

ADDENDA

**ANSI/ASHRAE/IBPSA Addendum a to
ANSI/ASHRAE Standard 140-2023**

Method of Test for Evaluating Building Performance Simulation Software

Approved by ASHRAE and the American National Standards Institute on August 29, 2025, and by the International Building Performance Simulation Association on August 11, 2025.

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FOREWORD

Addendum a adds time series results to the Standard 140 acceptance criteria for the thermal fabric test groups. The time series results included in the acceptance criteria are the daily hourly zone loads for February 1 and July 14 included in the standard output reports for the thermal fabric low-mass and high-mass test suite (Section 7).

Normative Annex A3 contains the ranges for specific test cases that will be applied to software results to determine if they fall in the acceptable ranges. The minimum number of range cases within the test group to pass has been updated to reflect the inclusion of more cases to the acceptance criteria.

Informative Annex B12 has been updated to include the procedure for developing the acceptance criteria ranges for time series results.

In addition, the range tables of Normative Annex A3 have been consolidated into fewer tables to make finding the acceptance ranges easier.

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

Addendum a to Standard 140-2023

Revise Annex A3 as follows.

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 A3.2) 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); and daily hourly time series results (e.g., February 1 Case 600).

For single-value results (see Tables A3-1, A3-4, A3-7 through A3-9), a software result is within a given range when the software result is greater than or 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 B12.1.1.1, “Acceptance Criteria Bounds Calculations,” “Equations for Single-Value Results.”)

For the time series ranges, comparison metrics (Pearson correlation coefficient [for curve shape] and root mean square error [for value scaling]) for the software results are calculated versus the representative curve results (see Tables A3-2 and A3-5), and then these metrics are compared to the ranges (see Tables A3-3 and A3-6). A software result is within a given range if both the calculated Pearson correlation coefficient is above the limit in the table and the calculated root mean square error value is below the limit in the table. (Informative Note: The setting of these ranges is based on the calculations shown in Informative Annex B12, Section B12.1.1.2, “Acceptance Criteria Bounds Calculations,” “Equations for Time Series Results.”)

The criteria are organized by test suite as follows. Tables A3-1 through A3-~~6~~ 4 are related to the building thermal envelope and fabric load tests of Section 7. Table A3-~~7~~ 5 is related to the space-cooling equipment performance tests of Sections 9.2.3 and 9.2.4. Tables A3-~~8~~ 6 and A3-~~7~~ are related to the space-heating equipment performance tests of Section 10. Tables A3-~~9~~ 8 through A3-~~13~~ are related to the air-side HVAC equipment performance tests of Section 11.

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

Range Case	Annual Heating Load (MWh/yr)*		Annual Sensible Cooling Load (MWh/yr)*	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Case 600	3.75	4.98	<u>5.00</u>	<u>6.83</u>
Case 610 – Case 600	–0.14	0.29	<u>–2.26</u>	<u>–0.80</u>
Case 620 – Case 600	–0.08	0.40	<u>–2.24</u>	<u>–1.64</u>
Case 630 – Case 620	0.02	0.74	<u>–1.68</u>	<u>–0.77</u>
Case 640 – Case 600	–2.17	–1.22	<u>–0.56</u>	<u>0.03</u>
Case 650 – Case 600	n/a	n/a	<u>–1.54</u>	<u>–0.95</u>
Case 660 – Case 600	–1.07	–0.16	<u>–3.09</u>	<u>–2.50</u>
Case 670 – Case 600	0.25	2.98	<u>0.05</u>	<u>0.84</u>
Case 680 – Case 600	–2.54	–1.90	<u>0.13</u>	<u>0.87</u>
Case 685 – Case 600	0.33	0.77	<u>2.70</u>	<u>3.31</u>
Case 695 – Case 685	–2.38	–1.94	<u>–0.21</u>	<u>0.44</u>

* For output specified in Sections 7.3.1.1 and 7.3.1.2 for heating and cooling loads, respectively.

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

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

* For output specified in Section 7.3.1.2

Table A3-2 Low Mass Building—Hourly Loads (kWh) with Heating > 0 and Cooling < 0 Representative Curves Used to Calculate Comparison Metrics

Hour	February 1							July 14					
	Case 600	Case 640	Case 660	Case 670	Case 680	Case 685	Case 695	Case 600	Case 660	Case 670	Case 680	Case 685	Case 695
1	2.08	0.08	1.82	2.62	1.17	2.12	1.31	0.00	0.00	0.00	0.00	-0.05	-0.14
2	2.22	0.60	1.90	2.73	1.32	2.24	1.41	0.00	0.00	0.00	0.00	0.03	-0.07
3	2.28	0.95	1.94	2.82	1.42	2.29	1.48	0.00	0.00	0.00	0.00	0.13	-0.02
4	2.33	1.19	2.00	2.91	1.50	2.33	1.53	0.00	0.00	0.12	0.00	0.25	0.04
5	2.35	1.32	2.02	2.95	1.53	2.35	1.55	0.00	0.00	0.33	0.00	0.34	0.11
6	2.35	1.40	2.03	2.94	1.55	2.35	1.56	0.00	0.00	0.22	0.00	0.24	0.06
7	2.36	1.45	2.05	2.92	1.55	2.36	1.55	0.00	0.00	0.00	0.00	-0.10	-0.10
8	1.88	3.06	1.71	2.39	1.16	1.88	1.16	0.00	0.00	0.00	0.00	-0.46	-0.33
9	0.55	1.75	0.82	0.84	0.17	0.55	0.06	0.00	0.00	0.00	0.00	-0.91	-0.63
10	0.00	0.08	0.08	0.00	-0.10	-1.11	-1.67	-0.23	-0.08	-0.26	-0.19	-1.55	-1.15
11	-1.28	-0.67	0.00	-1.14	-1.98	-3.12	-3.67	-1.23	-0.78	-1.51	-1.07	-2.40	-1.87
12	-3.23	-2.69	-0.47	-3.27	-4.13	-4.52	-5.21	-2.22	-1.41	-2.61	-1.89	-3.14	-2.54
13	-4.42	-4.17	-1.63	-4.62	-5.31	-5.41	-6.11	-2.70	-1.85	-3.26	-2.41	-3.49	-3.00
14	-4.67	-4.59	-2.15	-4.89	-5.57	-5.43	-6.13	-2.75	-2.00	-3.31	-2.49	-3.51	-3.05
15	-4.05	-4.02	-1.87	-4.12	-5.05	-4.70	-5.51	-2.59	-1.90	-3.06	-2.26	-3.23	-2.78
16	-2.93	-2.92	-1.28	-2.78	-3.94	-3.59	-4.40	-2.21	-1.69	-2.53	-1.90	-2.85	-2.34
17	-1.33	-1.32	-0.38	-0.99	-2.35	-1.88	-2.73	-1.76	-1.41	-1.94	-1.51	-2.40	-1.95
18	-0.04	-0.04	0.00	0.00	-0.51	-0.06	-0.88	-1.37	-1.13	-1.46	-1.19	-1.99	-1.62
19	0.09	0.09	0.08	0.46	0.00	1.07	0.18	-0.98	-0.85	-1.02	-0.88	-1.59	-1.30
20	0.98	0.98	0.85	1.62	0.00	1.67	0.67	-0.57	-0.52	-0.55	-0.57	-1.15	-0.99
21	1.64	1.64	1.41	2.22	0.20	2.03	1.00	-0.23	-0.24	-0.14	-0.33	-0.76	-0.73
22	2.06	2.06	1.78	2.60	0.72	2.28	1.24	-0.02	-0.06	0.00	-0.17	-0.55	-0.55
23	2.32	2.32	2.01	2.88	1.08	2.44	1.42	0.00	0.00	0.00	-0.05	-0.38	-0.43
24	2.44	0.00	2.10	2.99	1.29	2.50	1.52	0.00	0.00	0.00	0.00	-0.25	-0.31

Table A3-3 Low Mass Building—Time Series Ranges

Range Case	Minimum Pearson Correlation Coefficient for February 1 and July 14 Hourly Loads*	Maximum Root Mean Square Error for February 1 Hourly Loads*	Maximum Root Mean Square Error for July 14 Hourly Loads*
	Lower Limit	Upper Limit	Upper Limit
Case 600	0.879	0.4194	0.1921
Case 640 (February 1 only)	0.879	0.6559	n/a
Case 660	0.879	0.3087	0.1697
Case 670	0.879	0.7881	0.3018
Case 680	0.879	0.3990	0.2097
Case 685	0.879	0.4643	0.3218
Case 695	0.879	0.2069	0.2001

* For loads output specified in Section 7.3.8. The same lower limit value applies to February 1 and July 14 loads, except there are no July 14 hourly load result for Case 640.

Table A3-4 Table A3-3 High Mass Building—Annual Heating Load (MWh/yr)* Single-Value Ranges

Range Case	Annual Heating Load (MWh/yr)*		Annual Sensible Cooling Load (MWh/yr)*	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
Case 900	1.04	2.28	<u>2.35</u>	<u>2.60</u>
Case 900 – Case 910	–0.52	–0.02	<u>0.35</u>	<u>1.74</u>
Case 920 – Case 900	1.51	1.92	<u>0.08</u>	<u>0.48</u>
Case 930 – Case 920	0.20	1.15	<u>–1.19</u>	<u>–0.44</u>
Case 940 – Case 900	–0.82	–0.37	<u>–0.19</u>	<u>0.06</u>
Case 950 – Case 900	n/a	n/a	<u>–2.00</u>	<u>–1.56</u>
Case 960 – Case 900	0.96	1.12	<u>–1.81</u>	<u>–1.27</u>
Case 980 – Case 900	–1.65	–1.00	<u>1.09</u>	<u>1.41</u>
Case 985 – Case 900	0.64	0.81	<u>3.52</u>	<u>4.18</u>
Case 995 – Case 985	–1.83	–1.07	<u>0.63</u>	<u>1.15</u>

* For output specified in Sections 7.3.1.1 and 7.3.1.2 for heating and cooling loads, respectively.

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

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

* For output specified in Section 7.3.1.2

Table A3-5 High Mass Building—Hourly Loads (kWh) with Heating > 0 and Cooling <0 Representative Curves Used to Calculate Comparison Metrics

Hour	February 1					July 14			
	Case 900	Case 940	Case 980	Case 985	Case 995	Case 900	Case 980	Case 985	Case 995
1	0.98	0.00	0.00	1.13	0.42	-0.10	-0.22	-0.71	-0.64
2	1.08	0.00	0.00	1.23	0.54	-0.03	-0.16	-0.62	-0.58
3	1.18	0.00	0.00	1.33	0.63	0.00	-0.09	-0.53	-0.50
4	1.29	0.00	0.00	1.43	0.71	0.00	-0.02	-0.42	-0.43
5	1.37	0.00	0.00	1.50	0.77	0.00	0.00	-0.33	-0.35
6	1.44	0.00	0.10	1.57	0.81	0.00	0.00	-0.32	-0.37
7	1.51	0.00	0.22	1.62	0.84	0.00	-0.06	-0.40	-0.44
8	1.36	1.26	0.19	1.45	0.70	0.00	-0.16	-0.52	-0.54
9	0.79	1.58	0.00	0.87	0.25	-0.11	-0.27	-0.72	-0.67
10	0.27	0.84	0.00	0.35	-0.36	-0.36	-0.49	-1.04	-0.92
11	0.00	0.30	0.00	-0.25	-1.05	-0.66	-0.77	-1.43	-1.28
12	0.00	0.00	-0.11	-0.94	-1.80	-0.98	-1.05	-1.79	-1.58
13	0.00	0.00	-0.73	-1.59	-2.50	-1.22	-1.27	-2.04	-1.81
14	0.00	0.00	-1.17	-1.94	-2.79	-1.38	-1.40	-2.17	-1.89
15	-0.02	0.00	-1.35	-2.01	-2.83	-1.41	-1.39	-2.15	-1.89
16	-0.01	0.00	-1.28	-1.83	-2.72	-1.36	-1.28	-2.05	-1.78
17	0.00	0.00	-1.01	-1.36	-2.19	-1.26	-1.19	-1.94	-1.67
18	0.00	0.00	-0.47	-0.63	-1.40	-1.14	-1.08	-1.80	-1.55
19	0.00	0.00	-0.05	-0.19	-0.92	-1.01	-0.96	-1.63	-1.40
20	0.00	0.00	0.00	0.10	-0.65	-0.85	-0.81	-1.43	-1.22
21	0.00	0.09	0.00	0.34	-0.42	-0.70	-0.69	-1.27	-1.08
22	0.00	0.33	0.00	0.55	-0.23	-0.59	-0.59	-1.16	-0.98
23	0.08	0.54	0.00	0.71	-0.04	-0.49	-0.51	-1.05	-0.89
24	0.29	0.00	0.00	0.86	0.10	-0.37	-0.41	-0.94	-0.79

Table A3-6 High Mass Building—Time Series Ranges

Range Case	Minimum Pearson Correlation Coefficient for February 1 and July 14 Hourly Loads*	Maximum Root Mean Square Error for February 1 Hourly Loads*	Maximum Root Mean Square Error for July 14 Hourly Loads*
	Lower Limit	Upper Limit	Upper Limit
Case 900	0.879	0.3716	0.0967
Case 940 (February 1 only)	0.879	0.4298	n/a
Case 980	0.879	0.2969	0.0986
Case 985	0.879	0.4166	0.2053
Case 995	0.879	0.2944	0.2468

* For loads output specified in Section 7.3.8. The same lower limit value applies to February 1 and July 14 loads, except there are no July 14 hourly load results for Case 940.

Table A3-7 ~~Table A3-5~~ Annual Total Cooling Energy Consumption (kWh/yr)* Cooling Equipment Single-Value Ranges

Range Case	<u>Annual Total Cooling Energy Consumption (kWh/yr)*</u>	
	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 9.3.2.1.1(a)

Table A3-8 ~~Table A3-6~~ Furnace Input Energy (GJ)* Heating Equipment Single-Value Ranges

Range Case	<u>Furnace Input Energy (GJ)*</u>		<u>Cumulative Fan Energy (kWh)*</u>	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit
HE210	49.86	55.11	<u>279.55</u>	<u>308.98</u>
HE220 – HE210	–5.48	–0.23	<u>–30.21</u>	<u>–0.78</u>
HE230 – HE220	–9.10	–3.86	<u>186.29</u>	<u>216.78</u>

* For output specified in Sections 10.3.1.2 and 10.3.2.1 for furnace input energy and cumulative fan energy, respectively.

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

Range Case	Lower Limit	Upper Limit
HE210	<u>279.55</u>	<u>308.98</u>
HE220 – HE210	<u>–30.21</u>	<u>–0.78</u>
HE230 – HE220	<u>186.29</u>	<u>216.78</u>

* For output specified in Section 10.3.2.1

Table A3-9 Air-Side Equipment Single-Value Ranges

Range Case	Preheat-Coil Load (kW/h/h)*		Heating-Coil Load (kW/h/h)*		Cooling-Coil Total Load (kW/h/h)*		Cooling-Coil Sensible Load (kW/h/h)*		Zone 1 Reheat-Coil Load (kW/h/h)*		Zone 2 Reheat-Coil Load (kW/h/h)*	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
AE201	n/a	n/a	7.94	8.78	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
AE205	n/a	n/a	n/a	n/a	1.82	2.01	1.82	2.01	n/a	n/a	n/a	n/a
AE245 – AE205	n/a	n/a	n/a	n/a	0.20	0.39	0.20	0.39	n/a	n/a	n/a	n/a
AE206	n/a	n/a	n/a	n/a	2.54	2.85	1.62	1.79	n/a	n/a	n/a	n/a
AE226 – AE206	n/a	n/a	n/a	n/a	0.55	0.82	-0.23	-0.06	n/a	n/a	n/a	n/a
AE301	2.80	4.20	n/a	n/a	n/a	n/a	n/a	n/a	7.23	8.10	7.77	8.81
AE301 – AE401	-7.67	-6.16	n/a	n/a	n/a	n/a	n/a	n/a	2.70	3.60	2.87	3.93
AE305	n/a	n/a	n/a	n/a	8.77	9.85	8.77	9.85	1.92	2.46	2.02	2.71
AE305 – AE405	n/a	n/a	n/a	n/a	4.55	5.75	4.55	5.75	n/a	n/a	n/a	n/a
AE345 – AE305	n/a	n/a	n/a	n/a	-0.15	0.79	-0.15	0.79	-0.11	0.11	-0.12	0.12
AE345 – AE445	n/a	n/a	n/a	n/a	4.76	6.01	4.76	6.01	n/a	n/a	n/a	n/a
AE306	n/a	n/a	n/a	n/a	13.65	15.08	8.30	9.37	1.92	2.48	2.02	2.74
AE306 – AE406	n/a	n/a	n/a	n/a	5.42	6.86	4.64	5.73	n/a	n/a	n/a	n/a
AE326 – AE306	n/a	n/a	n/a	n/a	5.68	7.12	-0.91	-0.01	-0.11	0.11	-0.12	0.12
AE326 – AE426	n/a	n/a	n/a	n/a	11.21	12.65	4.27	5.31	n/a	n/a	n/a	n/a
AE401	9.75	10.77	n/a	n/a	n/a	n/a	n/a	n/a	4.27	4.72	4.63	5.12
AE405	n/a	n/a	n/a	n/a	3.90	4.31	3.90	4.31	0.00	0.00	0.00	0.00
AE445 – AE405	n/a	n/a	n/a	n/a	-0.15	0.26	-0.15	0.26	n/a	n/a	n/a	n/a
AE406	n/a	n/a	n/a	n/a	7.81	8.82	3.45	3.82	0.00	0.00	0.00	0.00
AE426 – AE406	n/a	n/a	n/a	n/a	0.20	1.02	-0.22	0.14	n/a	n/a	n/a	n/a

* For output specified in sections as follows: preheat coil, 11.3.3.2(a), 11.3.4.2; heating coil, 11.3.1.2(a), 11.3.2.2; cooling coil total, 11.3.1.2(d), 11.3.2.2, 11.3.3.2(d), 11.3.4.2; cooling coil sensible load 11.3.1.2(b), 11.3.2.2, 11.3.3.2(b), 11.3.4.2; zone 1 reheat coil, 11.3.3.2(f), 11.3.4.2; zone 2 reheat coil, 11.3.3.2(g), 11.3.4.2.

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 11.3.3.2(a) and 11.3.4.2

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

Range Case	Lower Limit	Upper Limit
AE201	7.94	8.78

* For output specified in Sections 11.3.1.2(a) and 11.3.2.2

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 11.3.1.2(d), 11.3.2.2, 11.3.3.2(d), and 11.3.4.2

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 11.3.1.2(b), 11.3.2.2, 11.3.3.2(b), and 11.3.4.2

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 11.3.3.2(f) and 11.3.4.2

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 11.3.3.2(g) and 11.3.4.2

Table A3-10 ~~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- 32	21-34	18-30
Thermal Fabric High Mass	A3- 43 , A3- 64	19-28	17-25
Cooling Equipment	A3- 75	14	12
Heating Equipment	A3- 86 , A3- 7	6	5
Air-side Equipment	A3- 98 , A3- 9 , A3- 10 , A3- 11 , A3- 12 , A3- 13	54	48

A3.2 Number of Results within Acceptance Range to Pass a Test Group. Table ~~A3-14~~ A3-10 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~~ A3-10.

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 A2.8, with all report blocks completed.

Revise Annex B12 as follows.

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. There are two different types of results included in the acceptance criteria: single-value results (e.g., annual totals) and time series results (e.g., hourly zone loads for a specific day). There are different calculation methodologies for each of these types of results.

B12.1.1.1 Equations for Single-Value Results. 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):

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

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

where

$\text{Median}_{\text{case}} \equiv$ median value of reference results for a given case

$\text{MAD}_{3\text{sigma}} \equiv$ 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

$\sigma \equiv$ standard deviation

$\Phi \equiv$ quantile function

$\text{erf} \equiv$ error function

The bounds of the confidence interval can be set in terms of \pm standard deviation from the average or \pm 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 ($\text{MAD}_{3\text{sigma}}$) of 2.024.

- b. Nonstatistical Bounds (NSB):

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

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

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

where

$\text{Median}_{\text{BC}} \equiv$ 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:

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

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

where

$\text{QAS}_{\text{case}} \equiv$ QAS value for a given case

$\text{QAS}_{\text{BC}} \equiv$ QAS value of the base case (BC) for a given case

B12.1.1.2 Equations for Time Series Results. The time series results are 24 hourly results for a single day. A representative curve is needed to provide values for the comparison to software results. This curve is determined by taking the median value of the reference set of software results at each hour.

Two different comparisons are made with the time series results: the shape of the curve of the data and the scale of the values. For the shape of the curve, the Pearson correlation coefficient (pcc) is used; for the scale of the values, the root mean square error (RMSE) is used.

The Pearson correlation coefficient measures the linear correlation between two sets of data. It is the ratio between the covariance of two variables and the product of their standard deviations; thus, it is essen-

tially a normalized measurement of the covariance, such that the result always has a value between -1 and 1 . A value of 1 denotes perfect correlation (the curves are exactly the same), -1 denotes a perfect inverse correlation (the curves are mirror images), and 0 denotes that there is no correlation between the curves.

$$pcc = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}}$$

where

n = sample size (number of data points in each curve)

x_i, y_i = the individual sample points indexed with i (x being the representative curve and y being the software results being compared)

\bar{x} = $\frac{1}{n} \sum_{i=1}^n x_i$ (the sample) mean; and analogously for \bar{y}

Root mean square error is the square root of the average of squared errors. The effect of each error on root mean square error is proportional to the size of the squared error; thus, larger errors have a disproportionately large effect on root mean square error. Consequently, root mean square error is sensitive to outliers.

$$RMSE = \sqrt{\sum (x_i - y_i)^2 / n}$$

Because the Pearson correlation coefficient is an absolute measure of the agreement of the shape of the curves, the MAD procedure is not appropriate for determining agreement, and a significance test for the correlation coefficient is used instead. The P-value of the Pearson correlation coefficient is the probability that the two curves are NOT in agreement (in this case, of the same shape), with greater values indicating greater disagreement. A P-value limit of 0.05 is used, meaning that if the P-value of the computed correlation coefficient is less than 0.05 , the two curves are considered to have the same shape. (A P-value of 0.05 approximates a 95% confidence interval based on a Student-T distribution.)

To find the P-value for a given test result compared to the reference, a test statistic, t , is computed as the ratio of the correlation coefficient to the standard error (σ_{pcc}) in the correlation coefficient.

$$t = \frac{pcc}{\sigma_{pcc}} = pcc \frac{\sqrt{(N-2)}}{\sqrt{1-pcc^2}}$$

where

pcc = Pearson correlation coefficient between the test result and the representative curve

σ_{pcc} = standard error (sample standard deviation) applied to the Pearson correlation coefficient over the number of data points (24) in each curve

N = number of reference test results sets used to create the representative curve

The higher the correlation coefficient, the larger the value of t . The probability (P-value) of obtaining this test statistic in error is determined from the Student-T distribution with $N-2$ degrees of freedom.¹

With $N = 5$ samples used to create the representative curve, for $P < 0.05$ one needs $t > 3.18$,² which corresponds to Pearson correlation coefficient > 0.879 . The Student-T distribution was chosen in place of the normal distribution because of the limited number of samples used to create the representative curve. Thus, any program's results with a Pearson correlation coefficient > 0.879 are considered to be significantly correlated with the representative curve.

For the root mean square error, the MAD procedure for single-value results (see Section B12.1.1.1) is used. However, the 3-sigma bounds used in the single-value comparisons were deemed too strict for the time series values for two reasons: (1) the time series comparisons were for the results for a single test case and not the difference between two test cases (i.e., differential sensitivity test results tend to subtract overall noise that may be present in any case taken by itself) and (2) there were 24 values being used rather than a single-value in the root mean square error (i.e., larger number of values emphasizing dynamic variations has greater opportunity for disagreement at any single point in time). Subsequently, a 5-sigma bound is used for the root mean square error comparison, which results in a MAD multiplier of 3.3725.

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:

1. https://en.wikipedia.org/wiki/Pearson_correlation_coefficient

2. https://en.wikipedia.org/wiki/Student%27s_t-distribution

- 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 Normative Annex A2, Attachment A2.8, 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 A3-10 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 $\leq 1\%$ 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. (Beginning with Standard 140-2023, 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

Daily hourly loads

Case 600

Case 640

Case 660

Case 670

Case 680

Case 685

Case 695

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

Daily hourly loads

Case 900

Case 940

Case 980

Case 985

Case 995

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~~34 range cases; $\text{21-34} \times 0.9 = \text{18.9-30.6}$; rounding down yields ~~18~~30 range cases.

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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.

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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.

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