Procedures for Verification of International Energy Conservation Code (IECC) Performance Path Calculation Tools

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Procedures for Verification of International Energy Conservation Code (IECC) Performance Path Calculation Tools

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Approved March 2014

1   Purpose

This publication provides procedures for verifying the accuracy of residential energy simulation software tools intended for use in determining compliance with the International Energy Conservation Code (IECC) using the Simulated Performance Alternative.

2   Scope

This procedure applies to the certification of software for IECC residential energy code compliance for all new and existing single family dwellings and all new and existing multifamily dwellings that are three stories or less above grade level. This procedure does not apply to multifamily dwellings that are greater than three stories above grade.

3   Procedures for Verification of International Energy Conservation Code Performance Path Calculation Tools

Because the performance path of the International Energy Conservation Code (IECC) is based on comparative performance analysis (Proposed Design as compared with the Standard Reference Design), computer simulation software modeling is required. In order to ensure the accuracy and comparability of IECC Simulated Performance Alternative calculation tools, software vendors seeking RESNET accreditation shall comply with the procedures specified by this publication. This publication shall apply to the 2006 IECC and the 2009 IECC.

3.1   National Standard

The IECC, hereinafter referred to as "the Code," shall be the national standard for the development and use of IECC Simulated Performance Alternative compliance software tools. Section 404 of the 2006 Code and Section 405 of the 2009 Code provide the technical basis for the development of IECC Simulated Performance Alternative compliance software tools that determine Code compliance. This document describes a set of verification protocols and tests that are required for RESNET accreditation of IECC Simulated Performance Alternative compliance software tools.

3.2   Software Verification Test Suite

RESNET has defined a suite of software tests for use in verifying IECC Simulated Performance Alternative compliance software tool accuracy and comparability. The RESNET Board of Directors has adopted this test suite as the verification tests that shall be used by RESNET to

accredit computerized IECC Simulated Performance Alternative compliance tools. The RESNET software verification test suite includes the following tests:

3.2.1 Building Loads Tests – ASHRAE Standard 140-2011, Class II, Tier 1 building loads tests were developed from the HERS BESTEST[1] for testing the accuracy of residential simulation software for predicting building loads. This test procedure has been adopted by RESNET and is a requirement for all software programs to be accredited. (See Section 4.1)

3.2.2 IECC Code Standard Reference Design auto-generation tests – These tests verify the ability of the software tool to automatically generate the IECC Standard Reference Design. (See Section 4.2.)

3.2.3 HVAC tests – These tests verify the accuracy and consistency with which software tools predict the performance of HVAC equipment, including furnaces, air conditioners, and air source heat pumps. (See Section 4.3.)

3.2.4 Duct distribution system efficiency tests – These tests verify the accuracy with which software tools calculate air distribution system losses. ASHRAE Standard 152 results are used as the basis for the test suite acceptance criteria. (See Section 4.4.)

3.2.5 Hot water system performance tests – These tests determines the ability of the software to accurately predict hot water system energy use. (See Section 4.5.)

3.3   Process for Accrediting Software Programs

The RESNET accreditation process provides a suite of verification tests to certify that IECC Simulated Performance Alternative compliance software tools conform to the verification criteria for each test. The software developer shall be required to submit the test results, test runs, and the software program with which the tests were conducted to RESNET. This information may be released by RESNET for review by any party, including competing software developers.

3.4   Process for Exceptions and Appeals

RESNET has established an appeals process that software developers may use if their software is so unique that they cannot be accurately tested through the RESNET software testing procedures. The elements of this appeal process are:

- The software provider's documentation of how the software or qualification program meets or exceeds the criteria established in the RESNET software verification procedures.
- The software developer's justification and documentation as to why the software is so unique that it cannot comply with the RESNET software tool testing protocols.

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[1] R. Judkoff and J. Neymark, 1995, "Home Energy Rating System Building Energy Simulation Test (HERS BESTEST), Volume 1, Report No. NREL/TP-472-7332a, National Renewable Energy Laboratory, Golden, Colorado. (online at: http://www.nrel.gov/docs/legosti/fy96/7332a.pdf)

- Independent evaluation of the software tool by RESNET in collaboration with independent experts. Based upon the results of the evaluation, RESNET may certify that the software tool meets or exceeds the performance criteria of RESNET's software tool verification procedures.

4   Test Suite Specifications and Acceptance Criteria

4.1   Building Loads Tests

4.1.1   Test Description

These tests are designed to verify building loads simulation consistency for residential software. Specifications and instructions for this suite of tests are found in ANSI/ASHRAE Standard 140-2011. The ANSI/ASHRAE Standard 140, Class II, Tier 1 test procedure has been adopted by RESNET and is a requirement for all software programs to be accredited.

Since the home configurations from this test suite are used for most of the other IECC software verification tests, it is highly recommended that this set of tests be completed prior to conducting the other verification tests prescribed by this procedure.

4.1.2   Acceptance Criteria

The acceptance criteria for this test suite are developed in accordance with Annex 22 of ANSI/ASHRAE Standard 140-2011 and are provided in Table 4.1.2(1) through Table 4.1.2(4) below.

<table>
<tr><th colspan="3">Table 4.1.2(1) Heating Loads:
Colorado Springs, CO</th></tr>
<tr><th>Case</th><th>range max</th><th>range min</th></tr>
<tr><td>L100AC</td><td>79.48</td><td>48.75</td></tr>
<tr><td>L110AC</td><td>103.99</td><td>71.88</td></tr>
<tr><td>L120AC</td><td>64.30</td><td>37.82</td></tr>
<tr><td>L130AC</td><td>53.98</td><td>41.82</td></tr>
<tr><td>L140AC</td><td>56.48</td><td>43.24</td></tr>
<tr><td>L150AC</td><td>71.33</td><td>40.95</td></tr>
<tr><td>L155AC</td><td>74.18</td><td>43.53</td></tr>
<tr><td>L160AC</td><td>81.00</td><td>48.78</td></tr>
<tr><td>L170AC</td><td>92.40</td><td>61.03</td></tr>
<tr><td>L200AC</td><td>185.87</td><td>106.41</td></tr>
<tr><td>L202AC</td><td>190.05</td><td>111.32</td></tr>
<tr><td>L302XC</td><td>90.52</td><td>52.66</td></tr>
<tr><td>L304XC</td><td>75.32</td><td>43.91</td></tr>
<tr><td>L322XC</td><td>118.20</td><td>68.35</td></tr>
<tr><td>L324XC</td><td>80.04</td><td>44.01</td></tr>
</table>

<table>
<tr><th colspan="3">Table 4.1.2(2) Heating Load Deltas:
Colorado Springs, CO</th></tr>
<tr><th>Case</th><th>range max</th><th>range min</th></tr>
<tr><td>L110AC-L100AC</td><td>28.12</td><td>19.37</td></tr>
<tr><td>L120AC-L100AC</td><td>-7.67</td><td>-18.57</td></tr>
<tr><td>L130AC-L100AC</td><td>-5.97</td><td>-27.50</td></tr>
<tr><td>L140AC-L100AC</td><td>-4.56</td><td>-24.42</td></tr>
<tr><td>L150AC-L100AC</td><td>-3.02</td><td>-12.53</td></tr>
<tr><td>L155AC-L150AC</td><td>6.88</td><td>-1.54</td></tr>
<tr><td>L160AC-L100AC</td><td>5.10</td><td>-3.72</td></tr>
<tr><td>L170AC-L100AC</td><td>17.64</td><td>7.12</td></tr>
<tr><td>L200AC-L100AC</td><td>107.66</td><td>56.39</td></tr>
<tr><td>L202AC-L200AC</td><td>9.94</td><td>-0.51</td></tr>
<tr><td>L302XC-L100AC</td><td>14.50</td><td>-3.30</td></tr>
<tr><td>L302XC-L304XC</td><td>17.75</td><td>5.66</td></tr>
<tr><td>L322XC-L100AC</td><td>39.29</td><td>15.71</td></tr>
<tr><td>L322XC-L324XC</td><td>38.27</td><td>20.21</td></tr>
</table>

Table 4.1.2(3) Cooling Loads: Las Vegas, NV				Table 4.1.2(4) Cooling Load Deltas: Las Vegas, NV		
Case	range max	range min		Case	range max	range min
L100AL	64.88	50.66		L110AL-L100AL	7.84	-0.98
L110AL	68.50	53.70		L120AL-L100AL	0.68	-8.67
L120AL	60.14	47.34		L130AL-L100AL	-13.71	-24.40
L130AL	45.26	32.95		L140AL-L100AL	-27.14	-38.68
L140AL	30.54	19.52		L150AL-L100AL	20.55	8.72
L150AL	82.33	62.41		L155AL-L150AL	-9.64	-22.29
L155AL	63.06	50.08		L160AL-L100AL	12.28	3.88
L160AL	72.99	58.61		L170AL-L100AL	-4.83	-15.74
L170AL	53.31	41.83		L200AL-L100AL	21.39	6.63
L200AL	83.43	60.25		L200AL-L202AL	14.86	2.03
L202AL	75.96	52.32				

4.2 IECC Standard Reference Design Auto-Generation Tests

This section contains the IECC Standard Reference Design auto-generation test suite for performance compliance tools. The test cases in this proposed test suite are designed to verify that software tools automatically generate accurate Standard Reference Designs given only the building information from the Proposed Design.

4.2.1 2006 IECC Standard Reference Design

4.2.1.1 Minimum Reporting Requirements

Software tools applying for verification shall provide evidence that their software meets the requirements of this test suite. The software tool provider or software vendor is responsible for producing the documentation needed to show that the software has been verified through this test suite. In some cases, the data needed to verify accuracy is of no interest or value to the end-user of the software, but in any case, the software tool must generate it. At a minimum, software tools applying for accreditation must report the following values for the Standard Reference Design:

1. Areas and overall U-factors (or R-values in the case of slab-on-grade construction) for all building components, including ceilings, walls, floors, windows (by orientation) and doors.
2. Overall solar-heat gain coefficient $(SHGC_o)$[2] of the windows during heating.
3. Overall solar-heat gain coefficient $(SHGC_o)$ of the windows during cooling.
4. Wall solar absorptance and infrared emittance
5. Roof solar absorptance and infrared emittance
6. Total internal gains to the home (Btu/day)
7. Specific leakage area (SLA) for the building, by zone or as SLA_o[3], as appropriate

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[2] The overall solar heat gain coefficient $(SHGC_o)$ of a fenestration is defined as the solar heat gain coefficient (SHGC) of the fenestration product taken in combination with the interior shade fraction for the fenestration.

8. Attic net free ventilation area (ft^2)
9. Crawlspace net free ventilation area (ft^2), if appropriate
10. Exposed masonry floor area and carpet and pad R-value, if appropriate
11. Heating system labeled ratings, including AFUE, COP, or HSPF, as appropriate.
12. Cooling system labeled ratings, including SEER or EER, as appropriate.
13. Thermostat schedule for heating and cooling
14. Distribution System Efficiency (DSE)
15. Mechanical ventilation kWh/yr, if appropriate

Software tools must have the ability to recreate or store the test case Standard Reference Designs as if they were Proposed Design such that they also can be simulated and evaluated as the Proposed Design.

4.2.1.2   IECC 2006 Auto-generation Test Case Descriptions

Test Case1. HERS BESTEST case L100 building configured as specified in the HERS BESTEST procedures, located in Baltimore, MD, including a total of 3 bedrooms and the following mechanical equipment: gas furnace with AFUE = 82% and central air conditioning with SEER = 11.0.

Test Case 2. HERS BESTEST case L100 configured on an un-vented crawlspace with R-7 crawlspace wall insulation, located in Dallas, TX, including a total of 3 bedrooms and the following mechanical equipment: electric heat pump with HSPF = 7.5 and SEER = 12.0.

Test Case 3. HERS BESTEST case L304 in Miami, configured as specified in the HERS BESTEST procedures, located in Miami, FL, including a total of 2 bedrooms and the following mechanical equipment: electric strip heating with COP = 1.0 and central air conditioner with SEER = 15.0.

Test Case 4. HERS BESTEST case L324 configured as specified as in the HERS BESTEST procedures, located in Colorado Springs, CO, including a total of 4 bedrooms and the following mechanical equipment: gas furnace with AFUE = 95% and no air conditioning.

Test Case 5. Recreate or store the Standard Reference Design created in Tests 1 through 4 as Proposed Design and simulate and evaluate them.

4.2.1.3   IECC 2006 Acceptance Criteria

4.2.1.3.1   Test Cases 1 – 4.
For test cases 1 through 4 the values contained in Table 4.2.1.3.1 shall be used as the acceptance criteria for software tool accreditation. For Standard Reference Design building components marked by an asterisk (*), the acceptance criteria may include a range equal to ± 0.05% of the listed value. For all other Standard Reference Design components the listed values are exact.

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[3] SLA$_O$ is the floor-area weighted specific leakage area of a home where the different building zones (e.g. basement and living zones) have different specific leakage areas.

Table 4.2.1.3.1 IECC 2006 Acceptance Criteria for Test Cases 1 – 4

Standard Reference Design Building Component	Test 1	Test 2	Test 3	Test 4
Above-grade walls (U_o)	0.082	0.082	0.082	0.060
Above-grade wall solar absorptance (α)	0.75	0.75	0.75	0.75
Above-grade wall infrared emittance (ε)	0.90	0.90	0.90	0.90
Basement walls (U_o)	n/a	n/a	n/a	0.059
Above-grade floors (U_o)	0.047	0.047	n/a	n/a
Slab insulation R-Value	n/a	n/a	0	0
Ceilings (U_o)	0.030	0.035	0.035	0.030
Roof solar absorptance (α)	0.75	0.75	0.75	0.75
Roof infrared emittance (ε)	0.90	0.90	0.90	0.90
Attic vent area* (ft^2)	5.13	5.13	5.13	5.13
Crawlspace vent area* (ft^2)	n/a	10.26	n/a	n/a
Exposed masonry floor area * (ft^2)	n/a	n/a	307.8	307.8
Carpet & pad R-Value	n/a	n/a	2.0	2.0
Door Area (ft^2)	40	40	40	40
Door U-Factor	0.40	0.65	1.20	0.35
North window area* (ft^2)	67.50	67.50	67.50	50.02
South window area* (ft^2)	67.50	67.50	67.50	50.02
East window area* (ft^2)	67.50	67.50	67.50	50.02
West window area* (ft^2)	67.50	67.50	67.50	50.02
Window U-Factor	0.40	0.65	1.20	0.35
Window $SHGC_o$ (heating)	0.34	0.34	0.34	0.34
Window $SHGC_o$ (cooling)	0.28	0.28	0.28	0.28
SLA_o (ft^2/ft^2)	0.00036	0.00036	0.00036	0.00036
Internal gains* (Btu/day)	66,840	66,840	62,736	107,572
Labeled heating system efficiency rating	AFUE = 78%	HSPF = 7.7	HSPF = 7.7	AFUE = 78%
Labeled cooling system efficiency rating	SEER = 13.0	SEER = 13.0	SEER = 13.0	SEER = 13.0
Air Distribution System Efficiency	0.80	0.80	0.80	0.80
Thermostat Type	Manual	Manual	Manual	Manual
Heating thermostat settings	68 F (all hours)	68 F (all hours)	68 F (all hours)	68 F (all hours)
Cooling thermostat settings	78 F (all hours)	78 F (all hours)	78 F (all hours)	78 F (all hours)

4.2.1.3.2   Test Case 5

Test case 5 requires that each of the Standard Reference Design for test cases 1-4 be stored or recreated in the software tool as Proposed Design and simulated as any other Proposed

Design would be simulated. If the resulting Proposed Design is correctly configured to be identical to its appropriate Standard Reference Design, code compliance calculations arising from normal operation of the software tool should produce virtually identical scoring criteria for both the Standard Reference Design and the Proposed Design for this round of tests. For test case 5, the energy use e-Ratio shall be calculated separately from the simulation results for heating and cooling, as follows:

e-Ratio = (Proposed Design energy use) / (Standard Reference Design energy use)

Acceptance criteria for these calculations shall be ± 0.5% of 1.00. Thus, for each of the preceding test cases (1-4), the e-Ratio resulting from these software tool simulations and the subsequent e-Ratio calculations shall be greater than or equal to 0.995 and less than or equal to 1.005.

4.2.2   2009 IECC Standard Reference Design

4.2.2.1   Minimum Reporting Requirements

Software tools applying for verification shall provide evidence that their software meets the requirements of this test suite. The software tool provider or software vendor is responsible for producing the documentation needed to show that the software has been verified through this test suite. In some cases, the data needed to verify accuracy is of no interest or value to the end-user of the software, but in any case, the software tool must generate it. At a minimum, software tools applying for accreditation must report the following values for the Standard Reference Design:

1. Areas and overall U-factors (or R-values in the case of slab-on-grade construction) for all building components, including ceilings, walls, floors, windows (by orientation) and doors.
2. Overall solar-heat gain coefficient $(SHGC_o)$[4] of the windows during heating.
3. Overall solar-heat gain coefficient $(SHGC_o)$ of the windows during cooling.
4. Wall solar absorptance and infrared emittance
5. Roof solar absorptance and infrared emittance
6. Total internal gains to the home (Btu/day)
7. Specific leakage area (SLA) for the building, by zone or as SLA_o[5], as appropriate
8. Attic net free ventilation area (ft^2)
9. Crawlspace net free ventilation area (ft^2), if appropriate
10. Exposed masonry floor area and carpet and pad R-value, if appropriate
11. Heating system labeled ratings, including AFUE, COP, or HSPF, as appropriate.
12. Cooling system labeled ratings, including SEER or EER, as appropriate.
13. Thermostat schedule for heating and cooling
14. Air distribution system characteristics, including locations of ducts and the air handler units, supply and return duct R-values and distribution system efficiency (DSE) or air distribution system leakage values (cfm_{25}).[6]

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[4] The overall solar heat gain coefficient (SHGCo) of a fenestration is defined as the solar heat gain coefficient (SHGC) of the fenestration product taken in combination with the interior shade fraction for the fenestration.
[5] SLAo is the floor-area weighted specific leakage area of a home where the different building zones (e.g. basement and living zones) have different specific leakage areas.

15. Mechanical ventilation kWh/yr, if appropriate

Software tools must have the ability to recreate or store the test case Standard Reference Designs as if they were Proposed Designs such that they also can be simulated and evaluated as the Proposed Design.

4.2.2.2   IECC 2009 Auto-generation Test Case Descriptions

<u>Test Case 1</u>. HERS BESTEST case L100 building configured as specified in the HERS BESTEST procedures, located in Baltimore, MD, including a total of 3 bedrooms and the following mechanical equipment: gas furnace with AFUE = 82% and central air conditioning with SEER = 16.0. Air distribution system ducts and air handler are located in the attic with tested leakage of 5.0 cfm25 to outdoors per 100 ft^2 of conditioned floor area.

<u>Test Case 2</u>. HERS BESTEST case L100 configured on an un-vented crawlspace with R-7 crawlspace wall insulation, located in Dallas, TX, including a total of 3 bedrooms and the following mechanical equipment: electric heat pump with HSPF = 8.2 and SEER = 15.0. Air distribution system ducts and air handler are located in the conditioned space with tested leakage of 3.0 cfm25 to outdoors per 100 ft^2 of conditioned floor area.

<u>Test Case 3</u>. HERS BESTEST case L304 in Miami, configured as specified in the HERS BESTEST procedures, located in Miami, FL, including a total of 2 bedrooms and the following mechanical equipment: electric strip heating with COP = 1.0 and central air conditioner with SEER = 17.0. Air distribution system ducts and air handler are located in the conditioned space with untested leakage.

<u>Test Case 4</u>. HERS BESTEST case L324 configured as specified as in the HERS BESTEST procedures, located in Colorado Springs, CO, including a total of 4 bedrooms and the following mechanical equipment: gas furnace with AFUE = 95% and no air conditioning. Air distribution system ducts and air handler are located in the basement with tested leakage of 7.0 cfm25 to outdoors per 100 ft^2 of conditioned floor area.

<u>Test Case 5</u>. Recreate or store the Standard Reference Design created in Tests 1 through 4 as Proposed Design and simulate and evaluate them.

4.2.2.3   IECC 2009 Acceptance Criteria

4.2.2.3.1   Test Cases 1 – 4

For test cases 1 through 4 the values contained in Table 4.2.2.3.1 shall be used as the acceptance criteria for software tool accreditation. For Standard Reference Design building components marked by an asterisk (*), the acceptance criteria may include a range equal to ± 0.05% of the listed value. For all other Standard Reference Design components the listed values are exact.

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[6] cfm25 = cubic feet per minute of air leakage to outdoors at a pressure difference between the duct interior and outdoors of 25 Pa.

Table 4.2.2.3.1 IECC 2009 Acceptance Criteria for Test Cases 1 – 4

Standard Reference Design Building Component	Test 1	Test 2	Test 3	Test 4
Above-grade walls (U_o)	0.082	0.082	0.082	0.057
Above-grade wall solar absorptance (α)	0.75	0.75	0.75	0.75
Above-grade wall infrared emittance (ε)	0.90	0.90	0.90	0.90
Basement walls (U_o)	n/a	n/a	n/a	0.059
Above-grade floors (U_o)	0.047	0.047	n/a	n/a
Slab insulation R-Value	n/a	n/a	0	0
Ceilings (U_o)	0.030	0.035	0.035	0.030
Roof solar absorptance (α)	0.75	0.75	0.75	0.75
Roof infrared emittance (ε)	0.90	0.90	0.90	0.90
Attic vent area* (ft^2)	5.13	5.13	5.13	5.13
Crawlspace vent area* (ft^2)	n/a	10.26	n/a	n/a
Exposed masonry floor area * (ft^2)	n/a	n/a	307.8	307.8
Carpet & pad R-Value	n/a	n/a	2.0	2.0
Door Area (ft^2)	40	40	40	40
Door U-Factor	0.35	0.50	1.20	0.35
North window area* (ft^2)	57.71	57.71	57.71	50.02
South window area* (ft^2)	57.71	57.71	57.71	50.02
East window area* (ft^2)	57.71	57.71	57.71	50.02
West window area* (ft^2)	57.71	57.71	57.71	50.02
Window U-Factor	0.35	0.50	1.20	0.35
Window $SHGC_o$ (heating)	0.34	0.255	0.255	0.34
Window $SHGC_o$ (cooling)	0.28	0.210	0.210	0.28
SLA_o (ft^2/ft^2)	0.00036	0.00036	0.00036	0.00036
Internal gains* (Btu/day)	66,840	66,840	62,736	107,572
Labeled heating system efficiency rating	AFUE = 82%	HSPF = 8.2	HSPF = 7.7	AFUE = 95%
Labeled cooling system efficiency rating	SEER = 16.0	SEER = 15.0	SEER = 17.0	SEER = 13.0
Distribution System Location	Attic	Conditioned	Conditioned	Conditioned
Supply duct R-Value	8.0	6.0	6.0	6.0
Return duct R-Value	6.0	6.0	6.0	6.0
Duct Leakage (cfm25 per CFA)	0.08	0.08	n/a	0.08
Distribution System Efficiency (DSE)	n/a	n/a	0.88	n/a
Thermostat Type	Manual	Manual	Manual	Manual
Heating thermostat settings	72 F (all hours)	72 F (all hours)	72 F (all hours)	72 F (all hours)
Cooling thermostat settings	75 F (all hours)	75 F (all hours)	75 F (all hours)	75 F (all hours)

4.2.2.3.2   Test Case 5

Test case 5 requires that each of the Standard Reference Design for test cases 1-4 be stored or recreated in the software tool as Proposed Designs and simulated as any other Proposed Design would be simulated. If the resulting Proposed Design is correctly configured to be identical to its appropriate Standard Reference Design, code compliance calculations arising from normal operation of the software tool should produce virtually identical scoring criteria for both the Standard Reference Design and the Proposed Design for this round of tests. For test case 5, the energy use e-Ratio shall be calculated separately from the simulation results for heating and cooling, as follows:

e-Ratio = (Proposed Design energy use) / (Standard Reference Design energy use)

Acceptance criteria for these calculations shall be ± 0.5% of 1.00. Thus, for each of the preceding test cases (1-4), the e-Ratio resulting from these software tool simulations and the subsequent e-Ratio calculations shall be greater than or equal to 0.995 and less than or equal to 1.005.

4.3 HVAC Tests

4.3.1 Required Capabilities

Tools must be capable of generating HVAC results using system type and efficiency as inputs. Additional efficiency information is allowable, but must not be required to operate the tool. Tools must also account for duct leakage, duct insulation levels and the presence of a programmable thermostat.

4.3.2 System Types.

The following system types that must be supported by all tools:
1. Compressor based air conditioning system
2. Oil, propane or natural gas forced air furnaces
3. Electric resistance forced air furnaces
4. Air source heat pump

Optional system types that may be supported include:
1. Evaporative cooling, direct, indirect or IDEC
2. Ground or water source heat pumps
3. "Dual fuel" systems that utilize an electric air or ground source heat pump for primary heating and fuel for backup heating. An example of this would be an electric air source heat pump with a gas furnace as a supplement or backup.
4. Radiant heating systems including but not limited to hot water radiant floor systems, baseboard systems and ceiling cable systems.
5. Hydronic systems.
6. Combo systems in which the system supplies both domestic hot water and space heating.
7. Active solar space heating systems

Capability tests do not currently exist for the above optional system types. The following table lists the efficiency metrics that are reported by manufacturers, which shall be used for each system type.

Table 4.3.2 HVAC Equipment Efficiency Metrics

HVAC Equipment Type	Heating Efficiency Metric	Cooling Efficiency Metric	Comments:
Gas or Fuel Furnaces	AFUE		Includes wall furnaces, floor furnaces and central forced air furnaces.
Electric Resistance Furnace	COP		Use COP of 1.0, an HSPF of 3.413 may be equivalent and acceptable for some tools.
Air Source Heat Pump <65 kBtu/h	HSPF	SEER	
Air Cooled Central Air Conditioner <65 kBtu/h		SEER	
Air Cooled Window Air Conditioner		EER	PTAC units are included in this category

4.3.3 Detailed Default Inputs.

Where tools use detailed modeling capabilities for HVAC simulation like DOE-2, the following values should be used as default values in the simulation tool to achieve the best results.

Table 4.3.3 Default Values for use with Detailed HVAC Simulation Tools

DOE-2 Keyword:	Description (units)	Value
HEATING-EIR	Heat Pump Energy Input Ratio compressor only, (1/cop)	$0.582*(1/(HSPF/3.413))$
COOLING-EIR	Air Conditioner Energy Input Ratio compressor only, (1/cop)	$0.941*(1/(SEER/3.413))$
DEFROST-TYPE	Defrost method for outdoor unit, (Reverse cycle)	REVERSE-CYCLE
DEFROST-CTRL	Defrost control method, (Timed)	TIMED
DEFROST-T (F)	Temperature below which defrost controls are activated, (^{o}F)	40°
CRANKCASE-HEAT	Refrigerant crankcase heater power, (kW)	0.05
CRANK-MAX-T	Temperature above which crankcase heat is deactivated, (^{o}F)	50°
MIN-HP-T (F)	Minimum temperature at which compressor operates, (^{o}F)	0°

DOE-2 Keyword:	Description (units)	Value
MAX-HP-SUPP-T	Temperature above which auxiliary strip heat is not available, (^{o}F)	50°
MAX-SUPPLY-T (heating, heat pump)	Maximum heat pump leaving air temperature from heating coil, (^{o}F)	105°
MAX-SUPPLY-T (heating, natural gas furnace)	Maximum gas furnace leaving air temperature from heating coil, (^{o}F)	120°
FURNACE-AUX	Natural gas furnace pilot light energy consumption, (Btu/h)	100
MIN-SUPPLY-T (cooling)	Minimum cooling leaving air temperature from cooling coil, (^{o}F)	55°
SUPPLY-KW	Indoor unit standard blower fan power, (kW/cfm)	0.0005
SUPPLY-DELTA-T	Air temperature rise due to fan heat, standard fan, (^{o}F)	1.580
SUPPLY-KW	Indoor unit standard blower fan power, high efficiency fan, (kW/cfm)	0.000375
SUPPLY-DELTA-T	Air temperature rise associated due to fan heat, high efficiency fan, (^{o}F)	1.185
COIL-BF	Coil bypass factor, (dimensionless)	0.241
Other parameters:		
Part load performance curves	Compressor part load performance curves	Henderson, et.al.[7]
Heating system size	Installed heat pump size, (kBtu/h)	Determined by Manual J (specified)
Coil airflow	Indoor unit air flow, (cfm)	30 cfm/(kBtu/h)
Cooling system size	Installed air conditioner size, (kBtu/h)	Determined by Manual J (specified)

4.3.4 Test Description and Acceptance Criteria.

The following test suites represent tests that tools must pass to be accredited. All tests are to be performed using the L100 building case described by the HERS BESTEST procedures.[8]

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[7] Henderson, H.I., D.S. Parker and Y.J. Huang, 2000. "Improving DOE-2's RESYS Routine: User Defined Functions to Provide More Accurate Part Load Energy Use and Humidity Predictions," Proceedings of 2000 Summer Study on Energy Efficiency in Buildings, Vol. 1, p. 113, American Council for an Energy-Efficient Economy, 1001 Connecticut Avenue, Washington, DC.

[8] Judkoff, R. and J. Neymark, 1995. "Home Energy Rating System Building Energy Simulation Test (HERS BESTEST)," Vol. 1 and 2, Report No. NREL/TP-472-7332, National Renewable Energy Laboratory, Golden, Colorado 80401-3393. (Also available online at http://www.nrel.gov/publications/.)

For each test case, acceptance criteria are provided. These criteria are based on reference results from 6 tools, which are capable of detailed hourly building simulation and HVAC modeling computations.[9] The criteria are established as the greater of the 90% confidence interval using the student t-test criteria or 10% of the mean results for the 6 sets of reference results. In order to pass a specific test, tools must predict percentage energy use changes for the specified heating and/or cooling system tests that falls between the upper and lower acceptance criteria for that test.

Tools that do not model the performance of HVAC equipment in detail must provide for climate adjusted equipment performance factors in order to fall within the acceptance criteria for these tests. Methods of adjusting the manufacturer's nameplate ratings to account for climate dependent performance have been reported.[10]

4.3.4.1   Test Suite 1 – Air Conditioning systems

Test to ensure that there is the proper differential electrical cooling energy consumption by cooling systems when the efficiency is varied between SEER 10 and a higher efficiency unit, taken to be SEER 13. For the purposes of this test assume zero duct leakage and all ducts and air handlers are in conditioned space.

Table 4.3.4.1 (1) Air Conditioning System Test Specifications

Test #	System Type	Capacity	Location	Efficiency
HVAC1a	Air cooled air conditioner	38.3 kBtu/h	Las Vegas, NV	SEER = 10
HVAC1b	Air cooled air conditioner	38.3 kBtu/h	Las Vegas, NV	SEER = 13

Table 4.3.4.1 (2) Air Conditioning System Acceptance Criteria

Test #	Average Change From Base Case	Low Acceptance Criteria	High Acceptance Criteria
HVAC1a	Base case	---	---
HVAC1b	-19.3	-21.2%	-17.4%

4.3.4.2   Test Suite 2 – Heating Systems

Test to ensure that there is differential heating energy consumed by heating systems when the efficiency is varied between a code minimum heating and a higher efficiency unit. The tests will be carried out for both electric and non-electric heating systems. For the purposes of this test assume zero duct leakage and all ducts and air handlers in conditioned space.

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[9] Two DOE-2.1E tools, two DOE-2.2 tools, Micropas version 6.5 and TRNSYS version 15.
[10] Fairey, P., D.S. Parker, B. Wilcox and M. Lombardi, "Climate Impacts on Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) for Air Source Heat Pumps." ASHRAE Transactions, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, GA, June 2004. (Also available online at http://www2.fsec.ucf.edu/en/publications/html/FSEC-PF-413-04/index.htm)

Table 4.3.4.2(1) Gas Heating System Test Specifications

Test #	System Type	Capacity	Location	Efficiency
HVAC2a	Gas Furnace	56.1 kBtu/h	Colorado Springs, CO	AFUE = 78%
HVAC2b	Gas Furnace	56.1 kBtu/h	Colorado Springs, CO	AFUE = 90%

Table 4.3.4.2(2) Gas Heating System Acceptance Criteria

Test #	Average Change From Base Case	Low Acceptance Criteria	High Acceptance Criteria
HVAC2a	Base case	---	---
HVAC2b	-12.9%	-13.3%	-11.6%

Table 4.3.4.2(3) Electric Heating System Test Specifications

Test #	System Type	Capacity	Location	Efficiency
HVAC2c	Air Source Heat Pump	56.1 kBtu/h	Colorado Springs, CO	HSPF = 6.8
HVAC2d	Air Source Heat Pump	56.1 kBtu/h	Colorado Springs, CO	HSPF = 9.85
HVAC2e	Electric Furnace	56.1 kBtu/h	Colorado Springs, CO	COP =1.0

Table 4.3.4.2(4) Electric Heating System Acceptance Criteria

Test #	Average Change From Base Case	Low Acceptance Criteria	High Acceptance Criteria
HVAC2c	Base case	---	---
HVAC2d	-22.9%	-29.0%	-16.7%
HVAC2e	61.3%	41.8%	80.8%

4.4 Duct Distribution System Efficiency (DSE) Tests (Suite 3)

Distribution System Efficiency (DSE) tests are designed to ensure that the impact of duct insulation, duct air leakage and duct location are properly accounted for in software. Tables 1 and 2 below describe the test specifications and the bounds criteria for these tests.

4.4.1   Test Description

For all tests, assume that the air-handling unit is in conditioned space. If the software tool being tested has the ability to modify inputs for duct area, assume that the supply duct area is equal to 20% of the conditioned floor area and the return duct area is equal to 5% of the conditioned floor area. The duct leakage shall be 250 cfm_{25} for cases 3d and 3h with the return and supply leakage fractions each set at 50%. All tests assume a natural gas forced air furnace and forced air cooling system with efficiencies of 78% AFUE = 78% for the heating system and SEER = 10 for the cooling system.

Furnace and air conditioner heating and cooling capacities shall be modified for each of the duct system efficiency test cases according to the values provided in Tables 1a and 2a. Similarly, the specified heating and cooling coil airflow (cfm) shall be altered by case using a value of 360 cfm/ton (30 cfm/kBtu) of capacity. Also, the exterior air film resistance of the duct system should be added to the specified duct R-values given in Tables 1a and 2a to obtain agreement for duct conductance. For non-insulated sheet metal ducts (R-0) the air film has a resistance of approximately R=1.5 ft^2-°F-hr/Btu and for insulated ducts (R=6) the air film has a resistance of R=1.0 as shown by test results obtained by Lauvray (1978) at a typical residential duct airflow rate of 530 fpm.[11] These values are currently established for the purposes of duct design calculations by ASHRAE within the Handbook of Fundamentals (2001, p. 34.15). Thus, unless the software undergoing test accounts for these film resistances, the uninsulated sheet metal duct (R=0 in Tables 3.5.3(1) and 3.5.4(1)) shall be entered as R=1.5 while the insulated ducts (R=6 in tables) shall be entered as R=7.

For the heating comparison test cases (Table 3.5.3(1)), which assume a basement, use the HERS BESTEST Case L322 home. The basement shall be unconditioned, have a floor area equal to the main floor area (1539 ft^2) and have R-11 insulation in the floor joists of the main floor with a framing fraction of 13%. The basement case has no basement wall insulation. For the cooling comparison test cases (Table 3.5.4(2)), use the HERS BESTEST case L100 home.

4.4.2 Acceptance Criteria

The acceptance criteria for these tests were established using ASHRAE Standard 152-04, using the spreadsheet tool constructed for the U.S. DOE *Building America* program by Lawrence Berkeley National Laboratory (LBNL).[12] In all cases, the input values for the Standard 152 calculations assumed the following:
- Single story building
- Single speed air conditioner/heating system
- System capacities as specified in Tables 1a and 2a
- Coil air flow = 360 cfm per 12,000 Btu/h
- Ducts located as specified in Tables 1a and 2a
- Supply duct area = 308 ft^2
- Return duct area = 77 ft^2
- Supply and return duct insulation of R=1.5 and R=7 for uninsulated (R=0) and insulated (R=6) ducts, respectively
- Supply and return duct leakage = 125 cfm each, where so specified in Tables 1a and 2a.

Following the ASHRAE Standard 152 analysis, the resulting DSE values were converted to a percentage change in heating and cooling energy use ("Target Delta" in Tables 3.5.3(2) and 3.5.4(2)) using the following calculation:

$$\% \text{ Change} = 1.0 - (1.0 / DSE)$$

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[11] T.L. Lauvray, 1978. "Experimental heat transmission coefficients for operating air duct systems," ASHRAE Journal, June, 1978.
[12] See http://www.eere.energy.gov/buildings/building_america/benchmark_def.html

Acceptance criteria were then established as this target delta plus and minus 5% to yield the values given in Tables 3.5.3(2) and 3.5.4(2) for heating and cooling test minimum and maximum acceptance criteria, respectively.

4.4.3 Heating Energy Tests

Table 4.4.3(1) Heating Energy DSE Comparison Test Specifications

Test #	Location	System Type	System Capacity (kBtu/h)	Duct Location	Duct Leakage	Duct R-val*
HVAC3a (base case)	Colorado Springs, CO	Gas Furnace	46.6	100% conditioned	None	R=0
HVAC3b	Colorado Springs, CO	Gas Furnace	56.0	100% in basement	None	R=0
HVAC3c	Colorado Springs, CO	Gas Furnace	49.0	100% in basement	None	R=6
HVAC3d	Colorado Springs, CO	Gas Furnace	61.0	100% in basement	250 cfm$_{25}$	R=6

* Duct R-value does not include air film resistances. For uninsulated ducts, this film resistance is approximately R=1.5 and for insulated ducts it is approximately R=1.0. If software does not consider this air film resistance in detail, then these air film resistances should be added.

Table 4.4.3(2) Heating Energy DSE Comparison Test Acceptance Criteria

Test #	Target Delta* Heating Energy Relative to HVAC3a	Minimum Delta* Heating Energy	Maximum Delta* Heating Energy
HVAC3a	Base case	---	---
HVAC3b	26.4%	21.4%	31.4%
HVAC3c	7.5%	2.5%	12.5%
HVAC3d	20%	15%	25%

* Delta = % Change in energy use = ((alternative – base case) / (base case)) * 100

4.4.4 Cooling Energy Tests

Table 4.4.4(1) Cooling Energy DSE Comparison Test Specifications

Test #	Location	System Type	System Capacity (kBtu/h)	Duct Location	Duct Leakage	Duct R-val*
HVAC3e (base case)	Las Vegas, NV	Air Conditioner	-38.4	100% conditioned	None	R=0
HVAC3f	Las Vegas, NV	Air Conditioner	-49.9	100% in attic	None	R=0
HVAC3g	Las Vegas, NV	Air Conditioner	-42.2	100% in attic	None	R=6
HVAC3h	Las Vegas, NV	Air Conditioner	-55.0	100% in attic	250 cfm$_{25}$	R=6

* Duct R-value does not include air film resistance. For uninsulated ducts, this film resistance is approximately R=1.5 and for insulated ducts it is approximately R=1.0. If software does not consider this air film resistance in detail, then these air film resistances should be added.

Table 4.4.4(2) Cooling Energy DSE Comparison Test Acceptance Criteria

Test #	Target Delta* Cooling Energy Relative to HVAC3e	Minimum Delta* Cooling Energy	Maximum Delta* Cooling Energy

HVAC3e	Base case	---	---
HVAC3f	31.2%	26.2%	36.2%
HVAC3g	11.5%	6.5%	16.5%
HVAC3h	26.1%	21.1%	31.1%
* Delta = % Change in energy use = ((alternative – base case) / (base case)) * 100			

4.5 Hot Water System Performance Tests

Hot water system tests are designed to determine if IECC performance compliance software tools accurately account for both the hot water usage rate (gallons per day) and the climate impacts (inlet water temperatures) of hot water systems. The tests are limited to standard gas-fired hot water systems and cannot be used to evaluate solar hot water systems, heat pump hot water systems, hot water systems that recover heat from air conditioner compressors (heat recovery or de-super heater systems), or other types of hot water systems. In addition, distribution losses associated with hot water distribution systems are not covered by this test.

4.5.1   Test Description

The following table provides summary specifications for the six required hot water tests. The tests are segregated into two sets of three tests – one set of cold climate tests (Duluth, MN) and one set of hot climate tests (Miami, FL).

Table 4.5.1 Summary Specifications for Standard Hot Water Tests

Test Number	System Type	Climate Location	System Efficiency	Number of Bedrooms
DHW-MN-56-2	40 gal, gas	Duluth, MN	EF = 0.56	2
DHW-MN-56-4	40 gal, gas	Duluth, MN	EF = 0.56	4
DHW-MN-62-2	40 gal, gas	Duluth, MN	EF = 0.62	2
DHW-FL-56-2	40 gal, gas	Miami, FL	EF = 0.56	2
DHW-FL-56-4	40 gal, gas	Miami, FL	EF = 0.56	4
DHW-FL-62-2	40 gal, gas	Miami, FL	EF = 0.62	2

Additional specifications used in the creation of the reference results that establish the hot water system test acceptance criteria are as follows:

4.5.1.1   Hot Water Draw Profile

The hot water draw profile is as specified by Table 3, ASHRAE Standard 90.2, as given in Table 4.5.1.1 below:

Table 4.5.1.1: Hourly Hot Water Draw Fraction for Hot Water Tests

Hour of Day	Daily Fraction	Hour of Day	Daily Fraction	Hour of Day	Daily Fraction
1	0.0085	9	0.0650	17	0.0370
2	0.0085	10	0.0650	18	0.0630
3	0.0085	11	0.0650	19	0.0630
4	0.0085	12	0.0460	20	0.0630

5	0.0085	13	0.0460	21	0.0630
6	0.0100	14	0.0370	22	0.0510
7	0.0750	15	0.0370	23	0.0510
8	0.0750	16	0.0370	24	0.0085

4.5.1.2 Inlet Mains Temperature

The cold-water inlet mains temperatures to the hot water system are calculated in accordance with the following formula:[13]

$$T_{mains} = (T_{amb,avg} + offset) + ratio * (\Delta T_{amb,max} / 2) * \sin (0.986 * (day\# - 15 - lag) - 90)$$

where:

T_{mains} = mains (supply) temperature to domestic hot water tank (ºF)
$T_{amb,avg}$ = annual average ambient air temperature (ºF)
$\Delta T_{amb,max}$ = maximum difference between monthly average ambient
       temperatures (e.g., $T_{amb,avg,july}$ – $T_{amb,avg,january}$) (ºF)
0.986 = degrees/day (360/365)
day# = Julian day of the year (1-365)
offset = 6°F
ratio = 0.4 + 0.01 ($T_{amb,avg}$ – 44)
lag = 35 – 1.0 ($T_{amb,avg}$ – 44)

4.5.1.3 Additional TRNSYS Simulation Parameters

Additional inputs for TRNSYS reference result simulations are as follows:

- Rated Power   40,000 Btu/hr
- Recovery efficiency: 0.78
- Tank UA for EF=0.56 system: 10.79 Btu/hr-F
- Tank UA for EF=0.62 system: 7.031 Btu/hr-F
- Tank set point temperature: 120 F
- Tank space temperature ("loss temp"): 75 F
- Tank stratification: 15 equal nodes
- Simulation time step: 1/16th hour

4.5.2 Acceptance Criteria

In each of the two sets of three test cases, the first test listed (DHW-xx-56-2) is the base case and the other two cases are the alternative cases. There are two metrics used for acceptance criteria a difference metric (delta) and an absolute metric (MBtu). The delta metric is the % change in energy use for the alternative cases with respect to the base case, which is determined as follows:

% Change = (alternative - base) / (base) * 100

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[13] NREL, "Building America Research Benchmark Definition." National Renewable Energy Laboratory, Golden, CO, December 29, 2004. May be found online at:
http://www.eere.energy.gov/buildings/building_america/pa_resources.html

The absolute metric is the projected hot water energy use given in millions of Btu (site MBtu). The acceptance criteria given in Table 4.5.2 below are determined from reference results from three different software tools – TRNSYS version15, DOE-2.1E (v.120) as used by EnergyGauge USA version 2.5, and RemRate version 12. Minimum and maximum acceptance criteria are determined as the 99% confidence interval for these reference results using the student t-test.

Table 4.5.2 Acceptance Criteria for Hot Water Systems Tests

Case	Mean	St Dev	99%CI	Minimum	Maximum
MN,0.56,4 (delta)	29.3%	0.58%	2.85%	26.5%	32.2%
MN,0.62,2 (delta)	-9.3%	0.51%	2.49%	-11.8%	-6.8%
FL,0.56,4 (delta)	24.1%	1.02%	5.01%	19.1%	29.1%
FL,0.62,2 (delta)	-13.6%	1.19%	5.87%	-19.5%	-7.7%
MN,0.56,2 (MBtu)	20.13	0.38	1.89	18.24	22.02
FL,0.56,2 (MBtu)	12.69	0.36	1.76	10.92	14.45
MN-FL (MBtu)	7.44	0.40	1.95	5.49	9.39