The test cases are presented in Section 13 with parametric variations summarized in Table B1-19 of Informative Annex B1. The addendum also includes updated informative example simulation results, which were vetted in simulation trials and are indicated in Informative Annex B8.*

*While a test suite covering only steady-state conduction scenarios may seem quite basic, the challenge of setting up experiments to emulate this in a facility also capable of dynamic natural climate tests is non-trivial. Additionally, the preliminary cases allow for rigorous input checks facilitated by having a physical truth standard, and lay the foundation for more dynamic artificial-climate and natural-climate cases applying ETNA data that are possible.*

***Empirical Validation Methodology and the Importance of a Physical Truth Standard***

*Measured data for the new test cases provide a physical truth standard, or target range, within the uncertainty of the measurements. When measurement uncertainty ranges are sufficiently narrow, such a physical truth standard is an improvement to the truth standards of the test cases of ASHRAE/IBPSA Standard 140-2023, which until this addendum are based on analytical verification tests and software-to-software comparative tests. Advantages and disadvantages of these types of tests are discussed in Informative Annex C1 and elsewhere [C-2].*

Important aspects of a physical truth standard are:

- *The physics underlying a set of algorithms are tested; this includes physical assumptions implicit to the analytical solutions underlying analytical verification tests that provide a mathematical truth standard but not a physical truth standard.*
- *Diagnostic output can be developed to detect and locate input errors: e.g., for the test cases of Section 13, by comparing modeled heat flow for each specified 1-D conduction path to the measurement-based heat flows. This captures input errors early in the testing process, minimizing the effect of input error propagation in a test suite. Such input error checking is also possible with analytical verification tests, but more difficult in software-to-software comparative tests.*

*The process for developing the physical truth standard and the test specification for the new test cases is as follows:*

- *Measure BLC, individual wall UA values, and individual interior and exterior surface combined convective and radiative heat transfer coefficients with measurement uncertainty quantified; this includes propagated spatial, temporal, and sensor uncertainties for all measured parameters.*
- *Characterize steady-state behavior of the test cells as inputs to software by imputing selected thermal conductivities consistent with measured individual bounding surface UA values.*
- *Provide validation accuracy targets for software results based on measurement uncertainty*
- *Develop test specifications for a variety of BPS software with timesteps of one hour or less that have a variety of input structures and modeling approaches*
- *Vet the test specification and final results via iterative field trials; for the tests of Section 13 the trials included seven BPS software programs run by the developers of all but one of the programs.*
- *This process is further elaborated in Informative Annex B23 and elsewhere [C-3].*

***Summary of Changes in This Addendum***

*A listing of substantive changes to Section 13 and related sections, annex, and accompanying electronic media* *follows (listed sections are normative unless otherwise indicated):*

- *New Section 13 "Building Thermal Fabric Empirical Validation Tests". This is the major substantive portion of the addendum.*
- *Updated Section 3, "Definitions, Abbreviations, and Acronyms"*
- *Updated Informative Section 4.2, "Applicability of Test Method"*
- *Updated Informative Section 4.3, "Organization of Test Cases," (overall Standard 140 road map) for consistency with addition of the Section 13 test cases.*
- *Updated Informative Section 4.4, "Comparing Output to Other Results," for addition of the Section 13 test cases measured data and example simulation results.*
- *Updated Section 5 "General Test Procedures", to include updates to Section 5.1 (Class I Test Procedures) related to addition of the new Section 13 test cases, and to Section 5.2 (Class II Test Procedures) consistent with the Section 5.1 updates.*
- *Updated Annex A1, "Weather Data," to include weather data used for Section 13.*
- *Updated Annex A2, "Standard Output Reports," to include updates related to the addition of the new results template, Std140_ET_Output.XLSX.*
- *Updated the following informative annexes to include new information relevant for the update of Section 13:*
    - *B1, "Tabular Summary of Test Cases"*
    - *B8, "Example Results for Weather Drivers Tests of Section 6, Building Thermal Envelope and Fabric Load Tests of Section 7, Ground-Coupled Slab-On-Grade Analytical Verification Tests of Section 8, and Building Thermal Fabric Empirical Validation Tests of Section 13"*
    - *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 Weather Drivers Tests of Section 6, Building Thermal Envelope and Fabric Load Tests of Section 7, Ground-Coupled Slab-On-Grade Analytical Verification Tests of Section 8, and Building Thermal Fabric Empirical Validation Tests of Section 13"*
    - *B23, "Supporting Material for Building Thermal Fabric Empirical Validation Tests of Section 13"*
    - *C2, "Informative References"*
- *Updated accompanying electronic files as called out in this addendum (See Readme 140-2023-B.DOCX with the accompanying electronic media located at [www.ashrae.org/140-2023-b](www.ashrae.org/140-2023-b) .)*

**Note:** In this addendum, changes to the current standard are indicated in the text by <u>underlining</u> (for additions) and ~~strikethrough~~ (for deletions) unless the instructions specifically mention some other means of indicating the changes.

**Addendum b to Standard 140-2023**

***Update the Contents section as shown. (Note: Some unaffected text is omitted for brevity.)***

***[Note to Reviewers: Contents included here for reviewer convenience. In the Contents, sections of the standard that are affected by this addendum are highlighted with blue background. Changes in text are indicated with underline/strikethrough. Page numbers are shown for material included in this review draft.]***

# CONTENTS
## ANSI/ASHRAE Standard 140-2023, Addendum *b*
## Method of Test for Evaluating Building Performance Simulation Software

**CONTENTS**

**CONTENTS**

**SECTION** **PAGE**

**CONTENTS**

**CONTENTS**



**Online Supporting Files: www.ashrae.org/140-2023-b** | data.ashrae.org/standard140

## 3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

### 3.1 Terms Defined for This Standard

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

…

***empirical validation:*** where outputs from a program, subroutine, algorithm, or software object are compared to measured data and related measurement uncertainties.

...

***physical truth standard:*** the standard of accuracy for predicting system behavior based on measured data and related measurement uncertainties.

…

### 3.2 Abbreviations and Acronyms Used in this Standard

…

| | |
|---|---|
| ρ | density |
| … | |
| 1D or 1-D | one dimensional |
| … | |
| 3D or 3-D | three dimensional |
| … | |
| ach or ACH | air changes per hour |
| … | |
| AMY | actual meteorological year |
| … | |
| BLC | building loss coefficient, same as overall building UA-value (W/K) |
| BPS | building performance simulation |
| … | |
| *cp* or Cp | specific heat, J/(kg·K) (Btu/[lb·°F]) |
| ... | |
| d | thickness, m |
| ETNA | Essais Thermique en climat Naturel et Artificiel", which translates as Thermal Tests in Natural and Artificial Climate |
| ... | |
| Ext. | exterior |
| ... | |
| GMT | Greenwich Mean Time |
| GMT+1 | Greenwich Mean Time plus one hour |
| *h* | convective surface coefficient, $W/(m^2·K)$ (Btu/[h·$ft^2$·°F]) |
| *hcomb,ext* or h,comb,ext | exterior combined convective and radiative surface heat transfer coefficient, $W/(m^2·K)$ |

| | |
|---|---|
| *hcomb,int* or h,comb,int | interior combined convective and radiative surface heat transfer coefficient, W/(m²·K) |
| h,comb,int,x | *h,comb,int* based on measured data for 1-D conduction heat flow path "x" W/(m2·K), where x represents one of the 16 heat flow paths specified for the test cells of Section 13 |
| *hconv,ext* | exterior convective surface heat transfer coefficient, W/(m²·K) |
| *hconv,int* | interior convective surface heat transfer coefficient, W/(m²·K) |
| ... | |
| HVAC | heating, ventilating, and air conditioning |
| … | |
| HWDsafr | heating system supply airflow rate for Cell A or B of Section 13, m³/h |
| … | |
| Int | interior |
| … | |
| *k* | thermal conductivity, W/(m·K) (Btu/[h·ft·°F]) |
| k,imp or $k_{imp}$ | imputed thermal conductivity, W/(m·K) |
| ... | |
| MM/DD/YY hh:mm | month/day/year hour:minute |
| … | |
| polysty | polystyrene |
| … | |
| PVC | polyvinyl chloride |
| *q* | heat flow, W or Wh/h |
| ... | |
| Qhtr | heating energy, Wh/h |
| q,x,conv | convective surface heat flux based on measured data for 1-D conduction heat flow path "x" (W/m2), where x represents one of the 16 heat flow paths specified for the test cells of Section 13 |
| q,x,rad | radiative surface heat flux based on measured data for 1-D conduction heat flow path "x" (W/m2), where x represents one of the 16 heat flow paths specified for the test cells of Section 13 |
| q,x,tot | total net convective and radiative surface heat flux based on measured data for 1-D conduction heat flow path "x" (W/m2), where x represents one of the 16 heat flow paths specified for the test cells of Section 13 |
| … | |
| R | unit thermal resistance, m²·K/W (h·ft²·°F/Btu) |
| … | |
| SI | Système Internationale |
| … | |
| Surf. | surface |
| ... | |

| | |
|---|---|
| *t* | thickness, m |
| … | |
| Tattic | air temperature of attic guard zone for Cell A or B of Section 13, °C |
| … | |
| Tcell | air temperature for test cell for Cell A or B of Section 13, °C |
| ... | |
| Teast | air temperature of east guard zone for Cell A or B of Section 13, °C |
| … | |
| T,intsurf,x | modeled interior surface temperature for 1-D conduction heat flow path "x" (°C), where x represents one of the 16 heat flow paths specified for the test cells of Section 13 |
| ... | |
| Tnorth | air temperature of north guard zone for Cell A or B of Section 13, °C |
| … | |
| Tsouth | air temperature of south guard zone for Cell A or B of Section 13, °C |
| … | |
| Twest | air temperature of west guard zone for Cell A or B of Section 13, °C |
| … | |
| *U* | unit thermal conductance or overall heat transfer coefficient, W/(m2·K) (Btu/[h·ft2·°F]) |
| UA | thermal conductance, W/K |
| … | |
| u(Qhtr) | measured heating energy uncertainty |
| … | |

**3.3 Subscripts**

…

## 4. METHODS OF TESTING

***Informative Note:*** Sections 4.2, 4.3, 4.4, and 4.5 and their subsections are informative material.

**4.1 General.** The test procedures shall be applied as specified in Normative Sections 5 through 13~~2~~. Content of the normative sections and organization of the test procedures are described in Sections 4.1.1 and 4.1.2 and in greater detail in Informative Section 4.3. Normative Annex A3, "Software Acceptance Criteria," includes tables of numerical ranges for test cases applied for establishing acceptable software and describes results submission.

Codes and standards that reference Standard 140 shall be permitted to call out specific sections within Standard 140 to require individual test cases or groups of test cases. Where specific sections are not called out for acceptance criteria, all test groups of Normative Annex A3 shall apply.

***Informative Note:*** Informative Section 4.5 provides additional items to consider for organizations citing Standard 140.

**4.1.1 Class I Test Cases.** The Class I test cases are detailed diagnostic tests for simulation software capable of hourly or subhourly simulation time steps. The requirements for these test cases are specified in Section 5.1.

**4.1.2 Class II Test Cases.** The Class II test cases are for all types of building load calculation methods regardless of time-step granularity. The requirements for these test cases are specified in Section 5.2.

**4.1.3 Normative Annexes.** The normative annexes to this standard are considered to be integral parts of the mandatory requirements of this standard, which, for reasons of convenience, are placed apart from all other normative elements.

**4.1.4 Informative Annexes.** The informative annexes and informative notes located within this standard contain additional information and are not mandatory or part of this standard.

***Informative Note:*** The remainder of Section 4 is informative material that provides background on the fundamentals and structure of the standard. Users of this standard should review Sections 4.2 through 4.5 before proceeding with this method of test.

**4.2 (*Informative*) Applicability of Test Method.** The method of test is provided for analyzing and diagnosing building energy simulation software ~~using~~ applying: software-to-software, software-to-analytical-solution, software-to-quasi-analytical-solution, ~~and~~ software-to-verified-numerical-model, and software-to-measured-data comparisons. The methodology allows different building energy simulation programs, representing different degrees of modeling complexity, to be tested by

- comparing the predictions from other building energy simulation programs to:
  - the Class I test example simulation, analytical solution, and verified numerical model results, along with empirical validation data, provided in Informative Annex B8,
  - ~~to~~ the Class I test example analytical and quasi-analytical solution and example simulation results in Informative Annex B16, ~~to~~
  - the Class II test example simulation results provided in Informative Annex B20,
  - ~~and/or to~~ other results (simulations, analytical and quasi-analytical solutions, or verified numerical model results) that were generated using this standard method of test;
- checking a program against a previous version of itself after internal code modifications to ensure that only the intended changes actually resulted;
- checking a program against itself after a single algorithmic change to understand the sensitivity between algorithms; and
- diagnosing the algorithmic sources and other sources of prediction differences. (Diagnostic logic flow diagrams are included in Informative Annex B9.)

**4.3 (*Informative*) Organization of Test Cases.** The specifications for determining test case configurations and input values are provided on a case-by-case basis in Sections 6 through 13~~2~~. 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 (Sections 6 through 11 and 13) are detailed diagnostic tests intended for simulation software capable of hourly or subhourly simulation time steps. The Class II test cases (Section 12) may be used for all types of building load calculation methods, regardless of time- step granularity. The Class I ~~(Sections 6 through 11)~~ test cases are designed for more detailed diagnosis of simulation models than the Class II ~~(Section 12)~~ 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; Informative 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 7.2.2.1.2), a case developed from modifications to a given base case (e.g., Case 600 in Section 7.2.1) will also serve as the base case for other cases. The cases are grouped as follows:

a. Class I Test Procedures
   1. Weather Drivers Tests (see Section 6)
   2. Building Thermal Envelope and Fabric Load Tests (see Section 7)
      i. Building Thermal Envelope and Fabric Load Base Case (see Section 7.1.1)
      ii. Building Thermal Envelope and Fabric Load Basic Tests (see Section 7.1.2)
         (a) Low mass (see Section 7.1.2.1)
         (b) High mass (see Section 7.1.2.2)
         (c) Free float (see Section 7.1.2.3)
      iii. Building Thermal Envelope and Fabric Load In-Depth Tests (see Section 7.1.3)
   3. Building Thermal Fabric Empirical Validation Tests (see Section 13)
   ~~3~~4. Ground-Coupled Slab-on-Grade Analytical Verification Tests (see Section 8)
   ~~4~~5. Space-Cooling Equipment Performance Tests (see Section 9)
      i. Space-Cooling Equipment Performance Analytical Verification Tests (see Section 9.1.1)
         (a) Space-Cooling Equipment Performance Analytical Verification Base Case (see Section 9.1.1.1)
         (b) Space-Cooling Equipment Performance Parameter Variation Analytical Verification Tests (see Section 9.1.1.2)
      ii. Space-Cooling Equipment Performance Comparative Tests (see Section 9.1.2)
         (a) Space-Cooling Equipment Performance Comparative Test Base Case (see Section 9.1.2.1)
         (b) Space-Cooling Equipment Performance Comparative Tests (see Section 9.1.2.2)
   ~~5~~6. Space-Heating Equipment Performance Tests (see Section 10)
      i. Space-Heating Equipment Performance Analytical Verification Base Case (see Section 10.1.1)
      ii. Space-Heating Equipment Performance Analytical Verification Tests (see Section 10.1.2)
      iii. Space-Heating Equipment Performance Comparative Tests (see Section 10.1.3)
   ~~6~~7. Air-Side HVAC Equipment Performance Tests (see Section 11)
      i. Air-Side HVAC Equipment Analytical Verification Test Cases (see Section 11.1.1)
         (a) Four-Pipe Fan-Coil (FC) System (see Section 11.1.1.1)
         (b) Single-Zone (SZ) System (see Section 11.1.1.2)
         (c) Constant-Volume Terminal Reheat (CV) System (see Section 11.1.1.3)
         (d) Variable-Air-Volume Terminal Reheat (VAV) System (see Section 11.1.1.4)

b. Class II Test Procedures
   1. Building Thermal Envelope and Fabric Load Tests (see Section 12)
      i. Building Thermal Envelope and Fabric Load Base Case (see Section 12.1.1)
      ii. Building Thermal Envelope and Fabric Load Tier 1 Tests (see Section 12.1.2)
      iii. Building Thermal Envelope and Fabric Load Tier 2 Tests (see Section 12.1.3)

**4.4 (*Informative*) Comparing Output to Other Results.** For Class I test procedures,

a. Informative Annex B8, Section B8.1, ~~gives~~ includes example simulation results for the building thermal envelope and fabric load tests of Section~~s~~ 7; ~~.2.1, 7.2.2, and 7.2.3;~~
b. Informative Annex B8, Section B8.2, ~~gives~~ includes analytical solution, verified numerical model, and example simulation results for the ground-coupled slab-on-grade tests of Section 8;

c. Informative Annex B8, Section B8.3, gives includes example simulation results for the weather drivers tests of Section 6; and

d. Informative Annex B8, Section B8.4, includes empirical data and example simulation results for the building thermal fabric empirical validation tests of Section 13; and

de. Informative Annex B16 gives includes quasi-analytical solution results and example simulation results for the HVAC equipment performance tests of Sections 9, 10, and 11.

For Class II test procedures (see Section 12), Informative Annex B20 gives example simulation results.

The user may choose to compare output with the example results provided in Informative Annex B8, Informative Annex B16, and Informative Annex B20 or with other results that were generated using this standard method of test (including self-generated quasi-analytical solutions related to cases where such solutions are provided). For Class I test procedures, information about how the example results were produced is included in Informative Annex B11 for building thermal envelope and fabric load comparative and empirical validation, ground-coupled slab-on-grade, and weather drivers tests; and in Informative Annex B17 for HVAC equipment performance tests. For Class II test procedures, information about how the example results were produced is included in Informative Annex B21.

For the convenience of users who wish to plot or tabulate their results along with the example results, electronic versions of the example results are included with the accompanying electronic media: for:

- Informative Annex B8 with the files Std140_TF_Results.xlsx and Std140_GC_Results.xlsx; for
- Informative Annex B16 with the files Std140_CE_a_Results.xlsx, Std140_CE_b_Results.xlsx, Std140_HE_Re-sults.xlsx, Std140_AE_FCSZ_Results.xlsx, and Std140_AE_CVVV_Results.xlsx; and for
- Informative Annex B20 with the file Std140_TF_Class2_Results.xls.
- And Ffor Informative Annex B8, Sections B8.3 and B8.4, a Python scripts for comparing user results to the example results is are available at https://data.ashrae.org/standard140.

Documentation for navigating these results files is included on the accompanying electronic media and is printed in Informative Annex B10.

**4.4.1 Criteria for Determining Agreement between Results.** The requirements of the normative sections of Standard 140 ensure that users follow the specified method of test and that test results are provided as specified. Acceptance criteria for selected outputs within selected test cases are provided in Normative Annex A3.

For output without specific acceptance criteria, there are no formal criteria for when results agree or disagree with either the example results provided in Informative Annex B8, Informative Annex B16, or Informative Annex B20, or with other results generated using this method of test. For such output, determination of when results agree or disagree is left to the organization referencing the method of test or to other users who may be running the tests for their own quality assurance purposes. In making this determination, the following should be considered:

a. Magnitude of results for individual cases.
b. Magnitude of difference in results between certain cases (e.g., Case 280 – Case 270).
c. Same direction of sensitivity (positive or negative) for difference in results between certain cases (e.g., Case 280 – Case 270).
d. 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 analytical verification tests, 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.
h. Availability of actual measured data, as in the thermal fabric empirical validation tests and/or weather

files used for many of the simulation test suites.

**4.4.2 Diagnostic Logic for Determining Causes of Differences among Results.** To help the user identify what algorithm in the tested program is causing specific differences between programs, diagnostic flow charts are provided as Informative Annex B9.

**4.5 (*Informative*) Citing Standard 140.**

***[Note to Reviewers: No further edits to Section 4 after here.]***

## 5. GENERAL TEST PROCEDURES

### 5.1 Class I Test Procedures

***Informative Note:*** Class I test procedures are detailed diagnostic tests intended for use with building energy simulation software tools having simulation time-steps of one hour or less. Energy analysis computer tools that do not meet this simulation time-step requirement but produce annual or seasonal results may be evaluated using the Class II Test Procedures of this standard (see Section 5.2). The Class I test cases are designed for more detailed diagnosis of simulation models than the Class II test cases.

**5.1.1 Modeling Approach.** This modeling approach shall apply to all of the test cases presented in Sections 6, 7, 8, 9, 10, ~~and~~ 11, and 13.

**5.1.1.1 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 Normative Annex A1, Section A1.5. TMY2, TMY3, and WYEC2 data are in hourly bins corresponding to local standard time.

**5.1.1.2 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 Note:*** For example, for the building thermal envelope and fabric load test cases of Sections 7.2.1, 7.2.2, and 7.2.3, interior air volume would be calculated as $6 \times 8 \times 2.7$ m = 129.6 $m^3$ ($19.7 \times 26.2 \times 8.9$ ft = 4576.8 $ft^3$).

**5.1.1.3 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.

**5.1.1.4 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, unless specified to be varied for a specific case. Consistent numerical settings shall be used for all tests in a given test suite. The option and numerical settings that are used shall be documented in the Standard Output Report (as specified in Normative Annex A2).

***a. Informative Notes:***

1. For examples:
   a. ~~, i~~If a program gives a choice of methods for modeling windows, the same window modeling method is to be applied for all cases.
   b. If a program gives a choice of methods for modeling interior surface convection, the same interior surface convection modeling method is to be applied for all cases, except for cases that specify a different method.
2. Test suites are outlined in Informative Section 4.3.

**5.1.1.5 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 (as specified in Normative Annex A2).

**5.1.1.6 Use of Nonspecified Inputs.**

Nonspecified inputs are defined as inputs applied in the program being tested that are not explicitly or sufficiently provided in the test specification.

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

a. Alternative constant exterior convective or combined (radiative and convective) surface coefficients in Sections 7.2.1.9.3, 7.2.3.1.4.3, 7.2.3.3.2, and 9.2.1.8
b. Alternative constant interior convective or combined (radiative and convective) surface coefficients in Sections 7.2.1.10.3, 7.2.3.1.4.4, 7.2.3.2.2, and 9.2.1.9
c. Alternative constant interior solar distribution fractions in Sections 7.2.1.12, 7.2.2.1.2.2, 7.2.2.1.6.2, 7.2.2.1.7.2, 7.2.2.2.7.4, 7.2.3.9.3, 7.2.3.10.2, and 7.2.3.12.2
d. Air density given at specific altitudes for the space-cooling and space-heating equipment cases in Sections 9.2.1.4.3, 9.2.3.4.3, and 10.2.1.4.3

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

**5.1.1.7 Simulation Initialization and Preconditioning**

**5.1.1.7.1** For the test cases of Section 8 (ground-coupled slab-on-grade analytical verification tests), see Section 5.1.1.8.2, and skip Section 5.1.1.7.2.

**5.1.1.7.2** For test cases other than those of Section 8, if the program being tested allows for preconditioning (simulation of an initial time period before recording ~~annual~~ simulation results for the time period of a given test case or series of test cases), ~~beginning January 1 hour 1),~~ that capability shall be applied.

***Informative Notes:***

1. For the test cases of Section 7, initialization may most affect annual peak heating load results and January monthly heating and peak heating load results.
2. For the test cases of Section 13, where an input (configuration) change cannot be scheduled, it may be better to use the first few days of data from a given test case for initialization, and compare output only for the final days or hours as indicated for a test case for validation purposes.

**5.1.1.8 Simulation Duration**

**5.1.1.8.1** Results for the tests of Sections 6, 7, 9.2.3, and 9.2.4 shall be taken from full annual simulations.

**5.1.1.8.2** For the tests of Section 8, 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.

**5.1.1.8.3** For the tests of Sections 9.2.1 and 9.2.2, 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 9.3.1.

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

**5.1.1.8.4** For the tests of Section 10, 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 10.3.

**5.1.1.8.5** For the tests of Section 11, the simulation shall be run until the final hour output agrees with the previous hour output. Provide output in accordance with Section 11.3.

**5.1.1.8.6** For the tests of Section 13, simulation duration shall be in accordance with the requirements of the software implementation of a given test case. Results for each test case shall be taken from the time period specified in the appropriate section of this test specification for a given test case. ***Informative Note:*** For example, for Case ET110A1, this time period is called out in Section 13.2.2.2.

**5.1.1.9 Numerical Settings**

**5.1.1.9.1 Timesteps and Convergence Tolerances.** Timesteps and convergence tolerances shall be in accordance with the requirements of the software implementation of a given test case. ***Informative Notes:***

1. For modeling thinner material layers within specified walls requiring finer spatial discretization and/or lighter layers with greater thermal diffusivity (e.g., an air gap), selection of too large of a timestep can cause inaccurate results and/or model instability.
2. If the software being tested allows user specification of convergence tolerance, it is recommended to demonstrate that the current level of heat-flow or temperature convergence tolerance yields negligible (e.g., ≤ 0.1%) change in results versus the next-finer convergence tolerance.
3. Model accuracy settings are further discussed in Informative Section 5.1.1.9.2.

**5.1.1.9.2 (*Informative*) Model Accuracy Settings.**

For the purpose of these tests, it is up to the discretion of the modeler to select the level of model accuracy (e.g., shorter timesteps, smaller tolerances, etc.), as long as use of consistent numerical settings are applied (see Section 5.1.1.4).

It may be of interest to software developers and/or other modelers to run the tests both at more granular accuracy and at more typical settings. More granular accuracy settings provide an optimum test of the ability to capture the tested building physics in a mathematical model. In this context, applying practical application settings, which likely require less run time, can check accuracy degradation versus the more granular model.

For the test cases of Section 13, uncertainty bounds on measurements and on aspects of the data derived from measurements (e.g., see Informative Annex B23) are important with respect to providing context for justifying model relative granularity. For example, if results for a model with more granular accuracy settings fall fully within uncertainty ranges (e.g., for best steady-state heating energy) but not when applying default settings, that may be an important finding.

**5.1.1.~~9~~10 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.

**5.1.2 General Reporting Requirements**

**5.1.2.1 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 5.1.1.4)
   3. Equivalent modeling methods used when the software does not allow direct input of specified values (as specified in Section 5.1.1.5)
   4. Nonspecified inputs (as specified in Section 5.1.1.6)
   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 5.1.1.~~9~~10)
   6. Omitted test cases and results (as specified in Section 5.1.2.3)
   7. Anomalous results (as specified in Section 5.1.2.4)
c. Results for simulated cases using the following files on the accompanying electronic media:
   1. Std140_WD_Output.xlsx for the weather drivers tests of Section 6
   2. Std140_TF_Output.xlsx for the building thermal envelope and fabric load tests of Section 7
   3. Std140_GC_Output.xls for the ground-coupled slab-on-grade analytical verification tests of Section 8
   4. Std140_CE_a_Output.xls for the space-cooling-equipment performance analytical verification tests

of Sections 9.2.1 and 9.2.2

5. Std140_CE_b_Output.xls for the space-cooling-equipment performance comparative tests of Sections 9.2.3and 9.2.4
6. Std140_HE_Output.xls for the space-heating-equipment performance tests of Section 10
7. Std140_AE_Output.xlsx for the air-side HVAC equipment performance analytical verification tests of Section 11
8. Std140_ET_Output.xlsx for the thermal fabric empirical validation tests of Section 13

For the specific output quantities required in the results report for each case, refer to Sections 6.3, 7.3, 8.3, 9.3, 10.3, ~~and~~ 11.3 and 13.3.

**5.1.2.2 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)

**5.1.2.3 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.

**5.1.2.4 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.

**5.2 Class II Test Procedures**

**…**

**5.2.1 Modeling Approach.** This modeling approach shall apply to all the test cases presented in Section 12.

…

**5.2.1.8 Numerical Settings**

**5.2.1.8.1 Timesteps and Convergence Tolerances.** Timesteps and convergence tolerances shall be in accordance with the requirements of the software implementation of a given test case. ***Informative Notes:***

1. For modeling thinner material layers within specified walls requiring finer spatial discretization and/or lighter layers with greater thermal diffusivity (e.g., an air gap), selection of too large of a timestep can cause inaccurate results and/or model instability.
2. If the software being tested allows user specification of convergence tolerance, it is recommended to demonstrate that the current level of heat-flow or temperature convergence tolerance yields negligible (e.g., ≤ 0.1%) change in results versus the next-finer convergence tolerance.
3. Model accuracy settings are further discussed in Informative Section 5.2.1.8.2.

**5.2.1.8.2 (*Informative*) Model Accuracy Settings.**

For the purpose of these tests, it is up to the discretion of the modeler to select the level of model accuracy (e.g., shorter timesteps, smaller tolerances, etc.), as long as use of consistent numerical settings are applied (see Section 5.1.1.4).

It may be of interest to software developers and/or other modelers to run the tests both at more granular accuracy and at more typical settings. More granular accuracy settings provide an optimum test of the ability to capture the tested building physics in a mathematical model. In this context, applying practical application settings, which likely require less run time, can check accuracy degradation versus the more granular model.

**5.2.1.9~~8~~ 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 just 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, that the implications of the changes are assessable.

**5.2.1.10~~9~~ Example Acceptance-Range Criteria.** Use of informative example acceptance-range criteria provided in Informative Annex B22 shall be permitted but is not mandatory. Where application of the criteria leads to identification of a disagreeing result that requires correction, the rules of Section 5.2.1.9~~8~~ for modifying simulation programs or inputs shall be applied.

….

**5.2.1 General Reporting Requirements**

**5.2.2.1 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 in 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 5.2.1.4)
   3. Equivalent modeling methods used when the software does not allow direct input of specified values (as specified in Section 5.2.1.5)
   4. 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 5.2.1.9~~8~~)
   5. Omitted test cases and results (as specified in Section 5.2.2.3)
   6. Anomalous results (as specified in Section 5.2.2.4)

…

***[Note to Reviewers: This page intentionally blank.]***

# 13 BUILDING THERMAL FABRIC EMPIRICAL VALIDATION TESTS

***[Note to Reviewers: Section 13 is all new. Tracked changes not shown.]***

## 13.1 Test Procedures

### 13.1.1 Objectives

These test cases, provided in detail in Section 13.2, are designed for empirical validation testing of the following in artificial-climate steady-state conditions:

- 1-D conduction modeling with and without window insulation
- Automated interior surface heat transfer algorithms.

These fundamental cases also provide a means for checking inputs versus diagnostic measurements, which mitigates the potential for input errors in these cases. While a test suite that concerns steady-state conduction seems quite basic, the ability to set up experiments to emulate this in a facility also capable of dynamic natural climate tests is non-trivial. This fundamental starting point also identifies differences that can be traced to differences in other calculations.

### 13.1.2 Overview: Empirical Validation, Test Facility, and Test Cases

In empirical validation testing software results are compared with measured data. The building thermal fabric empirical validation test cases test the ability of building performance simulation (BPS) software to model empirically measured test facility performance within the uncertainty of the measurements.

The empirical validation test facility is a building that contains two similarly designed and oriented twin test cells (Cell A and Cell B), with each separated and enclosed by five fixed and separately controlled guard zones. The wall and window facing 30° West of South (nominally “South”) can also be enclosed by a mobile thermal guard; this modular configuration of the south thermal guard zone provides the means for carrying out tests under natural or artificial climatic conditions.

Separately controlled guard zones in the artificial-climate configuration allow for the ability to measure both overall facility UA-value (building loss coefficient, BLC) and individual UA values of the test cells’ bounding surfaces (walls, floor, ceiling). Individual guard zone control also allows for driving heat through a single bounding surface such that, in combination with surface temperature measurements, measurement-based combined convective and radiative surface heat transfer coefficients are derived.

The facility applies a custom heating system designed to emulate the mixed-air assumption of building performance simulation (BPS) software, while providing a gentle airflow rate that is consistent with mechanically-driven HVAC system airflow rates. The heating system is also designed to be 100% efficient and to maximize convective (minimize radiative) output.

Only artificial-climate (fully guarded) conditions are applied for the current test suite. Temperatures are imposed on each side of the test cell boundary surfaces (walls, ceiling, floor, windows, door) via independent control of the test-cell and guard-zone air temperatures, with no solar flux incident on the exterior of the test cell bounding surfaces.

Six (6) test cases, there are three (3) in each test cell, are included as shown in Table 13-1. These cases represent the artificial climate steady-state BLC characterization configurations. They test steady-state 1-D conduction models with and without window insulation (reduced and greater heat transfer, respectively), and test interior surface heat transfer (h.t.) models. Of these, Case ET110A1 is initially specified, with the remaining cases of Table 13-1 specified as variations from that or other cases as shown in the table.

**Table 13-1 Steady-State, Artificial-Climate, Test Cases [a]**

| Case | Cell | Win. Ins. | Interior Surf. h.t. | Base Case | Section | Comments |
|---|---|---|---|---|---|---|
| **ET110A1** | A | Yes | h,comb [b] | -- | 13.2.2 | Simpler physics: suppressed window h.t.; |
| **ET100A1** | A | No | h,comb [b] | ET110A1 | 13.2.3 | Uninsulated window → greater heat transfer |
| **ET100A3** | A | No | Auto [c] | ET100A1 | 13.2.4 | Simple context for surface h.t. validation test |
| **ET110B1** | B | Yes | h,comb [b] | ET110A1 | 13.2.5 | Simpler physics: suppressed window h.t. |
| **ET100B1** | B | No | h,comb [b] | ET110B1 | 13.2.6 | Uninsulated window → greater heat transfer |
| **ET100B3** | B | No | Auto [c] | ET100B1 | 13.2.7 | Simple context for surface h.t. validation test |

a. Abbreviations: h.t. = heat transfer; Surf. = Surface; Win. Ins. = Window Insulation
b. Constant combined interior and exterior surface heat transfer coefficients.
c. Automated variation of interior convection and/or radiation heat transfer; algorithms applied within the program are selected by the modeler.

Window insulation is applied in the ET110A1 and ET110B1 base cases because the insulated windows allow for simpler modeling physics by suppressing the larger amount of heat transfer that occurs through uninsulated windows. Then uninsulated window heat transfer occurs in Cases ET100A1, ET100A3, ET100B1, and ET100B3.

Because there is no transmitted solar radiation in the artificial climate configuration, window material layers are specified as opaque materials (i.e., specified to be modeled as walls). This provides a simplified input scheme that initially alleviates the complexity of specifying empirically determined detailed window optical properties.

For characterizing individually measured as-built bounding surface UA values to model inputs, selected thermal conductivities are imputed based on empirically determined bounding surface UA-values along with interior and exterior combined convective and radiative surface heat transfer coefficients derived from steady-state measured data. Other material-property inputs are from catalog-based properties. Imputed thermal conductivities are further discussed in Section 13.2.1.3.

Cases ET100A3 and ET100B3 utilize the measurement-based effective constant combined interior surface heat transfer coefficients from separate characterization cases that are transposed to these cases. In this steady-state context the user may select any automated interior surface convection and radiation-exchange algorithms available in their program for validation within the uncertainty range of the steady-state combined coefficients specified in Cases ET100A1 and ET100B1.

## 13.2 Input Specifications

The test suite follows the sequence of Table 13-1; see Section 13.1. Case ET110A1 (see Section 13.2.2) is the artificial climate steady-state base case. Later sections describe specific changes to the base case needed for simulating further cases. Data needed for running the tests, along with other archived electronic files, are included with the electronic media accompanying the test specification; within this media see "Readme-140-2023-B.docx" for a guide to its contents. Information regarding the input-data files to use are given in the specifications for each test case.

### 13.2.1 Modeling Approach

In addition to the Modeling Approach of Section 5.1.1, the following shall apply.

#### 13.2.1.1 Time Convention

The time convention of Section 5.1.1.1 shall apply, along with the following:

- Local-site time is Greenwich Mean Time + 1 hour (GMT+1).

#### 13.2.1.2 Geometry Convention

The geometry convention of Section 5.1.1.2 shall apply, along with the following:

- All test cell and guard zone dimensions provided in Section 13.2, whether shown from inside or outside the test cell, are interior dimensions unless otherwise indicated.

#### 13.2.1.3 (*Informative*) Recommended Construction Assumptions of this Test Specification

Construction specifications (e.g., of Section 13.2.2.8) are presented as required characteristics and alternative construction specifications.

**13.2.1.3.1** Required characteristics include:

- Empirically determined UA values
- Construction details, as shown in the figures.

**13.2.1.3.2** Alternative construction specifications consist of material properties tables that include:

- Catalog values
- Imputed thermal conductivities for selected material layers.

**13.2.1.3.2.1** Recommended alternative construction specifications are intended for simulations applying 1-dimensional (1-D) thermal diffusion models and are derived based on the interior surface area of a given bounding surface. Informative Annex B23 describes calculation of imputed values.

**13.2.1.3.2.2** Selected thermal conductivities are imputed based on calorimetrically measured UA values, catalog material properties, specified constant interior and exterior combined surface heat transfer coefficients, and 1-D conduction analysis developed externally from the tested programs, as described in Informative Annex B23. These imputations are applied because use of nominal catalog values for 1-D heat-transfer modeling based on the interior surface areas of the bounding surfaces underestimates overall test cell BLC values and individual wall UA values. Such underestimation is attributable to the following aspects of as-built construction not included in catalog properties:

- Two-dimensional and or three-dimensional edge and corner effects
- Thermal bridges
- Atypical constructions that are difficult to characterize with catalog values (e.g., its floor and north wall with door and entry hatch)

Other aspects specific to the test facility that may cause further underestimation of UA values based only on catalog values, include:

- The test cells are only 16.5 m2 floor area with all thermal bounding surfaces active (i.e., exposed to large temperature differences), such that 2D and 3D conduction effects may be magnified versus a typical building with a smaller active corner-length to active surface-area ratio
- Use of interior dimensions (versus exterior or mid-point dimensions).

Thermal conductivity imputations also implicitly include:

- Infiltration load, which is low (< 0.1 ACH)
- 100% convective and 100% efficient heating system
- Other settings per the input specifications of Section 13.2.

For the more complex test cell bounding surfaces (i.e., floor, ceiling, windows), the test specification assumes the same multiple 1-D parallel path heat flows as applied for the imputed conductivities.

Imputed conductivities are only valid for the given conduction path.

**13.2.1.3.2.3** Justifications for developing alternative construction specifications are to:

- Develop a test specification that conforms with assumptions that can be made by most BPS software.
- Simplify inputs for modelers so that they can efficiently convey the real as-built experimental facility to their programs in a way that is likely to reduce the potential for interpretation and input errors
- Better emulate thermal mass modeling than with homogeneous blended layers (e.g., if material layers not requiring parallel conduction paths may be needed to test 3-D conduction or other advanced aspects models)
- Convey empirically determined UA-values to model inputs to reduce the potential of unexplainable basis differences in the tested model results versus measured data.
- Apply steady-state calorimetrically determined properties to reduce uncertainty of model results in later dynamic artificial and natural climate cases. These characterizations also mitigate noise in the more dynamic artificial climate and natural climate cases, allowing isolation of causes of later differences to other generally more complex drivers.

The resulting alternative constructions apply imputed thermal conductivities in a way that minimizes interference with how thermal mass would behave if modeled solely based on construction drawings and catalog material properties. The test-cell thermal mass is more important in later non-steady-state dynamic cases. However, the thermal mass is also important in the steady-state cases because it affects the amount of time it takes for the model to reach steady-state, where the initial conditions of the test cell and guard zones for Case ET110A1 are substantially different from the final steady-state conditions.

**13.2.1.3.3 Other modeling options not explicitly specified**

Users may develop inputs for other alternative modeling methods according to the instructions of Section 5.1.1.5 (Equivalent Modeling Methods). For this purpose, the modeler may apply supplementary information about test cell construction provided in Informative Annex B23, Section B23.6. Caveats:

a. Section B23.6 provides more construction detail but there are still unknowns and uncertainties, which is the nature of an empirical-validation specification based on real as-built construction versus ideal synthetic-construction based test specifications of analytical-verification and software-to-software comparative tests.

***b. Modelers applying methods other than the recommended alternative methods (see Section 13.2.1.3.2) should be aware, by including greater input detail or further input simplifications, that they may be increasing the potential for interpretation (and therefore input) errors with respect to their model.***

**13.2.1.4 (*Informative*) Simulating HVAC Equipment and Controls**

The test facility heating system is designed to emulate an ideal heater (100% efficient, 100% convective, well-mixed air, precise temperature control) intended to measure the building thermal load in a manner that matches assumptions typical of BPS software. The selected externally imputed thermal conductivities assume an idealized heating system along with other assumptions described in Section 13.2.1.3.2.2.

### 13.2.2 Case ET110A1: Artificial Climate Base Case, Steady-State Overall Building Loss Coefficient with Insulated Windows, Cell A, Applying Specified Catalog Material Properties Except for Selected Imputed Insulation Conductivities

#### 13.2.2.1 (*Informative*) Objectives and Method of the Test Case

##### 13.2.2.1.1 Objectives

a. For the given test cell properties and experimental data inputs, compare steady-state modeled heater energy to measured heater energy and compare steady-state modeled surface heat flow to measurement-based surface heat flow.
b. The comparisons also provide an input check of specified material properties and geometry related to correctly modeling individual surface UA-values for a given test cell in its given window configuration.

##### 13.2.2.1.2 Method

a. Guard-zone temperatures ($T_{guards}$) were set to approximately $T_{guards}$ = 10˚C and test cell temperature set to $T_{cell}$ = 35 ˚C. See data files listed in Section 13.2.2.2 for guard zone and test cell hourly temperatures (set points).
b. For an idealized heating system (that effectively outputs building load), apply comparisons during the best steady-state period of the empirical data for the following results:

- $Q_{htr,model}$ versus $Q_{htr,measured,avg}$, where:
  - $Q_{htr,model}$ ≡ the modeled heating energy consumption output
  - $Q_{htr,measured,avg}$ ≡ (the average measured heating energy consumption during the given best steady-state period) ± (measurement uncertainty [u])
- $Q_{surf,x,model}$ versus $Q_{wall,x,measured}$, where:
  - $Q_{surf,x,model}$ ≡ the modeled cumulative convective and radiative heat flow (gain) from the test cell into the given surface at its interior face
  - $Q_{wall,x,measured} = UA_{surface,x,measured}$ x ($T_{cell} – T_{guard,x}$), where
    1. $UA_{surface,x,measured}$ ≡ measured UA value from the test specification; for supporting information, see Informative Annex B23, Table B23-9 for Cell A and Table B23-10 for Cell B
    2. $T_{cell}$ ≡ measured test cell temperature
    3. $T_{guard,x}$ ≡ measured temperature of the guard zone corresponding to the given surface
  - Individual surface and/or heat flow path (or selected aggregated paths) comparisons allow isolation of differences for given walls or heat flow paths.

#### 13.2.2.2 Test Cell Conditions and Guard-zone Temperatures

##### 13.2.2.2.1 Test Cell Measured Data and Weather Input Data

Hourly data files and the test data sets durations for Case ET110A1 are listed in Table 13-2. These data files are included with the accompanying electronic media; see Readme-140-2023-B.docx. The following conventions apply to the data files:

- Preceding-hour time convention: e.g., the data corresponding to time 2:00 (hour 2) is the data averaged during the preceding hour period from 1:00 to 2:00.

- The time zone reference for the data is GMT+1.

**Table 13-2 Primary Data File Directory**

| File Name | Data Type | Time Step | Data Duration ("MM/DD/YYYY hh") [GMT+1] |
|---|---|---|---|
| ET110A-Measurements.csv [c] | Test Cell A | Hour | 01/26/2000 12 through 02/11/2000 09 |
| ET110meteo_within_Melun-071530_MY.2000.epw [a,b,c] | Local facility weather inserted within Melun, France AMY[d] data | Hour | 01/01/2000 01 through 12/31/2000 24 |

a. ***Informative Note:*** Epw format is described at: http://climate.onebuilding.org/papers/EnergyPlus_Weather_File_Format.pdf. [C-4]

b. ***Informative Note:*** In the artificial climate cases, for programs that model guard zones as boundary conditions applied to each test cell wall rather than as literal zones, the weather data is essentially dummy data – i.e., not used in the model other than to satisfy the requirement of most BPS software to have a weather data set.

c. ***Informative Note:*** For further supporting information regarding these data files, see Readme-140-2023-B.docx and Appendix A of the originating source document[c-1].

d. Abbreviation: AMY = annual meteorological year

The ET110A-Measurements.csv hourly data format is given in Table 13-3. The header labels of Table 13-3 apply as follows:

- "Column" identifies the column where the data appears as viewed with Microsoft Excel™
- "Label" is the data descriptor provided in Row 3 of the csv file
- "Usage" is the data purpose provided in Row 1 of the csv file, where data marked:
    - "Input" shall be applied as input to the software being tested
    - "Output" (only for data labeled "Qhtr") shall be applied for comparison with the Qhtr output of the software being tested; see Section 13.3.2 regarding software output requirements and Section 13.3.2.4 regarding comparison of software results to empirical data
- "Description" is a brief description of the measured data
- "Units" are the units of the measured data in Row 4 of the csv file.

  ***Informative Notes:***

  1. Within the .csv file each line contains data for one hour, and the first four lines include column labels and units.
  2. Cell A air (setpoint) temperature sensor locations are given in Figure 18 (Section 2.2.1.7.2) of the originating source document[c-1]. Guard zone temperature sensors were located centrally to represent average guard zone temperatures; the precise locations were not documented.

**Table 13-3 Cell A Hourly Data Format**

| Column | Label | Usage | Description | Units |
|---|---|---|---|---|
| A | Date | Input | Date and time in format "MM/DD/YYYY hh:mm" (preceding hour format, e.g., Hour 10:00 = 09:00-10:00) | |
| B | Tattic | Input | Attic air temperature [a] | ºC |
| C | Tcellar | Input | Cellar air temperature [a] | ºC |
| D | Tnorth | Input | North guard air temperature [a] | ºC |
| E | Teast | Input | East guard air temperature [a] | ºC |
| F | Tsouth | Input | South guard air temperature [a] | ºC |
| G | Twest | Input | West guard air temperature [a] | ºC |
| H | Tcell | Input | Test cell setpoint temperature [a] | ºC |
| I | Qfan | Input | Fan energy | Wh |
| J | HWDsafr | Input | Fan supply airflow rate, for heater with diffusers (HWD) | $m^3/h$ |
| K | Qhtr | Output | Heater energy | Wh |

a. See Figure 13-1 (Section 13.2.2.7.1) for location of zones.

### 13.2.2.2.2 (*Informative*) Input Data Checking for All Test Cases

Original test cell and local facility weather data were checked and corrected as described in Appendix A, Section A.2 of the originating source document[c-1]. The .csv and .epw files listed in Table 13-2 (Section 13.2.2.2.1) were compared within .xlsx workbooks to the content of the original source .xls and weather data files to ensure accurate conversions; see Informative file CSV+EPW_checks.zip included with the accompanying electronic media.

### 13.2.2.3 Site Description

Location and site data for the test cells is provided in Table 13-4. The facility is in a rural environment, without any obstacle (detached shading) on the South façade over a length of 100 meters.

**Table 13-4 Test Facility Geographic Situation**

| | |
|---|---|
| Latitude | 48°22' N |
| Longitude | 2° 49' E |
| Altitude | 104 m |
| Localization | Country, open terrain with scattered obstructions [a] |
| Soil reflectivity (estimation) | 0.2 |
| Orientation | "South wall" faces 30° West of South (see Figure 13-1, Section 13.2.2.7.1) |

a. ***Informative Note:*** Site localization corresponds with Terrain Category 3, documented in *2021 ASHRAE Handbook-Fundamentals* [B-7], p. 24.4, Table 1

### 13.2.2.4 Simulation Duration and Initialization

Simulation duration and initialization shall be in accordance with the requirements of the software implementation of a given test case.

***Informative Notes:***

1. The experimental data duration is as described in Table 13-2 (Section 13.2.2.2.1) for the file ET110A-Measurements.csv.
2. The intent of the simulation is to include as much of the provided experimental data as possible for the tested software. This data provides an initialization period ahead of the best steady-state data period; the best steady-state period is intended for comparing software output to measured data and empirical values derived from measured data (see Section 13.3.2.4).
3. If the tested software requires a longer initialization period than provided in the experimental data (e.g., for consistency with convergence tolerances), a typical technique of extending the data for the software should be applied. Such a technique is at the discretion of the modeler, and may be based on review of the first day or two of the csv file input data (see Section 13.2.2.2.1).
4. Test cell and guard-zone temperatures at the beginning of the test data (see Section 13.2.2.2.1) may be considered.

### 13.2.2.5 Timesteps and Convergence Tolerance

Timesteps (i.e., temporal discretization) and convergence tolerance shall be in accordance with the requirements of the software implementation of a given test case.

***Informative Notes:***

1. See Informative Notes with Section 5.1.1.9.1, except Item 2 here replaces Item 1 there.
2. For modeling thinner layers requiring finer spatial discretization and/or lighter layers with greater thermal diffusivity (e.g., an air gap), selection of too large of a timestep can cause inaccurate results and/or model instability. This may be a more important consideration for software applying a finite-difference representation to solve transient thermal conduction within wall layers.

### 13.2.2.6 Output Requirements

Output shall be provided as specified in Sections 13.3.1 and 13.3.2.

### 13.2.2.7 Building Geometry

a. All test cell and guard zone dimensions, whether shown from inside or outside the test cell, are interior dimensions unless otherwise indicated.
b. Cell A shall be defined initially.
c. Two options for modeling guard zones are specified depending on the capabilities of the tested programs:
    1) guard zones modeled as boundary conditions on the exterior side of each test cell bounding surface (Section 13.2.2.7.1)
    2) guard zones modeled as separate zones adjacent to the test cell bounding surfaces (Section 13.2.2.7.3).

***Informative Note:*** Defining guard zones as boundary conditions is recommended because:

- Hourly guard zone measured air temperature data is provided
- It is simpler than modeling six guard zones (less potential for input errors)
- While the test cell construction is well defined, the guard zone constructions (except for relevant walls comprising their boundaries with the test cell) are approximate.

**13.2.2.7.1 Summary geometry for models applying guard zones as boundary conditions**

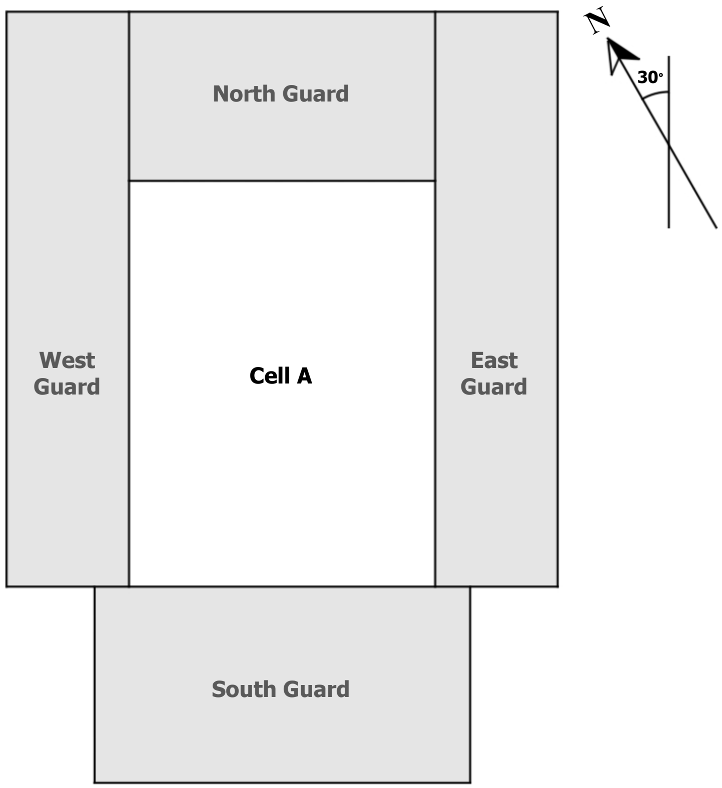
For programs that require modeling the guard zones as actual physical zones, see the instructions of Sections 13.2.2.7.2 and 13.2.2.7.3, and skip the remainder of this section.

As shown in Figure 13-1, the building is oriented 30° E of North, so that the test cell bounding surface that would nominally be called the "South" wall is oriented at 30° West of South, and the other walls are oriented and named accordingly with orientations offset 30° from their nominal cardinal directions.

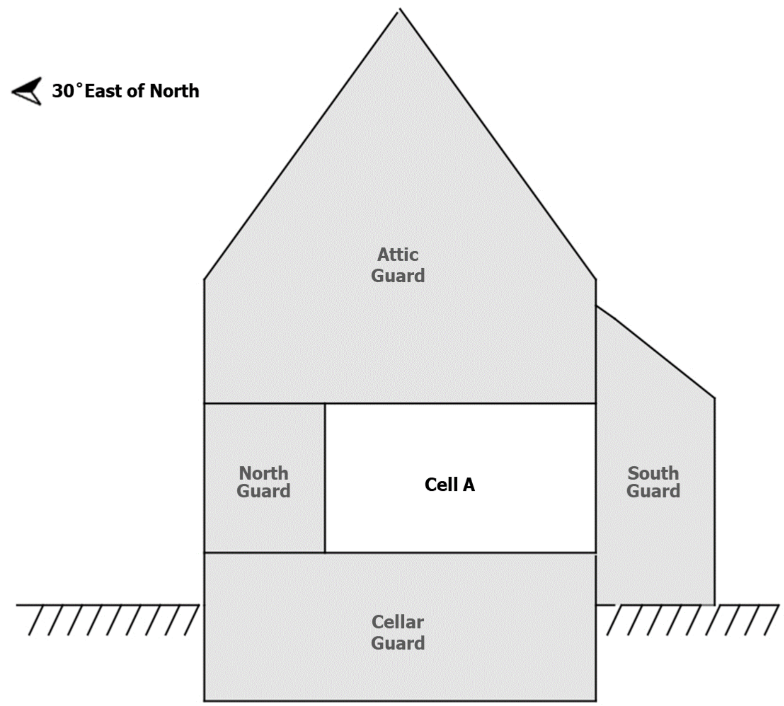
Figure 13-1 also shows the plan view and a sectional view of Cell A and indicates the names of its six guard zones. These names are associated with hourly data identifiers within the accompanying file ET110A-Measurements.csv (see previous Section 13.2.2.2.1); e.g., "Tsouth" designates the south guard zone temperature data provided in column F of the file.

Other information for defining the guard zones as boundary conditions, related to surface heat transfer and additional supporting data, are provided in Sections 13.2.2.10 (Surface Heat Transfer) and 13.2.2.15 (Thermal Guards).

***Informative Note:*** Figure 13-1 is a simplification based on the overall test cell floor plan from the originating source document[c-1].




*Plan View*




*Elevation Section View (looking 30° south of east through page)*

**Figure 13-1: Test Cell A, Summary Diagrams with Artificial-Climate Thermal Guards**

Note 1: Cell A internal dimension details are provided in Figure 13-2.

Note 2: Attic and cellar also fully cover ceiling and floor, respectively, of Cell A and west guard.

Note 3: For models applying guard zones as actual physical zones, guard zone dimensions are provided in Figures 13-6 through 13-8 (Section 13.2.2.7.3).

### 13.2.2.7.2 Test cell detailed geometry

The following sections specify the geometry of the test cell and its individual bounding surfaces and subsurfaces:

- Cell A primary inside surfaces (see Section 13.2.2.7.2.1); interior surface dimensions for the west wall, floor, and ceiling are taken directly from the figure in this section
- South wall and window (see Section 13.2.2.7.2.2)
- East wall and window (see Section 13.2.2.7.2.3)
- North wall and door (see Section 13.2.2.7.2.4)
- Surface area summary (see Section 13.2.2.7.2.5).

Within these sections dimensions are provided in meters (m).

#### 13.2.2.7.2.1 Cell A primary inside surfaces.

Figure 13-2 specifies the inside-surface (interior) dimensions of Cell A. Interior surface dimensions for the west wall, floor, and ceiling are taken directly from this figure.

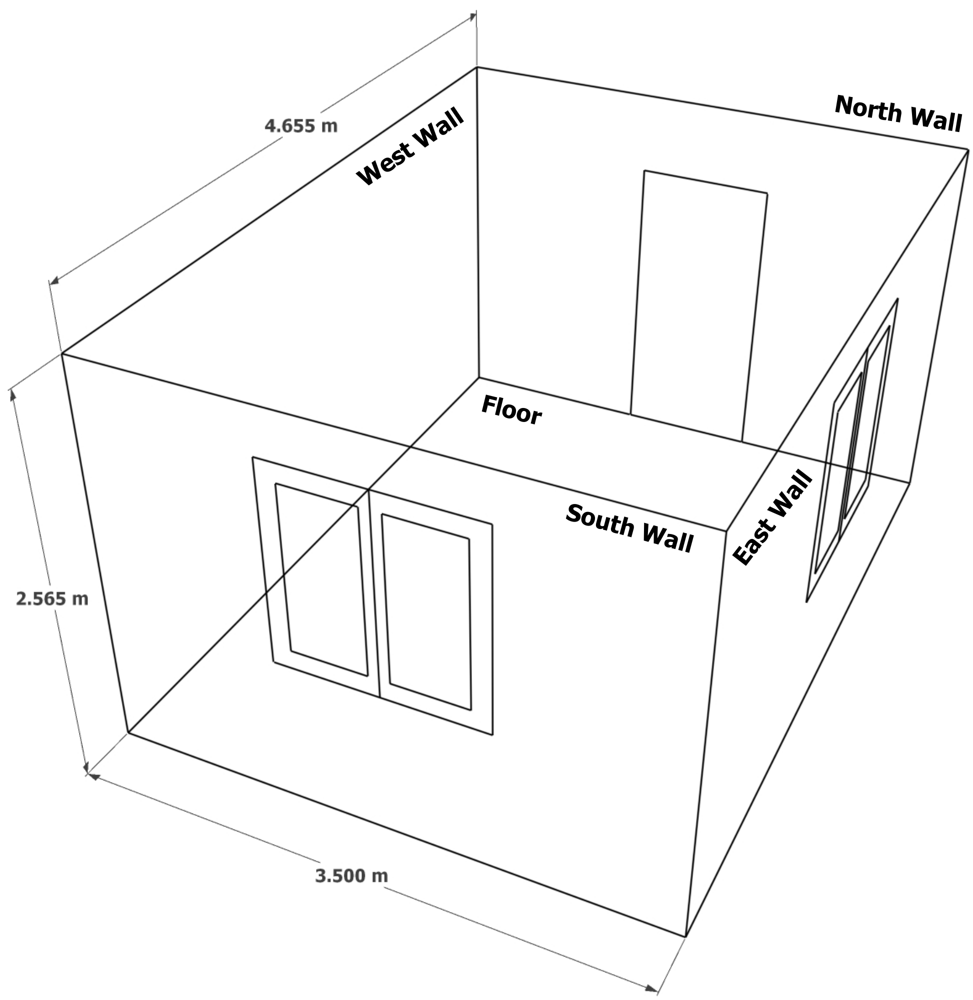



**Figure 13-2 Inside-Surface Dimensions of Cell A**

Note: Ceiling is at 2.565 m height, parallel to floor, with same dimensions as floor

### 13.2.2.7.2.2 South wall and window

Figure 13-3 specifies the south wall geometry as viewed from the exterior, including the position of the window in the south wall, and the dimensions of the window glazing panels and framework.

***Informative Note:*** In artificial climate cases, such as the ET110A1 base case, the windows may be modeled as walls, or subsections of walls, because there is no transmitted solar radiation.

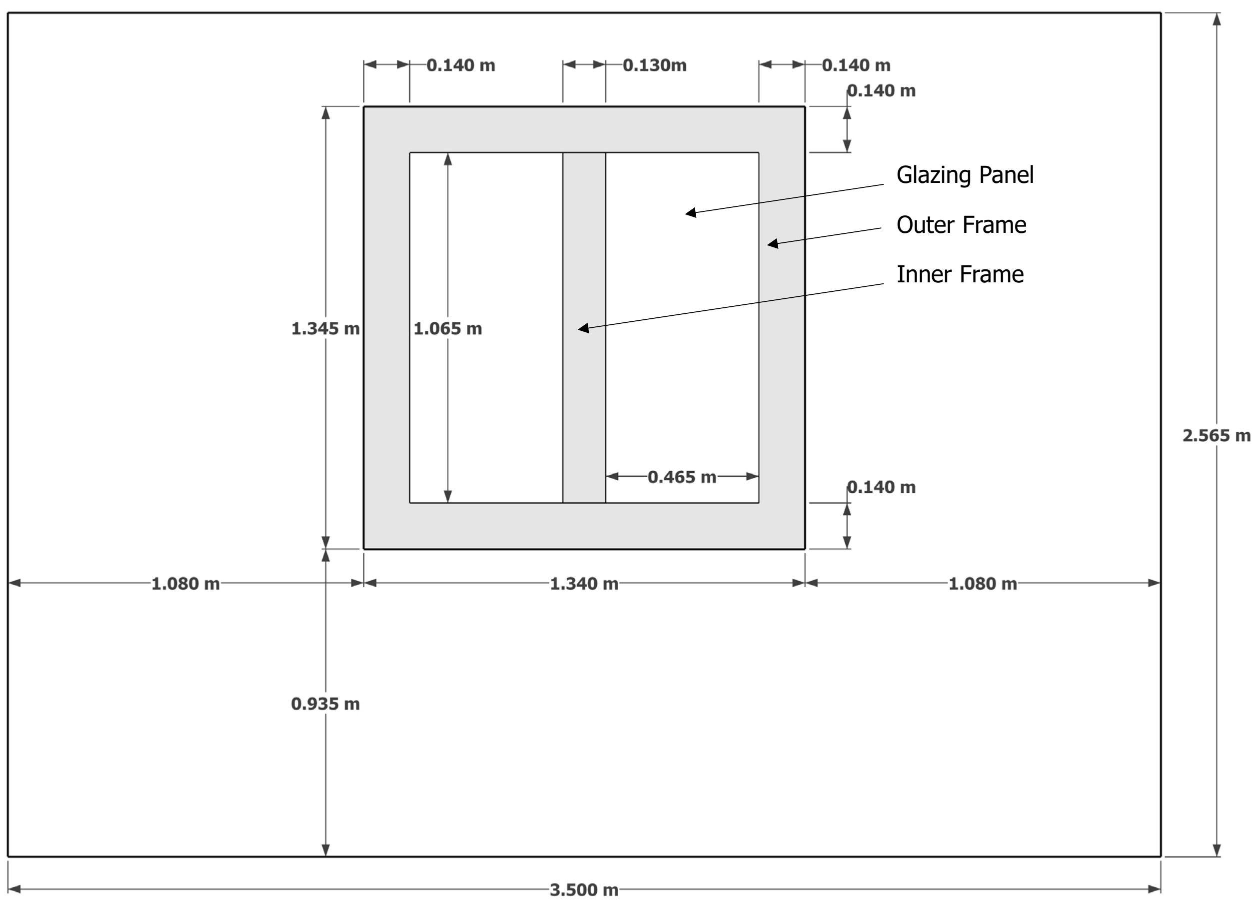



**Figure 13-3: Dimensioned south wall with window elevation, exterior view**

### 13.2.2.7.2.3 East wall and window

Figure 13-4 specifies the east wall geometry as viewed from the exterior, including the position of the window in the east wall and the dimensions of the window glazing panels and framework.

***Informative Note:*** In artificial climate cases, such as the ET110A1 base case, the windows may be modeled as walls, or subsections of walls, because there is no transmitted solar radiation.

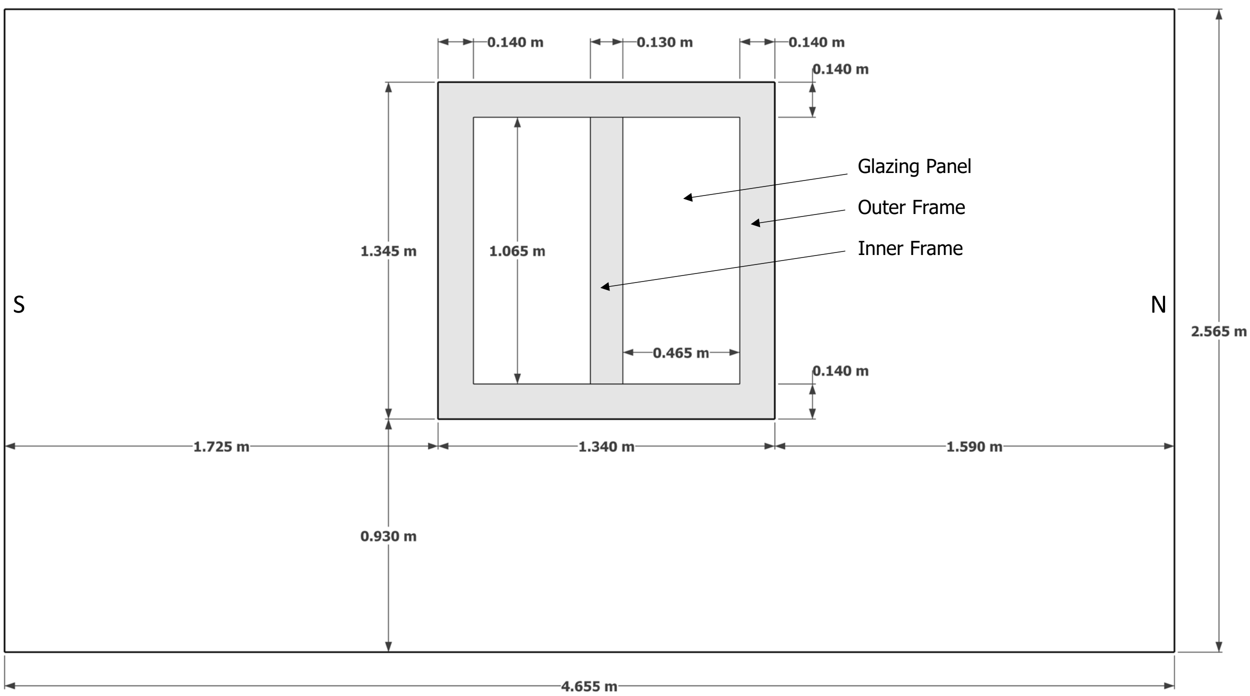



**Figure 13-4: Cell A dimensioned east wall with window elevation, exterior view**

### 13.2.2.7.2.4 North wall and door

Figure 13-5 specifies the north wall geometry as viewed from the exterior, including the position of the door in the north wall.

***Informative Note:*** Figure 13-5 shows a simplified version of the door that allows it to be modeled as a single 1-D conduction path, consistent with the blended door construction of Section 13.2.2.8.2.

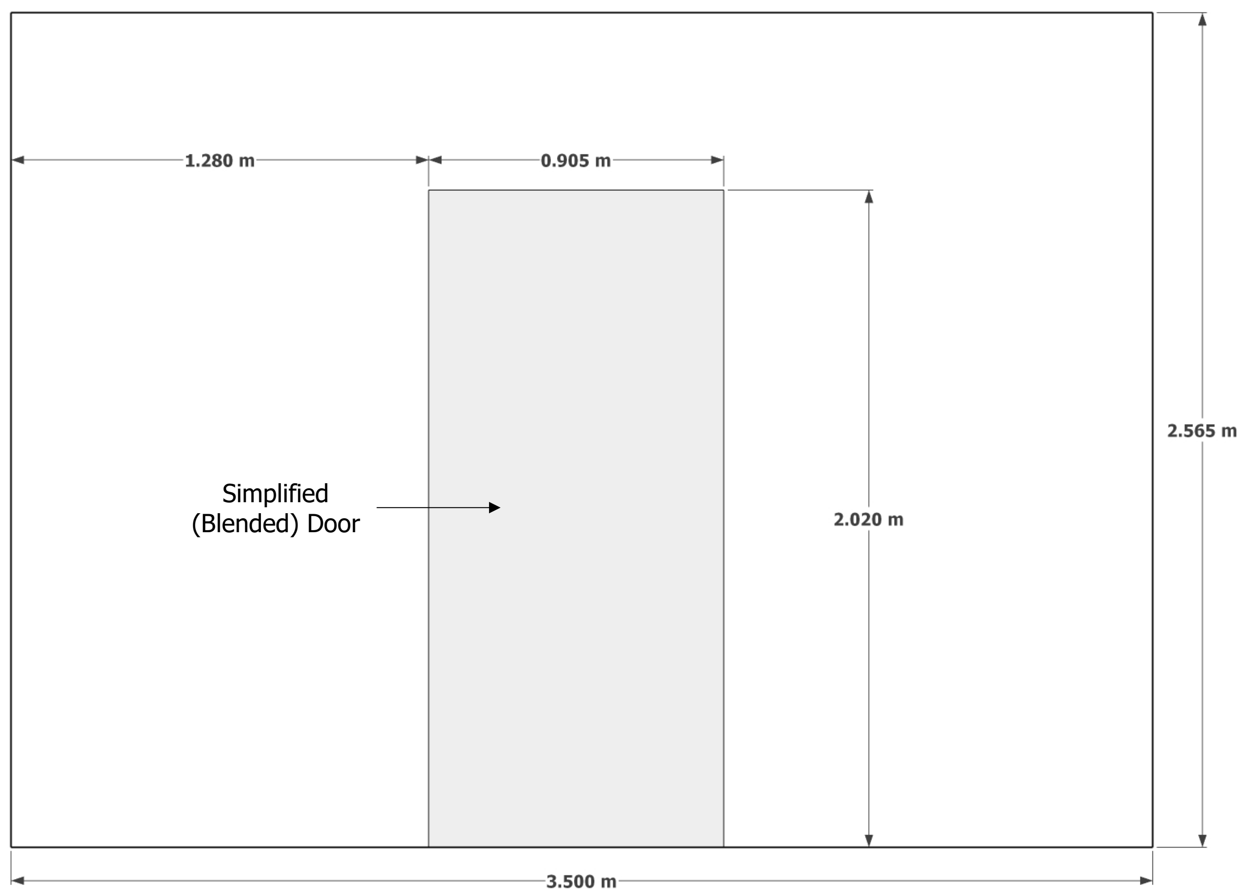



**Figure 13-5: Dimensioned north wall and door elevation, exterior view**

### 13.2.2.7.2.5 Surface area summary

Table 13-5 summarizes the component surface areas for each Cell A bounding surface type, along with overall totals for a given wall. This table includes the sub-areas for the 16 alternative 1-D conduction paths **shown in bold font** that are defined with the construction details of Section 13.2.2.8, as summarized in Section 13.2.2.8.1.2.

***Informative Note:*** This table is intended for checking geometry inputs by comparing tested-program intermediate geometry output with this table.

**Table 13-5 Cell A Boundary-Surface Areas [a]**

| | | | Spec Reference | |
|---|---|---|---|---|
| | **Envelope Component** | **Area [m$^2$]** | **Figures** | **Tables** |
| Floor | **Path 1 (Insulation)** | **13.3525** | 13-15, 13-16 | 13-13 |
| | **Path 2 (Beam Footer Portion)** | **1.4700** | 13-15, 13-16 | 13-14 |
| | **Path 3 (Beam Center Portion)** | **1.4700** | 13-15, 13-16 | 13-15 |
| | Floor Total | 16.2925 | 13-2 | -- |
| Ceiling | **Path 1 (Insulation)** | **14.4025** | 13-13, 13-14 | 13-11 |
| | **Path 2 (Planks [Joists])** | **1.8900** | 13-13, 13-14 | 13-12 |
| | Ceiling Total | 16.2925 | 13-2 | -- |
| North Wall | **North Wall Without Door** | **7.1494** | 13-5 | 13-6 |
| | **North Door Blended** | **1.8281** | 13-5, 13-10 | 13-7 |
| | North Wall Total | 8.9775 | 13-2, 13-5 | -- |
| East Wall | **East Wall Without Window** | **10.1378** | 13-4 | 13-8 |
| | **Window Path 1 (Glazing)** | **0.9905** | 13-4, 13-17, 13-18 | 13-16 |
| | **Window Path 2 (Inner Frame)** | **0.1385** | 13-4, 13-17, 13-18 | 13-17 |
| | **Window Path 3 (Outer Frame)** | **0.6734** | 13-4, 13-17, 13-18 | 13-18 |
| | East Wall Total | 11.9401 | 13-2, 13-4 | -- |
| South Wall | **South Wall Without Window** | **7.1752** | 13-3 | 13-9 |
| | **Window Path 1 (Glazing)** | **0.9905** | 13-3, 13-17, 13-18 | 13-16 |
| | **Window Path 2 (Inner Frame)** | **0.1385** | 13-3, 13-17, 13-18 | 13-17 |
| | **Window Path 3 (Outer Frame)** | **0.6734** | 13-3, 13-17, 13-18 | 13-18 |
| | South Wall Total | 8.9775 | 13-2, 13-3 | -- |
| West Wall | **West Wall Total** | **11.9401** | 13-2 | 13-10 |

Source: Argonne Box\Addendum_ETNA_140 \140-2023-Addendum-b-docx\Surface Area Check (041125).xlsx, 041125_A!B2:28

**a. Sub-areas for the 16 alternative 1-D conduction paths defined in Section 13.2.2.8 are shown in bold font.**

### 13.2.2.7.3 Alternative geometry for programs that require physically defining the guard zones

Users that apply guard zones as boundary conditions (per Section 13.2.2.7.1) in place of physically defining guard zone geometry and material constructions shall skip this section and continue with Section 13.2.2.8.

Figures 13-6 through 13-8 shall be applied for programs that require modeling the guard zones as actual physical zones. These figures show the plan view and section views of Cell A and its six guard zones, along with guard zone dimensions; see Figure 13-2 of Section 13.2.2.7.2.1 for test cell dimensions.

As shown in Figure 13-6, the building is oriented 30° E of North, so that the test cell bounding surface that would nominally be called the "South" wall is oriented at 30° West of South, and the other walls are oriented and named accordingly with orientations offset 30° from their nominal cardinal directions.

***Informative Note:*** Figure 13-6 shows both test cells, Cell A and Cell B, in case full facility detail is needed for developing a model with physically defined guard zones. For developing the Cell A model, it is only necessary to model the guard zones adjacent to Cell A. Cell B and the guard zones adjacent to Cell B may be added later when developing Case ET110B1 (Section 13.2.3).

Figures 13-6 through 13-8 also indicate the names of each guard zone. These names are associated with hourly data identifiers within the accompanying file ET110A-Measurements.csv (see previous Section 13.2.2.2.1); e.g., "Tsouth" designates the south guard zone temperature data provided in column F of the file.

***Informative Notes:***

1. The details of the guard zones are incomplete (see Section 13.2.2.15) relative to the level of detail provided for the test-cell zones. During development of the test specification, project-team modelers developed exterior-surface boundary conditions for each test-cell surface based on the given guard zone temperatures (see Section 13.2.2.2) and exterior surface heat transfer coefficients (see Section 13.2.2.10). Programs that require modeling of the guard zones (that do not allow definition of test-cell exterior surface boundary conditions) should develop models of the guard zones based on the dimensions provided in Figures 13-6 through 13-8 and approximate material descriptions of Section 13.2.2.15.

2. Guard zone dimensions include estimates based on drawings provided in Figures 2 through 4 of the originating source document[c-1].

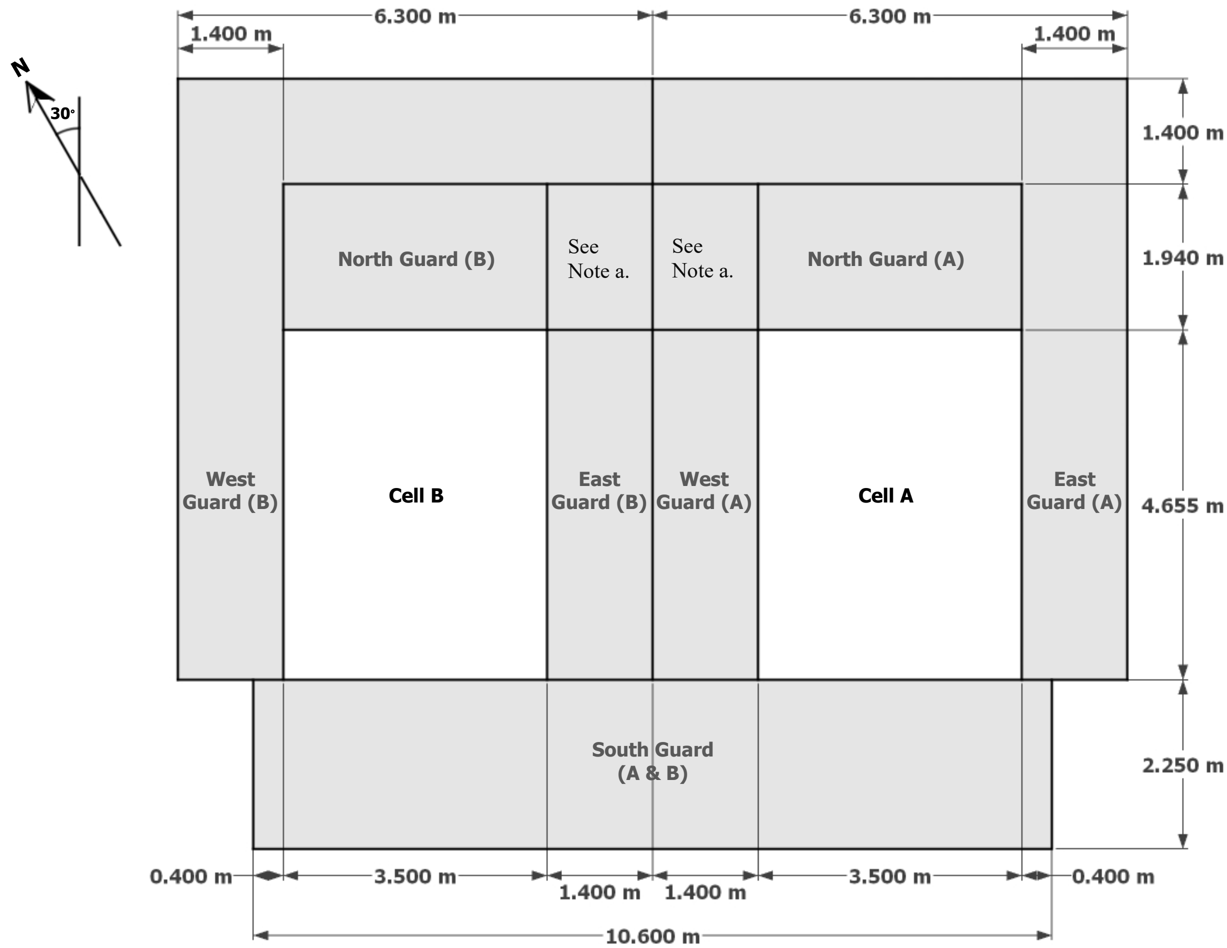



**Figure 13-6: Alternative summary geometry with guard zone dimensions: plan**

Notes for Figure 13-6:

a. For Cell A, this corner is either at north guard or west guard conditions or unconditioned depending on guard zone entry door positions, which were not recorded. Similarly for Cell B, the marked corner is either at north guard or east guard conditions or unconditioned depending on guard zone entry door positions, which were not recorded.
b. ***Informative Note:*** For developing the Cell A model, it is only necessary to model the guard zones adjacent to Cell A. Cell B and the guard zones adjacent to Cell B may be added later when developing Case ET110B1 (Section 13.2.3).

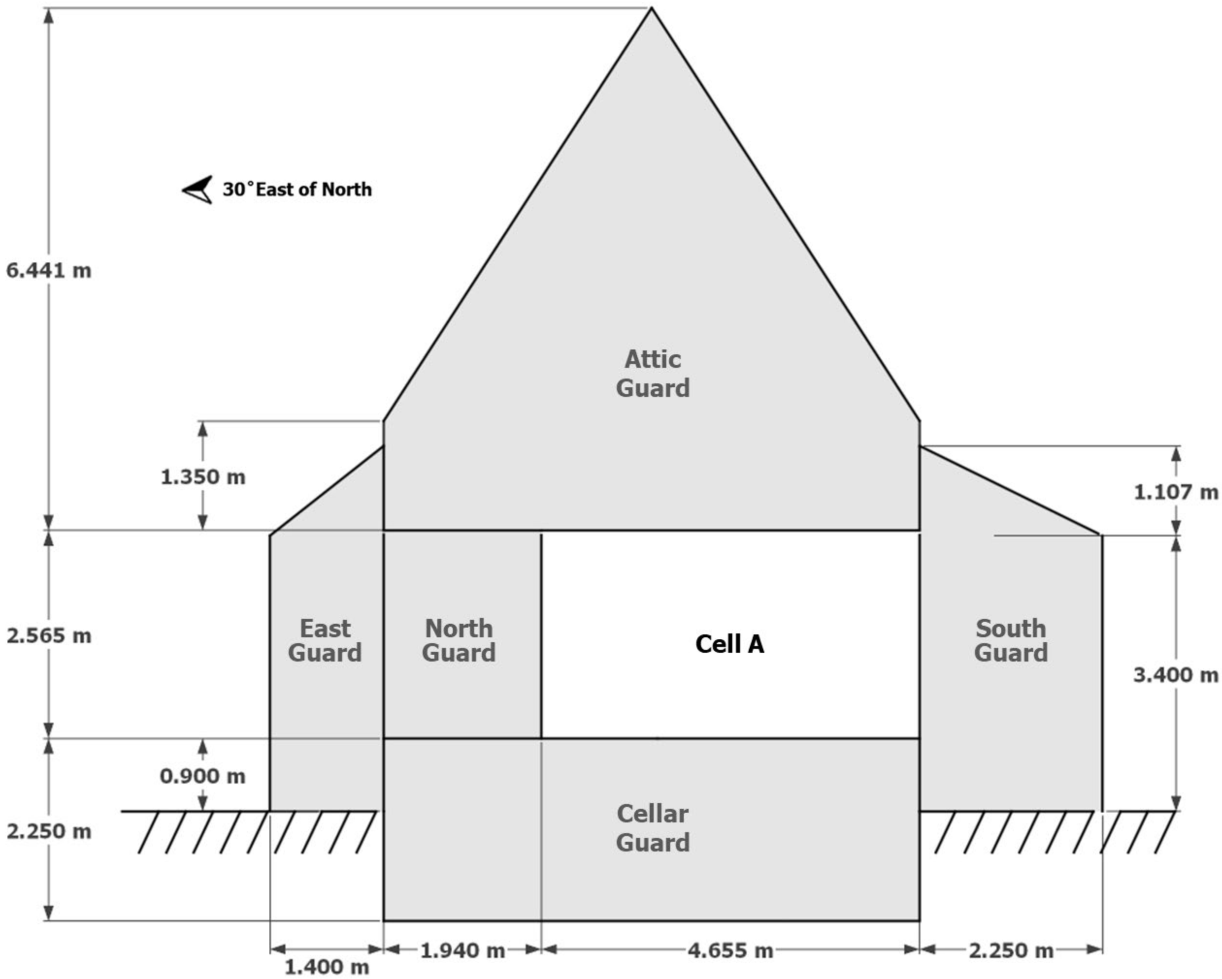



**Figure 13-7 Alternative summary geometry with guard zone dimensions: Cell A elevation section looking 30° north of west through page**

Notes for Figure 13-7:

- The section/elevation for Cell B is the same as that shown here for Cell A, except the guard zone just north of the north guard is the "west" guard (see Figure 13-6 plan view).
- The ground level of the cell is raised by 0.90 m above grade. The external walls of the cell are surrounded by thermal guards (either fully or partly depending on their configuration).

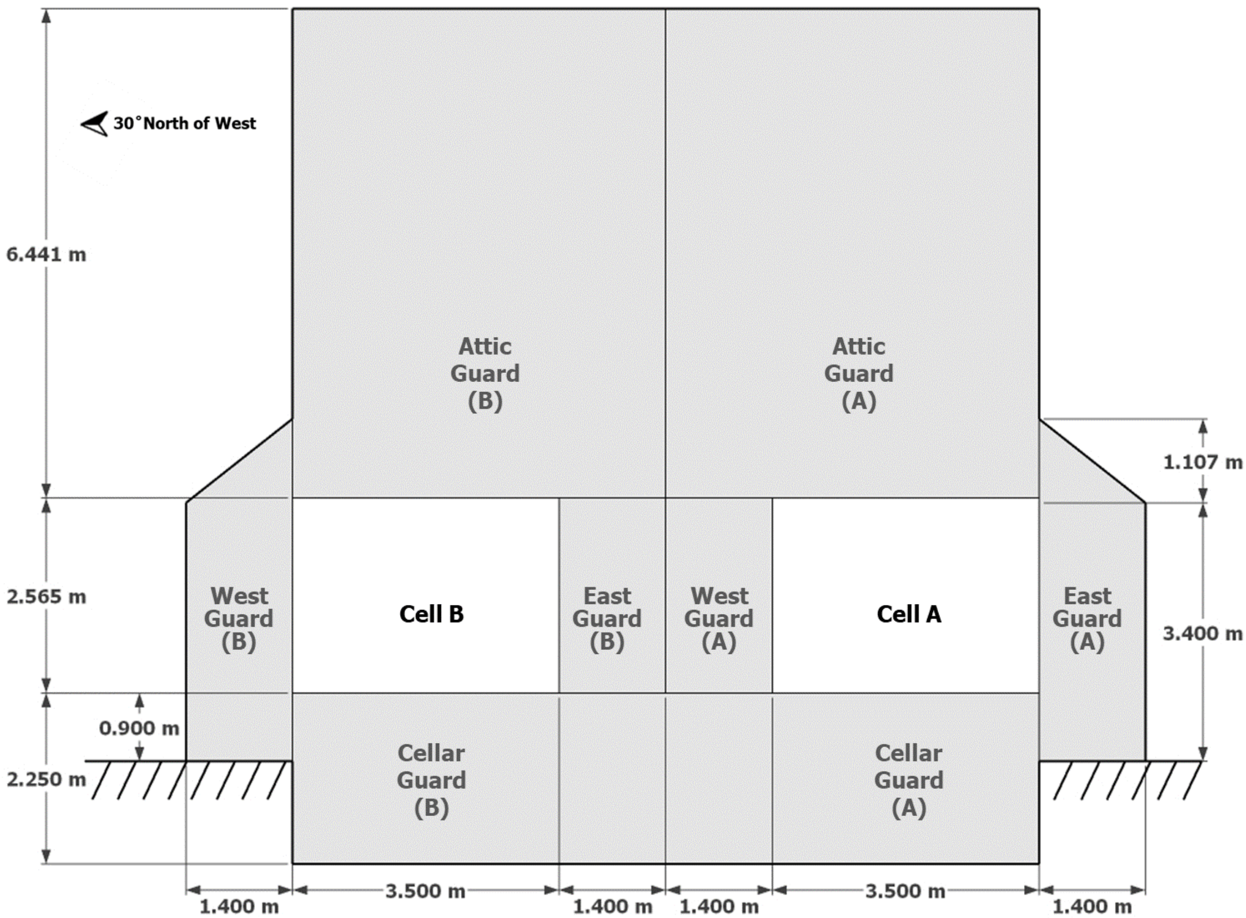



**Figure 13-8: Alternative summary geometry with guard zone dimensions: elevation section looking 30° east of north through page**

Notes:

- This section is cut along the apex of the attic roof.
- ***Informative Note:*** For developing the Cell A model, it is only necessary to model the guard zones adjacent to Cell A. Cell B and the guard zones adjacent to Cell B may be added later when developing Case ET110B1 (Section 13.2.3)

### 13.2.2.8 Test Cell Bounding Surface Material Constructions

The following sections specify material constructions of the test cell bounding surfaces and subsurfaces:

- Construction modeling options (Section 13.2.2.8.1)
- North wall and door (Section 13.2.2.8.2)
- East wall (Section 13.2.2.8.3)
- South wall (Section 13.2.2.8.4)
- West wall (Section 13.2.2.8.5)
- Ceiling (Section 13.2.2.8.6)
- Floor (Section 13.2.2.8.7)
- Window and insulation module within east and south walls (Section 13.2.2.8.8)

#### 13.2.2.8.1 Construction Modeling Options

In the following sections for each bounding surface, construction specifications are presented as required characteristics and alternative construction specifications.

**13.2.2.8.1.1** Required characteristics include:

- Empirically determined UA values
- Construction details, as shown in the figures.

**13.2.2.8.1.2** Alternative construction specifications consist of material properties tables that include:

- Catalog values
- Imputed thermal conductivities for selected material layers; imputed values are highlighted in yellow.
- 16 parallel 1-D conduction paths applied for determining the imputed thermal conductivities.

***Informative Notes:***

1. Material property tables in the following sections are intended for simulations applying 1-dimensional thermal diffusion models, and are derived based on the interior surface area of a given bounding surface.
2. Imputed properties are only valid for the given conduction paths.
3. The alternative construction specifications are recommended for use based on Section 13.2.1.3.
4. Merging conduction paths within a given bounding wall or combining bounding walls for the purpose of simplifying a model intended to apply the alternative construction specifications is not recommended, because the modeler would be required to re-evaluate:
    a. Listed imputed thermal conductivities
    b. Effective measured diagnostic surface heat fluxes and temperatures for the combined surfaces to diagnose disagreements with measured data.
5. Informative Annex B23 describes calculation of imputed values.

### 13.2.2.8.2 North Wall and Door

#### 13.2.2.8.2.1 Required characteristics

The north wall and door, which comprise the bounding surface between the test cell and the North Guard zone, shall have the following characteristics:

- UA = 6.06 W/K; total north wall + door. ***Informative Note:*** See Informative Annex B23 for supporting information.
- Construction as shown in Figures 13-9 and 13-10.
- Geometry as described in Figure 13-5 (see Section 13.2.2.7.2.4).

***Informative Note:*** Figure 13-10 is a simplified version of the door that allows it to be modeled as a single 1-D conduction path. See Informative Annex B23, Section B23.6 for supporting details.

For modelers requiring further guidance to specify inputs of material properties, apply the alternative construction specification of Section 13.2.2.8.2.2. ***Informative Note:*** Use of the Section 13.2.2.8.2.2 alternative is recommended (see Section 13.2.1.3).

#### 13.2.2.8.2.2 Alternative construction specification

**13.2.2.8.2.2.1** If the modeler does not require further guidance to develop inputs as specified in Section 13.2.2.8.2.1, skip the remaining instructions and proceed to Section 13.2.2.8.3.

**13.2.2.8.2.2.2** The north wall shall be divided into two parallel 1-D conduction path segments, corresponding to the method for which thermal conductivities of selected material layers were externally imputed. ***Informative Note:*** See Informative Annex B23 for details regarding external imputation of thermal conductivities.

Tables 13-6 and 13-7 provide thermal properties and thicknesses for each material layer of each parallel path (north wall and its door, respectively, for each table), with the material layer adjacent to the inside of the test cell at the top of the table, and then layers incrementally toward the guard zone for each row going down the table. Net inside surface area for each heat flow path is provided, respectively, in each table caption.

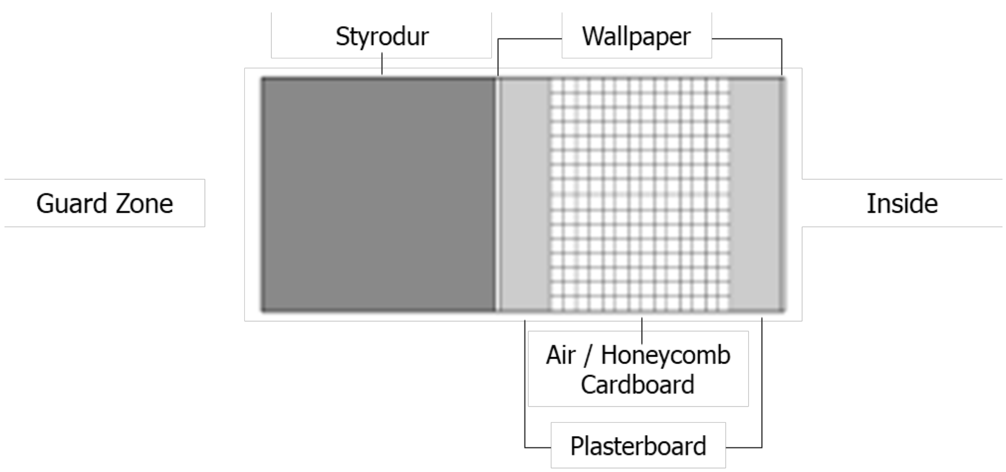
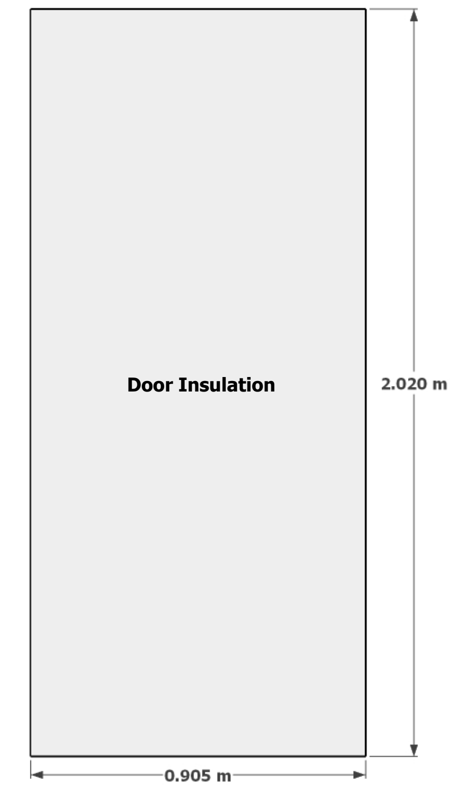



**Figure 13-9: Sectional view of the North wall**




**Door insulation module**

- There is one 0.060 m-thick layer of styrodur constructed such that there is a 0.038 m air gap between the inner surface of the insulation module and a simplified blended material layer; see horizontal section below.
- Door styrodur and wall styrodur have the same thermal properties.
- ***Informative Note:*** This simplification of the actual construction is intended to reduce the greater chance for input errors with the more complicated actual construction. See Informative Annex B23, Section B23.6 for greater detail.

**Horizontal Section, Door**

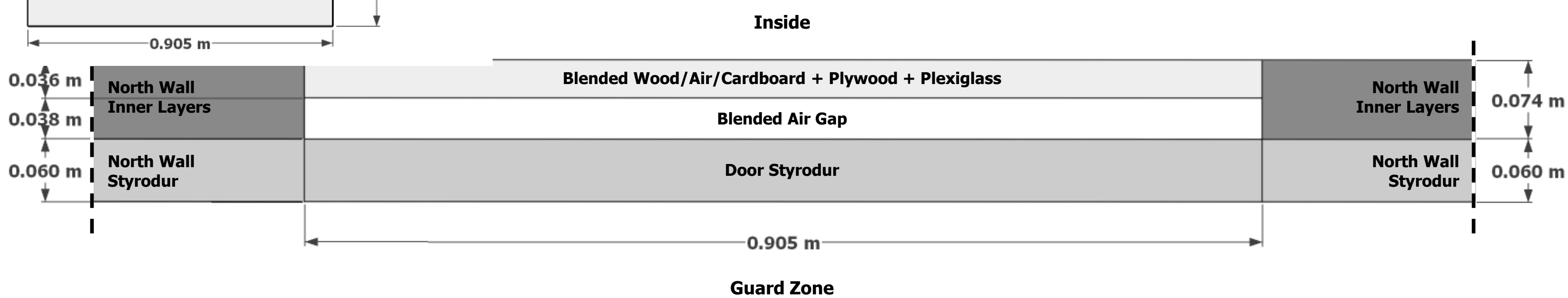



**Figure 13-10. Door within north wall including insulation (styrodur) and air gap between insulation and door**

**Table 13-6: Characteristics of the North wall**
(Net inside surface area = 7.1494 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |
| Air / Honeycomb Cardboard | 0.046 | 0.307[a] | 26.1 | 1340 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Styrodur | 0.060 | 0.0563 [b] | 18 | 1200 |

a. ***Informative Note:*** Equivalent conductivity with regard to the air, see 2021 *ASHRAE Handbook—Fundamentals* [c-5].
b. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 1.456 m²K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.

**Table 13-7: Characteristics of the Door**
(Net inside surface area = 1.8281 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| Blended Wood/Air/Cardboard + Plywood + Plexiglass[a] | 0.036 | 0.1643 [b] | 307 | 1317 |
| Blended Air Gap[a] | 0.038 | 0.254 [c] | 1.2 | 1000 |
| Styrodur (see Figure 13-10) | 0.060 | 0.0563 [b] | 18 | 1200 |

a. ***Informative Note:*** See Informative Annex B23, Section B23.6 for supporting information.
b. Imputed conductivity inputs highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.
c. Equivalent conductivity with regard to air. See 2021 *ASHRAE Handbook—Fundamentals* [c-5].
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 1.586 m²K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.

### 13.2.2.8.3 East Wall

### 13.2.2.8.3.1 Required characteristics

The east wall, which is the bounding surface between the test cell and the East Guard zone, shall have the following characteristics:

- UA values:
  - UA = 9.36 W/K; total east wall + window, measured without window insulation
  - UA = 6.86 W/K; total east wall + window with window insulation (see Section 13.2.2.8.8).
  - ***Informative Note:*** See Informative Annex B23 for supporting information.
- Construction as shown in Figure 13-11.

- Geometry as described in Figure 13-4 (see Section 13.2.2.7.2.3).

Construction of the window and its insulation module within the east wall is described separately in Section 13.2.2.8.8.

For modelers requiring further guidance to specify inputs of material properties, apply the alternative construction specification of Section 13.2.2.8.3.2. ***Informative Note:*** Use of the Section 13.2.2.8.3.2 alternative is recommended (see Section 13.2.1.3).

**13.2.2.8.3.2 Alternative construction specification**

**13.2.2.8.3.2.1** If the modeler does not require further guidance to develop inputs as specified in Section 13.2.2.8.3.1, skip the remaining instructions and proceed to Section 13.2.2.8.4.

**13.2.2.8.3.2.2** The east wall is a single 1-D conduction path, corresponding to the method for which thermal conductivities of selected material layers were externally imputed. (***Informative Note:*** See Informative Annex B23 for details regarding external imputation of thermal conductivities.)

Table 13-8 provides thermal properties and thicknesses with the material layer adjacent to the inside of the test cell at the top of the table and then layers incrementally toward the guard zone for each row going down the table.

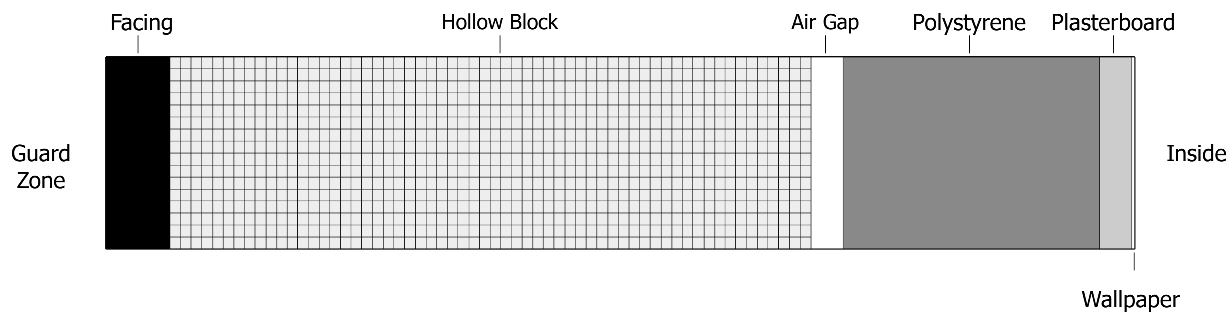



**Figure 13-11: Sectional view of the East and South walls**

**Table 13-8: Characteristics of the East wall.**
(Net inside surface area = 10.1378 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.010 | 0.35 | 850 | 800 |
| Polystyrene | 0.080 | 0.0407 [a] | 15 | 1200 |
| Air gap | 0.010 | 0.070 [b] | 1.2 | 1000 |
| Hollow block | 0.200 | 1.052 | 1200 | 950 |
| Facing | 0.020 | 1.15 | 1950 | 850 |

a. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.
b. ***Informative Note:*** Equivalent conductivity with regard to the air, see 2021 *ASHRAE Handbook—Fundamentals* [c-5].
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 2.549 m²K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.

**13.2.2.8.4 South Wall**

**13.2.2.8.4.1 Required characteristics**

The south wall, which is the bounding surface between the test cell and the South Guard zone, shall have the following characteristics:

- UA values:
  - UA = 8.07 W/K; total south wall + window, measured without window insulation
  - UA = 5.57 W/K; total south wall + window with window insulation (see Section 13.2.2.8.8).
  - ***Informative Note:*** See Informative Annex B23 for supporting information.
- Construction layers as shown in Figure 13-11 (see Section 13.2.2.8.3), similarly to the east wall, but with different UA-value and surface area (see bullets above and below, respectively).
- Geometry as described in Figure 13-3 (see Section 13.2.2.7.2.2).

Construction of the window and its insulation module within the south wall is described separately in Section 13.2.2.8.8.

For modelers requiring further guidance to specify inputs of material properties, apply the alternative construction specification of Section 13.2.2.8.4.2. ***Informative Note:*** Use of the Section 13.2.2.8.4.2 alternative is recommended (see Section 13.2.1.3).

**13.2.2.8.4.2 Alternative construction specification**

**13.2.2.8.4.2.1** If the modeler does not require further guidance to develop inputs as specified in Section 13.2.2.8.4.1, skip the remaining instructions and proceed to Section 13.2.2.8.5.

**13.2.2.8.4.2.2** The south wall is a single 1-D conduction path, corresponding to the method for which thermal conductivities of selected material layers were externally imputed. ***Informative Note:*** See Informative Annex B23 for details regarding external imputation of thermal conductivities.

Table 13-9 provides thermal properties and thicknesses, with the material layer adjacent to the inside of the test cell at the top of the table and then layers incrementally toward the guard zone for each row going down the table. ***Informative Note:*** The material properties of Table 13-9 are the same as that for the East wall (see Table 13-8), except for different imputed conductivity of selected materials; see the yellow-highlighted values in Table 13-9.

**Table 13-9: Characteristics of the South wall**
(Net inside surface area = 7.1752 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/m.K] | ρ<br>Density<br>[kg/m³] | Cp<br>Specific heat<br>[J/kg.K] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.010 | 0.35 | 850 | 800 |
| Polystyrene | 0.080 | 0.0383 [a] | 15 | 1200 |
| Air gap | 0.010 | 0.070 [b] | 1.2 | 1000 |
| Hollow block | 0.200 | 1.052 | 1200 | 950 |
| Facing | 0.020 | 1.15 | 1950 | 850 |

a. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.
b. ***Informative Note:*** Equivalent conductivity with regard to the air, see 2021 *ASHRAE Handbook—Fundamentals* [c-5].
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 2.672 $m^2K/W$
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.

#### 13.2.2.8.5 West Wall

#### 13.2.2.8.5.1 Required characteristics

The west wall, which is the bounding surface between the test cell and the West Guard zone, shall have the following characteristics:

- UA = 3.44 W/K. ***Informative Note:*** See Informative Annex B23 for supporting information.
- Construction as shown in Figure 13-12.
- Geometry as described in Figure 13-2 (see Section 13.2.2.7.2.1).

For modelers requiring further guidance to specify inputs of material properties, apply the alternative construction specification of Section 13.2.2.8.5.2. ***Informative Note:*** Use of the Section 13.2.2.8.5.2 alternative is recommended (see Section 13.2.1.3).

#### 13.2.2.8.5.2 Alternative construction specification

**13.2.2.8.5.2.1** If the modeler does not require further guidance to develop inputs as specified in Section 13.2.2.8.5.1, skip the remaining instructions and proceed to Section 13.2.2.8.6.

**13.2.2.8.5.2.2** The west wall is a single 1-D conduction path, corresponding to the method for which thermal conductivities of selected material layers were externally imputed. ***Informative Note:*** See Informative Annex B23 for details regarding external imputation of thermal conductivities.

Table 13-10 provides thermal properties and thicknesses with the material layer adjacent to the inside of the test cell at the top of the table and then layers incrementally toward the guard zone for each row going down the table.

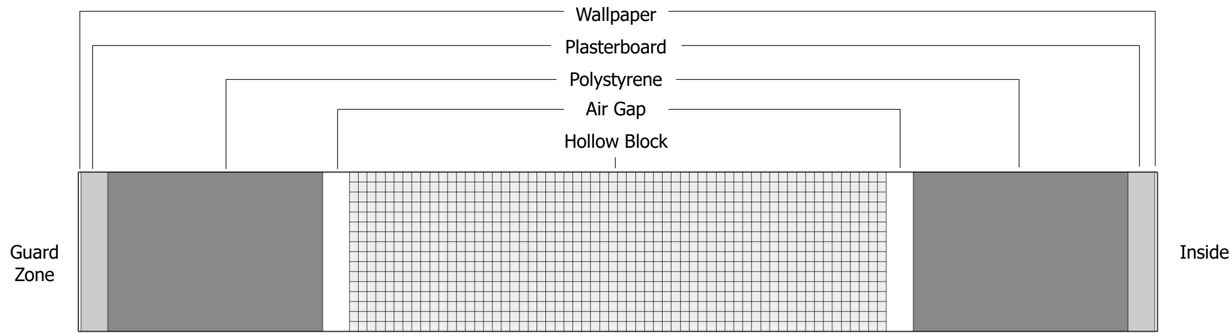



**Figure 13-12: Sectional view of the West wall**

**Table 13-10: Characteristics of the West wall**

(Net inside surface area = 11.9401 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.010 | 0.35 | 850 | 800 |
| Polystyrene | 0.080 | 0.0597 [a] | 15 | 1200 |
| Air gap | 0.010 | 0.070 [b] | 1.2 | 1000 |
| Hollow block | 0.200 | 1.052 | 1200 | 950 |
| Air gap | 0.010 | 0.070 [b] | 1.2 | 1000 |
| Polystyrene | 0.080 | 0.0597 [a] | 15 | 1200 |
| Plasterboard | 0.010 | 0.35 | 850 | 800 |
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |

a. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.
b. ***Informative Note:*** Equivalent conductivity with regard to the air, see 2021 *ASHRAE Handbook—Fundamentals* [c-5].
***Informative Note:*** Composite “air-to-air” R-value (R) for this heat flow path is:

- R = 3.472 m$^2$K/W
- This “air-to-air” value includes combined surface heat transfer coefficients of Section 13.2.2.10.

**13.2.2.8.6 Ceiling**

**13.2.2.8.6.1 Required characteristics**

The ceiling, which is suspended under the attic guard zone, shall have the following characteristics:

- UA = 2.67 W/K. ***Informative Note***: See Informative Annex B23 for supporting information.
- Construction as shown in Figure 13-13
- Geometry as described in Figure 13-2 (see Section 13.2.2.7.2.1).

For modelers requiring further guidance to specify inputs of material properties, apply the alternative construction specification of Section 13.2.2.8.6.2. ***Informative Note:*** Use of the Section 13.2.2.8.6.2 alternative is recommended (see Section 13.2.1.3).

**13.2.2.8.6.2 Alternative construction specification**

**13.2.2.8.6.2.1** If the modeler does not require further guidance to develop inputs as specified in Section 13.2.2.8.6.1, skip the remaining instructions and proceed to Section 13.2.2.8.7.

**13.2.2.8.6.2.2** The ceiling shall be divided into two parallel 1-D conduction path segments, corresponding to the method for which thermal conductivity of selected material layers were externally imputed. ***Informative Note:*** See Informative Annex B23 for details regarding external imputation of thermal conductivities.

Figure 13-14 illustrates the two parallel 1-D conduction heat flow paths (Path 1 and Path2) to be applied in the simulations.

Tables 13-11 and 13-12 provide the thermal properties and thicknesses for each material layer of each parallel path (Path 1 and Path 2, respectively for each table), with the layer adjacent to the inside of the test cell at the top of the table, and then layers incrementally toward the guard zone for each row going down the table. Net inside surface area for each heat flow path is provided, respectively, in each table caption.

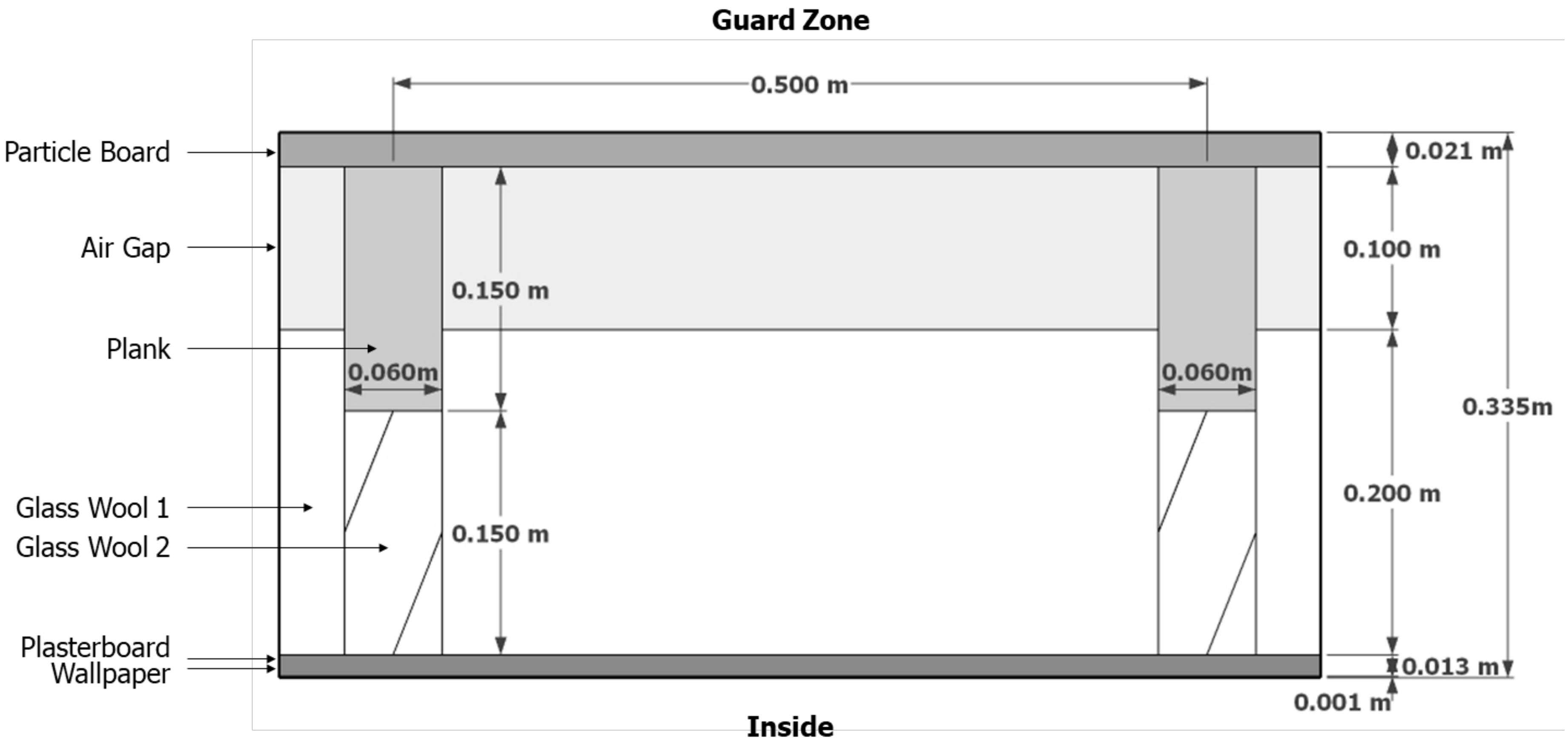



**Figure13-13: Sectional view of the ceiling (partial)**

Notes:

- The cross-section area of the ceiling planks (joists) is the equivalent of 9 joists, traversing east-west (see Table 13-5, Section 13.2.2.7.2.5).
- ***Informative Note:*** This is a simplification of the original figure; see Informative Annex B23, Section B23.6 for details.

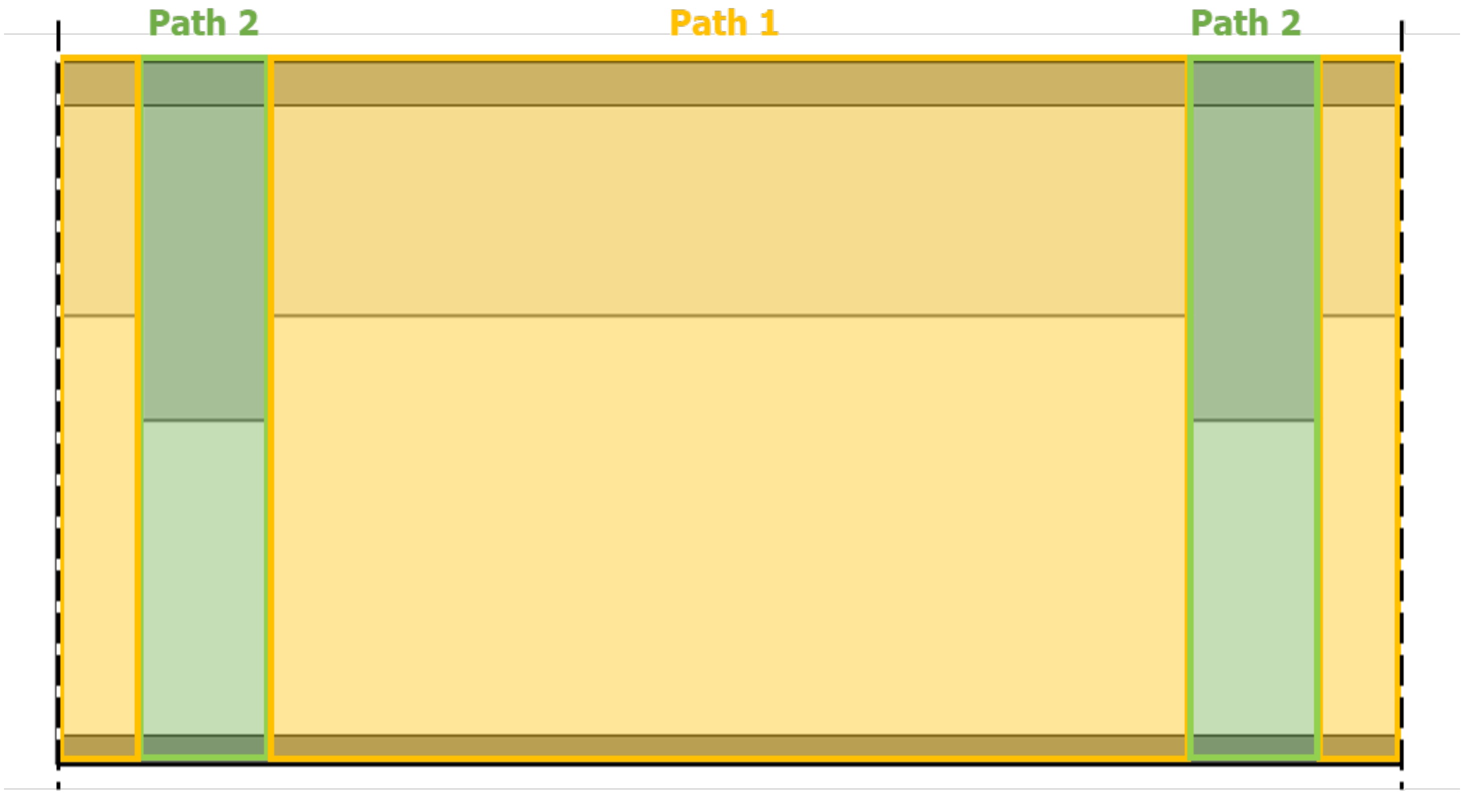



**Figure 13-14 Section/elevation view (same view as Figure 13-13) of the ceiling heat-flow paths**

**Table 13-11: Characteristics of the ceiling – Path 1**

(Net inside surface area = 14.4025 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/mK] | ρ<br>Density<br>[kg/m³] | $C_p$<br>Specific heat<br>[J/kgK] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |
| Glass wool 1 | 0.200 | 0.0364 [a] | 11 | 800 |
| Air gap | 0.100 | 0.618 [b] | 1.2 | 1000 |
| Particle board | 0.021 | 0.17 | 700 | 1200 |

a. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.
b. ***Informative Note:*** Equivalent conductivity with regard to the air, see 2021 *ASHRAE Handbook—Fundamentals* [c-5].
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 6.161 m²K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.

**Table 13-12: Characteristics of the ceiling – Path 2**

(Net inside surface area = 1.8900 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/mK] | ρ<br>Density<br>[kg/m³] | $C_p$<br>Specific heat<br>[J/kgK] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |
| Glass wool 2 | 0.150 | 0.0364 [a] | 11 | 800 |
| Planks | 0.150 | 0.15 | 500 | 1200 |
| Particle board | 0.021 | 0.17 | 700 | 1200 |

a. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 5.625 m²K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.

**13.2.2.8.7 Floor**

**13.2.2.8.7.1 Required characteristics**

The floor, which is suspended over the Cellar guard zone, shall have the following characteristics:

- UA = 6.32 W/K. ***Informative Note***: See Informative Annex B23 for supporting information.
- Construction as shown in Figure 13-15.
- Geometry as described in Figure 13-2 (see Section 13.2.2.7.2.1).

For modelers requiring further guidance to specify inputs of material properties, apply the alternative construction specification of Section 13.2.2.8.7.2. ***Informative Note:*** Use of the Section 13.2.2.8.7.2 alternative is recommended (see Section 13.2.1.3).

**13.2.2.8.7.2 Alternative construction specification**

**13.2.2.8.7.2.1** If the modeler does not require further guidance to develop inputs as specified in Section 13.2.2.8.7.1, skip the remaining instructions and proceed to Section 13.2.2.8.8.

**13.2.2.8.7.2.2** The floor is divided into three parallel 1-D conduction path segments, corresponding to the method for which thermal conductivities of selected material layers were externally imputed. ***Informative Note:*** See Informative Annex B23 for details regarding external imputation of thermal conductivities.

Figure 13-16 illustrates the three parallel 1-D conduction heat flow paths (Path 1, Path 2, and Path 3) to be applied in the simulations.

Tables 13-13, 13-14, and 13-15 provide thermal properties and thicknesses for each material layer of each parallel path (Path 1, Path 2, and Path 3, respectively for each table), with the layer adjacent to the inside of the test cell at the top of the table, and then layers incrementally toward the guard zone for each row going down the table. Net inside surface area for each heat flow path is provided, respectively, in each table caption.

**13.2.2.8.7.2.2.1** ***Informative Notes: For programs with ≤ 10-layer limit within a conduction path.*** The as-specified floor conduction paths are comprised of 11 material layers.

1. For programs that limit the number of material layers in a conduction path to 10 layers, the following work-arounds are recommended:
    - Floor Path 1: Merge the two insulated block layers per Table 13-13, Informative Note 2 (see notes below the table)
    - Floor Path 2: Merge the ceramic tile and glue cement layers per Table 13-14, Informative Note 2 (see notes below the table)
    - Floor Path 3: Merge the two concrete beam layers per Table 13-15, Informative Note 2 (see notes below the table).
2. These alternatives are recommended so that:
    - Adjacent material layers with same thermal properties are combined such that there should be negligible effect on results

   - Where there are no adjacent layers with same thermal properties for a construction, adjacent layers with similar properties are combined to minimize the effect on results.
3. If a tested program limits the number of material layers in a conduction path to < 10 layers, merge additional specified layers as needed applying above Informative Note 2 as generic guidance for merging layers.
4. For programs with ≤ 10 layer limit for a given conduction path, how layers were merged as an equivalent modeling method should be documented in Report Block C of S140outNotes.txt included with the accompanying electronic media.

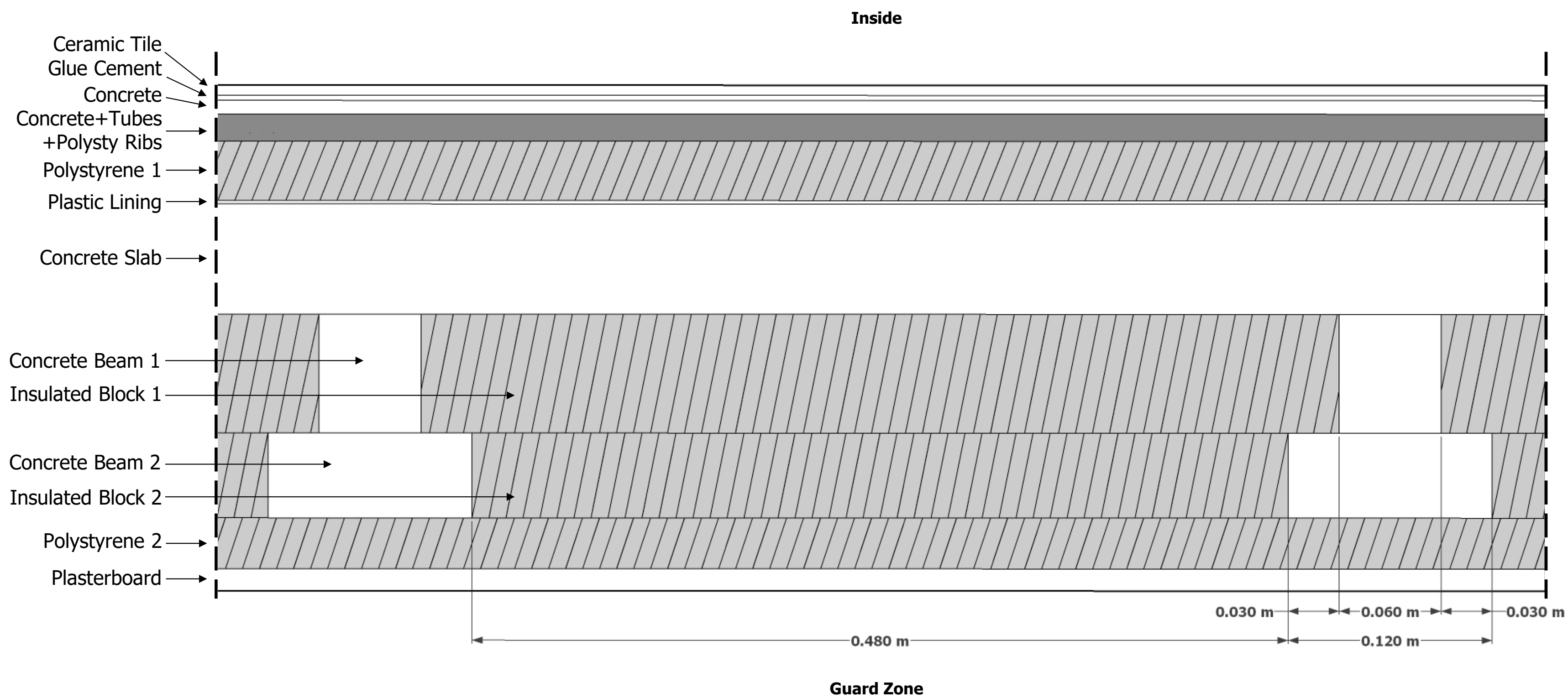



**Figure 13-15: Section/elevation view of the floor**

Notes:

- The cross-section area of the floor concrete beam components is equivalent to 7 concrete beams traversing east-west (see Table 13-5, Section 13.2.2.7.2.5).
- ***Informative Note:*** The "Concrete+Tubes+Polysty Ribs" in the upper portion of this figure is a simplification of previous floor figures from the originating source document[c-1]; also see Informative Annex B23, Section B23.6. The floor has the capability to be a hydronic heating/cooling radiative floor (water and heat pump). Radiant floor heating/cooling was inactive during these tests, with no water present

in the hydronic tubes. For the construction of the material layer containing the hydronic tubes, Tables 13-13, 13-14, and 13-15 provide a simplified aggregation.

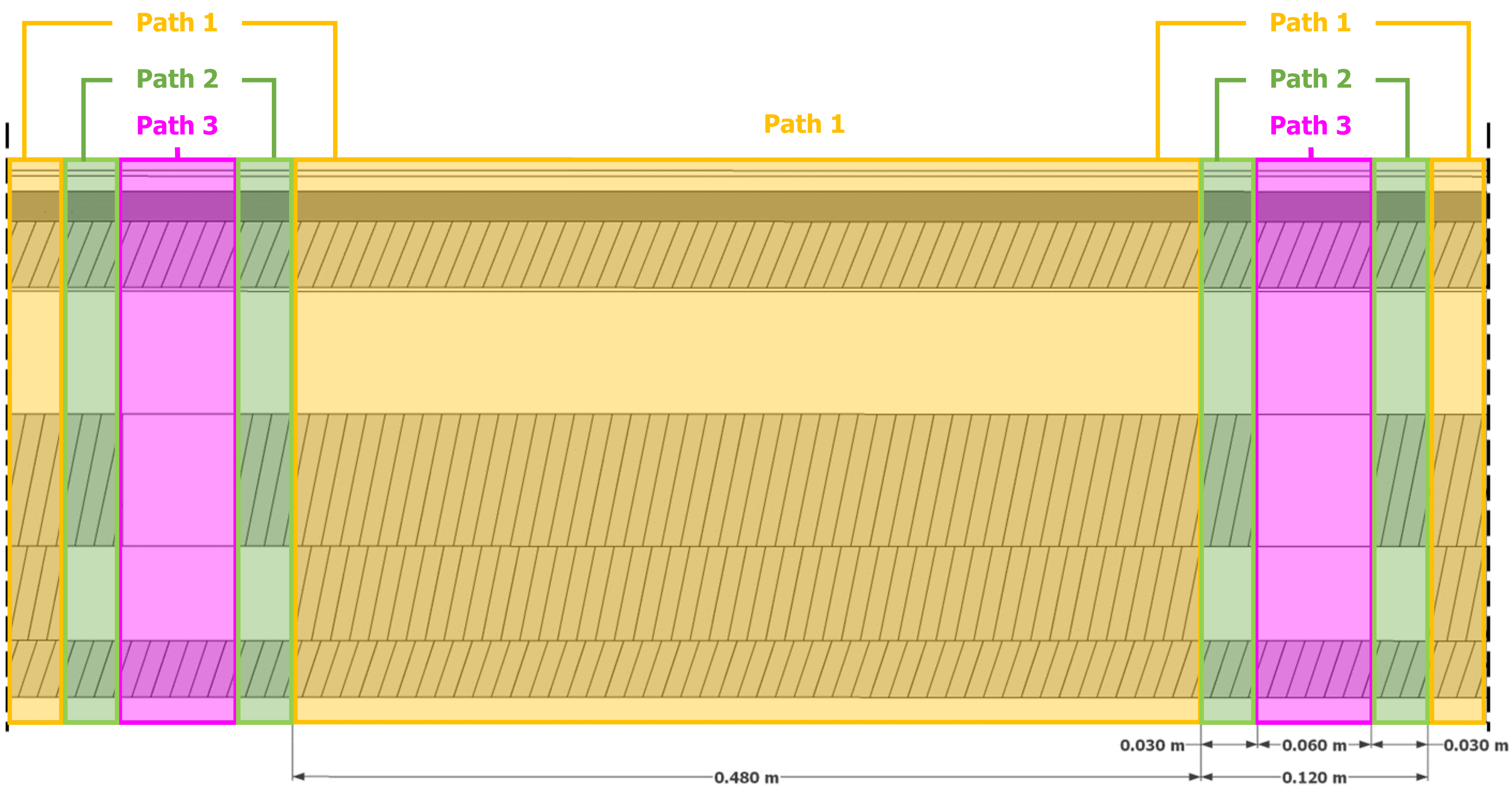



**Figure 13-16: Section/elevation view (same view as Figure 13-15) of the floor parallel heat-flow paths**

**Table 13-13: Characteristics of the floor – Path 1**
(Net inside surface area = 13.3525 m²)

| Material | d Thickness [m] | k Conductivity [W/mK] | ρ Density [$kg/m^3$] | Cp Specific heat [J/kgK] |
|---|---|---|---|---|
| Ceramic Tile | 0.006 | 1.75 | 2177 | 920 |
| Glue Cement | 0.003 | 1.50 | 1900 | 840 |
| Concrete | 0.008 | 1.75 | 2177 | 920 |
| Concrete + Tubes + Polysty Ribs [a] | 0.016 | 1.47 | 1813 | 954 |
| Polystyrene 1 | 0.035 | 0.0719 [b] | 16 | 1200 |
| Plastic Lining | 0.002 | 0.124 | 265 | 1170 |
| Concrete Slab | 0.065 | 1.75 | 2200 | 950 |
| Insulated Block 1 | 0.070 | 0.0719 [b] | 18 | 1200 |
| Insulated Block 2 | 0.050 | 0.0719 [b] | 18 | 1200 |
| Polystyrene 2 | 0.030 | 0.0719 [b] | 18 | 1200 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |

a. ***Informative Note:*** Based on Figure 13-15, for simplification, layer properties here assume a by-volume-averaged blended layer of concrete, polystyrene, tubes, and air within empty tubes. Documentation of how this layer was calculated is included in Informative Annex B23, Section B23.6.

b. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.

***Informative Notes:***

1. Composite "air-to-air" R-value (R) for this heat flow path is:
   - R = 2.928 $m^2K/W$
   - This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.
2. For programs with 10-layer per conduction path material limit, the following is recommended:
   - Combine the Insulated Block 1 and Insulated Block 2 layers as a single Insulated Block layer with thickness (d) = 0.120 m
   - Apply same values of k, ρ, and Cp for the merged layer as shown for the Insulated Block 1 (or Block 2) layer.
3. For programs with < 10-layer per conduction path material limit, apply Section 13.2.2.8.7.2.2.1, Informative Note 2 as generic guidance for merging additional layers.

**Table 13-14: Characteristics of the floor – Path 2**
(Net inside surface area = 1.4700 m²)

| Material | d Thickness [m] | k Conductivity [W/mK] | ρ Density [kg/m³] | Cp Specific heat [J/kgK] |
|---|---|---|---|---|
| Ceramic Tile | 0.006 | 1.75 | 2177 | 920 |
| Glue Cement | 0.003 | 1.50 | 1900 | 840 |
| Concrete | 0.008 | 1.75 | 2177 | 920 |
| Concrete + Tubes + Polysty Ribs [a] | 0.016 | 1.47 | 1813 | 954 |
| Polystyrene 1 | 0.035 | 0.0719 [b] | 16 | 1200 |
| Plastic Lining | 0.002 | 0.124 | 265 | 1170 |
| Concrete Slab | 0.065 | 1.75 | 2200 | 950 |
| Insulated Block 1 | 0.070 | 0.0719 [b] | 18 | 1200 |
| Concrete Beam 2 | 0.050 | 1.75 | 2200 | 950 |
| Polystyrene 2 | 0.030 | 0.0719 [b] | 18 | 1200 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |

a. ***Informative Note:*** Based on Figure 13-15, for simplification, layer properties here assume a by-volume-averaged blended layer of concrete, polystyrene, tubes, and air within empty tubes. Documentation of how this layer was calculated is included in Informative Annex B23, Section B23.6.
b. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.

***Informative Notes:***

1. Composite "air-to-air" R-value (R) for this heat flow path is:
   - R = 2.261 m$^2$K/W
   - This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.
2. For programs with 10-layer per conduction path material limit, the following is recommended:
   - Combine the Ceramic Tile and Glue Cement layers as a single Tile + Cement layer with the following properties:
     - d = 0.009 m
     - k = 1.658 W/(mK)
     - ρ = 2085 kg/m$^3$
     - Cp = 893 J/(kgK)
   - Documentation of how these properties were calculated is included in Informative Annex B23, Section B23.6.
3. For programs with < 10-layer per conduction path material limit, apply Section 13.2.2.8.7.2.2.1, Informative Note 2 as generic guidance for merging additional layers.

**Table 13-15: Characteristics of the floor – Path 3**
(Net inside surface area = 1.4700 m²)

| Material | d Thickness [m] | k Conductivity [W/mK] | ρ Density [kg/m³] | Cp Specific heat [J/kgK] |
|---|---|---|---|---|
| Ceramic Tile | 0.006 | 1.75 | 2177 | 920 |
| Glue Cement | 0.003 | 1.50 | 1900 | 840 |
| Concrete | 0.008 | 1.75 | 2177 | 920 |
| Concrete + Tubes + Polysty Ribs [a] | 0.016 | 1.47 | 1813 | 954 |
| Polystyrene 1 | 0.035 | 0.0719 [b] | 16 | 1200 |
| Plastic Lining | 0.002 | 0.124 | 265 | 1170 |
| Concrete Slab | 0.065 | 1.75 | 2200 | 950 |
| Concrete Beam 1 | 0.070 | 1.75 | 2200 | 950 |
| Concrete Beam 2 | 0.050 | 1.75 | 2200 | 950 |
| Polystyrene 2 | 0.030 | 0.0719 [b] | 18 | 1200 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |

a. ***Informative Note:*** Based on Figure 13-15, for simplification, layer properties here assume a by-volume-averaged blended layer of concrete, polystyrene, tubes, and air within empty tubes. Documentation of how this layer was calculated is included in Informative Annex B23, Section B23.6.

b. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.

***Informative Notes:*** Composite "air-to-air" R-value (R) for this heat flow path is:

1. Composite "air-to-air" R-value (R) for this heat flow path is:
   - R = 1.328 $m^2$K/W
   - This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.
2. For programs with 10-layer per conduction path material limit, the following is recommended:
   - Combine the Concrete Beam 1 and Concrete Beam 2 layers as a single Concrete Beam layer with thickness (d) = 0.120 m.
   - Apply same values of k, ρ, and Cp for merged layer as shown for the Concrete Beam 1 (or Beam 2) layer.
3. For programs with < 10-layer per conduction path material limit, apply Section 13.2.2.8.7.2.2.1, Informative Note 2 as generic guidance for merging additional layers.

### 13.2.2.8.8 Window and insulation module within east and south walls

#### 13.2.2.8.8.1 Required characteristics

Insulated windows are applied to both the south and east walls for the geometry shown in Figures 13-3 and 13-4 (see Sections 13.2.2.7.2.2 and 13.2.2.7.2.3), and shall have the following characteristics:

- UA = 2.50 W/K **reduction** to east and south wall uninsulated window UA values for the installed window insulation modules. I.e., window insulation reduces the overall wall + window UA-value from 9.36 W/K to 6.86 W/K for the east wall (see Section 13.2.2.8.3) and from 8.07 W/K to 5.57 W/K for the south wall (see Section 13.2.2.8.4). ***Informative Note***: See Informative Annex B23 for supporting information.
- Construction as shown in Figure 13-17.
- A window insulation module fills the rough opening in each wall (see Figures 13-3 and 13-4); each insulation module is applied to the external side of the window within the setback cavity that sets the window inward from the wall exterior surface (see Figure 13-17).

For modelers requiring further guidance to specify inputs of material properties, apply the alternative construction specification of Section 13.2.2.8.8.2. ***Informative Note:*** Use of the Section 13.2.2.8.8.2 alternative is recommended (see Section 13.2.1.3).

#### 13.2.2.8.8.2 Alternative construction specification

**13.2.2.8.8.2.1** If the modeler does not require further guidance to develop inputs as specified in Section 13.2.2.8.8.1, skip the remaining instructions and proceed to Section 13.2.2.9.

**13.2.2.8.8.2.2** The insulated window is divided into three parallel 1-D conduction path segments, corresponding to the method for which thermal conductivities of the selected material layers were externally imputed. ***Informative Note:*** See Informative Annex B23 for details regarding external imputation of thermal conductivities.

Figure 13-18 illustrates the three parallel 1-D conduction heat flow paths (Path 1, Path 2, and Path 3) to be applied in the simulations.

Tables 13-16, 13-17 and 13-18 provide thermal properties and thicknesses for each material layer of each parallel path (Path 1, Path 2, and Path 3, respectively, for each table), with the layer adjacent to the inside of the test cell at the top of the table, and then layers incrementally toward the guard zone for each row going down the table. Net inside surface area for each heat flow path is provided, respectively, in each table caption.

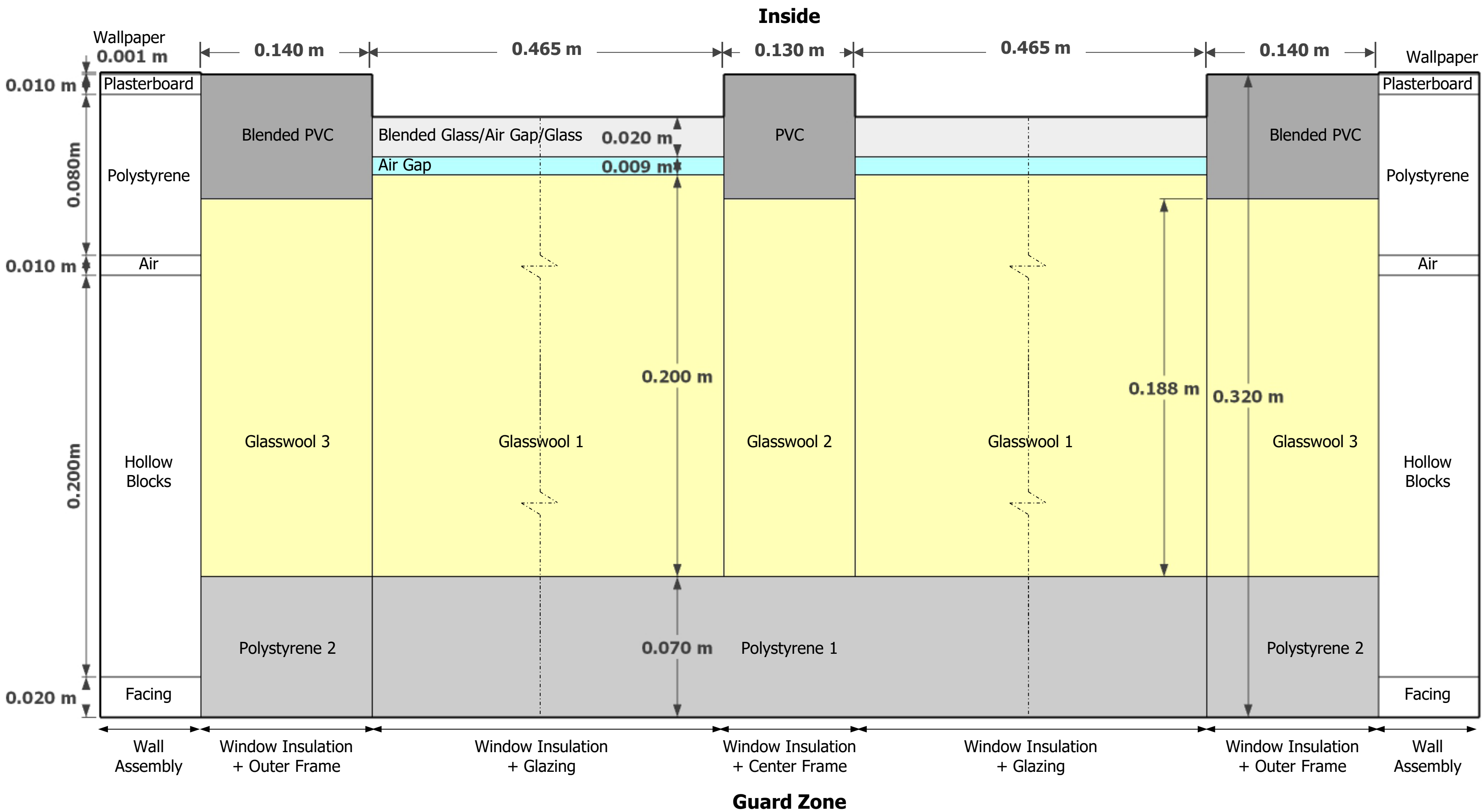



**Figure 13-17: Window Vertical Section (window and frame assembly), through the window and external setback cavity looking downward (or upward) – NOT TO SCALE**

- ***Informative Note:*** This figure is a simplification of the actual construction to reduce the greater chance for input errors with the more complicated actual construction. See Informative Annex B23, Section B23.6 for greater detail.

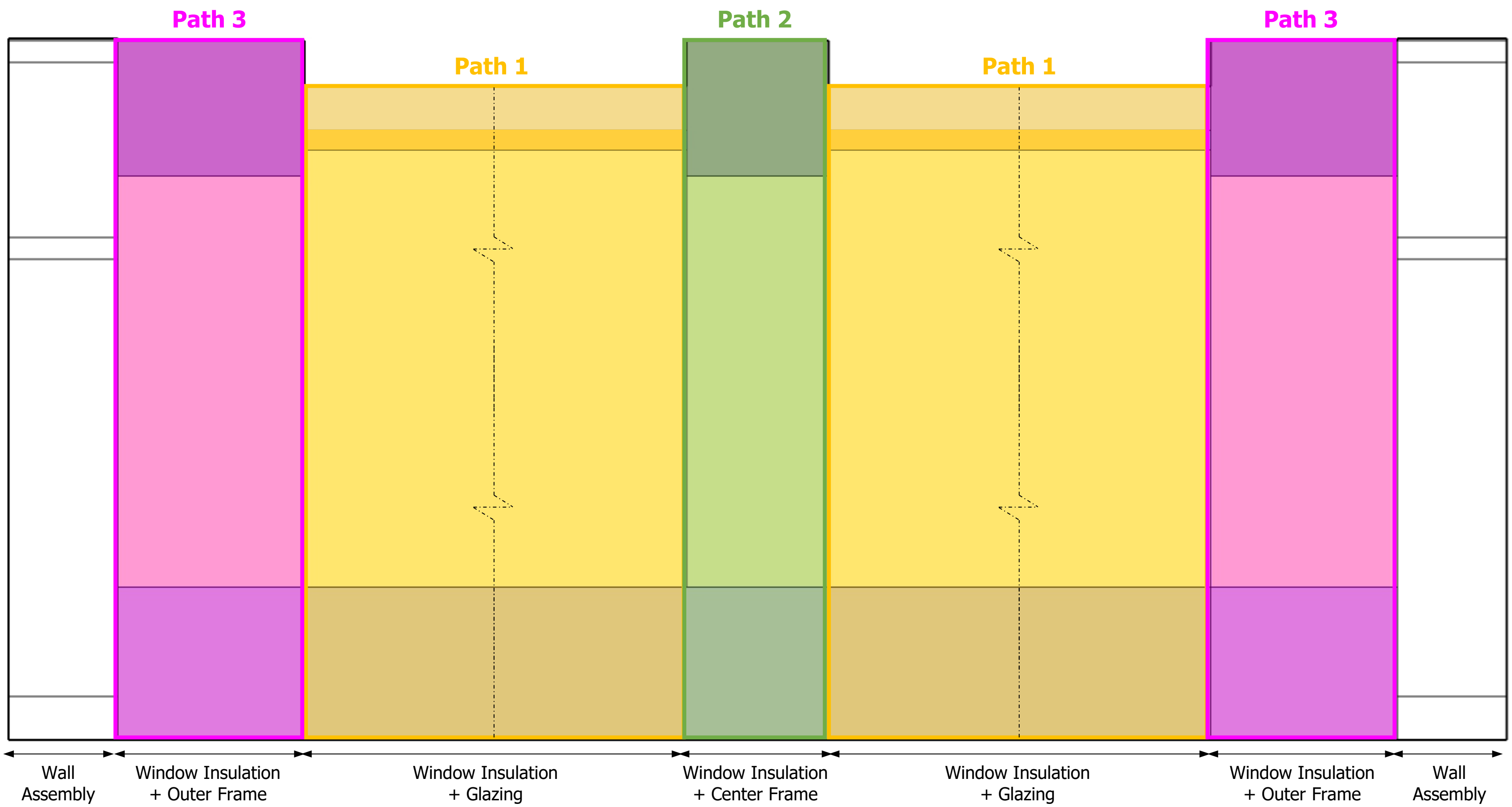



**Figure 13-18: Window vertical section view (window and frame assembly) of the insulated window parallel heat-flow paths, looking downward (or upward) – NOT TO SCALE**

**Table 13-16: Characteristics of insulated windows – Path 1**
(Net inside surface area = 0.9905 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| Blended Glass/Air Gap /Glass [a] | 0.020 | 0.124 | 1081 | 900 |
| Air Gap [b] | 0.009 | 0.1234 [c] | 1.2 | 1000 |
| Glasswool 1 | 0.200 | 0.0657 [c] | 11 | 800 |
| Polystyrene 1 | 0.070 | 0.0657 [c] | 16 | 1200 |

a. ***Informative Note:*** See Informative Annex B23, Section B23.6 for supporting information.
b. This air gap applies only to Path 1, i.e., the area over the glass pane as shown in Figures 13-17 and 13-18.
c. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 4.542 m²K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.

**Table 13-17: Characteristics of insulated windows – Path 2**
(Net inside surface area = 0.1385 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| PVC | 0.062 | 0.16 | 1380 | 1000 |
| Glasswool 2 | 0.188 [a] | 0.0657 [b] | 11 | 800 |
| Polystyrene 1 | 0.070 | 0.0657 [b] | 16 | 1200 |

a. The glasswool against the window frame is compressed from a total thickness of 0.2 m to 0.188 m.
b. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 4.513 m²K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.

**Table 13-18: Characteristics of insulated windows – Path 3**
(Net inside surface area = 0.6734 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| Blended PVC + facing + plasterboard [a] | 0.062 | 3.3570 [b,c] | 1442 | 975 |
| Glasswool 3 [d] | 0.188 [e] | 2.6227 [b,c] | 316 | 808 |
| Polystyrene 2 [d] | 0.070 | 2.6227 [b,c] | 320 | 1145 |

a. ***Informative Note:*** As a modeling simplification, the Path-3 window frame material includes the external setback cavity facing (known thermal bridge) and the plasterboard covering the facing on the test cell interior surface; see Informative Annex B23, Section B23.6 for supporting information.
b. ***Informative Note:*** For conduction heat transfer Path 3, all layers have greater imputed conductivities to account for 3-D conduction likely to occur because this path is a thermal bridge relative to the insulated window and opaque wall (see Tables 13-8, 13-9, 13-16, and 13-17).
c. Imputed conductivity input highlighted in yellow. ***Informative Note:*** This is based on Informative Annex B23.
d. ***Informative Note:*** As a modeling simplification, the Glasswool 3 and Polystyrene 2 materials include the external setback cavity facing (known thermal bridge); see Informative Annex B23, Section B23.6 for supporting information.
e. The glasswool against the window frame is compressed from a total thickness of 0.2 m to 0.188 m.
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 0.256 m²K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10.

### 13.2.2.9 Surface Radiative Properties

Table 13-19 indicates the solar absorptivity and infrared emissivity values corresponding to the surfaces of Cell A.

**Table 13-19 Surface Radiative Properties of Cell A [a]**

| Opaque Surface | Interior Radiative Properties | | Exterior Radiative Properties | |
|---|---|---|---|---|
| | Solar Absorptivity | Infrared Emissivity/ Absorptivity | Solar Absorptivity | Infrared Emissivity/ Absorptivity |
| North wall | 0.343 | 0.870 | 0.3 | 0.9 |
| East wall | 0.343 | 0.870 | 0.419 | 0.919 |
| South wall | 0.343 | 0.870 | 0.419 | 0.919 |
| West wall | 0.343 | 0.870 | 0.343 | 0.870 |
| Ceiling | 0.343 | 0.870 | 0.3 | 0.9 |
| Floor | 0.249 | 0.846 | 0.3 | 0.9 |
| Door (North) | 0.439 | 0.872 | 0.439 | 0.872 |
| Insulated Window Glazing | 0.5[b] | 0.9 | 0.419 | 0.919 |
| Insulated Window Frame | 0.343 | 0.870 | 0.419 | 0.919 |

a. Properties are from the originating source document[c-1], except where otherwise noted.

b. Rough estimate for unmeasured glass wool behind glazing.

### 13.2.2.10 Surface heat transfer

The constant interior and exterior combined convective and radiative surface coefficients (*h,comb,int* and *h,comb,ext*, respectively) of Table 13-20 shall be applied. Time-step varying calculation of surface heat transfer coefficients is prohibited. Use of constant values other than those of Table 13-20 is prohibited.

**Table 13-20 Interior and Exterior Combined Surface Heat Transfer Coefficients of Cell A**

| | Interior Surface *h,comb,int* (W/(m$^2$K)) | Exterior Surface *h,comb,ext* (W/(m$^2$K)) |
|---|---|---|
| North wall | 10.5 | 18 |
| East wall | 7.0 | 18 |
| South wall | 7.0 | 18 |
| West wall | 5.3 | 18 |
| Ceiling | 3.6 | 18 |
| Floor | 5.3 | 18 |
| Door (North) | 10.5 | 18 |
| Insulated Windows, East & South | | |
| Path 1 (through glass) | 7.0 | 18 |
| Path 2 (through inner frame) | 7.0 | 18 |
| Path 3 (through blended outer frame) | 12.0 | 18 |

***Informative Notes:***

1. Values of Table 13-20 are based on measured data; see Informative Annex B23, Section B23.5 for details.
2. The values of Table 13-20 are applied to develop imputed thermal conductivities of various wall constructions of Section 13.2.2.8; see Informative Annex B23 for details.
3. The greater coefficient of insulated window Path 3 shown in Table 13-20 is the same as that determined for the uninsulated window (see Section 13.2.4.9 [Case ET100A1]). This is for consistency with Path 3 having greater insulation conductivities to account for thermal bridging and 3-D conduction (see Table 13-18, informative note b).
4. 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 for interior and/or exterior surfaces as convective coefficients, and set respective surface emittances to 0 (or as low as the program being tested allows).

5. Constant surface coefficients presented here apply only to this test suite as they are specified for each test case and were determined only for the given test-case configurations; they should not be assumed to apply beyond this test suite.

### 13.2.2.11 Thermal Bridges

***Informative Notes:***

1. Listed material thermal conductivity imputations based on measured surface UA values (specified in Section 13.2.2.8) are intended to incorporate as-constructed variations of actual thermal properties relative to nominal thermal properties, including variations caused by unspecified thermal bridges.
2. Appendix D of the originating source document[c-1] includes details of junctions between surfaces.

### 13.2.2.12 Infiltration

Infiltration = 0 ACH.
***Informative Note:*** Listed material thermal conductivity imputations based on measured surface UA values (specified in Section 13.2.2.8) are intended to incorporate as-constructed variations of overall thermal properties relative to nominal thermal properties, including variations caused by unintended infiltration air leaks.

### 13.2.2.13 Interior solar distribution

A consistent interior solar distribution modeling method shall be applied for all test cases.

***Informative Note:*** In the artificial climate configuration, there is no incident solar radiation on any of the exterior surfaces of the actual test cell; therefore, there is no absorbed solar radiation on any of these surfaces and no transmitted solar radiation in the test cell.

### 13.2.2.14 Internal gains

For Case ET110A, hourly-integrated measured fan energy is included with the test data (see Section 13.2.2.2.1).

- Apply all fan energy as a sensible internal gain that is 100% convective.

***Informative Notes:***

1. The air distribution fan and its motor are located fully within the test cell such that all fan energy goes to heat within the test cell.
2. For the ET110A data acquisition period, hourly fan energy ranges from 0 to 225 Wh/h.
3. There are no other internal gains in the test cell (no lighting, no occupants, etc.).

### 13.2.2.15 Thermal Guards

While guard zone temperature data is fully available, guard zone construction details are approximate. Two methods of modeling guard zones are indicated depending on what the program being tested allows:

- For programs that allow guard zones to be modeled as bounding surface exterior boundary conditions, see Section 13.2.2.15.1
- For programs that require detailed modeling of guard-zone geometry (i.e., that do not have an option to model zones adjacent to the test cell as external boundary conditions), see Section 13.2.2.15.2

***Informative Note:*** Modeling guard zones as exterior surface boundary conditions, as in Section 13.2.2.15.1, is recommended because such a model reduces complexity and therefore reduces the potential for input errors.

**13.2.2.15.1 Modeling guard zones as exterior surface boundary conditions**

- Apply separate guard-zone air temperatures to each test cell bounding surface as specified in Section 13.2.2.2
- Apply exterior combined surface heat transfer coefficients to test cell bounding surfaces as specified in Section 13.2.2.10.
- Skip the remaining instructions and proceed to Section 13.2.2.16

**13.2.2.15.2 Detailed modeling of guard zone geometry and construction**

**13.2.2.15.2.1 Geometry.**
Apply overall test cell geometry of Figures 13-6 through 13-8; see Section 13.2.2.7.3.

**13.2.2.15.2.2 Constructions.**
Construction details of the guard zones are not provided, other than for each guard zone's surface in common with the test cell (primary surface) as described in Sections 13.2.2.8 (Cell A) and 13.2.3.7 (Cell B). Users shall develop an approximate model of each guard zone's other surfaces based on the following qualitative descriptions. ***Informative Note:*** For developing the Cell A model, it is only necessary to model the guard zones adjacent to Cell A. Cell B and the guard zones adjacent to Cell B may be added later when developing Case ET110B1 (Section 13.2.3)

**13.2.2.15.2.2.1 North, East (Cell A), West (Cell B), Cellar, and Attics Guard Zones**

The load bearing structure of these guard zones is a wooden structure (pine wood). Internal surfaces of the wall are covered with polystyrene and with plywood**.** The material used for external surfaces exposed to ambient weather conditions of the Cell A East, Cell B West, and Attic guards is metallic cladding.

Test cell windows (east window Cell A, west window Cell B) are shielded from direct infrared radiation exchange with the guard zone-to-ambient-bounded walls by large black plywood/insulation panels hung between walls and windows in the Cell A East and Cell B West guard zones, so that the guard zone air temperature is also appropriate for calculating infrared radiation exchange between the guard zone and the test cell windows.

***Informative Notes:***

1. North guard zones of Cell A and Cell B and generally other guards' constructions are further informed by the originating source document[c-1].
2. In Figures 2 and 3 of the originating source document[c-1], the following labeling is applied regarding the guard zones: "bisA" is Cell A North; "bisB" is Cell B North; "sas 1" is Cell A East; "sas 3" is Cell B West.

**13.2.2.15.2.2.2 West (Cell A) and East (Cell B) guard zones**

***Informative Note:*** These guard zone constructions are further informed by Figures 2 and 3 of the originating source document[c-1], where in Figure 2 the following labeling is applied regarding the guard zones: "Calcul" is Cell A West; "Escalier" is Cell B East.

**13.2.2.15.2.2.3 South Guard Zone**

Artificial climate is achieved by use of a single large mobile thermal guard zone affixed to the south side (bounding the south walls) of both test cells. This mobile thermal guard is made up of four blocks, assembled together. The load bearing structure is a steel structure. Interior surfaces of the guard zone exterior walls are covered with polyurethane (thickness: 0.20 m).

In the south thermal guard zone, infrared radiation exchange from the guard-zone surfaces to the window was not directly shielded by black plywood/insulation panels.

***Informative Note:*** In Figure 2 of the originating source document[c-1], "sas 2" is the mobile south guard.

**13.2.2.15.2.3 Guard zone interior surface heat transfer**

**13.2.2.15.2.3.1 Surfaces comprising test cell boundary walls.**

Apply exterior combined surface heat transfer coefficients to the exterior side of the test cell bounding surfaces as specified in Sections 13.2.2.10 (Cell A) and 13.2.3.9 (Cell B).

**13.2.2.15.2.3.2 All other guard-zone interior surfaces.**

Apply the exterior combined surface heat transfer coefficients specified in Sections 13.2.2.10 (Cell A) and 13.2.3.9 (Cell B) to the interior side of all guard zone bounding surfaces.

**13.2.2.15.2.4 Exterior surface heat transfer: South, East (Cell A), West (Cell B), and Attic**

For guard zones with exterior surfaces exposed to ambient conditions (having dynamic variation), the modeler shall select the following as allowed by their program:

- A time-step varying exterior surface convection heat transfer algorithm, or constant surface convection coefficient(s) applied to each exterior surface face
- A time-step varying exterior surface infrared radiation exchange algorithm.

**13.2.2.15.2.4.1 Exterior Surface Texture.**

For programs that allow variation of exterior surface heat transfer with surface texture, exterior surface texture shall be selected within the tested program consistent with the surface material indicated in Section 13.2.2.15.2.2.

**13.2.2.15.2.5 Guard Zones Temperature Control and Data.**

Apply separate guard-zone air temperatures to each guard zone as specified in Section 13.2.2.2.
***Informative Note:*** A cooling/heating system controls the individual guard-zone temperatures separately for each test cell, except for the cellar and the south guard zones as follows:

- For the cellar, a single control set point regulates the cellar guard zone temperatures for both Cell A (TcellarA) and Cell B (TcellarB). This resulted in an offset of about 0.1°C to 0.2°C between TcellarA and TcellarB.
- For the south guard zone, an individual cooling/heating system is installed in this guard zone and a single control point regulates the south guard zone temperatures for both Cell

A (TsouthA) and Cell B (Tsouth2B). This resulted in an offset of about 0.2°C to 0.3°C between TsouthA and TsouthB.

***Informative Note:*** Approximate set points are given in Appendix B of the originating source document[c-1]. Although the test cell temperatures are generally controlled within a range of 0.1°C, there is occasional drift outside that range. The guard zones exhibit somewhat greater temperature drift.

### 13.2.2.16 Mechanical System

***Informative Notes:***

1. A mechanical system is specified to provide the sensible heating needed to maintain the modeled heating setpoint temperatures.
2. For the purpose of the 1-D conduction test of ET110A, the mechanical system is idealized to match the assumptions applied during external imputation of selected thermal conductivities (see Section 13.2.2.8.1.2).
3. The intent of the mechanical system is to:
   a. Produce only pure heating load output
   b. Emulate the well-mixed zone air assumption common to BPS software, while providing realistic interior convective surface heat transfer.
4. Details of the mechanical system designed to emulate these idealizations are provided in Sections 2.2.1.7.1.3 and 2.2.1.7.2 of the originating source document[c-1].

### 13.2.2.16.1 Equipment Characteristics (Heater with Diffusers, HWD)

#### 13.2.2.16.1.1 Heater Power Capacity and Efficiency

a) Capacity:

i) For programs with idealized mechanical systems that implicitly assume unlimited or nearly unlimited capacity, such capacity shall be allowed, and proceed to Item b.

ii) For programs that do not provide an idealized mechanical system that implicitly assumes unlimited or nearly unlimited capacity, use the following for developing the heating capacity input to the software being tested:

Heating Capacity ≥ 1215 Wh/h

***Informative Note:*** For the Period 1, Case ET110A data acquisition period, i.e., from 00-01-26-12:00 through 00-02-11-09:00 (GMT+1), maximum measured hourly-integrated heating energy in Cell A is 1214.40 Wh/h, and the measured heating power at steady state is less than the maximum measured heating power. ***As the method of the test case is for programs to maintain hourly test cell air temperature (Tcell), any heating capacity entered into the software that is sufficient to maintain Tcell throughout the test case data acquisition period – without creating other issues (e.g., model instability) that may arise from excessive oversizing – is satisfactory.***

b) Efficiency:

- 100% efficient heater

- Equipment efficiency shall always be 100% independent of part loading, test-cell indoor dry-bulb temperature and humidity ratio, guard-zone dry-bulb temperature and humidity ratio, and/or other conditions
- No duct losses.

**13.2.2.16.1.2 Estimated Radiative Fraction**

Radiative fraction (F,rad) = 0

where, F,rad = (radiated energy)/(convected energy + radiated energy).

***Informative Note:*** This represents an idealized 100% convective air system.

**13.2.2.16.1.3 Fan Energy**

Fan energy shall be modeled as an internal gain (see Section 13.2.2.14) and shall not be modeled explicitly as part of the mechanical system. If the program being tested requires an air-distribution fan, it shall be specified to consume no energy.

**13.2.2.16.2 Thermostat**

**13.2.2.16.2.1 Thermostat Set Point.**

a) Apply setpoint values for test-cell air temperatures and guard-zone air temperatures included in the data file specified in Section 13.2.2.2. ***Informative Note:*** For Cases ET110A, ET110B, ET100A, and ET100B, test cell air temperature set point = 35°C. Although the test cell temperatures are generally controlled within a range of 0.1°C, there is occasional drift outside that range.

b) If the simulation program being tested allows, input hourly test cell air (setpoint) temperatures using either a detailed setpoint schedule input or an external input file, developed from the hourly data.

**13.2.2.16.2.2 Thermostat Control Features.**

**a) The thermostat shall sense only the test-cell air temperature.** ***Informative Note:*** This is a bulk average air temperature shielded from infrared and solar radiation as described in Figure 18 (Section 2.2.1.7.2) of the originating source document[c-1].

**b) The thermostat shall be nonproportional.** ***Informative Note:*** A nonproportional thermostat operates such that 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. A proportional thermostat throttles the heat addition rate (or extraction rate if there is cooling) 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).

### 13.2.3 Case ET110B1: Artificial Climate, Steady-State Overall Building Loss Coefficient with Insulated Windows, Cell B, Applying Specified Catalog Material Properties Except for Selected Imputed Insulation Conductivities

#### 13.2.3.1 (*Informative*) Objectives and Method of the Test Case

#### 13.2.3.1.1 Objectives

The objectives of this case are the same as for Case ET110A1, except applied for Cell B.

#### 13.2.3.1.2 Method

a. Case ET110B1, applying Cell B, is specified as an extension case based on the Cell A artificial climate base case (Case ET110A1).

b. As specified below, Cell B is constructed as a twin of Cell A except its East and West walls are juxtaposed versus Cell A, and Cell B has different imputed conductivities than Cell A based on different measured wall UA values. Cell B also has different test cell input and guard zone temperature data versus Cell A. Twin test cells are most useful for testing the ability to model sensitivities in the natural climate configuration. Therefore, it is necessary to characterize Cell B in parallel with Cell A, as shown in this test specification.

c. Similarly as Cell A (Case ET110A1), guard-zone temperatures ($T_{guards}$) were set to approximately $T_{guards}$ = 10˚C and test cell temperature set to $T_{cell}$ = 35 ˚C. See data files listed in Section 13.2.3.3 for guard zone and test cell hourly temperatures (set points). For an idealized heating system (that effectively outputs building load), apply results comparisons as listed with Objectives and Methods for Case ET110A1; see Informative Section 13.2.2.1.2, Item b.

#### 13.2.3.2 Extension Case Basis

Case ET110B1 shall be modeled exactly the same as Case ET110A1 except for changes detailed in the following sections.

#### 13.2.3.3 Test Cell Conditions and Guard-Zone Temperatures

Hourly data files and the test data sets durations for Case ET110B1 are listed in Table 13-21. These data files are included with the accompanying electronic media; see Readme-140-2023-B.docx. The data files apply the same conventions as Case ET110A1; see Section 13.2.2.2.1.

The ET110B-Measurements.csv hourly data format is given in Table 13-22. The header labels of Table 13-22 apply similarly as those for Table 13-3 (see Section 13.2.2.2.1), except “Usage” category “Output” (only for data labeled “Qhtr”) relates to the requirements of Section 13.3.3.

**Table 13-21 Primary Data File Directory (Case ET110B1)**

| File Name | Data Type | Time Step | Data Duration ("MM/DD/YYYY hh") |
|---|---|---|---|
| ET110B-Measurements.csv [d] | Test Cell B | Hour | 01/26/2000 12 through 02/11/2000 09 |
| ET110meteo_within_Melun-071530_MY.2000.epw [a,b,c,d] | Local facility weather inserted within Melun, France AMY data | Hour | 01/01/2000 01 through 12/31/2000 24 |

a. ***Informative Note:*** This is the same weather data provided for Case ET110A1.
b. ***Informative Note:*** Epw format is described at: http://climate.onebuilding.org/papers/EnergyPlus_Weather_File_Format.pdf. [c-4]
c. ***Informative Note:*** In the artificial climate cases, for programs that model guard zones as boundary conditions applied to each test cell wall rather than as literal zones, the weather data is essentially dummy data – i.e., not used in the model other than to satisfy the requirement of most BPS software to have a weather data set.
d. ***Informative Note:*** For further supporting information regarding these data files, see Readme-140-2023-B.docx and the originating source document[c-1].

**Table 13-22 Cell B Hourly Data Format**

| Column | Label | Usage | Description | Units |
|---|---|---|---|---|
| A | Date | Input | Date and time in format "MM/DD/YYYY hh:mm" (preceding hour format, e.g., Hour 10:00 = 09:00-10:00) | |
| B | Tattic | Input | Attic air temperature [a] | ºC |
| C | Tcellar | Input | Cellar air temperature [a] | ºC |
| D | Tnorth | Input | North guard air temperature [a] | ºC |
| E | Teast | Input | East guard air temperature [a] | ºC |
| F | Tsouth | Input | South guard air temperature [a] | ºC |
| G | Twest | Input | West guard air temperature [a] | ºC |
| H | Tcell | Input | Test cell setpoint temperature [a] | ºC |
| I | Qfan | Input | Fan energy | Wh |
| J | HWDsafr | Input | Fan supply airflow rate, for heater with diffusers (HWD) | $m^3/h$ |
| K | Qhtr | Output | Heater energy | Wh |

a. See Figure 13-19 (Section 13.2.3.6.1) and Figures 13-6 and 13-8 (Section 13.2.2.7.3, Case ET110A1) for location of Cell B guard zones.

***Informative Notes:***

1. Within the .csv file each line contains data for one hour, and the first four lines include column labels and units.
2. Cell B air (setpoint) temperature sensor locations are given in Figure 18 (Section 2.2.1.7.2) of the originating source document[c-1]. Guard zone temperature sensors were located centrally to represent average guard zone temperatures; the precise locations were not documented.

### 13.2.3.4 Simulation Duration and Initialization

Simulation duration and initialization shall be in accordance with the requirements of the software implementation of a given test case.

***Informative Notes:***

1. The experimental data duration is as described in Table 13-21 (Section 13.2.3.3) for the file ET110B-Measurements.csv.
2. The intent of the simulation is to include as much of the provided experimental data as possible for the tested software. This data provides an initialization period ahead of the best steady-state data period intended for comparing software output to measured data and empirical values derived from measured data (see Section 13.3.3.4).
3. If the tested software requires a longer initialization period than provided in the experimental data, a typical technique of extending the data for the software should be applied. Such a technique is at the discretion of the modeler, and may be based on review of the first day or two of the csv file input data (see Section 13.2.3.3).

### 13.2.3.5 Output Requirements.

Output shall be provided as specified in Sections 13.3.1 and 13.3.3.

### 13.2.3.6 Geometry.

Cell B shall be exactly the same as Cell A, except as described in the following sections.

Two options for modeling guard zones are specified depending on the capabilities of the tested programs:

1) guard zones modeled as boundary conditions on the exterior side of each test cell bounding surface (Section 13.2.3.6.1)
2) guard zones modeled as separate zones adjacent to the test cell bounding surfaces (Section 13.2.3.6.3).

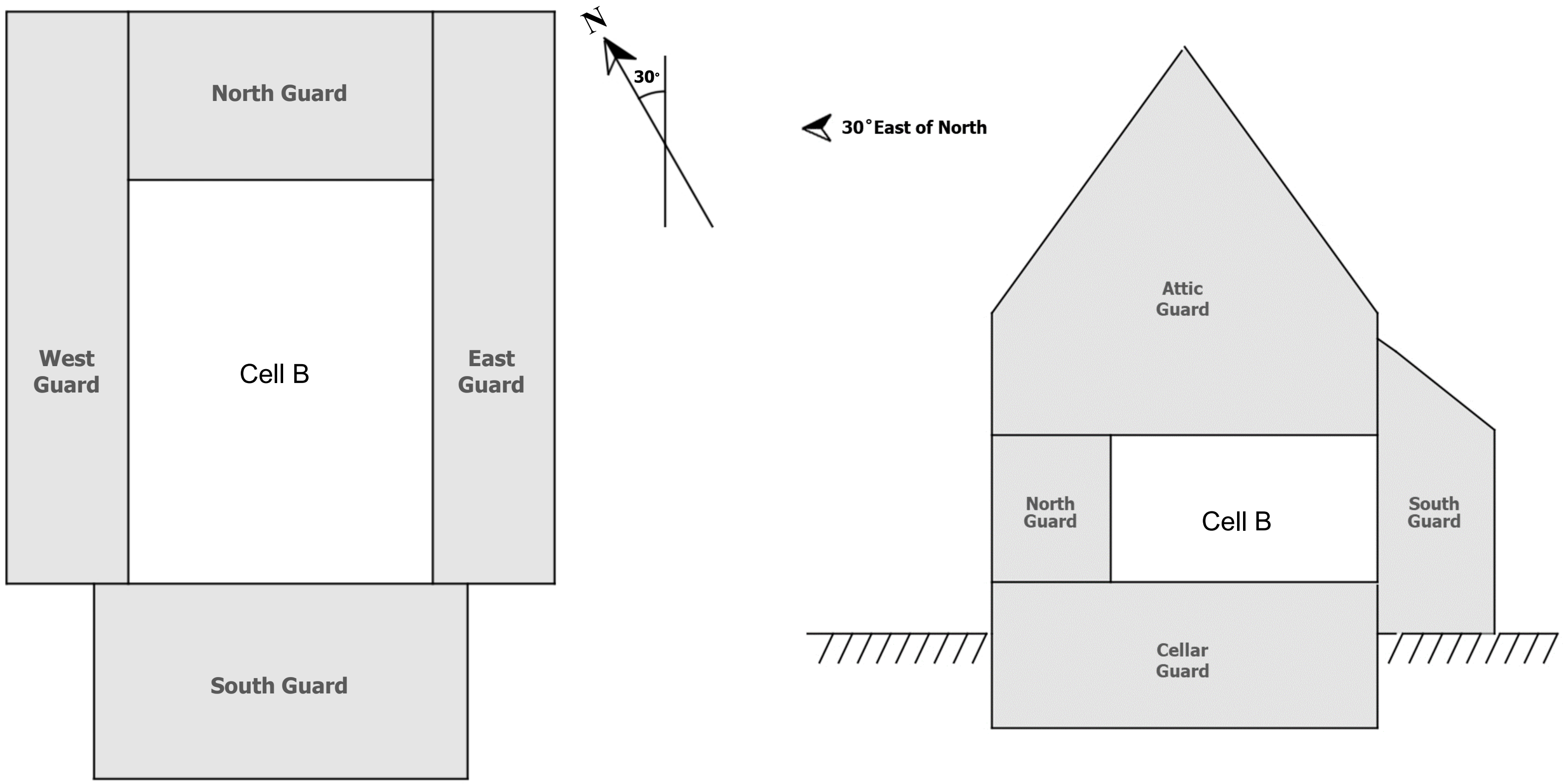
#### 13.2.3.6.1 Summary geometry for models applying guard zones as boundary conditions

For programs that require modeling the guard zones as actual physical zones, see the instructions of Sections 13.2.3.6.2 and 13.2.3.6.3, and skip the remainder of this section.

As shown in Figure 13-19, the building is oriented 30° E of North, so that the test cell bounding surface that would nominally be called the "South" wall is oriented at 30° West of South, and the other walls are oriented and named accordingly with orientations offset 30° from their nominal cardinal directions. ***Informative Note:*** This is the same orientation as Cell A.

Figure 13-19 also shows the plan view and a sectional view of Cell B and indicates the names of its six guard zones. These names are associated with hourly data identifiers within the accompanying file ET110B-Measurements.csv (see previous Section 13.2.3.3); e.g., "Tsouth" designates the south guard zone temperature data provided in column F of the file.

Other information for defining the guard zones as boundary conditions, related to surface heat transfer and additional supporting data, are provided in Sections 13.2.3.9 (Surface Heat Transfer) and 13.2.3.12 (Thermal Guards).




*Plan View*

*Elevation Section View (looking 30° south of east through page)*

**Figure 13-19: Test Cell B, Summary Diagrams with Artificial-Climate Thermal Guards**

Note 1: Cell B internal dimension details are provided in Figure 13-20.

Note 2: Attic and cellar also fully cover ceiling and floor, respectively, of Cell B and east guard.

Note 3: For models applying guard zones as actual physical zones, guard zone dimensions are provided in Figures 13-6 through 13-8 (see Section 13.2.2.7.3 [Case ET110A1]).

### 13.2.3.6.2 Test cell detailed geometry

Cell B shall be exactly the same as Cell A, except the east and west walls are juxtaposed applying the following:

- Section 13.2.3.6.2.1 replaces Section 13.2.2.7.2.1 (primary inside surfaces)
- Section 13.2.3.6.2.2 (west wall and window) replaces Section 13.2.2.7.2.3 (east wall and window)
- Section 13.2.3.6.2.3 replaces Section 13.2.2.7.2.5 (surface area summary)

All other Cell B geometry is the same as for Cell A.

#### 13.2.3.6.2.1 Cell B primary inside surfaces

Cell B shall be exactly the same as Cell A, except the east and west walls are juxtaposed

Figure 13-20 specifies the inside-surface (interior) dimensions of Cell B. Interior surface dimensions for the east wall, floor, and ceiling are taken directly from this figure.

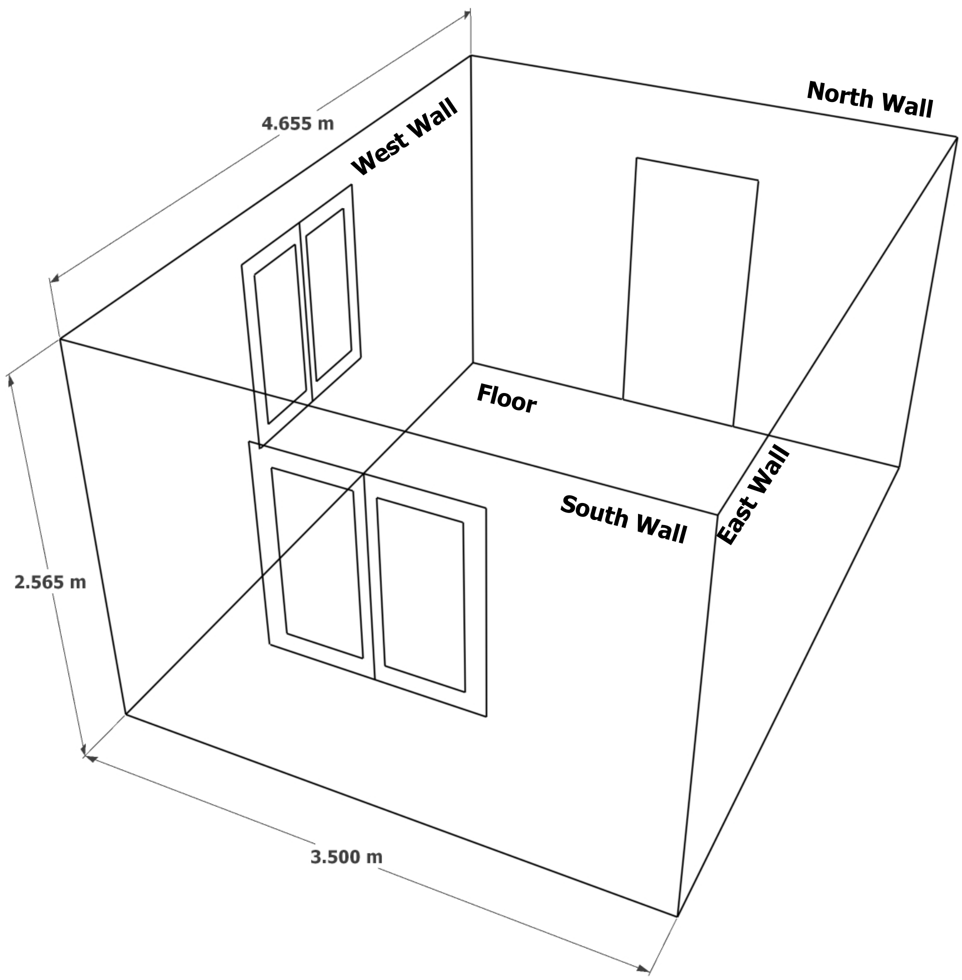



**Figure 13-20 Inside-Surface Dimensions of Cell B**

Note: Ceiling is at 2.565 m height, parallel to floor, with same dimensions as floor.

#### 13.2.3.6.2.2 West wall and window

Figure 13-21 specifies the west wall geometry as viewed from the exterior, including the position of the window in the west wall and the dimensions of the window glazing panels and framework. ***Informative Notes:***

1. This is the same geometry as for the Cell A east wall, except the dimensions that define the horizontal position of the window within the west wall have been juxtaposed.

2. As the west wall is guarded in both artificial and natural climate cases, the exact position of the window within the wall should not affect the results.

3. In cases with insulation applied externally to windows, such as Case ET110B1, the windows may be modeled as walls, or subsections of walls, because with window insulation in place (see Section 13.2.2.8.8 [Case ET110A1]) there is no transmitted solar radiation.

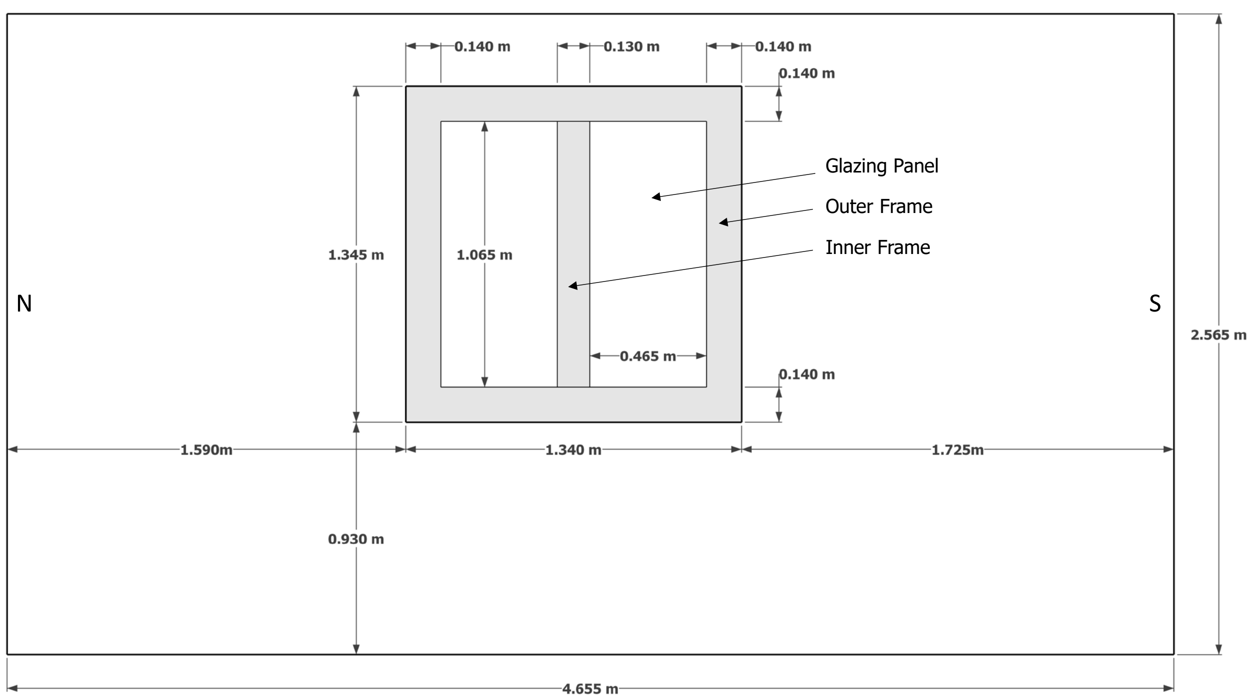



**Figure 13-21: Cell B dimensioned west wall with window elevation, exterior view**

### 13.2.3.6.2.3 Surface area summary.

The Cell B component surfaces areas shall be the same as for Cell A except the east and west walls are exchanged as shown in Table 13-23. This table indicates the component surface areas for the Cell B west wall, along with overall total areas for the west and east walls. This table also includes the sub-areas for the five alternative 1-D conduction paths that are exchanged **shown in bold font;** these are defined with the construction details of Section 13.2.3.7, as summarized in Section 13.2.3.7.1.2. See Table 13-5 (Section 13.2.2.7.2.5 [Case ET110A1]) for component surface areas for the floor, ceiling, north wall, and south wall.

***Informative Note:*** This table is intended for checking geometry inputs by comparing tested-program intermediate geometry output with this table.

**Table 13-23 Cell B Boundary-Surface Areas [a]**

| | | | Spec Reference | |
|---|---|---|---|---|
| | Envelope Component | Area [m$^2$] | Figures | Tables |
| West Wall | **West Wall Without Window** | **10.1378** | 13-21 | 13-27 |
| | **Window Path 1 (Glazing)** | **0.9905** | 13-21, 13-17, 13-18 | 13-35 |
| | **Window Path 2 (Inner Frame)** | **0.1385** | 13-21, 13-17, 13-18 | 13-36 |
| | **Window Path 3 (Outer Frame)** | **0.6734** | 13-21, 13-17, 13-18 | 13-37 |
| | West Wall Total | 11.9401 | 13-20, 13-21 | -- |
| East Wall | **East Wall Total** | **11.9401** | 13-20 | 13-29 |

Source: Argonne Box\Addendum_ETNA_140 \140-2023-Addendum-b-docx\Surface Area Check (041125).xlsx 041125_B!B2:F9

**a. Sub-areas for the five alternative 1-D conduction paths defined in Section 13.2.3.7 for the Cell B west and east walls are shown in bold font.**

### 13.2.3.6.3 Alternative geometry for programs that require physically defining the guard zones

Users that apply guard zones as boundary conditions (per Section 13.2.3.6.1) in place of physically defining guard zone geometry and material constructions shall skip this section and continue with Section 13.2.3.7.

Users with programs that require physically defining the guard zones shall apply the instructions of Section 13.2.2.7.3 (Case ET110A1) and apply guard zone geometry to Cell B as shown in Figures 13-6 through 13-8 there. In Figure 13-7, the dimensions depicted for Cell A and its guard zones are the same for Cell B, except the “East Guard” of Cell A becomes the “West Guard” (see the note with Figure 13-7).

Figures 13-6 through 13-8 also indicate the names of each guard zone. These names are associated with hourly data identifiers within the accompanying file ET110B-Measurements.csv (see previous Section 13.2.3.3); e.g., “Tsouth” designates the south guard zone temperature data provided in column F of the file.

**13.2.3.7 Test Cell Bounding Surface Material Constructions.**

The following sections specify material constructions of the test cell bounding surfaces and subsurfaces:

- Construction modeling options (Section 13.2.3.7.1)
- Required characteristics (Section 13.2.3.7.2)
- Alternative construction properties tables (Section 13.2.3.7.3)

## 13.2.3.7.1 Construction Modeling Options

In the following sections for each bounding surface, construction specifications are presented as required characteristics and alternative construction specifications.

**13.2.3.7.1.1** Required characteristics include:

- Empirically determined UA values
- Construction details, as shown in the figures.

**13.2.3.7.1.2** Alternative construction specifications consist of material properties tables that include:

- Catalog values
- Imputed thermal conductivities for selected material layers; imputed values are highlighted in yellow.
- 16 parallel 1-D conduction paths applied for determining the imputed thermal conductivities.

***Informative Notes:***

1. Material property tables in the following sections are intended for simulations applying 1-dimensional thermal diffusion models, and are derived based on the interior surface area of a given bounding surface.
2. Imputed properties are only valid for the given conduction paths.
3. The alternative construction specifications are recommended for use based on Section 13.2.1.3.
4. Informative Annex B23 describes calculation of imputed values.

## 13.2.3.7.2 Required Characteristics

Table 13-24 specifies UA values and cross-references required geometry and construction figures for each wall.

For modelers requiring further guidance to specify inputs of material properties, apply the alternative construction specification of Section 13.2.3.7.3. ***Informative Note:*** Use of the Section 13.2.3.7.3 alternative is recommended (see Section 13.2.1.3).

**Table 13-24 Cell B Required Characteristics (Case ET110B1)**

| Wall | UA Value, W/K | Geometry Figure | Construction Figure |
|---|---|---|---|
| North | 5.70 | Figure 13-5 [b] (Section 13.2.2.7.2.4) | Figure 13-9 [b] (Section 13.2.2.8.2.1) |
| Door | Included with North wall | Figure 13-5 [b] (Section 13.2.2.7.2.4) | Figure 13-10 [b] (Section 13.2.2.8.2.1) |
| East [a] | 3.02 | Figure 13-20 (Section 13.2.3.6.2.1) | Figure 13-12 [a] (Section 13.2.2.8.5.1) |
| South | 8.68 | Figure 13-3 [b] (Section 13.2.2.7.2.2) | Figure 13-11 [b] (Section 13.2.2.8.3.1) |
| West [a] | 8.94 | Figure 13-21 (Section 13.2.3.6.2.2) | Figure 13-11 [a] (Section 13.2.2.8.3.1) |
| Ceiling | 2.52 | Figure 13-20[c] (Section 13.2.3.6.2.1) | Figure 13-13 [b] (Section 13.2.2.8.6.1) |
| Floor | 7.28 | Figure 13-20 [c] (Section 13.2.3.6.2.1) | Figure 13-15 [b] (Section 13.2.2.8.7.1) |
| Window Insulation Module | Reduces west and south walls each by 2.44 W/K | Figure 13-3 [b] Figure 13-21 | Figure 13-17 [b] (Section 13.2.2.8.8.1) |

a. ***Informative Note:*** Cell B East and West walls are juxtaposed versus Cell A.

b. ***Informative Note:*** Same figure as for Cell A.

c. ***Informative Note:*** Ceiling and floor of Cell B have same geometry as Cell A.

### 13.2.3.7.3 Alternative Construction Specification

**13.2.3.7.3.1** If the modeler does not require further guidance to develop inputs as specified in Section 13.2.3.7.2, skip the remaining instructions and proceed to Section 13.2.3.8.

**13.2.3.7.3.2** Changes shall be made to selected imputed material thermal conductivities specified in Section 13.2.2.8 (Case ET110A1); imputed values for Cell B replacing imputed values for Cell A are indicated via footnotes and bold yellow-highlighted text in the following tables:

- Characteristics of the North wall: Table 13-25 replaces Table 13-6
- Characteristics of the Door: Table 13-26 replaces Table 13-7
- Characteristics of the West wall: Table 13-27 replaces Table 13-8 (Cell A East)
- Characteristics of the South wall: Table 13-28 replaces Table 13-9
- Characteristics of the East wall: Table 13-29 replaces Table 13-10 (Cell A West)
- Characteristics of the Ceiling – Path 1: Table 13-30 replaces Table 13-11
- Characteristics of the Ceiling – Path 2: Table 13-31 replaces Table 13-12
- Characteristics of the Floor – Path 1: Table 13-32 replaces Table 13-13
- Characteristics of the Floor – Path 2: Table 13-33 replaces Table 13-14
- Characteristics of the Floor – Path 3: Table 13-34 replaces Table 13-15
- Characteristics of Insulated Windows – Path 1: Table 13-35 replaces Table 13-16
- Characteristics of Insulated Windows – Path 2: Table 13-36 replaces Table 13-17

- Characteristics of Insulated Windows – Path 3: Table 13-37 replaces Table 13-18

**Table 13-25: Characteristics of the North wall (Case ET110B1)**
(Net inside surface area = 7.1494 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/m.K] | ρ<br>Density<br>[kg/m³] | Cp<br>Specific heat<br>[J/kg.K] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |
| Air / Honeycomb Cardboard | 0.046 | 0.307 | 26.1 | 1340 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Styrodur | 0.060 | **0.0518** [a] | 18 | 1200 |

**a. Imputed value for Case ET110B1.**
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:
- R = 1.547 m$^2$K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

**Table 13-26: Characteristics of the Door (Case ET110B1)**
(Net inside surface area = 1.8281 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/m.K] | ρ<br>Density<br>[kg/m³] | Cp<br>Specific heat<br>[J/kg.K] |
|---|---|---|---|---|
| Blended Wood/Air/Cardboard + Plywood + Plexiglass | 0.036 | **0.1514** [a] | 307 | 1317 |
| Blended Air Gap | 0.038 | 0.254 | 1.2 | 1000 |
| Styrodur (see Figure 13-10) | 0.060 | **0.0518** [a] | 18 | 1200 |

**a. Imputed value for Case ET110B1.**
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:
- R = 1.696 m$^2$K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

**Table 13-27: Characteristics of the West wall (Case ET110B1)**
(Net inside surface area = 10.1378 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/m.K] | ρ<br>Density<br>[kg/m³] | Cp<br>Specific heat<br>[J/kg.K] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.010 | 0.35 | 850 | 800 |
| Polystyrene | 0.080 | **0.0353** [a] | 15 | 1200 |
| Air gap | 0.010 | 0.070 | 1.2 | 1000 |
| Hollow block | 0.200 | 1.052 | 1200 | 950 |
| Facing | 0.020 | 1.15 | 1950 | 850 |

a. **Imputed value for Case ET110B1.**
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 2.852 m$^2$K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

**Table 13-28: Characteristics of the South wall (Case ET110B1)**
(Net inside surface area = 7.1752 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/m.K] | ρ<br>Density<br>[kg/m³] | Cp<br>Specific heat<br>[J/kg.K] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.010 | 0.35 | 850 | 800 |
| Polystyrene | 0.080 | **0.0503** [a] | 15 | 1200 |
| Air gap | 0.010 | 0.070 | 1.2 | 1000 |
| Hollow block | 0.200 | 1.052 | 1200 | 950 |
| Facing | 0.020 | 1.15 | 1950 | 850 |

a. **Imputed value for Case ET110B1.**
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 2.175 m$^2$K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

**Table 13-29: Characteristics of the East wall (Case ET110B1)**

(Net inside surface area = 11.9401 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/m.K] | ρ<br>Density<br>[kg/m³] | Cp<br>Specific heat<br>[J/kg.K] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.010 | 0.35 | 850 | 800 |
| Polystyrene | 0.080 | **0.0505** [a] | 15 | 1200 |
| Air gap | 0.010 | 0.070 | 1.2 | 1000 |
| Hollow block | 0.200 | 1.052 | 1200 | 950 |
| Air gap | 0.010 | 0.070 | 1.2 | 1000 |
| Polystyrene | 0.080 | **0.0505** [a] | 15 | 1200 |
| Plasterboard | 0.010 | 0.35 | 850 | 800 |
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |

**a. Imputed value for Case ET110B1.**

***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 3.960 m$^2$K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

**Table 13-30: Characteristics of the Ceiling – Path 1 (Case ET110B1)**

(Net inside surface area = 14.4025 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/mK] | ρ<br>Density<br>[kg/m$^3$] | $C_p$<br>Specific heat<br>[J/kgK] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |
| Glass wool 1 | 0.200 | **0.0340** [a] | 11 | 800 |
| Air gap | 0.100 | 0.618 | 1.2 | 1000 |
| Particle board | 0.021 | 0.17 | 700 | 1200 |

**a. Imputed value for Case ET110B1.**

***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 6.547 m$^2$K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

**Table 13-31: Characteristics of the Ceiling – Path 2 (Case ET110B1)**

(Net inside surface area = 1.8900 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/mK] | ρ<br>Density<br>[kg/m³] | $C_p$<br>Specific heat<br>[J/kgK] |
|---|---|---|---|---|
| Wallpaper | 0.001 | 0.14 | 700 | 1340 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |
| Glass wool 2 | 0.150 | **0.0340** [a] | 11 | 800 |
| Planks | 0.150 | 0.15 | 500 | 1200 |
| Particle board | 0.021 | 0.17 | 700 | 1200 |

**a. Imputed value for Case ET110B1.**

***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 5.914 $m^2K/W$
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

**Table 13-32: Characteristics of the Floor – Path 1 (Case ET110B1)**

(Net inside surface area = 13.3525 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/mK] | ρ<br>Density<br>[kg/m³] | Cp<br>Specific heat<br>[J/kgK] |
|---|---|---|---|---|
| Ceramic Tile | 0.006 | 1.75 | 2177 | 920 |
| Glue Cement | 0.003 | 1.50 | 1900 | 840 |
| Concrete | 0.008 | 1.75 | 2177 | 920 |
| Concrete + Tubes + Polysty Ribs | 0.016 | 1.47 | 1813 | 954 |
| Polystyrene 1 | 0.035 | **0.0853** [a] | 16 | 1200 |
| Plastic Lining | 0.002 | 0.124 | 265 | 1170 |
| Concrete Slab | 0.065 | 1.75 | 2200 | 950 |
| Insulated Block 1 | 0.070 | **0.0853** [a] | 18 | 1200 |
| Insulated Block 2 | 0.050 | **0.0853** [a] | 18 | 1200 |
| Polystyrene 2 | 0.030 | **0.0853** [a] | 18 | 1200 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |

**a. Imputed value for Case ET110B1.**

***Informative Notes:***

1. Composite "air-to-air" R-value (R) for this heat flow path is:
   - R = 2.524 $m^2K/W$
   - This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).
2. For programs with ≤ 10-layer per conduction path material limit, see Informative Notes 2 and 3 below Table 13-13 (Section 13.2.2.8.7.2.2 [Case ET110A1])

**Table 13-33: Characteristics of the Floor – Path 2 (Case ET110B1)**
(Net inside surface area = 1.4700 m²)

| Material | d Thickness [m] | k Conductivity [W/mK] | ρ Density [kg/m³] | Cp Specific heat [J/kgK] |
|---|---|---|---|---|
| Ceramic Tile | 0.006 | 1.75 | 2177 | 920 |
| Glue Cement | 0.003 | 1.50 | 1900 | 840 |
| Concrete | 0.008 | 1.75 | 2177 | 920 |
| Concrete + Tubes + Polysty Ribs | 0.016 | 1.47 | 1813 | 954 |
| Polystyrene 1 | 0.035 | **0.0853** [a] | 16 | 1200 |
| Plastic Lining | 0.002 | 0.124 | 265 | 1170 |
| Concrete Slab | 0.065 | 1.75 | 2200 | 950 |
| Insulated Block 1 | 0.070 | **0.0853** [a] | 18 | 1200 |
| Concrete Beam 2 | 0.050 | 1.75 | 2200 | 950 |
| Polystyrene 2 | 0.030 | **0.0853** [a] | 18 | 1200 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |

**a. Imputed value for Case ET110B1.**

***Informative Notes:***

1. Composite "air-to-air" R-value (R) for this heat flow path is:
   - R = 1.966 m²K/W
   - This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).
2. For programs with ≤ 10-layer per conduction path material limit, see Informative Notes 2 and 3 below Table 13-14 (Section 13.2.2.8.7.2.2 [Case ET110A1])

**Table 13-34: Characteristics of the Floor – Path 3 (Case ET110B1)**
(Net inside surface area = 1.4700 m²)

| Material | d Thickness [m] | k Conductivity [W/mK] | ρ Density [kg/m³] | Cp Specific heat [J/kgK] |
|---|---|---|---|---|
| Ceramic Tile | 0.006 | 1.75 | 2177 | 920 |
| Glue Cement | 0.003 | 1.50 | 1900 | 840 |
| Concrete | 0.008 | 1.75 | 2177 | 920 |
| Concrete + Tubes + Polysty Ribs [a] | 0.016 | 1.47 | 1813 | 954 |
| Polystyrene 1 | 0.035 | **0.0853** [a] | 16 | 1200 |
| Plastic Lining | 0.002 | 0.124 | 265 | 1170 |
| Concrete Slab | 0.065 | 1.75 | 2200 | 950 |
| Concrete Beam 1 | 0.070 | 1.75 | 2200 | 950 |
| Concrete Beam 2 | 0.050 | 1.75 | 2200 | 950 |
| Polystyrene 2 | 0.030 | **0.0853** [a] | 18 | 1200 |
| Plasterboard | 0.013 | 0.35 | 850 | 800 |

**a. Imputed value for Case ET110B1.**

***Informative Notes:***

1. Composite "air-to-air" R-value (R) for this heat flow path is:
   - R = 1.186 m²K/W

- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

2. For programs with ≤ 10-layer per conduction path material limit, see Informative Notes 2 and 3 below Table 13-15 (Section 13.2.2.8.7.2.2 [Case ET110A1])

**Table 13-35: Characteristics of Insulated Windows – Path 1 (Case ET110B1)**
(Net inside surface area = 0.9905 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| Blended Glass/Air Gap /Glass | 0.020 | 0.124 | 1081 | 900 |
| Air Gap | 0.009 | **0.1292** [a] | 1.2 | 1000 |
| Glasswool 1 | 0.200 | **0.0688** [a] | 11 | 800 |
| Polystyrene 1 | 0.070 | **0.0688** [a] | 16 | 1200 |

**a. Imputed value for Case ET110B1.**
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 4.356 m$^2$K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

**Table 13-36: Characteristics of Insulated Windows – Path 2 (Case ET110B1)**
(Net inside surface area = 0.1385 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| PVC | 0.062 | 0.16 | 1380 | 1000 |
| Glasswool 2 | 0.188 | **0.0688** [a] | 11 | 800 |
| Polystyrene 1 | 0.070 | **0.0688** [a] | 16 | 1200 |

**a. Imputed value for Case ET110B1.**
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 4.339 m$^2$K/W
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

**Table 13-37: Characteristics of Insulated Windows – Path 3 (Case ET110B1)**
(Net inside surface area = 0.6734 m²)

| Material | d<br>Thickness<br>[m] | k<br>Conductivity<br>[W/m.K] | ρ<br>Density<br>[kg/m³] | Cp<br>Specific heat<br>[J/kg.K] |
|---|---|---|---|---|
| Blended PVC + facing + plasterboard [b] | 0.062 | **3.5128 [a]** | 1442 | 975 |
| Glasswool 3 [c] | 0.188 | **2.7444 [a]** | 316 | 808 |
| Polystyrene 2 [c] | 0.070 | **2.7444 [a]** | 320 | 1145 |

a. **Imputed values for Case ET110B1.**

b. ***Informative Note:*** As a modeling simplification, the Path-3 window frame material includes the external setback cavity facing (known thermal bridge) and the plasterboard covering the facing on the test cell interior surface; see Informative Annex B23, Section B23.6 for supporting information.

c. ***Informative Note:*** As a modeling simplification, the Glasswool 3 and Polystyrene 2 materials include the external setback cavity facing (known thermal bridge); see Informative Annex B23, Section B23.6 for supporting information.

***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 0.251 $m^2K/W$
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

### 13.2.3.8 Surface Radiative Properties

The Cell B surface radiative properties shall be the same as for Cell A (see Section 13.2.2.9), except the east and west wall properties are exchanged as shown in Table 13-38.

**Table 13-38 Surface Radiative Properties of Cell B East and West Walls [a]**

| Opaque Surface | Interior Radiative Properties | | Exterior Radiative Properties | |
|---|---|---|---|---|
| | Solar Absorptivity | Infrared Emissivity/ Absorptivity | Solar Absorptivity | Infrared Emissivity/ Absorptivity |
| East wall | 0.343 | 0.870 | 0.343 | 0.870 |
| West wall | 0.343 | 0.870 | 0.419 | 0.919 |

a. Properties are from the originating source document[c-1], except where otherwise noted.

### 13.2.3.9 Surface Heat Transfer

The Cell B constant interior and exterior combined convective and radiative surface coefficients (($h_{,comb,int}$ and $h_{,comb,ext}$, respectively)) shall be the same as for Cell A (see Section 13.2.2.10), except the east and west wall coefficients are exchanged as shown in Table 13-39.

**Table 13-39 Interior and Exterior Combined Surface Heat Transfer Coefficients of Cell B East and West Walls**

| | Interior Surface *h,comb,int* (W/(m$^2$K)) | Exterior Surface *h,comb,ext* (W/(m$^2$K)) |
|---|---|---|
| East wall | 5.3 | 18 |
| West wall | 7.0 | 18 |
| Insulated Window West (like Cell A, East; see Table 13-20 [Section 13.2.2.10]) | | |
| Path 1 (through glass) | 7.0 | 18 |
| Path 2 (through inner frame) | 7.0 | 18 |
| Path 3 (through blended outer frame) | 12.0 | 18 |

***Informative Notes:***

1. Values of Table 13-39 are based on measured data; see Informative Annex B23, Section B23.5 for details.
2. The values of Table 13-39 (and Table 13-20 of Section 13.2.2.10 [Case ET110A1] for all other walls) are applied to develop imputed thermal conductivities of various wall constructions of Section 13.2.3.7; see Informative Annex B23 for details.
3. The greater coefficient of insulated window Path 3 shown in Table 13-39 is the same as that determined for the uninsulated window (see Section 13.2.4.9 [Case ET100A1]). This is for consistency with Path 3 having greater insulation conductivities to account for thermal bridging and 3-D conduction (see Table 13-18, informative note b).
4. 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 for interior and/or exterior surfaces as convective coefficients, and set respective surface emittances to 0 (or as low as the program being tested allows).
5. Constant surface coefficients presented here apply only to this test suite as they are specified for each test case and were determined only for the given test-case configurations; they should not be assumed to apply beyond this test suite.

### 13.2.3.10 Infiltration

Infiltration = 0 ACH.

***Informative Note:*** This is the same as for Cell A, see Section 13.2.2.12.

### 13.2.3.11 Internal gains

For Case ET110B1, hourly-integrated measured fan energy is included with the test data (see Section 13.2.3.3).

- Apply fan heat as a sensible internal gain that is 100% convective.

***Informative Notes:***

1. For the ET110B1 data acquisition period, hourly fan energy ranges from 0 to 216 Wh/h.

2. There are no other internal gains in the test cell (no lighting, no occupants, etc.).

**13.2.3.12 Thermal Guards**

While guard zone temperature data is fully available, guard zone construction details are approximate. Two methods of modeling guard zones are indicated depending on what the program being tested allows:

- For programs that allow guard zones to be modeled as bounding surface exterior boundary conditions, see Section 13.2.3.12.1
- For programs that require detailed modeling of guard-zone geometry (i.e., that do not have an option to model zones adjacent to the test cell as external boundary conditions), see Section 13.2.3.12.2

***Informative Note:*** Modeling guard zones as exterior surface boundary conditions, as in Section 13.2.3.12.1, is recommended because such a model reduces complexity and therefore reduces the potential for input errors.

**13.2.3.12.1 Modeling guard zones as exterior surface boundary conditions**

- Apply separate guard-zone air temperatures to each test cell bounding surface as specified in Section 13.2.3.3
- Apply exterior combined surface heat transfer coefficients to test cell bounding surfaces as specified in Section 13.2.3.9.
- Skip the remaining instructions and proceed to Section 13.2.3.13

**13.2.3.12.2 Detailed modeling of guard zone geometry and construction details**

**13.2.3.12.2.1 Geometry**

Apply overall test cell geometry of Figures 13-6 through 13-8; see Section 13.2.2.7.3 (Case ET110A1)

**13.2.3.12.2.2 Constructions**

Apply instructions of Section 13.2.2.15.2.2 (Case ET110A1); see instructions specific to Cell B.

**13.2.3.12.2.3 Guard Zone Interior Surface Heat Transfer**

Apply instructions of Section 13.2.2.15.2.3 (Case ET110A1); see instructions specific to Cell B.

**13.2.3.12.2.4 Guard Zone Exterior Surface Heat Transfer**

Apply instructions of Section 13.2.2.15.2.4 (Case ET110A1); see instructions specific to Cell B.

**13.2.3.12.2.5 Guard Zones Temperature Control and Data**

Apply separate guard-zone air temperatures to each guard zone as specified in Section 13.2.3.3.

***Informative Note:*** See informative notes with Section 13.2.2.15.2.5 (Case ET110A1).

#### 13.2.3.13 Mechanical System

The mechanical system for Cell B shall be exactly the same as for Cell A, except as specified in the following sections.

#### 13.2.3.13.1 Fan Energy

Fan energy shall be modeled as an internal gain (see Section 13.2.3.11) and shall not be modeled explicitly as part of the mechanical system. If the program being tested requires an air-distribution fan, it shall be specified to consume no energy. ***Informative Note:*** This is the same instruction as Case ET110A1 except the Cell B fan energy hourly data is as in Section 13.2.3.11.

#### 13.2.3.13.2 Thermostat Set Point.

Apply setpoint values for test-cell air temperatures and guard-zone air temperatures included in the data file specified in Section 13.2.3.3.

### 13.2.4 Case ET100A1: Artificial Climate, Steady-State Overall Building Loss Coefficient with Uninsulated Windows, Cell A, Applying Specified Catalog Material Properties Except for Selected Imputed Insulation Conductivities

#### 13.2.4.1 (*Informative*) Objectives and Method of the Test Case

#### 13.2.4.1.1 Objectives

The objectives of this case are the same as for Case ET110A1, except applied for the uninsulated window configuration.

#### 13.2.4.1.2 Method

a. Case ET100A1 is specified as an extension case based on the Cell A artificial climate base case (Case ET110A1).

b. Case ET100A1 has the same construction as ET110A1 except both the south and east windows are uninsulated. This construction provides:

- Basis for measuring the UA of the window insulation as $UA_{winins} = (BLC_{ET100A1} - BLC_{ET110A1}) / 2$, for each window of Cell A
    - where $BLC_{ET100A1}$ and $BLC_{ET110A1}$ are the measured building loss coefficients for Cases ET100A1 and ET110A1, respectively

c. Similarly as Case ET110A1, guard-zone temperatures ($T_{guards}$) were set to approximately $T_{guards}$ = 10˚C (the data is nearer to 10.5°C to match where the cellar, associated with the more massive floor, was controlled) and test cell temperature set to $T_{cell}$ = 35 ˚C. See data files listed in Section 13.2.4.3 for guard zone and test cell hourly temperatures (set points). For an idealized heating system (that effectively outputs building load), apply results comparisons as listed with Objectives and Methods for Case ET110A1; see Informative Section 13.2.2.1.2, Item b.

### 13.2.4.2 Extension Case Basis and Revision Summary

Case ET100A1 shall be modeled exactly the same as Case ET110A1 except for changes detailed in the following sections.

### 13.2.4.3 Test Cell Conditions and Guard-Zone Temperatures

Hourly data files and the test data sets durations for Case ET100A1 are listed in Table 13-40. These data files are included with the accompanying electronic media; see Readme-140-2023-B.docx. The data files apply the same conventions as Case ET110A1 (see Section 13.2.2.2.1).

The ET100A-Measurements.csv hourly data format is the same for the Case ET110A data as provided in Table 13-3 (see Section 13.2.2.2.1).

**Table 13-40 Primary Data File Directory (Case ET100A1)**

| File Name | Data Type | Time Step | Data Duration (“MM/DD/YYYY hh”) [GMT+1] |
|---|---|---|---|
| ET100A-Measurements.csv [d] | Test Cell A | Hour | 09/08/2000 16 through 09/18/2000 14 |
| ET110Meteo_within_Melun - 071530_MY.2000.epw [a,b,c,d] | Local facility weather inserted within Melun, France AMY data | Hour | 01/01/2000 01 through 12/31/2000 24 |

a. ***Informative Note:*** This is the same weather data provided for Case ET110A1. Unlike for the ET110 cases recorded during an earlier data period, local test facility weather data was not recorded for the solely artificial-climate data period during which Case ET100 occurred, so only nearby Melun data is provided for this case.

b. ***Informative Note:*** Epw format is described at: http://climate.onebuilding.org/papers/EnergyPlus_Weather_File_Format.pdf. [c-4]

c. ***Informative Note:*** In the artificial climate cases, for programs that model guard zones as boundary conditions applied to each test cell wall rather than as literal zones, the weather data is essentially dummy data – i.e., not used in the model other than to satisfy the requirement of most BPS software to have a weather data set.

d. ***Informative Note:*** For further supporting information regarding these data files, see Readme-140-2023-B.docx and Appendix A of the originating source document[c-1].

### 13.2.4.4 Simulation Duration and Initialization

Simulation duration and initialization shall be in accordance with the requirements of the software implementation of a given test case.

***Informative Notes:***

1. The experimental data duration is as described in Table 13-40 (Section 13.2.4.3) for the file ET100A-Measurements.csv.
2. The intent of the simulation is to include as much of the provided experimental data as possible for the tested software. This data provides an initialization period ahead of the best steady-state data period intended for comparing software output to measured data and empirical values derived from measured data (see Section 13.3.4.3).
3. If the tested software requires a longer initialization period than provided in the experimental data, a typical technique of extending the data for the software should be applied. Such a technique is at the discretion of the modeler, and may be based on review of the first day or two of the csv file input data (see Section 13.2.4.3).
4. In the experimental data (see Note 1 above), Case ET100A1 has a shorter lead time to the best steady-state data period than Case ET110A1 – 8 days versus almost 15 days – which makes appropriate initialization more important. E.g., internal simulation trials tested two different methods of initialization versus running the data as is, with both sensitivity tests reducing modeled Qhtr by 0.2% and corresponding better agreement versus measured Qhtr.

### 13.2.4.5 Output Requirements.

Output shall be provided as specified in Sections 13.3.1 and 13.3.4.

**13.2.4.6 (*Informative*) Geometry: Walls with Windows (South and West).**

1. Removal of window insulation for case ET100A1 has no effect on the south and east window geometry specifications of Sections 13.2.2.7.2.2 and 13.2.2.7.2.3 (from Case ET110A1), respectively.
2. In artificial-climate cases the windows may be modeled as walls, or subsections of walls, because there is no transmitted solar radiation.

**13.2.4.7 Test Cell Bounding Surface Material Constructions.**

The following sections specify material constructions of the test cell bounding surfaces and subsurfaces:

- Required characteristics (Section 13.2.4.7.1)
- Alternative construction properties tables (Section 13.2.4.7.2)

## 13.2.4.7.1 Required Characteristics

Table 13-41 specifies UA values for the south and east walls (including windows) and cross-references required geometry and construction figures for each wall.

***Informative Notes:***
1. These overall wall UA-values (without window insulation) are unchanged from Case ET110A1; they are provided here for clarity
2. All other bounding surface overall UA-values are also the same as for Case ET110A1.

**Table 13-41 Cell A Required Characteristics of South and East Walls (Case ET100A1)**

| Wall | UA Value, W/K | Geometry Figure | Construction Figures (Section) |
|---|---|---|---|
| South | 8.07 | Figure 13-3 [a]<br>(Section 13.2.2.7.2.2) | Figure 13-11 [a]<br>(Section 13.2.2.8.3.1) |
| East | 9.36 | Figure 13-4 [a]<br>(Section 13.2.2.7.2.3) | Figure 13-11 [a]<br>(Section 13.2.2.8.3.1) |
| Windows | Included with walls | Figures 13-3 and 13-4 [a] | Figure 13-22 |

a. ***Informative Note:*** Same figures as for Case ET110A1.

For modelers requiring further guidance to specify inputs of material properties, apply the alternative construction specification of Section 13.2.4.7.2. ***Informative Note:*** Use of the Section 13.2.4.7.2 alternative is recommended (see Section 13.2.1.3).

## 13.2.4.7.2 Alternative Construction Specification

**13.2.4.7.2.1** If the modeler does not require further guidance to develop inputs as specified in Section 13.2.4.7.1, skip the remaining instructions and proceed to Section 13.2.4.8.

**13.2.4.7.2.2** Window insulation shall be removed such that the window is uninsulated as shown in Figure 13-22. The uninsulated window is divided into three parallel 1-D conduction path segments corresponding to the method for which thermal conductivities of the selected material layers were externally imputed. ***Informative Note:*** See Informative Annex B23 for details regarding external imputation of thermal conductivities.

Figure 13-23 illustrates the three parallel 1-D conduction heat flow paths (Path 1, Path 2, and Path 3) to be applied in the simulations.

The following tables apply for window modeling, where the same 1-D conduction path net inside surface areas are applied (see table captions) as in Case ET110A1:

- Characteristics of uninsulated windows – Path 1: Table 13-42 replaces Table 13-16
- Characteristics of uninsulated windows – Path 2: Table 13-43 replaces Table 13-17
- Characteristics of uninsulated windows – Path 3: Table 13-44 replaces Table 13-18.

***Informative Note:*** Figures 13-22, 13-23 and Tables 13-42 through 13-44 are also applied for Case ET100B1 as specified in Section 13.2.5.7.

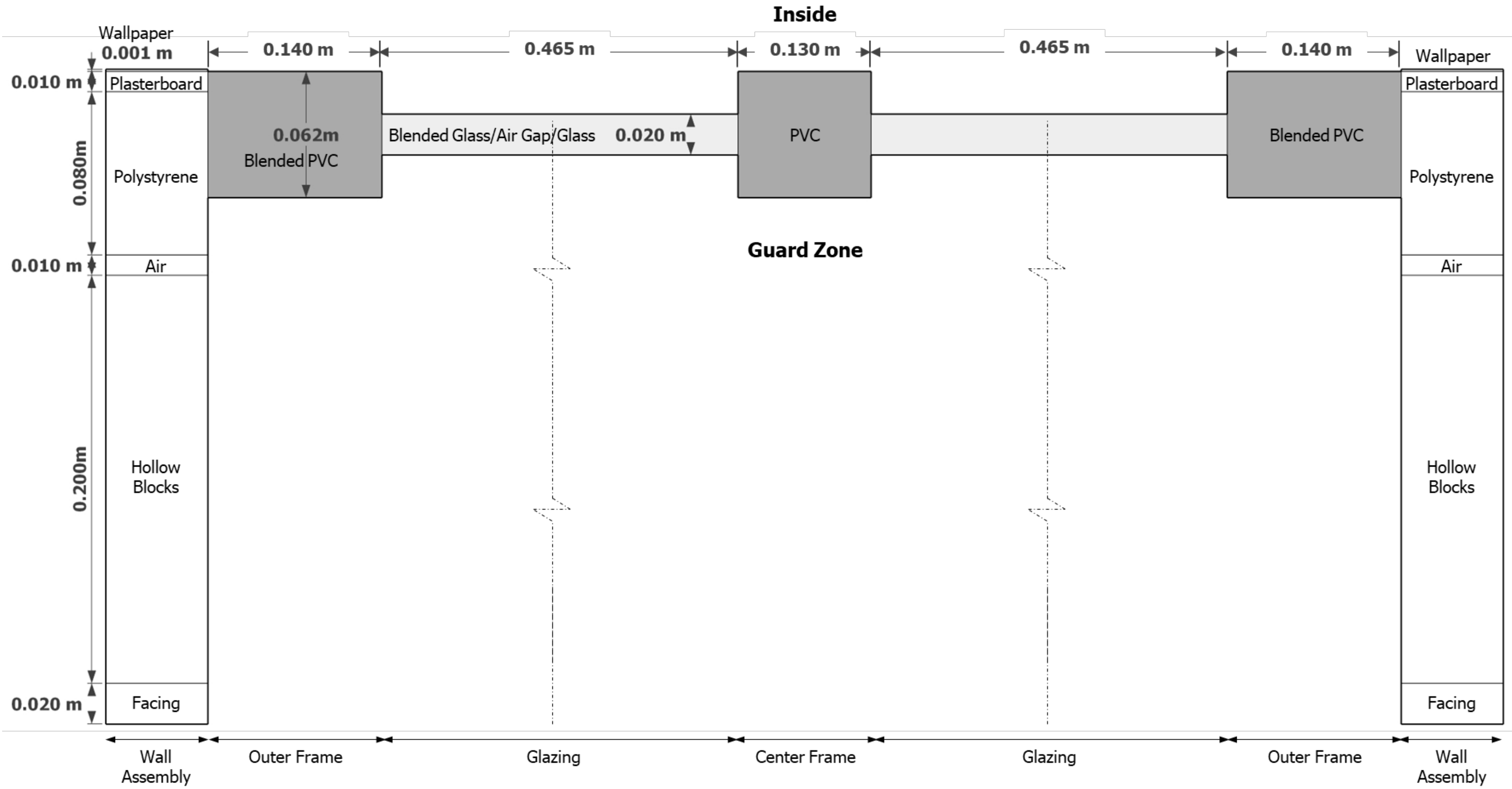



**Figure 13-22: Window Vertical Section (window and frame assembly), through the window and external setback cavity looking downward (or upward) – NOT TO SCALE**

- Notes: ***Informative Note:*** This figure is a simplification of the actual construction to reduce the greater chance for input errors with the more complicated actual construction. See Informative Annex B23, Section B23.6 for greater detail.

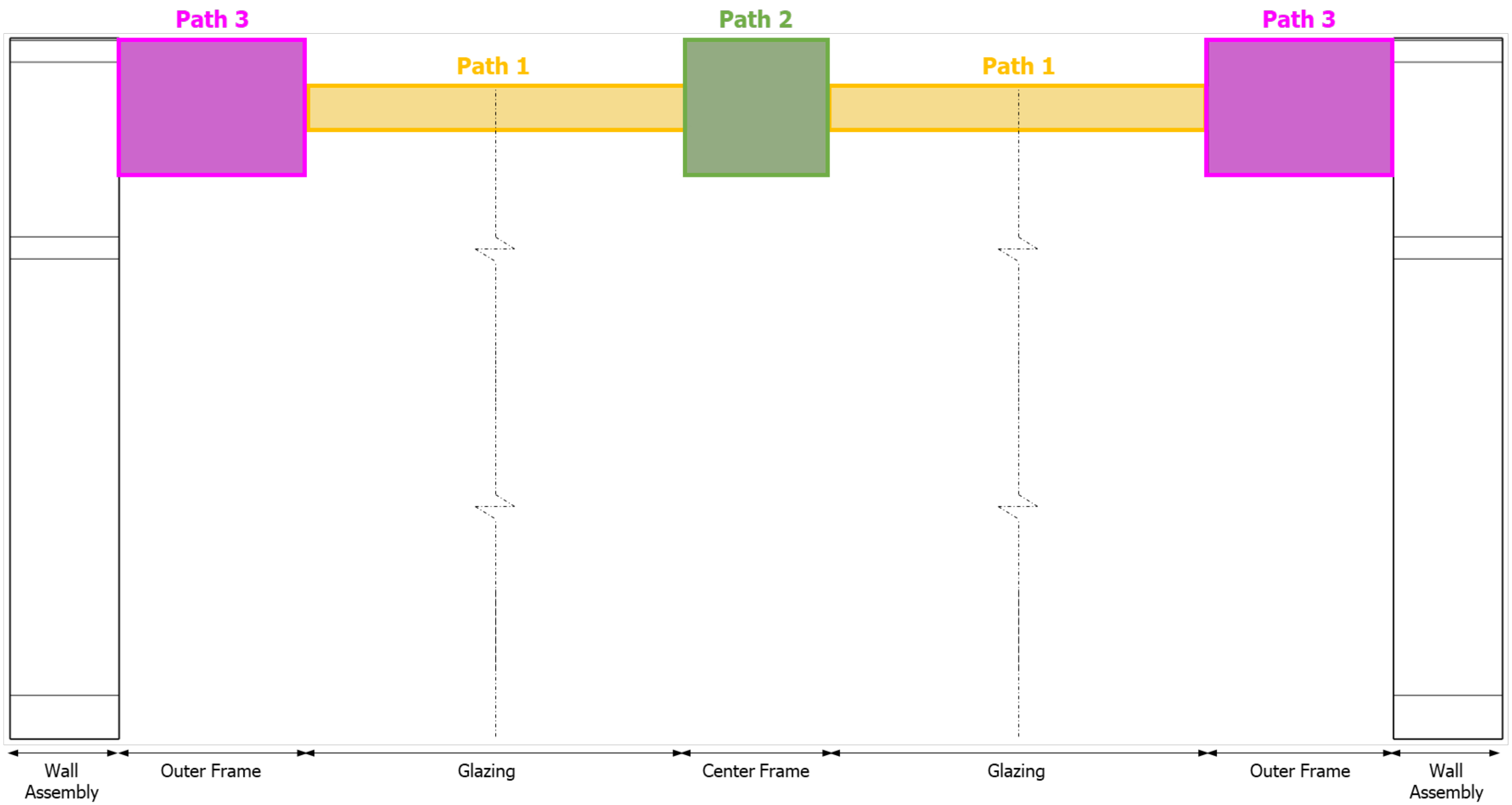



**Figure 13-23: Window vertical section view (window and frame assembly) of the uninsulated window parallel heat-flow paths, looking downward (or upward) – NOT TO SCALE**

**Table 13-42: Characteristics of uninsulated windows – Path 1 (ET100A1)**
(Net inside surface area = 0.9905 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| Blended Glass/Air Gap/Glass[a] | 0.020 | 0.124 | 1081 | 900 |

a. ***Informative Note:*** See Informative Annex B23, Section B23.6 for supporting information. This representation is consistent with the configuration applied for developing the imputed conductivities elsewhere. Optical properties are excluded as they are not needed for artificial climate cases that do not have transmitted solar radiation.
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 0.300 $m^2K/W$
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

**Table 13-43: Characteristics of uninsulated windows – Path 2 (ET100A1)**
(Net inside surface area = 0.1385 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| PVC | 0.062 | 0.16 | 1380 | 1000 |

***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 0.526 $m^2K/W$
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

**Table 13-44: Characteristics of uninsulated windows – Path 3 (ET100A1)**
(Net inside surface area = 0.6734 m²)

| Material | d Thickness [m] | k Conductivity [W/m.K] | ρ Density [kg/m³] | Cp Specific heat [J/kg.K] |
|---|---|---|---|---|
| Blended PVC + facing + plasterboard [a] | 0.062 | **0.267** [b,c] | 1442 | 975 |

a. ***Informative Note:*** As a modeling simplification, the Path-3 window frame material includes the external setback cavity facing (known thermal bridge) and the plasterboard covering the facing on the test cell interior surface; see Informative Annex B23, Section B23.6 for supporting information.
**b. Blended value based on catalog properties replacing imputed values from Case ET110A1.**
**c.** ***Informative Note:*** For Case ET110A1 (and ET110B1), imputed window insulation conductivities were determined separately from imputed opaque wall conductivities, where separate ET110A1 and ET110B1 opaque wall imputations (which are separately the same for ET100A1 and ET100B1, respectively) apply the uninsulated window catalog-based "Blended PVC + facing + plasterboard" properties shown here. Thus, application of this catalog-based value for Case ET100A1 (and ET100B1) is consistent with development of imputed values elsewhere. For supporting information, see Informative Annex B23 and "Imputation_of_k.xlsm" (included with the accompanying electronic media; see Readme 140-2023-B.docx).
***Informative Note:*** Composite "air-to-air" R-value (R) for this heat flow path is:

- R = 0.371 $m^2K/W$
- This "air-to-air" value includes combined surface heat transfer coefficients of Section 13.2.2.10 (Case ET110A1).

### 13.2.4.8 Surface Radiative Properties

The uninsulated window glazing and frame surface radiative properties are as shown in Table 13-45.

**Table 13-45 Surface Radiative Properties of Uninsulated Windows (ET100A1) [a]**

| Window Surface | Interior Radiative Properties | | Exterior Radiative Properties | |
|---|---|---|---|---|
| | Solar Absorptivity | Infrared Emissivity/ Absorptivity | Solar Absorptivity | Infrared Emissivity/ Absorptivity |
| Glass | **0.129** | 0.9 | **0.129** | **0.9** |
| Frame | 0.343 | 0.870 | **0.343** | **0.870** |

**a. Properties varying from Case ET110A1 (and Case ET110B1) are highlighted in bold font.**

***Informative Note:*** Table 13-45 is also applied for Case ET100B1 as specified in Section 13.2.5.8.

### 13.2.4.9 Interior Surface Heat Transfer

The coefficients (*h,comb,int*) of Table 13-46 shall be applied to the given window glazing and frame conduction paths. ***Informative Note:*** The exterior surface coefficients remain the same as in Case ET110A1.

**Table 13-46 Interior Combined Surface Heat Transfer Coefficients of Cell A Window (ET100A1) [a]**

| | Interior Surface *h,comb,int* (W/($m^2$K)) |
|---|---|
| Path 1 (through glass) | **12.0** |
| Path 2 (through inner frame) | **12.0** |
| Path 3 (through blended outer frame) | 12.0 |

**a. Properties varying from Case ET110A1 (and Case ET110B1) are highlighted in bold font.**

***Informative Notes:***

1. Table 13-46 is also applied for Case ET100B1 as specified in Section 13.2.5.9
2. Values of Table 13-46 are based on measured data for uninsulated windows; see Informative Annex B23, Section B23.5 for details. (The value for Path 3 here was also applied for Case ET110A1 per Informative Note 3 with Table 13-20 [Section 13.2.2.10].)
3. 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 for interior and/or exterior surfaces as convective coefficients, and set respective surface emittances to 0 (or as low as the program being tested allows).

4. Constant surface coefficients presented here apply only to this test suite as they are specified for each test case and were determined only for the given test-case configurations; they should not be assumed to apply beyond this test suite.

**13.2.4.10 Internal gains**

For Case ET100A1, hourly-integrated measured fan energy is included with the test data (see Section 13.2.4.3).

***Informative Note:*** For the ET100A1 data acquisition period, hourly fan energy ranges from 144.0 to 157.6 Wh/h.

**13.2.4.11 Thermal Guards**

While guard zone temperature data is fully available, guard zone construction details are approximate. Two methods of modeling guard zones are indicated depending on what the program being tested allows:

- For programs that allow guard zones to be modeled as bounding surface exterior boundary conditions, see Section 13.2.4.11.1
- For programs that require detailed modeling of guard-zone geometry (i.e., that do not have an option to model zones adjacent to the test cell as external boundary conditions), see Section 13.2.4.11.2

**13.2.4.11.1 Modeling guard zones as exterior surface boundary conditions**

- Apply separate guard-zone air temperatures to each test cell bounding surface as specified in Section 13.2.4.3
- Skip the remaining instructions and proceed to Section 13.2.4.12

**13.2.4.11.2 Detailed modeling of guard zone geometry and construction details**

- Apply separate guard-zone air temperatures to each guard zone as specified in Section 13.2.4.3

**13.2.4.12 Mechanical System**

**13.2.4.12.1 Fan Energy**

Fan energy shall be modeled as an internal gain as specified in Section 13.2.4.10.

**13.2.4.12.2 Thermostat Set Point.**

Apply setpoint values for test-cell air temperatures and guard-zone air temperatures included in the data file specified in Section 13.2.4.3.

### 13.2.5 Case ET100B1: Artificial Climate, Steady-State Overall Building Loss Coefficient with Uninsulated Windows, Cell B, Applying Specified Catalog Material Properties Except for Selected Imputed Insulation Conductivities

#### 13.2.5.1 (*Informative*) Objectives and Method of the Test Case

#### 13.2.5.1.1 Objectives

The objectives of this case are the same as for Case ET110B1, except applied for the uninsulated window configuration.

#### 13.2.5.1.2 Method

a. Case ET100B1 is specified as an extension case based on the Cell B artificial climate base case (Case ET110B1).

b. Case ET100B1 has the same construction as ET110B1 except both the south and west windows are uninsulated similarly to the south and east windows of Case ET100A1 (Section 13.2.4). This construction provides:

- Basis for measuring the UA of the window insulation as $UA_{winins} = (BLC_{ET100B1} - BLC_{ET110B1}) / 2$, for each window of Cell B
    - where $BLC_{ET100B1}$ and $BLC_{ET110B1}$ are the measured building loss coefficients for Cases ET100B1 and ET110B1, respectively

c. Similarly as Case ET110B1, guard-zone temperatures ($T_{guards}$) were set to approximately $T_{guards}$ = 10˚C (the data is nearer to 10.5°C to match where the cellar, associated with the more massive floor, was controlled) and test cell temperature set to $T_{cell}$ = 35 ˚C. See data files listed in Section 13.2.5.3 for guard zone and test cell hourly temperatures (set points). For an idealized heating system (that effectively outputs building load), apply results comparisons as listed with Objectives and Methods for Case ET110A1; see Informative Section 13.2.2.1.2, Item b.

#### 13.2.5.2 Extension Case Basis and Revision Summary

Case ET100B1 shall be modeled exactly the same as Case ET110B1 except for changes detailed in the following sections.

#### 13.2.5.3 Test Cell Conditions and Guard-Zone Temperatures

Hourly data files and the test data sets durations for Case ET100B1 are listed in Table 13-47. These data files are included with the accompanying electronic media; see Readme-140-2023-B.docx. The data files apply the same conventions as Case ET110A1 (see Section 13.2.2.2.1).

The ET100B-Measurements.csv hourly data format is the same for the Case ET110A data as provided in Table 13-3 (see Section 13.2.2.2.1).

**Table 13-47 Primary Data File Directory (Case ET100B1)**

| File Name | Data Type | Time Step | Data Duration ("MM/DD/YYYY hh") [GMT+1] |
|---|---|---|---|
| ET100B-Measurements.csv [d] | Test Cell B | Hour | 09/08/2000 16 through 09/18/2000 15 |
| ET110Meteo_within_Melun - 071530_MY.2000.epw [a,b,c,d] | Local facility weather inserted within Melun, France AMY data | Hour | 01/01/2000 01 through 12/31/2000 24 |

a. ***Informative Note:*** This is the same weather data provided for Case ET100A1; see Informative Note "a" with Table 13-40 (Section 13.2.4.3).

b. ***Informative Note:*** Epw format is described at: http://climate.onebuilding.org/papers/EnergyPlus_Weather_File_Format.pdf. [c-4]

c. ***Informative Note:*** In the artificial climate cases, for programs that model guard zones as boundary conditions applied to each test cell wall rather than as literal zones, the weather data is essentially dummy data – i.e., not used in the model other than to satisfy the requirement of most BPS software to have a weather data set.

d. ***Informative Note:*** For further supporting information regarding these data files, see Readme-140-2023-B.docx and the originating source document[c-1].

### 13.2.5.4 Simulation Duration and Initialization

Simulation duration and initialization shall be in accordance with the requirements software implementation of a given test case.

***Informative Notes:***

1. The experimental data duration is as described in Table 13-47 (Section 13.2.5.3) for the file ET100B-Measurements.csv.
2. The intent of the simulation is to include as much of the provided experimental data as possible for the tested software. This data provides an initialization period ahead of the best steady-state data period intended for comparing software output to measured data and empirical values derived from measured data (see Section 13.3.5.3).
3. If the tested software requires a longer initialization period than provided in the experimental data, a typical technique of extending the data for the software should be applied. Such a technique is at the discretion of the modeler, and may be based on review of the first day or two of the csv file input data (see Section 13.2.5.3).
4. In the experimental data (see Note 1 above), Case ET100B1 has a shorter lead time to the best steady-state data period than Case ET110B1 – 8 days versus almost 15 days – which makes appropriate initialization more important per Section 13.2.4.4, Informative Note 4.

### 13.2.5.5 Output Requirements.

Output shall be provided as specified in Sections 13.3.1 and 13.3.5.

**13.2.5.6 (*Informative*) Geometry: Walls with Windows (South and West).**

1. Removal of window insulation for case ET100B1 has no effect on the south and west window geometry specifications of Sections 13.2.2.7.2.2 (same as Cell A) and 13.2.3.6.2.2 (Cell B), respectively.
2. In artificial-climate cases the windows may be modeled as walls, or subsections of walls, because there is no transmitted solar radiation.

**13.2.5.7 Test Cell Bounding Surface Material Constructions.**

The following sections specify material constructions of the test cell bounding surfaces and subsurfaces:

- Required characteristics (Section 13.2.5.7.1)
- Alternative construction properties tables (Section 13.2.5.7.2)

### 13.2.5.7.1 Required Characteristics

Table 13-48 specifies UA values for the south and west walls (including windows) and cross-references required geometry and construction figures for each wall. ***Informative Notes:***

1. These overall wall UA-values (without window insulation) are unchanged from Case ET110B1; they are provided here for clarity
2. All other bounding surface overall UA-values are also the same as for Case ET110B1.

**Table 13-48 Cell B Required Characteristics of South and East Walls (Case ET100B1)**

| Wall | UA Value, W/K | Geometry Figure | Construction Figures (Section) |
|---|---|---|---|
| South | 8.68 | Figure 13-3 [a]<br>(Section 13.2.2.7.2.2) | Figure 13-11 [a]<br>(Section 13.2.2.8.3.1) |
| West | 8.94 | Figure 13-21 [b]<br>(Section 13.2.3.6.2.2) | Figure 13-11 [a]<br>(Section 13.2.2.8.3.1) |
| Windows | Included with walls | Figures 13-3 [a] and 13-21 [b] | Figure 13-22 [c]<br>(Section 13.2.4.7.2.2) |

a. ***Informative Note:*** Same figures as for Case ET110A1 and ET110B1.

b. ***Informative Note:*** Same figure as for Case ET110B1.

c. ***Informative Note:*** Same figure as for Case ET100A1.

For modelers requiring further guidance to specify inputs of material properties, apply the alternative construction specification of Section 13.2.5.7.2. ***Informative Note:*** Use of the Section 13.2.5.7.2 alternative is recommended (see Section 13.2.1.3).

### 13.2.5.7.2 Alternative Construction Specification

**13.2.5.7.2.1** If the modeler does not require further guidance to develop inputs as specified in Section 13.2.5.7.1, skip the remaining instructions and proceed to Section 13.2.5.8.

**13.2.5.7.2.2** Window insulation shall be removed such that the window is uninsulated as shown in Figure 13-22 (Section 13.2.4.7.2.2, Case ET100A1). As with Case ET100A1, the uninsulated window is divided into three parallel 1-D conduction path segments corresponding to the method for which thermal conductivities of the selected material layers were externally imputed. ***Informative Note:*** See Informative Annex B23 for details regarding external imputation of thermal conductivities.

Figure 13-23 (Section 13.2.4.7.2.2, Case ET100A1) illustrates the three parallel 1-D conduction heat flow paths (Path 1, Path 2, and Path 3) to be applied in the simulations.

The following tables from Section 13.2.4.7.2.2 (Case ET100A1) apply for window modeling for Case ET100B1, where the same 1-D conduction path net inside surface areas are applied (see table captions) as in Cases ET110A1 and ET110B1:

- Characteristics of uninsulated windows – Path 1: Table 13-42 (Case ET100A1) replaces Table 13-35 (Case ET110B1)
- Characteristics of uninsulated windows – Path 2: Table 13-43 (Case ET100A1) replaces Table 13-36 (Case ET110B1)
- Characteristics of uninsulated windows – Path 3: Table 13-44 (Case ET100A1) replaces Table 13-37 (Case ET110B1).

### 13.2.5.8 Surface Radiative Properties

The uninsulated window glazing and frame surface radiative properties are as shown in Table 13-45 (Section 13.2.4.8 [Case ET100A1]).

### 13.2.5.9 Interior Surface Heat Transfer

The coefficients (*h,comb,int*) of Table 13-46 (Section 13.2.4.9 [Case ET100A1]) shall be applied to the given window glazing and frame conduction paths.

### 13.2.5.10 Internal gains

For Case ET100B1, hourly-integrated measured fan energy is included with the test data (see Section 13.2.5.3).

***Informative Note:*** For the ET100B1 data acquisition period, hourly fan energy ranges from 148.0 to 168.0 Wh/h.

### 13.2.5.11 Thermal Guards

While guard zone temperature data is fully available, guard zone construction details are approximate. Two methods of modeling guard zones are indicated depending on what the program being tested allows:

- For programs that allow guard zones to be modeled as bounding surface exterior boundary conditions, see Section 13.2.5.11.1
- For programs that require detailed modeling of guard-zone geometry (i.e., that do not have an option to model zones adjacent to the test cell as external boundary conditions), see Section 13.2.5.11.2.

#### 13.2.5.11.1 Modeling guard zones as exterior surface boundary conditions

- Apply separate guard-zone air temperatures to each test cell bounding surface as specified in Section 13.2.5.3

- Skip the remaining instructions and proceed to Section 13.2.5.12

**13.2.5.11.2 Detailed modeling of guard zone geometry and construction details**

- Apply separate guard-zone air temperatures to each guard zone as specified in Section 13.2.5.3

**13.2.5.12 Mechanical System**

**13.2.5.12.1 Fan Energy**

Fan energy shall be modeled as an internal gain as specified in Section 13.2.5.10

**13.2.5.12.2 Thermostat Set Point.**

Apply setpoint values for test-cell air temperatures and guard-zone air temperatures included in the data file specified in Section 13.2.5.3.

### 13.2.6 Case ET100A3: Artificial Climate, Steady-State Overall Building Loss Coefficient with Uninsulated Windows, Cell A, Applying Specified Catalog Material Properties Except for Selected Imputed Insulation Conductivities – with User Selected Interior Surface Heat Transfer Algorithms

#### 13.2.6.1 (*Informative*) Objectives and Method of the Test Case

#### 13.2.6.1.1 Objectives

The objectives of this case are the same as for Case ET100A1, except applied for user selected interior surface heat transfer algorithms.

#### 13.2.6.1.2 Method

a. Case ET100A3 is the same as ET100A1 except the constant combined interior surface heat transfer coefficients are replaced with interior surface heat transfer algorithms selected by the modeler. This provides an empirical validation of interior surface heat transfer algorithms for use with the test cases based on comparisons of modeled results versus measured data ± measurement uncertainty (u).

b. For an idealized heating system (that effectively outputs building load), apply comparisons during the best steady-state period of the empirical data for the following results:

- As listed with Objectives and Methods for Case ET110A1; see Informative Section 13.2.2.1.2, Item b.
  - With respect to $Q_{surf,x,model}$ versus $Q_{wall,x,measured}$, for this test case it may be reasonable to expect greater differences for modeled versus measured data for bounding surfaces with greater UA values, because interior surface heat transfer may represent a greater proportion of overall thermal resistance for such surfaces.
- $h_{comb,int,x,model}$ versus $h_{comb,int,x,measured}$, where
  - $h_{comb,int,x,model} = Q_{surf,x,model} / (T_{cell,model} - T_{surf,int,x,model})$, where
    1. $T_{cell,model}$ ≡ model test cell temperature output (should be same as measured $T_{cell}$)
    2. $T_{surf,int,x,model}$ ≡ model interior surface temperature output
  - $h_{comb,int,x,measured}$ is the measured combined coefficient based on characterization test case measurements, as documented in Informative Annex B23, Section B23.5
  - Propagated u($h_{comb,int,x,measured}$) is provided with Std140_ET_Results.xlsx, sheet 'h_int_Summary_ET100A3_B3' (see Readme-140-2023-B.docx with accompanying electronic media), with supporting details provided in Informative Annex B23, Section B23.5.

#### 13.2.6.2 Extension Case Basis and Revision Summary

Case ET100A3 shall be modeled exactly the same as Case ET100A1 except for changes detailed in the following sections.

#### 13.2.6.3 Output Requirements.

Output shall be provided as specified in Sections 13.3.1 and 13.3.6.

**13.2.6.4 Interior Surface Heat Transfer**

**13.2.6.4.1 Interior Surface Heat Transfer Model.** The modeler shall select the following as allowed by their program:

a. A time-step varying interior surface convection heat transfer algorithm, or constant surface convection coefficient(s) applied to each conduction path interior surface face
   i. For tested programs with multiple options for time-step varying interior surface convection algorithms, the user shall select the most appropriate algorithm based on:
      a) the test cell geometry and construction
      b) the heating system fan supply airflow rate provided in the accompanying file ET100A-Measurements.csv (see Section 13.2.4.3 [Case ET100A1])
      c) the following physical description of the air distribution/heating system: The air-distribution system, shown in Figures 13-24 and 13-25, is installed in the center of the test cell and includes intake ducts located near the ceiling and 4 supply-air diffusers near the floor.
         - The supply-air diffuser orientation is perpendicular to the floor (air flow roughly parallel to the floor) with diffusers oriented at angles of 0°, 90°, 180° and 270° relative to the test cell length axis.
         - The diffusers are 0.55 m x 0.55 m with the bottom edge of each diffuser approximately 0.1 m above the floor, as shown in Figure 13-25.
         - Contained within the system are the air distribution fan and the heater.
         - Airflow rate is measured within the duct segment just after (below) the intake at top of system, see Figure 13-24; this is before air enters the fan, and the fan is before (above) the heater in the airflow system as air moves from the intake toward the diffusers.
         - ***Informative Notes:***
            1. This instruction is intended for the purpose of selecting an interior surface convection heat transfer algorithm from options a given software may provide.
            2. This instruction is not intended to affect modeling of the idealized mechanical system (see Section 13.2.2.16).
            3. Exact measurement of diffuser height above the floor is not available; this height is roughly inferred from location/visibility of the base of the instrument stand behind the front diffuser in the right side of Figure 13-24, along with the scale of Figure 13-25.
            4. Figure 13-25 is based on test facility design documentation.

b. A time-step varying interior surface infrared radiation exchange algorithm
   i. For tested programs with multiple options for time-step varying radiation exchange algorithms, the user shall select the most appropriate algorithm based on the test cell geometry and construction.
   ii. For programs that input interior surface emittances as ε = 0 (or as low as the software being tested allows), to model specified combined coefficients as convective coefficients in pre-requisite cases – e.g., see Section 13.2.2.10, Informative Note 4 (Case ET110A1):
      - Apply the interior surface emittances specified in Table 13-19 of Section 13.2.2.9 (Case ET110A1)

- Except, for uninsulated windows apply the interior surface emittances specified in Table 13-45 of Section 13.2.4.8 (Case ET100A1)

**13.2.6.4.2 Reporting.** The modeler shall indicate the applied algorithms or values in Report Block B (alternative modeling methods) of S140outNotes.txt included with the accompanying electronic media.

**13.2.6.4.3** ***Informative notes:***

1. This replaces the constant interior combined convective and radiative surface heat transfer coefficients specified for Case ET100A1
2. Fan supply airflow rate varies hourly around an average of approximately 20.7 ACH for the best steady-state data period of this test case
3. Sensitivity tests of interior surface convection heat transfer algorithms by the test specification authors are discussed in Informative Annex B9, Section B9.7.3.
4. Constant convection-only coefficients are not provided in this test specification
5. The exterior surface coefficients remain the same as in Case ET100A1.

**Figure 13-24: Heating and Air-Distribution System (left); Diffusers Close-Up (right)**

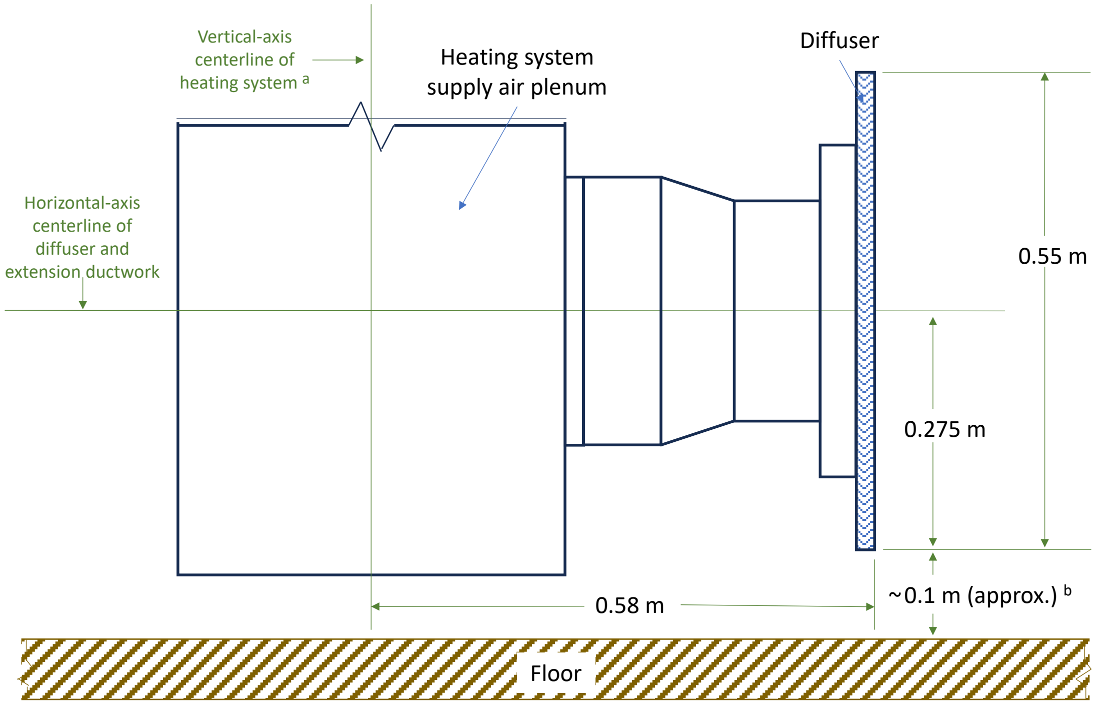



**Figure 13-25: Diffuser and Extension Ductwork without Insulation, Elevation Section**

Notes:

a. The vertical axis centerline of the heating system also corresponds with the center of the test cell floor and ceiling interior surfaces.

b. Regarding diffuser height above floor, see Section 13.2.6.4.1.a.i(c), Informative Note 3.

### 13.2.6.4.4 Interior Surface Texture.

For programs that allow variation of interior surface convection with surface texture, interior surface texture shall be selected within the tested program to best match the surface material indicated in Table 13-49

**Table 13-49 Interior Surface Type, Case ET100A3**

| Surface Type | Surface Material |
|---|---|
| Walls | Wallpaper |
| Ceiling | Wallpaper |
| Floor | Ceramic tile |
| Door | Wood, painted |
| Window panes | Glass |
| Window frames | PVC |

### 13.2.7 Case ET100B3: Artificial Climate, Steady-State Overall Building Loss Coefficient with Uninsulated Windows, Cell B, Applying Specified Catalog Material Properties Except for Selected Imputed Insulation Conductivities – with User Selected Interior Surface Heat Transfer Algorithms

#### 13.2.7.1 (*Informative*) Objectives and Method of the Test Case

#### 13.2.7.1.1 Objectives

The objectives of this case are the same as for Case ET100A1, except applied for user selected interior surface heat transfer algorithms.

#### 13.2.7.1.2 Method

a. Case ET100B3 is the same as ET100B1 except the constant interior combined surface heat transfer coefficients are replaced with interior surface heat transfer algorithms selected by the modeler. This provides an empirical validation of interior surface heat transfer algorithms for use with the test cases based on comparisons of modeled results versus measured data ± measurement uncertainty (u).

b. For an idealized heating system (that effectively outputs building load), apply comparisons as listed with Objectives and Methods for Case ET100A3; see Informative Section 13.2.6.1.2, Item b.

#### 13.2.7.2 Extension Case Basis and Revision Summary

Case ET100B3 shall be modeled exactly the same as Case ET100B1 except for changes detailed in the following sections.

#### 13.2.7.3 Output Requirements.

Output shall be provided as specified in Sections 13.3.1 and 13.3.7.

#### 13.2.7.4 Interior Surface Heat Transfer

**13.2.7.4.1 Interior Surface Heat Transfer Model.** The modeler shall select the following as allowed by their program:

a. A time-step varying interior surface convection heat transfer algorithm, or constant surface convection coefficient(s) applied to each conduction path interior surface face
    - For tested programs with multiple options for time-step varying interior surface convection algorithms, the user shall select the most appropriate algorithm based on:
        - the test cell geometry and construction
        - the heating system fan supply airflow rate provided in the accompanying file ET100B-Measurements.csv (see Section 13.2.5.3 [Case ET100B1])
        - the physical description of the air distribution described in Section 13.2.6.4.1.a.i(c) (Case ET100A3).

b. A time-step varying interior surface infrared radiation exchange algorithm.
    i. For tested programs with multiple options for time-step varying radiation exchange algorithms, the user shall select the most appropriate algorithm based on the test cell geometry and construction.
    ii. For programs that input interior surface emittances as $\varepsilon = 0$ (or as low as the software being tested allows), to model specified combined coefficients as

convective coefficients in pre-requisite cases – e.g., see Section 13.2.2.10, Informative Note 4 (Case ET110A1):

- Apply the interior surface emittances specified in of Section 13.2.3.8 (Case ET110B1)
- Except, for uninsulated windows apply the interior surface emittances specified in Section 13.2.5.8 (Case ET100B1). ***Informative Note:*** Section 13.2.5.8 cross-references back to Table 13-45 of Section 13.2.4.8 (Case ET100A1).

**13.2.7.4.2 Reporting.** The modeler shall indicate the applied algorithms or values in Report Block B (alternative modeling methods) of S140outNotes.txt included with the accompanying electronic media.

**13.2.7.4.3** ***Informative notes:***

1. This replaces the constant interior combined convective and radiative surface heat transfer coefficients specified for Case ET100B1
2. Fan supply airflow rate varies hourly around an average of approximately 21.5 ACH for the best steady-state data period of this test case
3. Sensitivity tests of interior surface convection heat transfer algorithms by the test specification authors are discussed in Informative Annex B9, Section B9.7.3.
4. Constant convection-only coefficients are not provided in this test specification
5. The exterior surface coefficients remain the same as in Case ET100B1.

**13.2.7.4.4 Interior surface Texture**

For programs that allow variation of interior surface convection with surface texture, interior surface texture shall be selected per instructions of Section 13.2.6.4.4 (Case ET100A3).

## 13.3 Output Requirements.

### 13.3.1 General Requirements

a. The values listed by test case below shall be provided and entered into the appropriate Standard Output Report; see Std140_ET_Output.xlsx included with the accompanying electronic media as specified in Normative Annex A2.
b. General reporting requirements of Section 5.1.2 shall apply.
c. Output shall apply the preceding-hour time convention of Section 13.2.1.1.
    - If the program being tested cannot provide output applying preceding-hour time convention, the user shall indicate the tested program output convention in Report Block B (alternative modeling methods) of S140outNotes.txt included with the accompanying electronic media.
d. Output precision shall be in accordance with that typically available in the model. Do not truncate or round the output. ***Informative Note:*** Std140_ET_Output.xlsx is formatted such that all entered results appear to the nearest hundredth decimal place, however, it maintains the full precision of the entered values.
e. Do not make changes to the output template. ***Informative Note:*** The template is set up for automated data handling; any changes to it will disrupt that process.

### 13.3.2 Case ET110A1

**13.3.2.1** Provide output applying sheet 'ET110A1' of the output template Std140_ET_Output.xlsx, included with the accompanying electronic media. The following requirements shall apply:

a. Table 13-50 lists required hourly-integrated-average outputs.
b. Output shall be provided for the experimental data duration time period indicated in Section 13.2.2.2.1. ***Informative Note:*** This is the same time period provided in Column A of the output template.

**13.3.2.2 Inside Surface Flux Output**

For software applying the 16 alternative 1-D conduction paths specified in Section 13.2.2.8.1.2 and related subsections of Section 13.2.2.8, this output (see Table 13-50) shall correspond with each 1-D conduction path specified in Section 13.2.2.8. ***Informative Note:*** This diagnostic output is provided to check modeling of individual 1-D conduction paths.

**13.3.2.2.1 Inside surface convective flux (Wh/m$^2$).** This is the convective flux (gain) from the test cell into the given surface at its interior face. A positive value indicates heat is flowing from the test cell into the surface.

**13.3.2.2.2 Inside surface radiative flux (Wh/m$^2$).** This is the radiative flux (gain) from the test cell into the given surface at its interior face. A positive value indicates heat is flowing from the test cell into the surface.

13.3.2.2.3 Inside surface combined convective and radiative flux (Wh/m$^2$). This is the sum of the convective and radiative fluxes; see Sections 13.3.2.2.1 and 13.3.2.2.2, respectively.

**13.3.2.3 Output Format**

Table 13-50 also describes format of the output template. Date and hour data described for worksheet column A is already provided in the template. Data for the other columns shall be provided for the program being tested.

**13.3.2.3.1** The following apply:

- Time zone is GMT+1
- Date is same as for the input data
- ***Informative Note:*** Reporting of test cell and guard zone air temperatures and fan energy are intended as measured-data input checks; the primary dependent variable is heating energy consumption (Qhtr).

**13.3.2.3.2** The header labels of Table 13-50 apply as follows:

- "Column" identifies the column where the data appears as viewed with Microsoft Excel™
- "Label" is the data descriptor provided in Row 4 of the output template
- "Usage" is the output purpose provided in Row 1 of the output template, where data marked:
    - "Input Check" data shall be applied for checking "input" data to the software being tested (see Section 13.2.2.2.1)
    - "Output" shall be applied for comparison with the provided:
        - "output" measured heating energy (see Section 13.2.2.2.1)
        - measurement-based individual surface heat flow output (see Section 13.3.2.4), for software applying the 16 alternative 1-D conduction paths specified for this test case. For software that cannot provide interior surface heat flow output, Report Block E (Omitted Test Cases and Results) of S140outNotes.txt (included with the accompanying electronic media) shall be completed. ***Informative Note:*** This output provides a proxy for material layer thickness and thermal conductivity input checks for each conduction path.
- "Description" is a brief description of the listed output; see Row 3 of the output template
- "Units" are the SI units of the measured data in Row 5 of the output template.

**Table 13-50 Cell A Hourly Output File Format**

| Column | Label | Usage | Description | Units |
|---|---|---|---|---|
| A | Date | Input Check | Date and time in format "MM-DD-YYYY hh:mm" (preceding hour format, e.g., Hour 10:00 = 09:00-10:00) | |
| B | Tattic | Input Check | Attic air temperature | ºC |
| C | Tcellar | Input Check | Cellar air temperature | ºC |
| D | Tnorth | Input Check | North guard air temperature | ºC |
| E | Teast | Input Check | East guard air temperature | ºC |
| F | Tsouth | Input Check | South guard air temperature | ºC |
| G | Twest | Input Check | West guard air temperature | ºC |
| H | Tcell | Input Check | Test cell air temperature | ºC |
| I | Qfan | Input Check | Fan energy consumption | Wh |
| J | HWDsafr | Input Check | Supply air flow rate, for heater with diffusers (HWD) | $m^3/h$ |

| | | | | |
|---|---|---|---|---|
| K | Qhtr | Output | Heater energy consumption | Wh |
| L | q,c1,conv | Output | Ceiling Path 1 inside surface convective flux [a] | Wh/m$^2$ |
| M | q,c1,rad | Output | Ceiling Path 1 inside surface radiative flux [a] | Wh/m$^2$ |
| N | q,c1,tot | Output | Ceiling Path 1 inside surface total convective and radiative flux [a] | Wh/m$^2$ |
| O | q,c2,conv | Output | Ceiling Path 2 inside surface convective flux [a] | Wh/m$^2$ |
| P | q,c2,rad | Output | Ceiling Path 2 inside surface radiative flux [a] | Wh/m$^2$ |
| Q | q,c2,tot | Output | Ceiling Path 2 inside surface total convective and radiative flux [a] | Wh/m$^2$ |
| R | q,f1,conv | Output | Floor Path 1 inside surface convective flux [a] | Wh/m$^2$ |
| S | q,f1,rad | Output | Floor Path 1 inside surface radiative flux [a] | Wh/m$^2$ |
| T | q,f1,tot | Output | Floor Path 1 inside surface total convective and radiative flux [a] | Wh/m$^2$ |
| U | q,f2,conv | Output | Floor Path 2 inside surface convective flux [a] | Wh/m$^2$ |
| V | q,f2,rad | Output | Floor Path 2 inside surface radiative flux [a] | Wh/m$^2$ |
| W | q,f2,tot | Output | Floor Path 2 inside surface total convective and radiative flux [a] | Wh/m$^2$ |
| X | q,f3,conv | Output | Floor Path 3 inside surface convective flux [a] | Wh/m$^2$ |
| Y | q,f3,rad | Output | Floor Path 3 inside surface radiative flux [a] | Wh/m$^2$ |
| Z | q,f3,tot | Output | Floor Path 3 inside surface total convective and radiative flux [a] | Wh/m$^2$ |
| AA | q,n,conv | Output | North wall inside surface convective flux [a] | Wh/m$^2$ |
| AB | q,n,rad | Output | North wall inside surface radiative flux [a] | Wh/m$^2$ |
| AC | q,n,tot | Output | North wall inside surface total convective and radiative flux [a] | Wh/m$^2$ |
| AD | q,d,conv | Output | Door inside surface convective flux [a] | Wh/m$^2$ |
| AE | q,d,rad | Output | Door inside surface radiative flux [a] | Wh/m$^2$ |
| AF | q,d,tot | Output | Door inside surface total convective and radiative flux [a] | Wh/m$^2$ |
| AG | q,e,conv | Output | East wall inside surface convective flux [a] | Wh/m$^2$ |
| AH | q,e,rad | Output | East wall inside surface radiative flux [a] | Wh/m$^2$ |
| AI | q,e,tot | Output | East wall inside surface total convective and radiative flux [a] | Wh/m$^2$ |
| AJ | q,ewin1,conv | Output | East window Path 1 inside surface convective flux [a] | Wh/m$^2$ |
| AK | q,ewin1,rad | Output | East window Path 1 inside surface radiative flux [a] | Wh/m$^2$ |
| AL | q,ewin1,tot | Output | East window Path 1 inside surface total conv. and rad. flux [a,b] | Wh/m$^2$ |
| AM | q,ewin2,conv | Output | East window Path 2 inside surface convective flux [a] | Wh/m$^2$ |
| AN | q,ewin2,rad | Output | East window Path 2 inside surface radiative flux [a] | Wh/m$^2$ |
| AO | q,ewin2,tot | Output | East window Path 2 inside surface total conv. and rad. flux [a,b] | Wh/m$^2$ |
| AP | q,ewin3,conv | Output | East window Path 3 inside surface convective flux [a] | Wh/m$^2$ |
| AQ | q,ewin3,rad | Output | East window Path 3 inside surface radiative flux [a] | Wh/m$^2$ |
| AR | q,ewin3,tot | Output | East window Path 3 inside surface total conv. and rad. flux [a,b] | Wh/m$^2$ |
| AS | q,s,conv | Output | South wall inside surface convective flux [a] | Wh/m$^2$ |
| AT | q,s,rad | Output | South wall inside surface radiative flux [a] | Wh/m$^2$ |
| AU | q,s,tot | Output | South wall inside surface total convective and radiative flux [a] | Wh/m$^2$ |
| AV | q,swin1,conv | Output | South window Path 1 inside surface convective flux [a] | Wh/m$^2$ |
| AW | q,swin1,rad | Output | South window Path 1 inside surface radiative flux [a] | Wh/m$^2$ |
| AX | q,swin1,tot | Output | South window Path 1 inside surface total conv. and rad. flux [a,b] | Wh/m$^2$ |
| AY | q,swin2,conv | Output | South window Path 2 inside surface convective flux [a] | Wh/m$^2$ |
| AZ | q,swin2,rad | Output | South window Path 2 inside surface radiative flux [a] | Wh/m$^2$ |
| BA | q,swin2,tot | Output | South window Path 2 inside surface total conv. and rad. flux [a,b] | Wh/m$^2$ |
| BB | q,swin3,conv | Output | South window Path 3 inside surface convective flux [a] | Wh/m$^2$ |
| BC | q,swin3,rad | Output | South window Path 3 inside surface radiative flux [a] | Wh/m$^2$ |
| BD | q,swin3,tot | Output | South window Path 3 inside surface total conv. and rad. flux [a,b] | Wh/m$^2$ |
| BE | q,w,conv | Output | West wall inside surface convective flux [a] | Wh/m$^2$ |

| | | | | |
|---|---|---|---|---|
| BF | q,w,rad | Output | West wall inside surface radiative flux [a] | Wh/m$^2$ |
| BG | q,w,tot | Output | West wall inside surface total convective and radiative flux [a] | Wh/m$^2$ |

a. See Section 13.3.2.2.
b. Abbreviations: "conv." = convective; "rad." = radiative

### 13.3.2.4 Comparing Software Output to Measured Data and Empirical Values Derived from Measured Data

Results comparisons shall be applied only for the given best steady-state period of the data; see Section 13.3.2.4.1.

The following measured data are provided for results comparisons for all models:

- Heater energy (Qhtr): see Section 13.3.2.4.2

The following empirical values derived from measured data are provided for results comparisons with software applying the 16 alternative 1-D conduction paths specified for this test case:

- Total surface heat fluxes (q,x,tot) for each conduction path (x): see Section 13.3.2.4.3

#### 13.3.2.4.1 Application of Best Steady-State Data

For Case ET110A1, the best steady-state time period is the 18 hour intervals of:

2/10/2000 16:00 to 2/11/2000 9:00, GMT+1

(The time interval applies "MM/DD/YYYY hh:mm" format and preceding hour interval time convention of Section 13.2.1.1)

***Informative Notes:***

1. Software results prior to the best steady-state period are not intended for model validation. I.e., software results are not expected to match measurements within a given uncertainty range prior to the beginning of the best steady-state period.
2. Determination of the best steady-state period for a given test case is described in Informative Annex B23, Section B23.2.

#### 13.3.2.4.2 Comparison of Heater Energy (Qhtr) Results

The primary results comparison is for Qhtr provided in ET110A-Measurements.csv (see Section 13.2.2.2.1), corresponding with the best steady-state period (last 18 rows of the csv file).

***Informative Notes:***

1. If the program has input the test case correctly, for steady-state output it is reasonable to expect modeled hourly output Qhtr during the best steady-state period that is mostly within averaged measured Qhtr ± u(Qhtr), Here, u(Qhtr) is ± 0.9% for a 2-sigma (95% confidence interval) uncertainty band.
2. The measured value for average of hourly-integrated best steady-state Qhtr (Wh) and its uncertainty range are shown in the column labeled "Qhtr_avg" of the designated table for the test case in sheet 'Qhtr_summary' of informative file "Std140_ET_Results.xlsx, included with the accompanying electronic media.

### 13.3.2.4.3 (*Informative*) Comparison of Inside Surface Flux Results

For software applying the 16 alternative 1-D conduction paths specified for this test case:

1. The measurement-based values for average of hourly integrated best steady-state individual-conduction-path heat flows are provided in the "SurfFlow [Wh/h] Measured" column of the designated table for the test case in sheet 'Surf_flow' of "Std140_ET_Results.xlsx", included with the accompanying electronic media.
   a. Average of hourly-integrated best steady-state individual conduction-path heat fluxes (Wh/m$^2$) are provided in sheet 'Surf_flux' of this file.
2. Hourly total surface fluxes (q,x,tot [Wh/m$^2$]) derived from measurements are provided in sheet 'ET110A' of the file ET100series-MeasBasedSurfFlux.xlsx, provided with the accompanying electronic media. Format of this file is provided in Informative Table 13-51. For the purpose of this comparison, data is only provided for the best steady-state period; see the last 18 rows in sheet 'ET110A'.
   a. Determination of measured UA and related values applied for this derivation is described in Informative Annex B23.
3. These files are provided for the purpose of comparing best-steady-state-period modeled individual conduction-path inside surface heat fluxes and/or flows to measurement-based individual conduction-path heat fluxes and/or flows derived from empirical measurements. As this output provides a proxy for material layer thickness and thermal conductivity input checks for each conduction path, it is recommended to compare results and fix input errors (if any are identified) prior to completing a final results set.
4. At steady state for a given heat flow path, modeled total inside surface heat fluxes and/or flows from the test cell into a given surface at its interior interface should be approximately equal to measurement-based individual conduction-path heat fluxes and/or flows from the test cell into a given guard zone. If there are no model input errors, any difference between modeled and measured results for this comparison may be attributable to: 1) minor deviations from steady-state (i.e., minor heat storage or release effects) in the measurements and/or the models, and/or 2) measurement uncertainty (see Informative Note 1 with Section 13.3.2.4.2), and/or 3) other minor differences between the modeled and measured systems (e.g., heating system control differences).

**Informative Table 13-51 Cell A Hourly Measurement-Based Heat-Flux File Format**

| Column | Label | Description | Units |
|---|---|---|---|
| A | Date | Date and time in format "MM-DD-YYYY hh:mm" (preceding hour format, e.g., Hour 10:00 = 09:00-10:00) | |
| B | q,c1,tot | Ceiling Path 1 | Wh/m$^2$ |
| C | q,c2,tot | Ceiling Path 2 | Wh/m$^2$ |
| D | q,f1,tot | Floor Path 1 | Wh/m$^2$ |
| E | q,f2,tot | Floor Path 2 | Wh/m$^2$ |
| F | q,f3,tot | Floor Path 3 | Wh/m$^2$ |
| G | q,n,tot | North wall | Wh/m$^2$ |
| H | q,d,tot | Door | Wh/m$^2$ |
| I | q,e,tot | East wall | Wh/m$^2$ |

| | | | |
|---|---|---|---|
| J | q,ewin1,tot | East window Path 1 | Wh/m$^2$ |
| K | q,ewin2,tot | East window Path 2 | Wh/m$^2$ |
| L | q,ewin3,tot | East window Path 3 | Wh/m$^2$ |
| M | q,s,tot | South wall | Wh/m$^2$ |
| N | q,swin1,tot | South window Path 1 | Wh/m$^2$ |
| O | q,swin2,tot | South window Path 2 | Wh/m$^2$ |
| P | q,swin3,tot | South window Path 3 | Wh/m$^2$ |
| Q | q,w,tot | West wall | Wh/m$^2$ |

### 13.3.3 Case ET110B1

**13.3.3.1** Provide output applying sheet '**ET110B1'** of the output template Std140_ET_Output.xlsx, included with the accompanying electronic media. The following requirements shall apply:

a. Output requirements of Section 13.3.2 (Case ET110A1) shall apply, except sheet 'ET110B1' columns AJ:BG shall have entries corresponding to Cell B hourly-integrated average outputs as shown in Table 13-52. ***Informative Note:*** The differences for Cell B in this table versus Cell A in Table 13-50 (see Section 13.3.2) are that the Cell B east wall, which has no window, requires flux output for only one 1-D conduction path and the Cell B west wall with window requires flux output for four 1-D conduction paths. The sequence of wall inside surface flux output entry remains the same as Cell A for the ceiling, floor, north wall and door, and the opaque portion of the east wall; see Table 13-50 for columns L:AI.

b. Output shall be provided for the same experimental data duration time period indicated in Section 13.2.3.3. ***Informative Note:*** This is the same time period provided in Column A of the output template.

**13.3.3.2 Inside Surface Flux Output**

For software applying the 16 alternative 1-D conduction paths specified in Section 13.2.3.7.1.2 and related subsections of Section 13.2.3.7.3.2, this output (see Table 13-52 shall correspond with each 1-D conduction path specified for Cell B in Section 13.2.3.7.3.2. Inside surface convective, radiative, and combined convective and radiative fluxes are defined in Sections 13.3.2.2.1, 13.3.2.2.2, and 13.3.2.2.3, respectively (Case ET110A1). ***Informative Note:*** This diagnostic output is provided to check modeling of individual 1-D conduction paths.

**13.3.3.3 Output Format**

The output format of Section 13.3.2.3 (Case ET110A1) shall apply, except the "Usage" categories of Table 13-52 apply section references specific to this test case as follows:

- "Input Check" data shall be applied for checking "input" data to the software being tested (see Section 13.2.3.3)
- "Output" shall be applied for comparison with the provided:
  - "output" measured heating energy (see Section 13.2.3.3)
  - measurement-based individual surface heat flow output (see Section 13.3.3.4), for software applying the 16 alternative 1-D conduction paths specified for this

test case. ***Informative Note:*** See informative note with "Output" item in Section 13.3.2.3.2 (Case ET110A1).

**Table 13-52 Cell B Hourly Output File Format Where Different from Cell A (Columns AJ to BG) [a]**

| Column | Label | Usage | Description | Units |
|---|---|---|---|---|
| AJ | q,s,conv | Output | South wall inside surface convective flux [a] | $Wh/m^2$ |
| AK | q,s,rad | Output | South wall inside surface radiative flux [a] | $Wh/m^2$ |
| AL | q,s,tot | Output | South wall inside surface total convective and radiative flux [a] | $Wh/m^2$ |
| AM | q,swin1,conv | Output | South window Path 1 inside surface convective flux [a] | $Wh/m^2$ |
| AN | q,swin1,rad | Output | South window Path 1 inside surface radiative flux [a] | $Wh/m^2$ |
| AO | q,swin1,tot | Output | South window Path 1 inside surface total conv.and rad. flux [a,b] | $Wh/m^2$ |
| AP | q,swin2,conv | Output | South window Path 2 inside surface convective flux [a] | $Wh/m^2$ |
| AQ | q,swin2,rad | Output | South window Path 2 inside surface radiative flux [a] | $Wh/m^2$ |
| AR | q,swin2,tot | Output | South window Path 2 inside surface total conv. and rad. flux [a,b] | $Wh/m^2$ |
| AS | q,swin3,conv | Output | South window Path 3 inside surface convective flux [a] | $Wh/m^2$ |
| AT | q,swin3,rad | Output | South window Path 3 inside surface radiative flux [a] | $Wh/m^2$ |
| AU | q,swin3,tot | Output | South window Path 3 inside surface total conv. and rad. flux [a,b] | $Wh/m^2$ |
| AV | q,w,conv | Output | West wall inside surface convective flux [a] | $Wh/m^2$ |
| AW | q,w,rad | Output | West wall inside surface radiative flux [a] | $Wh/m^2$ |
| AX | q,w,tot | Output | West wall inside surface total convective and radiative flux [a] | $Wh/m^2$ |
| AY | q, wwin1,conv | Output | West window Path 1 inside surface convective flux [a] | $Wh/m^2$ |
| AZ | q,wwin1,rad | Output | West window Path 1 inside surface radiative flux [a] | $Wh/m^2$ |
| BA | q,wwin1,tot | Output | West window Path 1 inside surface total conv. and rad. flux [a,b] | $Wh/m^2$ |
| BB | q,wwin2,conv | Output | West window Path 2 inside surface convective flux [a] | $Wh/m^2$ |
| BC | q,wwin2,rad | Output | West window Path 2 inside surface radiative flux [a] | $Wh/m^2$ |
| BD | q,wwin2,tot | Output | West window Path 2 inside surface total conv. and rad. flux [a,b] | $Wh/m^2$ |
| BE | q,wwin3,conv | Output | West window Path 3 inside surface convective flux [a] | $Wh/m^2$ |
| BF | q,wwin3,rad | Output | West window Path 3 inside surface radiative flux [a] | $Wh/m^2$ |
| BG | q,wwin3,tot | Output | West window Path 3 inside surface total conv. and rad. flux [a,b] | $Wh/m^2$ |

a. See Table 13-50, note a (Section 13.3.2 [Case ET110A1]).

b. Abbreviations: "conv." = convective; "rad." = radiative

### 13.3.3.4 Comparing Software Output to Measured Data and Empirical Values Derived from Measured Data

Results comparisons shall be applied only for the given best steady-state period of the data; see Section 13.3.3.4.1.

The following measured data are provided for results comparisons for all models:

- Heater energy (Qhtr): see Section 13.3.3.4.2

The following empirical values derived from measured data are provided for results comparisons with software applying the 16 alternative 1-D conduction paths specified for this test case:

- Total surface heat fluxes (q,x,tot) for each conduction path (x): see Section 13.3.3.4.3

***Informative Note:*** This is a similar comparison method as in Case ET110A1, except references to sections, tables, and accompanying files are specific to this test case.

### 13.3.3.4.1 Application of Best Steady-State Data

The best steady-state time period for ET110B1 is the same as for ET110A1; see Section 13.3.2.4.1.

### 13.3.3.4.2 Comparison of Heater Energy (Qhtr) Results

The primary results comparison is for Qhtr provided in ET110B-Measurements.csv (see Section 13.2.3.3), corresponding with the best steady-state period (last 18 rows of the csv file).

***Informative Notes:***

1. If the program has input the test case correctly, for steady-state output it is reasonable to expect modeled hourly output Qhtr during the best steady-state period that is mostly within averaged measured Qhtr ± u(Qhtr), Here, u(Qhtr) is ± 1.0% for a 2-sigma (95% confidence interval) uncertainty band.
2. See Section 13.3.2.4.2 (Case ET110A1), Informative Item 2.

### 13.3.3.4.3 (*Informative*) Comparison of Inside Surface Flux Results

For software applying the 16 alternative 1-D conduction paths specified for this test case:

1. See Informative Section 13.3.2.4.3 (Case ET110A1), Item 1
2. Hourly total surface fluxes (q,x,tot [Wh/m$^2$]) derived from measurements are provided in sheet 'ET110B' of the file ET100series-MeasBasedSurfFlux.xlsx, provided with the accompanying electronic media. Format of this file is provided in Informative Table 13-53. For the purpose of this comparison, data is only provided for the best steady-state period; see the last 18 rows in sheet 'ET110B'.
    a. Determination of measured UA and related values applied for this derivation is described in Informative Annex B23.
3. See Informative Section 13.3.2.4.3 (Case ET110A1), Item 3.
4. See Informative Section 13.3.2.4.3 (Case ET110A1), Item 4, except measurement uncertainty relates to Informative Note 1 with Section 13.3.3.4.2.

**Table 13-53 Cell B Hourly Measurement-Based Heat-Flux File Format**

| **Column** | **Label** | **Description** | **Units** |
|---|---|---|---|
| A | Date | Date and time in format "MM-DD-YYYY hh:mm" (preceding hour format, e.g., Hour 10:00 = 09:00-10:00) | |
| B | q,c1,tot | Ceiling Path 1 | Wh/m$^2$ |
| C | q,c2,tot | Ceiling Path 2 | Wh/m$^2$ |

| | | | |
|---|---|---|---|
| D | q,f1,tot | Floor Path 1 | Wh/m$^2$ |
| E | q,f2,tot | Floor Path 2 | Wh/m$^2$ |
| F | q,f3,tot | Floor Path 3 | Wh/m$^2$ |
| G | q,n,tot | North wall | Wh/m$^2$ |
| H | q,d,tot | Door | Wh/m$^2$ |
| I | q,e,tot | East wall | Wh/m$^2$ |
| J | q,s,tot | South wall | Wh/m$^2$ |
| K | q,swin1,tot | South window Path 1 | Wh/m$^2$ |
| L | q,swin2,tot | South window Path 2 | Wh/m$^2$ |
| M | q,swin3,tot | South window Path 3 | Wh/m$^2$ |
| N | q,w,tot | West wall | Wh/m$^2$ |
| O | q,wwin1,tot | West window Path 1 | Wh/m$^2$ |
| P | q,wwin2,tot | West window Path 2 | Wh/m$^2$ |
| Q | q,wwin3,tot | West window Path 3 | Wh/m$^2$ |

### 13.3.4 Case ET100A1

**13.3.4.1** Provide output applying sheet **'ET100A1'** of the output template Std140_ET_Output.xlsx, which is included with the accompanying electronic media.

**13.3.4.2** Output requirements and format of Section 13.3.2 (Case ET110A1) shall apply, except:

- Output shall be provided for the experimental data duration time period indicated in Section 13.2.4.3. ***Informative Note:*** This is the same time period provided in Column A of the output template.
- Section 13.3.4.3 regarding comparison of output replaces Section 13.3.2.4.

**13.3.4.3 Comparing Software Output to Measured Data and Empirical Values Derived from Measured data.**

Results comparisons shall be applied only for the given best steady-state period of the data; see Section 13.3.4.3.1.

The following measured data are provided for results comparisons for all models:

- Heater energy (Qhtr): see Section 13.3.4.3.2

The following empirical values derived from measured data are provided for results comparisons with software applying the 16 alternative 1-D conduction paths specified for this test case:

- Total surface heat fluxes (q,x,tot) for each conduction path (x): see Section 13.3.4.3.3

***Informative Note:*** This is a similar comparison method as in Case ET110A1, except references ''////////////////////////to sections, tables, and accompanying files are specific to this test case.

**13.3.4.3.1 Application of Best Steady-State Data**

For Case ET100A1, the best steady-state time period is the 55 hours intervals of:

9/16/2000 8:00 to 9/18/2000 14:00, GMT+1

(The time interval applies "MM/DD/YYYY hh:mm" format and preceding hour interval time convention of Section 13.2.1.1)

***Informative Note:*** See Informative Notes with Section 13.3.2.4.1 (Case ET110A1).

### 13.3.4.3.2 Comparison of Heater Energy (Qhtr) Results

The primary results comparison is for Qhtr provided in ET100A-Measurements.csv (see Section 13.2.4.3), corresponding with the best steady-state period (last 55 rows of the csv file).

***Informative Notes:***

1. If the program has input the test case correctly, for steady-state output it is reasonable to expect modeled hourly output Qhtr during the best steady-state period that is mostly within averaged measured Qhtr ± u(Qhtr), Here, u(Qhtr) is ± 0.7% for a 2-sigma (95% confidence interval) uncertainty band.
2. See Section 13.3.2.4.2 (Case ET110A1), Informative Note 2.

### 13.3.4.3.3 (*Informative*) Comparison of Inside Surface Flux Results

For software applying the 16 alternative 1-D conduction paths specified for this test case:

1. See Informative Section 13.3.2.4.3 (Case ET110A1), Item 1
2. Hourly total surface fluxes (q,x,tot [Wh/m$^2$]) derived from measurements are provided in sheet 'ET100A' of the file ET100series-MeasBasedSurfFlux.xlsx, provided with the accompanying electronic media. Format of this file is provided in Informative Table 13-51 (see Section 13.3.2.4.3 [Case ET110A1]). For the purpose of this comparison, data is only provided for the best steady-state; see the last 55 rows in sheet 'ET100A'.
    a. Determination of measured UA and related values applied for this derivation is described in Informative Annex B23.
3. See Informative Section 13.3.2.4.3 (Case ET110A1), Item 3.
4. See Informative Section 13.3.2.4.3 (Case ET110A1), Item 4, except measurement uncertainty relates to Informative Note 1 with Section 13.3.4.3.2.

## 13.3.5 Case ET100B1

**13.3.5.1** Provide output applying sheet '**ET100B1'** of the output template Std140_ET_Output.xlsx, which is included with the accompanying electronic media.

**13.3.5.2** Output requirements and format of Section 13.3.3 (Case ET110B1) shall apply, except:

- Output shall be provided for the experimental data duration time period indicated in Section 13.2.5.3. ***Informative Note:*** This is the same time period provided in Column A of the output template.
- Section 13.3.5.3 regarding comparison of output replaces Section 13.3.3.4.

### 13.3.5.3 Comparing Software Output to Measured Data and Empirical Values Derived from Measured data.

Results comparisons shall be applied only for the given best steady-state period of the data; see Section 13.3.5.3.1.

The following measured data are provided for results comparisons for all models:

- Heater energy (Qhtr): see Section 13.3.5.3.2

The following empirical values derived from measured data are provided for results comparisons with software applying the 16 alternative 1-D conduction paths specified for this test case:

- Total surface heat fluxes (q,x,tot) for each conduction path (x): see Section 13.3.5.3.3

***Informative Note:*** This is a similar comparison method as in Case ET110A1, except references to sections, tables, and accompanying files are specific to this test case.

### 13.3.5.3.1 Application of Best Steady-State Data

The best steady-state time period for ET100B1 is the same as for ET100A1; see Section 13.3.4.3.1.

### 13.3.5.3.2 Comparison of Heater Energy (Qhtr) Results

The primary results comparison is for Qhtr provided in ET100B-Measurements.csv (see Section 13.2.5.3), corresponding with the best steady-state period (last 56 rows of the csv file, excluding the final row).

***Informative Notes:***

1. If the program has input the test case correctly, for steady-state output it is reasonable to expect modeled hourly output Qhtr during the best steady-state period that is mostly within averaged measured Qhtr ± u(Qhtr), Here, u(Qhtr) is ± 0.9% for a 2-sigma (95% confidence interval) uncertainty band.
2. See Section 13.3.2.4.2 (Case ET110A1), Informative Note 2.

### 13.3.5.3.3 (*Informative*) Comparison of Inside Surface Flux Results

For software applying the 16 alternative 1-D conduction paths specified for this test case:

1. See Informative Section 13.3.2.4.3 (Case ET110A1), Item 1.
2. Hourly total surface fluxes (q,x,tot [$Wh/m^2$]) derived from measurements are provided in sheet 'ET100B' of the file ET100series-MeasBasedSurfFlux.xlsx, provided with the accompanying electronic media. Format of this file is provided in Informative Table 13-53 (see Section 13.3.3.4.3 [Case ET110B1]). For the purpose of this comparison, data is only provided for the best steady-state period; see the last 55 rows in sheet 'ET100B'.
    a. Determination of measured UA and related values applied for this derivation is described in Informative Annex B23.
3. See Informative Section 13.3.2.4.3 (Case ET110A1), Item 3.
4. See Informative Section 13.3.2.4.3 (Case ET110A1), Item 4, except measurement uncertainty relates to Informative Note 1 with Section 13.3.5.3.2.

## 13.3.6 Case ET100A3

**13.3.6.1** Provide output applying sheet '**ET100A3'** of the template Std140_ET_Output.xlsx, which is included with the accompanying electronic media.

**13.3.6.2** Output requirements and format of Section 13.3.4 (Case ET100A1) shall apply, except:

- For software applying the 16 alternative 1-D conduction paths specified for this test case, inside surface temperature output shall also be provided as specified in Section 13.3.6.3. For software that cannot provide interior surface temperature output, Report Block E (Omitted Test Cases and Results) of S140outNotes.txt (included with the accompanying electronic media) shall be completed.
- Section 13.3.6.4 regarding comparison of output replaces Section 13.3.4.3.

### 13.3.6.3 Inside surface temperature output

For software applying the 16 alternative 1-D conduction paths specified for this test case, the following output shall be provided:

- Hourly integrated-average inside surface temperatures (°C) output as specified in Table 13-54; these are the temperatures of each surface at its interior face
- This output corresponds with each 1-D conduction path specified for the test case.

**Table 13-54 Appended Hourly Inside Surface Temperature Output (ET100A3) [a]**

| Column | Label | Usage | Description | Units |
|---|---|---|---|---|
| BH | T,c1 | Output | Ceiling Path 1 inside surface temperature | °C |
| BI | T,c2 | Output | Ceiling Path 2 inside surface temperature | °C |
| BJ | T,f1 | Output | Floor Path 1 inside surface temperature | °C |
| BK | T,f2 | Output | Floor Path 2 inside surface temperature | °C |
| BL | T,f3 | Output | Floor Path 3 inside surface temperature | °C |
| BM | T,n | Output | North wall inside surface temperature | °C |
| BN | T,d | Output | Door inside surface temperature | °C |
| BO | T,e | Output | East wall inside surface temperature | °C |
| BP | T,ewin1 | Output | East window Path 1 inside surface temperature | °C |
| BQ | T,ewin2 | Output | East window Path 2 inside surface temperature | °C |
| BR | T,ewin3 | Output | East window Path 3 inside surface temperature | °C |
| BS | T,s | Output | South wall inside surface temperature | °C |
| BT | T,swin1 | Output | South window Path 1 inside surface temperature | °C |
| BU | T,swin2 | Output | South window Path 2 inside surface temperature | °C |
| BV | T,swin3 | Output | South window Path 3 inside surface temperature | °C |
| BW | T,w | Output | West wall inside surface temperature | °C |

a. See Section 13.3.6.1.

### 13.3.6.4 Comparing Software Output to Measured Data and Empirical Values Derived from Measured data.

Results comparisons shall be applied only for the given best steady-state period of the data; see Section 13.3.6.4.1.

The following measured data are provided for results comparisons for all models:

- Heater energy (Qhtr): see Section 13.3.6.4.2

The following empirical values derived from measured data are provided for results comparisons with software applying the 16 alternative 1-D conduction paths specified for this test case:

- Total surface heat fluxes (q,x,tot) for each conduction path (x): see Section 13.3.6.4.3
- Combined convective and radiative interior surface heat transfer coefficients for the best steady-state period (h,comb,int,x) for each conduction path (x): see Section 13.3.6.4.4.

***Informative Note:*** This is a similar comparison method as in Case ET110A1, except references to sections, tables, and accompanying files are specific to this test case. The inside surface temperature output, included for Case ET100A3, allows comparison of effective modeled combined interior surface heat transfer coefficients to measurement-based values.

**13.3.6.4.1 Application of Best Steady-State Data**

The best steady-state time period for ET100A3 is the same as for ET100A1; see Section 13.3.4.3.1.

**13.3.6.4.2 Comparison of Heater Energy (Qhtr) Results**

The primary results comparison is for Qhtr provided in ET100A-Measurements.csv (see Section 13.2.4.3, Case ET100A1), corresponding with the best steady-state period (last 55 rows of the csv file).

***Informative Notes:***

1. An uncertainty band around Qhtr maybe be characterized by averaged measured Qhtr ± u(Qhtr), Here, u(Qhtr) is ± 0.7% for a 2-sigma (95% confidence interval) uncertainty band.
2. See Section 13.3.2.4.2 (Case ET110A1), Informative Note 2.

**13.3.6.4.3 (*Informative*) Comparison of Inside Surface Flux Results**

See Informative Section 13.3.4.3.3 (Case ET100A1), except the following replaces its Item 4: For Case ET100A3, best-steady-state modeled total surface fluxes may vary from measurement-based individual conduction-path heat fluxes.

**13.3.6.4.4 (*Informative*) Comparison of Interior Surface Temperature (T,intsurf,x) Results**

The following applies for software applying the 16 alternative 1-D conduction paths specified for this test case.

1. For comparing T,intsurf,x results, equivalent modeled interior combined convective and radiative surface coefficients (h,comb,int,x) for each conduction path are based on h,comb,int,x = q,x,tot,model / (Tcell – T,intsurf,x), where q,x,tot,model is the total combined convective and radiative interior surface heat flux for a given conduction path "x", taken from the model, and Tcell and T,intsurf,x (for a given conduction path "x") are also taken from the model for this comparison.
2. The effective modeled combined coefficients are compared to the measured interior combined coefficients given for Case ET100A1, as specified in Sections 13.2.2.10 (Case ET110A1) and 13.2.4.9 (ET100A1).
3. Measurement-based values of h,comb,int,x ($W/m^2K$) and their uncertainty ranges are provided in sheet 'h_int_summary_ET100A3_B3' (see column with "Measurement and

Uncertainty Range" values headed "h,comb,avg") of informative file "Std140_ET_Results.xlsx", included with the accompanying electronic media.

4. In this comparison, h,comb,int,x as proxy for T,intsurf,x provides a better basis for scaling modeled versus measurement-based temperature differences than directly comparing modeled T,intsurf,x with T,intsurf,x derived from measurements.

### 13.3.7 Case ET100B3

**13.3.7.1** Provide output applying sheet **'ET100B3'** of the template Std140_ET_Output.xlsx, which is included with the accompanying electronic media.

**13.3.7.2** Output requirements and format of Section 13.3.5 (Case ET100B1) shall apply, except:

- For software applying the 16 alternative 1-D conduction paths specified for this test case, inside surface temperature output shall also be provided as specified in Section 13.3.7.3. For software that cannot provide interior surface temperature output, Report Block E (Omitted Test Cases and Results) of S140outNotes.txt (included with the accompanying electronic media) shall be completed.
- Section 13.3.7.4 regarding comparison of output replaces Section 13.3.5.3.

**13.3.7.3 Inside surface temperature output**

For software applying the 16 alternative 1-D conduction paths specified for this test case, the following output shall be provided:

- Hourly integrated-average inside surface temperatures (°C) output as specified in Table 13-55; these are the temperatures of each surface at its interior face
- This output corresponds with each 1-D conduction path specified for the test case.

**Table 13-55 Appended Hourly Inside Surface Temperature Output (ET100B3) [a]**

| Column | Label | Usage | Description | Units |
|---|---|---|---|---|
| BH | T,c1 | Output | Ceiling Path 1 inside surface temperature | °C |
| BI | T,c2 | Output | Ceiling Path 2 inside surface temperature | °C |
| BJ | T,f1 | Output | Floor Path 1 inside surface temperature | °C |
| BK | T,f2 | Output | Floor Path 2 inside surface temperature | °C |
| BL | T,f3 | Output | Floor Path 3 inside surface temperature | °C |
| BM | T,n | Output | North wall inside surface temperature | °C |
| BN | T,d | Output | Door inside surface temperature | °C |
| BO | T,e | Output | East wall inside surface temperature | °C |
| BP | T,s | Output | South wall inside surface temperature | °C |
| BQ | T,swin1 | Output | South window Path 1 inside surface temperature | °C |
| BR | T,swin2 | Output | South window Path 2 inside surface temperature | °C |
| BS | T,swin3 | Output | South window Path 3 inside surface temperature | °C |
| BT | T,w | Output | West wall inside surface temperature | °C |
| BU | T,wwin1 | Output | West window Path 1 inside surface temperature | °C |
| BV | T,wwin2 | Output | West window Path 2 inside surface temperature | °C |
| BW | T,wwin3 | Output | West window Path 3 inside surface temperature | °C |

a. See Section 13.3.7.1.

### 13.3.7.4 Comparing Software Output to Measured Data and Empirical Values Derived from Measured data.

Results comparisons shall be applied only for the given best steady-state period of the data; see Section 13.3.7.4.1.

The following measured data are provided for results comparisons for all models:

- Heater energy (Qhtr): see Section 13.3.7.4.2

The following empirical values derived from measured data are provided for results comparisons with software applying the 16 alternative 1-D conduction paths specified for this test case:

- Total surface heat fluxes (q,x,tot) for each conduction path (x): see Section 13.3.7.4.3
- Combined convective and radiative interior surface heat transfer coefficients for the best steady-state period (h,comb,int,x) for each conduction path (x): see Section 13.3.6.4.4.

***Informative Note:*** This is a similar comparison method as in Case ET100A3, except references to sections, tables, and accompanying files are specific to this test case.

#### 13.3.7.4.1 Application of Best Steady-State Data

The best steady-state time period for ET100B3 is the same as for ET100A1; see Section 13.3.4.3.1.

#### 13.3.7.4.2 Comparison of Heater Energy (Qhtr) Results

The primary results comparison is for Qhtr provided in ET100B-Measurements.csv (see Section 13.2.5.3, Case ET100B1), corresponding with the best steady-state period (last 56 rows of the csv file, excluding the final row).

***Informative Notes:***

1. An uncertainty band around Qhtr maybe be characterized by averaged measured Qhtr ± u(Qhtr), Here, u(Qhtr) is ± 0.9% for a 2-sigma (95% confidence interval) uncertainty band.
2. See Section 13.3.2.4.2 (Case ET110A1), Informative Note 2.

#### 13.3.7.4.3 (*Informative*) Comparison of Inside Surface Flux Results

See Informative Section 13.3.5.3.3 (Case ET100B1), except the following replaces its Item 4: For Case ET100B3, best-steady-state modeled total surface fluxes may vary from measurement-based individual conduction-path heat fluxes.

#### 13.3.7.4.4 (*Informative*) Comparison of Interior Surface Temperature (T,intsurf,x) Results

See Informative Section 13.3.6.4.4 (Case ET100A3), except the effective modeled combined coefficients are compared to the measured interior combined coefficients given for Case ET100B1, as specified in Sections 13.2.2.10 (Case ET110A1), 13.2.3.9 (Case ET110B1), and 13.2.5.9 (Case ET100B1).

[Note to reviewers : This page Intentionally blank.]

[Note to ASHRAE Staff: Section break about here]

***[Note to Reviewers: Edits to existing sections apply tracked changes (underline/strikethrough text) to indicate proposed changes to Standard 140-2023. Only text needed for indicating changes is shown.]***

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

## NORMATIVE ANNEX A1 WEATHER DATA

…

**A1.10 EPW Weather Data Format.** EPW weather data are provided in comma separated value (CSV) file format. The EPW data format has eight file header lines followed by 8760 lines of data, each with 36 data fields, as described below.

**A1.10.1 File Headers.** The first eight rows of each file is the file header that describes the location, design conditions, typical/extreme periods, ground temperatures, whether holidays and/or daylight savings time are considered, comments, and the data period covered by the data.

**A1.10.2 Hourly Records.** Following the file headers, 8760 rows of hourly data records provide one (1) year of solar radiation, illuminance, and meteorological data, along with their source and uncertainty flags.

***Informative Notes:***

1. 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). For meteorological elements (with some exceptions), observations or measurements were made *at the hour indicated*. Some of the meteorological elements had observations, measurements, or estimates made at other intervals.
2. The EPW format is further described at http://climate.onebuilding.org/papers/EnergyPlus_Weather_File_Format.pdf.

**A1.11 Weather Data for Building Thermal Fabric Empirical Validation Tests.** Full-year EPW weather data listed in Table A1-27 shall be used as specified in Section 13. See Section A1.10 for details about the EPW weather data file format.

…

**Table A1-27 EPW Weather Data for Building Thermal Fabric Empirical Validation Tests**

| **Data File** | **Applicable Cases** | **Applicable Cases' Sections** |
|---|---|---|
| ET110meteo_within_Melun-071530_MY.2000.epw | ET110A1, ET110B1, ET100A1, ET100B1, ET100A3, ET100B3 | 13.2.2, 13.2.3, 13.2.4, 13.2.5, 13.2.6, 13.2.7 |

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

## NORMATIVE ANNEX A2
## STANDARD OUTPUT REPORTS

The Standard Output Reports, consisting of the following forms provided in the electronic media accompanying this standard, shall be used:

a. Output results for cases of Section 6 (Std140_WD_Output.xlsx, spreadsheet file)
b. Output results for cases of Section 7 (Std140_TF_Output.xlsx, spreadsheet file)
c. Output results for cases of Section 8 (Std140_GC_Output.xls, spreadsheet file)
d. Output results for cases of Sections 9.2.1 and 9.2.2 (Std140_CE_a_Output.xls, spreadsheet file)
e. Output results for cases of Sections 9.2.3 and 9.2.4 (Std140_CE_b_Output.xls, spreadsheet file)
f. Output results for cases of Section 10 (Std140_HE_Output.xls, spreadsheet file)
g. Output results for cases of Section 11 (Std140_AE_Output.xlsx, spreadsheet file)
h. Output results for cases of Section 12 (sheet “TF_Class2_Output” within Std140_TF_Class2_Results.xls spreadsheet file)
i. Output results for cases of Section 13 (Std140_ET_Output.xlsx, spreadsheet file)
~~i~~j. Modeling notes (S140outNotes.TXT, text file reprinted as Attachment A2.9~~8~~)

For entering output results into the above XLS and XLSX template files, the user shall follow the instructions provided at the top of the appropriate electronic spreadsheet file or designated sheet within the spreadsheet file. These instructions are reprinted as Attachments A2.1, A2.2, A2.3, A2.4, A2.5, A2.6,~~ and~~ A2.7, and A2.8 respectively, within this section; instructions for sheet “TF_Class2_Output” within Std140_TF_- Class2_Results.xls are not reprinted here.

For entering modeling notes into S140outNotes.TXT, the report author shall create one modeling notes text document for each section of tests, for example, as follows:

a. S140outNotes_6.TXT for the Class-I weather drivers tests of Section 6
b. S140outNotes_7.TXT for the Class-I building thermal envelope and fabric load tests of Section 7
c. S140outNotes_8.TXT for the Class-I ground-coupled slab-on-grade tests of Section 8
d. S140outNotes_9A.TXT for the Class-I space-cooling equipment performance analytical verification tests of Sections 9.2.1 and 9.2.2
e. S140outNotes_9B.TXT for the Class-I space-cooling equipment performance comparative tests of Sections 9.2.3 and 9.2.4
f. S140outNotes_10.TXT for the Class-I space-heating equipment performance tests of Section 10
g. S140outNotes_11.TXT for the Class-I air-side HVAC equipment performance analytical verification tests of Section 11
h. S140outNotes_12.TXT for the Class-II test procedures of Section 12
i. S140outNotes_13.TXT for the Class-I thermal fabric empirical validation test procedures of Section 13

***Informative Note:*** For entering modeling notes into S140outNotes.TXT, the format of the examples applying S140outNotes_Examples.TXT given in Informative Attachment A2.10~~9~~ within this section is recommended.

…

### Attachment A2.8—Instructions for Entering Results into Std140_ET_Output.xlsx

INSTRUCTIONS:

1. Use specified units.
2. In the “Program Info” sheet, complete the information about the program submission in Cells B1 through B7.
3. The tabs to the right of the “Program Info” tab are output template sheets for each test case. In the output template sheets:
    a. Enter the simulation results into the appropriate sheet starting in row 6.

b. Enter the hourly output for each specified variable in the assigned column for the experimental duration time period specified for each test case (corresponds with the row labels of Column A), and applying the time convention of the test specification.

4. The results are analyzed using an automatic script. If the data are not placed in the appropriate columns and rows, the comparison script will fail.

***[Note to Reviewers: A2.8 and A2.9 renumbered to A2.9 and A2.10 respectively and cross referencing within 140 revised accordingly.]***

### Attachment A2.98—Standard 140 Output Form—Modeling Notes (S140outNotes.TXT)

**…**

### Informative Attachment A2.109—Examples of Modeling Notes (S140outNotes_Examples.TXT)

***Informative Note:*** Attachment A2.109 is all informative material and is not part of the Standard.

**…**

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

## NORMATIVE ANNEX A3
## SOFTWARE ACCEPTANCE CRITERIA

…

**A3.3 Submission of Results.** Test results shall be provided in the normative output forms of Normative Annex A2. Submittals shall also include a complete set of reports, as described in Normative Annex A2, Attachment A2.98, with all report blocks completed.

**(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

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 B1-18 are listed below.
Abbreviations used for Tables B1-4, B1-5,~~ and~~ B1-19, and B1-20 are listed with those tables.

…

**Table B1-1 Description of Test-Case Tabular Summary Tables**

| Tables | Description of Test Cases | Sections | Units |
|---|---|---|---|
| B1-2, B1-3 | Class-I building thermal fabric envelope and fabric load, comparative | 7.2 | SI |
| B1-4, B1-5 | Class-I ground-coupled slab-on-grade, analytical verification | 8.2 | SI |
| B1-6 | Space-cooling equipment performance, analytical verification | 9.2.1, 9.2.2 | SI |
| B1-7 | Space-cooling equipment performance, analytical verification | 9.2.1, 9.2.2 | I-P |
| B1-8 | Space-cooling equipment performance, comparative | 9.2.3, 9.2.4 | SI |
| B1-9 | Space-heating equipment, analytical verification and comparative | 10.2 | SI |
| B1-10, B1-12, B1-14, B1-16 | Air-side HVAC equipment performance, analytical verification | 11.2 | I-P |
| B1-11, B1-13, B1-15, B1-17 | Air-side HVAC equipment performance, analytical verification | 11.2 | SI |
| B1-18 | Weather drivers, analytical verification and comparative | 6.2 | SI |
| B1-19 | Class-I building thermal fabric, empirical validation | 13.2 | SI |
| B1-20~~19~~ | Class-II building thermal fabric envelope and fabric load, comparative | 12.2 | I-P |

…

**Table B1-19 Thermal Fabric Empirical Validation, Steady-State, Artificial-Climate, Case Descriptions for Section 13.2**

| **Case** | **Cell** | **Win. Ins.** | **Interior Surf. h.t.** | **Base Case** | **Comments** |
|---|---|---|---|---|---|
| **ET110A1** | A | Yes | h,comb [c] | -- | Simpler physics: suppressed window h.t.; |
| **ET100A1** | A | No | h,comb [c] | ET110A1 | Uninsulated window → greater heat transfer |
| **ET100A3** | A | No | Auto [d] | ET100A1 | Simple context for surface h.t. validation test |
| **ET110B1** | B | Yes | h,comb [c] | ET110A1 | Simpler physics: suppressed window h.t. |
| **ET100B1** | B | No | h,comb [c] | ET110B1 | Uninsulated window → greater heat transfer |
| **ET100B3** | B | No | Auto [d] | ET100B1 | Simple context for surface h.t. validation test |

ABBREVIATIONS
h.t.: heat transfer
k,imp: imputed thermal conductivites; see Note a.
Surf.: surface
Win Ins.: insulated windows, i.e., windows having insulation packed into the external setback cavity.
NOTES
a. Constant combined interior and exterior surface heat transfer coefficients.
b. Automated variation of interior convection and/or radiation heat transfer; algorithms applied within the program are selected by the modeler.

***[Note to Reviewers: Table B1-19 header revised to "B1-20 in two places, as shown.]***

**Table B1-2019 Section 12.2 Case Descriptions**

**…**

**Table B1-2019 Section 12.2 Case Descriptions *(Continued)***

**….**

**(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 WEATHER DRIVERS TESTS OF SECTION 6, BUILDING THERMAL ENVELOPE AND FABRIC LOAD TESTS OF SECTION 7, ~~AND~~ GROUND-COUPLED SLAB-ON-GRADE TESTS OF SECTION 8, AND BUILDING THERMAL FABRIC EMPIRICAL VALIDATION TESTS OF SECTION 13

Example results from various detailed building energy simulation programs that applied the tests of Sections 6, 7, ~~and~~ 8, and 13 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 8, and the empirical measurements and selected measurement uncertainties for the thermal fabric empirical validation tests of Section 13. 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, Sections B9.4 (for the tests of Sections 7 and 8), B9.6 (for the tests of Section 6), and B9.7 (for the tests of Section 13).

For generating example simulation results presented in this annex, along with using consistent modeling methods, ~~simulationists~~ modelers 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.

For software-to-software comparative tests, or modeled results within any of the tests that do not have an analytical-verification or empirical-validation truth standard, ~~T~~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~~ the given 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 or measured data uncertainty ranges should not be perceived as better or worse than a program that yields values at the borders of the range.

…

***[Note to Reviewers: Following text is all new. Edit tracking not shown.]***

## B8.4 Building Thermal Fabric Empirical Validation Tests of Section 13.

**B8.4.1 Example Results Files.** Example modeled results are compared with measured data in XLSX and PDF files in the electronic media accompanying this standard. These files are provided for the best-steady-state hours specific to each test case as follows:

- Std140_ET_Results.XLSX: Results tables of average heater energy, surface flux, and effective interior combined convective and radiative surface heat transfer coefficients; see the "Introduction" sheet there. The tabulated interior combined surface heat transfer results include propagated uncertainties for measurement-based values.
- Std140_ET_Qhtr_HourlyPlots.PDF: Hourly heater energy results charts, which include measurement uncertainty bounds for the best-steady-state hours based on applying propagated uncertainty to the average measured heater energy over the best-steady-state hours
- Input check XLS and PDF files: These files are included to document the types of files that were developed for input checking. They show minor reasonable differences that occurred for some programs after all previous measured-data input errors for all programs were resolved during the simulation trials.
- XLS files providing measurements and surface fluxes based on measurements.
- Std140_ET_Results.docx includes complete documentation of the accompanying results files and is printed in Informative Annex B10, Section B10.8.

Nomenclature used in the tables and figures is defined in Section B8.4.4. For a summary of how example results were developed, see Informative Annex B11, Section B11.2. More detailed information about the application of measured data is included in informative Annex B23.

For the convenience of users who wish to compile their results along with the example results, see the Python™ scripts and related instructions available on data.ashrae.org/standard140. When comparing results using the charts, it is important to consider the scale of the results. It is possible that differences that look large on a chart are actually insignificant, but the scale of the chart magnifies the difference. Similarly, large scales can make significant differences look insignificant. To clarify the scale of differences, charts with both magnified and unmagnified (full scale) y-axes are provided.

**B8.4.2 Importance of Measured Data.**

**B8.4.2.1 Physical Truth Standard.** The building thermal fabric empirical validation test cases of Section 13 apply the measured data as a physical truth standard within the uncertainty of the measurements. Application of measured data is an important methodological advance that provides a physical accuracy truth standard, which in turn provides a foundation for greater diagnostic capability than a method that only compares software to each other. The measured data allowed identification of bugs in the software that were not traceable from comparing software only to other software, e.g., applying the cases of Section 7.

It is important to understand caveats associated with applying an empirically-based physical truth standard that must include measurement uncertainties. While such an approximate truth standard tests both the solution process and appropriateness of the software implementation of a given test case within experimental uncertainty, there are practical limits (typically a function of available resources) to reducing experimental uncertainty as the complexity of an experiment increases. For example, we would expect the uncertainty of characterizing material property inputs to increase for non-steady-state cases in artificial climate when thermal mass is active, and then increase further for natural climate cases where solar gains are transmitted through windows.

**B8.4.2.2 Empirical Characterization of Inputs.** The measurements allow for empirical characterization of inputs. This drives an accurate representation of the test facility in the models, which allows for diagnosis of differences between models and measurements. For the steady-state cases of Section 13, input characterization focused on imputing selected thermal conductivities based on empirically determined bounding-surface UA-values derived from steady-state measured data. The process for the imputations is as follows:

- Determine best steady-state periods for each test case from temporal uncertainty analysis.

- Determine UA values of each test cell bounding surface based on empirical data; this was possible because the test facility has 6 separately controllable guard zones for each test cell (12 guard zones in total).
- Determine constant combined (convective and radiative) heat transfer coefficients ($h_{comb,int}$) for each test cell bounding surface based on empirical data. ***Caveat:*** In dynamic simulations, constant combined coefficients are not recommended, but they are useful for characterizing conductivities at steady state.
- Impute selected material conductivities ($k_{imp}$) within each bounding surface based on measured UA values and measured surface heat transfer coefficients. Values of $k_{imp}$ implicitly include the following aspects of as-built construction characterized by measured UA values: 2D and 3D conduction, thermal bridges, infiltration, and other unspecified as-built conditions.

Further discussion of how measured data was applied to characterize inputs is provided in Informative Annex B23 and elsewhere[c-3].

**B8.4.3 Example Simulation Results.** The simulation programs used to generate example results for the building thermal fabric empirical validation tests of Section 13 are described in Informative Annex B11, Section B11.4.

**B8.4.3.1 Purpose of Including Example Simulation Results with Empirical Validation Tests.** Because the steady-state measured data comprises a reliable set of results with low measurement and input uncertainty, the primary purposes of including example simulation results for the test cases are to 1) demonstrate vetting of the test specification, and 2) allow software developers and other modelers to compare their relative agreement (or disagreement) versus the measured data to that for other simulation results. Perfect agreement within experimental uncertainties among simulations and the measured data is not necessarily expected. The results indicate the degree of agreement that is possible between simulation results and measured data. Because the physical assumptions of a simulation may be different from those inherent to an experimental facility – e.g., how the facility is controlled, how the data are collected and processed, and how software inputs are characterized and presented by the specification authors – a tested program may disagree with empirical data without necessarily being incorrect. However, it is worthwhile to investigate the sources of the differences, especially in cases where measurement uncertainties are known to be small.

**B8.4.3.2 Input Checks, Individual Surface Heat Flows, and Heater + Fan Energy.** During the simulation trials, results comparisons (see Section B8.4.1) in the following sequence were recommended for the best-steady-state hours for the insulated-window and uninsulated-window base cases (Cases ET100A1, ET100B1, ET110A1, and ET110B1):

a. Input check results files are compared initially. This check demonstrates proper reading of .csv files containing measured temperatures, heater and fan powers, and supply airflow rate data.
b. Heat flows for each specified 1-D conduction path “x” (Q,x) are then compared with measurement-based values to check that material thicknesses and thermal conductivities, along with constant combined interior and exterior surface heat transfer coefficients, are correctly input to the models.
c. Finally, heating energy (Qhtr) is compared with measurements and measurement uncertainty (Qhtr ± u(Qhtr). In addition to this, Σ(Q,x) for all specified 1-D heat flow paths versus total heater plus fan energy within the test cell (Qhtr + Qfan) checks the steady-state energy balance of individual heat flows and total energy use.

**B8.4.3.3 Effective Combined Coefficients for Cases with User Selected Interior Surface Heat Transfer Algorithms.** Cases ET100A3 and ET100B3 evaluate user selected interior surface heat transfer algorithms, where heating system supply airflow rates are provided so that algorithms that account for adjusting surface heat transfer as a function of supply airflow rate can also be tested. For the best-steady-state hours, measurement-based combined convective and radiative interior surface coefficients for each 1-D heat flow path “x” (h,comb,int,x,meas) ± u(h,comb,int,x,meas) provides a basis for comparing appropriateness of selected automated calculations, where effective modeled coefficients for a given heat flow path (h,comb,int,x,model) are determined from: h,comb,int,x,model = Q,x,model / (Tcell – T,surf,int,x,model).

As a fraction of measured quantities u(h,comb,int,x)/h,comb,int,x > u(Qhtr)/Qhtr, but the target ranges for h,comb,int,x,meas are still useful with greatest uncertainties occurring for the more insulated walls that have smaller air-to-surface temperature differences (Tcell – T,surf,int,x).

Evaluation of user selected interior surface heat transfer algorithms are important for non-steady-state empirical validation test cases that are possible.

**B8.4.4 Nomenclature for Section 13 Results Files.** Results are shown using case designators; e.g., "ET110A1" is Case ET110A1 (see Section 13.2.2). Program and measured-data designations used in the results tables and figures are defined below.

| | |
|---|---|
| CSE | California Simulation Engine, Version 0.926.0 (see Table B11-4); simulation model |
| DesignBuilder | DesignBuilder, Version 8.0.0.067 (see Table B11-4); simulation model |
| DeST | DeST 2.0, Version 20220712 (see Table B11-4); simulation model |
| EnergyPlus | EnergyPlus, Version 23.1 (see Table B11-4); simulation model |
| ESP-r | ESP-r, Version 13.3.16 (see Table B11-4); simulation model |
| IES-VE | IES-VE, Version 2023.5.2.0 (see Table B11-4); simulation model |
| Measured or Measurement | ETNA test facility measurement data |
| TRNSYS | TRNSYS, Version 18.04 (see Table B11-4); simulation model |

For additional abbreviations and acronyms applied in the results files, see Std140_ET_Results.docx included with the accompanying electronic media.

***[Note to Reviewers: Edits to existing sections apply tracked changes (underline/strikethrough text) to indicate proposed changes to Standard 140-2023. Only text needed for indicating changes is shown.]***

**(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 B9-12~~1~~ 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 Annex B8 and Informative Annex 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. 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.
h. Availability of measured data including measurement uncertainties.

**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 5.1.2.1(c). 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 or measured data, then recheck the inputs against the specified values. Use the diagnostic logic flow diagrams to help isolate the source of the difference.

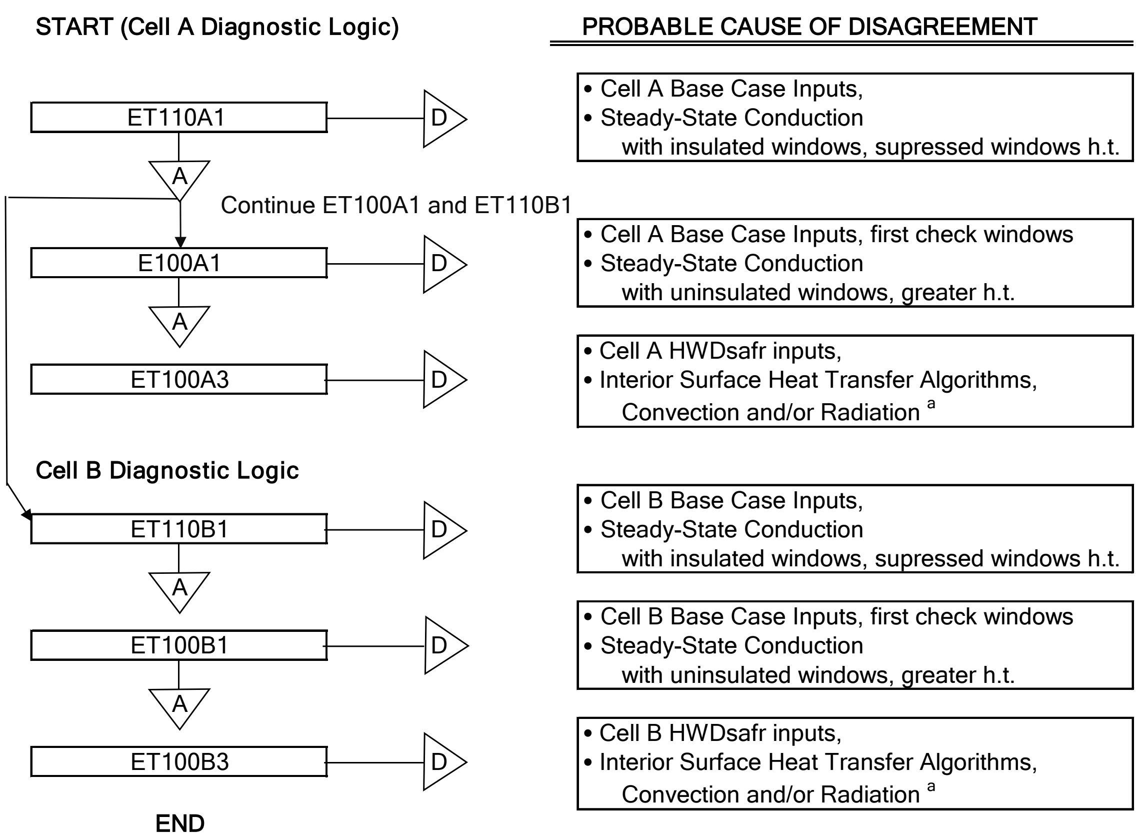
If no input error can be found, then look for an error in the software. If an error is found, then fix it and rerun the tests. If, in the engineering judgment of the user, the disagreement is caused by a reasonable difference in algorithms between the tested software ~~and~~ versus the example results or other tested software, or versus application of an algorithm or set of algorithms relative to a measured data configuration, then continue with the next test case.

…

**B9.7 Diagnostic Logic Flow Diagram for Building Thermal Fabric Empirical Validation Tests (Section 13)**

**B9.7.1 Introduction.** An empirical validation test suite is different from the other test suites in that it applies a physical truth standard within the uncertainty of the experiments. Additionally, inputs are provided that are intended to accurately characterize the test facility and its measured data. This means that prior to drawing conclusions related to accuracy of algorithms, inputs should be checked according to the scheme of Section B8.4.3.2. Figure B9-12 shows the test cases and the algorithm or set of algorithms being tested with each case. If a program demonstrates a difference for a test case, the relevant inputs noted in the figure should first be checked before concluding that the tested algorithms may be causing the differences.

For the convenience of users who wish to compile their results along with the example results, see the Python[TM] scripts and related instructions available on data.ashrae.org/standard140.




ABBREVIATIONS d: ...\ETNAflow.xls
A = Agree; D = Disagree. Agreement/disagreement is determined relative to measured data.
h.t. = heat transfer; HWDsafr = heating system supply air flow rate

Note a. See Section B9.7.3.

**Figure B9-12: ET-Series Steady-State Cases Diagnostic Logic Flow Diagram**

…

**B9.7.2 Consideration of Measured Data.** At a minimum, the user should compare output with the measured data and its uncertainties; see Informative Annex B8, Section B8.4. The user may also choose to compare output with the example simulation results in that section or with other results that were generated using Section 13 of this test procedure. In making a determination of agreement of results for the tests of Section 13, the user should consider that the measured data represents a physical truth standard within the provided ranges of uncertainty, i.e., that there is a physical accuracy target. Information about how the measured data was produced, and how inputs were characterized based on measurements, is included in Informative Annex B23.

**B9.7.3 Consideration of User Selected Interior Surface Convection Heat Transfer Algorithms for Cases ET100A3 and ET100B3.** The authors of the Section 13 test suite observed or concluded the following based on model sensitivity tests for Cases ET100A3 and ET100B3:

- A substantial difference between modeled heating energy results for buoyancy-driven versus mechanically-driven interior surface heat transfer algorithms
- Heating energy differences among application of various mechanically-driven interior surface heat transfer algorithms that are less substantial than buoyancy versus mechanically-driven algorithms generally
- Some mechanically-driven correlations intended for specific diffuser installations (e.g., embedded in ceiling) may not be appropriate to a ceiling where the heating system configuration of Figure 13-24 (see Section 13.2.6.4.1) is applied
- Further detail is provided in Informative Annex B23, Section B23.7.

The ability to precisely specify surface heat transfer is limited by the uncertainty of the available interior surface heat transfer data.

**B9.8~~7~~ Examples**

**B9.8~~7~~.1 Example Using Flow Diagrams for Building Thermal Envelope and Fabric Load Tests (Sections 7.2.1 and 7.2.2).**

**…**

**B9.8~~7~~.2 Example Using Flow Diagrams for Ground-Coupled Slab-on-Grade Analytical Verification Tests (Section 8).**

**…**

**B9.8~~7~~.3 Example Using Flow Diagrams for Space-Cooling Equipment Performance Analytical Verification Tests (Sections 9.2.1 and 9.2.2).**

…

**B9.8~~7~~.4 Example Using Flow Diagrams for HVAC Equipment Performance Comparative Tests (Sections 9.2.3 and 9.2.4).**

…

**(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 INFORMATIVE RESULTS ~~SPREADSHEETS~~ PROVIDED WITH THE STANDARD

For the convenience of users, a printout of documentation for navigating the example results files is included below.

…

***[Note to Reviewers: Following text is all new. Edit tracking not shown.]***

**B10.8 Documentation for Std140_ET_Results.xlsx, Std140_ET_Qhtr_HourlyPlots.pdf, Input check xlsx and pdf files, and xlsx files providing measurement and surface fluxes based measurements (given in Std140_ET_Results.docx).** These files contain the measured data and informative example software results for the Section 13 building thermal fabric empirical validation tests as described in Informative Annex B8, Section B8.4. Descriptions for each file or set of files follows.

- **Std140_ET_Results.xlsx**
  - This workbook provides summary analysis of measured and modeled heater energy (Qhtr), and diagnostic surface heat flow analysis for each of the sixteen specified 1-D conduction heat flow paths, during the best steady-state hours for the given test cases.
  - All content applies to the best steady-state-hours for the given cases.
  - Content of each workbook sheet is provided in Table B10-9
  - Notes regarding further content details are provided at the top of sheets where applicable.

**Table B10-9. Index of Sheets in Std140_ET_Results.xlsx**

| Sheet | Description |
|---|---|
| Introduction | • Overview of the information in the workbook and the programs for which results are included<br>• Instructions for comparing new results (entered into the Std140_ET_Output.xlsx workbook) with the measured data and software example results for the tests. (The "Readme" sheet within the Std140_ET_Output.xlsx workbook provides a general overview of that workbook and instructions for adding new results there.) |
| Qhtr_summary | Comparison of measured and software-generated best steady-state hourly-integrated Qhtr (Wh/h) for each test case |
| Surf_flow | Comparison of measurement-based and software-generated total surface heat flows and total heating energy (Qhtr + Qfan), (Wh/h). Content of sheet 'Surf_flux' feeds this sheet. |
| Surf_flux | Comparison of measurement-based and software-generated total surface heat fluxes (Wh/m$^2$) |
| h_int_summary_ET100A3_B3 | ET100A3, ET100B3: comparison of measurement-based and software-generated surface heat transfer coefficients (W/m$^2$K) with uncertainty ranges. Content of sheets 'h_int_ET100A3' and 'h_int_ET100B3' feeds this sheet. |
| h_int_ET100A3 | ET100A3: comparison of measurement-based and software-generated total surface heat fluxes (Wh/m$^2$) and interior surface heat transfer coefficients (W/m$^2$K) |
| h_int_ET100B3 | ET100B3: comparison of measurement-based and software-generated total surface heat fluxes (Wh/m$^2$) and interior surface heat transfer coefficients (W/m$^2$K) |
| Qhtr_source_data | Measured and software-generated Qhtr source data applied for this workbook |
| Flux_software_source_data | Software-generated interior surface convective, radiative, and total (convective + radiative) heat flux, and interior surface temperature source data, applied for this workbook |
| Flux_meas_source_data | Measured and measurement-based source data applied for this workbook |

- **Std140_ET_Qhtr_HourlyPlots.pdf**
  - The hourly output of Qhtr from all example software tools plotted together with measurements for individual test cases.
    - Versions of plots are shown with y-axes magnified and unmagnified.
  - The measurement data and its measurement uncertainty boundaries are depicted using a black line plot with circle marker and a gray shaded area, respectively.
- **Input check xls and pdf files:** These files are included to document the types of files that were developed, applying a Python™ script for input checking. They show minor reasonable differences that occurred for some programs after all previous measured-data input errors for all programs were resolved during the simulation trials. Remaining differences are attributable to legitimate modeling differences among software tools, including: hourly time convention and conversion of input values to processed output values (e.g., propagation of precision limits).
  - **Inp_Chk_HourlyDiff_x.xlsx** (software tool name as "x")
    - Isolates input differences beyond threshold tolerances and provides the magnitude of each difference relative to the threshold value for a given software tool during best-steady-state hours, where hourly difference = (hourly measurement) – (hourly simulation output)
    - Separate workbook sheets are provided for each test case.
  - **Inp_Chk_ErrorPlots_x.pdf** (software tool name as "x")
    - These files document the greater-than-threshold reported input differences that occurred for a given software, test case, and input, and are plotted along with the corresponding measurements, where y-axes were selected that intentionally magnify the differences. These are remaining differences after input errors, if any, were corrected during the simulation trials. In all cases these differences have logical justifications and were deemed inconsequential to the overall results. Ultimately, this demonstrates that the selected input difference tolerances provide an optimal balance of reasonably flagging differences while minimizing false

indicators. I.e., at too granular of a tolerance all inputs would be flagged because of reasonable precision limits in software and at too loose of a tolerance then consequential input errors would be missed.

- For a tool with no error plots, there were no greater-than-threshold input differences after input errors, if any, were corrected during the simulation trials.

- **xls files providing measurements and surface fluxes based on measurements**
  - **ET100AB-Measurement.xlsx & ET110AB-Measurement.xlsx:** Along with normative measured input data provided in .csv files (see Section 13.2), measurement uncertainty bounds are provided in separate sheets for Cell A and Cell B within each file.
  - **ET100series-MeasBasedSurfFlux.xlsx:** The following sheet or sheet groups are provided
    - 'Contents_Instructions': Overview and instructions
    - 'ET110A', 'ET110B', 'ET100A', 'ET100B': Best-steady-state measurement-based surface heat flux data and derivation details for each of the sixteen specified 1-D conduction heat flow paths for each test cell configuration. This data is for comparing with modeled interior surface total fluxes. During the simulation trials this data was useful for identifying input errors related to individual heat flow paths.

When implementing a new results comparison, a new comparison spreadsheet and plots are created automatically using a Python script. So, it is vital that all of the information entered in the Std140_ET_Output.xlsx workbook is entered in the appropriate cells. **See data.ashrae.org/standard140 for information on downloading and using the Python script to generate the comparison spreadsheet and plots with the new results included.**

**…**

***[Note to Reviewers: Edits to existing sections apply tracked changes (underline/strikethrough text) to indicate proposed changes to Standard 140-2023. Only text needed for indicating changes is shown.]***

**B10.9~~8~~ Documentation for Std140_TF_Class2_Results.xls (given in Std140_TF_Class2_Results.docx).**

**…**

**(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 WEATHER DRIVERS TESTS OF SECTION 6, BUILDING THERMAL ENVELOPE AND FABRIC LOAD TESTS OF SECTION 7, ~~AND~~ GROUND-COUPLED SLAB-ON-GRADE TESTS OF SECTION 8, AND BUILDING THERMAL FABRIC EMPIRICAL VALIDATION TESTS OF SECTION 13

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 Sections 6, 7, ~~and~~ 8, and 13. 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.

For the test cases of Section 6, for some output variables from the test cases, values from the source weather files can be used as a truth standard.

For the test cases of Section 13, measured data provides a physical truth standard within the uncertainty of the measurements.

…

**B11.1.4 Legitimate Modeling Differences.** We define legitimate modeling differences or disagreement as where:

a. the program's test case inputs conform to the test specification
b. reviewers have not identified a disqualifying algorithmic deficiency as the cause of disagreement.

Criterion “a”~~1~~ is directly determinable from the simulation-trial participant modeler reports (see Part III, Section 3.9 of the test-suite-update final report [B-14]). Regarding criterion “b”~~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) [B-55] and further developed here, include:

a. 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.
b. 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 “a”~~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.

…

***[Note to Reviewers: Following text is new for the Standard; tracked changes not shown.]***

**B11.4 Results for Building Thermal Fabric Empirical Validation Cases of Section 13.** The programs used to generate the example results for Section 13 are described in Table B11-4. Under the “Simulation Program” column, the first entry in each cell is the proper program name and version number. The entries in the “Abbreviation” column are the abbreviations for the programs used in Informative Annex B8, Section B8.4.

The “Authoring Organization” column indicates the university, national research facility, or industry organization with expertise in building science that wrote the simulation software. The “Implemented by” column indicates the university, national research facility, or industry organization with expertise in building science that performed the simulations. The majority of participating organizations that performed simulations ran software written by their organization.

**Table B11-4 Computer Programs, Program Authors, and Producers of Section 13 Example Results**

| Simulation Program | Authoring Organization | Implemented by | Abbreviation |
|---|---|---|---|
| Source ETNA measurement data | Provided in the accompanying files | Electricité de France, France; J. Neymark and Associates/ Argonne National Laboratory, United States | Measured or Measurement |
| California Simulation Engine, Version 0.926.0 | J.R. Barnaby/C.S. Barnaby/Big Ladder Software LLC/Wrightsoft Corp., United States | Big Ladder Software LLC, United States | CSE |

| | | | |
|---|---|---|---|
| DesignBuilder, Version 8.0.0.067 (EnergyPlus 23.1) | DesignBuilder Software Ltd., United Kingdom | DesignBuilder Software Ltd., United Kingdom | DesignBuilder |
| DeST 2.0, Version 20220712 | Tsinghua University, China | Beijing University of Civil Engineering and Architecture/ Southeast University/Tsinghua University, China | DeST |
| EnergyPlus, Version 23.1 | U.S. Department of Energy, Building Technologies Office, United States | Argonne National Laboratory, United States | EnergyPlus |
| ESP-r, Version 13.3.16 | University of Strathclyde, United Kingdom | University of Strathclyde, United Kingdom | ESP-r |
| IES-VE, Version 2023.5.2.0 | Integrated Environmental Solutions, United Kingdom | Integrated Environmental Solutions, United Kingdom | IES-VE |
| TRNSYS, Version 18.04 | Solar Energy Laboratory, University of Wisconsin, United States; Thermal Energy System Specialists, LLC, United States | Thermal Energy System Specialists, LLC, United States | TRNSYS |

To minimize the potential for user error, internal simulation trials were initially run by the Argonne National Laboratory (Argonne) project team with EnergyPlus and TRNSYS. For these internal trials a separate member of the project team checked the input files for both programs and reported input errors to the modelers. For the "external" industry simulation trials (outside of the Argonne project team), interior surface total convective and radiative fluxes for all individual heat flow path best-steady-state results were compared with measurement-based values; this effectively checked the modeled UA value and related material thicknesses and thermal conductivity inputs for each conduction path.

For the purpose of the industry simulation trials, the participants were requested to submit results for the test cases at more granular accuracy settings if there is a substantial difference in results for more granular versus typical accuracy settings.

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 requested to be documented in modeler reports (see individual simulation-trial participant "ModRep_Proforma_ET100Series…PDF" files included in the electronic accompanying files available on data.ashrae.org/standard140). Arbitrary modification of a simulation program's input or internal code for the sole 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 data.ashrae.org/ standard140.**

**B11.4.1 Selection of Programs for Producing Example Results.** The criteria for selection of programs used for producing example results required that

a. the program be a true simulation based on hourly weather data and calculational time increments of one (1) hour or less.
b. the program was currently maintained at the time of publication of the originating test suite.
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 this test suite, where improvements were made for some of the programs. Additionally, the programs (to various extents) have been subjected to other comparative, empirical validation and/or analytical verification tests, such as those referenced in Informative Annex C1 and 2021 *ASHRAE Handbook—Fundamentals* [B-7], Chapter 19, Section 8.

**B11.4.2 Legitimate Modeling Differences.** Legitimate modeling differences or disagreements are defined in Section B11.1.4.

For the current results set, the seven programs have good agreement. I.e., where specified constant combined convective and radiative interior surface heat transfer coefficients and thermal conductivities imputed from measured values (see Informative Annex B23) are applied (Cases ET110A1 ET110B1, ET100A1, and ET100B1), all model results are within the uncertainty range of measured overall heating energy, and modeled interior surface fluxes for the 16 individual heat flow paths have good agreement with measurement-based values. Results differences for cases with user selected interior surface heat transfer algorithms (Cases ET100A3 and ET100B3) can be attributed to legitimate modeling differences among the selected algorithms.

***[Note to Reviewers: Edits to existing sections apply tracked changes (underline/strikethrough text) to indicate proposed changes to Standard 140-2023. Only text needed for indicating changes is shown.]***

## INFORMATIVE ANNEX B12
## DEVELOPMENT OF ACCEPTANCE CRITERIA

**…**

**B12.1.2 Reference Software for Setting Bound Limits.**

…

The results from a reference software

- include justification via Normative Annex A2, Attachment A2.9~~8~~, Item G ("Report Block for Anomalous Results") if they fall outside of the established bounds and
- pass the minimum number of tests indicated for each test group in Table A3-14 for which a given reference software provided results.

…

## INFORMATIVE ANNEX B20
## EXAMPLE RESULTS FOR SECTION 12 TEST PROCEDURES

**…**

For the convenience of users who wish to plot or tabulate their results along with the example results, an electronic version of the example results has been included with the file Std140_TF_Class2_Results.xls on the accompanying electronic media. Documentation regarding Std140_TF_Class2_Results.xls is included in Std140_TF_Class2_Results.docx; a summary printout is included in Informative Annex B10, Section B10.9~~8~~.

…

***[Note to Reviewers: Following text is new for the Standard; tracked changes not shown.]***

**(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 B23
## Supporting Information for Building Thermal Fabric Empirical Validation Tests of Section 13

See Informative Annex-B23.pdf and related accompanying files, included with the accompanying electronic media (see Readme-140-2023-B.docx).

…

***[Note to Reviewers: Edits to existing sections apply tracked changes (underline/strikethrough text) to indicate proposed changes to Standard 140-2023. Only text needed for indicating changes is shown.]***

**(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 <u>C1</u> ~~B23~~
## VALIDATION METHODOLOGIES AND OTHER RESEARCH RELEVANT TO STANDARD 140

***[Note to ASHRAE Staff for next continuous maintenance revision:***

- ***Renumber all Section numbers of this informative annex from "B23…" to "C1…"]***
- ***Update cross references from "B23…" to "C1…" ("B23" may occur about 43 times as section number or informative cross-references in 140-2023).]***

…

.

.

**(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 C2 ~~B24~~
## INFORMATIVE REFERENCES

***[Note to Reviewers: Existing 140-2023 references called out in addendum new language are shown without tracking in addition to new references called out by the addendum with edit tracking.]***

***[Note to ASHRAE Staff for next continuous maintenance revision:***

- ***Renumber "B-" references to "C-" and their citations. (not trivial for 100+ refs with 400+ cites)]***

…

B-7. ASHRAE. 2021. *ASHRAE Handbook—Fundamentals*. Atlanta: ASHRAE.

…

B-83. Neymark, J., P. Girault, G. Guyon, R. Judkoff, R. LeBerre, J. Ojalvo, and P. Reimer. 2005. *The ETNA BESTEST Empirical Validation Data Set.* Building Simulation 2005, Ninth International IBPSA Conference, Montréal, Canada, August 15–18, 2005. International Building Performance Simulation Association.

…

C-1. Neymark, J., Girault, P., Guyon, G., Judkoff, R., LeBerre, R., Ojalvo, J., Reimer, P. (2004). *ETNA BESTEST Empirical Validation Test Specification.* Golden, Colorado, US: J. Neymark & Associates; Moret sur Loing, France: Electricité de France. This document is provided as file ETNA-testspec-010904PubDom+minorformats061713.pdf with the accompanying electronic media; see Readme-140-2023-B.

C-2. *ASHRAE 2021 Handbook of Fundamentals.* (2021). Atlanta, GA: ASHRAE. See Chapter 19, Section 8, "Validation and Testing".

C-3. J. Neymark, J. Kim, R. Muehleisen, T. McDowell, Z. Zeng, C. Barnaby, B. Bhandari, L. Buckley, N. Kruis, N. Oliver, V. Panek, P. Strachan, A. Tindale, B. Tokarzewski, W. Wei, D. Yan, X. Zhou. (2025), "ETNA Empirical Validation: Initial Steady-State Cases and Simulation Trials." *Proceedings of Building Simulation 2025.* Brisbane, Australia, 24-27 Aug 2025. International Building Performance Simulation Association.

C-4. EnergyPlus Weather File (EPW) Data Dictionary. (2022). http://climate.onebuilding.org/papers/EnergyPlus_Weather_File_Format.pdf

C-5. *ASHRAE 2021 Handbook of Fundamentals.* (2021a). Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers. See pp. 26.7, 26.14, 26.15. Cites the following:
- Robinson, H.E. and F.J. Powlitch. (1954). *The thermal insulating value of airspaces*. National Bureau of Standards (now National Institute of Standards and Technology). NBS Report 3030.
- Robinson, H.E., F.J. Powell, and L.A. Cosgrove. (1957). *Thermal resistance of airspaces and fibrous insulations bounded by reflective surfaces.* National Bureau of Standards (now National Institute of Standards and Technology). Building Materials and Structures Report 151.

***[Note to ASHRAE Staff: following references are cited by Informative Annex B23 within Informative accompanying file "AnnexB23.pdf"]***

C-6. Nakahama, H. (2008). Estimation method for temperature uncertainty of temperature chambers (JTM K 08). Espec test center corp, 1-14.

C-7. ANSI C12.20 (2022). https://en.wikipedia.org/wiki/ANSI_C12.20

C-8. Yazdanian, M., J. Klems. (1994). "Measurement of the Exterior Convective Film Coefficient for Windows in Low-Rise Buildings."*ASHRAE Transactions 100(1) 1994.* Atlanta, Georgia, US: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. Also published as LBL-34717. Berkeley, California. Lawrence Berkeley National Laboratory.

C-9. U.S. Department of Energy. (2022). EnergyPlus™ Version 22.1.0 Documentation Engineering Reference. https://energyplus.net/assets/nrel_custom/pdfs/pdfs_v22.1.0/EngineeringReference.pdf

C-10. Li F., Chen G., Zhang Y., Hao Y., Si Z. Fundamental Properties and Thermal Transferability of Masonry Built by Autoclaved Aerated Concrete Self-Insulation Blocks. Materials (Basel). 2020 Apr 3;13(7):1680. doi: 10.3390/ma13071680. PMID: 32260236; PMCID: PMC7178685.

C-11. Designing Buildings, The Construction Wiki. Specific Heat Capacity. https://www.designingbuildings.co.uk/wiki/Specific_heat_capacity

C-12. Neymark, J.; Kim, J.; Muehleisen, R.; Zeng, Z.; McDowell, T. (2025b). "ETNA BESTEST Empirical Validation". Presentation to ASHRAE SSPC 140, Feb 10, 2025. Peachtree Corners, GA: ASHRAE. This is provided as file "SSPC140-ETNA-SimTrialSummarySlides-Orlando-021025a" with the accompanying electronic media; see Readme-140-2023-B.

C-13. Neymark, J.; Kim, J.; Muehleisen, R.; Zeng, Z.; McDowell, T. (2024). "ETNA BESTEST Empirical Validation". Presentation to ASHRAE SSPC 140, Jun 24, 2024. Peachtree Corners, GA: ASHRAE. This is provided as file "SSPC140-ETNA-SimTrialSummarySlides-Indy-062424" with the accompanying electronic media; see Readme-140-2023-B.

C-14. Fisher, D.E. and C.O. Pedersen. 1997. "Convective Heat Transfer in Building Energy and Thermal Load Calculations", ASHRAE Transactions, Vol. 103, Pt. 2.

**(This annex 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.)**

## INFORMATIVE ANNEX DC
## ADDENDA DESCRIPTION

***[Note to ASHRAE Staff for next continuous maintenance revision:***

- ***Update here for next CM revision***
- ***Update "Table C-1" to "Table "D-1"]***

**NOTE**

**Approved addenda, errata, or interpretations for this standard can be downloaded free of charge from the ASHRAE website at www.ashrae.org/technology.**

## POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

**ASHRAE · 180 Technology Parkway · Peachtree Corners, GA 30092 · www.ashrae.org**

## About ASHRAE

Founded in 1894, ASHRAE is a global professional society committed to serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration, and their allied fields.

As an industry leader in research, standards writing, publishing, certification, and continuing education, ASHRAE and its members are dedicated to promoting a healthy and sustainable built environment for all, through strategic partnerships with organizations in the HVAC&R community and across related industries.

To stay current with this and other ASHRAE Standards and Guidelines, visit www.ashrae.org/standards, and connect on LinkedIn, Facebook, Twitter, and YouTube.

## Visit the ASHRAE Bookstore

ASHRAE offers its Standards and Guidelines in print, as immediately downloadable PDFs, and via ASHRAE Digital Collections, which provides online access with automatic updates as well as historical versions of publications. Selected Standards and Guidelines are also offered in redline versions that indicate the changes made between the active Standard or Guideline and its previous edition. For more information, visit the Standards and Guidelines section of the ASHRAE Bookstore at www.ashrae.org/bookstore.

## IMPORTANT NOTICES ABOUT THIS STANDARD

**To ensure that you have all of the approved addenda, errata, and interpretations for this Standard, visit www.ashrae.org/standards to download them free of charge.**

**Addenda, errata, and interpretations for ASHRAE Standards and Guidelines are no longer distributed with copies of the Standards and Guidelines. ASHRAE provides these addenda, errata, and interpretations only in electronic form to promote more sustainable use of resources.**

Product code: 86892 11/23