Procedures for Verification of RESNET Accredited HERS Software Tools

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1. Purpose

This publication provides procedures for the verification and accreditation of software tools used for calculating home energy ratings.

2. Scope

This procedure applies to the certification of residential Home Energy Rating Systems (HERS) software tools for all new and existing single family dwelling units and all new and existing multifamily dwelling units. This procedure employs a set of standard operating conditions representative of typical residences. As such, it may not accurately reflect the energy use of residences that depart from these standard operating conditions.

3. Procedures for Accreditation of Computerized HERS Rating Tools

Because Home Energy Rating Systems (HERS) are based on comparative performance analysis (Rated Home as compared with the HERS Reference Home), computer software modeling is required. In order to ensure the accuracy and comparability of HERS tools, software vendors seeking RESNET accreditation shall comply with the procedures prescribed by this document.

3.1 National Standard

RESNET's Mortgage Industry National Home Energy Rating System (MINHERS)[1] Standard shall be the national standard for the development and use of HERS software tools. MINHERS provides the technical basis for the development of HERS software tools that comply with MINHERS. This document describes the verification tests that are required for RESNET accreditation of HERS software tools.

3.2 Software Verification Test Suite

The RESNET Software Verification Committee has defined a suite of software tests for use in verifying HERS 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 HERS rating tools. The RESNET software verification test suite includes the following tests:

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[1] MINHERS adopts ANSI/RESNET/ICC Standard 301 including all addenda and normative appendices with a number of noted exceptions.

3.2.1 ANSI/ASHRAE Standard 140, Class II, Tier 1 tests

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 (See Section 4.1).

3.2.2 HERS Reference Home auto-generation tests

These tests verify the ability of the software tool to automatically generate the HERS Reference Home (See Section 4.2).

3.2.3 HERS method tests

These tests verify that software tools can accurately calculate the HERS Index that is used as the numerical indicator of relative performance for a home (See Section 4.3).

3.2.4 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 4.4).

3.2.5 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 4.5).

3.2.6 Hot water system performance tests

These tests determine the ability of the software to accurately predict hot water system energy use (See Section 4.6).

3.3 Process for Accrediting Software Programs

The RESNET accreditation process provides a suite of verification tests to certify that rating 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. This process is expected to result in compliance without a costly bureaucratic review and approval process.

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.
- 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. RESNET will render a determination regarding certification within 90 days of receipt of appeal and supporting materials.

4. Test Suite Specifications and Acceptance Criteria

All test homes below are based on ASHRAE Standard 140 test cases. Unless otherwise specified, all assumptions should solely reflect the ASHRAE Standard 140 test specification. Where applicable, simulation results shall be generated using TMY3 site 724660, Colorado Springs Muni AP (for heating related tests) and TMY3 site 723860, Las Vegas McCarran Intl AP (for cooling related tests) and not the original TMY data referenced by ASHRAE Standard 140.[2]

4.1 ANSI/ASHRAE Standard 140, Class II, Tier 1 Tests

Standard 140, Class II Tests were developed from the HERS BESTEST[3] for testing the accuracy of simulation software for predicting building loads. The ANSI/ASHRAE Standard 140-2023, Class II, Tier 1 test procedure has been adopted by RESNET and is a requirement for all software programs to be accredited.

Acceptance criteria for this suite of tests shall be as follows:

Annual Heating Loads Colorado Springs, CO			Annual Heating Load Deltas Colorado Springs, CO		
Case	range max	range min	Case	range max	range min
L100AC	61.35	48.07	L110AC-L100AC	29.62	17.53
L110AC	82.96	74.30	L120AC-L100AC	-9.44	-16.08
L120AC	48.09	35.98	L130AC-L100AC	-5.89	-12.92
L130AC	49.95	39.74	L140AC-L100AC	0.24	-12.14
L140AC	51.97	45.72	L150AC-L100AC	-3.37	-10.90
L150AC	55.54	39.13	L155AC-L150AC	6.42	-0.56
L155AC	58.15	42.17	L160AC-L100AC	4.54	-1.96
L160AC	63.40	48.30	L170AC-L100AC	15.14	8.15

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[2] The purpose of the ANSI/ASHRAE Standard 140 test cases is to test the capability of the simulation engine to accurately represent building physics. These tests are not intended to be representative of actual buildings or modeling best practices. Some of the conditions and assumptions are simplified to more effectively isolate and highlight certain aspects of building physics within the tests.

[3] 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)

Case	range max	range min	Case	range max	range min
L170AC	74.24	58.15	L200AC-L100AC	79.06	71.16
L200AC	137.68	121.76	L202AC-L200AC	11.26	3.20
L202AC	146.84	126.71	L302XC-L100AC	22.68	-25.78
L302XC	81.73	24.59	L302XC-L304XC	11.47	-3.14
L304XC	70.27	27.72	L322XC-L100AC	32.01	7.79
L322XC	91.66	57.57	L322XC-L324XC	38.95	5.49
L324XC	56.47	48.33			

Annual Cooling Loads Las Vegas, NV			Annual Cooling Load Deltas Las Vegas, NV		
Case	range max	range min	Case	range max	range min
L100AL	58.66	42.50	L110AL-L100AL	6.91	0.69
L110AL	61.33	47.72	L120AL-L100AL	-0.22	-8.24
L120AL	51.69	41.15	L130AL-L100AL	-9.74	-18.53
L130AL	41.85	31.54	L140AL-L100AL	-20.48	-30.58
L140AL	29.35	21.03	L150AL-L100AL	15.77	7.51
L150AL	73.48	50.55	L155AL-L150AL	-11.15	-16.52
L155AL	59.72	36.63	L160AL-L100AL	12.76	6.75
L160AL	68.60	52.26	L170AL-L100AL	-6.58	-12.95
L170AL	47.58	34.16	L200AL-L100AL	17.59	11.62
L200AL	73.51	57.07	L200AL-L202AL	14.14	5.12
L202AL	60.72	50.19			

4.2 HERS Reference Home Auto-Generation Tests

This section contains the Reference Home auto-generation test suite for HERS rating tools. The test cases in this proposed test suite are designed to verify that software tools automatically generate accurate Reference Homes given only the building information from the Rated home.

4.2.1 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 Reference Home:

1. Areas and overall U-factors (or R-values in the cases of conditioned basement and 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. Sensible internal gains to the home (Btu/day)
7. Latent internal gains to the home (Btu/day)
8. Specific leakage area (SLA) for the building, by zone or as SLA_o[5], as appropriate
9. Attic net free ventilation area (ft^2)
10. Crawlspace net free ventilation area (ft^2), if appropriate
11. Exposed masonry floor area and carpet and pad R-value, if appropriate
12. Heating system labeled ratings, including AFUE, COP, or HSPF, as appropriate.
13. Cooling system labeled ratings, including SEER or EER, as appropriate.
14. Thermostat schedule for heating and cooling
15. Air Distribution System Efficiency (DSE)
16. Mechanical ventilation kWh/y, if appropriate
17. DHW pipe length refPipeL (ft)
18. DHW loop length refLoopL (ft)

4.2.2 Auto-generation Test Descriptions

Only the geometry of the ASHRAE Standard 140 test cases shall be used in these tests. Internal gains, and other assumptions not explicitly described below shall reflect the Energy Rating Reference Home configuration in MINHERS. Reference Home supplemental mechanical ventilation air exchange is always balanced with no recovery.

4.2.2.1 Test Case1. ASHRAE Standard 140 case L100 building geometry configured as specified in the Standard 140 procedures except that the envelope leakage shall be 3.0 ach50, located in Baltimore, MD (TMY3 site 724060, BALTIMORE BLT-WASHNGTN INT'L), including a total of 3 bedrooms and the following mechanical equipment: gas furnace with AFUE = 82% and central air conditioning with SEER = 11.0; no whole-dwelling mechanical ventilation system; a gas range/oven and clothes dryer; all other appliances are electric.

4.2.2.2 Test Case 2. ASHRAE Standard 140 case L100 building geometry except that the envelope leakage shall be 3.0 ach50, configured on an un-vented crawlspace with R-7 crawlspace wall insulation, located in Dallas, TX (TMY3 site 722590, DALLAS-FORT WORTH INTL AP), including a total of 3 bedrooms and the following mechanical equipment: electric heat pump with HSPF = 7.5 and SEER

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[4] 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.

[5] 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.

= 12.0; exhaust-only whole-dwelling mechanical ventilation system; all appliances are electric.

4.2.2.3 Test Case 3. ASHRAE Standard 140 case L304 building geometry in Miami, configured as specified in the Standard 140 procedures except that the envelope leakage shall be 5.0 ach50, located in Miami, FL (TMY3 site 722020, MIAMI INTL AP), 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; balanced whole-dwelling mechanical ventilation without energy recovery system; all appliances are electric.

4.2.2.4 Test Case 4. ASHRAE Standard 140 case L324 building geometry configured as specified in the Standard 140 procedures except that the envelope leakage shall be 3.0 ach50, located in Colorado Springs, CO (TMY3 site 724660, COLORADO SPRINGS MUNI AP), including a total of 4 bedrooms and the following mechanical equipment: gas furnace with AFUE = 95% and no air conditioning; balanced whole-dwelling mechanical ventilation system with a 60% energy recovery system; a gas range/oven and clothes dryer; all other appliances are electric.

4.2.2.5 e-Ratio Tests. Recreate or store the Reference Homes (Reference Home A in Figure 4-1) created in Tests 1 through 4 as Rated Homes (Rated Home B in Figure 4-1), with the following modification: Rated Home B is identical to Reference Home A, except that it has a balanced mechanical ventilation system without heat recovery and a fan efficiency of 0.7 W/cfm. Note: Rated Home B

still has the same mechanical ventilation flow rate as Reference Home A. These tests are specifically designed to yield an e-Ratio of 1.0.
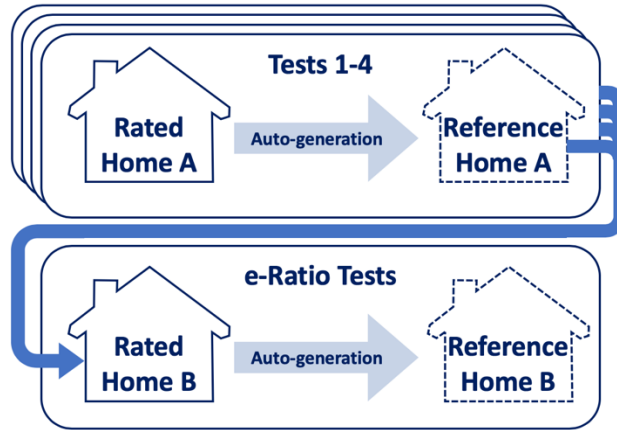

Figure 4-1: Diagram Illustrating the e-Ratio Tests

4.2.3   Acceptance Criteria

4.2.3.1 Test Cases 1 – 4

For test cases 1 through 4 the values contained in Table 4-1 shall be used as the acceptance criteria for software tool accreditation. For Reference Home building components marked by an asterisk (*), the acceptance criteria may include a range equal to ± 0.1% of the listed value. For all other Reference Home components the listed value is exact.

Table 4-1: Acceptance Criteria for Test Cases 1 – 4

Reference Home 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 or insulation R-Value)	n/a	n/a	n/a	U-0.059 or R-10
Above-grade floors (U_o)	0.047	0.047	n/a	n/a
Slab insulation R-Value	n/a	n/a	0	0
Ceilings (Uo)	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)	69.26	69.26	69.26	102.63
South window area* (ft^2)	69.26	69.26	69.26	102.63

Reference Home Building Component	Test 1	Test 2	Test 3	Test 4
East window area* (ft^2)	69.26	69.26	69.26	102.63
West window area* (ft^2)	69.26	69.26	69.26	102.63
Window U-Factor	0.40	0.65	1.20	0.35
Window SHGC$_o$	0.33	0.33	0.33	0.33
SLA$_o$ (ft^2/ft^2)	0.00036	0.00036	0.00036	0.00036
Sensible Internal gains* (Btu/day)[6]	55142	52,470	47,839	82,721
Latent Internal gains* (Btu/day)	13,635	12,565	9,150	17,734
Labeled heating system rating and efficiency	AFUE = 78%	HSPF = 7.7	HSPF = 7.7	AFUE = 78%
Labeled cooling system rating and efficiency	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)
Mechanical ventilation (kWh/y)*	0.0	223.9	288.1	763.4
DHW pipe length refPipeL (±0.1 ft)	88.5	88.5	88.5	98.5
DHW loop length refLoopL (±0.1 ft)	156.9	156.9	156.9	176.9

4.2.3.2 e-Ratio Tests

4.2.3.3 e-Ratio Tests require that each of the Reference Homes for test cases 1-4 be stored or recreated in the software tool as a Rated Home and simulated as any other rated home would be simulated, except as noted in in Section 4.2.2.5. If the resulting Rated Home B (see Figure 4-1) is correctly configured to be identical to its appropriate Reference Home B, rating calculations arising from normal operation of the software tool should produce virtually identical scoring criteria for both the Reference Home and the Rated Home for this round of tests. For the e-Ratio tests, the modified loads e-Ratio shall be calculated separately from the simulation results, as follows:

e-Ratio = (Total normalized Modified Loads) / (Total Reference Loads)

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.

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[6] Sensible gains based on the annual refrigeration energy input (prior to corrections for space temperatures)

4.3 HERS Method Tests

The HERS Method tests are intended to determine the ability of HERS tools to accurately calculate the HERS Index given a set of Reference Home End Use Loads (REUL), Reference Home End Use Energy Consumptions (EC_r), Rated Home End Use Energy Consumptions (EC_x), the applicable manufacturers equipment performance ratings (MEPR), and the Index Adjustment Design savings (IAD_{SAVE}). All hot water values shall be calculated according to the procedures in MINHERS.

4.3.1 Minimum Reporting Requirements

At a minimum, all software tools must report the following values:

4.3.1.1 Reference Home End Use Loads (REUL) to the nearest 0.1 MBtu

     i.   Heating (MBtu)
     ii. Cooling (MBtu)
     iii. Hot water (MBtu)

4.3.1.2 Reference Home End Use Energy Consumption (EC_r) to the nearest 0.1 MBtu

     i.   Heating (MBtu)
     ii. Cooling (MBtu)
     iii. Hot Water (MBtu)

4.3.1.3 Rated Home End Use Energy Consumption (EC_x) to the nearest 0.1 MBtu

     i.   Heating (MBtu)
     ii. Cooling (MBtu)
     iii. Hot Water (MBtu)

4.3.1.4 Manufacturer's Equipment Performance Ratings (MEPR)

     i.   Heating system (HSPF, COP, AFUE)
     ii. Cooling system (SEER, EER or COP)
     iii. Hot Water system (EF)

4.3.1.5 Index Adjustment Design savings (IAD_{SAVE})

4.3.2 Test Description

> Only the geometry of the ASHRAE Standard 140 test cases shall be used in these tests. Internal gains, air exchange, and other assumptions not explicitly described below shall reflect the Energy Rating Reference Home configuration in MINHERS.

> Home Energy Ratings for the following cases, located in Colorado Springs, CO, shall be computed, reporting the values listed above.

4.3.2.1 Case L100A-01: Using the ASHRAE Standard 140 L100 case, create a 3-bedroom Rated Home containing the following equipment:

   i.   Heating system – electric HP with HSPF = 6.8
   ii. Cooling system – electric A/C with SEER = 10.0
   iii. Hot Water – 40 gal electric with EF = 0.88
   iv. All the equipment are to be located inside the conditioned space and heating and air conditioning ductwork are to be located in the conditioned space and have zero (0) air leakage.
   v.   All appliances are standard electric

4.3.2.2 Case L100A-02: Identical to Case L100A-01 except for the following:

   i.   Hot water heater is changed to a tankless natural gas with EF = 0.82
   ii. Range/oven and clothes dryer are changed to standard natural gas.

4.3.2.3 Case L100A-03: Identical to Case L100A-01 except for the following:

   i.   Space heating system is changed to a natural gas furnace with AFUE = 78%
   ii. Number of bedrooms is changed from 3 to 2
   iii. Range/oven and clothes dryer are changed to standard natural gas.

4.3.2.4 Case L100A-04: Identical to Case L100A-01 except for the following:

   i.   Space heating system is changed to a high efficiency HP with HSPF = 9.85
   ii. Number of bedrooms is changed from 3 to 4.

4.3.2.5 Case L100A-05: Identical to Case L100A-01 except for the following:

   i.   Space heating system is changed to a natural gas furnace with AFUE = 96%
   ii. Range/oven and clothes dryer are changed to standard natural gas.

4.3.3   Acceptance Criteria

Using the calculation spreadsheet provided by RESNET on its Accredited HERS Software Tools webpage, software tools shall demonstrate that the difference between the HERS Indices calculated by the software tool and those calculated by the calculation spreadsheet provided with this Test Standard is less than 0.5% of the index reported by the software tool for all cases.

4.4 HVAC Tests

4.4.1   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.

4.4.2 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 4-2: 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

4.4.3 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: 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°
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

DOE-2 Keyword:	Description (units)	Value
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)

4.4.4 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 ASHRAE Standard 140 procedures.

For each test case, acceptance criteria are provided. 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.

4.4.4.1 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 4-4: 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

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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.

Table 4-5: Air Conditioning System Acceptance Criteria

Test #	Low Acceptance Criteria	High Acceptance Criteria
HVAC1a	---	---
HVAC1b	-24.59%	-18.18%

4.4.4.2 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.

Table 4-6: 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 4-7: Gas Heating System Acceptance Criteria

Test #	Low Acceptance Criteria	High Acceptance Criteria
HVAC2a	---	---
HVAC2b	-13.13%	-12.60%

Table 4-8: 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 4-9: Electric Heating System Acceptance Criteria

Test #	Low Acceptance Criteria	High Acceptance Criteria
HVAC2c	---	---
HVAC2d	-42.73%	-15.88%
HVAC2e	59.35%	110.25%

4.5 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. Table 4-10, Table 4-11, Table 4-12 and Table 4-13 below describe the test specifications and the bounds criteria for these tests.

4.5.1 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 Table 4-10 and Table 4-12. 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 Table 4-10 and Table 4-12 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-^oF-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.[8] 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 Table 4-10 and Table 4-12) 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 4-10), which assume a basement, begin with the ASHRAE Standard 140 Case L322 home and make the following modifications. The basement shall be unconditioned, and therefore the infiltration rate and Infiltration Volume shall match that of the ASHRAE Standard 140 Case L100 home, not the L322 home. The basement floor area shall be 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

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[8] T.L. Lauvray, 1978. "Experimental heat transmission coefficients for operating air duct systems," ASHRAE Journal, June, 1978.

the cooling comparison test cases (Table 4-12), use the ASHRAE Standard 140 case L100 home.

4.5.2 Acceptance Criteria

Acceptance criteria are provided in Table 4-11 and Table 4-13 for heating and cooling test minimum and maximum acceptance criteria, respectively.

4.5.3 Heating Energy Tests

Table 4-10: 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 4-11: Heating Energy DSE Comparison Test Acceptance Criteria

Test #	Minimum Delta* Heating Energy	Maximum Delta* Heating Energy
HVAC3a	---	---
HVAC3b	9.45%	25.72%
HVAC3c	3.11%	6.53%
HVAC3d	7.40%	19.77%
* Delta = % Change in energy use = ((alternative – base case) / (base case)) * 100		

4.5.4 Cooling Energy Tests

Table 4-12: 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 4-13: Cooling Energy DSE Comparison Test Acceptance Criteria

Test #	Minimum Delta* Cooling Energy	Maximum Delta* Cooling Energy
HVAC3e	---	---
HVAC3f	18.69%	29.39%
HVAC3g	5.23%	8.79%
HVAC3h	16.32%	27.47%
* Delta = % Change in energy use = ((alternative – base case) / (base case)) * 100		

4.6 Hot Water System Performance Tests

Hot water system tests are designed to determine if HERS 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. Distribution losses and other features associated with hot water distribution systems are covered in the hot water gallons per day, per MINHERS.

4.6.1 Test Description

Only the geometry of the ASHRAE Standard 140 Case L100A shall be used in these tests. Internal gains, and other assumptions not explicitly described below shall reflect the Energy Rating Reference Home configuration in MINHERS.

Case L100AD-HW-01 (base case)
  Climate location: Duluth, MN (TMY3 site 727450, DULUTH INTERNATIONAL ARPT)
  Bedrooms: 2
  Type: 40 gallon storage
  Fuel: gas
  Efficiency: EF = 0.56
  Recovery Efficiency: RE = 0.78
  DHW Heater Location: conditioned space
  Plumbing fixtures: Standard flow
  Pipe insulation: None
  Piping length = Reference Home piping length
  Recirculation: None (Standard system)
  DWHR: None

Case L100AD-HW-02 (distribution base case)
  Same as Case L100AD-HW-01 except with 4 bedrooms

Case L100AD-HW-03
  Same as Case L100AD-HW-01 except gas water heater has EF=0.62

Case L100AD-HW-04
  Same as Case L100AD-HW-02 except with all low-flow fixtures (all bath faucets and showers ≤ 2gpm)

Case L100AD-HW-05
  Same as Case L100AD-HW-02 except with recirculation
    • Control = none
    • 50 W pump
    • Loop length is same as reference loop length
    • Branch length is 10 ft
    • All hot water pipes insulated to R-3

Case L100AD-HW-06
  Same as Case L100AD-HW-05 except with Control = Manual Demand

Case L100AD-HW-07
  Same as Case L100AD-HW-02 except with Drain Water Heat Recovery
    • DWHR efficiency = 54%
    • All showers connected to DWHR unit
    • DWHR preheats both hot and cold supplies for showers

Cases L100AM-HW-01 through L100AM-HW-07
  Same as Cases L100AD-HW except climate location = Miami, FL (TMY3 site 722020, MIAMI INTL AP)

The preceding list of Cases specifies the 14 required hot water tests. The first 3 tests for each climate location are the water heating tests. The other 4 tests for each climate location exercise the distribution system features. Overall the hot water tests are organized as one set of cold climate tests (Duluth, MN) and one set of hot climate tests (Miami, FL).

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

4.6.1.1 Hot Water Draw Profile

The hot water draw profile is as specified by Table 3, ASHRAE Standard 90.2, as given in Table 4-14 below:

Table 4-14: 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

4.6.2   Hot Water Acceptance Criteria

There are two metrics used for acceptance criteria: a difference metric (delta) and an absolute metric (MBtu/y). The delta metric is the absolute change in energy use given in millions of Btu (MBtu/y) for the alternative cases with respect to the base case, which is determined as follows:

$$Delta = base - alternative$$

The absolute metric is the projected hot water energy use given in millions of Btu (MBtu/y). The acceptance criteria given in Table 4-15 below are determined from reference results from three different software tools – EnergyGauge USA version 6.2, Ekotrope v4.0, and OpenStudio-ERI v0.10.0 Beta. Minimum and maximum acceptance criteria for each result are determined by the range of results from the reference tools, with a minimum range of 0.5 MBtu/y.

4.6.2.1 Water Heating Tests

In the water heating tests, the first test listed (L100Ax- HW-01) is the base case and the next two cases are the alternative cases.

4.6.2.2 Hot Water Distribution Tests

For the hot water distribution system tests, the base case is always L100Ax-HW-02. Cases -04 through -07 test various aspects of the hot water distribution system.

Table 4-15: Acceptance Criteria for Hot Water Tests

Test Cases	Minimum	Maximum	Range
(Duluth MN)	(MBtu)	(MBtu)	(MBtu)
L100AD-HW-01	19.34	19.88	0.53
L100AD-HW-02	25.76	26.55	0.79
L100AD-HW-03	17.20	17.70	0.50
L100AD-HW-04	24.94	25.71	0.78
L100AD-HW-05	55.93	57.58	1.65
L100AD-HW-06	22.61	23.28	0.67
L100AD-HW-07	20.51	21.09	0.58
(Miami FL)	(MBtu)	(MBtu)	(MBtu)
L100AM-HW-01	10.74	11.24	0.50
L100AM-HW-02	13.37	13.87	0.50
L100AM-HW-03	8.83	9.33	0.50
L100AM-HW-04	13.06	13.56	0.50
L100AM-HW-05	30.84	31.55	0.71
L100AM-HW-06	12.09	12.59	0.50
L100AM-HW-07	11.84	12.34	0.50
(Duluth deltas)	(Δ MBtu)	(Δ MBtu)	(Δ MBtu)
MN (1-2 delta)	-6.77	-6.27	0.50
MN (1-3 delta)	1.92	2.42	0.50
MN (2-4 delta)	0.58	1.08	0.50
MN (2-5 delta)	-31.03	-30.17	0.86
MN (2-6 delta)	2.95	3.45	0.50
MN (2-7 delta)	5.09	5.59	0.50
(Miami deltas)	(Δ MBtu)	(Δ MBtu)	(Δ MBtu)
FL (1-2 delta)	-2.88	-2.38	0.50
FL (1-3 delta)	1.67	2.17	0.50
FL (2-4 delta)	0.07	0.57	0.50
FL (2-5 delta)	-17.82	-17.32	0.50
FL (2-6 delta)	1.04	1.54	0.50
FL (2-7 delta)	1.28	1.78	0.50
(MN-FL deltas)	(Δ MBtu)	(Δ MBtu)	(Δ MBtu)
MN-FL (01)	8.37	8.87	0.50
MN-FL (02)	12.26	12.77	0.51
MN-FL (03)	8.13	8.63	0.50
MN-FL (04)	11.75	12.25	0.50
MN-FL (05)	25.05	26.04	0.99
MN-FL (06)	10.35	10.85	0.50
MN-FL (07)	8.46	8.96	0.50

5.   General Requirements

Accredited software tools shall be required to fulfill the requirements defined in this section.

5.1   Calculation Timestep Frequency

Accredited software tools shall perform energy calculations at a minimum frequency of once per hour. The software shall simulate the dynamic response of thermal mass associated with the dwelling unit based on the thermal history established in calculations from prior timesteps.

5.2   Modeling Methods and Numerical Settings

The software shall perform HERS analysis simulations using the same modeling methods and numerical settings that are tested in the Software Verification Test Suite defined in this document with the following exceptions:
1. Methods for characterizing building systems and/or building components not tested by the Software Verification Test Suite are permitted.
2. When conflicting modeling methods are required by the National Standard and the Software Verification Test Specifications, the National Standard's methods shall be used. Examples include:
    a. Weather driven infiltration
    b. Internal gain schedules
3. Numerical settings representing higher resolution of calculation are permitted. Examples include:
    a. shorter timesteps
    b. smaller convergence tolerances

5.3   Minimum Output

The software shall provide users with the capability of generating the following outputs for every HERS analysis.

5.3.1   RESNET National Building Registry XML

The software shall demonstrate the capability of generating an XML file consistent with the RESNET national building registry schema (https://github.com/natresnet/buildingregistry-schema-v2), including the following components of the HERS Index calculation:

- HERS Index
- Reference Home End Use Loads (REUL)
- Reference Home End Use Energy Consumptions (EC_r)
- Rated Home End Use Energy Consumptions (EC_x)
- Purchased Energy Fraction
- IAD_{SAVE}

5.3.2 HERS Diagnostic Output

The software shall provide the capability to output the values as outlined in the HERS Diagnostic Output Schema (https://resnet-us.github.io/hers-diagnostic-schema/). This capability may be limited to diagnostic purposes and need not be available to all users.

5.4 User Input Verification

Accredited software tools shall be required to verify the reasonableness and internal consistency of certain user inputs as specified by this section. Accredited software tools shall generate user warnings, software errors that prohibit further calculation and National Building Registry flags as specified by this section.

5.4.1 Building Attribute Verification

The software inputs for building attributes specified in Table 5-1 shall be verified by accredited software tools. Where the Action listed in Table 5-1 is 'Error' accredited software tools shall not complete the rating calculations until the input error is remediated. Where the Action is 'Warning' the accredited software tools shall store a warning flag in the building input file that is specific to the attribute and that can be transmitted to the RESNET National Building Registry when the building file is submitted for registration.

Table 5-1: Building attribute verification limits and required actions

Building Attribute	Limits	Action
Stories above grade	$1 <= SAG <= 4$	Warning
Average ceiling height	$7 <= (Volume / CFA) <= 15$	Warning
Below grade slab floors	$=> 1$ below grade wall	Warning
Below grade walls	$=> 1$ below grade slab floor	Warning
Crawlspace perimeter (ft)	$1 <= perimeter <= (EFA^{0.5} * 7)$	Warning
Basement perimeter (ft)	$1 <= perimeter <= (EFA^{0.5} * 7)$	Warning
Slab on grade perimeter (ft)	$1 <= perimeter <= (EFA^{0.5} * 7)$	Warning
Foundation wall height (ft)	$0 < height <= 20$	Warning
Basement wall depth (ft)	$2 <= depth <= (wall\ height – 0.5)$	Warning
Uncond. foundation space	$=> 1$ floor above foundation space	Error
Enclosure floor area	$<=$ enclosure ceiling area	Warning
Enclosure floor area	$<=$ conditioned floor area	Error
Enclosure gross wall area	$27 <= (EGWA / (CFA*NCS)^{0.5}) <= 105$	Warning
Above grade gross wall area	$>=$ door area + window area	Error
Rating date	$<=$ current date	Error

Acronyms:
CFA = Conditioned Floor Area (total)
SAG = Stories Above Grade
EFA = Enclosure Floor Area of the specific building attribute
EGWA = Enclosure Gross Wall Area (total)

NCS = Number of conditioned stories including conditioned basements
Where ***Enclosure*** shall mean the relevant building components comprising the bounding elements of the Rated Home's Conditioned Space.

5.4.2 Mechanical Ventilation System Verification

5.4.2.1 Accredited software tools shall verify that mechanical ventilation fan energy use values are within the bounds specified in Table 5-2. Where the limits provided by Table 5-2 are exceeded, accredited software tools shall store a warning flag in the building input file that is specific to the system type and that can be transmitted to the RESNET National Building Registry when the building file is submitted for registration.

Table 5-2: Mechanical ventilation system fan energy consumption limits

System Type	Exhaust fan	Supply fan	System total
Exhaust	=> 0.12 W/cfm	n/a	=> 0.12 W/cfm
Supply	n/a	=> 0.12 W/cfm	=> 0.12 W/cfm
Balanced	=> 0.12 W/cfm	=> 0.12 W/cfm	=> 0.24 W/cfm
ERV	n/a	n/a	=> 0.48 W/cfm
Central Fan Integrated Supply (CFIS - fan cycler or similar):			
PSC motor (SEER <= 13; AFUE <= 90%)			=> 0.48 W/cfm
ECM motor (SEER => 15; AFUE => 92%)			=> 0.36 W/cfm

5.4.2.2 For the purposes of calculating the impacts of whole-house ventilation systems in the Rated Home, accredited software tools shall ensure that the time-averaged ventilation rate is equal to or greater than the minimum allowed by MINHERS, regardless of the user's entry.[9]

5.4.3 Appliance Verification

5.4.3.1 Clothes washers and clothes dryers

Accredited software tools shall verify that user inputs for clothes washers and clothes dryers do not exceed the limits specified by Table 5-3. Accredited software tools shall provide user warnings where these limits are exceeded. In all cases, where the limits provided by Table 5-3 are exceeded, accredited software tools shall store a warning flag in the building input file that is specific to the attribute and that can be transmitted to the RESNET National Building Registry when the building file is submitted for registration.

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[9] For example, if the whole house ventilation fan requirement is 50 cfm continuous and the whole house ventilation system is intermittent with a 33% duty cycle (typical of a fan cycler system), the ventilation rate during the 33% duty cycle must be 150 cfm for the Rated Home calculations. Software users can be warned of this requirement (and its implementation in the software) but shall not be allowed to override it.

Table 5-3: Clothes washer and clothes dryer input limits

Attribute	Limits	Action
Clothes washers (kWh/y)	(21*Nbr + 73) > CWkWh > (1.92*Nbr + 6.77)	Warning
Electric dryers (kWh/y)	(163*Nbr + 577) > eCDkWh > (16.3*Nbr + 50.5)	Warning
Gas dryers (therms/y)	(5.9*Nbr + 20.6) > gCDtherms > (0.877*Nbr + 3.09)	Warning
Gas dryers (kWh/y)	(12.9*Nbr + 45.5) > gCDkWh > (1.94*Nbr + 6.82)	Warning
Hot water savings (gpd)	HWgpdSave < (0.634*Nbr +2.24)	Warning

5.4.4 Reference Home Input Option

The software shall allow the user to select Rated Home inputs equivalent to the Reference Home specification according to MINHERS Standard for any building feature. This capability may be limited to diagnostic purposes and need not be available to all users.