ADDENDA

ANSI/ASHRAE Addendum b to
ANSI/ASHRAE Standard 140-2020

Method of Test for Evaluating Building Performance Simulation Software

Approved by ASHRAE and the American National Standards Institute on January 31, 2023.

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FOREWORD

Purpose of the Addendum

Addendum b adds software acceptance criteria to Standard 140, allowing organizations citing Standard 140 to require the results from software used for their purposes to be within the ranges included in this addendum. This provides those organizations with a measure of the acceptability of a building performance simulation software program based on the tests included in Standard 140. The acceptance criteria were developed by a working group including members of both ASHRAE Standing Standard Project Committee 140 (SSPC 140) and ASHRAE Standard Project Committee 90.1 (SSPC 90.1) Energy Cost Budget (ECB) subcommittee. Related project funding for development was provided by the U.S. Department of Energy through Argonne National Laboratory.

Background

Prior to this addendum, Standard 140 included test cases with example results to evaluate building performance software but did not include any information on when a software's results would be considered acceptable for the test cases. This meant that organizations that cited Standard 140 would only require that software ran the tests and not that their results had to be within a specific range of results. Historically, this caused confusion for jurisdictions adopting standards that reference Standard 140 (such as Standard 90.1) when trying to determine if certain software passed or failed Standard 140, when simply running the tests was all that was required.

To address that issue, this addendum introduces acceptance criteria to Standard 140 for determining if a software is suitable for a citing organization's application. The acceptance criteria divide a subset of the Standard 140 test cases into test groups and into further results subsets for individual test cases and sensitivity tests (differences between selected individual test cases). The acceptance criteria also provide statistically derived acceptance ranges, against which tested software's results are compared. The number of the test ranges that the software's results must be within to be considered acceptable for a specific test group is also defined.

Informative sections on the development of the acceptance criteria procedure and advice to the citing organizations have also been added. These sections are intended to clarify the process of citing Standard 140 and provide guidance regarding appropriate considerations when approving software for an organization's purposes.

All major building energy modeling software developers were invited to participate in the process to determine the acceptance ranges, and many software developers participated. The acceptance ranges were set so that most commonly used software programs are within the ranges, and additional software are expected to be within the ranges as software developers address outlying results. Overall, this approach will encourage building performance simulation software to be more accurate and consistent.

The acceptance criteria are presented in new Normative Annex A3 and Informative Annex B12.

Summary of Changes in This Addendum

A listing of the substantive changes to Sections 5.6, and related sections, annexes, and accompanying electronic media, follows (listed Sections are normative unless otherwise indicated):

- *Updated Section 3.1, "Definitions," includes new defined terms.*
- *Updated Section 4.1, "General," includes reference to acceptance criteria.*
- *New Informative Section 4.5 "Citing Standard 140," includes advice to organizations citing Standard 140.*
- *Updated Section 5.1.4, "Consistent Modeling Methods," includes requirements for consistent numerical settings.*
- *New Annex A3, "Software Acceptance Criteria," includes the procedure for comparing software's results for acceptance.*
- *New Informative Annex B12, "Development of Acceptance Criteria," includes a description of the procedure used to develop the acceptance criteria.*

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

Addendum b to Standard 140-2020

Add the following new terms to Section 3.1.

[. . .]

calculation engine: the component of the software that performs the building performance simulation calculations. (See *software*.)

[. . .]

input interface: the component of the software used for communicating the inputs to the calculation engine. (See *software* and *calculation engine*.)

[. . .]

numerical settings: software settings related to minimum resolution (e.g., maximum time step, maximum convergence tolerance, etc.). (See *software*.)

[. . .]

output interface: the component of the software for processing, storing, and displaying the outputs of the calculation engine. (See *software* and *calculation engine*.)

[. . .]

***software*:** a package consisting of the user interface, input interface, calculation engine, and output interface, including any nesting of these elements within multiple input/output interfaces where applicable. (See *user interface*, *input interface*, *calculation engine*, and *output interface*.)

[. . .]

user interface: the component of the software for users to specify inputs to the input interface and for the output interface or calculation engine to display outputs to the user. (See *software*, *input interface*, *output interface*, and *calculation engine*.)

Revise Section 4.1 as shown. The remainder of Section 4.1 is unchanged.

4.1 General. The test procedures shall be applied as specified in Normative Sections 5 through 8. 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, "Acceptable Software 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 ~~specify~~ require individual test cases or groups of test cases. Where specific sections are not called out for acceptance criteria, all test groups of Annex A3 shall apply.

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

Add new Informative Section 4.5 as shown.

4.5 (*Informative*) Citing Standard 140. Organizations or standards that cite Standard 140 and require results submittal should explicitly define the scope of testing, which portions of the acceptance criteria apply, and how tested programs can be used for their purposes. Considerations include but are not necessarily limited to the following:

a. Sections of Standard 140 to be completed: Standard 140 is organized into sections that test different modeling aspects (e.g., building thermal fabric, equipment performance). Not all sections may apply to the organization's purpose in requiring building simulation and testing using Standard 140. Organizations should review sections and only cite those that are important for their purposes. For example, an organization that is interested in the performance of low-rise residential buildings may wish to only include the tests of Section 7 in its testing requirements.
b. Acceptance criteria test groups applicability: The acceptance criteria are grouped by the tested modeling aspect (e.g., building thermal fabric, equipment performance). Not all the modeling aspects may apply to the organization's purpose in requiring building simulation and testing using Standard 140. Organizations should review the test groups and only cite those needed to test modeling aspects that are important for their purposes. For example, an organization that is interested in the thermal performance of buildings, and not heating and cooling equipment performance, may wish to only include the thermal fabric test groups (e.g., low-mass building and high-mass building) in its acceptance criteria requirements.

c. Untested algorithm usage in simulations performed for the organization's purposes: An organization citing Standard 140 should explicitly state whether untested algorithms are allowed to be used in simulations performed for their purposes. Because Standard 140 does not test all aspects of building performance simulation, this decision may not be straightforward.

The intent of Standard 140 is to be a "P.E. exam" for software. This implies that if a software passes the Standard 140 test cases, which test a subset of algorithms applied in BPS software, the passing software is deemed as satisfactory to be applied for all BPS modeling applications, including applications not explicitly covered by the Standard 140 test cases. Based on this intent, an organization citing Standard 140 should avoid restricting untested algorithms unless there is clear cause to do otherwise or clear cause to specify the particular algorithms that must be tested where the current version of Standard 140 provides relevant tests.

d. Untested alternative algorithm usage in simulations performed for the organization's purposes: An organization citing Standard 140 should explicitly state whether untested alternative algorithms are allowed to be used in simulations performed for their purposes. Because Standard 140 does not test all possible algorithms for specific aspects of building performance simulation, this decision may not be straightforward. This is because software may have several algorithms available for specific calculations. When running the Standard 140 test cases, the most appropriate or best practice algorithms may be selected. It is not practical to run all of the algorithm options for a given modeling aspect, because some may not be appropriate given the context of the test case, and/or the number of combinations and permutations of algorithm options is too large to run in a reasonable time frame.

The following discussion gives examples of why it is appropriate to allow alternative algorithms with more-or-less detailed inputs than the algorithm chosen by the modeler running the test cases for a given program.

1. There are situations where simple algorithms are prescribed for a Standard 140 test case because they make differences in results among software easier to diagnose. However, in practice, a more detailed algorithm would be more accurate for the purposes of an organization citing Standard 140. For example, many of the test cases specify a constant infiltration rate, meaning most programs would set an infiltration rate and not use a weather-driven infiltration calculation. The weather-driven infiltration calculation may be more appropriate, or even required, for the calculations for the organization's purposes. If untested alternative algorithms are not allowed, then software would have to use the constant infiltration rate and not the weather-driven infiltration algorithms.

2. A test case specification may describe more details for an aspect of the model than is needed or is practical for an organization's purposes. For example, most of the windows in Standard 140 are specified with full detailed window inputs (e.g., including specular angle-dependent optical properties), but an organization citing Standard 140 may only specify the NFRC rating properties of a window (U-value and SHGC) and not require the full specular properties. In this case, it would be more appropriate for the software to be tested using the same NFRC rating inputs for the window that are available to the users of the software for the organization's purposes, and for an organization to not allow the software to be tested using the more detailed window model inputs provided in the test case description when those same inputs are not available to the user in practice.

If unsure about whether untested alternative algorithms should be permitted for simulations performed for the organization's purposes, allow more detailed algorithms than those prescribed by the test cases to be used; when the test cases allow for equivalent or alternative modeling inputs or algorithms, restrict the software to the modeling inputs and algorithms used in the test cases.

e. Untested numerical settings (for example, time steps and tolerances) usage in simulations performed for the organization's purposes: Similar to the algorithms in software, there are a number of numerical settings that can influence the outputs from the software. These include settings such as the time step used in the calculations and tolerances used for determining convergence. An organization citing Standard 140 should explicitly state whether untested numerical settings are allowed for their purposes. For example, if for a given tested program the test cases were run with a 15-minute time step, the organization may want to restrict software from running with a longer time step, such as 1 hour. However, it is possible that the test cases are run with a longer time step, such as 1 hour, and the organization would not want to restrict software from running with a shorter time step. Different test suites may have different numerical settings based on the nature of the tests included in the test suite. For example, programs running the air-side equipment test suite may need to use smaller time steps than for the thermal fabric test suites in order to promote convergence. The thermal fabric test suites likely use numerical settings closest to those common in whole-building simulations. If unsure about how the untested numerical settings apply for an

organization's purposes, allow numerical settings at the same resolution or at a higher resolution (e.g., shorter time steps) than those tested in thermal fabric tests (Sections 5.2.1 and 5.2.2) to be used.

f. Non-user-accessible input internal modifications for the purposes of testing in accordance with the test descriptions of this standard, but not made available to the user in the publicly available software: In some cases, an algorithm or input that is available in the calculation engine is restricted from the user by the user interface, and this non-user-accessible input is more appropriate for the test case. For example, the calculation engine can perform calculations with a constant infiltration rate as described in the test case, but the user interface restricts the user from selecting this option. Organizations citing Standard 140 should explicitly state whether using non-user-accessible inputs to perform the tests is allowed for their purposes. If unsure about whether non-user-accessible inputs may be used in testing, allow them to be used.

g. Source code changes for the purpose of running tests that are not made available in the publicly available software: In some cases, a software is not capable of running a test case without a change to the source code, and the developers don't believe releasing the software with the change is appropriate. For example, a test case requires a coil bypass factor of 0, which is not a realistically feasible bypass factor. A software's algorithms do not allow for a bypass factor of 0 to be used. The developer modifies the code to allow the bypass factor of 0 to run the test case and check if the software performs within the acceptable criteria. The developer does not want to release the modified source code because it allows the user to specify an unrealistic condition. Organizations citing Standard 140 should explicitly state whether using software without the modified source code is allowed for their purposes. If unsure about whether changes to non-publicly released source code may be used, do not allow non-publicly released source code to be used.

h. Untested versions of the software: New release versions of a software may include changes to the calculation engine and/or to ancillary processes (i.e., input interface, output interface, and/or user interface) that do not affect the calculated results. Organizations citing Standard 140 should explicitly state whether using untested versions of a software is allowed for their purposes. If unsure about whether untested versions of the software may be used, do not allow untested versions of the software that include changes to the calculation engine to be used.

Revise Section 5.1.4 as shown.

5.1.4 Consistent Modeling Methods. Where options exist within a simulation program for modeling a specific thermal behavior, consistent modeling methods shall be used for all cases. Consistent numerical settings shall be used for all tests in a given test suite. The option and numerical settings that ~~is~~ are used shall be documented in the Standard Output Report (as specified in Normative Annex A2).

***Informative Notes*:**

1. For example, if a program gives a choice of methods for modeling windows, the same window modeling method is to be applied for all cases.
2. Test suites are outlined in Informative Section 4.3.

Add new Normative Annex A3 as shown.

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

NORMATIVE ANNEX A3
SOFTWARE ACCEPTANCE CRITERIA

This annex provides the acceptance criteria for the software. In order to comply, the software must demonstrate that a sufficient number of software results (see Section A.2) are within the ranges specified in Section A3.1 for each set of test cases.

Software includes the calculation engine and the corresponding user interface. The testing of software only meets the requirements of this annex for that software and cannot be used as a proxy for documenting compliance of another software that uses the same calculation engine but a different user interface.

A3.1 Class I Software Ranges. Tables A3-1 through A3-13 give the acceptance criteria ranges for the test groups. Ranges are given for both selected individual test-case results (e.g., Case 600) and differences between the results of two test cases, i.e., result sensitivities (e.g., Case 610 – Case 600). A software result is within a given range when the software result is equal to or greater than the lower limit and less than or equal to the upper limit shown for the given range in the tables. (***Informative Note:*** The setting of these ranges is based on the calculations shown in Informative Annex B12, Section B12.1, "Acceptance Criteria Bounds Calculations.")

Table A3-1 Low Mass Building—Annual Heating Load (MWh/yr)*

Range Case	Lower Limit	Upper Limit
Case 600	3.75	4.98
Case 610 – Case 600	–0.14	0.29
Case 620 – Case 600	–0.08	0.40
Case 630 – Case 620	0.02	0.74
Case 640 – Case 600	–2.17	–1.22
Case 660 – Case 600	–1.07	–0.16
Case 670 – Case 600	0.25	2.98
Case 680 – Case 600	–2.54	–1.90
Case 685 – Case 600	0.33	0.77
Case 695 – Case 685	–2.38	–1.94

* For output specified in Section 6.2.1.1.1

Table A3-2 Low Mass Building—Annual Sensible Cooling Load (MWh/yr)*

Range Case	Lower Limit	Upper Limit
Case 600	5.00	6.83
Case 610 – Case 600	–2.26	–0.80
Case 620 – Case 600	–2.24	–1.64
Case 630 – Case 620	–1.68	–0.77
Case 640 – Case 600	–0.56	0.03
Case 650 – Case 600	–1.54	–0.95
Case 660 – Case 600	–3.09	–2.50
Case 670 – Case 600	0.05	0.84
Case 680 – Case 600	0.13	0.87
Case 685 – Case 600	2.70	3.31
Case 695 – Case 685	–0.21	0.44

* For output specified in Section 6.2.1.1.2

Table A3-3 High Mass Building—Annual Heating Load (MWh/yr)*

Range Case	Lower Limit	Upper Limit
Case 900	1.04	2.28
Case 900 – Case 910	–0.52	–0.02
Case 920 – Case 900	1.51	1.92
Case 930 – Case 920	0.20	1.15
Case 940 – Case 900	–0.82	–0.37
Case 960 – Case 900	0.96	1.12
Case 980 – Case 900	–1.65	–1.00
Case 985 – Case 900	0.64	0.81
Case 995 – Case 985	–1.83	–1.07

* For output specified in Section 6.2.1.1.1

Table A3-4 High Mass Building—Annual Sensible Cooling Load (MWh/yr)*

Range Case	Lower Limit	Upper Limit
Case 900	2.35	2.60
Case 900 – Case 910	0.35	1.74
Case 920 – Case 900	0.08	0.48
Case 930 – Case 920	–1.19	–0.44
Case 940 – Case 900	–0.19	0.06
Case 950 – Case 900	–2.00	–1.56
Case 960 – Case 900	–1.81	–1.27
Case 980 – Case 900	1.09	1.41
Case 985 – Case 900	3.52	4.18
Case 995 – Case 985	0.63	1.15

* For output specified in Section 6.2.1.1.2

Table A3-5 Annual Total Cooling Energy Consumption (kWh/yr)*

Range Case	Lower Limit	Upper Limit
CE300	33497	37023
CE310 – CE300	2671	6197
CE320 – CE300	2610	6136
CE330 – CE320	–766	2760
CE330 – CE300	3697	7223
CE340 – CE300	3172	6698
CE330 – CE340	–1393	2133
CE350 – CE300	–5354	–1828
CE360 – CE300	18084	21610
CE400 – CE300	–5783	–2179
CE410 – CE300	–5929	–371
CE420 – CE300	–3945	–419
CE430 – CE300	–4762	–1236
CE440 – CE300	–3694	–168

* For output specified in Section 6.3.2.1.1.1(a)

Table A3-6 Furnace Input Energy (GJ)*

Range Case	Lower Limit	Upper Limit
HE210	49.86	55.11
HE220 – HE210	–5.48	–0.23
HE230 – HE220	–9.10	–3.86

* For output specified in Section 6.4.1.2

Table A3-7 Heating Equipment Cumulative Fan Energy (kWh)*

Range Case	Lower Limit	Upper Limit
HE210	279.55	308.98
HE220 – HE210	–30.21	–0.78
HE230 – HE220	186.29	216.78

* For output specified in Section 6.4.2.1

Table A3-8 Preheat-Coil Load (kWh/h)*

Range Case	Lower Limit	Upper Limit
AE301	2.80	4.20
AE401	9.75	10.77
AE301 – AE401	–7.67	–6.16

* For output specified in Sections 6.5.3.2(a) and 6.5.4.2

Table A3-9 Heating-Coil Load (kWh/h)*

Range Case	Lower Limit	Upper Limit
AE201	7.94	8.78

* For output specified in Sections 6.5.1.2(a) and 6.5.2.2

Table A3-10 Cooling-Coil Total Load (kWh/h)*

Range Case	Lower Limit	Upper Limit
AE205	1.82	2.01
AE245 – AE205	0.20	0.39
AE206	2.54	2.85
AE226 – AE206	0.55	0.82
AE305	8.77	9.85
AE305 – AE405	4.55	5.75
AE345 – AE305	–0.15	0.79
AE345 – AE445	4.76	6.01
AE306	13.65	15.08
AE306 – AE406	5.42	6.86
AE326 – AE306	5.68	7.12
AE326 – AE426	11.21	12.65
AE405	3.90	4.31
AE445 – AE405	–0.15	0.26
AE406	7.81	8.82
AE426 – AE406	0.20	1.02

* For output specified in Sections 6.5.1.2(d), 6.5.2.2, 6.5.3.2(d), and 6.5.4.2

Table A3-11 Cooling-Coil Sensible Load (kWh/h)*

Range Case	Lower Limit	Upper Limit
AE205	1.82	2.01
AE245 – AE205	0.20	0.39
AE206	1.62	1.79
AE226 – AE206	–0.23	–0.06
AE305	8.77	9.85
AE305 – AE405	4.55	5.75
AE345 – AE305	–0.15	0.79
AE345 – AE445	4.76	6.01
AE306	8.30	9.37
AE306 – AE406	4.64	5.73
AE326 – AE306	–0.91	–0.01
AE326 – AE426	4.27	5.31
AE405	3.90	4.31
AE445 – AE405	–0.15	0.26
AE406	3.45	3.82
AE426 – AE406	–0.22	0.14

* For output specified in Sections 6.5.1.2(b), 6.5.2.2, 6.5.3.2(b), and 6.5.4.2

Table A3-12 Zone 1 Reheat-Coil Load (kWh/h)*

Range Case	Lower Limit	Upper Limit
AE301	7.23	8.10
AE401	4.27	4.72
AE301 – AE401	2.70	3.60
AE305	1.92	2.46
AE345 – AE305	–0.11	0.11
AE306	1.92	2.48
AE326 – AE306	–0.11	0.11
AE405	0.00	0.00
AE406	0.00	0.00

* For output specified in Sections 6.5.3.2(f) and 6.5.4.2

Table A3-13 Zone 2 Reheat-Coil Load (kWh/h)*

Range Case	Lower Limit	Upper Limit
AE301	7.77	8.81
AE401	4.63	5.12
AE301 – AE401	2.87	3.93
AE305	2.02	2.71
AE345 – AE305	–0.12	0.12
AE306	2.02	2.74
AE326 – AE306	–0.12	0.12
AE405	0.00	0.00
AE406	0.00	0.00

* For output specified in Sections 6.5.3.2(g) and 6.5.4.2

Table A3-14 Acceptance Range Pass Criteria

Test Group	Tables of Ranges	Number of Range Cases in Test Group	Minimum Number of Range Cases within the Test Group to Pass
Thermal Fabric Low Mass	A3-1, A3-2	21	18
Thermal Fabric High Mass	A3-3, A3-4	19	17
Cooling Equipment	A3-5	14	12
Heating Equipment	A3-6, A3-7	6	5
Air-side Equipment	A3-8, A3-9, A3-10, A3-11, A3-12, A3-13	54	48

Tables A3-1 through A3-4 are related to the building thermal envelope and fabric load tests of Sections 5.2.1, 5.2.2, and 5.2.3. Table A3-5 is related to the space-cooling equipment performance tests of Section 5.3. Tables A3-6 and A3-7 are related to the space-heating equipment performance tests of Section 5.4. Tables A3-8 through A3-13 are related to the air-side HVAC equipment performance tests of Section 5.5.

A3.2 Number of Results within Acceptance Range to Pass a Test Group. Table A3-14 gives the number of range cases for which a software's results must be within the acceptable ranges to pass a test group. Software shall pass a test group when the count of results computed for each range case, from the corresponding tables of ranges, meets or exceeds the minimum count required in Table A3-14.

Informative Note: See Informative Annex B12, Section B12.4 for a description of the procedures used to determine the numbers in the table.

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 A2.7, with all report blocks completed.

Add new Annex B12 as 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 B12
DEVELOPMENT OF ACCEPTANCE CRITERIA

B12.1 Acceptance Criteria Bounds Calculations. The results from a reference set of software programs (see Section B12.1.2), also called "reference results" here, are used to calculate the upper and lower limits for the acceptance criteria.

B12.1.1 Equations for Setting Bound Limits. The upper and lower limits for each range case applied for acceptance criteria are set by selecting the lower minimum value and higher maximum value of the following:

a. Statistical Bounds (SB):

$$\text{Minimum: MinSB} = \text{Median}_{case} - \text{MAD}_{3sigma}$$

$$\text{Minimum: MaxSB} = \text{Median}_{case} + \text{MAD}_{3sigma}$$

where

Median_{case} ≡ median value of reference results for a given case

MAD_{3sigma} ≡ median absolute deviation (MAD) with 99.73% (3 sigma) confidence interval for the reference results of a given case

and

$$\text{MAD}(X) = \text{Median}[|X - \text{Median}(X)|]$$

for a normal distribution, we can relate MAD to the standard deviation as

$$\text{MAD} = \sigma\Phi^{-1}\left(\frac{3}{4}\right) = \sigma\sqrt{2}\,\text{erf}^{-1}\left(\frac{1}{2}\right) \approx 0.6745\,\sigma$$

where

σ ≡ standard deviation

Φ ≡ quantile function

erf ≡ error function

The bounds of the confidence interval can be set in terms of ± standard deviation from the average or ± MAD from the median. In this case, a 99.73% confidence interval results from three standard deviations (or 3 sigma), which leads to a MAD multiplier (MAD_{3sigma}) of 2.024.

b. Nonstatistical Bounds (NSB):

1. Where no quasi-analytical solution results exist for an acceptance criteria test group:

$$\text{Minimum: MinNSB} = \text{Median}_{case} - \text{Median}_{BC} \times 0.05$$

$$\text{Maximum: MaxNSB} = \text{Median}_{case} + \text{Median}_{BC} \times 0.05$$

where

Median_{BC} ≡ median value of reference results of base case (BC) for a given case

2. Where quasi-analytical solution results (QAS) exist for an acceptance criteria test group:

$$\text{Minimum: MinNSB} = \text{QAS}_{case} - \text{QAS}_{BC} \times 0.05$$

$$\text{Maximum: MaxNSB} = \text{QAS}_{case} + \text{QAS}_{BC} \times 0.05$$

where

QAS_{case} ≡ QAS value for a given case

QAS_{BC} ≡ QAS value of the base case (BC) for a given case

B12.1.2 Reference Software for Setting Bound Limits. The reference set of software for setting the bound limits is selected based on the following criteria:

- A single set of results per calculation engine is included (multiple user interfaces for the same calculation engine are not included).
- Results are submitted by the calculation engine copyright holder(s) or by a modeler designated by the calculation engine copyright holder(s), applying a user interface specified by the calculation engine copyright holder(s) if appropriate.
- The set of selected software should represent a diversity of modeling methods, such as control-based and load-based.
- The calculation engine should be actively, reasonably, and widely used and actively maintained.
- Software satisfies the following:
  - Able to run at a time step of an hour or less
  - Able to include hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat set points, and HVAC system operation
  - Include thermal mass effects
- If a software did not participate in the simulation trials for the initial development of a test suite, then prior to the submittal, its results are reviewed and undergo iterative rounds of review and revisions as determined during the submission review process. The reviewer comments and submitter responses are documented from each round, with a logical basis for corrections to programs or inputs included in the documentation. This review process only applies to the initial submittal of a software and not subsequent submittals of that software for version updates.

The results from a reference software

- include justification via Annex A2, Attachment A2.7, 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.

The results from a reference software may be updated for each new public release of the calculation engine. For future continuous maintenance revisions of Standard 140, SSPC 140 may

- include any additional software in the acceptance criteria-bounds reference set that apply and meet the criteria for inclusion;
- remove any software from the reference set that no longer meet the criteria for inclusion; and
- update the acceptance criteria with the most recent results from the reference set of software.

The current reference set of software used to determine the acceptance criteria are (in alphabetical order): CSE, DeST, DOE-2.2, EnergyPlus, ESP-r, IDA ICE, IES-VE, TAS, and TRNSYS. Not all software are applied for all test groups.

B12.2 Acceptance Criteria Results Comparison. Given that the upper and lower acceptance bound limits for the test cases are determined from the reference set of software, the results from other software can be compared against those limits. A software result is designated as an outlier for a given acceptance-criteria range case if that result is less than the lower limit or greater than the upper limit.

Tolerances will be used for comparisons to bounds.

a. A relative tolerance of 1% (i.e., numbers within ≤ 1% of each other are considered equivalent)
b. An absolute tolerance of 1E-4 (i.e., numbers within 1E-4 of each other are considered equivalent even if that is more than 1%)

B12.3 Acceptance Criteria Tests Included. Not all test suites and test cases included in Standard 140 are appropriate to be used in acceptance criteria. The following criteria are applied in determining which test results are used in the acceptance criteria:

- A test group has enough of the reference set of software that can adequately perform all of the tests within the test group to produce statistically meaningful acceptance ranges. (In Standard 140-2020 Addendum *b*, which first introduced the acceptance criteria, there are at least five reference-set software that can adequately perform the tests within each test group.)
- The tests are grouped to provide separate acceptance criteria for different sections of the standard.
- When available, acceptance-criteria tests include outputs such as annual total load, energy use, or other annual summations based on realistic, time-varying conditions.
- Differences between the results of two tests (i.e., result sensitivities) are preferred.
- A base case for each test suite or portion of the test suite should be included.

Based on these criteria, the following five test groups were selected for the acceptance criteria (selected outputs within each test group are also described, and Test Group 5 has separate selected outputs specific to its test cases):

1. Thermal Fabric Low Mass Test Group Range Cases
   Annual heating load and annual sensible cooling load
   Case 600
   Case 610 – Case 600
   Case 620 – Case 600
   Case 630 – Case 620
   Case 640 – Case 600
   Case 650 – Case 600 (cooling only)
   Case 660 – Case 600
   Case 670 – Case 600
   Case 680 – Case 600
   Case 685 – Case 600
   Case 695 – Case 685
2. Thermal Fabric High Mass Test Group Range Cases
   Annual heating load and annual sensible cooling load
   Case 900
   Case 900 – Case 910
   Case 920 – Case 900
   Case 930 – Case 920
   Case 940 – Case 900
   Case 950 – Case 900 (cooling only)
   Case 960 – Case 900
   Case 980 – Case 900

Case 985 – Case 900
Case 995 – Case 985

3. Cooling Equipment Test Group Range Cases
   Annual total cooling energy consumption
   CE300
   CE310 – CE300
   CE320 – CE300
   CE330 – CE320
   CE330 – CE300
   CE340 – CE300
   CE330 – CE340
   CE350 – CE300
   CE360 – CE300
   CE400 – CE300
   CE410 – CE300
   CE420 – CE300
   CE430 – CE300
   CE440 – CE300
4. Heating Equipment Test Group Range Cases
   Furnace input energy and cumulative fan energy
   HE210
   HE220 – HE210
   HE230 – HE220
5. Air-side Equipment Test Group Range Cases
   Heating-coil load
   AE201

   Preheat-coil load
   AE301
   AE401
   AE301 – AE401

   Cooling-coil total load and cooling-coil sensible load
   AE205
   AE245 – AE205
   AE206
   AE226 – AE206
   AE305
   AE305 – AE405
   AE345 – AE305
   AE345 – AE445
   AE306
   AE306 – AE406
   AE326 – AE306
   AE326 – AE426
   AE405
   AE445 – AE405
   AE406
   AE426 – AE406

   Reheat-coil loads—zone 1 and zone 2
   AE301
   AE401
   AE301 – AE401
   AE305
   AE345 – AE305
   AE306
   AE326 – AE306
   AE405
   AE406

B12.4 Acceptance Criteria Overall Passing. Because there may be legitimate physical modeling reasons (see Informative Annex B11, Section B11.1.4) why a software's results would fall outside of the acceptance range for an individual test or difference between two tests, it is not reasonable to expect a software to pass all acceptance criteria for every test in a test group.

To determine the number of range cases for which a software's results need to be within the acceptance ranges to pass a test group, the number of range cases in the test group is multiplied by 0.9, and the resulting number is rounded down to the nearest integer. For example, for the thermal fabric low mass test group, there are 21 range cases; 21 × 0.9 = 18.9; rounding down yields 18 range cases.

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.

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