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ANSI/ASHRAE Standard 140-2004

ASHRAE STANDARD

Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs

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[Informative Note: Additions are shown in this addendum by underlining and deletions are shown by ~~strikethrough~~ except when an informative note makes it clear that the entire material that follows is to be added or deleted as a whole.]

[Informative Note: The revisions shown in this addendum are to the current version of the standard,* ANSI/ASHRAE Standard 140-2004, *as it has been modified by Addendum a, which has also been published.]

(This foreword is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

[Informative Note: Revise foreword as indicated to include new material regarding Cases CE300-CE545 and some language refinements to the mathematical truth standard discussion that were included in the validation section of the* 2005 Handbook—Fundamentals*.]

FOREWORD

This Standard Method of Test (SMOT) can be used for identifying and diagnosing predictive differences from whole building energy simulation software that may possibly be caused by algorithmic differences, modeling limitations, input differences, or coding errors. The current set of tests included herein consists of

- *comparative tests that focus on building thermal envelope and fabric loads and mechanical equipment performance*

and

- *analytical verification tests that focus on mechanical equipment performance.*

These tests are part of an overall validation methodology described in Annex B18.

This procedure tests software over a broad range of parametric interactions and for a number of different output types, thus minimizing the concealment of algorithmic differences by compensating errors. Different building energy simulation programs, representing different degrees of modeling complexity, can be tested. However, some of the tests may be incompatible with some building energy simulation programs.

The tests are a subset of all the possible tests that could occur. A large amount of effort has gone into establishing a sequence of tests that examine many of the thermal models relevant to simulating the energy performance of a building and its mechanical equipment. However, because building energy simulation software operates in an immense parameter space, it is not practical to test every combination of parameters over every possible range of function.

The tests consist of a series of carefully described test case building plans and mechanical equipment specifications. Output values for the cases are compared and used in conjunction with diagnostic logic to determine the sources of predictive differences. For the building thermal envelope and fabric load cases of Section 5.2, the "basic" cases (Sections 5.2.1 and 5.2.2) test the ability of the programs to model such combined effects as thermal mass, direct solar gain windows, window-shading devices, internally generated heat, infiltration, sunspaces, and deadband and setback thermostat control. The "in-depth" cases (Section 5.2.3) facilitate diagnosis by allowing excitation of specific heat transfer mechanisms. The space cooling equipment cases of Section 5.3 test the ability of programs to model the performance of unitary space-cooling equipment using manufacturer design data presented as empirically derived performance maps. In the~~se~~ steady-state analytical verification cases of Sections 5.3.1 and 5.3.2, which utilize a typical range of performance data, the following parameters are varied: sensible internal gains, latent internal gains, zone thermostat setpoint (entering dry-bulb temperature), and outdoor dry-bulb temperature. Parametric variations isolate the effects of the parameters singly and in various combinations and isolate the influence of part-loading of equipment, varying sensible heat ratio, "dry" coil (no latent load) versus "wet" coil (with dehumidification) operation, and operation at typical Air-Conditioning and Refrigeration Institute (ARI) rating conditions. The comparative test cases of Sections 5.3.3 and 5.3.4 utilize an expanded range of performance data, an outside air mixing system and hourly varying weather data and internal gains. In these cases the following parameters are varied: sensible internal gains, latent internal gains, infiltration rate, outside air fraction, thermostat setpoints, and economizer control settings. Results analysis also isolates the influence of part loading of equipment, ODB sensitivity, and "dry" coil (no latent load) versus "wet" coil (with dehumidification) operation. These cases help to scale the significance of simulation results disagreements for a realistic context, which is less obvious in the steady-state cases described above. The space heating equipment cases of Section 5.4 test the ability of programs to model the performance of residential fuel-fired furnaces. These tests are divided into two tiers. The Tier 1 cases (Section 5.4.1 and 5.4.2—Analytical Verification Tests) employ simplified boundary conditions and test the basic functionality of furnace models. Boundary conditions that are more realistic are used in the Tier 2 cases (Section 5.4.3—Comparative Tests), where specific aspects of furnace models are examined. The full set of space heating test cases is designed to test the implementation of specific algorithms for modeling the following aspects of furnace performance: furnace steady-state efficiency, furnace part-load ratio, furnace fuel consumption, circulating fan operation, and draft fan operation. These cases also test the effects of thermostat setback and undersized capacity.

For consistent numbering of test cases within the standard, case numbers used for the mechanical equipment tests in Sections 5.3.3, 5.3.4 and 5.4 have been changed from the numbering used in the original research reports where the test specifications were developed. For example, in Section 5.3.3, Case CE300 was named Case E300 in the original research.

Case numbers for mechanical equipment tests included in Sections 5.3.1 and 5.3.2 will be similarly revised as editorial changes in the next continuous maintenance revision.

The tests have a variety of uses including

a. *comparing the predictions from other building energy programs to the example results provided in the informative Annexes B8 and B16 and/or to other results that were generated using this SMOT;*
b. *checking a program against a previous version of itself after internal code modifications to ensure that only the intended changes actually resulted;*
c. *checking a program against itself after a single algorithmic change to understand the sensitivity between algorithms; and*
d. *diagnosing the algorithmic sources and other sources of prediction differences (diagnostic logic flow diagrams are included in the informative Annex B9).*

Regarding the ~~example building fabric load~~comparative test results of Annex B8 and selected parts of Annex B16, the building energy simulation computer programs used to generate these results have been subjected to a number of analytical verification, empirical validation, and comparative testing studies. However, there is no such thing as a completely validated building energy simulation computer program. All building models are simplifications of reality. The philosophy here is to generate a range of results from several programs that are generally accepted as representing the state of the art in whole building energy simulation programs. To the extent possible, input errors or differences have been eliminated from the presented results. Thus, for a given case, the range of differences between comparative test results presented in ~~the~~ informative Annexes B8 and B16 represents legitimate algorithmic differences among these computer programs. ~~for comparative envelope tests.~~ For any given case, a tested program may fall outside this range without necessarily being incorrect. However, it is worthwhile to investigate the source of significant differences, as the collective experience of the authors of this standard is that such differences often indicate problems with the software or its usage, including, but not limited to,

- *user input error, where the user misinterpreted or incorrectly entered one or more program inputs;*
- *a problem with a particular algorithm in the program;*
- *one or more program algorithms used outside their intended range.*

Also, for any given case, a program that yields values in the middle of the range established by the ~~Annex B8~~comparative test example results should not be perceived as better or worse than a program that yields values at the borders of the range.

~~The Annex B16~~Analytical verification test results for the HVAC equipment performance tests include both quasi-analytical solutions and simulation results in selected sections of informative Annex B16. In general, it is difficult to develop worthwhile test cases that can be solved analytically or quasi-analytically, but such solutions are extremely useful when possible. Analytical or quasi-analytical solutions represent a "mathematical truth standard." That is, given the underlying physical assumptions in the case definitions, there is a mathematically correct solution for each case. In this context, the underlying physical assumptions regarding the mechanical equipment as defined in Sections 5.3 and 5.4 are representative of typical manufacturer data normally used by building design practitioners; many "whole-building" simulation programs are designed to work with this type of data. It is important to understand the difference between a "mathematical truth standard" and an "absolute truth standard." In the former, we only test the solution process for a model, not the appropriateness of the solution; that is, we accept the given underlying physical assumptions while recognizing that these assumptions represent a simplification of physical reality. An approximate truth standard from an experiment tests both the solution process and appropriateness of the model within experimental uncertainty. The ultimate or "absolute" validation truth standard would be comparison of simulation results with a perfectly performed empirical experiment, ~~the inputs for which are perfectly specified to those doing the simulation (the simulationists)~~with all simulation inputs perfectly defined.

~~The minor disagreements among the two sets of~~ The quasi-analytical and analytical solution results presented in selected parts of Annex B16 represent a mathematical truth standard. ~~are small enough to~~This allows identification of bugs in the software that would not otherwise be apparent from comparing software only to other software and therefore improves the diagnostic capabilities of the test procedure. The primary purpose of also including simulation results for the ~~Section 5.3~~ cases where analytical or quasi-analytical solutions exist ~~in Annex B16~~ is to allow simulationists to compare their relative agreement (or disagreement) versus the analytical or quasi-analytical solution results to that for other simulation results. Perfect agreement among simulations and analytical or quasi-analytical solutions is not necessarily expected. The results give an indication of the ~~sort~~ degree of agreement that is possible between simulation results and ~~the~~ analytical or quasi-analytical solution results. Because the physical assumptions of a simulation may be different from those for ~~the~~ analytical or quasi-analytical solutions, a tested program may disagree with ~~the quasi-analytical~~such solutions without necessarily being incorrect. However, it is worthwhile to investigate the sources of differences as noted above.

3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

3.1 Terms Defined for This Standard

[Informative Note: Revise following definitions to include language also relevant to new Sections 5.3.3, 5.3.4, and 6.3.2. The definition of "net refrigeration effect" is included for convenient referral.]

coefficient of performance (COP): for a cooling (refrigeration) system, the ratio, using the same units in the numerator as in the denominator, of the net refrigeration effect to the corresponding energy input. For the purpose of calculating COP, corresponding energy input is the related cooling energy consumption, except for cases CE300–CE440 (see Sections 5.3.3, 5.3.4.1, and 5.3.4.2) where the indoor air distribution fan energy is included only during times when heat is being extracted by the evaporator coil. (Also see *net refrigeration effect* and *cooling energy consumption.*)

cooling energy consumption: the site electric energy consumption of the mechanical cooling equipment including the compressor, air distribution fan (regardless of whether the compressor is on or off), condenser fan, and related auxiliaries.

COP2: is the ratio, using the same units, of the gross total evaporator coil load to the sum of the compressor and outdoor condenser fan energy consumptions. (Also see *gross total evaporator coil load*.)

COP degradation factor (CDF): multiplier (≤1) applied to the full-load system COP or COP2. CDF is a function of part-load ratio. (Also see *part-load ratio*.)

dew-point temperature: the temperature of saturated air at a given humidity ratio and pressure. As moist air is cooled at constant pressure, the dew point is the temperature at which condensation begins. (Also see *humidity ratio*.)

economizer: a control system that conserves energy, usually by using outside air and control logic to maintain a fixed minimum of outside air when increased outside-air flow rates are not called for.

entering dry-bulb temperature (EDB): the temperature that a thermometer would measure for air entering the evaporator coil. For a draw-through fan configuration with no heat gains or losses in the ductwork and no outside air mixed with return air, EDB equals the indoor dry-bulb temperature. For a similar configuration but when outside air is mixed with return air, EDB equals the mixed-air dry-bulb temperature.

entering wet-bulb temperature (EWB): the temperature that the wet-bulb portion of a psychrometer would measure if exposed to air entering the evaporator coil. For a draw-through fan with no heat gains or losses in the ductwork and no outside air mixed with return air, this would also be the zone air wet-bulb temperature. For a similar configuration but when outside air is mixed with return air, EWB equals the mixed-air wet-bulb temperature. For mixtures of water vapor and dry air at atmospheric temperatures and pressures, the wet-bulb temperature is approximately equal to the adiabatic saturation temperature (temperature of the air after undergoing a theoretical adiabatic saturation process). The wet-bulb temperature given in psychrometric charts is really the adiabatic saturation temperature.

evaporator coil loads: the actual sensible heat and latent heat removed from the distribution air by the evaporator coil. These loads include indoor air distribution fan heat for times when the compressor is operating, and they are limited by the system capacity (where system capacity is a function of operating conditions). Sensible evaporator coil load applies only to sensible heat removal. Latent evaporator coil load applies only to latent heat removal. (Also see *sensible heat* and *latent heat*.)

gross total coil load (or gross total evaporator coil load): the sum of the sensible heat and latent heat removed from the distribution air by the evaporator coil.

infiltration: leakage of air through any building element (e.g., walls, windows, and doors).

net refrigeration effect: the rate of heat removal (sensible + latent) by the evaporator coil, as regulated by the thermostat (i.e., not necessarily the full load capacity), after deducting internal and external heat transfers to air passing over the evaporator coil. For the tests of Section 5.3, the net refrigeration effect is the evaporator coil load less the actual air distribution fan heat for the time when the compressor is operating; at full load, this is also the adjusted net total capacity. (Also see *adjusted net total capacity*, *evaporator coil load*, *sensible heat*, and *latent heat*.)

part-load ratio for cooling (PLR): the ratio of the net refrigeration effect to the adjusted net total capacity for the cooling coil. As shown in Annex B13, for the purpose of calculating the COP degradation factor (CDF), defining PLR as the ratio of gross total evaporator coil load to the gross total capacity produces an equivalent CDF. (Also see *net refrigeration effect*, ~~and~~ *adjusted net total capacity, COP degradation factor, gross total evaporator coil load,* and *gross total capacity*.)

relative humidity: is the ratio of the mole fraction of water vapor in a given moist air sample to the mole fraction in an air sample that is saturated and at the same temperature and pressure. This is equivalent to the ratio of partial pressure of the water vapor in a sample to the saturation pressure at the same temperature.

3.2 Abbreviations and Acronyms Used in This Standard

[Informative Note: Add acronyms to Section 3.2 as shown]

Abs	absorptance
ACH	air changes per hour
ADP	apparatus dew point
ANSI	American National Standards Institute
Apr.	April
ARI	Air-Conditioning and Refrigeration Institute

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BESTEST	Building Energy Simulation Test and Diagnostic Method
BF	bypass factor
BHP	brake horsepower
Cd	degradation coefficient
CDF	coefficient of performance degradation factor
CFM	cubic feet per minute
CIBSE	Chartered Institution of Building Services Engineers
COP	coefficient of performance
COP2	alternative coefficient of performance (see Section 3.1)
Coef	coefficient
Cp	specific heat (J/kg·K)
DBT	dry-bulb temperature (°C)
Dec.	December
E,W,N,S	east, west, north, south
EDB	entering dry-bulb temperature
EER	energy efficiency ratio
EWB	entering wet-bulb temperature
Ext	exterior
FF	free-floating thermostat control strategy (no heating or cooling)
High-mass	heavy mass
HIR	heat-input ratio
HVAC	heating, ventilating, and air conditioning
HVAC BESTEST	International Energy Agency Building Energy Simulation Test and Diagnostic Method for Heating, Ventilating, and Air-Conditioning Equipment Models
ID	indoor
I.D.	inside diameter
IDB	indoor dry-bulb temperature
Int	interior
IP	inch-pound
Jan.	January
k	thermal conductivity (W/m·K)
Low mass	light mass
Mar.	March
N/A	not applicable
NOAA	National Oceanic and Atmospheric Administration
Nov.	November
NSRDB	National Solar Radiation Database
O.D.	outside diameter
Oct.	October
ODB	outdoor dry-bulb temperature
PLF	part-load factor
PLR	part-load ratio for cooling
PLR_f	part-load ratio for furnace
R	unit thermal resistance (m·K/W)
Refl	reflectance
SEER	seasonal energy efficiency ratio
SHC	gross sensible capacity (kW thermal)
SHGC	solar heat gain coefficient
SHR	sensible heat ratio
SI	Système Internationale
STP	standard temperature and pressure
Surf	surface
t	thickness (m)
T	zone air temperature
TC	gross total capacity (kW thermal)
TMY	Typical Meteorological Year
TMY2	Typical Meteorological Year 2
Trans	solar transmittance
TUD	Technische Universität Dresden
U	unit thermal conductance or overall heat transfer coefficient (W/m·K)
UA	thermal conductance (W/K)
WBAN	Weather Bureau Army Navy
wg	water gauge
WYEC2	Weather Year for Energy Calculations 2

4. METHODS OF TESTING

[Informative Note: Make revisions in Section 4 as shown; all of Section 4 is shown here. Changes include reference to the new test cases of Sections 5.3.3 and 5.3.4, inclusion of reporting requirements for simulation inputs (4.3.2), rules for modifying programs or simulation inputs (4.4.3), and editorial changes. The word "section" was added in places where section cross-referencing is indicated, to facilitate future searches on cross-referenced sections for future revisions.]

4.1 Applicability of Test Method

The method of test is provided for analyzing and diagnosing building energy simulation software using software-to-software, software-to-quasi-analytical-solution, and software-to-analytical-solution comparisons. The methodology allows different building energy simulation programs, representing different degrees of modeling complexity, to be tested by

- comparing the predictions from other building energy simulation programs to the example simulation results provided in ~~the~~ informative~~onal~~ Annex B8, to the example analytical and quasi-analytical solutions and simulation results in the informative Annex B16, and/or to other results (simulations or analytical and quasi-analytical solutions) that were generated using this standard method of test;
- checking a program against a previous version of itself after internal code modifications to ensure that only the intended changes actually resulted;
- checking a program against itself after a single algorithmic change to understand the sensitivity between algorithms;
- diagnosing the algorithmic sources of prediction differences; diagnostic logic flow diagrams are included in the informational Annex B9.

4.2 Organization of Test Cases

The specifications for determining input values are provided case by case in Section 5. Weather information required for use with the test cases is provided as described in Annex A1. Annex B1 provides an overview for all the test cases and contains information on those building parameters that change from case to case; Annex B1 is recommended for preliminary review of the tests, but do not use it for defining the cases. Additional information regarding the meaning of the cases is shown in the informational Annex B9 on diagnostic logic. In some instances (e.g., Case 620, Section 5.2.2.1.2), a case developed from modifications to a given base case (e.g., Case 600 ~~(~~Section 5.2.1) will also serve as the base case for other cases. The cases are grouped as:

a. Building Thermal Envelope and Fabric Load Base Case (see Section 4.2.1)
b. Building Thermal Envelope and Fabric Load Basic Tests (see Section 4.2.2)
   - Low mass (see Section 4.2.2.1)
   - High mass (see Section 4.2.2.2)
   - Free float (see Section 4.2.2.3)
c. Building Thermal Envelope and Fabric Load In-Depth Tests (see Section 4.2.3)
d. Space-Cooling Equipment Performance Analytical Verification Base Case (see Section 4.2.4)
e. Space-Cooling Equipment Performance Parameter Variation Analytical Verification Tests (see Section 4.2.5)
f. Space-Cooling Equipment Performance Comparative Test Base Case (see Section 4.2.6)
g. Space-Cooling Equipment Performance Comparative Tests (see Section 4.2.7)
h. ~~f.~~ Space-Heating Equipment Performance Analytical Verification Base Case (see Section 4.2.8~~6~~)
i. ~~g.~~ Space-Heating Equipment Performance Analytical Verification Tests (see Section 4.2.9~~7~~)
j. ~~h.~~ Space-Heating Equipment Performance Comparative Tests (see Section 4.2.10~~8~~)

4.2.1 Building Thermal Envelope and Fabric Load Base Case. The base building plan is a low mass, rectangular single zone with no interior partitions. It is presented in detail in Section 5.2.1.

4.2.2 Building Thermal Envelope and Fabric Load Basic Tests. The basic tests analyze the ability of software to model building envelope loads in a low mass configuration with the following variations: window orientation, shading devices, setback thermostat, and night ventilation.

4.2.2.1 The low mass basic tests (Cases 600 through 650) utilize lightweight walls, floor, and roof. They are presented in detail in Section 5.2.2.1.

4.2.2.2 The high mass basic tests (Cases 900 through 960) utilize masonry walls and concrete slab floor and include an additional configuration with a sunspace. They are presented in detail in Section 5.2.2.2.

4.2.2.3 Free-float basic tests (Cases 600FF, 650FF, 900FF, and 950FF) have no heating or cooling system. They analyze the ability of software to model zone temperature in both low mass and high mass configurations with and without night ventilation. The tests are presented in detail in Section 5.2.2.3.

4.2.3 Building Thermal Envelope and Fabric Load In-Depth Tests. The in-depth cases are presented in detail in Section 5.2.3.

4.2.3.1 In-depth Cases 195 through 320 analyze the ability of software to model building envelope loads for a nondeadband on/off thermostat control configuration with the following variations among the cases: no windows, opaque windows, exterior infrared emittance, interior infrared emittance, infiltration, internal gains, exterior shortwave absorptance, south solar gains, interior shortwave absorptance, window orientation, shading devices, and thermostat setpoints. These are a detailed set of tests designed to isolate the effects of specific algorithms. However, some of the cases may be incompatible with some building energy simulation programs.

4.2.3.2 In-depth Cases 395 through 440, 800, and 810 analyze the ability of software to model building envelope loads in a deadband thermostat control configuration with the following variations: no windows, opaque windows, infiltra-

tion, internal gains, exterior shortwave absorptance, south solar gains, interior shortwave absorptance, and thermal mass. This series of in-depth tests is designed to be compatible with more building energy simulation programs. However, the diagnosis of software using this test series is not as precise as for Cases 195 through 320.

4.2.4 Space-Cooling Equipment Performance Analytical Verification Base Case. The configuration of the base-case (Case E100) building is a near-adiabatic rectangular single zone with only user-specified internal gains to drive steady-state cooling load. Mechanical equipment specifications represent a simple unitary vapor-compression cooling system or, more precisely, a split-system, air-cooled condensing unit with an indoor evaporator coil. Performance of this equipment is typically modeled using manufacturer design data presented in the form of empirically derived performance maps. This case is presented in detail in Section 5.3.1.

4.2.5 Space-Cooling Equipment Performance Parameter Variation Analytical Verification Tests. In these steady-state cases (cases E110 through E200), the following parameters are varied: sensible internal gains, latent internal gains, zone thermostat setpoint (entering dry-bulb temperature [EDB]), and ODB. Parametric variations isolate the effects of the parameters singly and in various combinations and isolate the influence of: part loading of equipment, varying sensible heat ratio, "dry" coil (no latent load) versus "wet" coil (with dehumidification) operation, and operation at typical Air-Conditioning and Refrigeration Institute (ARI) rating conditions. In this way the models are tested in various domains of the performance map. These cases are presented in detail in Section 5.3.2.

4.2.6 Space-Cooling Equipment Performance Comparative Test Base Case. The configuration of this base case (Case CE300) is a near-adiabatic rectangular single zone with user-specified internal gains and outside air to drive dynamic (hourly varying) loads. The cases apply realistic, hourly varying annual weather data for a hot and humid climate. The mechanical system is a vapor-compression cooling system similar to that described in Section 4.2.4, except that it is a larger system and includes an expanded performance data set covering a wider range of operating conditions (i.e., wider range of ODB, EDB, and EWB (entering wet-bulb temperature). Also, an air mixing system is present so that outside-air mixing and economizer control models can be tested. This case is presented in detail in Section 5.3.3.

4.2.7 Space-Cooling Equipment Performance Comparative Tests. In these cases (cases CE310 through CE545), which apply the same weather data as Case CE300, the following parameters are varied: sensible internal gains, latent internal gains, infiltration rate, outside air fraction, thermostat setpoints, and economizer control settings. Results analysis also isolates the influence of part loading of equipment, ODB sensitivity, and "dry" coil (no latent load) versus "wet" coil (with dehumidification) operation. These cases help to scale the significance of simulation results disagreements for a realistic context, which is less obvious in the steady-state cases described above. These cases are presented in detail in Section 5.3.4.

4.2.8~~6~~ Space-Heating Equipment Performance Analytical Verification Base Case The configuration of the base-case (Case HE100) building is a rectangular single zone near-adiabatic on five faces with one heat exchange surface (the roof). Mechanical equipment specifications represent a simple unitary fuel-fired furnace with a circulating fan and a draft fan. Performance of this equipment is typically modeled using manufacturer design data presented in the form of empirically derived performance maps. This case is presented in detail in Section 5.4.1.

4.2.9~~7~~ Space-Heating Equipment Performance Analytical Verification Tests In these cases (cases HE110 through HE170), the following parameters are varied: efficiency, weather (resulting in different load conditions from full load to part load to no load to time-varying load), circulating fan operation, and draft fan operation. In this way the basic functionalities of the models are tested in various domains of the performance map. These cases are presented in detail in Section 5.4.2.

4.2.10~~8~~ Space-Heating Equipment Performance Comparative Tests In these cases (cases HE210 through HE230), the following parameters are varied: weather (realistic temperature conditions are used), thermostat control strategy, and furnace size (undersized furnace). In this way the models are tested with more realistic conditions in various domains of the performance map. These cases also test the interactions between furnace, control, and zone models. They are presented in detail in Section 5.4.3.

4.3 Reporting Results

4.3.1 Standard Output Reports. The standard output reports included on the accompanying CD shall be used. Instructions regarding these reports are included in Annex A2. Information required for this report includes:

a. Software name and version number.
b. ~~documentation of modeling methods used when alternative methods are available in the software~~ Modeling documentation using "S140outNotes.TXT" on the accompanying CD for: ~~, and~~
   - Modeling methods used when alternative methods are available in the software
   - Equivalent modeling methods used when the software does not allow direct input of specified values
   - Omitted test cases and results
   - Changes to source code for the purpose of running the tests, where such changes are not available in publicly released versions of the software
c. Results for simulated cases using the following files on the accompanying CD:
   - Sec5-2out.XLS for the building thermal envelope and fabric load tests of Section 5.2
   - Sec5-3Aout.XLS for the space cooling equipment performance analytical verification tests of Sections 5.3.1 and 5.3.2
   - Sec5-3Bout.XLS for the space cooling equipment performance comparative tests of Sections 5.3.3 and 5.3.4
   - Sec5-4out.xls for the space heating equipment performance tests of Section 5.4.

Output quantities to be included in the results report are called out specifically for each case, as they appear in the appropriate subsections of Sections 5.2, ~~Section~~ 5.3~~,~~ and ~~Section~~ 5.4.

If a program being tested omits a test case, the modeler shall provide an explanation using the modeler report template provided in Annex A2.

4.3.2 Simulation Input Files. All supporting data required for generating results with the tested software shall be saved, including:

- Input files
- Processed weather data
- Intermediate files containing calculations used for developing inputs
- A "Readme-softwarename-yymmdd.pdf" file that briefly describes the contents of the above files according to their file type (i.e., their ".xyz" file extension).

4.4 Comparing Output to Other Results

Annex B8 gives example simulation results for the building thermal envelope and fabric load tests. Annex B16 gives quasi-analytical solution results and example simulation results for the HVAC equipment performance tests. The user may choose to compare output with the example results provided in Annex B8 and Annex B16 or with other results that were generated using this standard method of test (including self-generated quasi-analytical solutions related to the HVAC equipment performance tests). Information about how the example results were produced is included in informational Annex B11 and Annex B17 for building thermal envelope and fabric load tests and for HVAC equipment performance tests, respectively. For the convenience to users who wish to plot or tabulate their results along with the example results, electronic versions of the example results have been included on the accompanying CD for Annex B8 with the file~~s~~ RESULTS5-2.XLS, ~~(for Annex B8),~~and with the following files for Annex B16: RESULTS5-3A.XLS, ~~(for Annex B16)~~RESULTS5-3B and RESULTS5-4.XLS~~(also for Annex B16) on the accompanying CD~~. Documentation ~~regarding RESULTS5-2.XLS, RESULTS5-3.XLS and RESULTS5-4.XLS have~~for navigating these results files has been included ~~with the files~~on the accompanying CD, and is printed ~~out~~ in Annex B10.

4.4.1 Criteria for Determining Agreement Between Results. There are no formal criteria for when results agree or disagree. Determination of when results agree or disagree is left to the user. In making this determination, the user should consider the following:

a. Magnitude of results for individual cases.

b. Magnitude of difference in results between certain cases (e.g., "Case 610 - Case 600").

c. Same direction of sensitivity (positive or negative) for difference in results between certain cases (e.g., "Case 610 - Case 600").

d. If results are logically counterintuitive with respect to known or expected physical behavior.

e. Availability of analytical or quasi-analytical solution results (i.e., mathematical truth standard as described in informative Annex B16, Section B16.2).

f. For the ~~HVAC~~ space-cooling and space-heating equipment performance tests of Sections 5.3 and 5.4, the degree of disagreement that occurred for other simulation results in Annex B16 versus the quasi-analytical solution results.

g. Example simulation results do not represent a truth standard.

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

4.4.3 Rules for Modifying Simulation Programs or Simulation Inputs. Modifications to simulation programs or simulation inputs shall have a mathematical, physical, or logical basis and shall be applied consistently across tests. Arbitrary modification of a simulation program's input or internal code just for the purpose of more closely matching a given set of results shall not be allowed.

If changes are made to the source code of the software for the purpose of performing tests, and these changes are not available in publicly released versions of the software, then the changes shall be documented in sufficient detail using the modeler report template provided in Annex A2, so that the implications of the changes can be assessed.

5. TEST PROCEDURES

5.1 Modeling Approach

[*Informative Note: Make revisions to Section 5.1 as noted. Tables and figures cited in this section of the addendum are located at the end of the Section 5 text.*]

This modeling approach shall apply to all the test cases presented in Sections 5.2, 5.3, and 5.4.

5.1.1 Time Convention. All references to time in this specification are to local standard time and assume that *hour 1 = the interval from midnight to 1 a.m*. Do not use daylight savings time or holidays for scheduling. TMY weather data are in hourly bins corresponding to solar time as described in Annex A1, Section A1.4. TMY2 and WYEC2 data are in hourly bins corresponding to local standard time.

5.1.2 Geometry Convention. If the program being tested includes the thickness of walls in a three-dimensional definition of the building geometry, then wall, roof, and floor thicknesses shall be defined such that the interior air volume of the building model remains as specified (e.g., for the cases of Section 5.2, 6 m × 8 m × 2.7 m = 129.6 m^3). Make the thicknesses extend exterior to the currently defined internal volume.

5.1.3 Nonapplicable Inputs. In some instances the specification will include input values that do not apply to the input structure of the program being tested. When this occurs, disregard the nonapplicable inputs and continue. Such inputs are in the specification for those programs that may need them.

5.1.4 Consistent Modeling Methods. Where options exist within a simulation program for modeling a specific thermal behavior, consistent modeling methods shall be used for all cases. For example, if a software gives a choice of methods for modeling windows, the same window modeling method shall be used for all cases. Document which option was used in the Standard Output Report (see Annex A2).

5.1.5 Equivalent Modeling Methods. Where a program or specific model within a program does not allow direct input of specified values, or where input of specified values causes instabilities in a program's calculations, modelers should develop equivalent inputs that match the intent of the test specification as nearly as the software being tested allows. Such equivalent inputs are to be developed based on the data provided in the test specification, and such equivalent inputs shall have a mathematical, physical, or logical basis and shall be applied consistently throughout the test cases. The modeler shall document the equivalent modeling method in the Standard Output Report (Annex A2).

5.1.6~~5~~ Simulation Initialization and Preconditioning. If ~~your~~the ~~software~~program being tested allows, begin the simulation initialization process with zone air conditions that equal the outdoor air conditions. If ~~your~~the program being tested allows for preconditioning (iterative simulation of an initial time period until temperatures or fluxes, or both, stabilize at initial values), use that capability.

5.1.7~~6~~ Simulation Duration

5.1.7~~6~~.1 Results for the tests of Sections 5.2, 5.3.3 and 5.3.4 are to be taken from a full annual simulation.

5.1.7~~6~~.2 For the tests of Sections 5.3.1 and 5.3.2, run the simulation for at least the first two months for which the weather data are provided. Give output for the second month of the simulation (February) in accordance with Section 6.3.1. The first month of the simulation period (January) serves as an initialization period.

5.1.7~~6~~.3 For the tests of Section 5.4, run the simulation for at least the three first months for which the weather data are provided. Give output for the first three months of the year (January 1–March 31) in accordance with Section 6.4.

[*Informative Note: Clarify Annex A1 reference in Section 5.2.3.6 as shown*]

5.2.3.6 Case 230: Infiltration. Case 230 is exactly the same as Case 220 except infiltration rate = 1.0 ACH, continuously (24 hours per day for the full year).

The weather data file provided on the accompanying CD and as described in Annex A1, Section A1.1, is a high altitude site (1609 m above sea level) with an air density roughly 80% of that at sea level.

5.3 Input Specification for Space-Cooling Equipment Performance Tests

[Informative note regarding future editorial changes for the next continuous maintenance revision: To be consistent with the test case naming convention of Standard 140-2004 Addenda* a *and* b*, editorial changes will be included for the next continuous maintenance revision to rename the following test cases.

Old Name	*New Name*
E100	*CE100*
E110	*CE110*
E120	*CE120*
E130	*CE130*
E140	*CE140*
E150	*CE150*
E160	*CE160*
E165	*CE165*
E170	*CE170*
E180	*CE180*
E185	*CE185*
E190	*CE190*
E195	*CE195*
E200	*CE200*]

[*Informative Note: Revise title and introduction of section 5.3.1 as shown*]

5.3.1 Case E100: Base Case Building and Mechanical System for Analytical Verification Tests. Begin with Case E100. Case E100 shall be modeled as detailed in this section and its subsections. The bulk of the work for implementing the ~~Section 5.3~~ tests of Sections 5.3.1 and 5.3.2 is assembling an accurate base building model. It is recommended that base building inputs be double-checked and disagreements in results be diagnosed before going on to the other cases.

[*Informative Note: Revise sections 5.3.1.1 and 5.3.1.2 to clarify cross references as shown*]

5.3.1.1 Weather Data. This case requires either HVBT461.TMY or HVBT461A.TM2 data provided on the

accompanying CD as described in Annex A1, Section A1.2.1. ***Note:*** Other cases call for different weather files as needed.

5.3.1.2 Output Requirements. Case E100 requires all of the output described in Section 6.3.1. ***Note:*** All of the ~~Section 5.3~~ tests of Sections 5.3.1 and 5.3.2 have the same output requirements.

[*Informative Note: Sections 5.3.1.4.5, 5.3.1.7, 5.3.1.8, and 5.3.1.9 are included here for convenient review referral; there are no changes indicated for those sections except minor revisions to the way units are shown.*]

5.3.1.4.5 Although the zone is modeled as if suspended above the ground, for software that requires input of ground thermal properties, the ground in the vicinity of the building is dry packed soil with the following characteristics:

Soil thermal conductivity (k)	=	1.3 W/(m·K)~~m·K~~
Soil density	=	1500 kg/m^3
Soil specific heat	=	800 J/(kg·K) ~~kg·K~~
Deep ground temperature	=	10°C

5.3.1.7 Opaque Surface Radiative Properties. Interior and exterior opaque surface solar (visible and ultraviolet wavelengths) absorptances and infrared emittances are included in Table 24.

5.3.1.8 Exterior Combined Radiative and Convective Surface Coefficients. If the program being tested automatically calculates exterior surface radiation and convection, this section may be disregarded. If the program being tested does not calculate this effect, then use 29.3 W/(m^2·K) ~~m^2·K~~ for all exterior surfaces. This value is based on a mean annual wind speed of 4.02 m/s for a surface with roughness equivalent to rough plaster or brick and is consistent with informative Annex B4.

5.3.1.9 Interior Combined Radiative and Convective Surface Coefficients. If the program being tested automatically calculates interior surface radiation and convection, then this section can be disregarded. If the program being tested does not calculate these effects, then use the constant combined radiative and convective surface coefficients given in Table 25.

The radiative portion of these combined coefficients may be taken as 5.13 W/(m^2·K) ~~m^2·K~~ [0.90 Btu/(h·ft^2·°F)] for an interior infrared emissivity of 0.9.

If the program being tested does not allow you to schedule these coefficients, then use 8.29 W/(m^2·K) ~~m^2·K~~ [1.46 Btu/(h·ft^2·°F)] for all horizontal surfaces. If different values can be justified, then use different values.

Informative Annex B5 includes background information about combined radiative and convective film coefficients.

[*Informative Note. Make the following editorial revision to last paragraph of 5.3.1.10.1 to have language consistent with Section 5.3.4.3.1.3 (given later)*]

5.3.1.10.1 General Information.

Note that, in one of the field-trial simulations, simultaneous use of "0" outside air and "0" infiltration caused an error in the simulations. ~~We worked around t~~This error was avoided by specifying minimum outside air = 0.000001 ft^3/min. ~~We~~ It is recommended to do~~ing~~ a sensitivity test to check that using 0 for both these inputs does not cause a problem.

[*Informative Note: Create subsection numbering for Section 5.3.1.10.2 so that the subsections can be called out in Section 5.3.3.10.2, with editorial changes to 5.3.1.10.2 as shown.*]

5.3.1.10.2 Thermostat Control Strategy.

Heat = off

Cool = on if zone air temperature > 22.2°C (72.0°F); otherwise *Cool* = off.

5.3.1.10.2.1 There is no zone humidity control. This means that the zone humidity level will float in accordance with zone latent loads and moisture removal by the mechanical system.

5.3.1.10.2.2 The thermostat senses only the zone air temperature; the thermostat itself does not sense any radiant heat transfer exchange with the interior surfaces.

5.3.1.10.2.3 The controls for this system are ideal in that the equipment is assumed to maintain the setpoint exactly when it is operating and not overloaded. There are no minimum ON or OFF time-duration requirements for the unit and no hysteresis control band (e.g., there is no ON at setpoint + x°C or OFF at setpoint – y°C). If ~~your~~ the software being tested requires input for these, use the minimum values ~~your~~ the software allows.

5.3.1.10.2.4 The thermostat is nonproportional in the sense that when the conditioned zone air temperature exceeds the thermostat cooling setpoint, the heat extraction rate is assumed to equal the maximum capacity of the cooling equipment corresponding to environmental conditions at the time of operation. A proportional thermostat model can be made to approximate a nonproportional thermostat model by setting a very small throttling range (the minimum allowed by your program). A COP = f(PLR) curve is given in Section 5.3.1.10.4 to account for equipment cycling.

[Informative Note: Editorial changes will be included in Section 5.3.1.10.3 for the next continuous maintenance revision of Standard 140 to delete informative reference 6 (and renumber all following references throughout the Standard), and to revise Note* a *of Tables 26a through 26f to read as "Performance rated at 900 CFM (0.425 m^3/s), with 25 feet (7.62 m) of 3/4 in. (19.05 mm) suction and 5/16 in. (7.94 mm) liquid lines." Also, make editorial updates to accompanying file E100MAP.xls as needed for consistency.]

[Informative Note: Revise filename as shown, and in the accompanying electronic files.]

5.3.1.10.3.1 For convenience, an electronic file (~~PERFMAP140~~E100MAP.XLS) that contains these tables is included on the accompanying CD.

[***Informative Note: Revise reference to Annex B17 in last paragraphs of 5.3.1.10.3.3 and 5.3.1.10.3.4 as shown.***]

5.3.1.10.3.3 Validity of Listed Data (VERY IMPORTANT).

...

Note that in this example linear interpolation was used to find the "maximum EWB" dry-coil condition. Use of other or additional performance data points (e.g., to develop more generalized curve fits) is also possible for the purpose of interpolation or extrapolation. Also see informative Annex B17, Section B17.1.1.2, regarding analytical solution results.

...

5.3.1.10.3.4 Extrapolation of Performance Data.

Note that in this example linear extrapolation was used to find the "maximum EWB" dry-coil condition. Use of other or additional performance data points (e.g., to develop more generalized curve fits) is also possible for the purpose of interpolation or extrapolation. Also see informative Annex B17, Section B17.1.1.2, regarding analytical solution results.

[Informative Note: Make editorial revisions to cases E100-E200 in 5.3.1.10.3.9 as shown.]

5.3.1.10.3.9 5.3.1.10.3.9 Minimum Supply Air Temperature. This system is a variable temperature system, meaning that the supply air temperature varies with the operating conditions. If ~~your~~the software being tested requires an input for minimum allowable supply air temperature, use

Minimum supply air temperature ≤ 7.7°C (45.9°F)

This value is the lowest value of ADP that occurs in ~~the Section 5.3 test~~ cases E100-E200 based on the quasi-analytical solutions for Case E110 presented in HVAC BESTEST.[8]

If ~~your~~the software being tested does not require this input, ignore this information.

[***Informative Note: Create subsection numbering for Section 5.3.1.10.4 so that the subsections can be called out by Section 5.3.3.10.4, with editorial changes to 5.3.1.10.4 as shown.***]

5.3.1.10.4 Part-Load Operation.

5.3.1.10.4.1 The system ~~COP~~ efficiency degradation that results from part-load operation is described in Figure 10. In this figure the COP degradation factor (CDF) is a multiplier to be applied to the full-load system COP (as defined in Section 3) at a given part-load ratio (PLR), where

COP(PLR) = (full load COP(ODB,EWB,EDB)) ~~*~~× CDF(PLR).

This representation is based on information provided by ~~the~~ an equipment manufacturer. It might be helpful to think of the efficiency degradation as being caused by additional start-up run time required to bring the evaporator coil temperature down to its equilibrium temperature for the time(s) when the compressor is required to operate during an hour with part load.

5.3.1.10.4.2 ~~Then, b~~Because the controller is ideal ON/OFF cycling (see Section 5.3.1.10.2.3),

Hourly fractional run time = PLR/CDF.

5.3.1.10.4.3 In Figure 10, the PLR is calculated by

(*net refrigeration effect*) / (*adjusted net total capacity*) ,

where the *net refrigeration effect* and the *adjusted net total capacity* are as defined in Section 3.

PLR may be alternatively calculated as

(*gross total coil load*) / (*gross total capacity*) ,

where the *gross total coil load* and *gross total capacity* are as defined in Section 3. Demonstration of the similarity of these definitions of PLR is included in Annex B13, Section B13.2.

5.3.1.10.4.4 Simplifying assumptions in Figure 10 are as follows:

- There is no minimum on/off time for the compressor and related fans; they may cycle on/off as often as necessary to maintain the setpoint.
- The decrease in efficiency with increased on/off cycling at very low PLR remains linear.

5.3.1.10.4.5 Annex B13, Section B13.1 includes additional details about how Figure 10 was derived.

5.3.1.10.4.6 If ~~your~~ the software being tested utilizes the cooling coil bypass factor, model the BF as independent of (not varying with) the PLR.

5.3.1.10.6 Fans.

[***Informative Note: Clarify Annex B15 cross-reference as shown.***]

5.3.1.10.6.1 Indoor Air Distribution Fan.

- Indoor fan power = 230 W.
- Airflow rate = 0.425 m^3/s = 1529 m^3/h = 900 CFM.
- Total combined fan and motor efficiency = 0.5.
- Total fan pressure = 271 Pa = 1.09 in. w.g. (water gauge).
- Supply air temperature rise from fan heat = 0.44°C = 0.8°F.
- Air distribution efficiency = 100% (adiabatic ducts).

For further discussion of these inputs, see Annex B15, Section B15.1.

The draw-through indoor air distribution fan cycles on and off with the compressor. For calculating additional heating of the distribution air related to waste heat from the indoor distribution fan, assume that the distribution fan motor is mounted in the distribution airstream so that **100% of the heat from fan energy use goes to the distribution (supply) air**.

[***Informative Note: Revise title of section 5.3.2 as shown***]

5.3.2 Space-Cooling Equipment Performance Parameter Variation Analytical Verification Tests

[***Informative Note: Clarify cross-references in sections 5.3.2.1.1, 5.3.2.1.4, 5.3.2.2.3.1, 5.3.2.2.6, 5.3.2.2.8, and 5.3.2.2.9.1 to reflect subdivision of Annex A1, Section A1.2 as shown.***]

5.3.2.1.1 Case E110: Reduced Outdoor Dry-Bulb Temperature. Case E110 is exactly the same as Case E100 except the applicable weather data file is

HVBT294.TMY or HVBT294A.TM2.

These data are provided on the CD accompanying this standard as described in Annex A1, Section A1.2.1.

5.3.2.1.4 Case E140: Reduced Outdoor Dry-Bulb Temperature at Low Part-Load Ratio. Case E140 is exactly the same as Case E130 except the applicable weather data file is

HVBT294.TMY or HVBT294A.TM2.

These data are provided in the files accompanying this standard as described in Annex A1, Section A1.2.1.

5.3.2.2.3 Case E165: Variation of Thermostat Setpoint and Outdoor Dry-Bulb Temperature at High Sensible Heat Ratio. Case E165 is exactly the same as Case E160 except the thermostat control strategy and weather data are changed as noted below.

5.3.2.2.3.1 Weather Data

HVBT406.TMY or HVBT406A.TM2

These data are provided in the files accompanying this standard as described in Annex A1, Section A1.2.1.

5.3.2.2.6 Case E185: Increased Outdoor Dry-Bulb Temperature at Low Sensible Heat Ratio. Case E185 is exactly the same as Case E180 except the applicable weather data file is

HVBT461.TMY or HVBT461A.TM2.

These data are provided in the files accompanying this standard as described in Annex A1, Section A1.2.1.

5.3.2.2.8 Case E195: Increased Outdoor Dry-Bulb Temperature at Low Sensible Heat Ratio and Low Part-Load Ratio. Case E195 is exactly the same as Case E190 except the ~~weather~~ applicable weather data file is

HVBT461.TMY or HVBT461A.TM2.

These data are provided in the files accompanying this standard as described in Annex A1, Section A1.2.1.

5.3.2.2.9 Case E200: Full-Load Test at ARI Conditions. This case compares simulated performance of mechanical equipment to the manufacturer's listed performance at full load and at ARI-specified operating conditions. Case E200 is exactly the same as Case E150 except for the changes noted below.

5.3.2.2.9.1 Weather Data

HVBT350.TMY or HVBT350A.TM2.

These data are provided in the files accompanying this standard as described in Annex A1, Section A1.2.1.

[*Informative Note: Add entirely new Sections 5.3.3 and 5.3.4.*]

5.3.3 Case CE300: Comparative Test Base Case Building and Mechanical System. Begin with Case CE300. Case CE300 shall be modeled as detailed in this section and its subsections.

The bulk of the work for implementing the tests of Sections 5.3.3 and 5.3.4 is assembling an accurate base building model. It is recommended that base building inputs be double-checked and disagreements in results be diagnosed before going on to the other cases.

5.3.3.1 Weather Data. This case requires the CE300.TM2 data provided on the accompanying CD as described in Annex A1, Section A1.2.2.

5.3.3.2 Output Requirements. Case CE300 requires the following output:

a. Annual summation, mean, and hourly-integrated maximum and minimum results in accordance with Section 6.3.2.1
b. Additional annual and hourly outputs only applicable to case CE300 in accordance with Section 6.3.2.2.

5.3.3.3 Building Geometry. The base building is a 196-m^2 floor area, single-story building with rectangular-prism geometry as shown in Figure 13. Zone air volume is 588 m^3.

5.3.3.4 Building Envelope Thermal Properties. The base building zone is intended as a near-adiabatic test cell with cooling load driven by user-specified scheduled internal gains. Tables 29a and 29b list material properties in Système Internationale (SI) and English (IP) units, respectively; abbreviations used in these tables are listed in Section 3.2.

5.3.3.4.1 The building insulation has been made very thick to effectively thermally decouple the zone from ambient conditions. If the software being tested does not allow this much insulation, use the thickest insulation the software will permit and reduce the floor, roof, and wall areas to achieve the thermal conductance (UA) values listed in Table 29a (SI) or 29b (IP). The zone air volume must remain at 588 m^3.

5.3.3.4.2 Materials of the space have no thermal or moisture capacitance and there is no moisture diffusion through them. If the software being tested requires inputs for thermal capacitance, moisture capacitance, or moisture diffusion, use the minimum values the software allows.

5.3.3.4.3 Air density at sea level is 1.201 kg/m^3.

5.3.3.4.4 The floor has the same exterior film coefficient as the other walls, as if the entire zone were suspended above the ground.

5.3.3.4.5 For software that requires input of ground thermal properties, use values of Section 5.3.1.4.5.

5.3.3.5 Infiltration. Infiltration rate = 0.0 air changes per hour (ACH) for the entire simulation period.

5.3.3.6 Internal Heat Gains. Sensible and latent internal heat gains are as indicated in Table 30.

5.3.3.6.1 Table 30 lists hourly values for a given period. In the first row of values, for example, the 2931 W of sensible gains and 0 W of latent gains are applied for each hour from 12 A.M. until 8 A.M. for the entire period from January 1 through March 10. Similarly, the second row of values indicates 2931 W of sensible gains and 366 W of latent gains for each hour from 8 A.M until 8 P.M for the same period. Values are provided in both SI and IP units. Additionally, the corresponding fraction of a given hourly value relative to the maximum hourly value for the year is given for the convenience of

users who may need to provide input in such a format. In the first row of values for sensible gains, for example, the "frac v. max" value of 0.15625 is the result of: (10,000 British thermal units [Btu]/h) / (64,000 Btu/h). Note that 64,000 Btu/h, which is the hourly sensible heat gain for the period from 14:00 until 16:00 for the period beginning April 21 and ending October 12 (and October 19 through November 5), is the maximum hourly sensible internal gain input for the year.

5.3.3.6.2 Sensible gains are 100% convective.

5.3.3.6.3 Zone sensible and latent internal gains are assumed to be distributed evenly throughout the zone air. These are internally generated sources of heat that are not related to the operation of the mechanical cooling system or its air distribution fan.

5.3.3.6.4 If the software being tested requires input of water vapor mass flow rate rather than latent internal gains, use the heat of vaporization that the software assumes for condensation at the coil to convert the latent gains to water vapor mass flow rate for each listed time period.

5.3.3.6.5 If the software being tested requires input of total internal gains, use the sum of sensible + latent internal gains for each listed time period.

5.3.3.7 Opaque Surface Radiative Properties. Same as for cases E100-E200; see Section 5.3.1.7.

5.3.3.8 Exterior Combined Radiative and Convective Surface Coefficients. Same as for cases E100-E200; see Section 5.3.1.8.

5.3.3.9 Interior Combined Radiative and Convective Surface Coefficients. Same as for cases E100-E200; see Section 5.3.1.9.

5.3.3.10 Mechanical System. The mechanical system represents a simple unitary vapor compression cooling system or, more precisely, a split-system, air-cooled condensing unit with an indoor evaporator coil and with an outside air mixing system. Figure 14 is a schematic diagram of this system. See Section 3 for definitions of terminology used in this section.

5.3.3.10.1 General Information.

- 100% convective air system.
- Zone air perfectly mixed.
- An outside-air mixing system is included (as shown in Figure 14).
- Single-speed draw-through indoor-air distribution fan, continuous operation.
- Outdoor condenser fan, cycling on and off with the compressor.
- Air-cooled condenser.
- Single-speed reciprocating compressor, R-22 refrigerant, no cylinder unloading.
- No system hot-gas bypass.
- The compressor, condenser, and condenser fan are located outside the conditioned zone.
- All moisture that condenses on the evaporator coil (latent load) leaves the system through a condensate drain.
- Crankcase heater and other auxiliary energy = 0.

5.3.3.10.2 Thermostat Control Strategy.

Heat = off

Cool = on if temperature > 25.0°C (77.0°F); otherwise *Cool* = off.

The thermostat control strategy is the same as for cases E100-E200; see Sections 5.3.1.10.2.1 through 5.3.1.10.2.4.

5.3.3.10.3 Full-Load Cooling System Performance Data. Tables 31a and 31b give a sample expanded set of data for equipment full-load capacity and full-load performance data. The tables contain gross capacity data, which are the full capacities of the unit without any fan heat subtracted out. Table 31a is in SI units; Table 31b is in IP units. Notes that also include specific units for various quantities presented in the tables are given on the last page of each table. Data are included for 2.78°C (5°F) increments of EDB and EWB and 5.56°C (10°F) increments of ODB. Data are also included for typical rating conditions of ODB/EDB/EWB = 35.00°C/26.67°C/19.44°C (95°F/80°F/67°F).

5.3.3.10.3.1 For convenience, an electronic file (CE300MAP.XLS) containing Tables 31a and 31b is included on the accompanying CD.

5.3.3.10.3.2 These tables use ODB, EDB, and EWB as independent variables for performance data; the locations of EDB and EWB are shown in Figure 14. In these tables each block of data represents an f(EDB, EWB) data set for a different ODB.

The data set includes ranges where only limited system operation is recommended. These ranges are indicated by background shading in the upper-left and lower-right regions of the tables (see the electronic version of CE300MAP.XLS).

The data set assumes that the refrigerant charge is always optimal at each listed full-load operating point. For the purpose of the test cases, assume that the refrigerant charge is always optimal.

The unit as described actually uses a 1242 W fan. So the adjusted net capacity is

$$(\text{net cap})_{\text{adj}} = (\text{gross cap})_{\text{listed}} - (\text{fan power}).$$

For example, for the net total (sensible + latent) capacity at ODB = 95°F, EDB = 75°F, and EWB = 65°F and 4000 CFM:

$$(\text{net cap})_{\text{adj}} = 32{,}122\ \text{W} - 1242\ \text{W} = 30{,}880\ \text{W}.$$

The technique for determining net sensible capacities is similar.

5.3.3.10.3.3 Validity of Listed Data (VERY IMPORTANT). EWB given for the listed compressor kW (kilowatts) and gross capacities given in Tables 31a and 31b are valid only for "wet" coils (when dehumidification is occurring). A dry-coil condition—no dehumidification—occurs when the entering air humidity ratio is decreased to the point where the entering air dew-point temperature is less than the effective coil surface temperature (apparatus dew point). In Tables 31a and 31b, the dry-coil data (indicated with *italics*) are evident for conditions where the listed sensible capacity is equal to the corresponding total capacity. For a given EDB and ODB, the compressor power, total capacity, and sensible capacity for wet coils change with varying

EWB. Once the coil becomes dry, for a given EDB, compressor power and capacities remain constant with decreasing EWB.[7]

For the purpose of interpolating data between listed wet-coil and dry-coil data points, it is necessary to evaluate the maximum EWB for the occurrence of the listed dry-coil data point. One method for establishing the maximum EWB where total and sensible capacities are equal is to linearly extrapolate EWB for a given EDB and ODB. For example, the data shown in Table 32a (extracted from Table 31a, SI units) and Table 32b (extracted from Table 31b, IP units) can be used to determine the dry-coil compressor power for ODB/EDB = 35.00°C/26.67°C (95.0°F/80°F).

At the dry-coil condition:

Gross total capacity = gross sensible capacity
= 31.05 kW thermal (105.9 kBtu/h)

where these data are listed in the row in Tables 31a and 31b (for ODB = 35.00°C [95°F]) for EWB = 15.56°C (60°F).

Linear extrapolation based on gross total capacity gives

Maximum EWB for the dry-coil condition
= 17.11°C (62.77°F).

Linear extrapolation based on gross sensible capacity gives

Maximum EWB for the dry-coil condition
= 17.00°C (62.63°F).

Therefore, maximum dry-coil EWB 17.05°C (62.7°F).

(The difference in values of maximum EWB based on extrapolation using total capacity versus sensible capacity may be attributable to a small amount of error associated with assuming linearity in this determination, or there may be some uncertainty in the listed values. The listed compressor power data were not used for extrapolating EWB because they have fewer significant digits than the capacity data.)

5.3.3.10.3.4 Extrapolation of Performance Data. Allow the software being tested to perform any necessary extrapolations. (The need for doing extrapolations has been minimized by the inclusion of an expanded performance data set and by specifying reduced internal gains during cooler weather.)

5.3.3.10.3.5 Cooling Coil Bypass Factor. If the software being tested does not require an input for bypass factor (BF), or automatically calculates it based on other inputs, ignore this information.

For this system,

BF = 0.070.

This value was provided by the manufacturer. For this system, BF varies only with airflow rate, which is constant for these test cases.

5.3.3.10.3.6 Minimum Supply Air Temperature. This system is a variable temperature system, meaning that the supply air temperature varies with the operating conditions. If the software being tested requires an input for minimum allowable supply air temperature, use

Minimum supply air temperature ≤ 1.46°C (34.6°F).

Calculation of minimum supply air temperature is presented in HVAC BESTEST, Volume 2.[B-1]

If the software being tested does not require this input, ignore this information.

5.3.3.10.4 Part-Load Operation Part-load operation is the same as for cases E100-E200, with comments and exceptions as follows.

5.3.3.10.4.1 See Section 5.3.1.10.4.1.

5.3.3.10.4.2 When the simplifying assumption is made that continuous operation of the air distribution fan has a negligible effect on the compressor's part-load energy use, CDF from Figure 10 (Section 5.3.1.10.4.1) applies to COP2 as well as to COP (see Section 3 for definitions). That is,

(COP2 at part load) = (CDF) × (COP2 at full load),

Because the compressor controller is assumed to provide ideal on/off cycling (see Section 5.3.1.10.2.3),

hourly fractional compressor and outdoor fan run time
= PLR/CDF.

5.3.3.10.4.3 See Section 5.3.1.10.4.3.

5.3.3.10.4.4 See Section 5.3.1.10.4.4.

5.3.3.10.4.5 Because there is a continuously operating indoor air fan in the CE300 and CE400 series cases, the definition of PLR (as in Section 5.3.1.10.4.3) applying gross total evaporator coil load and gross total capacity is more convenient to apply. If the software being tested is defining PLR based on net refrigeration effect and adjusted net capacity, then for the CE300 and CE400 series cases, indoor air distribution fan operation for times when the evaporator coil is not removing heat must still be considered in the simulation. Indoor air distribution fan operation for times when the evaporator coil is not removing heat does not affect the net refrigeration effect or the adjusted net total capacity.

5.3.3.10.4.6 For cases CE300–CE440, the CDF (defined in Section 5.3.1.10.4.1) is not applicable to the continuously operating indoor air distribution fan energy consumption.

5.3.3.10.4.7 See Section 5.3.1.10.4.5.

5.3.3.10.4.8 See Section 5.3.1.10.4.6.

5.3.3.10.5 Fans.

5.3.3.10.5.1 Indoor Air Distribution Fan.

- Airflow rate = 1.888 m^3/s = 6796 m^3/h = 4000 CFM
- Indoor fan electric power = 1242 W
- Indoor fan mechanical shaft power = 1167 W (1.565 brake horsepower [BHP])
- External static fan pressure = 74.7 Pa = 0.3 in. w.g. (water gauge)
- Fan static efficiency = 0.121
- Motor/drive efficiency = 0.940
- Supply air temperature rise from fan heat = 0.54°C = 0.97°F
- Air distribution efficiency = 100% (adiabatic ducts).

For further discussion of these inputs, see Annex B15, Section B15.2.

The draw-through indoor air distribution fan operates continuously at 4000 CFM (6796.0 m^3/h) for the entire simulation period. For calculating additional heating of the distribution air related to waste heat from the indoor distribution fan, assume that the distribution fan motor is mounted in the distribution airstream so that 100% of the heat from fan energy use goes to the distribution (supply) air.

5.3.3.10.5.2 Outdoor Condenser Fan.

Outdoor fan power = 930 W.

The draw-through outdoor condenser fan cycles on and off with the compressor.

5.3.3.10.6 Outside Air. The indoor air distribution fan operates continuously at 4000 CFM (6796.0 m^3/h). Dampers are adjusted to continuously supply 15% outside air mixed with the return air; that is, of the 4000 CFM (6796.0 m^3/h) of mixed supply air, 600 CFM (1019.4 m^3/h) is outside air and 3400 CFM (5776.6 m^3/h) is return air. As fresh air is introduced from the outside, a corresponding amount of zone air exits through the relief damper (see Figure 14).

5.3.4 Space Cooling Equipment Performance Comparative Tests. It is recommended to double check the Case CE300 base-case inputs and to diagnose Case CE300 result disagreements before going on to the other test cases.

5.3.4.1 Basic Tests (CE300 Series). This section describes sequential revisions to the base case required to model additional CE300 series cases. Case CE300 is the base case for all the CE300 series cases.

5.3.4.1.1 Case CE310: High Latent Gains. Case CE310 is exactly the same as Case CE300 except for changes as follows.

5.3.4.1.1.1 Internal Gains. The latent internal heat gains are revised according to Table 33. Only the latent internal gains are changed; sensible internal gains shown here are the same as for Case CE300.

5.3.4.1.1.1.1 Modeling details for internal gains of Case CE300 also apply here; see Sections 5.3.3.6.2 through 5.3.3.6.5.

5.3.4.1.1.2 Output Requirements. The required outputs for these cases are the same as for Case CE300, except that they *exclude* the outputs of Section 6.3.2.2 (annual weather data checks and June 28 hourly outputs).

5.3.4.1.2 Case CE320: High Infiltration. Case CE320 is exactly the same as Case CE300 except for changes as follows.

5.3.4.1.2.1 Infiltration Schedule. See below:

Time Period	Infiltration Rate
Jan. 1—April 20	1.734 ach (1019.4 m^3/h, 600 cfm)
April 21—Oct. 12	
00:00 to 08:00	1.734 ach (1019.4 m^3/h, 600 cfm)
08:00 to 20:00	11.558 ach (6796.0 m^3/h, 4000 cfm)
20:00 to 24:00	1.734 ach (1019.4 m^3/h, 600 cfm)
Oct. 13—Dec. 31	1.734 ach (1019.4 m^3/h, 600 cfm)

Note: Infiltration is leakage of air through any building element (e.g., walls, windows, and doors). The listed infiltration rates are independent of factors such as wind speed and indoor/outdoor temperature difference.

5.3.4.1.2.2 Outside Air. Outside air fraction = 0.0 (no outside air) for the full annual simulation period.

5.3.4.1.2.3 Output Requirements. Same as for Case CE310; see Section 5.3.4.1.1.2.

5.3.4.1.3 Case CE330: High Outside Air. Case CE330 is exactly the same as Case CE300 except for changes as follows.

5.3.4.1.3.1 Outside Air. Outside air fraction (as a percentage of total fan flow, OA%) is scheduled as follows:

Time Period	OA Fraction
Jan. 1—April 20	15%
April 21—Oct. 12	
00:00 to 08:00	15%
08:00 to 20:00	100%
20:00 to 24:00	15%
Oct. 13—Dec. 31	15%

Note: An outside air fraction of 15% corresponds to 4000 CFM (6796.0 m^3/h) of mixed air containing 600 CFM (1019.4 m^3/h) of outside air and 3400 CFM (5776.6 m^3/h) of return air. Similarly, an outside air fraction of 100% corresponds to 4000 CFM (6796.0 m^3/h) of mixed air containing 4000 CFM (6796.0 m^3/h) of outside air and 0 CFM (0 m^3/h) of return air.

5.3.4.1.3.2 Output Requirements. Same as for Case CE310; see Section 5.3.4.1.1.2.

5.3.4.1.4 Case CE340: Infiltration and Outside Air Interaction. Case CE340 is exactly the same as Case CE300 except for changes as follows.

5.3.4.1.4.1 Infiltration Schedule. See below:

Time Period	Infiltration Rate
Jan. 1—April 20	0 ach
April 21—Oct. 12	
00:00 to 08:00	0 ach
08:00 to 20:00	5.779 ach (3398.0 m^3/h; 2000 cfm)
20:00 to 24:00	0 ach
Oct. 13—Dec. 31	0 ach

Note: Infiltration is leakage of air through any building element (e.g., walls, windows, and doors). The listed infiltration rates are independent of factors such as wind speed and indoor/outdoor temperature difference.

5.3.4.1.4.2 Outside Air. See below:

Time Period	OA Fraction
Jan. 1—April 20	15%
April 21—Oct. 12	
00:00 to 08:00	15%
08:00 to 20:00	50%
20:00 to 24:00	15%
Oct. 13—Dec. 31	15%

Note: An outside air fraction of 15% corresponds to 4000 CFM (6796.0 m^3/h) of mixed air containing 600 CFM (1019.4 m^3/h) of outside air and 3400 CFM (5776.6 m^3/h) of return air. Similarly, an outside air fraction of 50% corresponds to 4000 CFM (6796.0 m^3/h) of mixed air containing 2000 CFM (3398.0 m^3/h) of outside air and 2000 CFM (3398.0 m^3/h) of return air.

5.3.4.1.4.3 Output Requirements. Same as for Case CE310; see Section 5.3.4.1.1.2.

5.3.4.1.5 Case CE350: Thermostat Setup. Case CE350 is exactly the same as Case CE300 except for changes as follows.

5.3.4.1.5.1 Thermostat Schedule. The thermostat is scheduled as follows for the entire year:

Time Period	Cooling Setpoint
Jan. 1—April 20	25°C (77°F)
April 21—Oct. 12	
00:00 to 07:00	35°C (95°F)
07:00 to 20:00	25°C (77°F)
20:00 to 24:00	35°C (95°F)
Oct. 13—Dec. 31	25°C (77°F)

Note: For April 21 through October 12, the cooling setpoint is lowered at 07:00, which is 1 hour before the internal gains increase.

5.3.4.1.5.2 Output Requirements. Same as for Case CE310; see Section 5.3.4.1.1.2.

5.3.4.1.6 Case CE360: Undersized System. Case CE360 is exactly the same as Case CE300 except for changes as follows.

5.3.4.1.6.1 Internal Heat Gains. The internal heat gains are revised according to Table 34. Only the sensible internal gains are changed for the period from April 21 through October 12; the latent internal gains and other sensible internal gains shown in the table are the same as for Case CE300.

5.3.4.1.6.1.1 Modeling details for internal gains of Case CE300 also apply here; see Sections 5.3.3.6.2 through 5.3.3.6.5.

5.3.4.1.6.2 Output Requirements. Same as for Case CE310; see Section 5.3.4.1.1.2.

5.3.4.2 Economizer Series (CE400 Series). This section describes sequential revisions to the base case required to model the CE400 economizer-series cases. Base cases for a given economizer case are as follows:

Case	Basis for that Case
CE400	CE300
CE410	CE400
CE420	CE400
CE430	CE400
CE440	CE430

5.3.4.2.1 Case CE400: Economizer with ODB/IDB Control and Integrated Compressor Control. Case CE400 is exactly the same as Case CE300 except for changes as follows.

5.3.4.2.1.1 Economizer and Compressor Control Strategy (CE400). The outside air and relief dampers (see Figure 14) are adjusted using economizer control based on ODB and return air temperature as described below. Because these cases assume no thermal losses or gains in the ducts, the return air temperature and the zone air temperature (IDB) may be assumed to be equal.

Economizer = ON AND Compressor = OFF IF IDB > 25.0°C (77.0°F) AND ODB ≤ IDB AND all cooling load for the given hour are compensated by the economizer.

Economizer = ON AND Compressor = ON IF IDB > 25.0°C (77.0°F) AND ODB ≤ IDB AND all cooling load for the given hour are NOT compensated by the economizer.
(In this configuration outside air is at the 100% maximum setting for the full hour.)

Economizer = OFF AND Compressor = ON IF IDB > 25.0°C (77.0°F) AND ODB > IDB.

Economizer = OFF AND Compressor = OFF IF IDB ≤ 25.0°C (77.0°F),

where for

Economizer = ON, outside air is provided as needed up to 100% outside air for the entire hour, but not less than the 15% minimum outside air setting for any time during the hour

Economizer = OFF, outside air is provided at the 15% minimum outside air setting for that hour

Compressor = ON, the compressor and condenser fan will operate only as long as necessary to handle the sensible cooling load not compensated by the economizer

Compressor = OFF, the compressor and condenser fan do not operate for the hour.

Note that there is no lower limit temperature, which means that the economizer control strategy is not affected by how cold the outside air may become.

5.3.4.2.1.1 Output Requirements. Same as for Case CE310; see Section 5.3.4.1.1.2.

5.3.4.2.2 Case CE410: Economizer with ODB/IDB Control and Nonintegrated Compressor. Case CE410 is exactly the same as Case CE400 except while the economizer is operating, the compressor is not allowed to operate. The economizer takes precedence over the compressor but is only allowed to operate whenever it can satisfy the entire cooling load by itself.

5.3.4.2.2.1 Economizer and Compressor Control Strategy (CE410).

Economizer = ON AND Compressor = OFF IF IDB > 25.0°C (77.0°F) AND ODB ≤ IDB AND all cooling load for the given hour is compensated by the economizer.

Economizer = ON AND Compressor = ON NOT allowed.

Economizer = OFF AND Compressor = ON IF IDB > 25.0°C (77.0°F) AND {(ODB > IDB) OR (all cooling load for the given hour CANNOT be compensated by the economizer)}.

Economizer = OFF AND Compressor = OFF IF IDB ≤ 25.0°C (77.0°F).

Economizer/Compressor ON/OFF are as defined for Case CE400.

5.3.4.2.3 Case CE420: Economizer with ODB Limit Control. Case CE420 is exactly the same as Case CE400 except when ODB > 20°C (68°F), the outside air and relief dampers are maintained at 15% outside air.

5.3.4.2.3.1 Economizer and Compressor Control Strategy (CE420).

Economizer = ON AND Compressor = OFF IF IDB > 25.0°C (77.0°F) AND ODB ≤ 20.0°C (68.0°F) AND all cooling load for the given hour is compensated by the economizer.

Economizer = ON AND Compressor = ON IF IDB > 25.0°C (77.0°F) AND ODB ≤ 20.0°C (68.0°F) AND all cooling load for the given hour is NOT compensated by the economizer.
(In this configuration outside air is at the 100% maximum setting for the full hour.)

Economizer = OFF AND Compressor = ON IF IDB > 25.0°C (77.0°F) AND ODB > 20.0°C (68.0°F).

Economizer = OFF AND Compressor = OFF IF IDB ≤ 25.0°C (77.0°F).

Economizer/Compressor ON/OFF are as defined for Case CE400.

5.3.4.2.4 Case CE430: Enthalpy Economizer with Integrated Compressor Control. Case CE430 is exactly the same as Case CE400 except the outside air and relief dampers are adjusted using economizer control based on outdoor air enthalpy (h_{amb}) and return air enthalpy (h_{ra}) as described below. Because these cases assume no thermal losses or gains in the ducts, the return air enthalpy and the zone air enthalpy may be assumed to be equal. Enthalpy has units of energy per mass of dry air.

5.3.4.2.4.1 Economizer and Compressor Control Strategy (CE430).

Economizer = ON AND Compressor = OFF IF IDB > 25.0°C (77.0°F) AND $h_{amb} \leq h_{ra}$ AND all cooling load for the given hour is compensated by the economizer.

Economizer = ON AND Compressor = ON IF IDB > 25.0°C (77.0°F) AND $h_{amb} \leq h_{ra}$ AND all cooling load for the given hour is NOT compensated by the economizer.
(In this configuration outside air is at the 100% maximum setting for the full hour.)

Economizer = OFF AND Compressor = ON IF IDB > 25.0°C (77.0°F) AND $h_{amb} > h_{ra}$.

Economizer = OFF AND Compressor = OFF IF IDB ≤ 25.0°C (77.0°F).

Economizer/Compressor ON/OFF are as defined for Case CE400.

5.3.4.2.5 Case CE440: Economizer with Enthalpy Limit Control. Case CE440 is exactly the same as Case CE430 except when h_{amb} > 47.25 kJ/kg (28.0 Btu/lb), the outside air and relief dampers are maintained at 15% outside air.

5.3.4.2.5.1 Economizer and Compressor Control Strategy (CE440).

Economizer = ON AND Compressor = OFF IF IDB > 25.0°C (77.0°F) AND $h_{amb} \leq$ 47.25 kJ/kg (28.0 Btu/lb) AND all cooling load for the given hour is compensated by the economizer.

Economizer = ON AND Compressor = ON IF IDB > 25.0°C (77.0°F) AND $h_{amb} \leq$ 47.25 kJ/kg (28.0 Btu/lb) AND all cooling load for the given hour is NOT compensated by the economizer.
(In this configuration outside air is at the 100% maximum setting for the full hour.)

Economizer = OFF AND Compressor = ON IF IDB > 25.0°C (77.0°F) AND h_{amb} > 47.25 kJ/kg (28.0 Btu/lb).

Economizer = OFF AND Compressor = OFF IF IDB ≤ 25.0°C (77.0°F).

Economizer/Compressor ON/OFF are as defined for Case CE400.

5.3.4.3 Cases with No Outside Air, Annual Simulation Context (CE500 Series). This section describes sequential revisions to the base case required to model the CE500-series cases. Base cases for a given case are as follows:

Case	Basis for that Case
CE500	CE300
CE510	CE500
CE520	CE500
CE522	CE520
CE525	CE520
CE530	CE500
CE540	CE530
CE545	CE540

5.3.4.3.1 Case CE500: Base Case with No Outside Air. Case CE500 is exactly the same as Case CE300 except for the changes as follows.

5.3.4.3.1.1 Internal Heat Gains. The hourly internal gains are as indicated in Table 35. For this case the "frac v. max" values in Table 35 are the same for both sensible and latent loads.

5.3.4.3.1.1.1 Modeling details for internal gains of Case CE300 also apply here; see Sections 5.3.3.6.2 through 5.3.3.6.5.

5.3.4.3.1.2 Indoor Fan Control and Part-Load Operation. The indoor air distribution fan cycles on and off with the compressor.

For this type of control CDF applies to the indoor fan energy consumption (see Section 5.3.1.10.4). Although the fan now cycles rather than operating continuously, the equivalence still holds for using gross total capacity to calculate PLR as an alternative to using net refrigeration effect and adjusted net capacity; see Annex B13, Section B13.2.

5.3.4.3.1.3 Outside Air. Outside air fraction = 0.0 (no outside air) for the full annual simulation period.

Note that in one of the field-trial simulations for Case E100, simultaneous use of "0" outside air and "0" infiltration caused an error in the simulations. This error was avoided by specifying minimum outside air = 0.000001 ft^3/min. It is recommended to do a sensitivity test to check that using 0 for both these inputs does not cause a problem.

5.3.4.3.1.4 Output Requirements.

a. Annual summations according to Section 6.3.2.1.1
b. Annual means according to Section 6.3.2.1.2
c. Annual hourly-integrated maximum values according to Section 6.3.2.1.3
d. Annual hourly-integrated maxima and minima according to Section 6.3.2.3
e. PLR sensitivity results according to Section 6.3.2.4
f. ODB sensitivity results according to Section 6.3.2.5.

5.3.4.3.2 Case CE510: High Part-Load Ratio. Case CE510 is exactly the same as Case CE500 except for the changes as follows.

5.3.4.3.2.1 Internal Heat Gains. The hourly internal gains are as indicated in Table 36. The loads are only changed from Case CE500 for the period of April 21 through October 11. This results in changes to the listed "frac v. max" multipliers for the other time periods. For this case the "frac v. max" values in Table 36 are the same for both sensible and latent loads.

5.3.4.3.2.1.1 Modeling details for internal gains of Case CE300 also apply here; see Sections 5.3.3.6.2 through 5.3.3.6.5.

5.3.4.3.2.2 Output Requirements.

a. Annual hourly-integrated maximum values according to Section 6.3.2.1.3
b. Annual hourly-integrated maxima and minima according to Section 6.3.2.3
c. PLR sensitivity results according to Section 6.3.2.4

5.3.4.3.3 Case CE520: Reduced Thermostat Set Point (EDB = 15°C). Case CE520 is exactly the same as Case CE500 except for the changes as follows.

5.3.4.3.3.1 Thermostat Control Strategy.

Heat = off.

Cool = on if zone air temperature > 15.0°C (59.0°F); otherwise Cool = off.

All other features of the thermostat remain as before.

5.3.4.3.3.2 Output Requirements.

a. Annual summations according to Section 6.3.2.1.1
b. Annual means according to Section 6.3.2.1.2
c. Annual hourly-integrated maximum values according to Section 6.3.2.1.3
d. Annual hourly-integrated maxima and minima according to Section 6.3.2.3

5.3.4.3.4 Case CE522: Reduced Thermostat Set Point (EDB = 20°C). Case CE522 is exactly the same as Case CE520 except the thermostat control strategy is as described below.

Heat = off.

Cool = on if zone air temperature > 20.0°C (68.0°F); otherwise Cool = off.

All other features of the thermostat remain as before.

5.3.4.3.5 Case CE525: Increased Thermostat Set Point (EDB Sensitivity). Case CE525 is exactly the same as Case CE520 except the thermostat control strategy is as described below.

Heat = off.

Cool = on if zone air temperature > 35.0°C (95.0°F); otherwise Cool = off.

All other features of the thermostat remain as before.

5.3.4.3.6 Case CE530: Dry Coil. Case CE530 is exactly the same as Case CE500 except for the changes as follows.

5.3.4.3.6.1 Internal Gains. The latent internal gains are 0 for the entire annual simulation period. The sensible internal gains remain as in Case CE500.

If the software being tested requires input of total internal gains, use the sensible internal gains for each listed time period.

5.3.4.3.6.2 Output Requirements.

a. Annual summations according to Section 6.3.2.1.1
b. Annual means according to Section 6.3.2.1.2
c. Annual hourly-integrated maximum values according to Section 6.3.2.1.3
d. Annual hourly-integrated maxima and minima according to Section 6.3.2.3
e. ODB sensitivity results according to Section 6.3.2.5.

5.3.4.3.7 Case CE540: Reduced Thermostat Setpoint (EDB Sensitivity). Case CE540 is exactly the same as Case CE530 except for the changes as follows.

5.3.4.3.7.1 Thermostat Control Strategy.

Heat = off.

Cool = on if zone air temperature > 15.0°C (59.0°F); otherwise Cool = off.

All other features of the thermostat remain as before.

5.3.4.3.7.2 Output Requirements.

a. Annual summations according to Section 6.3.2.1.1
b. Annual means according to Section 6.3.2.1.2
c. Annual hourly-integrated maximum values according to Section 6.3.2.1.3
d. Annual hourly-integrated maxima and minima according to Section 6.3.2.3

5.3.4.3.8 Case CE545: Increased Thermostat Setpoint (EDB Sensitivity). Case CE545 is exactly the same as Case CE540 except the thermostat control strategy is as described below.

Heat = off.

Cool = on if zone air temperature > 35.0°C (95.0°F); otherwise Cool = off.

All other features of the thermostat remain as before.

[Informative Note: Revise Table and Figure numbers of Section 5.4 as shown.]

5.4.1.3 Building Geometry The base case building is a 48 m^2 floor area, single-story, low mass building with rectangular prism geometry and internal measurements as shown in Figure ~~13~~15. The zone air volume is 129.6 m^3.

Figure ~~13~~15: Base case building with heat transfer surface.

5.4.1.4.1 Material properties for the exterior wall, floor, and roof are listed in Table ~~29~~37. The roof will be modeled as the heat transfer surface. The insulation in the walls and floors has been made very thick and resistant to heat transfer to effectively thermally decouple the zone from ambient conditions, i.e., they are made to be near-adiabatic. If your software does not allow the specified insulation levels, use the thickest insulation your program will permit and reduce the floor and wall areas to achieve the same UA values as defined in Table ~~29~~37. The zone air volume must remain 129.6 m^3.

Table ~~29~~37. Material Specifications for Base Case

Figure ~~14~~16: Base case building with all surfaces near-adiabatic.

5.4.1.9.2 Building Envelope Thermal Properties. Material properties for the exterior wall, floor and roof are as listed in Table ~~30~~38.

Table ~~30~~38. Material Specifications for Base Case

5.4.1.10.4 Part-Load Operation. Residential furnaces cycle on and off to meet their load at off-design conditions. The part-load ratio (PLR) is used to predict the energy use of a furnace under part-load conditions and is defined as

$$PLR_f = \frac{\text{load placed on furnace}}{\text{furnace capacity}}$$

where the *Load Placed on Furnace* is integrated over the simulation time step and *Furnace Capacity* is the capacity of the furnace to supply heat for that time step.

The part-load factor (PLF) represents the degradation in furnace efficiency due to part-load operation:

$$PLF = \frac{\text{part load efficiency}}{\text{steady-state efficiency}} = \frac{\eta_{\text{part load}}}{\eta}$$

For simulation programs, the part-load performance can be defined in terms of a part-load curve, as a plot of PLF vs. PLR_f. The part-load curve chosen for this suite of test cases is illustrated in Figure ~~15~~17.

Figure ~~15~~17: Part-Load Factor Curve.

5.4.2.4 Case HE140: Periodically Varying Part-Load Test. The objective of this test case is to examine a program's ability to accurately respond to variations in load. In Case HE140, a weather file with a sinusoidally varying outdoor temperature is used. This case is designed to ensure that the model operates over the full range of the part-load curve. This represents a more challenging test on whether the part-load ratio is properly implemented.

Case HE140 is exactly the same as Case HE110 except the applicable weather file is HE140W.WY2.

These data are provided in the files accompanying this standard as described in Annex A1, Section A1.3.

These weather data are represented by Figure ~~16~~18, which is a plot of the outdoor temperature varying over the range of +20°C to –20°C over a 24-hour period.

Figure ~~16~~18: Temperature varying sinusoidally from +20°C to –20°C over a 24-hour period.

5.4.3.1 Case HE220: Setback Thermostat. The objective of this test case is to test the effects of setback temperatures on furnace fuel consumption. Since the zone and building fabric have very low thermal mass, the zone air's temperature should follow the setpoint schedule.

Case HE220 is the same as Case HE210, except that the zone setpoint temperature follows the relationship illustrated in Figure ~~17~~19.

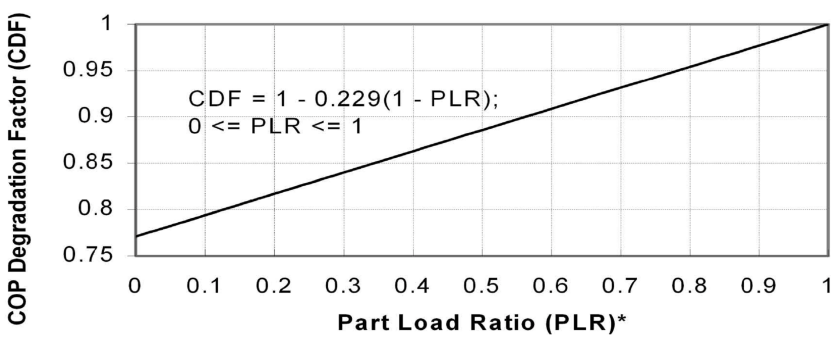
Figure ~~17~~19: Setback temperatures over a 24-hour period.

TABLE 24 Opaque Surface Radiative Properties

	Interior Surface	Exterior Surface
Solar absorptance	0.6	0.1
Infrared emittance	0.9	0.9

TABLE 25 Interior Combined Surface Coefficient versus Surface Orientation

Orientation of Surface and Heat Flow	Interior Combined Surface Coefficient
Horizontal heat transfer on vertical surfaces	8.29 W/(m^2·K) ~~m^{2}K~~ (1.46 Btu/(h·ft^2·°F))
Upward heat transfer on horizontal surfaces	9.26 W/(m^2·K) ~~m^{2}K~~ (1.63 Btu/(h·ft^2·°F))
Downward heat transfer on horizontal surfaces	6.13 W/(m^2·K) ~~m^{2}K~~ (1.08 Btu/(h·ft^2·°F))



*PLR = (Net Refrigeration Effect)/(Adjusted Net Total Capacity)

Figure 10 Cooling equipment part-load performance (COP degradation factor versus PLR).

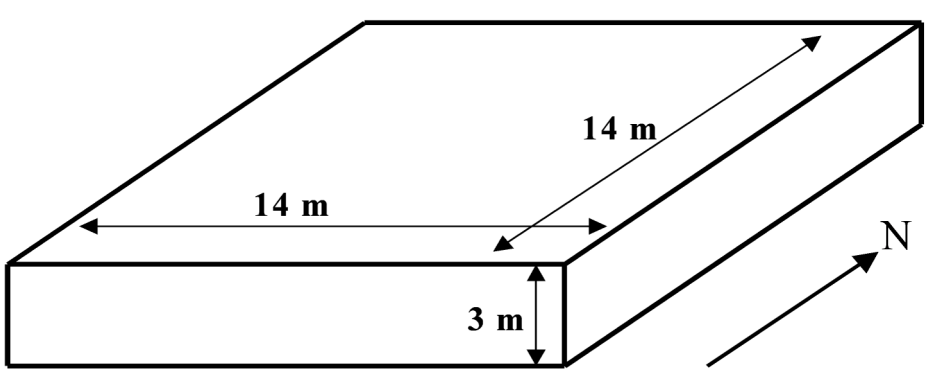


Figure 13 HVAC BESTEST Case CE300: near-adiabatic envelope geometry.

TABLE 29a Material Specifications Case CE300 (SI Units)

EXTERIOR WALL (inside to outside)

ELEMENT	k (W/(m·K))	Thickness (m)	U (W/(m²·K))	R (m²·K/W)
Int Surf Coef			8.290	0.121
Insulation[a]	0.00308	1.000	0.00308	325.000
Ext Surf Coef			29.300	0.034
Total air - air			0.00308	325.155
Total surf - surf			0.00308	325.000

FLOOR (inside to outside)

ELEMENT	k (W/(m·K))	Thickness (m)	U (W/(m²·K))	R (m²·K/W)
Int Surf Coef[b]			8.290	0.121
Insulation[a]	0.00308	1.000	0.00308	325.000
Ext Surf Coef			29.300	0.034
Total air - air			0.00308	325.155
Total surf - surf			0.00308	325.000

ROOF (inside to outside)

ELEMENT	k (W/(m·K))	Thickness (m)	U (W/(m²·K))	R (m²·K/W)
Int Surf Coef[b]			8.290	0.121
Insulation[a]	0.00308	1.000	0.00308	325.000
Ext Surf Coef			29.300	0.034
Total air - air			0.00308	325.155
Total surf - surf			0.00308	325.000

SUMMARY

COMPONENT	AREA (m²)	UA (W/K)
Wall	168.000	0.517
Floor	196.000	0.603
Roof	196.000	0.603
Infiltration[c]		0.000
Total UA		1.722

ACH	VOLUME (m³)	ALTITUDE (m)
0.00	588.0	3.0

[a] This level of insulation defines a near-adiabatic condition such that conduction gains are < 1% of the total cooling load. If your software does not allow this much insulation, then reduce the floor, roof and wall areas to achieve the listed UA values, but keep volume as listed.

[b] The interior film coefficient for floors and ceilings is a compromise between upward and downward heat flow for summer and winter.

[c] Infiltration derived from:
ACH × Volume × (specific heat of air) × (density of air at specified altitude).

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TABLE 29b Material Specifications Case CE300 (I-P Units)

EXTERIOR WALL (inside to outside)

ELEMENT	k (Btu/(h·ft·F))	Thickness (ft)	U (Btu/(h·ft^2·F))	R (h·ft^2·F/Btu)
Int Surf Coef			1.461	0.684
Insulation[a]	0.00178	3.281	0.000542	1844.202
Ext Surf Coef			5.163	0.194
Total air - air			0.000542	1845.080
Total surf - surf			0.000542	1844.202

FLOOR (inside to outside)

ELEMENT	k (Btu/(h·ft·F))	Thickness (ft)	U (Btu/(h·ft^2·F))	R (h·ft^2·F/Btu)
Int Surf Coef[b]			1.461	0.684
Insulation[a]	0.00178	3.281	0.000542	1844.202
Ext Surf Coef			5.163	0.194
Total air - air			0.000542	1845.080
Total surf - surf			0.000542	1844.202

ROOF (inside to outside)

ELEMENT	k (Btu/(h·ft·F))	Thickness (ft)	U (Btu/(h·ft^2·F))	R (h·ft^2·F/Btu)
Int Surf Coef[b]			1.461	0.684
Insulation[a]	0.00178	3.281	0.000542	1844.202
Ext Surf Coef			5.163	0.194
Total air - air			0.000542	1845.080
Total surf - surf			0.000542	1844.202

SUMMARY

COMPONENT	AREA (ft^2)	UA (Btu/(h·F))
Wall	1808.337	0.980
Floor	2109.726	1.143
Roof	2109.726	1.143
Infiltration[c]		0.000
Total UA		3.267

ACH	VOLUME (ft^3)	ALTITUDE (ft)	UAinf (Note 3) (Btu/(h·F))
0.000	20765	9.84	0.000

[a] This level of insulation defines a near-adiabatic condition such that conduction gains are < 1% of the total cooling load. If your software does not allow this much insulation, then reduce the floor, roof and wall areas to achieve the listed UA values, but keep volume as listed.

[b] The interior film coefficient for floors and ceilings is a compromise between upward and downward heat flow for summer and winter.

[c] Infiltration derived from:
ACH × Volume × (specific heat of air) × (density of air at specified altitude).

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TABLE 30 Case CE300 Hourly Internal Gains Schedule (I-P and SI Units)

		SENSIBLE			LATENT		
Period	Time	Watts	Btu/h	frac v. max[a]	Watts	Btu/h	frac v. max[a]
Jan. 1 thru Mar. 10	0:00 - 8:00	2931	10000	0.15625	0	0	0.00
	8:00 - 20:00	2931	10000	0.15625	366	1250	0.25
	20:00 - 24:00	2931	10000	0.15625	0	0	0.00
Mar. 11 thru Apr. 10	0:00 - 9:00	2931	10000	0.15625	0	0	0.00
	9:00 - 18:00	7034	24000	0.37500	1466	5000	1.00
	18:00 - 24:00	2931	10000	0.15625	0	0	0.00
Apr. 11[b]	0:00 - 8:00	2931	10000	0.15625	0	0	0.00
	8:00 - 20:00	2931	10000	0.15625	366	1250	0.25
	20:00 - 24:00	2931	10000	0.15625	0	0	0.00
Apr. 12 thru Apr. 20	0:00 - 8:00	2931	10000	0.15625	0	0	0.00
	8:00 - 19:00	9379	32000	0.50000	1466	5000	1.00
	19:00 - 24:00	2931	10000	0.15625	0	0	0.00
Apr. 21 thru Oct. 12	0:00 - 8:00	7034	24000	0.37500	0	0	0.00
	8:00 - 12:00	9379	32000	0.50000	1466	5000	1.00
	12:00 - 14:00	14069	48000	0.75000	1466	5000	1.00
	14:00 - 16:00	18758	64000	1.00000	1466	5000	1.00
	16:00 - 20:00	9379	32000	0.50000	1466	5000	1.00
	20:00 - 24:00	7034	24000	0.37500	0	0	0.00
Oct. 13 thru Oct. 18	0:00 - 8:00	2931	10000	0.15625	0	0	0.00
	8:00 - 16:00	9379	32000	0.50000	1466	5000	1.00
	16:00 - 24:00	2931	10000	0.15625	0	0	0.00
Oct. 19 thru Nov. 05	0:00 - 8:00	2931	10000	0.15625	0	0	0.00
	8:00 - 12:00	9379	32000	0.50000	1466	5000	1.00
	12:00 - 14:00	14069	48000	0.75000	1466	5000	1.00
	14:00 - 16:00	18758	64000	1.00000	1466	5000	1.00
	16:00 - 20:00	9379	32000	0.50000	1466	5000	1.00
	20:00 - 24:00	7034	24000	0.37500	0	0	0.00
Nov. 06 thru Dec. 31[b]	0:00 - 8:00	2931	10000	0.15625	0	0	0.00
	8:00 - 20:00	2931	10000	0.15625	366	1250	0.25
	20:00 - 24:00	2931	10000	0.15625	0	0	0.00

Note: listed values are the internal gain for each hour within the specified period.

[a] "frac v. max" is the corresponding fraction for the given hourly value relative to the maximum value for the year. This is included for convenience of users who may need to provide this input.

[b] Same schedule as for Jan. 1 through Mar. 10.

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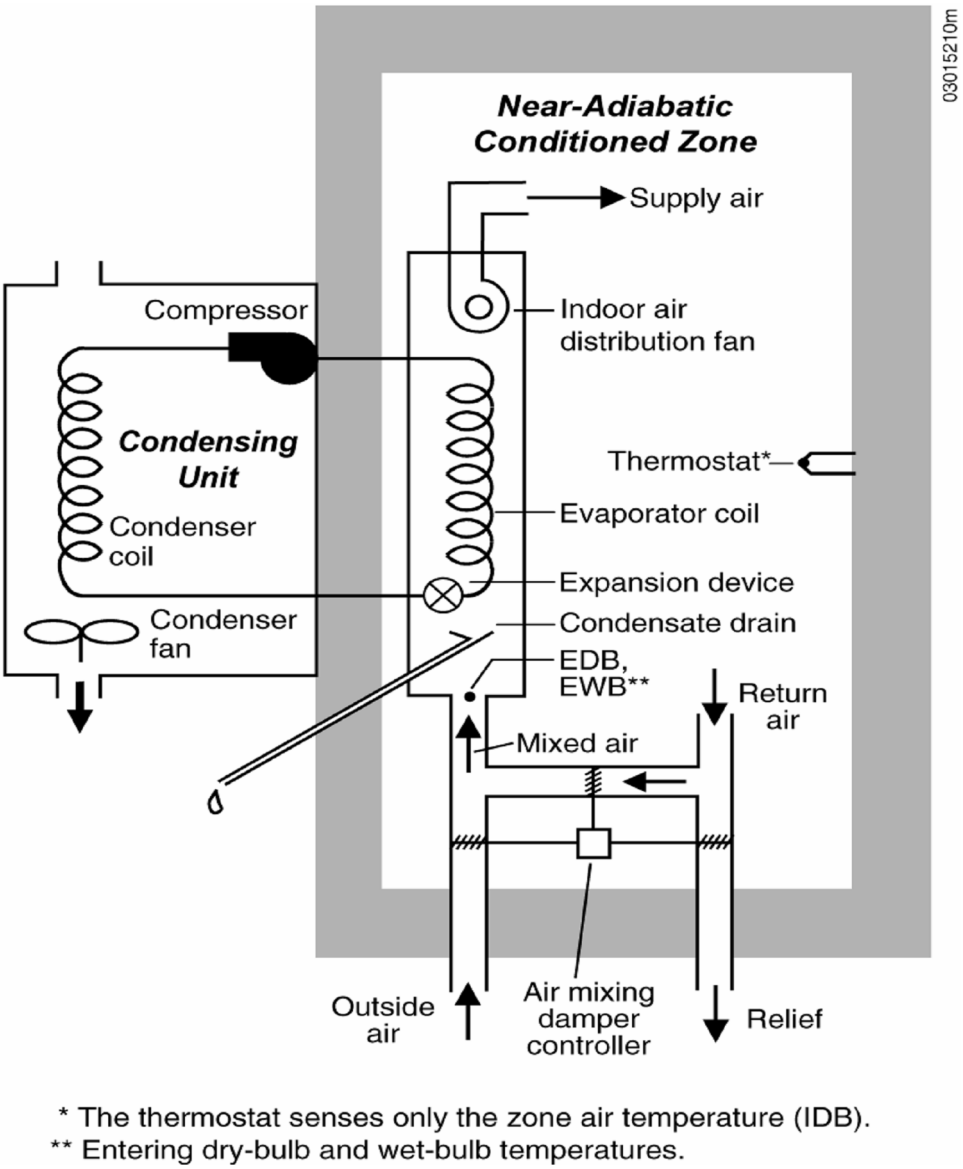


Figure 14 Unitary split air-conditioning system consisting of an air-cooled condensing unit and indoor evaporator coil, and with an outside-air mixing system.

TABLE 31a Equipment Full-Load Performance with Gross Capacities (SI Units)

ODB (°C)	12.78									
EWB		EDB (°C)								
(°C)		12.78	15.56	18.33	21.11	23.89	26.67	29.44	32.22	35.00
4.44	TC	*27.05*								
	SHC	*27.05*								
	kW	*6.0*								
7.22	TC	27.46	*28.81*	*30.60*						
	SHC	26.15	*28.81*	*30.60*						
	kW	6.0	*6.1*	*6.3*						
10.00	TC	29.81	29.86	*30.60*	*32.41*					
	SHC	20.54	26.27	*30.60*	*32.41*					
	kW	6.2	6.2	*6.3*	*6.4*					
12.78	TC	32.50	32.52	32.56	32.86	*34.23*				
	SHC	14.62	20.42	26.18	31.43	*34.23*				
	kW	6.4	6.4	6.4	6.4	*6.6*				
15.56	TC		35.31	35.44	35.42	35.58	36.25	*37.99*		
	SHC		14.41	20.20	25.86	31.38	35.94	*37.99*		
	kW		6.6	6.6	6.6	6.7	6.7	*6.8*		
18.33	TC			38.43	38.48	38.54	38.59	38.92	*39.91*	*41.83*
	SHC			14.14	19.83	25.49	31.04	36.18	*39.91*	*41.83*
	kW			6.9	6.9	6.9	6.9	6.9	*7.0*	*7.1*
21.11	TC				41.65	41.77	41.84	41.88	42.02	42.53
	SHC				13.74	19.40	25.00	30.53	35.85	36.36
	kW				7.1	7.1	7.1	7.1	7.2	7.2
23.89	TC					45.02	45.20	45.31	45.37	45.43
	SHC					13.27	18.87	24.42	29.91	35.26
	kW					7.4	7.4	7.4	7.4	7.4
26.67	TC						48.65	48.89	48.99	49.04
	SHC						12.73	18.29	23.79	29.20
	kW						7.7	7.7	7.7	7.7
29.44	TC							52.35	52.66	52.85
	SHC							12.13	17.63	23.09
	kW							8.0	8.0	8.0
32.22	TC								56.34	56.66
	SHC								11.50	16.95
	kW								8.3	8.3
35.00	TC									60.29
	SHC									10.84
	kW									8.6

ODB (°C)	18.33									
EWB		EDB (°C)								
(°C)		12.78	15.56	18.33	21.11	23.89	26.67	29.44	32.22	35.00
4.44	TC	*26.00*								
	SHC	*26.00*								
	kW	*6.5*								
7.22	TC	26.26	*27.73*	*29.49*						
	SHC	25.36	*27.73*	*29.49*						
	kW	6.6	*6.7*	*6.9*						
10.00	TC	28.52	28.60	*29.49*	*31.27*					
	SHC	19.83	25.56	*29.49*	*31.27*					
	kW	6.8	6.8	*6.9*	*7.1*					
12.78	TC	31.13	31.17	31.19	31.58	*33.09*				
	SHC	13.92	19.74	25.46	30.63	*33.09*				
	kW	7.1	7.1	7.1	7.1	*7.3*				
15.56	TC		33.91	34.00	34.02	34.18	34.96	*36.80*		
	SHC		13.76	19.53	25.22	30.66	34.91	*36.80*		
	kW		7.3	7.3	7.3	7.4	7.4	*7.6*		
18.33	TC			36.87	36.99	37.05	37.10	37.49	*38.68*	
	SHC			13.49	19.21	24.87	30.39	35.41	*38.68*	
	kW			7.6	7.6	7.6	7.6	7.7	*7.8*	
21.11	TC				40.06	40.15	40.25	40.27	40.46	41.05
	SHC				13.14	18.79	24.40	29.91	35.18	39.82
	kW				7.9	7.9	7.9	7.9	8.0	8.0
23.89	TC					43.35	43.52	43.61	43.67	43.76
	SHC					12.70	18.30	23.85	29.34	34.67
	kW					8.2	8.2	8.2	8.3	8.3
26.67	TC						46.88	47.04	47.19	47.25
	SHC						12.20	17.74	23.25	28.67
	kW						8.6	8.6	8.6	8.6
29.44	TC							50.50	50.77	50.91
	SHC							11.65	17.13	22.57
	kW							8.9	8.9	8.9
32.22	TC								54.28	54.60
	SHC								11.05	16.47
	kW								9.2	9.3
35.00	TC									58.24
	SHC									10.43
	kW									9.6

TABLE 31a Equipment Full-Load Performance with Gross Capacities (SI Units), *continued*

ODB (°C)	23.89									
EWB		EDB (°C)								
(°C)		12.78	15.56	18.33	21.11	23.89	26.67	29.44	32.22	35.00
4.44	TC	*24.88*								
	SHC	*24.88*								
	kW	*7.1*								
7.22	TC	25.06	*26.59*	*28.31*						
	SHC	24.52	*26.59*	*28.31*						
	kW	7.1	*7.3*	*7.6*						
10.00	TC	27.20	27.29	*28.31*	*30.08*					
	SHC	19.12	24.80	*28.31*	*30.08*					
	kW	7.4	7.4	*7.6*	*7.8*					
12.78	TC	29.72	29.77	29.81	30.26	*31.86*				
	SHC	13.22	19.05	24.78	29.74	*31.86*				
	kW	7.7	7.7	7.7	7.8	*8.0*				
15.56	TC		32.44	32.48	32.52	32.74	*33.68*	*35.53*		
	SHC		13.09	18.83	24.54	29.94	*33.68*	*35.53*		
	kW		8.0	8.0	8.0	8.1	*8.2*	*8.4*		
18.33	TC			35.29	35.42	35.47	35.54	35.99	*37.39*	
	SHC			12.84	18.56	24.22	29.70	34.61	*37.39*	
	kW			8.4	8.4	8.4	8.4	8.4	*8.6*	
21.11	TC				38.38	38.48	38.56	38.57	38.83	39.51
	SHC				12.52	18.17	23.78	29.26	34.48	38.90
	kW				8.7	8.7	8.7	8.7	8.8	8.8
23.89	TC					41.59	41.75	41.85	41.89	41.97
	SHC					12.11	17.71	23.27	28.74	34.04
	kW					9.1	9.1	9.1	9.1	9.1
26.67	TC						44.96	45.17	45.30	45.37
	SHC						11.64	17.19	22.69	28.12
	kW						9.4	9.4	9.5	9.5
29.44	TC							48.48	48.76	48.92
	SHC							11.12	16.61	22.06
	kW							9.8	9.8	9.9
32.22	TC								52.09	52.49
	SHC								10.56	15.98
	kW								10.2	10.2
35.00	TC									55.98
	SHC									9.98
	kW									10.6

ODB (°C)	29.44									
EWB		EDB (°C)								
(°C)		12.78	15.56	18.33	21.11	23.89	26.67	29.44	32.22	35.00
4.44	TC	*23.74*								
	SHC	*23.74*								
	kW	*7.7*								
7.22	TC	23.80	*25.40*	*27.11*						
	SHC	23.59	*25.40*	*27.11*						
	kW	7.7	*7.9*	*8.2*						
10.00	TC	25.82	25.94	*27.11*	*28.84*					
	SHC	18.39	24.02	*27.11*	*28.84*					
	kW	8.0	8.0	*8.2*	*8.4*					
12.78	TC	28.25	28.31	28.34	28.91	*30.60*				
	SHC	12.50	18.33	24.03	28.76	*30.60*				
	kW	8.3	8.4	8.4	8.4	*8.7*				
15.56	TC		30.89	30.95	30.98	31.24	*32.39*	*34.20*		
	SHC		12.39	18.15	23.85	29.17	*32.39*	*34.20*		
	kW		8.7	8.7	8.7	8.8	*8.9*	*9.2*		
18.33	TC			33.68	33.77	33.82	33.92	34.47	*36.04*	
	SHC			12.17	17.89	23.54	29.01	33.71	*36.04*	
	kW			9.1	9.1	9.1	9.1	9.2	*9.4*	
21.11	TC				36.64	36.75	36.83	36.87	37.15	*37.97*
	SHC				11.88	17.54	23.14	28.63	33.74	*37.82*
	kW				9.5	9.5	9.5	9.5	9.5	*9.7*
23.89	TC					39.74	39.90	40.01	40.03	40.15
	SHC					11.51	17.10	22.66	28.13	33.40
	kW					9.9	9.9	9.9	9.9	9.9
26.67	TC						43.01	43.20	43.33	43.41
	SHC						11.07	16.61	22.11	27.54
	kW						10.3	10.3	10.4	10.4
29.44	TC							46.40	46.67	46.81
	SHC							10.58	16.07	21.50
	kW							10.7	10.8	10.8
32.22	TC								49.93	50.27
	SHC								10.06	15.48
	kW								11.2	11.2
35.00	TC									53.64
	SHC									9.51
	kW									11.7

TABLE 31a Equipment Full-Load Performance with Gross Capacities (SI Units), *continued*

ODB (°C)	35.00									
EWB		EDB (°C)								
(°C)		12.78	15.56	18.33	21.11	23.89	26.67	29.44	32.22	35.00
7.22	TC	22.57	*24.19*	*25.85*						
	SHC	22.56	*24.19*	*25.85*						
	kW	8.6	*8.5*	*8.8*						
10.00	TC	24.42	24.56	*25.85*	*27.56*					
	SHC	17.66	23.20	*25.85*	*27.56*					
	kW	8.6	8.6	*8.8*	*9.1*					
12.78	TC	26.79	26.81	26.85	*27.56*	*29.28*				
	SHC	11.77	17.60	23.27	*27.56*	*29.28*				
	kW	9.0	9.0	9.0	*9.1*	*9.4*				
15.56	TC		29.32	29.37	29.39	29.72	*31.05*	*32.82*		
	SHC		11.68	17.46	23.15	28.33	*31.05*	*32.82*		
	kW		9.4	9.4	9.4	9.4	*9.7*	*9.9*		
18.33	TC			32.01	32.07	32.12	32.26	32.92	*34.63*	
	SHC			11.49	17.20	22.87	28.28	32.68	*34.63*	
	kW			9.8	9.8	9.8	9.9	10.0	*10.2*	
19.44*	TC						33.28			
	SHC						26.04			
	kW						10.0			
21.11	TC				34.82	34.94	35.02	35.05	35.41	*36.45*
	SHC				11.22	16.87	22.48	27.96	32.97	*36.45*
	kW				10.2	10.3	10.3	10.3	10.3	*10.5*
23.89	TC					37.81	37.96	38.07	38.10	38.28
	SHC					10.87	16.47	22.03	27.49	32.72
	kW					10.7	10.7	10.7	10.7	10.8
26.67	TC						40.96	41.15	41.29	41.33
	SHC						10.48	16.02	21.52	26.95
	kW						11.2	11.2	11.2	11.7
29.44	TC							44.23	44.49	44.64
	SHC							10.03	15.51	20.95
	kW							11.7	11.7	11.7
32.22	TC								47.66	47.92
	SHC								9.54	14.95
	kW								12.2	12.2
35.00	TC									51.18
	SHC									9.03
	kW									12.7

ODB (°C)	40.56									
EWB		EDB (°C)								
(°C)		12.78	15.56	18.33	21.11	23.89	26.67	29.44	32.22	35.00
7.22	TC	*21.34*	*22.92*	*24.56*						
	SHC	*21.34*	*22.92*	*24.56*						
	kW	*8.8*	*9.1*	*9.4*						
10.00	TC	22.95	23.16	*24.56*	*26.23*					
	SHC	16.89	22.33	*24.56*	*26.23*					
	kW	9.1	9.1	*9.4*	*9.7*					
12.78	TC	25.27	25.26	25.35	*26.24*	*27.93*				
	SHC	11.03	16.86	22.51	*26.24*	*27.93*				
	kW	9.6	9.5	9.6	*9.7*	*10.1*				
15.56	TC		*27.68*	*27.73*	27.75	28.17	*29.65*			
	SHC		10.96	16.74	22.42	27.41	*29.65*			
	kW		10.0	10.0	10.0	10.1	*10.4*			
18.33	TC			30.28	30.34	30.37	30.56	*31.39*	*33.17*	
	SHC			10.80	16.51	22.18	27.51	*31.39*	*33.17*	
	kW			10.5	10.5	10.5	10.6	*10.7*	*11.0*	
21.11	TC				32.98	33.12	33.17	33.21	33.67	*34.97*
	SHC				10.57	16.23	21.82	27.26	32.13	*34.97*
	kW				11.0	11.0	11.0	11.0	11.1	*11.3*
23.89	TC					35.85	36.01	36.08	36.13	36.37
	SHC					10.26	15.85	21.40	26.86	32.00
	kW					11.5	11.5	11.5	11.5	11.6
26.67	TC						38.86	39.07	39.18	39.22
	SHC						9.89	15.42	20.91	26.37
	kW						12.0	12.1	12.1	12.1
29.44	TC							42.00	42.24	42.38
	SHC							9.47	14.94	20.37
	kW							12.6	12.6	12.6
32.22	TC								45.27	45.55
	SHC								9.03	14.42
	kW								13.1	13.2
35.00	TC									48.65
	SHC									8.54
	kW									13.7

TABLE 31a Equipment Full-Load Performance with Gross Capacities (SI Units), *continued*

ODB (°C)	46.11									
EWB		EDB (°C)								
(°C)		12.78	15.56	18.33	21.11	23.89	26.67	29.44	32.22	35.00
7.22	TC	*20.08*	*21.64*	*23.24*						
	SHC	*20.08*	*21.64*	*23.24*						
	kW	*9.3*	*9.6*	*10.0*						
10.00	TC	21.45	21.74	*23.24*	*24.87*					
	SHC	16.13	21.39	*23.24*	*24.87*					
	kW	9.6	9.6	*10.0*	*10.4*					
12.78	TC	23.68	23.69	23.80	*24.87*	*26.53*				
	SHC	10.27	16.12	21.71	*24.87*	*26.53*				
	kW	10.1	10.1	10.1	*10.4*	*10.7*				
15.56	TC		26.01	26.06	26.09	26.61	*28.22*			
	SHC		10.23	16.01	21.68	26.38	*28.22*			
	kW		10.6	10.6	10.6	10.7	*11.1*			
18.33	TC			28.52	28.57	28.58	28.84	*29.93*	*31.67*	
	SHC			10.10	15.83	21.49	26.69	*29.93*	*31.67*	
	kW			11.2	11.2	11.2	11.2	*11.5*	*11.8*	
21.11	TC				31.12	31.22	31.26	31.36	31.91	*33.42*
	SHC				9.89	15.56	21.15	26.57	31.16	*33.42*
	kW				11.7	11.7	11.7	11.8	11.9	*12.2*
23.89	TC					33.82	34.00	34.06	34.11	34.44
	SHC					9.62	15.22	20.78	26.21	31.23
	kW					12.3	12.3	12.3	12.3	12.4
26.67	TC						36.71	36.90	37.02	37.08
	SHC						9.29	14.81	20.32	25.75
	kW						12.8	12.9	12.9	12.9
29.44	TC							39.72	39.95	40.10
	SHC							8.91	14.36	19.82
	kW							13.4	13.5	13.5
32.22	TC								42.77	43.12
	SHC								8.50	13.88
	kW								14.0	14.1
35.00	TC									46.05
	SHC									8.04
	kW									14.7

Notes:
1. TC = gross total capacity (kW thermal)
2. SHC = gross sensible heat capacity (kW thermal)
3. kW = compressor power (kW)
4. ODB = ambient dry-bulb temperature = air temperature (°C) entering condenser
5. EDB = dry-bulb temperature (°C) entering indoor coil
6. EWB = wet-bulb temperature (°C) entering indoor coil
7. Airflow rate = indoor coil airflow rate (6796 m^3/h [4000 ft^3/min (cfm)] for all data)
8. Shaded upper left cells = potential for freezing indoor coil
9. Shaded lower right cells = compressor outside operating envelope
CANNOT RUN HERE (for prolonged operation)
10. Each point has optimum charge (R22 charge not constant)
11. Computer model used to generate catalog data
12. Computer model based on test data
13. Computer model validated within the operating envelope of compressor
14. Computer model iterates and determines if the coil is wet or dry

TABLE 31b Equipment Full-Load Performance with Gross Capacities (I-P Units)

ODB (°F)	55									
EWB		EDB (°F)								
(°F)		55	60	65	70	75	80	85	90	95
40	TC	*92.3*								
	SHC	*92.3*								
	kW	*6.0*								
45	TC	93.7	*98.3*	*104.4*						
	SHC	89.2	*98.3*	*104.4*						
	kW	6.0	*6.1*	*6.3*						
50	TC	101.7	101.9	*104.4*	*110.6*					
	SHC	70.1	89.6	*104.4*	*110.6*					
	kW	6.2	6.2	*6.3*	*6.4*					
55	TC	110.9	110.9	111.1	112.1	*116.8*				
	SHC	49.9	69.7	89.3	107.2	*116.8*				
	kW	6.4	6.4	6.4	6.4	*6.6*				
60	TC		120.5	120.9	120.9	121.4	123.7	*129.6*		
	SHC		49.2	68.9	88.2	107.1	122.6	*129.6*		
	kW		6.6	6.6	6.6	6.7	6.7	*6.8*		
65	TC			131.1	131.3	131.5	131.7	132.8	*136.2*	*142.7*
	SHC			48.2	67.7	87.0	105.9	123.4	*136.2*	*142.7*
	kW			6.9	6.9	6.9	6.9	6.9	*7.0*	*7.1*
70	TC				142.1	142.5	142.8	142.9	143.4	145.1
	SHC				46.9	66.2	85.3	104.1	122.3	124.0
	kW				7.1	7.1	7.1	7.1	7.2	7.2
75	TC					153.6	154.2	154.6	154.8	155.0
	SHC					45.3	64.4	83.3	102.0	120.3
	kW					7.4	7.4	7.4	7.4	7.4
80	TC						166.0	166.8	167.1	167.3
	SHC						43.4	62.4	81.2	99.6
	kW						7.7	7.7	7.7	7.7
85	TC							178.6	179.7	180.3
	SHC							41.4	60.1	78.8
	kW							8.0	8.0	8.0
90	TC								192.2	193.3
	SHC								39.3	57.8
	kW								8.3	8.3
95	TC									205.7
	SHC									37.0
	kW									8.6

ODB (°F)	65									
EWB		EDB (°F)								
(°F)		55	60	65	70	75	80	85	90	95
40	TC	*88.7*								
	SHC	*88.7*								
	kW	*6.5*								
45	TC	89.6	*94.6*	*100.6*						
	SHC	86.5	*94.6*	*100.6*						
	kW	6.6	*6.7*	*6.9*						
50	TC	97.3	97.6	*100.6*	*106.7*					
	SHC	67.7	87.2	*100.6*	*106.7*					
	kW	6.8	6.8	*6.9*	*7.1*					
55	TC	106.2	106.4	106.4	107.7	*112.9*				
	SHC	47.5	67.4	86.9	104.5	*112.9*				
	kW	7.1	7.1	7.1	7.1	*7.3*				
60	TC		115.7	116.0	116.1	116.6	119.3	*125.5*		
	SHC		47.0	66.6	86.0	104.6	119.1	*125.5*		
	kW		7.3	7.3	7.3	7.4	7.4	*7.6*		
65	TC			125.8	126.2	126.4	126.6	127.9	*132.0*	
	SHC			46.0	65.6	84.9	103.7	120.8	*132.0*	
	kW			7.6	7.6	7.6	7.6	7.7	*7.8*	
70	TC				136.7	137.0	137.3	137.4	138.0	140.1
	SHC				44.8	64.1	83.3	102.1	120.0	135.8
	kW				7.9	7.9	7.9	7.9	8.0	8.0
75	TC					147.9	148.5	148.8	149.0	149.3
	SHC					43.3	62.4	81.4	100.1	118.3
	kW					8.2	8.2	8.2	8.3	8.3
80	TC						159.9	160.5	161.0	161.2
	SHC						41.6	60.5	79.3	97.8
	kW						8.6	8.6	8.6	8.6
85	TC							172.3	173.2	173.7
	SHC							39.7	58.4	77.0
	kW							8.9	8.9	8.9
90	TC								185.2	186.3
	SHC								37.7	56.2
	kW								9.2	9.3
95	TC									198.7
	SHC									35.6
	kW									9.6

TABLE 31b Equipment Full-Load Performance with Gross Capacities (I-P Units), *continued*

ODB (°F)	75									
EWB		EDB (°F)								
(°F)		55	60	65	70	75	80	85	90	95
40	TC	*84.9*								
	SHC	*84.9*								
	kW	*7.1*								
45	TC	85.5	*90.7*	*96.6*						
	SHC	83.7	*90.7*	*96.6*						
	kW	7.1	*7.3*	*7.6*						
50	TC	92.8	93.1	*96.6*	*102.6*					
	SHC	65.2	84.6	*96.6*	*102.6*					
	kW	7.4	7.4	*7.6*	*7.8*					
55	TC	101.4	101.6	101.7	103.2	*108.7*				
	SHC	45.1	65.0	84.5	101.5	*108.7*				
	kW	7.7	7.7	7.7	7.8	*8.0*				
60	TC		110.7	110.8	110.9	111.7	*114.9*	*121.2*		
	SHC		44.7	64.3	83.7	102.2	*114.9*	*121.2*		
	kW		8.0	8.0	8.0	8.1	*8.2*	*8.4*		
65	TC			120.4	120.8	121.0	121.3	122.8	*127.6*	
	SHC			43.8	63.3	82.6	101.3	118.1	*127.6*	
	kW			8.4	8.4	8.4	8.4	8.4	*8.6*	
70	TC				131.0	131.3	131.6	131.6	132.5	134.8
	SHC				42.7	62.0	81.1	99.8	117.7	132.7
	kW				8.7	8.7	8.7	8.7	8.8	8.8
75	TC					141.9	142.4	142.8	142.9	143.2
	SHC					41.3	60.4	79.4	98.1	116.1
	kW					9.1	9.1	9.1	9.1	9.1
80	TC						153.4	154.1	154.5	154.8
	SHC						39.7	58.6	77.4	95.9
	kW						9.4	9.4	9.5	9.5
85	TC							165.4	166.4	166.9
	SHC							37.9	56.7	75.3
	kW							9.8	9.8	9.9
90	TC								177.7	179.1
	SHC								36.0	54.5
	kW								10.2	10.2
95	TC									191.0
	SHC									34.0
	kW									10.6

ODB (°F)	85									
EWB		EDB (°F)								
(°F)		55	60	65	70	75	80	85	90	95
40	TC	*81.0*								
	SHC	*81.0*								
	kW	*7.7*								
45	TC	81.2	*86.7*	*92.5*						
	SHC	80.5	*86.7*	*92.5*						
	kW	7.7	*7.9*	*8.2*						
50	TC	88.1	88.5	*92.5*	*98.4*					
	SHC	62.7	82.0	*92.5*	*98.4*					
	kW	8.0	8.0	*8.2*	*8.4*					
55	TC	96.4	96.6	96.7	98.6	*104.4*				
	SHC	42.6	62.5	82.0	98.1	*104.4*				
	kW	8.3	8.4	8.4	8.4	*8.7*				
60	TC		105.4	105.6	105.7	106.6	*110.5*	*116.7*		
	SHC		42.3	61.9	81.4	99.5	*110.5*	*116.7*		
	kW		8.7	8.7	8.7	8.8	*8.9*	*9.2*		
65	TC			114.9	115.2	115.4	115.7	117.6	*123.0*	
	SHC			41.5	61.0	80.3	99.0	115.0	*123.0*	
	kW			9.1	9.1	9.1	9.1	9.2	*9.4*	
70	TC				125.0	125.4	125.6	125.8	126.8	129.6
	SHC				40.5	59.8	78.9	97.7	115.1	129.0
	kW				9.5	9.5	9.5	9.5	9.5	9.7
75	TC					135.6	136.1	136.5	136.6	137.0
	SHC					39.3	58.4	77.3	96.0	114.0
	kW					9.9	9.9	9.9	9.9	9.9
80	TC						146.7	147.4	147.9	148.1
	SHC						37.8	56.7	75.4	94.0
	kW						10.3	10.3	10.4	10.4
85	TC							158.3	159.2	159.7
	SHC							36.1	54.8	73.4
	kW							10.7	10.8	10.8
90	TC								170.4	171.5
	SHC								34.3	52.8
	kW								11.2	11.2
95	TC									183.0
	SHC									32.4
	kW									11.7

TABLE 31b Equipment Full-Load Performance with Gross Capacities (I-P Units), *continued*

ODB (°F)	95									
EWB		EDB (°F)								
(°F)		55	60	65	70	75	80	85	90	95
45	TC	77.0	*82.5*	*88.2*						
	SHC	77.0	*82.5*	*88.2*						
	kW	8.6	*8.5*	*8.8*						
50	TC	83.3	83.8	*88.2*	*94.0*					
	SHC	60.2	79.2	*88.2*	*94.0*					
	kW	8.6	8.6	*8.8*	*9.1*					
55	TC	91.4	91.5	91.6	*94.0*	*99.9*				
	SHC	40.2	60.1	79.4	*94.0*	*99.9*				
	kW	9.0	9.0	9.0	*9.1*	*9.4*				
60	TC		100.0	100.2	100.3	101.4	*105.9*	*112.0*		
	SHC		39.9	59.6	79.0	96.7	*105.9*	*112.0*		
	kW		9.4	9.4	9.4	9.4	*9.7*	*9.9*		
65	TC			109.2	109.4	109.6	110.1	112.3	*118.1*	
	SHC			39.2	58.7	78.0	96.5	111.5	*118.1*	
	kW			9.8	9.8	9.8	9.9	10.0	*10.2*	
67	TC						113.5			
	SHC						88.9			
	kW						10.0			
70	TC				118.8	119.2	119.5	119.6	120.8	*124.4*
	SHC				38.3	57.6	76.7	95.4	112.5	*124.4*
	kW				10.2	10.3	10.3	10.3	10.3	*10.5*
75	TC					129.0	129.5	129.9	130.0	130.6
	SHC					37.1	56.2	75.1	93.8	111.6
	kW					10.7	10.7	10.7	10.7	10.8
80	TC						139.8	140.4	140.9	141.0
	SHC						35.8	54.6	73.4	91.9
	kW						11.2	11.2	11.2	11.7
85	TC							150.9	151.8	152.3
	SHC							34.2	52.9	71.5
	kW							11.7	11.7	11.7
90	TC								162.6	163.5
	SHC								32.5	51.0
	kW								12.2	12.2
95	TC									174.6
	SHC									30.8
	kW									12.7

ODB (°F)	105									
EWB		EDB (°F)								
(°F)		55	60	65	70	75	80	85	90	95
45	TC	*72.8*	*78.2*	*83.8*						
	SHC	*72.8*	*78.2*	*83.8*						
	kW	*8.8*	*9.1*	*9.4*						
50	TC	78.3	79.0	*83.8*	*89.5*					
	SHC	57.6	76.2	*83.8*	*89.5*					
	kW	9.1	9.1	*9.4*	*9.7*					
55	TC	86.2	86.2	86.5	*89.5*	*95.3*				
	SHC	37.6	57.5	76.8	*89.5*	*95.3*				
	kW	9.6	9.5	9.6	*9.7*	*10.1*				
60	TC		94.4	94.6	94.7	96.1	*101.2*			
	SHC		37.4	57.1	76.5	93.5	*101.2*			
	kW		10.0	10.0	10.0	10.1	*10.4*			
65	TC			103.3	103.5	103.6	104.3	*107.1*	*113.2*	
	SHC			36.8	56.3	75.7	93.9	*107.1*	*113.2*	
	kW			10.5	10.5	10.5	10.6	*10.7*	*11.0*	
70	TC				112.5	113.0	113.2	113.3	114.9	*119.3*
	SHC				36.0	55.4	74.4	93.0	109.6	*119.3*
	kW				11.0	11.0	11.0	11.0	11.1	*11.3*
75	TC					122.3	122.9	123.1	123.3	124.1
	SHC					35.0	54.1	73.0	91.7	109.2
	kW					11.5	11.5	11.5	11.5	11.6
80	TC						132.6	133.3	133.7	133.8
	SHC						33.7	52.6	71.3	90.0
	kW						12.0	12.1	12.1	12.1
85	TC							143.3	144.1	144.6
	SHC							32.3	51.0	69.5
	kW							12.6	12.6	12.6
90	TC								154.4	155.4
	SHC								30.8	49.2
	kW								13.1	13.2
95	TC									166.0
	SHC									29.1
	kW									13.7

TABLE 31b Equipment Full-Load Performance with Gross Capacities (I-P Units), *continued*

ODB (°F)	115									
EWB		EDB (°F)								
(°F)		55	60	65	70	75	80	85	90	95
45	TC	*68.5*	*73.8*	*79.3*						
	SHC	*68.5*	*73.8*	*79.3*						
	kW	*9.3*	*9.6*	*10.0*						
50	TC	73.2	74.2	*79.3*	*84.9*					
	SHC	55.0	73.0	*79.3*	*84.9*					
	kW	9.6	9.6	*10.0*	*10.4*					
55	TC	80.8	80.8	81.2	*84.9*	*90.5*				
	SHC	35.1	55.0	74.1	*84.9*	*90.5*				
	kW	10.1	10.1	10.1	*10.4*	*10.7*				
60	TC		88.7	88.9	89.0	90.8	*96.3*			
	SHC		34.9	54.6	74.0	90.0	*96.3*			
	kW		10.6	10.6	10.6	10.7	*11.1*			
65	TC			97.3	97.5	97.5	98.4	*102.1*	*108.0*	
	SHC			34.5	54.0	73.3	91.1	*102.1*	*108.0*	
	kW			11.2	11.2	11.2	11.2	*11.5*	*11.8*	
70	TC				106.2	106.5	106.7	107.0	108.9	*114.0*
	SHC				33.8	53.1	72.2	90.6	106.3	*114.0*
	kW				11.7	11.7	11.7	11.8	11.9	*12.2*
75	TC					115.4	116.0	116.2	116.4	117.5
	SHC					32.8	51.9	70.9	89.4	106.5
	kW					12.3	12.3	12.3	12.3	12.4
80	TC						125.3	125.9	126.3	126.5
	SHC						31.7	50.5	69.3	87.9
	kW						12.8	12.9	12.9	12.9
85	TC							135.5	136.3	136.8
	SHC							30.4	49.0	67.6
	kW							13.4	13.5	13.5
90	TC								145.9	147.1
	SHC								29.0	47.4
	kW								14.0	14.1
95	TC									157.1
	SHC									27.4
	kW									14.7

Notes:
1. TC = gross total capacity (kBtu/h)
2. SHC = gross sensible heat capacity (kBtu/h)
3. kW = compressor power (kW)
4. ODB = ambient dry-bulb temperature = air temperature (°F) entering condenser
5. EDB = dry-bulb temperature (°F) entering indoor coil
6. EWB = wet-bulb temperature (°F) entering indoor coil
7. CFM = indoor coil airflow rate in ft^3/min (cfm), 4000 cfm for all data
8. Shaded upper left cells = potential for freezing indoor coil
9. Shaded lower right cells = compressor outside operating envelope CANNOT RUN HERE (for prolonged operation)
10. Each point has optimum charge (R22 charge not constant)
11. Computer model used to generate catalog data
12. Computer model based on test data
13. Computer model validated within the operating envelope of compressor
14. Computer model iterates and determines if the coil is wet or dry

TABLE 32a Determination of Maximum Dry-Coil EWB Using Extrapolation (SI Units)

EWB (°C)	Gross Total Capacity (kW thermal)	Gross Sensible Capacity (kW thermal)	Compressor Power (kW)
17.11 (on TC); 17.00 (on SHC)	31.05	31.05	9.7
18.33	32.26	28.28	9.9
21.11	35.02	22.48	10.3

Note: Italicized values are not specifically listed with the original performance data; they are determined based on the accompanying discussion. Data in normal font are from the original performance data.

TABLE 32b Determination of Maximum Dry-Coil EWB Using Extrapolation (I-P Units)

EWB (°F)	Gross Total Capacity (kBtu/h)	Gross Sensible Capacity (kBtu/h)	Compressor Power (kW)
62.77 (on TC); 62.63 (on SHC)	105.9	105.9	9.7
65	110.1	96.5	9.9
70	119.5	76.7	10.3

Note: Italicized values are not specifically listed with the original performance data; they are determined based on the accompanying discussion. Data in normal font are from the original performance data.

TABLE 33 Case CE310 Hourly Internal Gains Schedule (I-P and SI)

		SENSIBLE			LATENT		
Period	Time	Watts	Btu/h	frac v. max[a]	Watts	Btu/h	frac v. max[a]
Jan. 1 thru Mar. 10	0:00 - 8:00	2931	10000	0.15625	0	0	0.00000
	8:00 - 20:00	2931	10000	0.15625	1466	5000	0.15625
	20:00 - 24:00	2931	10000	0.15625	0	0	0.00000
Mar. 11 thru Apr. 10	0:00 - 9:00	2931	10000	0.15625	0	0	0.00000
	9:00 - 18:00	7034	24000	0.37500	7034	24000	0.75000
	18:00 - 24:00	2931	10000	0.15625	0	0	0.00000
Apr. 11[b]	0:00 - 8:00	2931	10000	0.15625	0	0	0.00000
	8:00 - 20:00	2931	10000	0.15625	1466	5000	0.15625
	20:00 - 24:00	2931	10000	0.15625	0	0	0.00000
Apr. 12 thru Apr. 20	0:00 - 8:00	2931	10000	0.15625	0	0	0.00000
	8:00 - 19:00	9379	32000	0.50000	7034	24000	0.75000
	19:00 - 24:00	2931	10000	0.15625	0	0	0.00000
Apr. 21 thru Oct. 12	0:00 - 8:00	7034	24000	0.37500	7034	24000	0.75000
	8:00 - 12:00	9379	32000	0.50000	7034	24000	0.75000
	12:00 - 14:00	14069	48000	0.75000	9379	32000	1.00000
	14:00 - 16:00	18758	64000	1.00000	9379	32000	1.00000
	16:00 - 20:00	9379	32000	0.50000	7034	24000	0.75000
	20:00 - 24:00	7034	24000	0.37500	7034	24000	0.75000
Oct. 13 thru Oct. 18	0:00 - 8:00	2931	10000	0.15625	0	0	0.00000
	8:00 - 16:00	9379	32000	0.50000	7034	24000	0.75000
	16:00 - 24:00	2931	10000	0.15625	0	0	0.00000
Oct. 19 thru Nov. 05	0:00 - 8:00	2931	10000	0.15625	1466	5000	0.15625
	8:00 - 12:00	9379	32000	0.50000	7034	24000	0.75000
	12:00 - 14:00	14069	48000	0.75000	9379	32000	1.00000
	14:00 - 16:00	18758	64000	1.00000	9379	32000	1.00000
	16:00 - 20:00	9379	32000	0.50000	7034	24000	0.75000
	20:00 - 24:00	7034	24000	0.37500	7034	24000	0.75000
Nov. 06 thru Dec. 31[b]	0:00 - 8:00	2931	10000	0.15625	0	0	0.00000
	8:00 - 20:00	2931	10000	0.15625	1466	5000	0.15625
	20:00 - 24:00	2931	10000	0.15625	0	0	0.00000

Note: listed values are the internal gain for each hour within the specified period.

[a] "frac v. max" is the corresponding fraction for the given hourly value relative to the maximum value for the year. This is included for convenience of users who may need to provide this input.

[b] Same schedule as for Jan. 1 through Mar. 10.

CE300intgains1.xls CE310sch!

TABLE 34 Case CE360 Hourly Internal Gains Schedule (I-P and SI)

		SENSIBLE			LATENT		
Period	Time	Watts	Btu/h	frac v. max[a]	Watts	Btu/h	frac v. max[a]
Jan. 1 thru Mar. 10	0:00 - 8:00	2931	10000	0.10000	0	0	0.00
	8:00 - 20:00	2931	10000	0.10000	366	1250	0.25
	20:00 - 24:00	2931	10000	0.10000	0	0	0.00
Mar. 11 thru Apr. 10	0:00 - 9:00	2931	10000	0.10000	0	0	0.00
	9:00 - 18:00	7034	24000	0.24000	1466	5000	1.00
	18:00 - 24:00	2931	10000	0.10000	0	0	0.00
Apr. 11[b]	0:00 - 8:00	2931	10000	0.10000	0	0	0.00
	8:00 - 20:00	2931	10000	0.10000	366	1250	0.25
	20:00 - 24:00	2931	10000	0.10000	0	0	0.00
Apr. 12 thru Apr. 20	0:00 - 8:00	2931	10000	0.10000	0	0	0.00
	8:00 - 19:00	9379	32000	0.32000	1466	5000	1.00
	19:00 - 24:00	2931	10000	0.10000	0	0	0.00
Apr. 21 thru Oct. 12	0:00 - 8:00	29310	100000	1.00000	0	0	0.00
	8:00 - 12:00	29310	100000	1.00000	1466	5000	1.00
	12:00 - 14:00	29310	100000	1.00000	1466	5000	1.00
	14:00 - 16:00	29310	100000	1.00000	1466	5000	1.00
	16:00 - 20:00	29310	100000	1.00000	1466	5000	1.00
	20:00 - 24:00	29310	100000	1.00000	0	0	0.00
Oct. 13 thru Oct. 18	0:00 - 8:00	2931	10000	0.10000	0	0	0.00
	8:00 - 16:00	9379	32000	0.32000	1466	5000	1.00
	16:00 - 24:00	2931	10000	0.10000	0	0	0.00
Oct. 19 thru Nov. 05	0:00 - 8:00	2931	10000	0.10000	0	0	0.00
	8:00 - 12:00	9379	32000	0.32000	1466	5000	1.00
	12:00 - 14:00	14069	48000	0.48000	1466	5000	1.00
	14:00 - 16:00	18758	64000	0.64000	1466	5000	1.00
	16:00 - 20:00	9379	32000	0.32000	1466	5000	1.00
	20:00 - 24:00	7034	24000	0.24000	0	0	0.00
Nov. 06 thru Dec. 31[b]	0:00 - 8:00	2931	10000	0.10000	0	0	0.00
	8:00 - 20:00	2931	10000	0.10000	366	1250	0.25
	20:00 - 24:00	2931	10000	0.10000	0	0	0.00

Note: listed values are the internal gain for each hour within the specified period.

[a] "frac v. max" is the corresponding fraction for the given hourly value relative to the maximum value for the year. This is included for convenience of users who may need to provide this input.

[b] Same schedule as for Jan. 1 through Mar. 10.

CE300intgains1.xls CE360sch!

TABLE 35 Case CE500 Hourly Internal Gains Schedule (I-P and SI Units)

		SENSIBLE			LATENT		
Period	Time	Watts	Btu/h	frac v. max[a]	Watts	Btu/h	frac v. max[a]
Jan. 1 thru Mar. 10	0:00 - 8:00	0	0	0.00000	0	0	0.000
	8:00 - 20:00	0	0	0.00000	0	0	0.000
	20:00 - 24:00	0	0	0.00000	0	0	0.000
Mar. 11 thru Apr. 10	0:00 - 9:00	0	0	0.00000	0	0	0.000
	9:00 - 16:00	7034	24000	0.37500	2858	9750	0.375
	16:00 - 24:00	0	0	0.00000	0	0	0.000
Apr. 11[b]	0:00 - 8:00	0	0	0.00000	0	0	0.000
	8:00 - 20:00	0	0	0.00000	0	0	0.000
	20:00 - 24:00	0	0	0.00000	0	0	0.000
Apr. 12 thru Apr. 20	0:00 - 8:00	0	0	0.00000	0	0	0.000
	8:00 - 17:00	9379	32000	0.50000	3810	13000	0.500
	17:00 - 24:00	0	0	0.00000	0	0	0.000
Apr. 21 thru Oct. 11	0:00 - 8:00	7034	24000	0.37500	2858	9750	0.375
	8:00 - 12:00	9379	32000	0.50000	3810	13000	0.500
	12:00 - 14:00	14069	48000	0.75000	5715	19500	0.750
	14:00 - 16:00	18758	64000	1.00000	7621	26000	1.000
	16:00 - 20:00	9379	32000	0.50000	3810	13000	0.500
	20:00 - 24:00	7034	24000	0.37500	2858	9750	0.375
Oct. 12 thru Oct. 18	0:00 - 8:00	0	0	0.00000	0	0	0.000
	8:00 - 14:00	9379	32000	0.50000	3810	13000	0.500
	14:00 - 24:00	0	0	0.00000	0	0	0.000
Oct. 19 thru Nov. 05	0:00 - 8:00	0	0	0.00000	0	0	0.000
	8:00 - 12:00	9379	32000	0.50000	3810	13000	0.500
	12:00 - 14:00	14069	48000	0.75000	5715	19500	0.750
	14:00 - 16:00	18758	64000	1.00000	7621	26000	1.000
	16:00 - 20:00	9379	32000	0.50000	3810	13000	0.500
	20:00 - 24:00	7034	24000	0.37500	2858	9750	0.375
Nov. 06 thru Dec. 31[b]	0:00 - 8:00	0	0	0.00000	0	0	0.000
	8:00 - 20:00	0	0	0.00000	0	0	0.000
	20:00 - 24:00	0	0	0.00000	0	0	0.000

Note: listed values are the internal gain for each hour within the specified period.

[a] "frac v. max" is the corresponding fraction for the given hourly value relative to the maximum value for the year. This is included for convenience of users who may need to provide this input.

[b] Same schedule as for Jan. 1 through Mar. 10.

CE300intgains1.xls CE500sch!

TABLE 36 Case CE510 Hourly Internal Gains Schedule (I-P and SI Units)

		SENSIBLE			LATENT		
Period	Time	Watts	Btu/h	frac v. max[a]	Watts	Btu/h	frac v. max[a]
Jan. 1 thru Mar. 10	0:00 - 8:00	0	0	0.00000	0	0	0.00000
	8:00 - 20:00	0	0	0.00000	0	0	0.00000
	20:00 - 24:00	0	0	0.00000	0	0	0.00000
Mar. 11 thru Apr. 10	0:00 - 9:00	0	0	0.00000	0	0	0.00000
	9:00 - 16:00	7034	24000	0.33333	2858	9750	0.33333
	16:00 - 24:00	0	0	0.00000	0	0	0.00000
Apr. 11[b]	0:00 - 8:00	0	0	0.00000	0	0	0.00000
	8:00 - 20:00	0	0	0.00000	0	0	0.00000
	20:00 - 24:00	0	0	0.00000	0	0	0.00000
Apr. 12 thru Apr. 20	0:00 - 8:00	0	0	0.00000	0	0	0.00000
	8:00 - 17:00	9379	32000	0.44444	3810	13000	0.44444
	17:00 - 24:00	0	0	0.00000	0	0	0.00000
Apr. 21 thru Oct. 11	0:00 - 8:00	21103	72000	1.00000	8573	29250	1.00000
	8:00 - 12:00	21103	72000	1.00000	8573	29250	1.00000
	12:00 - 14:00	21103	72000	1.00000	8573	29250	1.00000
	14:00 - 16:00	21103	72000	1.00000	8573	29250	1.00000
	16:00 - 20:00	21103	72000	1.00000	8573	29250	1.00000
	20:00 - 24:00	21103	72000	1.00000	8573	29250	1.00000
Oct. 12 thru Oct. 18	0:00 - 8:00	0	0	0.00000	0	0	0.00000
	8:00 - 14:00	9379	32000	0.44444	3810	13000	0.44444
	14:00 - 24:00	0	0	0.00000	0	0	0.00000
Oct. 19 thru Nov. 05	0:00 - 8:00	0	0	0.00000	0	0	0.00000
	8:00 - 12:00	9379	32000	0.44444	3810	13000	0.44444
	12:00 - 14:00	14069	48000	0.66667	5715	19500	0.66667
	14:00 - 16:00	18758	64000	0.88889	7621	26000	0.88889
	16:00 - 20:00	9379	32000	0.44444	3810	13000	0.44444
	20:00 - 24:00	7034	24000	0.33333	2858	9750	0.33333
Nov. 06 thru Dec. 31[b]	0:00 - 8:00	0	0	0.00000	0	0	0.00000
	8:00 - 20:00	0	0	0.00000	0	0	0.00000
	20:00 - 24:00	0	0	0.00000	0	0	0.00000

Note: listed values are the internal gain for each hour within the specified period.

[a] "frac v. max" is the corresponding fraction for the given hourly value relative to the maximum value for the year. This is included for convenience of users who may need to provide this input.

[b] Same schedule as for Jan. 1 through Mar. 10.

CE300intgains1.xls CE510sch!

6. OUTPUT REQUIREMENTS

[Informative Note: Clarify Annex B1 reference in 6.1.1 as shown]

6.1 Annual Outputs for Building Thermal Envelope and Fabric Load Tests of Section 5.2

6.1.1 All Non-Free-Float Cases. In this description the term "free-float cases" refers to cases designated with FF in the case description (i.e., 600FF, 650FF, 900FF, 950FF); non-free-float cases are all the other cases described in Section 5.2 (Tables B1-1a and B1-1b of Annex B1 include~~s~~ an informational summary listing of ~~all~~ the cases of Section 5.2).

[Informative Note: Revise table number as shown]

6.2 Daily Hourly Output for Building Thermal Envelope and Fabric Load Tests of Section 5.2. If the program being tested can produce hourly outputs, then produce the following hourly values for the specified days. To produce this output, run the program for a normal annual run. Do not just run the required days because the results could contain temperature history errors. Required outputs are listed for specific cases in Table ~~31~~39.

TABLE ~~31~~ 39 Daily Hourly Output Requirements for Building Thermal Envelope and Fabric Load Tests of Section 5.2

[Informative Note: Subdivide 6.3 into 6.3.1 and entirely new 6.3.2 as shown]

6.3 Output Requirements for Space-Cooling Equipment Performance Tests of Section 5.3. See Section 3 for definitions of terms used below.

6.3.1 Analytical Verification Tests of Sections 5.3.1 and 5.3.2. ~~6.3.1~~ The outputs listed immediately below are to include loads or consumptions (as appropriate) for the entire month of February (the second month in the weather data sets). ~~The terms *cooling energy consumption*, *evaporator coil loads*, *zone cooling loads*, and *coefficient of performance* are defined in Section 3.~~

6.3.1.1 Cooling energy consumptions (kWh)

a. Total consumption (compressor and fans)
b. Disaggregated compressor consumption
c. Disaggregated indoor air distribution fan consumption
d. Disaggregated outdoor condenser fan consumption

6.3.1.2 Evaporator coil loads (kWh)

a. Total evaporator coil load (sensible + latent)
b. Disaggregated sensible evaporator coil load
c. Disaggregated latent evaporator coil load

6.3.1.3 Zone cooling loads (kWh)

a. Total cooling load (sensible + latent)
b. Disaggregated sensible cooling load
c. Disaggregated latent cooling load

6.3.1.4~~2~~ The outputs listed immediately below are to include the mean value for the month of February and the hourly-integrated maximum and minimum values for the month of February.

a. Calculated coefficient of performance (COP) (dimensionless)

[(Net refrigeration effect) / (total cooling energy consumption)]

b. Zone dry-bulb temperature (°C)
c. Zone humidity ratio (kg moisture/kg dry air)

6.3.2 Comparative Tests of Sections 5.3.3 and 5.3.4.

6.3.2.1 Cases CE300 – CE545 (for output period January 1 – Dec 31).

6.3.2.1.1 Annual Summations (except Case CE510). The outputs listed immediately below are to include summed loads or consumptions (as appropriate) for the full annual simulation (full year).

6.3.2.1.1.1 Cooling energy consumption (kilowatt-hours [kWh])

a. Total consumption (compressor + outdoor condenser fan + indoor air distribution fan)
b. Disaggregated compressor consumption
c. Disaggregated outdoor condenser fan consumption
d. Disaggregated indoor air distribution fan consumption

6.3.2.1.1.2 Evaporator coil loads (kWh)

a. Total evaporator coil load (sensible + latent)
b. Disaggregated sensible evaporator coil load
c. Disaggregated latent evaporator coil load.

6.3.2.1.2 Annual Means (except Case CE510). The outputs listed immediately below are to include the mean value for the full annual simulation.

a. Zone indoor dry-bulb temperature (IDB; °C)
b. Zone humidity ratio (kg moisture/kg dry air)
c. Zone relative humidity (%)
d. Coefficient of performance excluding indoor fan energy consumption (COP2).

The mean value for COP2 is calculated as

$$COP2_{mean} = \Sigma(\text{total evaporator coil load}) / [\Sigma(\text{compressor consumption}) + \Sigma(\text{outdoor fan consumption})],$$

where Σ indicates annual summation of the given value. For example, if for an annual simulation

Total coil load (sensible + latent) = 28500 kWh thermal, and

Combined compressor and outdoor-fan consumption is 6240 kWh electric, then

$$COP2_{mean} = 28500 \text{ kWh} / 6240 \text{ kWh} = 4.567.$$

6.3.2.1.3 Annual Hourly Maximum Values Only. The outputs listed immediately below are to include the hourly-integrated maximum values for the full annual simu-

lation. Maximum values are to include date and hour of occurrence; if there are multiple hours of occurrence for the maximum value, give the time and date for the first hour of the maximum value occurrence.

6.3.2.1.3.1 Total cooling energy consumption (compressor and both fans) (Wh)

6.3.2.1.3.2 Evaporator coil loads (Wh)

a. Total evaporator coil load (sensible + latent)
b. Disaggregated sensible evaporator coil load
c. Disaggregated latent evaporator coil load.

6.3.2.1.4 Annual Maxima and Minima (Except Cases CE500-CE545). The outputs listed immediately below are to include the hourly-integrated maximum and minimum values for the full annual simulation. Maximum and minimum values are to include date and hour of occurrence. If there are multiple hours of occurrence for the maximum and/or minimum values, give the time and date for the first hour of the occurrence.

a. Zone indoor dry-bulb temperature (IDB, °C)
b. Zone humidity ratio (kg moisture/kg dry air)
c. Zone relative humidity (%)
d. Coefficient of performance excluding indoor fan energy consumption (COP2)

If the software being tested does not output enough significant digits, maximum and minimum values for COP2 can be generated by rounding uncertainty. If this is the case, when determining maximum and minimum COP2, it will be necessary to filter out lower part-load ratio (PLR) outputs (e.g., for PLR < 0.01).

6.3.2.2 Additional Outputs for Case CE300 Only.

6.3.2.2.1 Annual Means and Maximum Values (Weather Data Checks). The outputs listed immediately below are to include the mean value for the full annual simulation and the hourly-integrated maximum values for the full annual simulation. Maximum values are to include date and hour of occurrence. If there are multiple hours of occurrence for the maximum value, give the time and date for the first hour of the occurrence.

a. ODB (°C)
b. Outdoor humidity ratio (kg/kg)

6.3.2.2.2 Hourly Outputs for June 28 (all 24 Hours):

a. Compressor electric consumption (Wh)
b. Outdoor condenser fan electric consumption (Wh)
c. Total evaporator coil load (sensible + latent) (Wh)
d. Sensible evaporator coil load (Wh)
e. Latent evaporator coil load (Wh)
f. COP2
g. Zone humidity ratio (kg/kg)
h. ODB (°C)
i. Entering dry-bulb temperature (EDB), same as mixed air dry-bulb temperature (°C)
j. Entering wet-bulb temperature (EWB), same as mixed air wet-bulb temperature (°C)
k. Outdoor humidity ratio (kg/kg)

The hourly data are to consist of 24 values for each day. The first hour (hour 1) is defined to run from midnight (0:00) to 1 a.m. (1:00). To produce this output, run the program for a normal annual run. Do not run only the required days because the results could contain temperature history errors.

6.3.2.3 Cases CE500-CE545 Annual Maxima and Minima. The outputs listed immediately below are to include the hourly-integrated maximum and minimum values from a full annual simulation. Maximum and minimum values are to include date and hour of occurrence. If there are multiple hours of occurrence for the maximum and/or minimum values, give the time and date for the first hour of the occurrence.

6.3.2.3.1 For Output Period January 1 – December 31

a. Maximum zone indoor dry-bulb temperature (IDB, °C)
b. Maximum zone humidity ratio (kg moisture/kg dry air)
c. Maximum COP2
d. Minimum COP2

If the software being tested does not output enough significant digits, maximum and minimum values for COP2 can be generated by rounding uncertainty. If this is the case, when determining maximum and minimum COP2, it will be necessary to filter out lower part-load ratio (PLR) outputs (e.g., for PLR < 0.01).

6.3.2.3.2 For Output Period April 1 – December 31

a. Minimum zone indoor dry-bulb temperature (IDB, °C)
b. Minimum zone humidity ratio (kg moisture/kg dry air)
c. Maximum zone relative humidity (%)
d. Minimum zone relative humidity (%)

Extract this output from a normal annual run. Do not do an additional simulation beginning on April 1 because the above results could contain temperature history errors. These four values are selected after the first three months of simulation to avoid differences in results that could be caused by differences in zone initialization techniques.

6.3.2.4 PLR Sensitivity, Cases CE500 and CE510 Only (for Output Period May 1 – September 30). For a sensitivity test of performance as a function of PLR, include for cases CE500 and CE510 only the following outputs for the period of May 1 through September 30. Extract this output from a normal annual run. Do not run only the required months because the results could contain temperature history errors.

6.3.2.4.1 Summed Values

a. Total cooling energy consumption (compressor + outdoor condenser fan + indoor air distribution fan, kWh)
b. Compressor electric consumption (kWh)
c. Outdoor condenser fan electric consumption (kWh)
d. Indoor air distribution fan electric consumption (kWh)
e. Total evaporator coil load (sensible + latent), (kWh)

f. Sensible evaporator coil load (kWh)

g. Latent evaporator coil load (kWh)

6.3.2.4.2 Mean Values

a. COP2 = Σ(total coil load) / [Σ(compressor energy) + Σ(outdoor fan energy)], for May through September 30

b. Zone IDB (°C)

c. Zone humidity ratio (kg/kg)

d. Zone relative humidity (%)

6.3.2.5 ODB Sensitivity, Cases CE500 and CE530 Only, Average Daily Outputs for April 30 and June 25 Only. For a sensitivity test of performance as a function of ODB, include the following daily average per hour outputs (consumptions and coil loads are full-day sums divided by 24 [hours]) for April 30 and June 25 (0:00–24:00):

a. Total cooling energy consumption (compressor + outdoor condenser fan + indoor air distribution fan, Wh)

b. Compressor electric consumption (Wh)

c. Outdoor condenser fan electric consumption (Wh)

d. Indoor air distribution fan electric consumption (Wh)

e. Total evaporator coil load (sensible + latent), (Wh)

f. Sensible evaporator coil load (Wh)

g. Latent evaporator coil load (Wh)

h. COP2 = Σ(total coil load) / [Σ(compressor energy) + Σ(outdoor fan energy)], for the given day

i. Zone humidity ratio (kg/kg)

j. ODB (°C)

k. EDB (°C)

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

ANNEX A1
WEATHER DATA

[Informative Note: Subdivide A1.2 into A1.2.1 and A1.2.2 as shown. Revise titles of Tables A1-2, A1-3a, and A1-3b as shown. Also revise section references as shown.]

A1.2 Weather Data for Space Cooling Equipment Performance Tests

A1.2.1 Analytical Verification Test Weather Data

The weather data listed in Table A1-2 shall be used as called out in Sections 5.3.1 and 5.3.2. These data files represent TMY and TMY2 format weather data files, respectively, with modifications so that the initial fundamental series of mechanical equipment tests may be very tightly controlled. The TMY-format data are three-month-long data files used in the original field trials of the test procedure; the TMY2-format data are year-long data files that may be more convenient for users. For the purposes of HVAC BESTEST, which uses a near-adiabatic building envelope, the TMY and TMY2 data sets are equivalent. (Note that there are small differences in solar radiation, wind speed, etc., that result in a sensible loads difference of 0.2%–0.3% in cases with low internal gains [i.e., E130, E140, E190, and E195]. This percentage load difference is less [0.01%–0.04%] for the other cases because they have higher internal gains. These TMY and TMY2 data are not equivalent for use with a non-near-adiabatic building envelope.)

Ambient dry-bulb and dew-point temperatures are constant in all the weather files; constant values of ambient dry-bulb temperature vary among the files according to the file name. Site and weather characteristics are summarized in Tables A1-3a and A1-3b for the TMY and TMY2 data files, respectively. Details about the TMY and TMY2 weather data file formats are included in Sections A1.4 and A1.5, respectively.

[Informative note regarding future editorial changes for the next continuous maintenance revision: To be consistent with the weather data naming convention of Standard 140-2004 Addenda a and b, editorial changes will be included for the next continuous maintenance revision to rename the following weather data files as follows:

HVBT461.TMY to become CE100.TMY
HVBT461A.TM2 to become CE100A.TM2
HVBT294.TMY to become CE110.TMY
HVBT294A.TM2 to become CE110A.TM2
HVBT406.TMY to become CE165.TMY
HVBT406A.TM2 to become CE165A.TM2
HVBT350.TMY to become CE200.TMY
HVBT350A.TM2 to become CE200A.TM2.]

TABLE A1-2 Weather Data for Space Cooling Equipment Performance Analytical Verification Tests

TABLE A1-3a Site and Weather Summary for Space Cooling Equipment Performance Analytical Verification Tests—TMY Data

TABLE A1-3b Site and Weather Summary for Space Cooling Equipment Performance Analytical Verification Tests—TMY2 Data

[Informative Note: Add new section A1.2.2]

A1.2.2 Comparative Test Weather Data. The full-year weather data file CE300.TM2 provided on the accompanying CD shall be used for performing the tests called out in Sections 5.3.3 and 5.3.4. Site and weather characteristics of the data file are summarized in Table A1-4. This data file represents TMY2 format weather data; details about TMY2 weather data file format are included in Section A1.5.

[*Informative Note: Revise table numbers and references to the tables after Table A1-4 as shown*]

A1.3 Weather Data for Space Heating Equipment Performance Tests. Weather data listed in table ~~A1-4~~A1-5 shall be used as called out in section 5.4. These data are presented in WYEC2 format. See section A1.6 for a detailed description of the WYEC2 format. Site characteristics are summarized in Table ~~A1-5~~A1-6.

Table ~~A1-4~~A1-5. Weather Data for Space Heating Equipment Performance Tests

Table ~~A1-5~~A1-6. Site Summary for Space Heating Equipment Performance Tests— WYEC2 Data

A1.4 TMY Weather Data Format

For those programs that do not have Typical Meteorological Year (TMY) weather processors, TMY weather data file format is provided in Table ~~A1-6~~A1-7. This reprint of tables also includes some additional notes based on experience with TMY data. If this summary is insufficient, the complete documentation on TMY weather data[9] can be obtained from the National Climatic Data Center (NCDC) in Asheville, North Carolina. Their address is Federal Building, Asheville, NC 28801-2733, telephone 828-271-4800. Informative Annex B2 contains additional background information regarding TMY weather data.

A1.5 TMY2 Weather Data Format

For those programs that do not have Typical Meteorological Year 2 (TMY2) weather processors, TMY2 weather data file format is described below. If this summary is insufficient, the complete documentation on TMY2 weather data[11] can be obtained at http://rredc.nrel.gov/solar/pubs/tmy2.

A1.5.1 File Header. The first record of each file is the file header that describes the station. The file header contains the WBAN number, city, state, time zone, latitude, longitude, and elevation. The field positions and definitions of these header elements are given in Table ~~A1-7~~A1-8, along with sample FORTRAN and C formats for reading the header. A sample of a file header and data for January 1 is shown in Figure A1-1.

A1.5.2 Hourly Records. Following the file header, 8,760 hourly data records provide one year of solar radiation, illuminance, and meteorological data, along with their source and uncertainty flags. Table ~~A1-8~~A1-9 provides field positions,

element definitions, and sample FORTRAN and C formats for reading the hourly records.

TABLE ~~A1-6~~A1-7 Typical Meteorological Year Data Format

TABLE ~~A1-7~~A1-8 Header Elements in the TMY2 Format (For First Record of Each File)

TABLE ~~A1-8~~A1-9 Data Elements in the TMY2 Format (For All Except the First Record)

A1.6 WYEC2 Weather Data Format. For those programs that do not have Weather Year for Energy Calculations 2 (WYEC2) weather processors, WYEC2 weather data file format is described below.

Weather files in WYEC2 format consist of 8760 identical fixed format records (8784 records for leap years), one for each hour of each day of the year. Each record is 116 characters (plus 2 for CR/LF) in length and is organized according to table ~~A1-9~~A1-10.

All WYEC2 values are for Local Standard Time. Irradiance and illuminance fields contain data integrated over the hour, meteorological fields contain observations made at the end of the hour. For example, hour 12 contains irradiance/illuminance from hour 11 to 12 and meteorological observations made at hour 12.

Table ~~A1-9~~A1-10. Data Elements in the WYEC2 Format

TABLE A1-4 Site and Weather Summary for Space Cooling Equipment Performance Comparative Tests

Weather type	Hot, humid summer
Weather format	TMY2
Latitude	30.0° north
Longitude (local site)	90.3° west
Altitude	3 m (9.8 ft)
Time zone (standard meridian longitude)	6 (90° west)
Ground reflectivity	0.2
Site	Flat, unobstructed, located exactly at weather station
Mean annual outdoor dry-bulb temperature (ODB)	19.9°C (67.8°F)
Minimum annual ODB	–4.4°C (24.0°F)
Maximum annual ODB	35.0°C (95.0°F)
Mean annual dew-point temperature	14.7°C (58.5°F)
Mean annual humidity ratio	0.0116 kg moisture/kg dry air (0.0116 lb moisture/lb dry air)
Mean annual wind speed	3.6 m/s (8.1 mph)
Maximum annual wind speed	13.9 m/s (31.1 mph)
Global horizontal solar radiation annual total	1680 kWh/m (532.5 kBtu/ft^2)
Direct normal solar radiation annual total	1498 kWh/m (474.8 kBtu/ft^2)

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

ANNEX A2
STANDARD OUTPUT REPORTS

[*Informative Note: Add item c and corresponding attachment A2.3 references as shown, renumber current references, and make editorial changes (for consistency) as shown*]

The standard output reports consists of ~~four~~ five forms provided on the CD accompanying this standard:

a. Output Results for Cases of Section 5.2 ~~Cases~~ (Sec5-2out.XLS, spreadsheet file)
b. Output Results for Cases of Sections 5.3.1 and 5.3.2 ~~Cases~~ (Sec5-3Aout.XLS, spreadsheet file)
c. Output Results for Cases of Sections 5.3.3 and 5.3.4 (Sec5-3Bout.XLS, spreadsheet file)
d. ~~c.~~Output Results for Cases of Section 5.4 ~~Cases~~ (Sec5-4out.XLS, spreadsheet file)
e. ~~d.~~Modeling Notes (S140outNotes.TXT, text file reprinted as Attachment ~~A2.4~~A2.5)

For entering output results into Sec5-2out.XLS, Sec5-3Aout.XLS, Sec5-3Bout.XLS, and Sec5-4out.XLS, follow the instructions provided at the top of the appropriate electronic spreadsheet file. These instructions are reprinted as Attachments A2.1, A2.2, ~~and~~ A2.3, and A2.4 ,respectively, within this section.

For entering modeling notes into S140outNotes.TXT, use the format of the following examples given as Attachments ~~A2.5,~~ A2.6, ~~and~~ A2.7, A2.8, and A2.9 within this section.

[Informative Note: Revise title of Attachment A2.2 as shown.]

Attachment A2.2 Instructions for Entering Results into Sec5-3Aout.XLS

HVAC BESTEST Cases E100-E200 Output Form Sec5-3Aout.XLS

[Informative Note: Add new Attachment A2.3 as shown.]

Attachment A2.3 Instructions for Entering Results into Sec5-3Bout.XLS

Sec5-3Bout.XLS
Output spreadsheet for HVAC BESTEST, Cases CE300 - CE545

INSTRUCTIONS:

1. Use specified units.

2. Data entry is restricted to the following ranges:

B62..L82:	Annual Sums, Annual Means, and Other
M62..N62:	Annual Means, CE300 Only
B89..L112:	June 28 Hourly Output, Case CE300
B120..L121:	Case CE500 Average Daily Outputs
B129..L130:	Case CE530 Average Daily Outputs
Q62..AB81:	Annual Hourly Integrated Maxima, Consumptions and Loads
AC62..AH62:	Annual Hourly Integrated Maxima, Case CE300 - Weather Check
Q89..AN108:	Annual Hourly Integrated Maxima and Minima, COP2 and Zone

3. Annual totals are consumption and/or loads just for the entire annual simulation. Similarly, annual means, maxima, and minima are those values that occur for the entire annual simulation. "May-Sep" results are taken using May 1 - September 30 data extracted from a full annual simulation.
4. Output terminology is defined in the output section of the specification for each case where applicable or in the Glossary (Appendix C).
5. Format dates using the appropriate two-digit date followed by a three-letter month code and two-digit hour code (24-hour clock) as shown below.

MONTH	CODE
JANUARY	Jan
FEBRUARY	Feb
MARCH	Mar
APRIL	Apr
MAY	May
JUNE	Jun
JULY	Jul
AUGUST	Aug
SEPTEMBER	Sep
OCTOBER	Oct
NOVEMBER	Nov
DECEMBER	Dec

For example, a maximum value occurring on August 16 during the 15th hour interval (2-3 P.M.) should be input as:

DATE	HOUR
16-Aug	15

[Informative Note: Change the current Attachment A2.3 to A2.4 as shown.]

Attachment ~~A2.3~~A2.4 Instructions for Entering Results into Sec5-4out.XLS

[Informative Note: Change the current Attachment A2.4 to A2.5 as shown, with the additional revisions as shown. Update S140outNotes.txt to include revisions detailed below; for the accompanying files, replace previous version of S140outNotes.txt with the updated version in the following accompanying file folders: "Sec5-2Files," "Sec5-3Afiles," "Sec5-3Bfiles," and "Sec5-4files."]

Attachment ~~A2.4~~A2.5 Standard 140 Output Form—Modeling Notes

STANDARD 140 OUTPUT FORM - MODELING NOTES
INSTRUCTIONS: See Annex A2.

SOFTWARE:

VERSION:

REPORT BLOCK FOR ALTERNATIVE MODELING METHODS

DOCUMENT BELOW THE MODELING METHODS USED IF ALTERNATIVE MODELING

METHODS OR ALGORITHMS ARE AVAILABLE IN THE SOFTWARE BEING TESTED.
(See Annex A2 for examples.)

Describe the Effect Being Simulated ~~Effect~~:

Optional Settings or Modeling Capabilities:

Setting or Capability Used:

Physical Meaning of Option Used:

[Informative note: Delete redundant text just below. Append new report blocks below.]

~~Simulated Effect:~~

~~Optional Settings or Modeling Capabilities:~~

~~Setting or Capability Used:~~

~~Physical Meaning of Option Used:~~

(Include more alternative feature descriptions using this format if applicable to the test.)

REPORT BLOCK FOR EQUIVALENT MODELING METHODS

DOCUMENT BELOW THE EQUIVALENT INPUTS USED IF EQUIVALENT MODELING METHODS WERE USED
(See Annex A2 for examples.)

Describe the Effect Being Simulated:

Section(s) of the Standard where Relevant Inputs are Specified:

Equivalent Input(s) Used:

Physical, Mathematical, or Logical Justification of the Equivalent Input(s)—provide supporting calculations, if relevant:

(Include more equivalent modeling method descriptions using this format, if applicable to the test.)

REPORT BLOCK FOR OMITTED TEST CASES AND RESULTS

DOCUMENT BELOW THE REASONS FOR OMITTING RESULTS
(see Annex A2 for examples)

List the Case(s) where Results Were Omitted, and which Results Were Omitted for the Case(s):

Explanation for Omitting the Test Case(s) Results:

(Include explanations for omitting other test case results using this format, if applicable to the test.)

REPORT BLOCK FOR CHANGES TO SOURCE CODE FOR THE PURPOSE OF RUNNING THE TESTS WHERE SUCH CHANGES ARE NOT AVAILABLE IN PUBLICLY RELEASED VERSIONS OF THE SOFTWARE.

DOCUMENT BELOW THE REASONS FOR SPECIFIC CHANGES TO THE SOURCE CODE
(See Annex A2 for examples.)

List the Change(s) to the source code:

List the Test Case(s) Relevant to the Change(s) in the Source Code:

Explanation of Why the Change Is Not Included in the Publicly Released Version of the Software:

(Include explanations for more changes to non-publicly released versions of the software using this format, if applicable to the test.)

[Informative Note: Renumber and revise title of Attachment A2.5 (renumbered in Addendum a to Standard 140-2004) to Attachment A2.6 as shown below. Delete the headers for Attachments A2.6 and A2.7, and append to new Attachment A2.6 the text previously included under those now deleted headers.]

Attachment ~~A2.5.~~A2.6 Example of Modeling Notes, ~~for BLAST 3.0~~[5] Report Block for Alternative Modeling Methods

STANDARD 140 OUTPUT FORM—MODELING NOTES

INSTRUCTIONS: See Annex A2.

SOFTWARE: *BLAST 3.0*[5]

VERSION: *Level 193*

REPORT BLOCK FOR ALTETERNATIVE MODELING METHODS

DOCUMENT BELOW THE MODELING METHODS USED IF ALTERNATIVE MODELING METHODS OR ALGORITHMS ARE AVAILABLE IN THE SOFTWARE BEING TESTED.
(See Annex A2 for examples.)

Simulated Effect:

Convective heat transfer and radiative exchange related to both interior and exterior surfaces

Optional Settings or Modeling Capabilities (from simplest to most detailed):

HEAT BALANCE = 0; HEAT BALANCE = 1; HEAT BALANCE = 2 Setting or Capability Used: HEAT BALANCE = 2

Physical Meaning of Option Used:

Interior surface convection based on zone air and interior surface delta T. Exterior surface heat transfer has separate heat transfer coefficients for radiative exchange to sky and ground and convection to ambient air.

Simulated Effect:

Interior transmitted solar radiation distribution

Optional Settings or Modeling Capabilities (from simplest to most detailed):

SOLAR DISTRIBUTION = 0; SOLAR DISTRIBUTION = 1
Setting or Capability Used: *SOLAR DISTRIBUTION = 1*

Physical Meaning of Option Used:

Beam radiation falling on each surface is calculated by ray tracing. Beam radiation not initially absorbed is diffusely reflected.

~~Attachment A2.6. Example of Modeling Notes for DOE-2.1E[12]~~

STANDARD 140 OUTPUT FORM - MODELING NOTES

INSTRUCTIONS: See Annex A2.

SOFTWARE: *DOE-2.1E*[12]

VERSION: *W54*

REPORT BLOCK FOR ALTETERNATIVE MODELING METHODS

DOCUMENT BELOW THE MODELING METHODS USED IF ALTERNATIVE MODELING METHODS OR ALGORITHMS ARE AVAILABLE IN THE SOFTWARE BEING TESTED.
(See Annex A2 for examples.)

Simulated Effect:

Thermal behavior of windows

Optional Settings or Modeling Capabilities:

1. "Shading Coefficient"

2. *GLASS-TYPE-CODE ≤ 11*

3. *GLASS-TYPE-CODE ≤ 1000*

3A. Existing window used from W4LIB.DAT 3B. Custom window developed and added to W4LIB.DAT

Setting or Capability Used:

3B. GLASS-TYPE-CODE ≥ 1000 with custom window developed and added to W4LIB.DAT

Physical Meaning of Option Used:

Windows modeled using thermal and optical properties developed with WINDOW 4.0.[13]

~~Attachment A2.7 Example of Modeling Notes for ESP-r/HOT3000[A-2]~~

STANDARD 140 OUTPUT FORM – MODELING NOTES

INSTRUCTIONS: See Annex A2.

SOFTWARE: *ESP-r/HOT3000*[A-2]

VERSION: *bpsh3k version 1.1 and 1.7*

REPORT BLOCK FOR ALTETERNATIVE MODELING METHODS

DOCUMENT BELOW THE MODELING METHODS USED IF ALTERNATIVE MODELING METHODS OR ALGORITHMS ARE AVAILABLE IN THE SOFTWARE BEING TESTED.
(See Annex A2 for examples)

Simulated Effect:

Zone temperature controller

Optional Settings or Modeling Capabilities:

- Basic controller for heating/cooling
- Free-float controller
- Basic pre-heat or pre-cool controller
- Fixed heat injection and extraction
- PID control action for heating/cooling
- Flux connection between zone and plant
- Multi-stage control with hysteresis
- Variable supply temp with constraints
- Heat pipe from outside to inside
- Separate flux ON and OFF setpoints
- Match sensed/recorded value (ideal)
- Match sensed/recorded value (on/off)
- Time-proportioning (on/off) control
- Floating "three position" control
- Optimum start control
- Optimum stop control
- Fuzzy Logic PI-PD control
- Null controller
- Multi-sensor heating/cooling
- Evaporative source (surface)
- Slave capacity controller

Setting or Capability Used:

ESP-r/H3K basic (ideal) controller used with heating capacity of 20 kW while the furnace capacity is set to 10 kW.

Physical Meaning of Option Used:

In ESP-r, the controller has a defined capacity. When the load of the space is less than the capacity, the setpoint is maintained and the actual load is reported. If the load is greater than the capacity of the controller, ESP-r sets the load equal to the controller's capacity. In this case the actual load is not met and the setpoint is not satisfied.

A value greater than 10 kW is used for the ideal controller heating capacity to allow the load of the zone to exceed 10 kW if this is what the solution dictates. This way, the load on the furnace is not limited to a maximum of 10 kW and it is possible to predict the proper number of under heating hours for the zone.

This is an issue only with test HE230.

[Informative Note: Include examples for new modeler report blocks as Attachments A2.7 through A2.9 below.]

Attachment A2.7 Examples of Modeling Notes, Report Block for Equivalent Modeling Methods

REPORT BLOCK FOR EQUIVALENT MODELING METHODS

DOCUMENT BELOW THE EQUIVALENT INPUTS USED IF EQUIVALENT MODELING METHODS WERE USED (See Annex A2 for examples.)

Describe the Effect Being Simulated:

Thermal decoupling of floor from ground.

Section(s) of the Standard where Relevant Inputs are Specified:

5.2.1.4, 5.2.1.5

Equivalent Input(s) Used:

Floor modeled as perfectly decoupled from ground.

Physical, Mathematical or Logical Justification of the Equivalent Input(s)—provide supporting calculations, if relevant:

Logical Justification: Section 5.2.1.5 states that "the state-of-the-art in ground modeling is not very good even in detailed building energy simulation programs. To reduce uncertainty regarding testing or other aspects of simulating the building envelope, the floor insulation has been made very thick to effectively decouple the floor thermally from the ground."

It is clear from this statement the intent is to eliminate floor-to-ground heat transfer to reduce the uncertainty in results that it will introduce. The prescribed method of doing this is to model a floor with very high R-value ($R=25.374\ m^2 \cdot K/W$ or $U=0.039\ W/m^2 \cdot K$). This assumes that a software program cannot perfectly eliminate floor-to-ground heat transfer and therefore must minimize the error due to floor-to-ground heat transfer via use of a large floor R-value.

The subject program cannot comply with the prescribed floor R-value; however, the subject program can perfectly decouple the floor from the ground. Because perfect decoupling is interpreted as meeting the intent of section 5.2.1.5, perfect decoupling was used as an equivalent modeling approach.

Describe the Effect Being Simulated:

Thermostat control and equipment capacity.

Section(s) of the Standard where Relevant Inputs are Specified:

5.2.1.13.1
5.2.1.13.2

Equivalent Input(s) Used:

Heating Setpoint = 20 °C, Throttling Range = 0.1 K, Heating Capacity = 3.935 kW
Cooling Setpoint = 27 °C, Throttling Range = 0.1 K, Cooling Capacity = 3.935 kW

Physical, Mathematical, or Logical Justification of the Equivalent Input(s)—provide supporting calculations, if relevant:

Logical Justification:

Together Sections 5.2.1.13.1 and 5.2.1.13.2 require use of a non-proportional thermostat with which the heat extraction rate is effectively infinite when the zone air temperature exceeds 27°C and the heat addition rate is effectively infinite when the zone air temperature falls below 20°C. The intent of these sections is to establish conditions for which equipment cooling or heating output exactly matches the zone load. This eliminates system effects and system dynamics that could obscure the focus of this test suite, which is zone thermal loads, not system coil loads.

In the subject software program, use of the prescribed inputs constitutes an unstable control system. For example, the moment the zone air temperature exceeds 27°C, the system will provide 1000 kW of cooling to the zone. This quantity of cooling far exceeds the cooling demand, so the zone is overcooled, pushing the zone air temperature below 20°C. The moment this happens, the system provides 1000 kW of heating to the zone. This quantity of heating far exceeds the heating demand, so the zone is overheated, pushing the zone air temperature above 27°C. A system with this control will rapidly oscillate between cooling and heating. The system simulation algorithm in the subject program will not be able to converge on a solution state for any hour because of the unstable nature of this control.

To resolve this problem, a small throttling range was used with the prescribed setpoints, and the cooling and heating capacities were set to values close to the peak cooling and heating demands of the zone. These inputs were chosen empirically by tuning the inputs until thermostat control instability was eliminated and differences between the system cooling coil load and the zone cooling load and between the system heating coil load and the zone heating load were minimized as much as possible. This approach meets the intent of Sections 5.2.1.13.1 and 5.2.1.13.2.

Note: In the subject program the 3.935 kW capacity is not specified directly. Instead it is indirectly defined via supply airflow rate and supply temperature. The supply airflow was 565.6 L/s, the cooling supply air temperature was 20°C, and the heating supply air temperature was 27°C. This yields the capacities as follows. The 0.994 factor is the standard 1.207 density × heat capacity × correction factor corrected for site altitude.

Cooling Capacity = 0.994 × 565.6 L/s × (27 °C–20 °C) = 3935 W = 3.935 kW

Heating Capacity = 0.994 × 565.6 L/s × (20 °C–27 °C) = 3935 W = 3.935 kW

Attachment A2.8 Examples of Modeling Notes, Report Block for Omitted Test Cases and Results

REPORT BLOCK FOR OMITTED TEST CASES AND RESULTS

DOCUMENT BELOW THE REASONS FOR OMITTING RESULTS
(see Annex A2 for examples)

List the Case(s) Where Results Were Omitted and Which Results Were Omitted for the Case(s):

All results omitted for the following tabulated cases:

600	*600FF*	*230*	*300*	*420*
610	*650FF*	*240*	*310*	*430*
620	*195*	*250*	*320*	*440*
630	*200*	*270*	*395*	
640	*210*	*280*	*400*	
650	*220*	*290*	*410*	

Explanation for Omitting the Test Case(s) Results:

These test cases require modeling lightweight building construction (approx 12 lb/ft^2 floor area). This is residential weight construction. The subject software program is intended for modeling commercial buildings and consequently the minimum building construction weight is 30 lb/ft^2 floor area. Since the required building construction weight for these test cases is well outside the range of intended program operation, these test cases cannot be performed.

List the Case(s) Where Results Were Omitted and Which Results Were Omitted for the Case(s):

Case 960 – Sunspace, all results

Explanation for Omitting the Test Case(s) Results:
The required inputs to model this type of configuration are not available in this software program. Case 960 models a passive solar sun room using a modified Trombe wall. In order to model this configuration, the associated algorithm would need to compute:

a. The hourly proportion of solar radiation absorbed by the individual sunlit surfaces within the sunlit portion of the Trombe wall
b. The effect of introducing infiltration in the Trombe wall section
c. Adjacent space heat transfer between the Trombe wall and the interior room.

Attachment A2.9 Example of Modeling Notes, Report Block for Changes to Source Code for the Purpose of Running the Tests, Where Such Changes Are Not Available in Publicly Released Versions of the Software

REPORT BLOCK FOR CHANGES TO SOURCE CODE FOR THE PURPOSE OF RUNNING THE TESTS, WHERE SUCH CHANGES ARE NOT AVAILABLE IN PUBLICLY RELEASED VERSIONS OF THE SOFTWARE

DOCUMENT BELOW THE REASONS FOR SPECIFIC CHANGES TO THE SOURCE CODE

List the Change(s) to the source code:

Include capability for hourly varying schedules, where such schedules may be varied for any day of the year, for sensible and latent internal gains, infiltration, outside air, and zone thermostat. Currently for the subject software's publicly released version, such hourly schedules may only be varied monthly, beginning on the first day of each month and continuing through the entire month.

List the Test Case(s) Relevant to the Change(s) in the Source Code:

More flexible schedules are needed as follows:
Internal Gains: All cases of Sections 5.3.3 and 5.3.4 (i.e., Cases CE300 through CE545)
Infiltration and/or Outside Air: Cases CE320, CE330, and CE340 only
Thermostat: Case CE350 only.

Explanation of Why the Change Is Not Included in the Publicly Released Version of the Software:

Users of the subject software appear to be satisfied with hourly schedules limited to monthly variation. Changing the source code to accommodate the test cases of Sections 5.3.3 and 5.3.4 for the purpose of testing the calculation engine is justifiable. However, without known demand from users for additional scheduling flexibility, it is difficult to justify additional costs related to enhancing the user interface and revising software documentation.

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

ANNEX B1
TABULAR SUMMARY OF TEST CASES

[Informative Note: Revise introduction as shown]

Tables B1-1a and B1-1b include a tabular summary of the building thermal envelope and fabric load test cases described in Section 5.2, in SI units only. Tables B1-2a and B1-2b include a tabular summary of the Space Cooling Equipment Performance Analytical Verification test cases described in Sections 5.3.1 and 5.3.2, in SI and I-P units, respectively. Table B1-3 includes a tabular summary of the Space Cooling Equipment Performance Comparative Test cases described in Sections 5.3.3 and 5.3.4, in SI units only. Table ~~B1-3~~B1-4 summarizes the Space Heating Equipment test cases described in Section 5.4, in SI units only.

Nomenclature

Abbreviations and symbols used in Tables B1-1a, B1-1b, B1-2a, B1-2b, B1-3 and B1-4~~3~~ are listed below.

[Informative Note: Add the following abbreviations to the nomenclature used in Table B1-3.]

Apr.	April
COP	coefficient of performance
high	greater loads relative to "mid"
high2	greater loads relative to "mid2"
Infil.	infiltration (natural ventilation)
mid	internal gains schedules are relatively high daytime and low nighttime periodically/seasonally adjusted values
mid2	similar to "mid" but with cooler-month internal gains = 0 for 0 cooling at ODB < 55°F for 0 OA.
OA	outside air
Oct.	October

[Informative Note: Revise titles of tables B1-2a and B1-2b as shown.]

TABLE B1-2a Space Cooling Equipment BESTEST Analytical Verification Test Case Descriptions (SI Units).

TABLE B1-2b Space Cooling Equipment BESTEST Analytical Verification Test Case Descriptions (I-P Units).

[Informative Note: Renumber current Table B1-3 (of Addendum a) as Table B1-4 as shown]

TABLE ~~B1-3~~B1-4. Space Heating Equipment BESTEST Cases Descriptions

[Informative Note: Insert new table B1-3 as shown.]

TABLE B1-3 Space Cooling Equipment BESTEST Comparative Test Case Descriptions

DYNAMIC TESTS - Hot and Humid Weather (New Orleans, LA), Near-Adiabatic Building Envelope						
Case	Internal Gains Sensible	Internal Gains Latent	Cooling Setpoint (°C)	Infil. (ACH)	Outside Air (ACH)	Comments
Preliminary Series						
CE300 Base Case (15% OA)	mid	mid	25	0	1.734	Supply fan runs continously, compressor cycles as needed, expanded performance data. Tests outside air versus CE500.
CE310 High latent load	mid	high	25	0	1.734	Tests high latent load versus CE300.
CE320 Infiltration	mid	mid	25	11.558 [a]	0.000	Tests high infiltration versus CE300, CE330.
CE330 Outside air	mid	mid	25	0	11.558 [a]	Tests high outside air versus CE300, CE320.
CE340 Infil./OA interaction	mid	mid	25	5.779 [a]	5.779 [a]	Tests infil./OA interaction versus CE300, and CE320 or CE330.
CE350 Thermostat set up	mid	mid	25/35	0	1.734	Tests thermostat set up control versus CE300.
CE360 Undersize	high	mid	25	0	1.734	Tests overloaded system versus CE300.
Economizer Series					**Min OA**	**(Temperature control: CE400, CE410, CE420)**
CE400 Temperature control	mid	mid	25	0	1.734	Tests temperature economizer versus CE300.
CE410 Compressor lockout	mid	mid	25	0	1.734	Tests CE400 with compressor lockout versus CE300.
CE420 ODB limit	mid	mid	25	0	1.734	Tests ODB limit (20°C) control versus CE300.
						(Enthalpy control: CE430, CE440)
CE430 Enthalpy control	mid	mid	25	0	1.734	Tests enthalpy control versus CE300.
CE440 Outdoor enthalpy limit	mid	mid	25	0	1.734	Tests outdoor enthalpy limit control versus CE300.
0% OA Cases					**OA**	**(Wet coils: CE500 - CE525)**
CE500 Base Case (0% OA)	mid2	mid2	25	0	0 [b]	Like CE100 but with dynamics & expanded performance data. Supply fan cycles ON/OFF with compressor. Hourly output tests COP f(ODB).
CE510 High PLR	high2	high2	25	0	0 [b]	High PLR. SHR same as CE500. Tests PLR versus CE500.
CE520 Low EDB = 15°C	mid2	mid2	15	0	0 [b]	Tests EDB = 15°C versus CE500.
CE522 Low EDB = 20°C	mid2	mid2	20	0	0 [b]	Tests EDB = 20°C versus CE500.
CE525 High EDB	mid2	mid2	35	0	0 [b]	Tests EDB = 35°C versus CE500, CE520.
						(Dry coils: CE530 - CE545)
CE530 Dry Coil	mid2	0	25	0	0 [b]	Tests dynamic dry-coil expanded performance versus CE500. Hourly output tests COP f(ODB).
CE540 Dry Coil, Low EDB	mid2	0	15	0	0 [b]	Tests EDB = 15°C versus CE530.
CE545 Dry Coil, High EDB	mid2	0	35	0	0 [b]	Tests EDB = 35°C versus CE530.

Abbreviations: ACH = air changes per hour; COP = coefficient of performance; EDB = entering dry-bulb temperature; Infil. = infiltration; OA = outside air; ODB = outdoor dry-bulb temperature; PLR = part load ratio; SHR = sensible heat ratio.

Notes:
"mid" internal gains schedules are relatively high daytime and low nighttime periodically/seasonally adjusted values. See case descriptions for details.
"mid2" is similar to "mid" but with 0 cooler-month internal gains to get 0 cooling at ODB <55°F for 0 OA. See case descriptions.
"high" and "high2" are greater loads relative to "mid" and "mid2," respectively.

[a] Apr. 21 - Oct. 12, 8:00 - 20:00 only; see case descriptions for specific schedule.
[b] OA = 0 implies fan cycles ON/OFF with compressor.

CE300case15.xls, d:a2..n47; Aug 16, 2006

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

ANNEX B2
ABOUT TYPICAL METEOROLOGICAL YEAR (TMY) WEATHER DATA

[Informative Note: Clarify Annex A1 cross-reference in second paragraph of Annex B2 as shown.]

For these reasons, SPC 140 decided to keep the original TMY weather data and the detailed documentation of the TMY weather data format. For Sections 5.3.1 and 5.3.2, either TMY-format data or TMY2-format data may be used as described in Annex A1, Section A1.2.1.

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

ANNEX B9
DIAGNOSING THE RESULTS USING THE FLOW DIAGRAMS

[Informative Note: Revise Annex B9 as shown. New Figures B9-5, B9-6, and B9-7 are included at the end of the text of this annex; Figures B9-1 through B9-4, not shown here, remain as is. The full text of Annex B9 has been included for review convenience.]

B9.1 General Description. Figures B9-1 through B9-7~~5~~ contain a set of flow diagrams that serve as a guide for diagnosing the cause of disagreeing results that may arise from using this method of test. These flow diagrams list the feature(s) being tested, thus indicating potential sources of algorithmic differences.

B9.2 Comparing Tested Software Results to Other Example Results

B9.2.1 "Example results" are either results presented in informative Annexes B8 and B16 or other results that were generated using this standard method of test.

B9.2.2 In this annex we provide no formal criteria for when results agree or disagree. Determination of when results agree or disagree is left to the user. In making this determination the user should consider

a. magnitude of results for individual cases,
b. magnitude of difference in results between certain cases (e.g., "Case 610–Case 600"),
c. same direction of sensitivity (positive or negative) for difference in results between certain cases (e.g., "Case 610–Case 600"),
d. if results are logically counterintuitive with respect to known or expected physical behavior,
e. availability of analytical or quasi-analytical solution results (i.e., mathematical truth standard as described in informative Annex B16, Section B16.2),
f. for ~~the HVAC equipment performance~~ analytical verification test cases, ~~of Section 5.3,~~ the degree of disagreement that occurred for other simulation results in Annex B16 versus the quasi-analytical or analytical solution results,
g. example simulation results do not represent a truth standard.

B9.2.3 Check the program being tested for agreement (see Section B9.2.2) with example results for both the absolute outputs and the sensitivity (or "delta") outputs. For example, when comparing to the example results shown in informative Annex B8 for Case "610-600" in the "low mass basic" flow diagram (Figure B9-1), the program results are compared with both the Case 610 example results and the Case 610-600 example sensitivity results.

B9.2.4 Compare all available output types specified for each case that can be produced by the program being tested, as described in Section 6. ~~For the tests of Section 5.2, this includes appropriate calculated solar radiation, free float, and hourly results if the software being tested is capable of producing that type of output. For the tests of Section 5.3, this includes appropriate energy consumption, coil load, zone load, zone temperature, and humidity ratio results if the software being tested is capable of producing that type of output.~~ A disagreement with any one of the output types may be cause for concern.

B9.2.5 There are some cases where it is possible to proceed even if disagreements were uncovered in the previous case. For example, using Figure B9-1, in Case 610, inability to model a shading overhang would not affect the usefulness of the program for modeling buildings with unshaded windows. Thus, the flow diagram has an extra arrow connecting Case 610 and Case 620, which denotes that you may proceed regardless of the results for Case 610. Where cases are connected by a single arrow, a satisfactory result is required in order to proceed to the next case. For example, in Case 620, the inability to model transmitted radiation through an unshaded east window makes it difficult to proceed with these tests until the disagreement is reconciled.

B9.3 If Tested Software Results Disagree with Example Results. If the tested program shows disagreement (as defined above in informative Section B9.2.2) with the example results, then re-check the inputs against the specified values. Use the diagnostic logic flow diagrams to help isolate the source of the difference. If no input error can be found, then look for an error in the software. If an error is found, then fix it and rerun the tests. If in the engineering judgement of the user the disagreement is ~~due to~~caused by a reasonable difference in algorithms between the tested software and the example results or other tested software, then continue with the next test case.

B9.4 Diagnostic Logic Flow Diagrams for Building Thermal Envelope and Fabric Load Tests (Section 5.2)

B9.4.1 Low-Mass and High-Mass Basic Tests. The first flow diagram (Figure B9-1) begins with the base building (Case 600). It is very important to have confidence in your Case 600 results before proceeding to the other cases. If output from the tested program agrees satisfactorily with other example results for Case 600, then check other output according to the flow diagram. Once the low-mass basic cases have been checked, proceed with the high-mass basic (900 series) cases (Figure B9-3).

B9.4.2 In-Depth Tests. These tests provide detailed diagnostic capability. The "in-depth test" flow diagram (Figure B9-2) indicates two possible diagnostic paths, A1 through A11 or B1 through B10. Selecting path A versus path B depends on the capabilities of the program being tested. Path A is the preferable diagnostic path. Use Path A if the software being tested is literal enough in its treatment of building physics to allow input of those cases. Otherwise, Path B will still

help to identify algorithmic sources of differences, but less definitively because of interacting effects.

B9.4.3 Mass Interaction Tests. Further diagnostic information can be obtained regarding thermal mass interactions using the diagnostic logic flow diagram of Figure B9-4. When disagreement among results occurs, this diagram sometimes returns to the low-mass, in-depth diagnostics (Figure B9-2) even though the program may have already showed agreement in the low-mass basic tests. The reason for this is that the high-mass cases may reveal disagreements that the low-mass cases did not expose because

a. the disagreement is more readily detectable when mass is present,
b. the disagreement was not previously detectable because of compensating differences,
c. the disagreement was not previously detectable because of other unknown interactions.

B9.5 Diagnostic Logic Flow Diagrams for ~~HVAC~~ Space Cooling Equipment Performance Tests (Section 5.3). Flow diagrams are included here for cases E100–E200 (Figure B9-5) and cases CE300–CE545 (Figures B9-6 and B9-7).

B9.5.1 ~~General Description~~Analytical Verification Tests, Cases E100-E200.

B9.5.1.1 Introduction. Cases E100–E200 (see Sections 5.3.1 and 5.3.2) are to be run first. These ~~The E100 series cases (E100 through E200)~~ are steady-state cases that test basic performance map modeling capabilities and utilize comparisons with quasi-analytical solutions that constitute a mathematical truth standard. The diagnostic logic flow diagram for these cases (Figure B9-5) indicates similar diagnostics for dry-coil and wet-coil (without and with dehumidification) cases. This is really one continuous diagnostic path to be implemented for both dry-coil and wet-coil cases. Performing and analyzing results of the E100 series tests in blocks, such as E100–E140 and E150–E200, or E100–E200, all at once is recommended. For the E100 series cases, if a disagreement is uncovered for one of the cases, then fix it and rerun all the E100 series cases. It is very important to have confidence in the results for cases E100–E200 before proceeding to the other cases.

B9.5.1.2 Consideration of Quasi-Analytical Solution Results. As a minimum, the user should compare output with the quasi-analytical solution results found in Annex B16, Section B16.5.1. The user may also choose to compare output with the example simulation results in ~~Annex B16~~ that section or with other results that were generated using Sections 5.3.1 and 5.3.2 of this test procedure. Information about how the quasi-analytical solutions and example simulation results were produced is included in Annex B17. For convenience to users who wish to plot or tabulate their results along with the quasi-analytical solution or example simulation results, or both, an electronic version of the example results has been included with the file RESULTS5-3A.XLS on the accompanying CD. Regarding determination of agreement of results discussed in B9.2.2, in making this determination for the ~~HVAC~~space cooling equipment performance analytical verification tests of Sections 5.3.1 and 5.3.2, the user should consider that the quasi-analytical solution results given in Annex B16, Section B16.5.1 represent a "mathematical truth standard" (i.e., a mathematically provable and deterministic set of results based on acceptance of the underlying physical assumptions represented by the case specifications, discussed further in Annex B16, Section B16.2). Note that although the underlying physical assumptions of the case definitions of the mechanical equipment are consistent with those of typical manufacturer equipment performance data, they are by definition a simplification of reality and may not fully represent real empirical behavior.

B9.5.2 Comparative Tests, Cases CE300-CE545. After successfully completing cases E100–E200, go on to cases CE300–CE545 (see Sections 5.3.3 and 5.3.4). These cases test additional model features under more dynamic (hourly varying) conditions. Example simulation results for cases CE300–CE545 (see Annex B16, Section B16.5.2) do not include analytical solutions, so analytical verification versus a mathematical truth standard is not possible for those cases. The flow diagrams for cases CE300–CE545 may be used in two ways. The most powerful but time-consuming way is to perform all cases CE300–CE545 and then use the diagnostic logic in the flow diagrams to analyze the results. The least time-consuming way is to perform the tests in sequence according to the flow diagrams, beginning with Figure B9-6.

The flow diagram of Figure B9-6 begins with a basic performance test (Case CE300). It is very important to have confidence in your Case CE300 results before proceeding to the other cases. If output from the tested program agrees satisfactorily with other example results for Case CE300, then continue to check output for the remaining cases according to the flow diagram. If output from the tested program disagrees with other example results for Case CE300, then follow the diagnostic logic accordingly. The diagnostic logic for cases CE500–CE545 is presented in Figure B9-7. Cases CE500–CE545 test similar effects as cases E100–E200 but in an hourly dynamic context using expanded performance data without analytical verification. The sensitivity result "CE500–CE300" isolates the effect of outside air but with some noise because of varying internal gains schedules between Case CE300 and Case CE500 and because the air distribution fan cycles with the compressor in Case CE500. In contrast with steady-state cases E100–E200 that were solved analytically, the more realistic nature of cases CE300–CE545 allows us to gauge the importance of being able to simulate various effects accurately in terms of annual energy performance. For example, a large percentage difference for a given result that has only a very small impact on annual energy use may not be of concern, whereas a small percentage difference with a large impact on annual energy use may be deemed important.

There are some cases where it is possible to proceed even if disagreements were uncovered in the previous case. For example, in Case CE410, inability to model an economizer with compressor lockout does not necessarily affect the usefulness of the program (or the ability to further test the program) for modeling other types of economizer controls or other mechanical equipment features. Thus, the flow diagram

has an extra arrow connecting Case CE410 and Case CE420, which shows that you may proceed regardless of the results for Case E410. Where cases are connected by a single arrow, a satisfactory result is required in order to proceed to the next case. For example, in Case CE310, the inability to model latent load removal makes it difficult to proceed with these tests until the disagreement is reconciled.

B9.6 Examples

B9.6.1 Example Using Flow Diagrams for Building Thermal Envelope and Fabric Load Tests (Section 5.2). A program shows agreement with Case 600 but shows large disagreement with the example results of annual sensible cooling load predictions for Case 610. Figure B9-1 suggests the potential algorithmic source of the difference is with the shading algorithm and directs the user to look at the sensitivity results for shading as represented by the difference between the output values from Cases 600 and 610. The flow diagram then directs the user to diagnostic A12. Diagnostic A12 will either confirm shading as the source of the difference or direct the user to additional diagnostics if the shading algorithm is okay. The logic is sequential in that to show disagreement with 610-600 and to show agreement with A12 indicates differences elsewhere in 610-600 and, therefore, possible compensating differences in 600. To show disagreement with both 610-600 and A12 confirms a shading algorithm as the source of the difference.

IEA BESTEST[14] gives examples of how the tests were used to trace and correct specific algorithmic and input errors in the programs used to produce the example results of informative Annex B8.

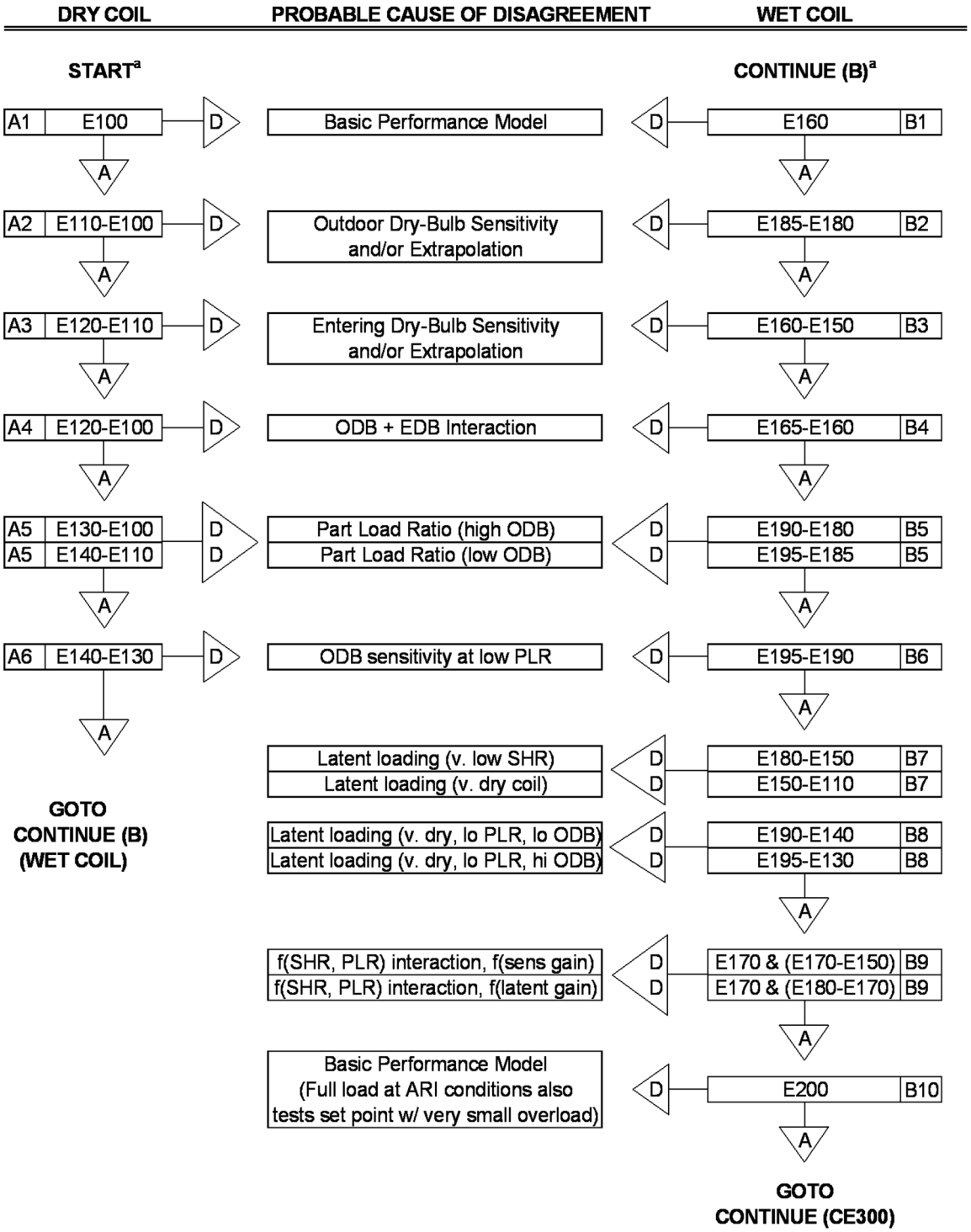
B9.6.2 Example Using Flow Diagrams for ~~HVAC~~ Space Cooling Equipment Performance Analytical Verification Tests (Sections 5.3.1 and 5.3.2). A program shows agreement with Case E100, but shows large disagreement with the quasi-analytical solution results of energy consumption predictions for Case E130. Figure B9-5 suggests the potential algorithmic source of the difference is with the algorithm for incorporating part-load operating effects into the energy consumption for a dry coil.

HVAC BESTEST Volume 1[8] gives examples of how the tests were used to trace and correct specific algorithmic and input errors in the programs used in the field trials for which results are given in informative Annex B16, Section B16.5.1.

B9.6.3 Example Using Flow Diagrams for HVAC Equipment Performance Comparative Tests (Sections 5.3.3 and 5.3.4). A program shows disagreement with CE300. Because this is the base case for the CE300 series, Figure B9-6 suggests a number of potential sources of algorithmic differences including dynamic variation of load, 15% outside air (mixed with return air), continuous indoor fan operation, or hourly dynamic equipment performance as f(EDB, EWB, ODB, PLR). The user is directed to check diagnostics C1 and C2 utilizing Case CE500 (see Figure B9-7). If the disagreement persists for C1 and/or C2, this likely eliminates outside air mixing and continuous fan operation as the cause of the problem. The user is then directed to run the remainder of the CE500-series cases and if the disagreement persists to also recheck results from cases E100–E200 (see Figure B9-5). If the cause of the disagreement persists for the remaining CE500-series cases, and the E100 results are still satisfactory, then the problem is likely isolated to performance-map parameter f(ODB, EWB, EDB) sensitivity over the expanded range of performance data or some other problem related to hourly dynamic modeling.

HVAC BESTEST Volume 2[B-1] gives examples of how the tests were used to trace and correct specific algorithmic and input errors in the programs used in the field trials for which results are given in informative Annex B16, Section B16.5.2.

[Informative Note: Delete the current Figure B9-5 and replace it with new Figure B9-5. New Figures B9-6 and B9-7 are added below.]



ABBREVIATIONS

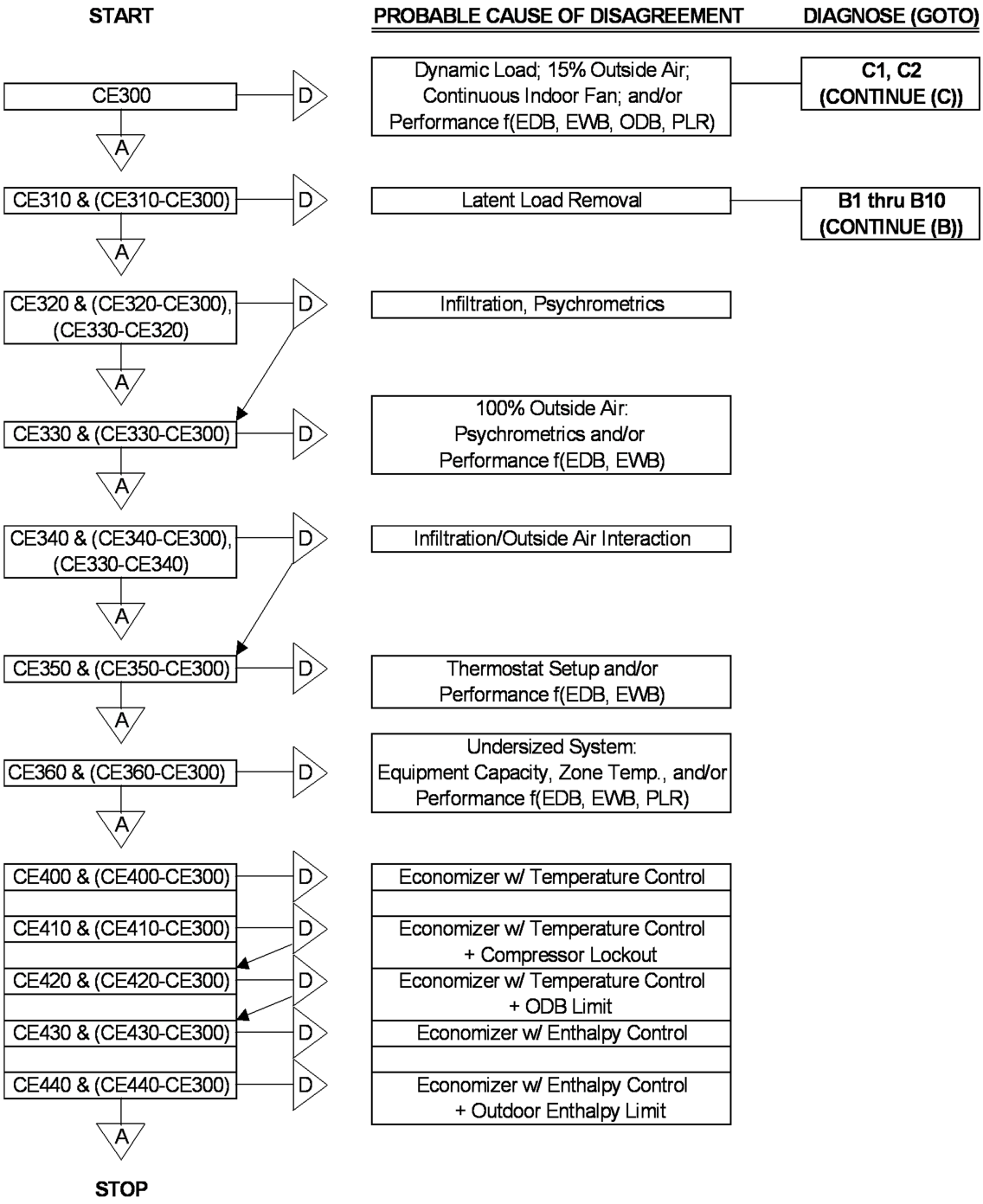
A = Agree; i.e., agree with analytical solution results for the case itself and the sensitivity case. E.g., to check for agreement regarding Case E130, compare example results for Case E130 and E130-E100 sensitivity.

D = Disagree; i.e., show disagreement with analytical solution results.

NOTES

[a] It is better to perform/analyze results of these tests in blocks such as E100-E140 and E150-E200.

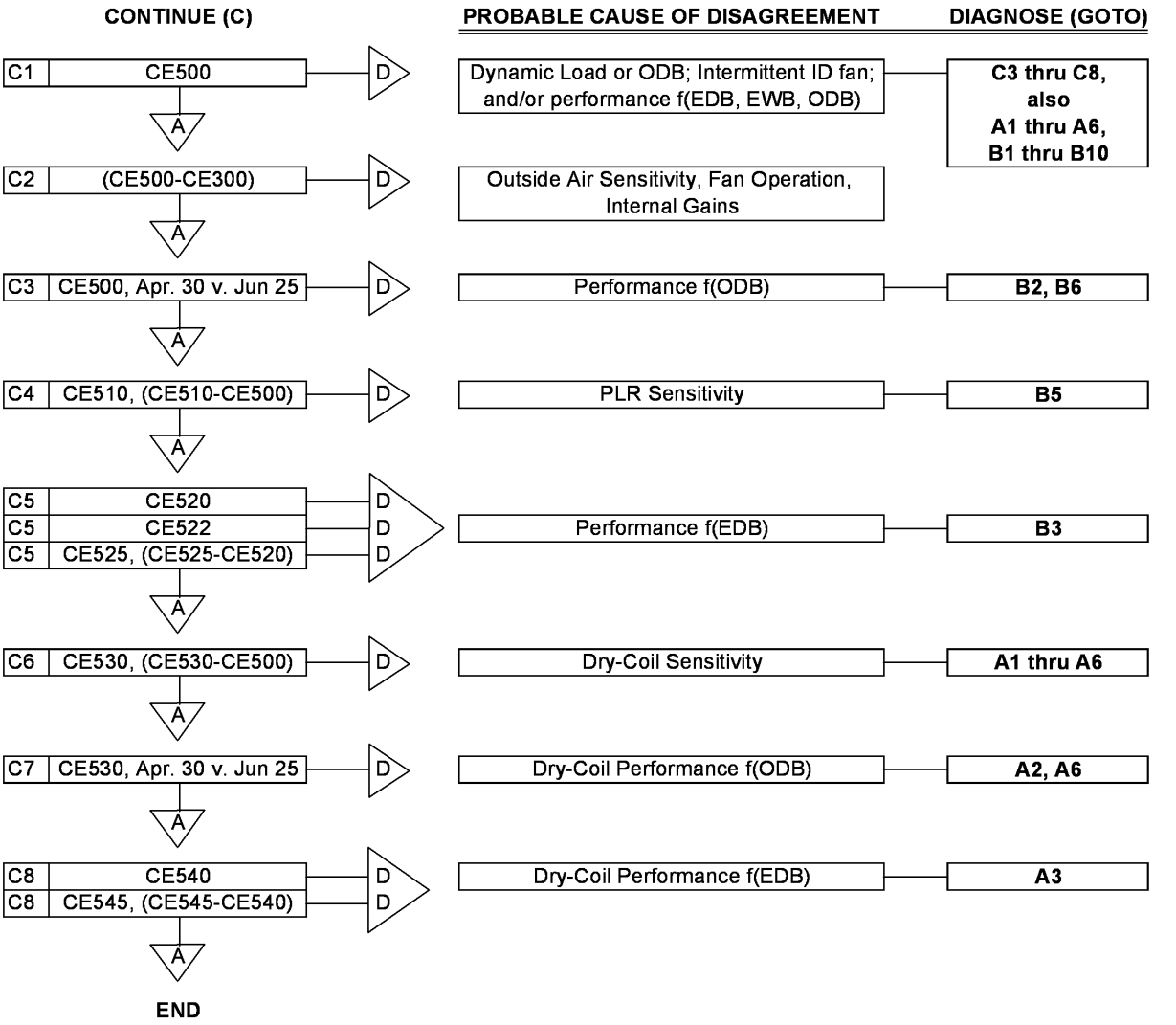
Figure B9-5 Cases E100–E200 (steady-state analytical verification) diagnostic logic flow diagram.



ABBREVIATIONS

A = Agree; D = Disagree. For the CE300 series, agreement/disagreement is determined relative to example simulation results or other user-provided results and the sensitivity case.

Figure B9-6 Cases CE300–CE440 (comparative test cases with outside air) diagnostic logic flow diagram.



ABBREVIATIONS
A = Agree; D = Disagree. For the CE300 series, agreement/disagreement is determined relative to example simulation results or other user-provided results and the sensitivity case.

Figure B9-7 Cases CE500–CE545 (comparative test cases without outside air) diagnostic logic flow diagram.

(This annex is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

ANNEX B10
INSTRUCTIONS FOR WORKING WITH RESULTS SPREADSHEETS PROVIDED WITH THE STANDARD

[Informative Note: In file names, change "5-3" to "5-3A" as shown.]

B10.2 Documentation for RESULTS5-3A.XLS (given in RESULTS5-3A.DOC). Import data so that Cell A1 of Sec5-3Aout.XLS is in A1 of Sheet "YD" (your data). Check that the first value (Total Consumption kWh for E100) is in YD!B25. See Sheet A (rows 13-26) for tabulation of results locations. Your data will then appear in column L of Sheet A, in the rightmost column of each table on Sheet Q, and on the right side of the last 5 sheets (used for making the charts). Chart update of "your data" is not automated.

[Informative Note: Renumber Section B10.3 as B10.4 as shown.]

~~B10.3~~B10.4 Documentation for RESULTS5-4.XLS (given in RESULTS5-4.DOC).

[Informative Note: Insert new section B10.3 as shown.]

B10.3 Documentation for RESULTS5-3B.XLS (Given in RESULTS5-3B.DOC). Import data so that Cell A1 of Sec5-3Bout.XLS is in A1 of Sheet "YD" (your data). Check that the first value (Total Consumption kWh for CE300) is in YD!B62. See Sheet A (rows 56-130) for tabulation of results locations. Your data will then appear in column H of Sheet A; in the rightmost columns of each table in Sheets Q, R, T, Qdata, Rdata, Sdata, and Tdata; and beginning in row 198 of Sheet S. Contents of these sheets are described below. Chart update of "your data" is not automated.

Contents of Sheets:

Sheet	Description
'A'	**Unformatted data compilation, all programs**
'B' – 'G'	**Results from each simulation program.**
'YD'	For inputting new results (**your data**); see above for instructions. Data input to this sheet will pass through into sheets A, Q, R, S, T, Qdata, Rdata, Sdata, and Tdata.
'I','J'	**Extra blank sheets** for simulation program data. Data input to these sheets will pass into sheet 'A' but NOT through to sheets Q, R, S, T, Qdata, Rdata, Sdata, and Tdata.
'Q'	Formatted summary results tables including simulations' **annual mean** results and statistics. "Your data" automatically appears on the right side of each table. See below for Sheet Q table locations.
'R'	Formatted summary results tables including simulations' **annual hourly maximum and minimum** results and statistics. "Your data" automatically appears on the right side of each table. See below for Sheet R table locations.
'S'	Formatted summary results tables including simulations' **June 28 hourly** results. "Your data" automatically appears in the bottommost table. See below for Sheet S table locations.
'T'	Formatted summary results tables including simulations' **sensitivities to annual mean, maximum and minimum** results and statistics. "Your data" automatically appears on the right side of each table. See below for Sheet T table locations.
'Qdata' through 'Tdata'	These sheets are similar to 'Q' thru 'T' but formatted for use as **source data for charts**.
'Qtot' through 'HrOHR'	Summary **charts** (one per sheet). Import of "your data" into these charts is not automated. However, the data do automatically appear on the right side of the tables used for making the charts. To get your data to appear requires adjusting the source data setting for each chart; see below for more tables regarding the contents of each sheet.

Contents of Sheet Q (Annual Mean Results, Formatted):

Description	Cell Range
Space Cooling Electricity Consumption (Total, Compressor, Supply Fan, Condenser Fan)	A6 – N105
Weather Data Checks	A109 – N119
Coil Loads: Total, Sensible, Latent	A125 – N198
Various Annual Means (COP2, IDB, Humidity Ratio, Relative Humidity)	A205 – N304
F(ODB) Sensitivities, CE500 and CE530, April 30 and June 25 (Consumptions, Loads, COP2, Zone Conditions)	A316 – N402

Contents of Sheet R (Annual Hourly Maximum and Minimum Results, Formatted):

Description	Cell Range
Aggregated Total Electricity Consumption and Disaggregated Coil Loads (Total, Sensible, Latent)	A7 – AA102
COP2	A111 – AA157
IDB	A159 – AA206
Humidity Ratio and Relative Humidity	A215 – AA310

Contents of Sheet S (June 28 Hourly Results, Formatted):

Description	Cell Range
TRNSYS-TUD	A3 – N32
DOE-2.2	A35 – N62
DOE-2.1E-E	A66 – N95
ENERGYPLUS	A98 – N125
CODYRUN	A130 – N159
HOT3000	A162 – N189
Your Software	A193 – N221

Contents of Sheet T (Sensitivities: Annual Mean, Maximum and Minimum Results. Formatted):

Description	Cell Range
Mean Electricity Consumptions (Total, Compressor, Supply Fan, Condenser Fan)	A6 – N94
Mean Coil Loads: Sensible, Latent	A99 – N142
Various Annual Means (COP2, IDB, Humidity Ratio, Relative Humidity)	A145 – N234
Maximum and Minimum Aggregated Total Electricity Consumption and Disaggregated Coil Loads (Total, Sensible, Latent)	A242 – N330
Maximum and Minimum COP2 and IDB	A339 – N429
Maximum and Minimum Humidity Ratio and Relative Humidity	A431 – N519

Contents of Sheet Qdata (Annual Mean Results, Unformatted):

Description	Cell Range
Space Cooling Electricity Consumption (Total, Compressor, Supply Fan, Condenser Fan)	A6 – I105
Total Electricity Consumption BEFORE BESTESTing	M8 – S30
Weather Data Checks	A109 – I119
Coil Loads: Total, Sensible, Latent	A125 – I198
Various Annual Means (COP2, IDB, Humidity Ratio, Relative Humidity)	A205 – I304
F(ODB) Sensitivities, CE500 and CE530, April 30 and June 25 (Consumptions and Loads)	A316 – R357
F(ODB) Sensitivities, CE500 and CE530, April 30 and June 25 (COP2 and Zone Conditions)	A370 – I401

Contents of Sheet Rdata (Annual Hourly Maximum and Minimum Results, Unformatted):

Description	Cell Range
Aggregated Total Electricity Consumption and Disaggregated Coil Loads (Total, Sensible, Latent)	A6 – I100
COP2 and IDB	A111 – I204
Humidity Ratio and Relative Humidity	A215 – I308

Contents of Sheet Sdata (June 28 Hourly Results, Unformatted):

Description	Cell Range
Electricity Consumptions: Compressor + OD Fan, OD Fan, Compressor	A5 – W31
Coil Loads: Sensible, Latent	A33 – O59
Humidity Ratio, COP2	A62 – H118
ODB, EDB, EWB, OHR	A122 – O208

Contents of Sheet Tdata (Sensitivities: Annual Mean, Maximum and Minimum Results. Unformatted):

Description	Cell Range
Mean Electricity Consumptions (Total, Compressor, Supply Fan, Condenser Fan)	A6 – I94
Mean Coil Loads: Sensible, Latent	A99 – I142
Various Annual Means (COP2, IDB, Humidity Ratio, Relative Humidity)	A145 – I234
Maximum and Minimum Aggregated Total Electricity Consumption and Disaggregated Coil Loads (Total, Sensible, Latent)	A242 – I330
Maximum and Minimum COP2 and IDB	A339 – I429
Maximum and Minimum Humidity Ratio and Relative Humidity	A431 – I519

(This annex is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

ANNEX B11
PRODUCTION OF EXAMPLE RESULTS FOR BUILDING THERMAL ENVELOPE AND FABRIC LOAD TESTS

[Informative Note: Revise README.DOC to README*.DOC in last paragraph of introductory section of Annex B11 as shown.]

Input decks used to generate the results are provided on the CD accompanying this standard; see the README*.DOC file on the CD. The IEA participants that ran SERIRES 1.2 only provided two input decks with their results. IEA participants that ran simulations for ESP, S3PAS, and TASE did not supply input decks with their results.

[Informative Note: Clarify Annex A1 cross-reference in B11.3 as shown]

B11.3 Hourly Time Convention. Details of differences in modeling methods utilized by various software are given in Part II of *IEA BESTEST*.[14] That reference does not discuss how the specified time convention is modeled by various simulation software. For Standard 140, the time convention for the input specification and hourly outputs is standard time, while the time convention for Typical Meteorological Year (TMY) weather data is solar time (see Annex A1, Section A1.4~~3~~, for discussion of the difference between solar time and standard time). The time convention is therefore most correctly modeled by software that rebins TMY data into hourly data based on local standard time. A tabulation of how the time convention was modeled by some of the software used to generate the example results given in informative Annex B8 is noted in Table B11-3.

Since software being tested by Standard 140 may not be rebinning TMY data, it is important to understand the potential differences in Standard 140 results that can be generated by applying a time convention different from that specified in Section 5.1.1. In Standard 140 such differences are minimized and are primarily related to the equation of time (see Annex A1, Section A1.4~~3~~) because the building site has been located within 0.1º longitude of the standard meridian. For this reason Standard 140 does not provide a good test for the ability to calculate solar incidence angles for longitudes far away from the standard meridian.

[Informative Note: Revise informative Annex B13 as shown below]

(This annex is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

ANNEX B13
COP DEGRADATION FACTOR (CDF) AS A FUNCTION OF PART-LOAD RATIO (PLR)

B13.1 Derivation of CDF Based on Performance Data.

Per the equipment manufacturer (D Cawley),

CDF = 1 - Cd(1-PLR), 0 <= PLR <= 1
CDF = 1, PLR => 1 (1)

where Cd is assumed constant for a given unit.

Cd can be determined from listed performance data using:

SEER = EERb (1 - 0.5Cd) which solves for Cd as,

Cd = (1 - SEER/ EERb)/ 0.5 (2)

where EERb = (Adjusted Net Total Capacity)/ (Cooling Energy Consumption) at EDB = 80 F, EWB = 67 F, ODB =82 F; listed SEER = 12.90
Adjusted Net Total Capacity (Qnetcap,adj) is used to account for fan heat assumed for gross capacity calculation being different from actual fan heat.

Note: The procedures for independently calculating Cd and EERb from measured data are given in ANSI/ ARI 210/ 240-89.

Calculations to obtain EERb

Extrapolate performance based on manufacturer data (Qnetcap,list), for EDB = 80, EWB = 67.

ODB (°F)	Total Capacities Qnetcap,list (kBtu/ h)	Qnetcap,adj (kBtu/ h)	Qcomp (kW)	Qfans (kW)	EER
90	27.6	27.9	1.79	0.34	13.13
85	28.4	28.7	1.71	0.34	14.03
82					extrap 14.57

Eqn (2) implies Cd =	0.229

So for some points along the CDF f(PLR) linear curve using Equation (1)

PLR	CDF
1.0	1.000
0.9	0.977
0.8	0.954
0.7	0.931
0.6	0.908
0.5	0.885
0.4	0.862
0.3	0.840
0.2	0.817
0.1	0.794
0.0	0.771

cdfvplr.xls; May 14, 2001

For real equipment, the representation of Figure 10 (see Section 5.3.1.10.4.1) is reasonable for PLR greater than or equal to approximately 0.1; for PLR less than or equal to approximately 0.1, Figure 10 indicates less efficiency degradation than that suggested by more detailed information.[29] However, real equipment that cycles ON/OFF has controls that prevent operation at PLR less than or equal to approximately 0.05. Thus, ~~F~~for the purpose of testing the basic capability of simulation software to model part-load effects, ~~in the context of these analytical verification tests,~~ Figure 10 is reasonable.

B13.2 PLR Definition Similarity. ~~We have defined~~ PLR in cases E100-E200 (Sections 5.3.1 and 5.3.2) is defined based on guidance from ~~the~~ an equipment manufacturer as

$$\text{PLR1} = Qnet \,/\, CAPnet$$

where

Qnet = net refrigeration effect,

CAPnet = adjusted net total capacity.

For cases CE300-CE545 (Sections 5.3.3 and 5.3.4), and for simulation software that generally define part-load ratio based on gross total coil load and gross total capacity, ~~We wish~~ it is desirable to check the equivalence of defining PLR as

$$\text{PLR2} = Qgtc \,/\, CAPgtc$$

where

Qgtc = gross total coil load,

CAPgtc = gross total capacity.

The net refrigeration effect = *Qgtc* – *Qfan* where *Qfan* is the indoor air distribution fan heat.

For cases CE500–CE545 (and cases E100–E200), where the compressor and all fans cycle on/off together, the net refrigeration effect is the *evaporator coil load* less the air distribution fan heat. For cases CE300–CE440, where the indoor air distribution fan is always on, the net refrigeration effect is the *evaporator coil load* less the air distribution fan heat for times when the evaporator coil is removing heat.

The adjusted net capacity = *CAPgtc* – *Pfan* where *Pfan* ~~=~~ is the indoor air distribution fan rated power.

[Informative Note: the equal sign in the line above is to be deleted in the 2007 edition.]

Then, for PLR1 = PLR2 to be true implies

$$Qgtc \,/\, CAPgtc = (Qgtc - Qfan) \,/\, (CAPgtc - Pfan),$$

which is true if

$$Qfan \,/\, Pfan = Qgtc \,/\, CAPgtc,$$

that is, if the fan heat for a given period is the fan's run-time fraction for that period multiplied by the fan power, where *Qgtc*/*CAPgtc* inherently defines the required fraction of a time period that the evaporator coil is to be removing heat at a given capacity. The above relation is true if there is no additional fan run time (and fan heat) associated with additional compressor start-up run time, which occurs during part-load operation. This is true for cases CE300-CE440, where the indoor fan is always on and may be thought of as only being accounted for in the net refrigeration effect term when the coil is actually cold enough to remove heat (i.e., additional start-up run time not included). (For this discussion we are ignoring that the coil removes heat at a small rate during start-up, a rate that gradually increases until the evaporator coil temperature reaches stability.) Then for cases CE300-CE440,

$$Qfan = Pfan \times \text{PLR2} = Pfan \times Qgtc \,/\, CAPgtc,$$

and it would follow that PLR1 = PLR2.

For cases E100-E200, because the indoor fan cycles on/off with the compressor, ~~we originally defined~~ the net refrigeration effect was originally defined to subtract out fan heat for the time when the compressor is operating (which is longer than the time that the coil is actually removing heat at rated capacity).

For that situation, which also applies to cases CE500-CE545, it is useful to think of

$$Qfan \,/\, Pfan = \text{PLR} \,/\, \text{CDF}.$$

However, this relation implies

$$Qfan \,/\, Pfan \neq Qgtc \,/\, CAPgtc$$

with the theoretical result that PLR1 ≠ PLR2.

An analysis of the difference between PLR1 and PLR2 and corresponding resultant CDF1 and CDF2 that could be used in evaluating part-load performance is shown below in the spreadsheet tables. This analysis applies reasonable hypothetical values of coil capacity and fan power. ~~for the equipment at ARI rating conditions. From this~~The analysis ~~we observe~~indicates (see far right column of the spreadsheet table) that the resulting difference between CDF1 and CDF2 and, therefore, the compressor energy consumptions related to applying those CDFs, is <0.1%, ~~<0.05%,~~ which is negligible. Thus, ~~we conclude that~~ for the purpose of calculating CDF, either PLR1 or PLR2 may be used.

[Informative Note: Delete the table immediately below, and replace it with the tables below it.]

PLR2	CAPgtc (Btu/h)	Qgtc (Btu/h)	Pfan (Btu/h)	CDF2	Qfan (Btu/h)	Qfan/ Pfan	Qnet (Btu/h)	CAPnet (Btu/h)	PLR1= Qnet/ CAPnet	PLR2/ PLR1	PLR2 - PLR1	CDF1	CDF2/ CDF1
0.01	27920	279.2	785	0.7733	10	0.013	269	27135	0.0099	1.0086	0.0001	0.7733	1.00002511
0.1	27920	2792	785	0.7939	99	0.126	2693	27135	0.0992	1.0076	0.0008	0.7937	1.00021661
0.2	27920	5584	785	0.8168	192	0.245	5392	27135	0.1987	1.0065	0.0013	0.8165	1.00036385
0.3	27920	8376	785	0.8397	280	0.357	8096	27135	0.2983	1.0056	0.0017	0.8393	1.00045190
0.39	27920	10889	785	0.8603	356	0.453	10533	27135	0.3882	1.0047	0.0018	0.8599	1.00048772
0.4	27920	11168	785	0.8626	364	0.464	10804	27135	0.3982	1.0046	0.0018	0.8622	**1.00048942**
0.41	27920	11447	785	0.8649	372	0.474	11075	27135	0.4081	1.0045	0.0019	0.8645	1.00049068
0.42	27920	11726	785	0.8672	380	0.484	11346	27135	0.4181	1.0044	0.0019	0.8668	1.00049153
0.43	27920	12006	785	0.8695	388	0.495	11617	27135	0.4281	1.0044	0.0019	0.8690	1.00049195
0.435	27920	12145	785	**0.8706**	**392**	**0.500**	11753	27135	**0.4331**	**1.0043**	**0.0019**	**0.8702**	**1.00049201**
0.44	27920	12285	785	0.8718	396	0.505	11889	27135	0.4381	1.0043	0.0019	0.8713	1.00049197
0.45	27920	12564	785	0.8741	404	0.515	12160	27135	0.4481	1.0042	0.0019	0.8736	1.00049158
0.46	27920	12843	785	0.8763	412	0.525	12431	27135	0.4581	1.0041	0.0019	0.8759	1.00049079
0.47	27920	13122	785	0.8786	420	0.535	12703	27135	0.4681	1.0040	0.0019	0.8782	1.00048961
0.48	27920	13402	785	0.8809	428	0.545	12974	27135	0.4781	1.0039	0.0019	0.8805	1.00048804
0.5	27920	13960	785	0.8855	443	0.565	13517	27135	0.4981	1.0038	0.0019	0.8851	**1.00048378**
0.6	27920	16752	785	0.9084	518	0.661	16234	27135	0.5983	1.0029	0.0017	0.9080	1.00044129
0.7	27920	19544	785	0.9313	590	0.752	18954	27135	0.6985	1.0021	0.0015	0.9310	1.00036734
0.8	27920	22336	785	0.9542	658	0.838	21678	27135	0.7989	1.0014	0.0011	0.9539	1.00026658
0.9	27920	25128	785	0.9771	723	0.921	24405	27135	0.8994	1.0007	0.0006	0.9770	1.00014299
0.99	27920	27641	785	0.9977	779	0.992	26862	27135	0.9899	1.0001	0.0001	0.9977	1.00001508

Continuously operating fan, compressor cycling (start-up) does not create any additional fan ON time.

PLR2	CAPgtc (Btu/h)	Qgtc (Btu/h)	Pfan (Btu/h)	CDF2	Qfan (Btu/h)	Qfan/ Pfan	net refr (Btu/h)	adjnetcap (Btu/h)	PLR1 = net refr/ CAPnet	PLR2/ PLR1	CDF1	CDF2/ CDF1
0.1	100000	10000	4000	0.7939	400	0.100	9600	96000	0.1000	1.0000	0.7939	1.00000
0.5	100000	50000	4000	0.8855	2000	0.500	48000	96000	0.5000	1.0000	0.8855	**1.00000**
0.9	100000	90000	4000	0.9771	3600	0.900	86400	96000	0.9000	1.0000	0.9771	1.00000

So for E300 the ratio of net refr effect to adj net cap exactly equals the ratio of Qgtc to CAPgtc, as shown previously.

Fan cycles ON/OFF with compressor, compressor cycling creates additional fan ON time.

PLR2	CAPgtc (Btu/h)	Qgtc (Btu/h)	Pfan (Btu/h)	CDF2	Qfan (Btu/h)	Qfan/ Pfan	net refr (Btu/h)	adjnetcap (Btu/h)	PLR1 = net refr/ CAPnet	PLR2/ PLR1	CDF1	CDF2/ CDF1
0.1	100000	10000	4000	0.7939	504	0.126	9496	96000	0.0989	0.9892	0.7937	1.000312
0.35	100000	35000	4000	0.8512	1645	0.411	33355	96000	0.3474	0.9927	0.8506	1.000687
0.4	100000	40000	4000	0.8626	1855	0.464	38145	96000	0.3973	0.9934	0.8620	1.000705
0.45	100000	45000	4000	0.8741	2059	0.515	42941	96000	0.4473	0.9940	0.8734	**1.000708**
0.5	100000	50000	4000	0.8855	2259	0.565	47741	96000	0.4973	0.9946	0.8849	**1.000697**
0.55	100000	55000	4000	0.897	2453	0.613	52547	96000	0.5474	0.9952	0.8963	1.000673
0.9	100000	90000	4000	0.9771	3684	0.921	86316	96000	0.8991	0.9990	0.9769	1.000206

Notes regarding the above spreadsheet table:

Bold font indicates value of CDF2/CDF1 at PLR2 = 0.5, and value of PLR2 at maximum value of CDF2/CDF1.

For the case where the fan cycles on/off with the compressor, ~~T~~the total fan run-time fraction, including the additional start-up run time during which no or little cooling occurs, = PLR/CDF. Actually, fan heat should be slightly higher because the additional fan run time due to CDF creates a slight amount of additional fan heat that, in turn, causes slightly more additional run time. In accord with the analytical solution by Dresden University of Technology (discussed in informative Annex B17, Section B17.1.1.2), the additional run time (fan heat) for mid-PLR Case E170 is 0.5% greater if this effect is taken into account. ~~Since~~Because this is a 0.5% effect on a quantity that makes up at most 4% of the total coil load (i.e., 0.02% effect overall), ~~then~~ for the purpose of calculating CDF = f(PLR), ~~we ignore it~~it can be ignored.

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[Informative Note: Subdivide Annex B15 into B15.1 and add new B15.2 as shown.]

ANNEX B15
INDOOR FAN DATA EQUIVALENCE

B15.1 For Cases E100-E200 (Sections 5.3.1 and 5.3.2). Fan performance data for indoor fan power (230 W) and airflow rate (900 CFM = 0.425 m^3/s) are based on dry air at standard fan rating conditions. ASHRAE defines a standard condition as 1 atmosphere (101.325 kPa or 14.696 psi) and 68°F (20°C) with a density of 0.075 lb/ft^3 (1.204 kg/m^3).[31]

The fan efficiency of 0.5 is based on a discussion with the unitary system manufacturer. The **total fan pressure** is based on[33]

$$Eff = Q \times \Delta P / W$$

where

Q = indoor fan airflow rate (m^3/s),
ΔP = total fan pressure (Pa),
W = fan electric power input (W)
Eff = total fan plus motor and drive efficiency (motor/drive in airstream).

Solving for ΔP,

$$\Delta P = W \times Eff / Q$$
$$= 230 \text{ W} \times 0.5 / 0.425 \text{ m}^3/\text{s} = \mathbf{271\ Pa = \Delta P}.$$

The supply air temperature rise from fan heat is based on

$$q_{fan} = \rho \times c_p \times Q \times \Delta T \times C$$

where

q_{fan} = fan heat (Btu/h or W),
ρ = standard air density = 0.075 lb/ft^3 (1.204 kg/m^3),
c_p = specific heat of air (Btu/(lb·°F) or kJ/(kg·K)),
Q = indoor fan airflow rate (ft^3/min or m^3/s),
ΔT = supply air temperature rise from fan heat (°F or °C),
C = units conversion constant.

Solving for ΔT,

$$\Delta T = q_{fan} / (\rho \times c_p \times Q \times C)$$

where

q_{fan} = 230 W = 785 Btu/h; Q = 900 CFM = 0.425 m^3/s,
c_p = 0.24 Btu/(lb·°F)~~lb·F~~ for dry air, or
c_p = 0.2445 Btu/(lb·°F)~~lb·F~~ when humidity ratio = 0.01.[31]

Then,

$$\Delta T = 785 \text{ Btu/h} / \{0.075 \text{ lb/ft}^3 \times 900 \text{ ft}^3/\text{min} \times 60 \text{ min/h} \times 0.2445 \text{ Btu/(lb·°F)}\}$$

$$\mathbf{\Delta T = 0.793°F\ (0.441\ °C)}$$

or

for c_p = 0.24 Btu/(lb·°F), **ΔT = 0.808°F (0.449°C)**.

B15.2 For Cases CE300-CE545 (Sections 5.3.3 and 5.3.4).

Fan performance data for indoor fan electric power (1242 W), mechanical shaft power (1.565 BHP = 1167 W), and airflow rate (4000 CFM = 1.888 m^3/s) are based on dry air at standard fan rating conditions. ASHRAE defines a standard condition as 1 atmosphere (101.325 kPa or 14.696 psi) and 68°F (20°C) with a density of 0.075 lb/ft^3 (1.204 kg/m^3).[31]

The static pressure of 0.3 in. w.g. (74.7 Pa) is based on the Air-Conditioning and Refrigeration Institute (ARI) rating condition, according to the provider of the performance data.

The **fan static efficiency** is based on:[33, B-2]

$$Eff_s = Q \times \Delta P_s / W_{sh},$$

where

Q = indoor fan airflow rate (m^3/s),
ΔP_s = static fan pressure (Pa),
W_{sh} = fan shaft power input (W),
Eff_s = static fan efficiency.

Solving for Eff_s

$$Eff_s = 1.888 \text{ m}^3/\text{s} \times 74.7 \text{ Pa} / 1167 \text{ W} = 0.121 = 12.1\%.$$

The **motor/drive efficiency** is based on

$$Eff_m = W_{sh} / W,$$

where

Eff_m = motor/drive efficiency,
W_{sh} = fan shaft power input (W),
W fan = electric power input (W).

Solving for Eff_m

$$Eff_m = 1167 \text{ W} / 1242 \text{ W} = 0.940 = 94.0\%.$$

The **supply air temperature rise from fan heat** is based on

$$q_{fan} = \rho \times c_p \times Q \times \Delta T \times C$$

where

q_{fan} = fan heat (Btu/h or W), motor/drive in airstream,
ρ = standard air density = 0.075 lb/ft^3 (1.204 kg/m^3),
c_p = specific heat of air (Btu/(lb·°F) or kJ/(kg·K)),
Q = indoor fan airflow rate (ft^3/min or m^3/s),
ΔT = supply air temperature rise from fan heat (°F or °C),
C = units conversion constant.

Solving for ΔT

$$\Delta T = q_{fan} / (\rho \times c_p \times Q \times C),$$

where

q_{fan} = 1242 W = 4237 Btu/h; Q = 4000 CFM = 1.888 m^3/s,
c_p = 0.24 Btu/(lb·°F) for dry air, or
c_p = 0.2445 Btu/(lb·°F) when humidity ratio = 0.01.[31]

Then, $\Delta T = 4237 \text{ Btu/h} / \{ 0.075 \text{ lb/ft}^3 \times 4000 \text{ ft}^3/\text{min} \times 60 \text{ min/h} \times 0.2445 \text{ Btu/(lb·°F)} \}$

$$\mathbf{\Delta T = 0.963°F\ (0.535°C)}$$

or

for c_p = 0.24 Btu/(lb·°F), **ΔT = 0.981°F (0.545°C)**.

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ANNEX B16
ANALYTICAL AND QUASI-ANALYTICAL SOLUTION RESULTS AND EXAMPLE SIMULATION RESULTS FOR HVAC EQUIPMENT PERFORMANCE TESTS

[Informative Note: Revise Sections B16.1 through B16.3 as shown below.]

B16.1 Introduction

The results from quasi-analytical solutions and various detailed building energy simulation programs applied to the tests of Section 5.3 and 5.4 are presented here in tabular and graphic form. These results can be used for a comparison with the software being tested. Alternatively, a user can run a number of different programs through the Standard Method of Test or generate their own quasi-analytical solution results and draw comparisons from those results independently or in conjunction with the results listed here. In either case, when making comparisons, the user should employ the diagnostic logic presented in informative Annex B9.

For convenience to users who wish to plot or tabulate their results along with the example results, an electronic version of the analytical and quasi-analytical solution results and example simulation results has been included with the spreadsheet files RESULTS5-3A.XLS, RESULTS5-3B.XLS and RESULTS5-4.XLS ~~in~~on the accompanying CD~~files~~. Spreadsheet navigation instructions are included in RESULTS5-3A.DOC, RESULTS5-3B.DOC and RESULTS5-4.DOC, and have been printed out in informative Annex B10, Sections B10.2, B10.3 and B10.4~~3~~, respectively, for convenience.

B16.2 Importance of Analytical and Quasi-Analytical Solution Results

A characteristic difference between the Annex B8 results for the building thermal envelope and fabric load tests versus the Annex B16 results for the HVAC equipment performance tests is that the Annex B16 results of Sections B16.5.1 and B16.6 include quasi-analytical solutions. In general, it is difficult to develop worthwhile test cases that can be solved analytically or quasi-analytically, but such solutions are extremely useful when possible. Analytical or quasi-analytical solutions represent a "mathematical truth standard"; that is, given the underlying physical assumptions in the case definitions, there is a mathematically correct solution for each case. In this context, the underlying physical assumptions regarding the mechanical equipment as defined in cases E100-E200 and HE100-HE170 are representative of typical manufacturer data normally used by building design practitioners. Many "whole-building" simulation programs are designed to work with this type of data.

It is important to understand the difference between a "mathematical truth standard" and an "absolute truth standard." In the former, we only test the solution process for a model, not the appropriateness of the solution; that is, we accept the given underlying physical assumptions while recognizing that these assumptions represent a simplification of physical reality. An approximate truth standard from an experiment tests both the solution process and appropriateness of the model within experimental uncertainty. The ultimate or "absolute" validation truth standard would be comparison of simulation results with a *perfectly performed* empirical experiment, ~~the inputs for which are~~ with all simulation inputs *perfectly defined.* ~~*specified* to the simulationists.~~ In reality, an experiment is performed and the experimental object is specified within some acceptable range of uncertainty. Such experiments are possible, but expensive. We recommend developing a set of empirical validation experiments in the future.

~~The minor disagreements among the two sets of~~ The quasi-analytical and analytical solution results presented in selected parts of Annex B16 represent a mathematical truth standard. ~~are small enough to~~ This allows identification of bugs in the software that would not otherwise be apparent from comparing software only to other software and therefore improves the diagnostic capabilities of the test procedure. Further discussion of how quasi-analytical and analytical solutions were developed is included in Annex B17.

B16.3 Example Simulation Results

The building energy simulation computer programs used to generate example results are described in informative Annex B17.

B16.3.1 Results for Analytical Verification Tests.

B16.3.1.1 Because the quasi-analytical and analytical solution results constitute a reliable set of theoretical results (a mathematical truth standard), the primary purpose of including simulation results for the E100–E200 and HE100-HE170 cases in ~~Annex~~ Sections B16.5.1 and B16.6 is to allow simulationists to compare their relative agreement (or disagreement) versus the quasi-analytical and analytical solution results to that for other simulation results. Perfect agreement among simulations and analytical or quasi-analytical solutions is not necessarily expected. The results give an indication of what sort of agreement is possible between simulation results and the analytical or quasi-analytical solution results.

B16.3.1.2 Because the physical assumptions of a simulation may be different from those for the analytical or quasi-analytical solutions, a tested program may disagree with ~~the quasi-analytical~~ such solutions without necessarily being incorrect. However, it is worthwhile to investigate the sources of the differences.

B16.3.2 Results for Comparative Tests. The computer programs used to generate example results for Section B16.5.2 have been subjected to a number of analytical verification, empirical validation, and comparative testing studies. However, there is no such thing as a completely validated building energy simulation computer program. All building models are simplifications of reality. The philosophy here is to generate a range of results from several programs that are

generally accepted as representing the state-of-the-art in whole building energy simulation programs. Regarding the presented results, input errors or differences have been eliminated to the extent possible. Thus, for a given case, the range of differences between results presented in informative Section B16.5.2 represents algorithmic differences among these computer programs for comparative space cooling equipment tests. For any given case, a tested program may fall outside the range of given example results without necessarily being incorrect. Also, for any given case, a program that yields values in the middle of the range of the example results should not be perceived as better or worse than a program that yields values at the borders of the range.

B16.3.3 General Comments Regarding Simulation Results.

B16.3.3.1 ~~However, i~~It is worthwhile to investigate the source of differences for a given set of simulation results in both the analytical verification and comparative tests ~~as~~because the collective experience of the authors of this standard is that such differences often indicate problems with the software or its usage, including, but not limited to,

a. user input error, where the user misinterpreted or misentered one or more program inputs;
b. problem with a particular algorithm in the program;
c. one or more program algorithms used outside their intended range.

B16.3.3.2 For generating example simulation results presented in this annex, along with using consistent modeling methods, simulationists were requested to use the most detailed modeling methods their software allows. The example simulation results were the product of numerous iterations to incorporate clarifications to the test specifications, simulation input deck corrections, and simulation software improvements. Where improvements to simulation programs or simulation inputs were made as a result of running the tests, such improvements must have mathematical and physical bases and must be applied consistently across tests. Arbitrary modification of a simulation program's input or internal code just for the purpose of more closely matching a given set of results is not allowed. For a summary of how quasi-analytical solution and simulation results were developed, see informative Annex B17. For more detailed information about these results, see *HVAC BESTEST Volume 1,*[8] *HVAC BESTEST Volume 2,*[B-1] and *HVAC BESTEST for Fuel-Fired Furnaces.*[A-6]

B16.4 Nomenclature

[Informative Note: Add the following abbreviations to the nomenclature used in Section B16.5.2]

Results are grouped by case numbers, e.g., "E100" is Case E100 (Section 5.3.1). Sensitivity results are listed using two case numbers separated by a minus sign, e.g., "E110-100" is the difference between Case E110 (Section 5.3.2.1.1) and Case E100.

Analytical	quasi-analytical solution
Apr	April
ARI	Air-Conditioning & Refrigeration Institute
Aug	August
CA-SIS	CA-SIS VI (see Table B17-1)
CIEMAT	Centro de Investigaciones Energeticas, Medioambientales y Technologicas
CLM2000	CLIM2000 2.1.6 (see Table B17-1)
CODYRUN	CODYRUN/LGIMAT (see Table B17-2)
Comp.	compressor
Compr.	compressor
COP	coefficient of performance
COP2	alternative coefficient of performance, see Section 3.1
Ctrl.	control
Dec	December
Del	sensitivity between listed cases
Delta	sensitivity between listed cases
DOE21E	DOE-2.1E ESTSC version- 088 or DOE-2.1E JJHirsch version- 133 (see Table B17-1) (for section B16.5.1)
DOE21E-E	DOE-2.1E, ESTSC version 120 (see Table B17-2) (for Section B16.5.2)
DOE-2.1E	DOE-2.1E, JJHirsch version- 133 (for Section B16.6)
DOE-2.1E-E	DOE-2.1E, ESTSC version 120 (see Table B17-2) (for Section B16.5.2)
DOE-2.2	DOE-2.2 version NT42j (see Table B17-2)
dry	dry coil
Ec.	economizer
EDF	Electricité de France
Energy+	EnergyPlus 1.0.0.023 (see Table B17-1) (for section B16.5.1) *[Informative note: Editorial changes will be included for the next continuous maintenance revision of Standard 140 to re-label EnergyPlus results of Section B16.5.1 from "Energy+" to either "EnergyPlus" or "E+" as appropriate.]*
EnergyPlus	EnergyPlus 1.1.0.020 (see Table B17-2) (for Section B16.5.2) EnergyPlus 1.0.2.008 (for Section B16.6)
Enth	enthalpy
Feb	February
GARD	GARD Analytics
Hi	high
HOT3000	HOT3000/ESP-r (see Table B17-2)
HTAL1	quasi-analytical solution with ideal controller by Hochschule Technik & Architektur Luzern
HTAL2	quasi-analytical solution with realistic controller model by Hochschule Technik & Architektur Luzern
Hum.	humidity
IDB	indoor dry-bulb temperature
Inf or Infl	infiltration

Jan	January
Jul	July
Jun	June
kWh	kilowatt hours
kWh,e	kilowatt hours, electrical
kWh,th	kilowatt hours, thermal
lat	latent internal gains
Lim.	limit
lo	low
m	mid-range
Mar	March
Max	maximum
Min	minimum
Nov	November
NRCan	Natural Resources Canada
NREL	National Renewable Energy Laboratory
OA	outside air
Oct	October
OD	outdoor
ODB	outdoor dry-bulb temperature
OHR	outdoor humidity ratio
PL	part-load ratio
PLR	part-load ratio
Qcoil,lat	latent coil load
Qcoil,s	sensible coil load
Qcoil,t	total sensible + latent coil load
Qcomp	compressor electric energy
Q ID fan	indoor fan electric energy
Q OD fan	outdoor fan electric energy
Qtot	total electric energy of compressor + both fans
sens	sensible internal gains
Sep	September
SH	sensible heat ratio
SHR	sensible heat ratio
T	temperature
Temp.	temperature
TRNSYS	TRNSYS-TUD (see Table B17-2)
TRN-id	TRNSYS-TUD with ideal controller (see Table B17-1)
TRN-re	TRNSYS-TUD with realistic controller (see Table B17-1)
Tstat	thermostat
TUD	Technische Universitat Dresden
UR	University of Reunion Island
v.	versus
Wh	watt hours
Wh,e	watt hours, electrical
Wh,th	watt hours, thermal
w/	with
×	multiplied by
@	at
50/50	50% outside air, 50% infiltration air

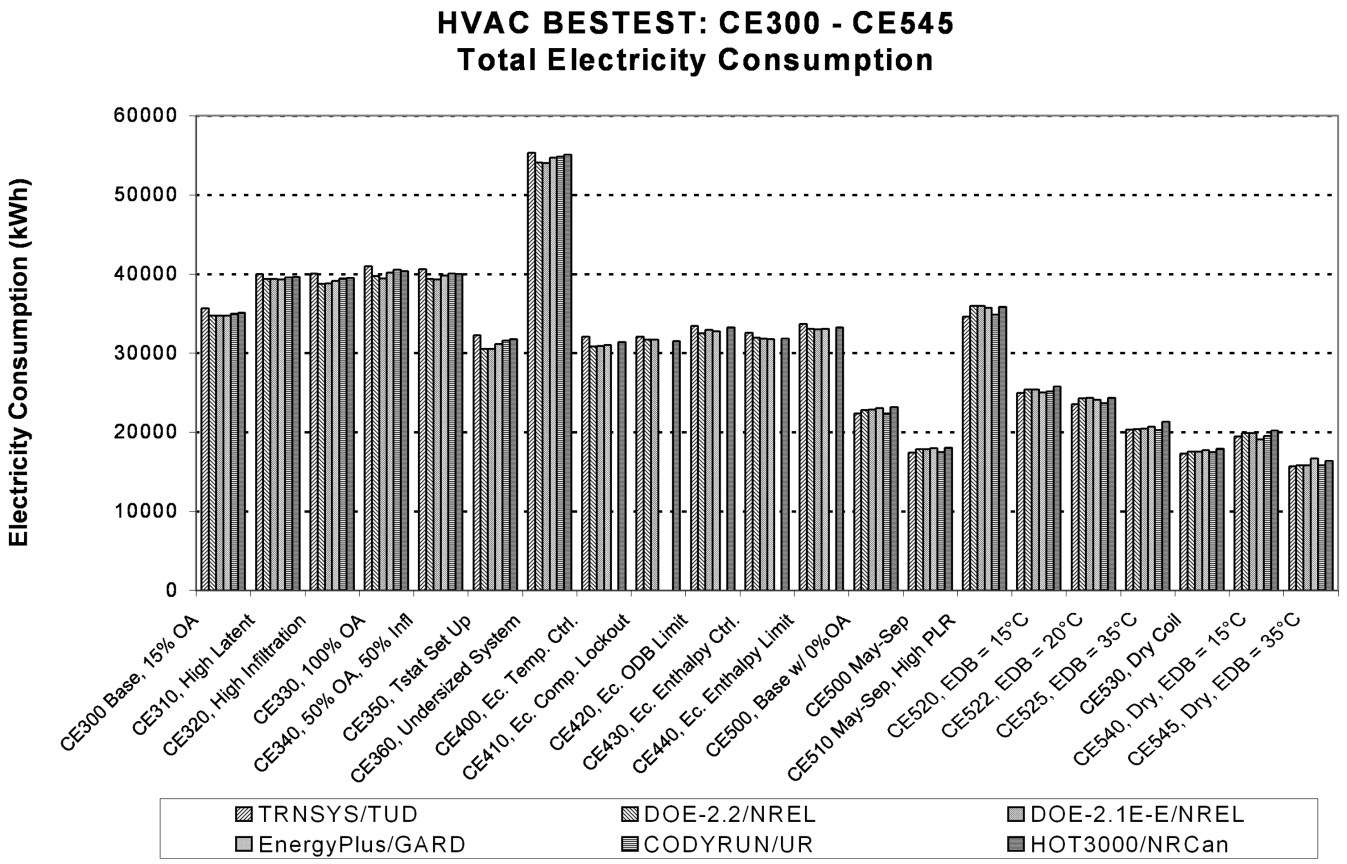
[Informative Note: Revise title of Section B16.5; create Section B16.5.1 for current Standard 140-2004 space cooling analytical verification results. Create section B16.5.2 and put new space cooling comparative test results in it; these tables and graphs follow.]

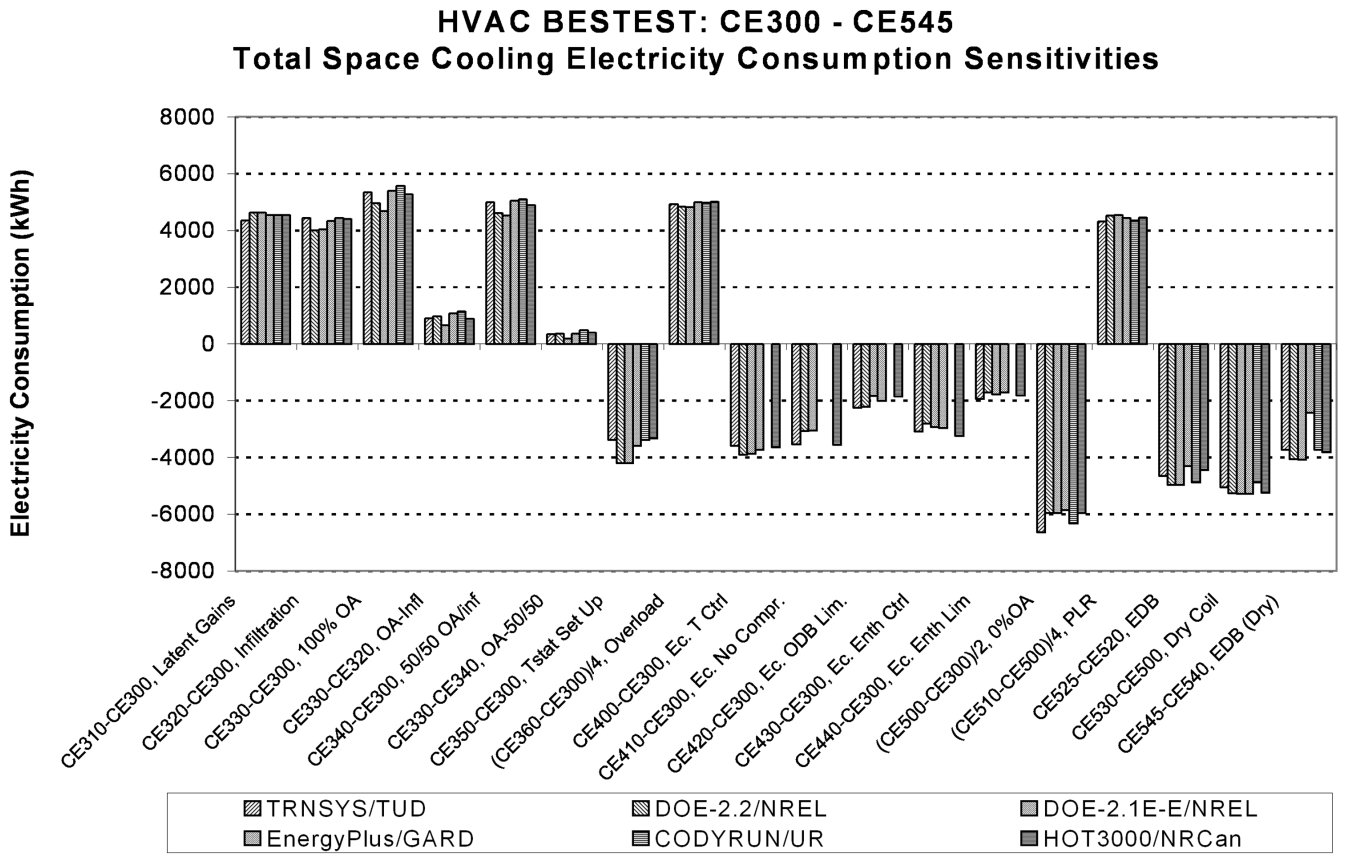
B16.5 Tables and Graphs of Results for Space Cooling Equipment ~~Cases E100-E200~~

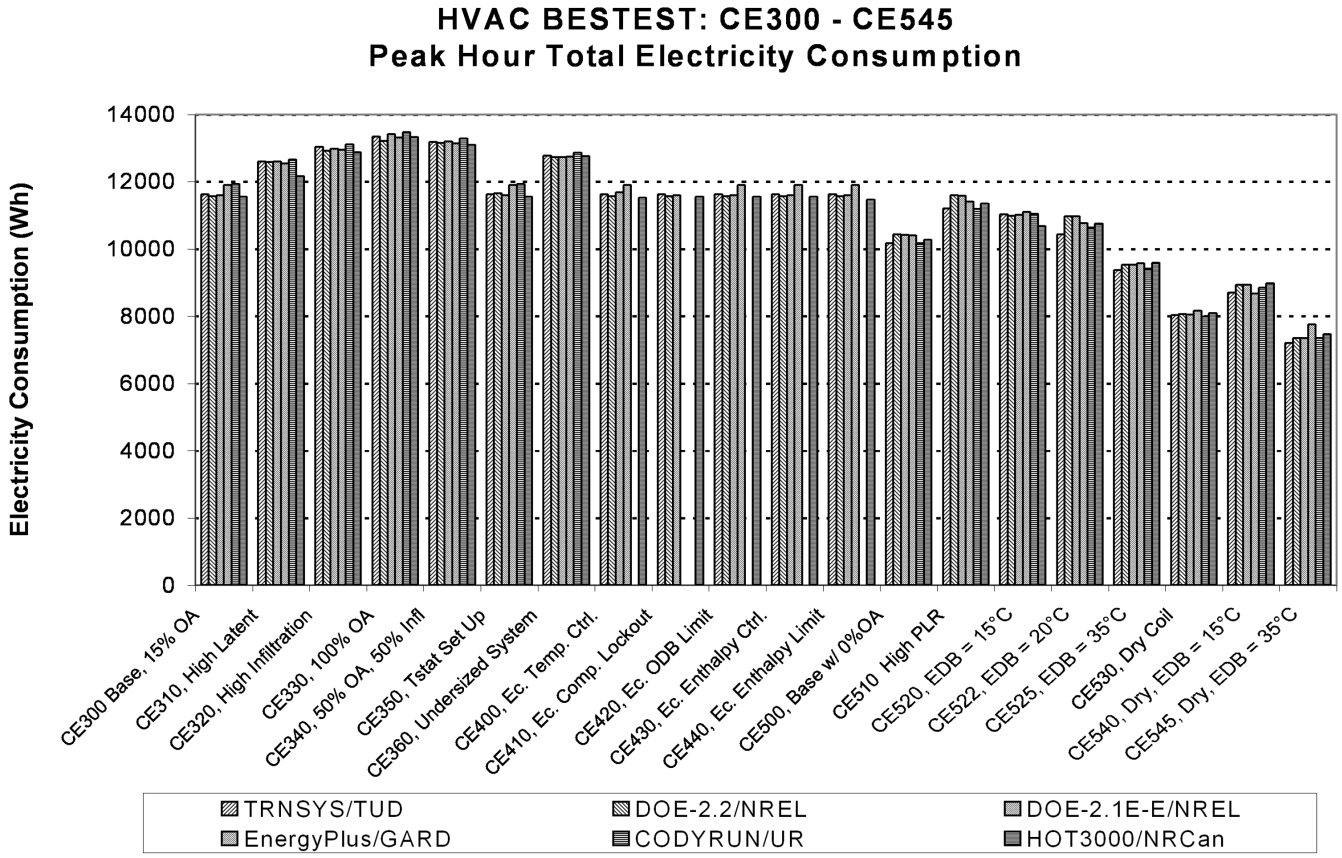
B16.5.1 Analytical Verification Test Results, Cases E100-E200

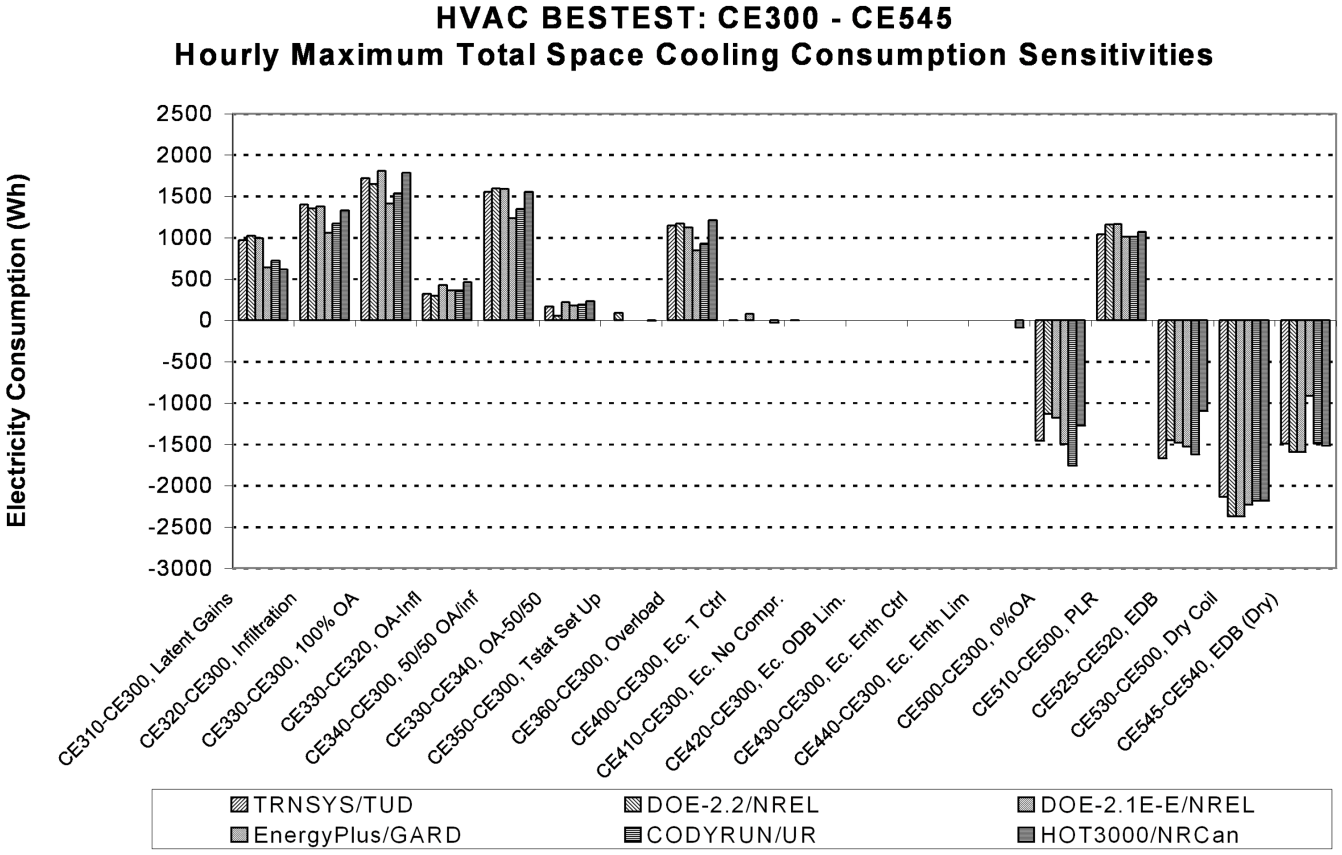
[Informative Note. These are the results currently published after Section B16.4 of Standard 140-2004 (designated as Section B16.5 of Addendum a)]

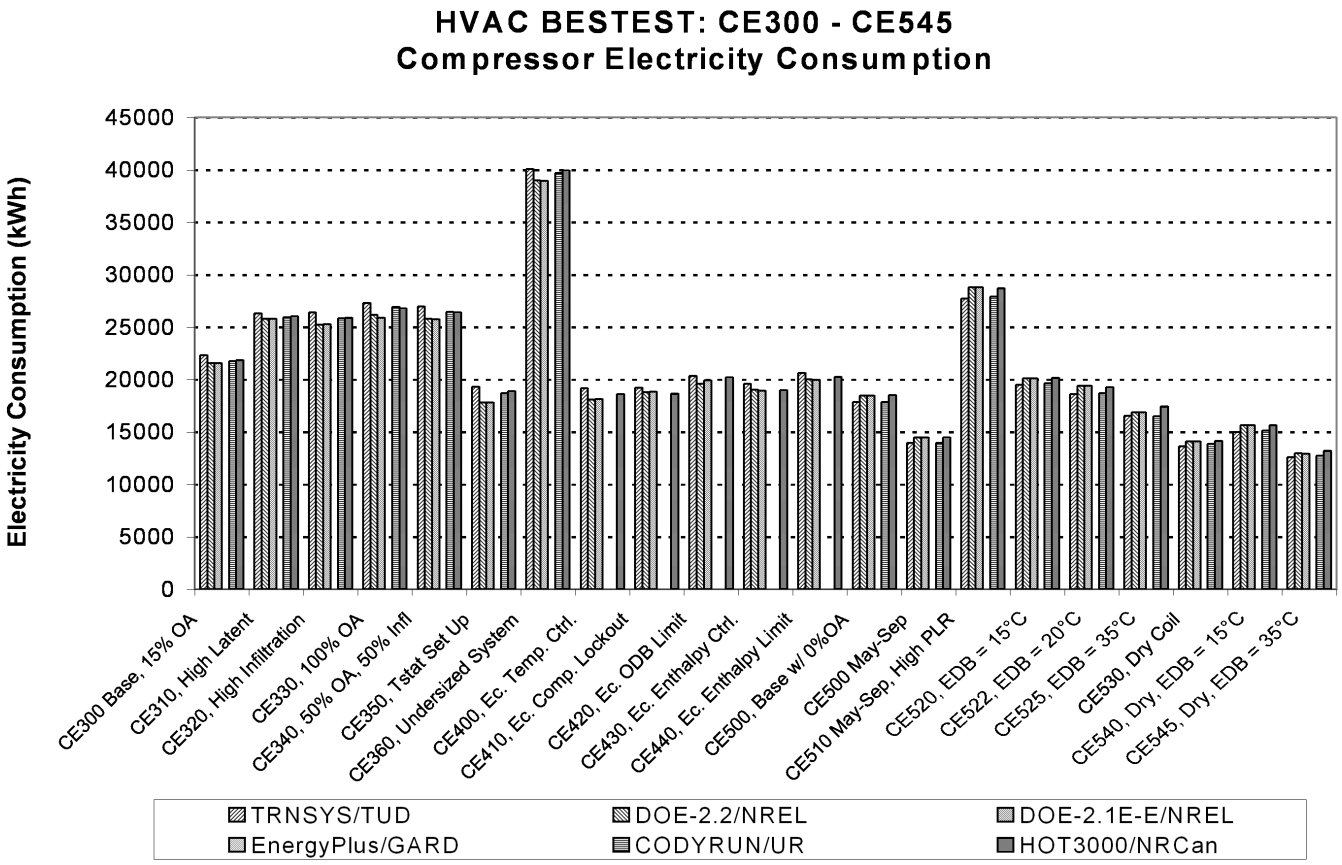
B16.5.2 Comparative Test Results, Cases CE300-CE545

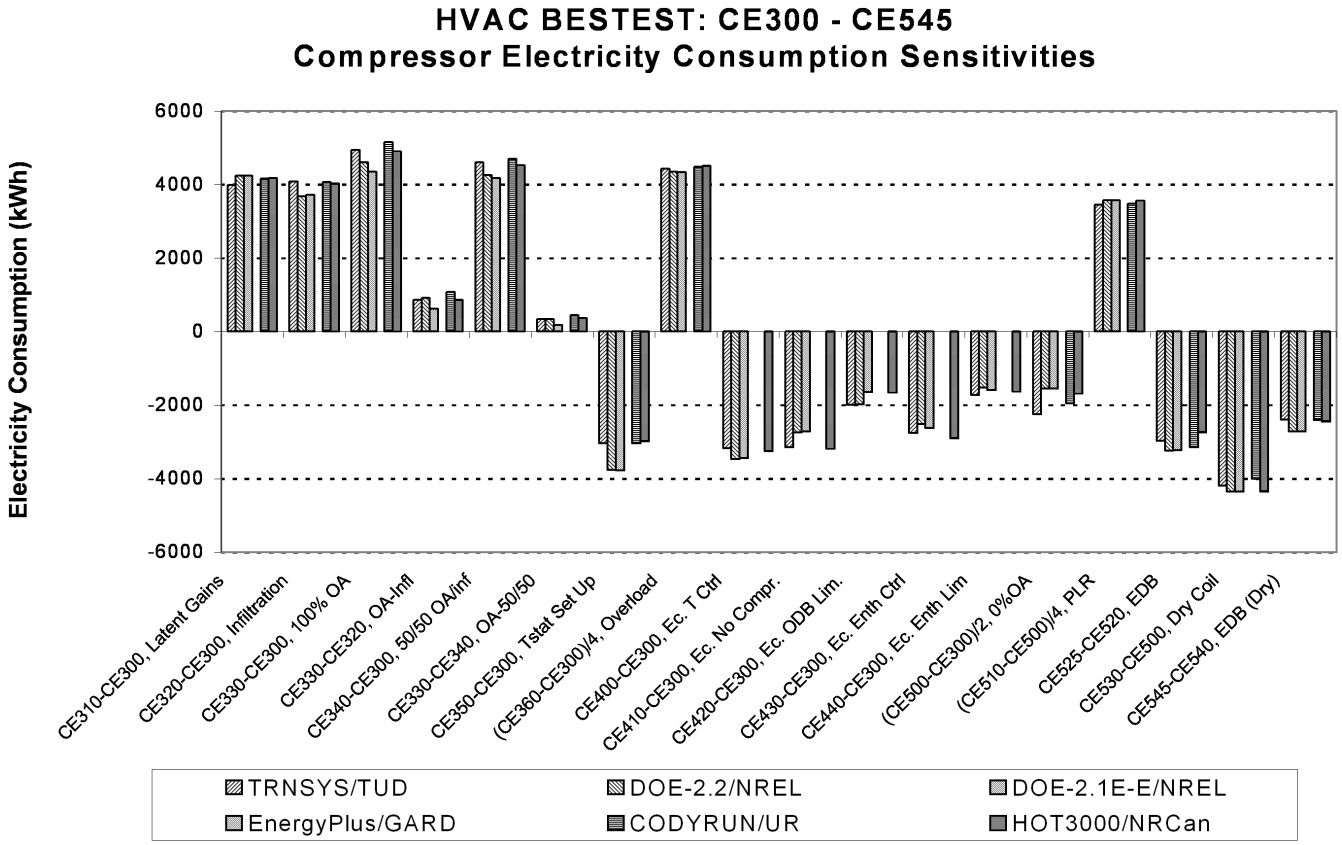

HVAC BESTEST: CE300 - CE545
Total Electricity Consumption
Electricity Consumption (kWh)
60000
50000
40000
30000
20000
10000
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE500 May-Sep
CE510 May-Sep, High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

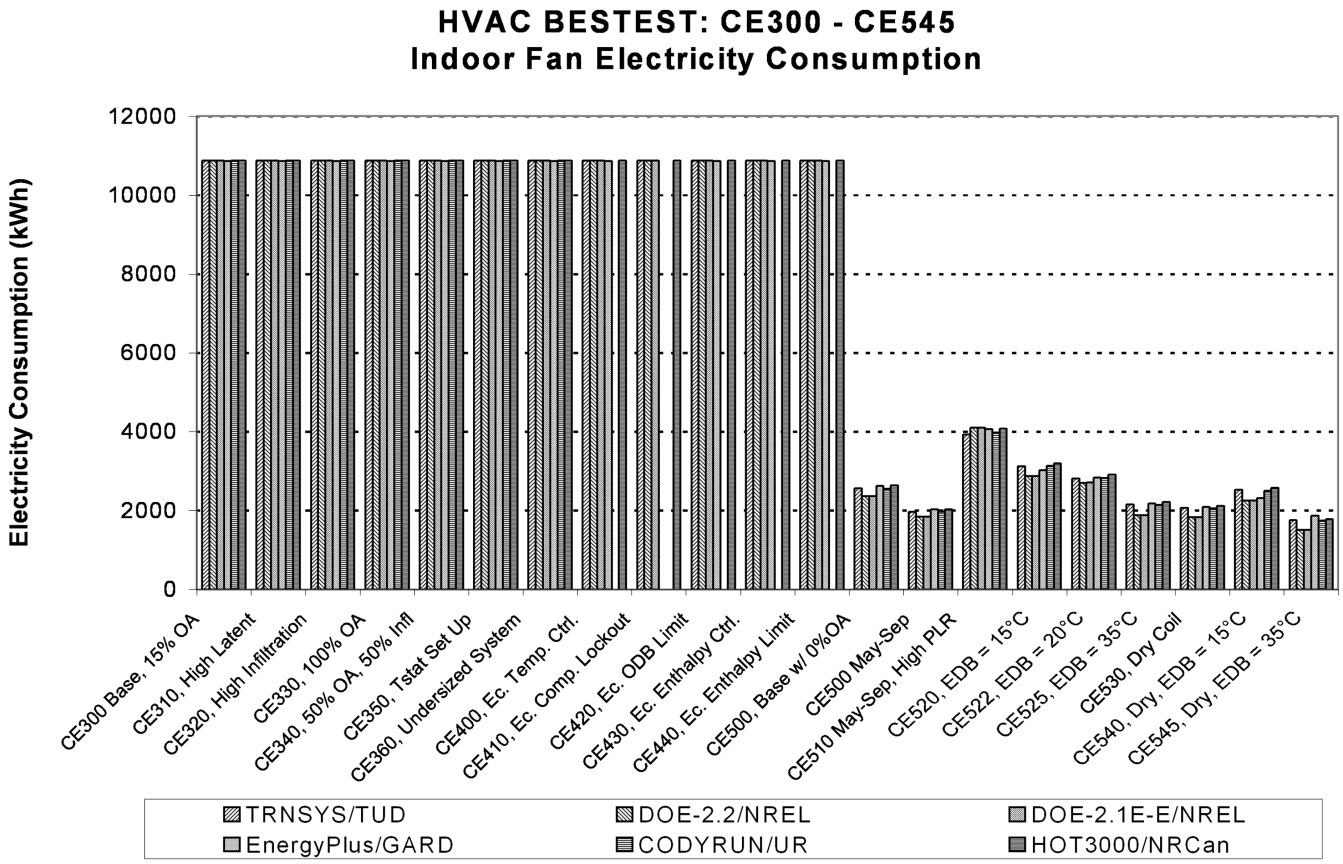

HVAC BESTEST: CE300 - CE545
Total Space Cooling Electricity Consumption Sensitivities
Electricity Consumption (kWh)
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
(CE360-CE300)/4, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
(CE500-CE300)/2, 0%OA
(CE510-CE500)/4, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

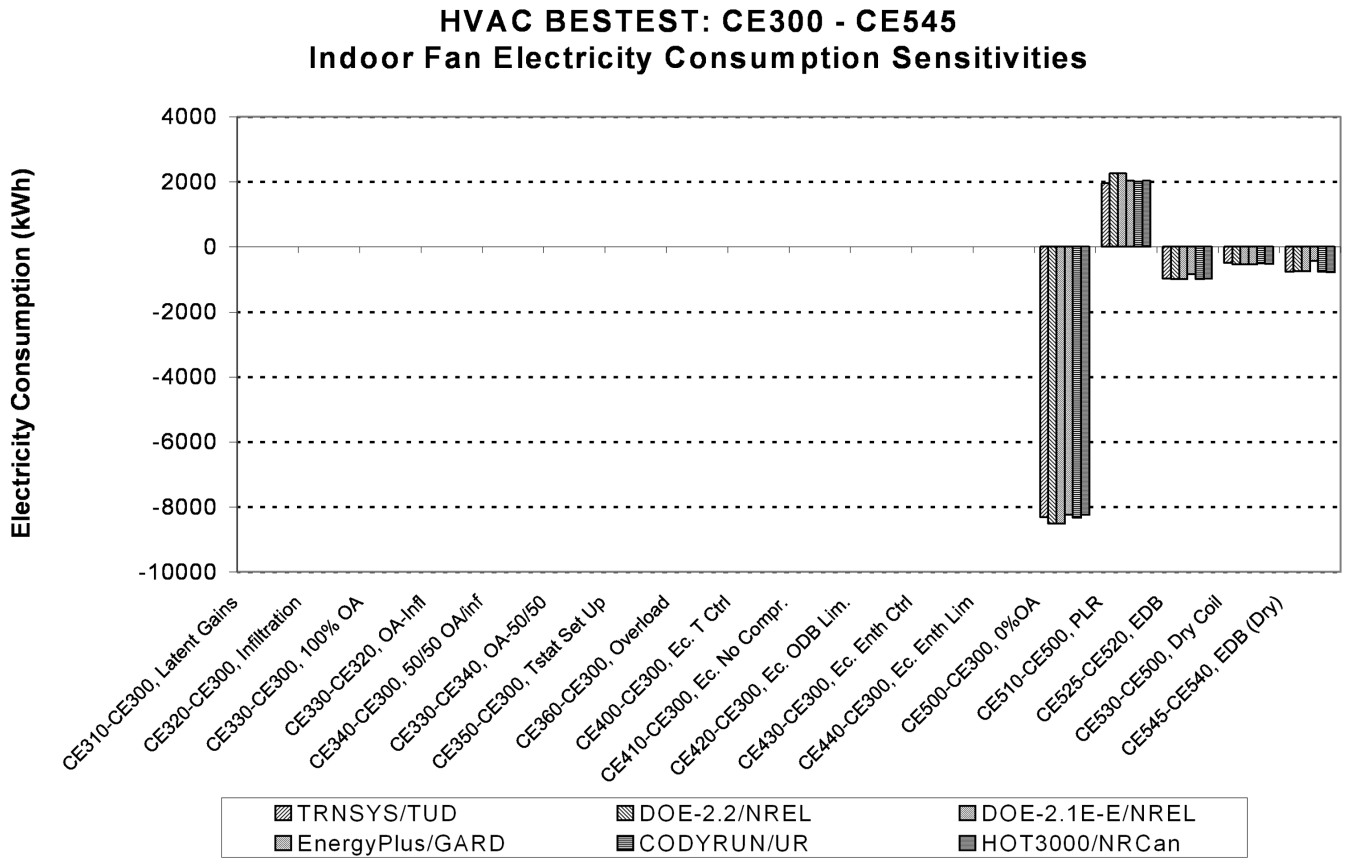

HVAC BESTEST: CE300 - CE545
Peak Hour Total Electricity Consumption
Electricity Consumption (Wh)
14000
12000
10000
8000
6000
4000
2000
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

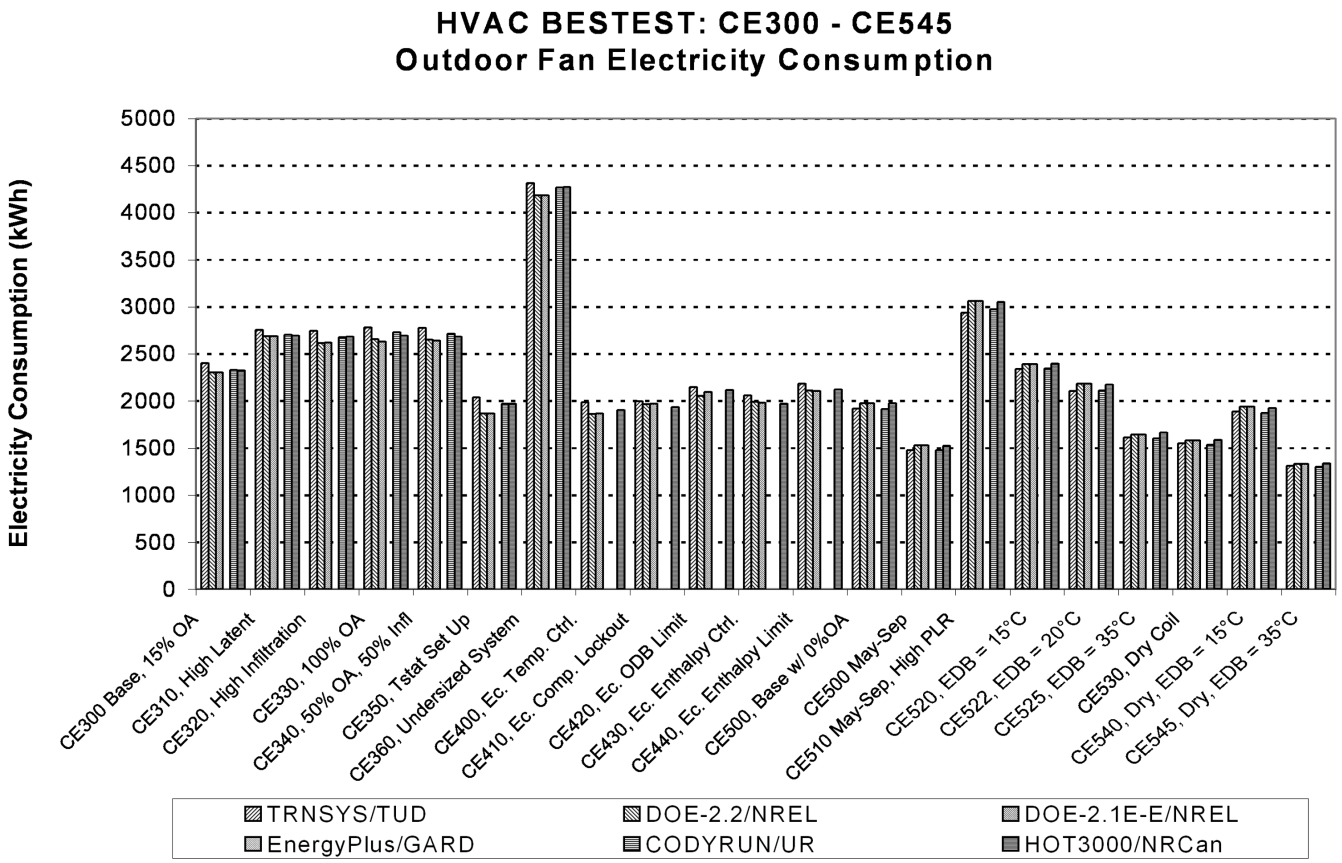

HVAC BESTEST: CE300 - CE545
Hourly Maximum Total Space Cooling Consumption Sensitivities
Electricity Consumption (Wh)
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

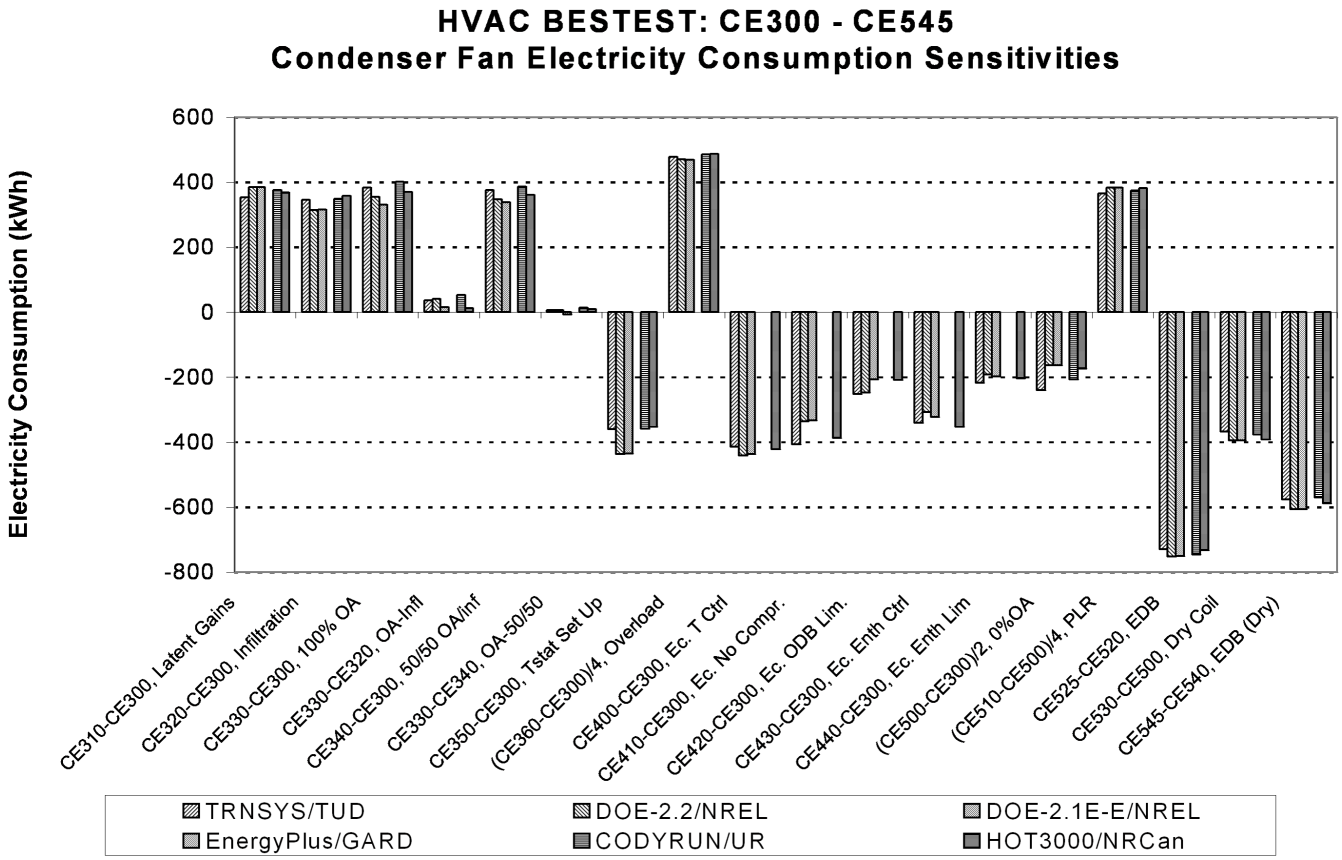

HVAC BESTEST: CE300 - CE545
Compressor Electricity Consumption
Electricity Consumption (kWh)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE500 May-Sep
CE510 May-Sep, High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

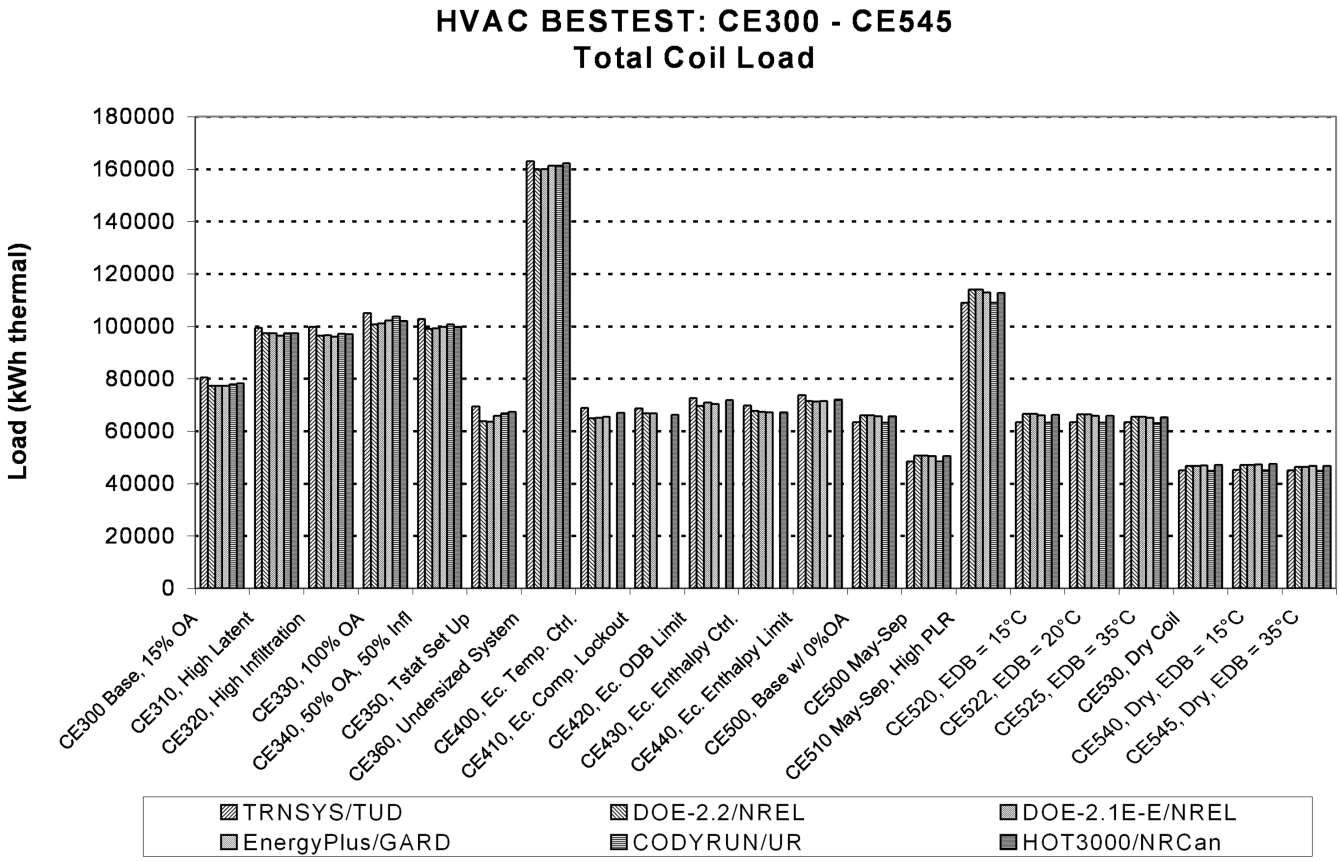

HVAC BESTEST: CE300 - CE545
Compressor Electricity Consumption Sensitivities
Electricity Consumption (kWh)
6000
4000
2000
0
-2000
-4000
-6000
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
(CE360-CE300)/4, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
(CE500-CE300)/2, 0%OA
(CE510-CE500)/4, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

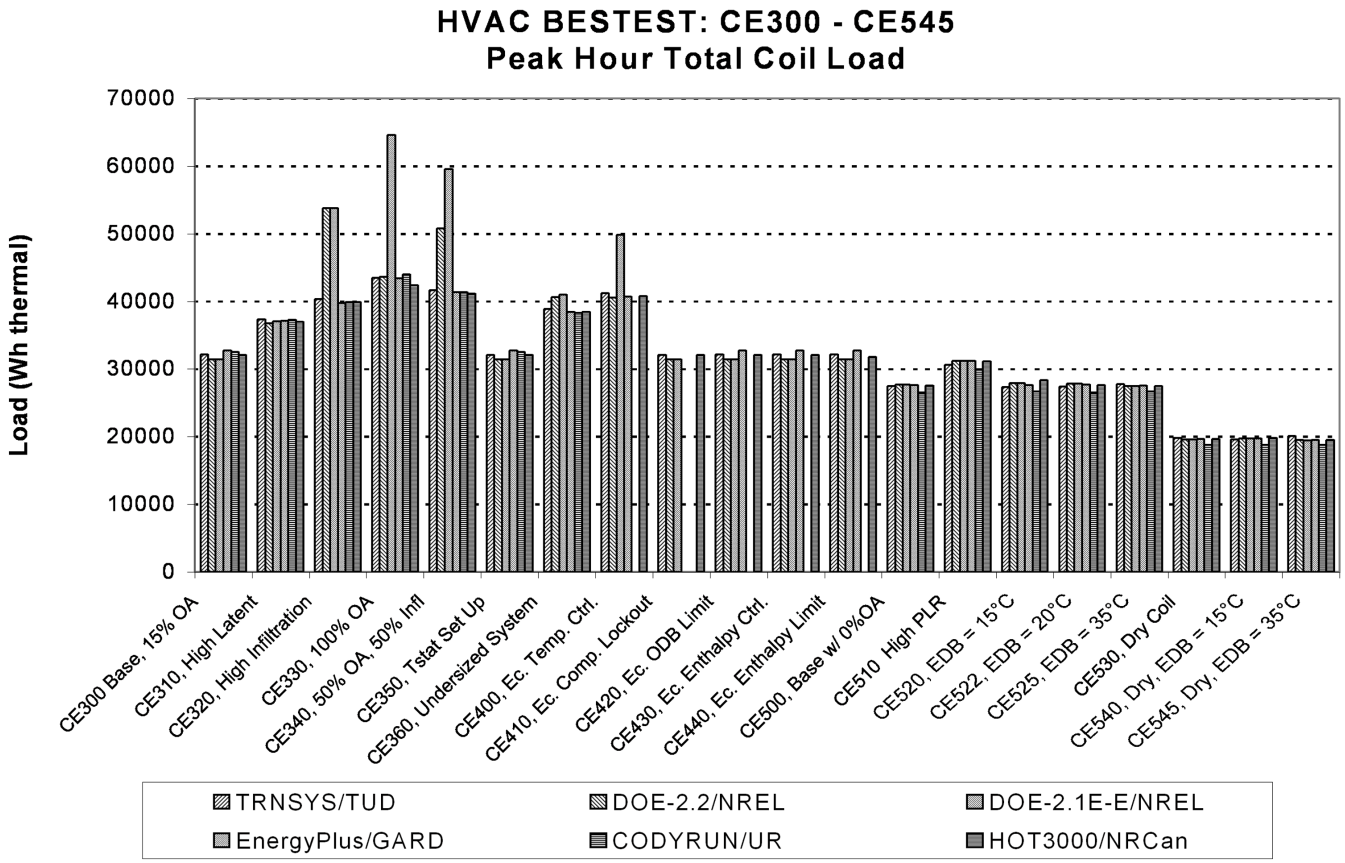

HVAC BESTEST: CE300 - CE545
Indoor Fan Electricity Consumption
Electricity Consumption (kWh)
12000
10000
8000
6000
4000
2000
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE500 May-Sep
CE510 May-Sep, High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

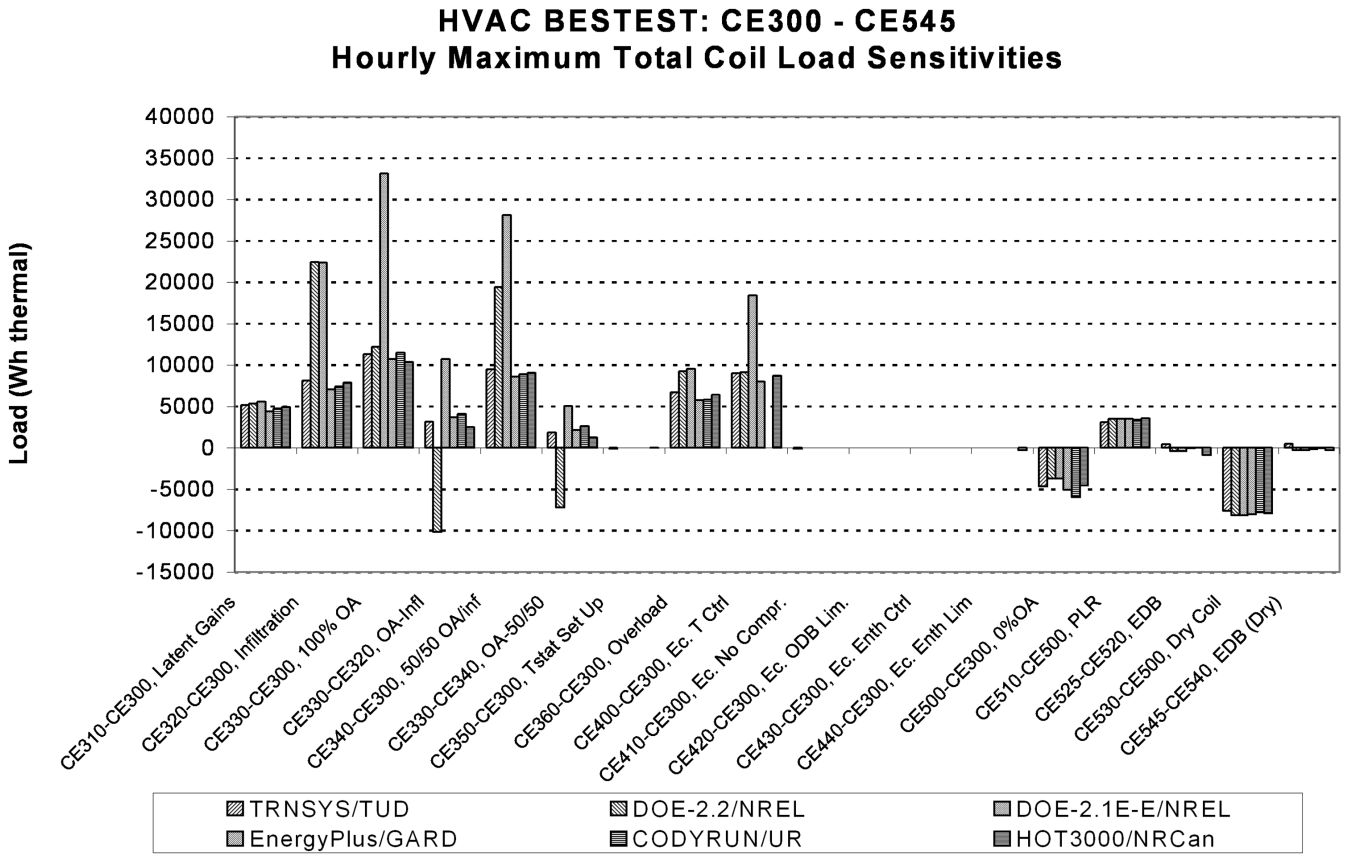

HVAC BESTEST: CE300 - CE545
Indoor Fan Electricity Consumption Sensitivities
Electricity Consumption (kWh)
4000
2000
0
-2000
-4000
-6000
-8000
-10000
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

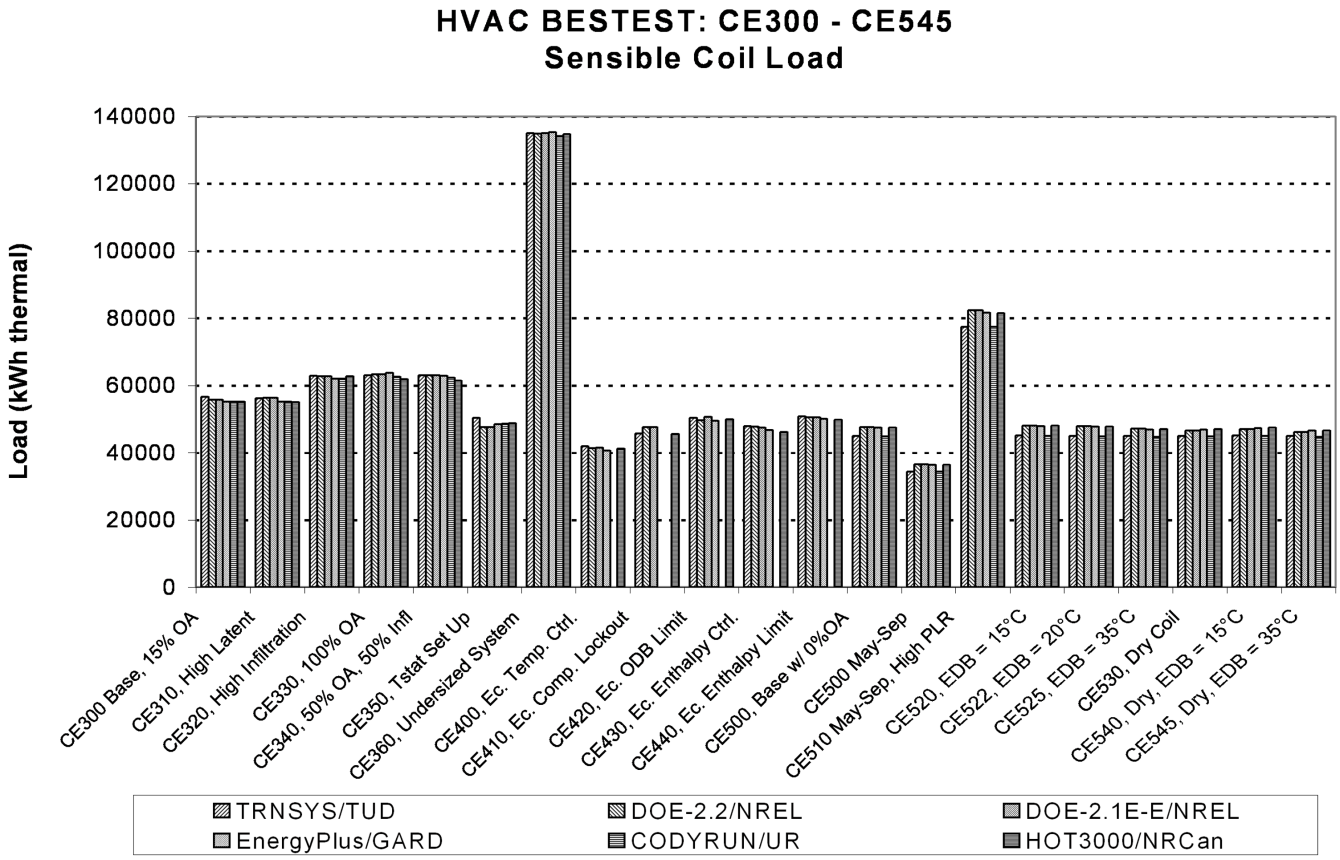

HVAC BESTEST: CE300 - CE545
Outdoor Fan Electricity Consumption
Electricity Consumption (kWh)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE500 May-Sep
CE510 May-Sep, High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

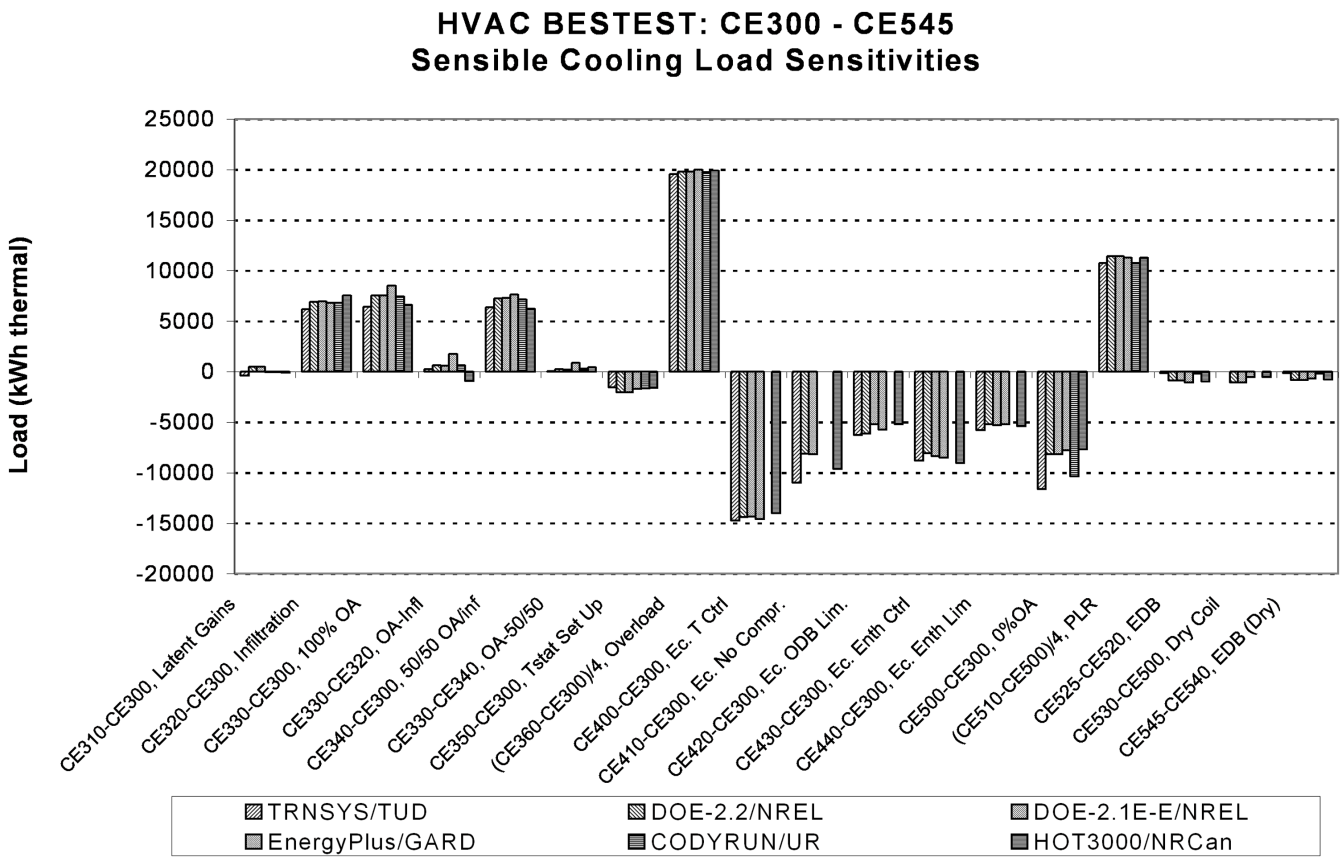

HVAC BESTEST: CE300 - CE545
Condenser Fan Electricity Consumption Sensitivities
Electricity Consumption (kWh)
600
400
200
0
-200
-400
-600
-800
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
(CE360-CE300)/4, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
(CE500-CE300)/2, 0%OA
(CE510-CE500)/4, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

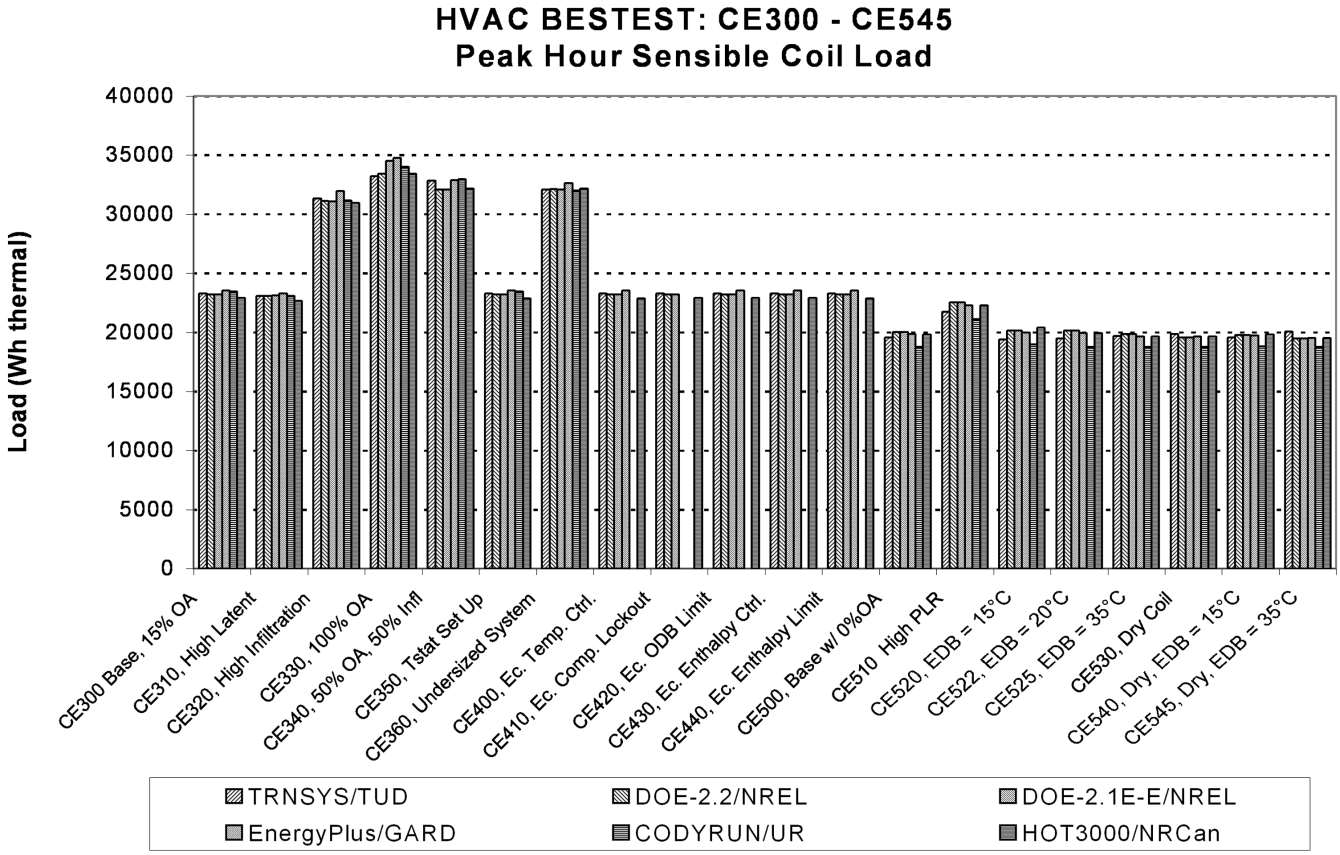

HVAC BESTEST: CE300 - CE545
Total Coil Load
Load (kWh thermal)
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE500 May-Sep
CE510 May-Sep, High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

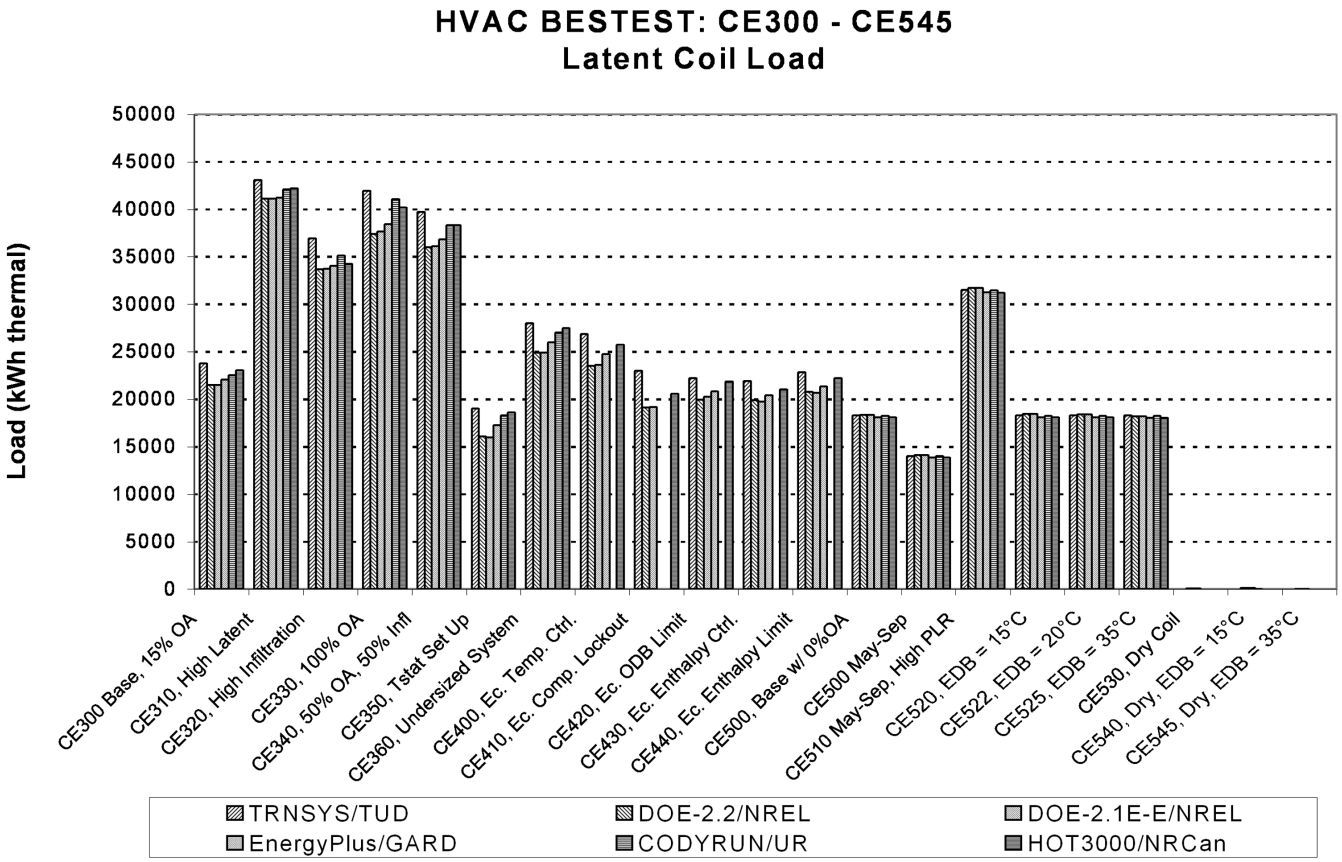

HVAC BESTEST: CE300 - CE545
Peak Hour Total Coil Load
Load (Wh thermal)
70000
60000
50000
40000
30000
20000
10000
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

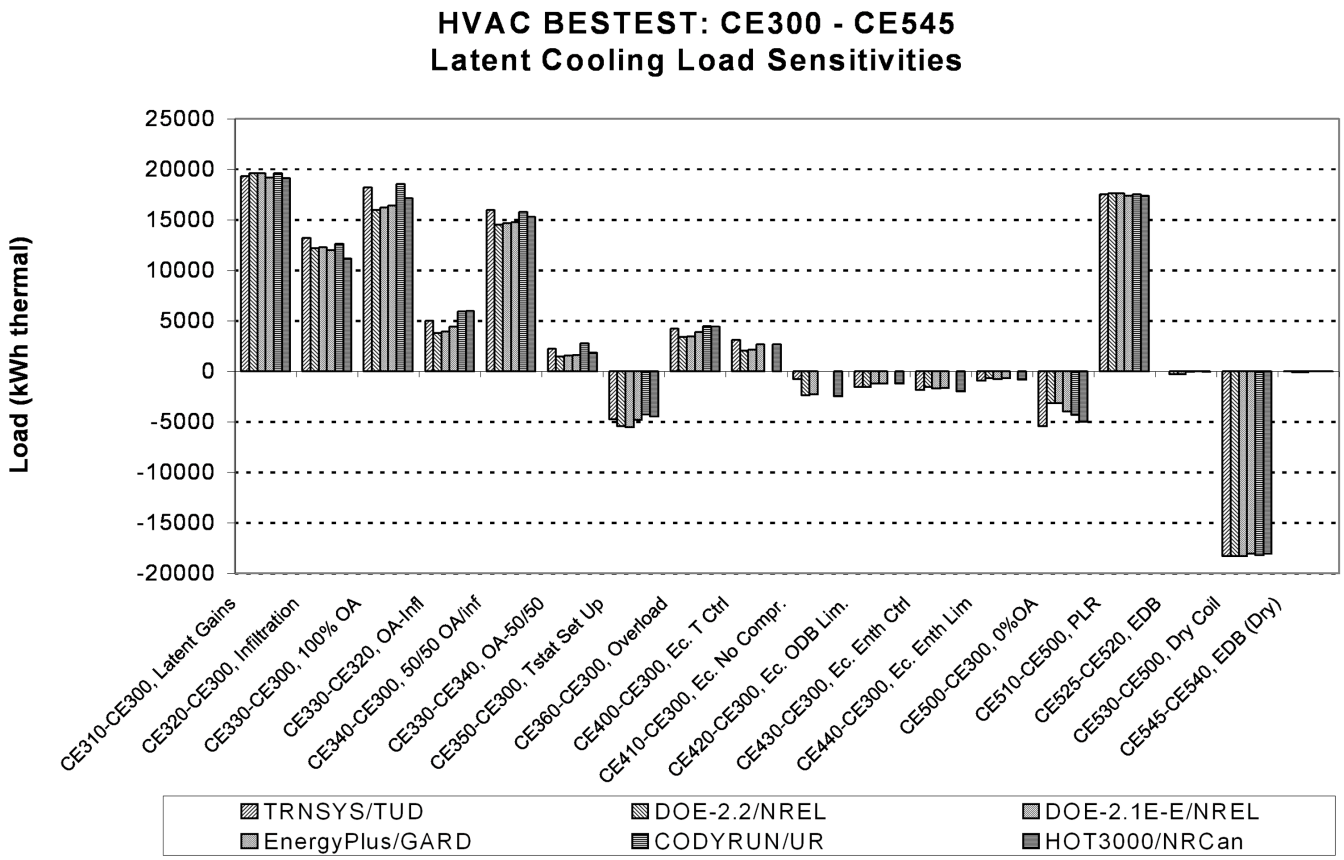

HVAC BESTEST: CE300 - CE545
Hourly Maximum Total Coil Load Sensitivities
Load (Wh thermal)
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
-10000
-15000
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/Inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

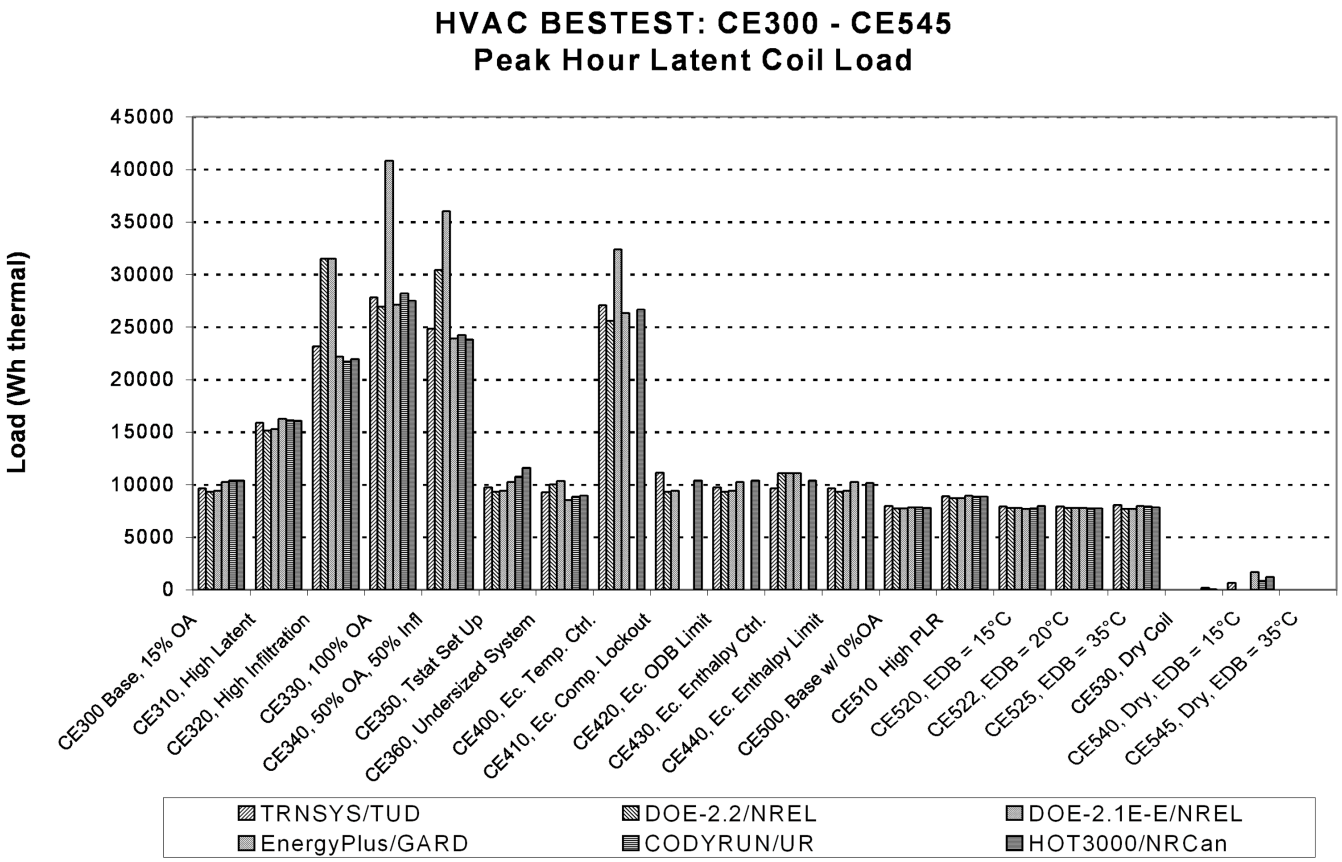

HVAC BESTEST: CE300 - CE545
Sensible Coil Load
Load (kWh thermal)
140000
120000
100000
80000
60000
40000
20000
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE500 May-Sep
CE510 May-Sep, High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

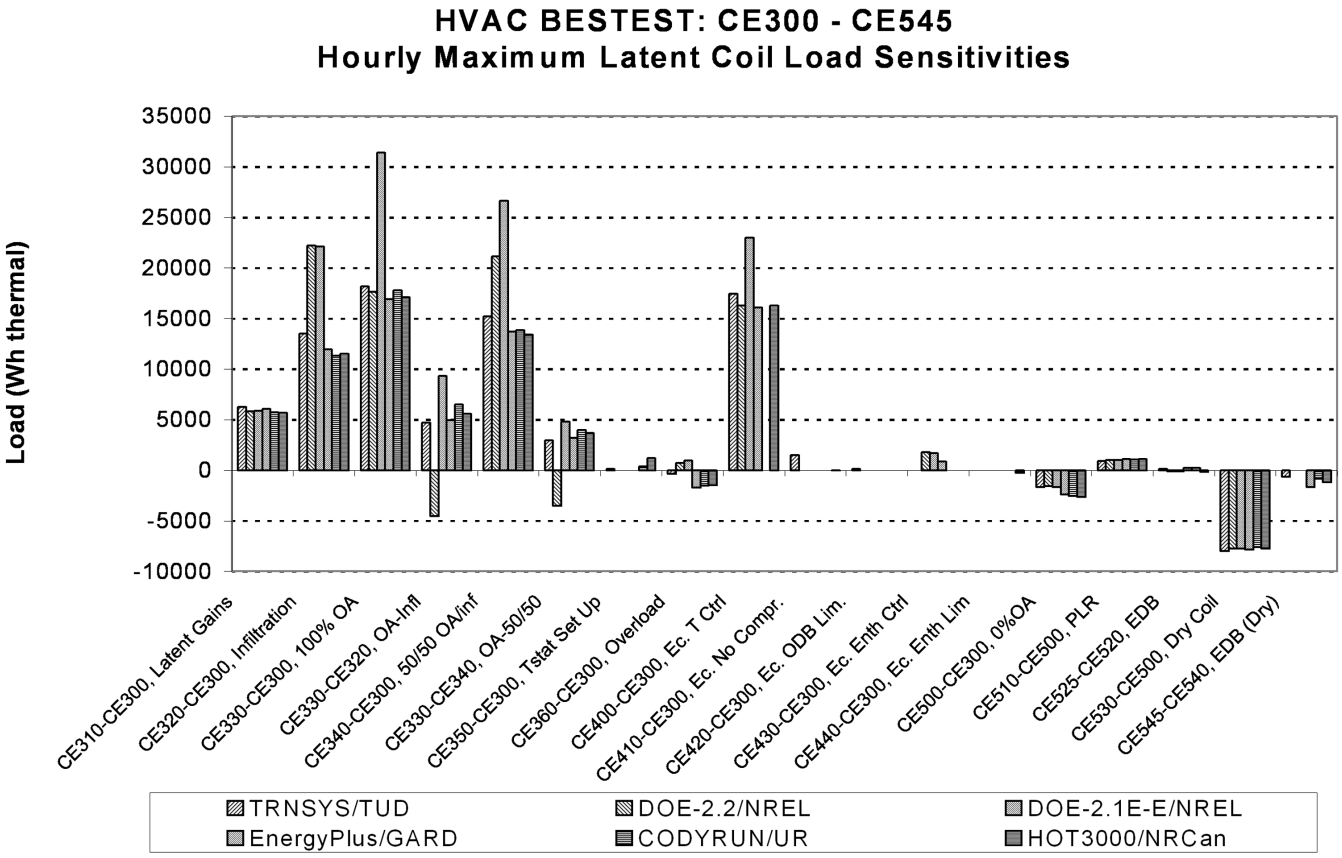

HVAC BESTEST: CE300 - CE545
Sensible Cooling Load Sensitivities
Load (kWh thermal)
25000
20000
15000
10000
5000
0
-5000
-10000
-15000
-20000
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
(CE360-CE300)/4, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
(CE510-CE500)/4, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

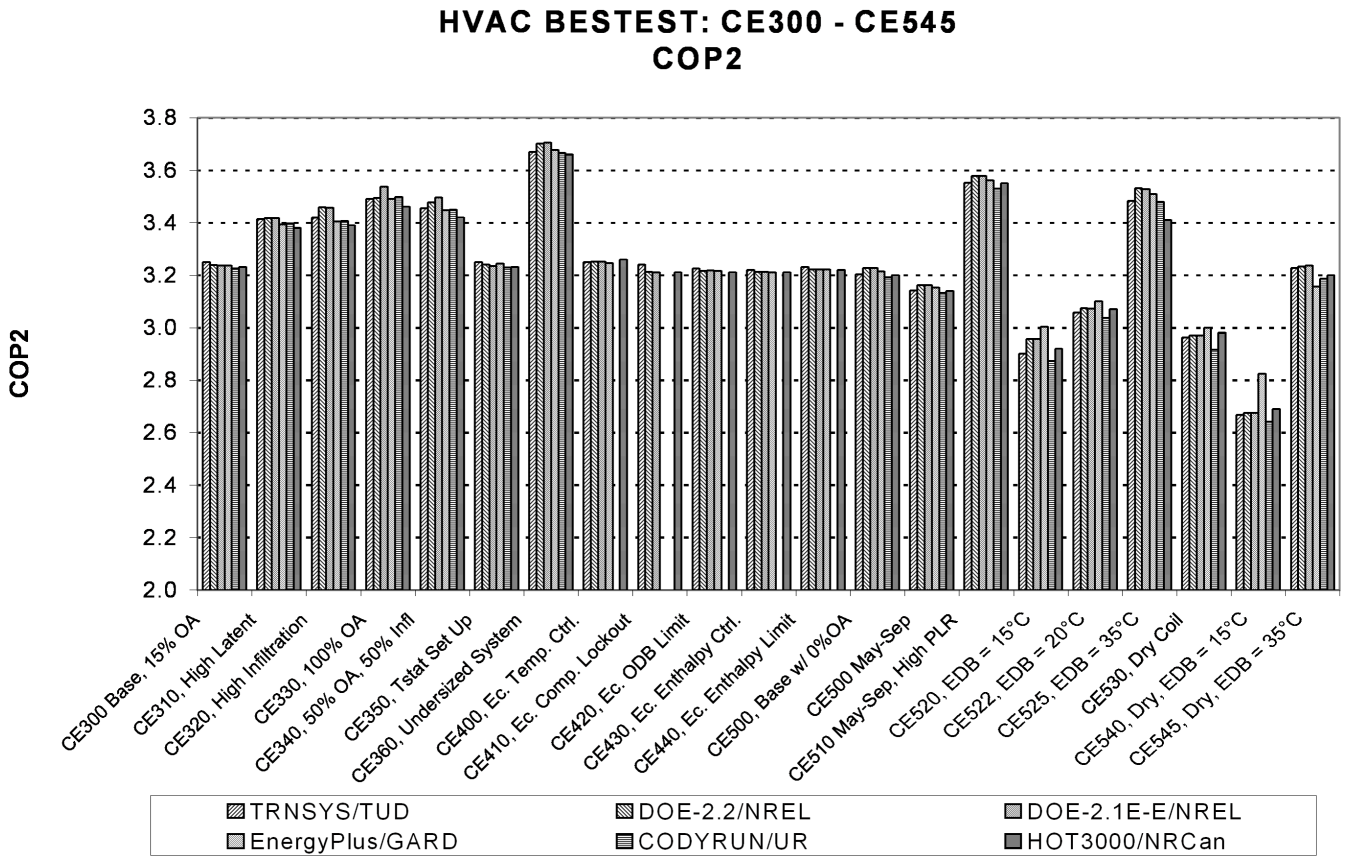

HVAC BESTEST: CE300 - CE545
Peak Hour Sensible Coil Load
Load (Wh thermal)
40000
35000
30000
25000
20000
15000
10000
5000
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

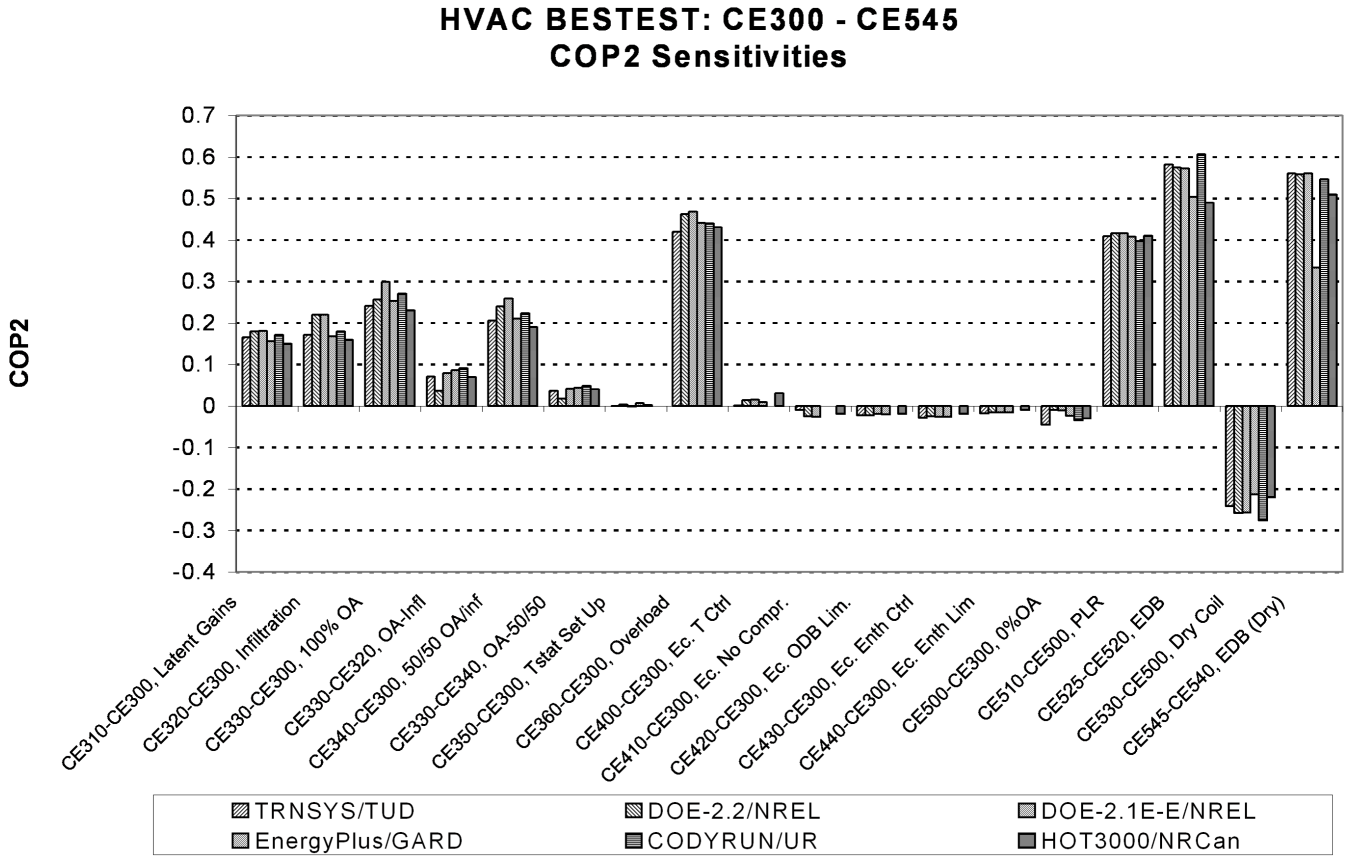

HVAC BESTEST: CE300 - CE545
Latent Coil Load
Load (kWh thermal)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE500 May-Sep
CE510 May-Sep, High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

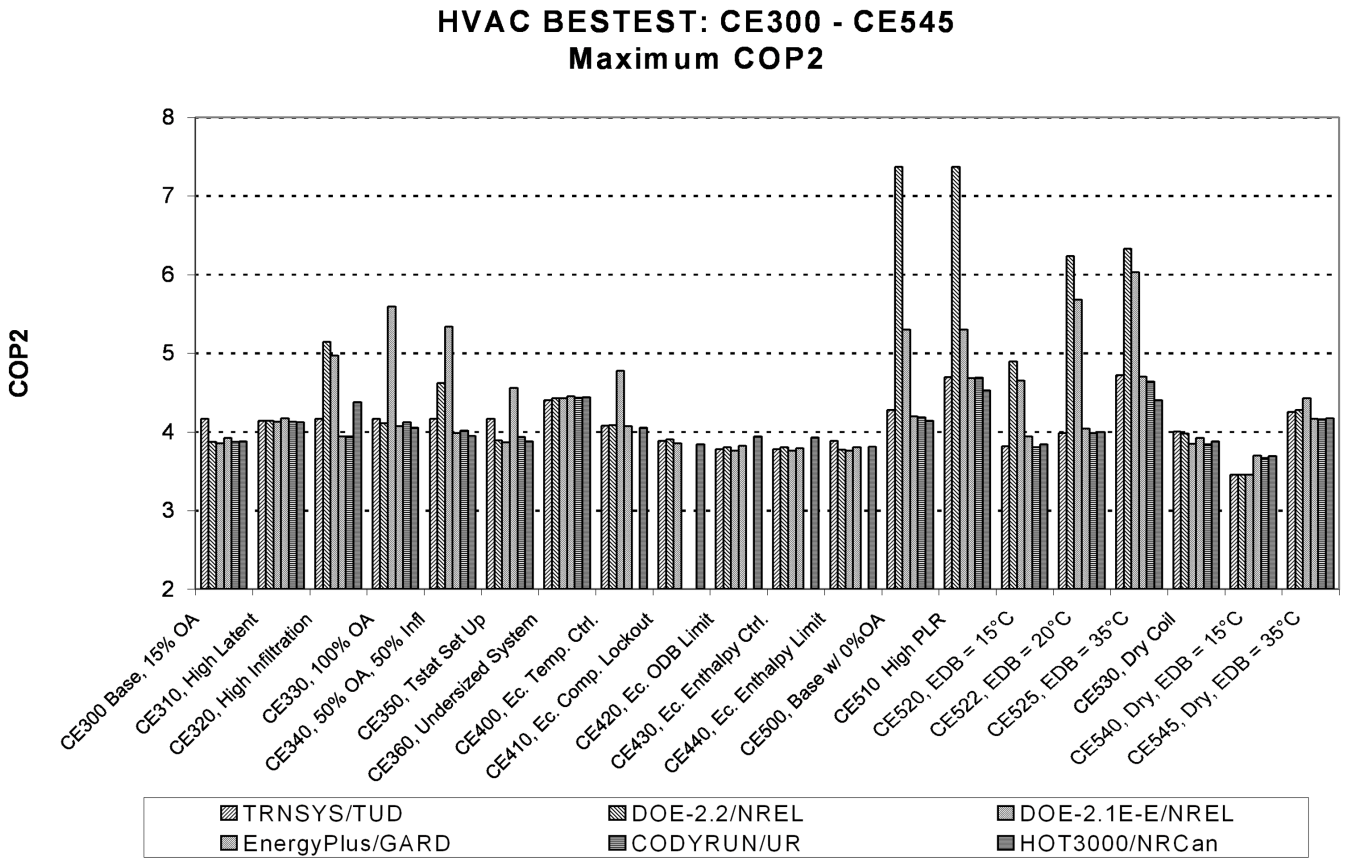

HVAC BESTEST: CE300 - CE545
Latent Cooling Load Sensitivities
Load (kWh thermal)
25000
20000
15000
10000
5000
0
-5000
-10000
-15000
-20000
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

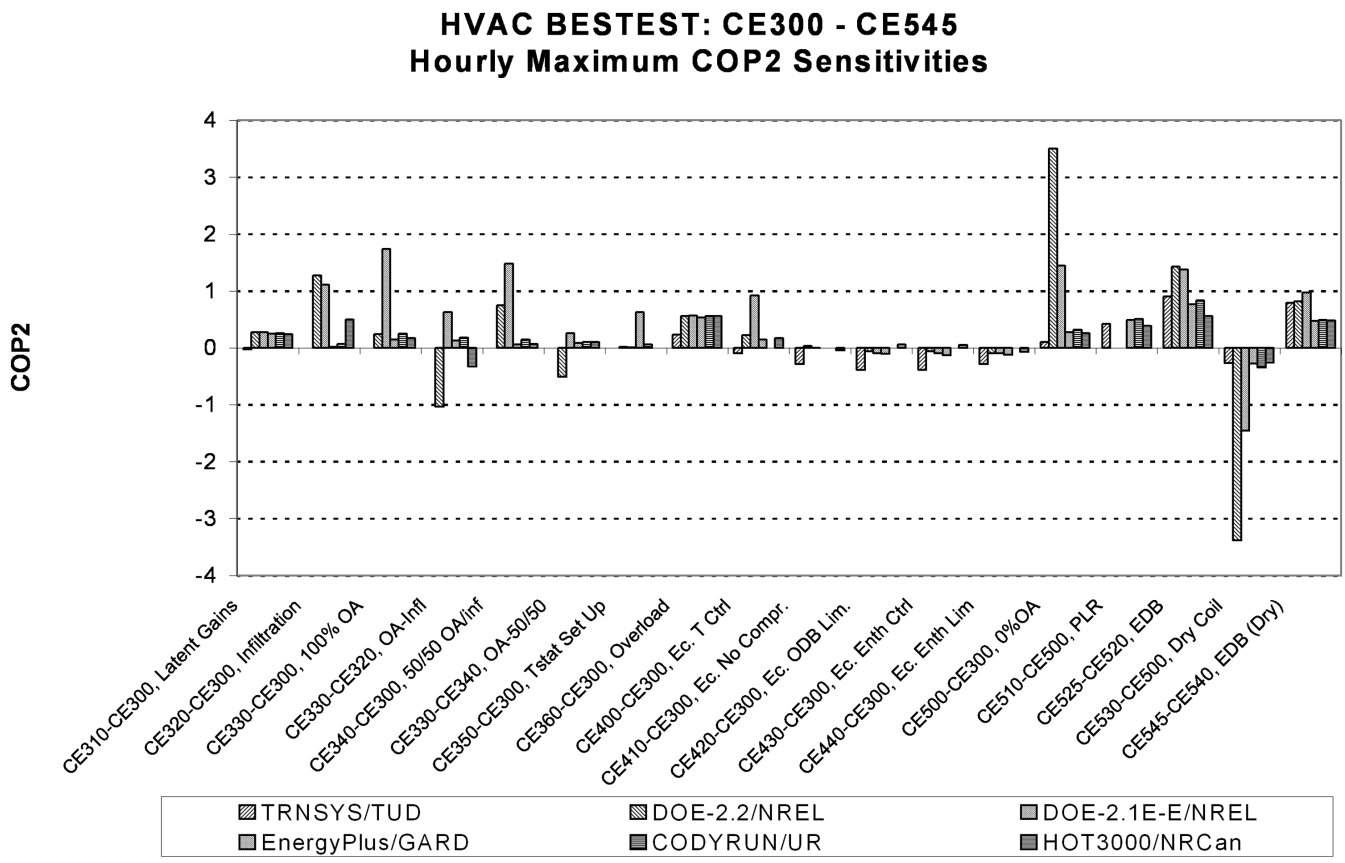

HVAC BESTEST: CE300 - CE545
Peak Hour Latent Coil Load
Load (Wh thermal)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

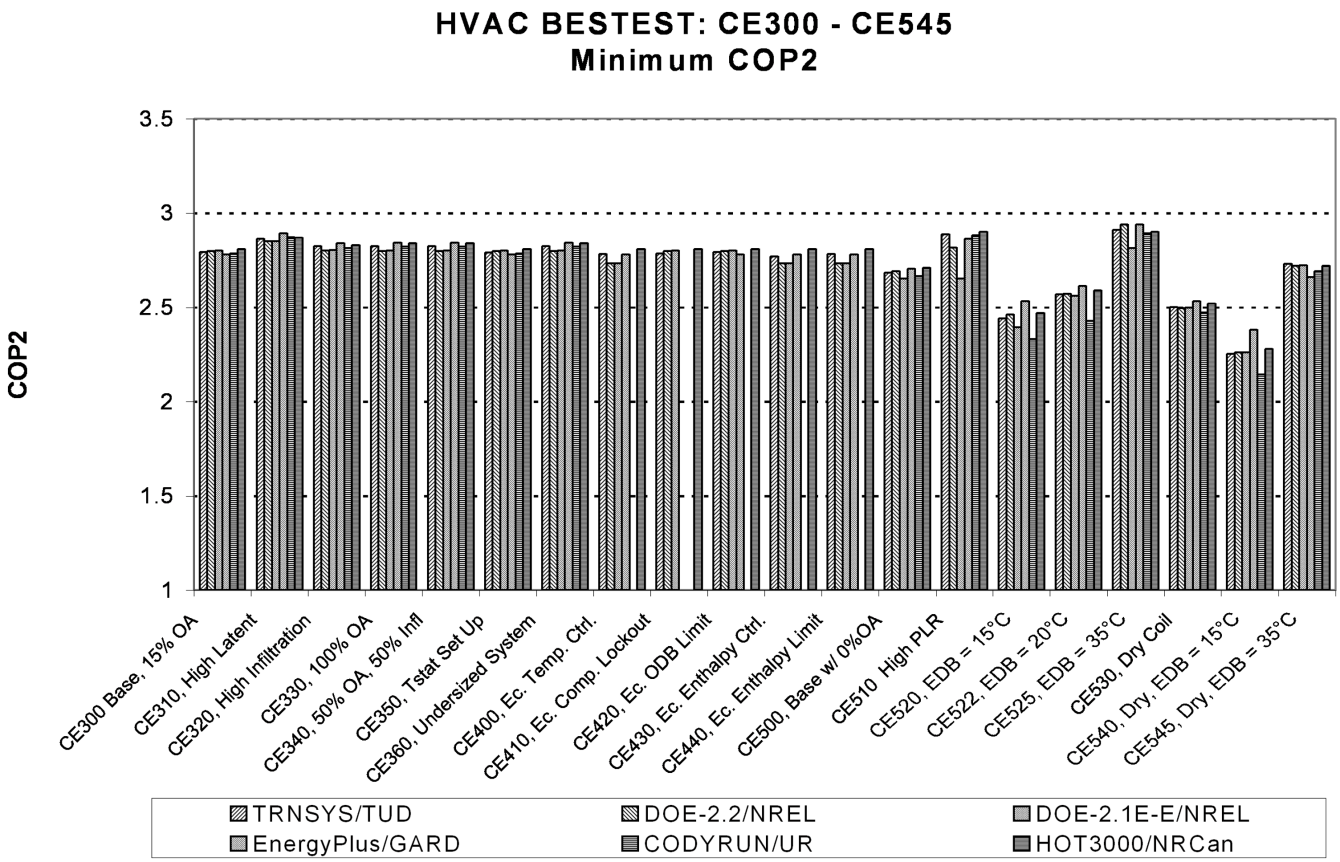

HVAC BESTEST: CE300 - CE545
Hourly Maximum Latent Coil Load Sensitivities
Load (Wh thermal)
35000
30000
25000
20000
15000
10000
5000
0
-5000
-10000
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/Inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

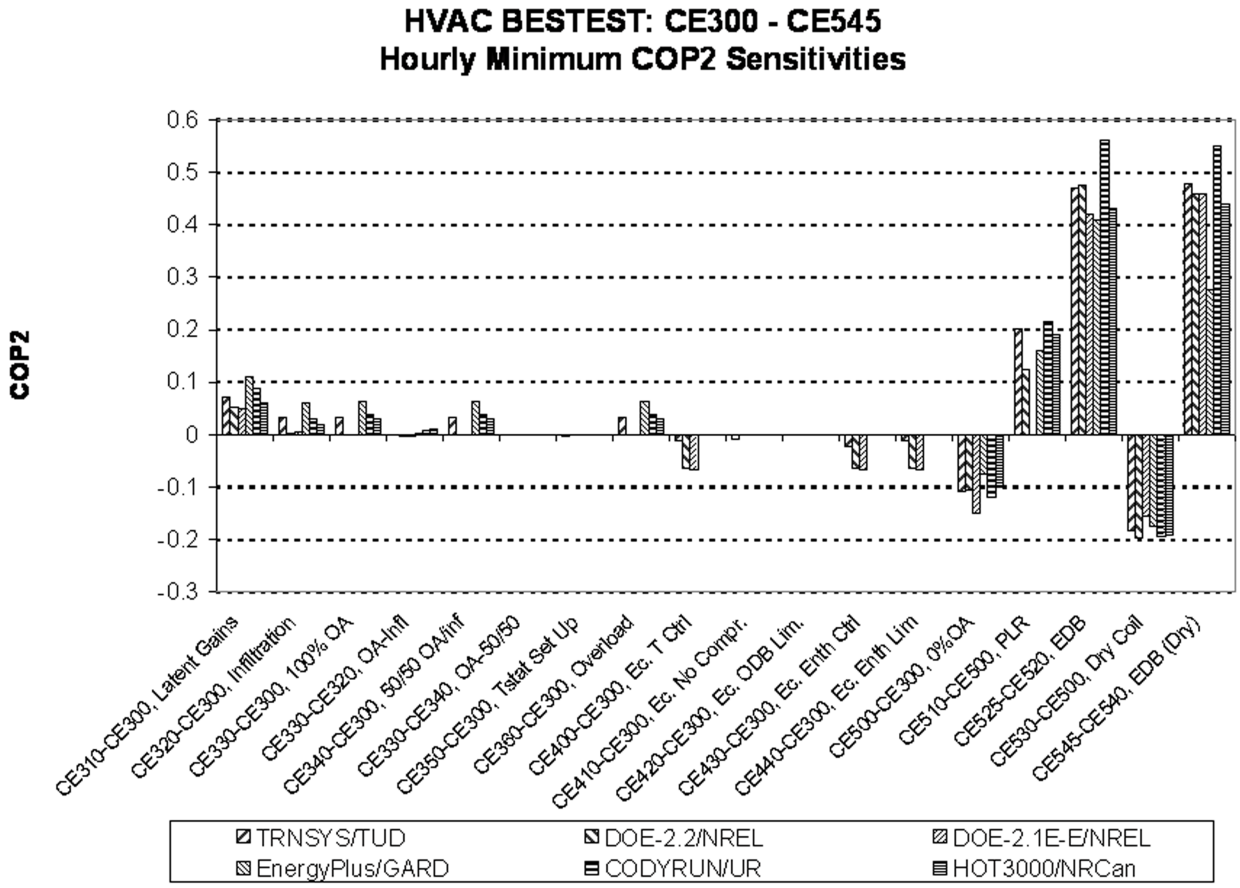

HVAC BESTEST: CE300 - CE545
COP2
COP2
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE500 May-Sep
CE510 May-Sep, High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

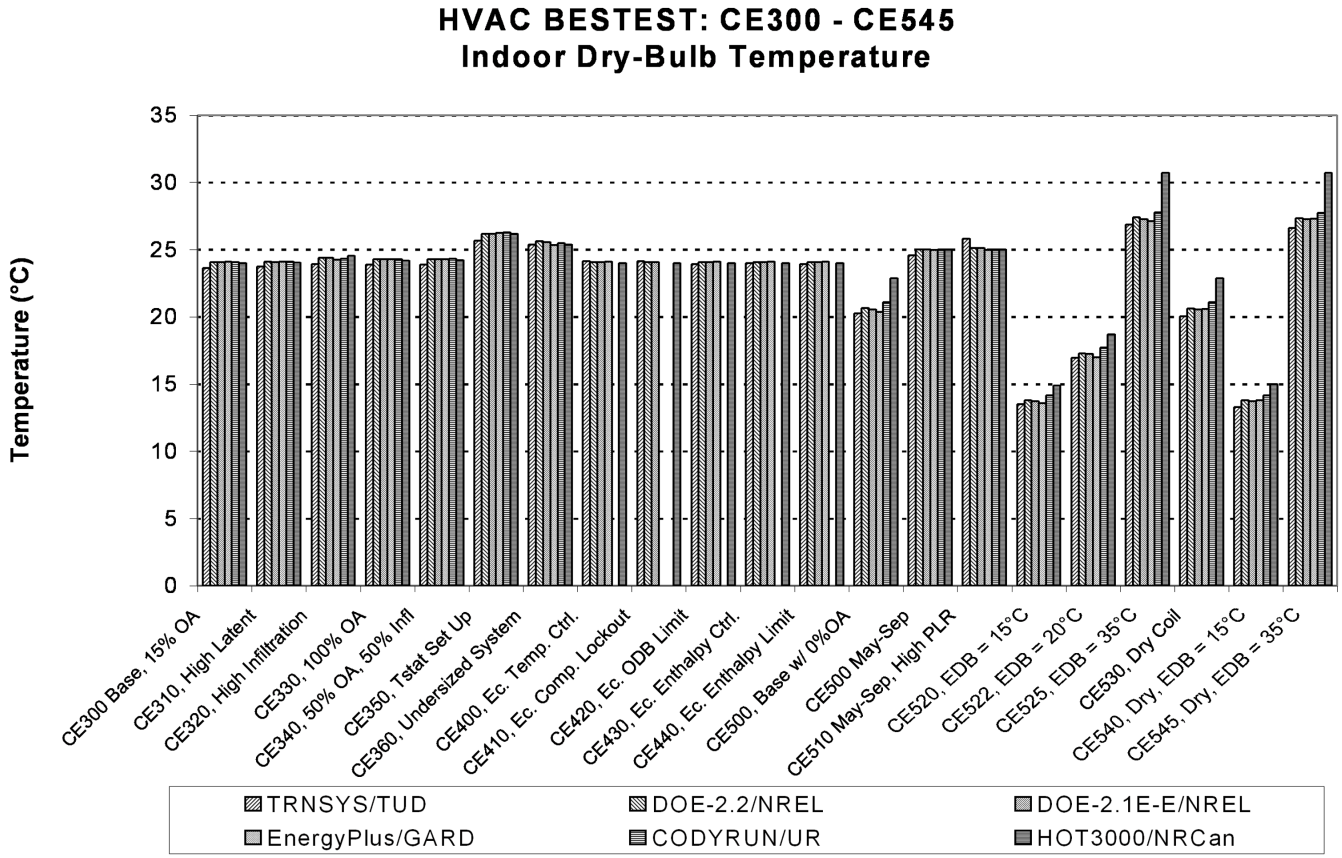

HVAC BESTEST: CE300 - CE545
COP2 Sensitivities
COP2
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

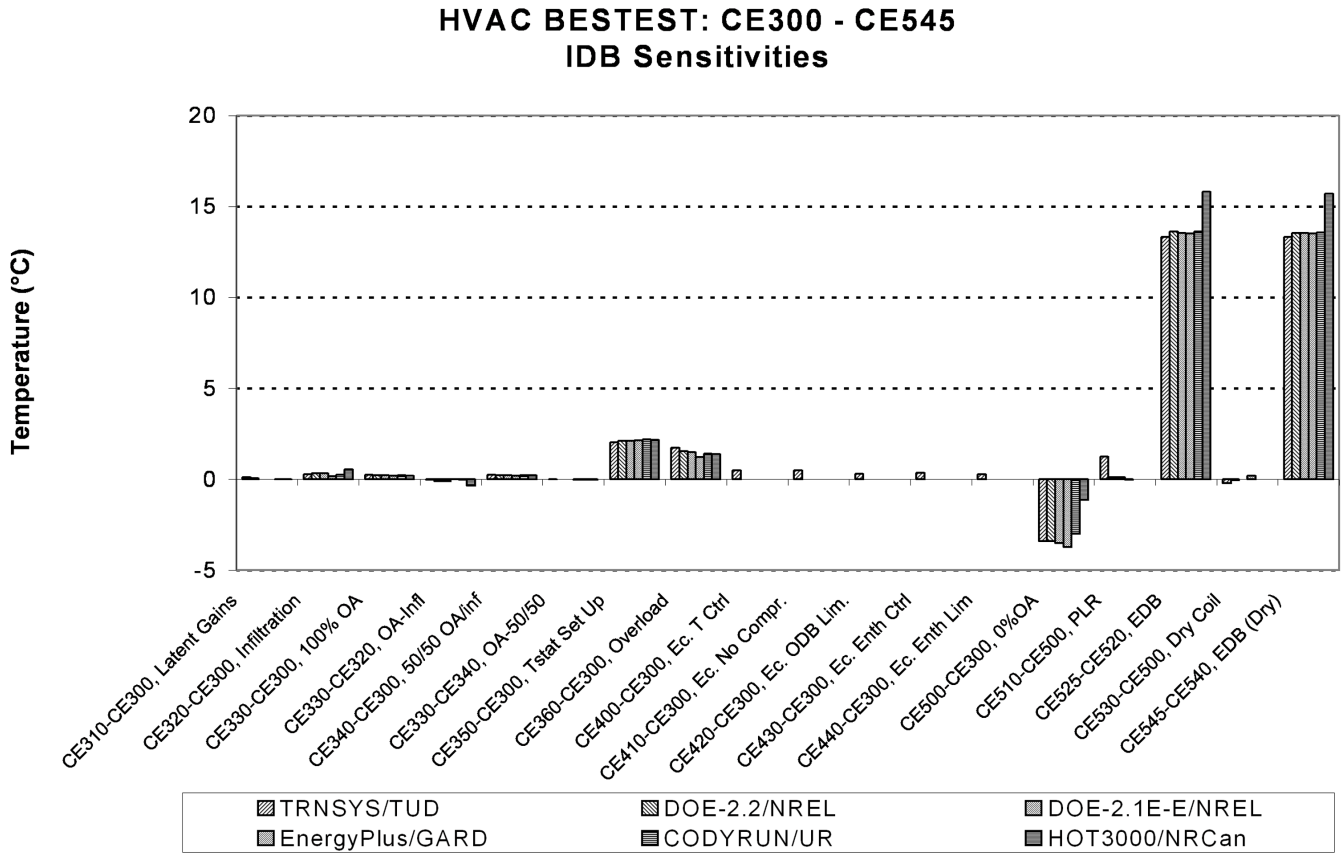

HVAC BESTEST: CE300 - CE545
Maximum COP2
COP2
8
7
6
5
4
3
2
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

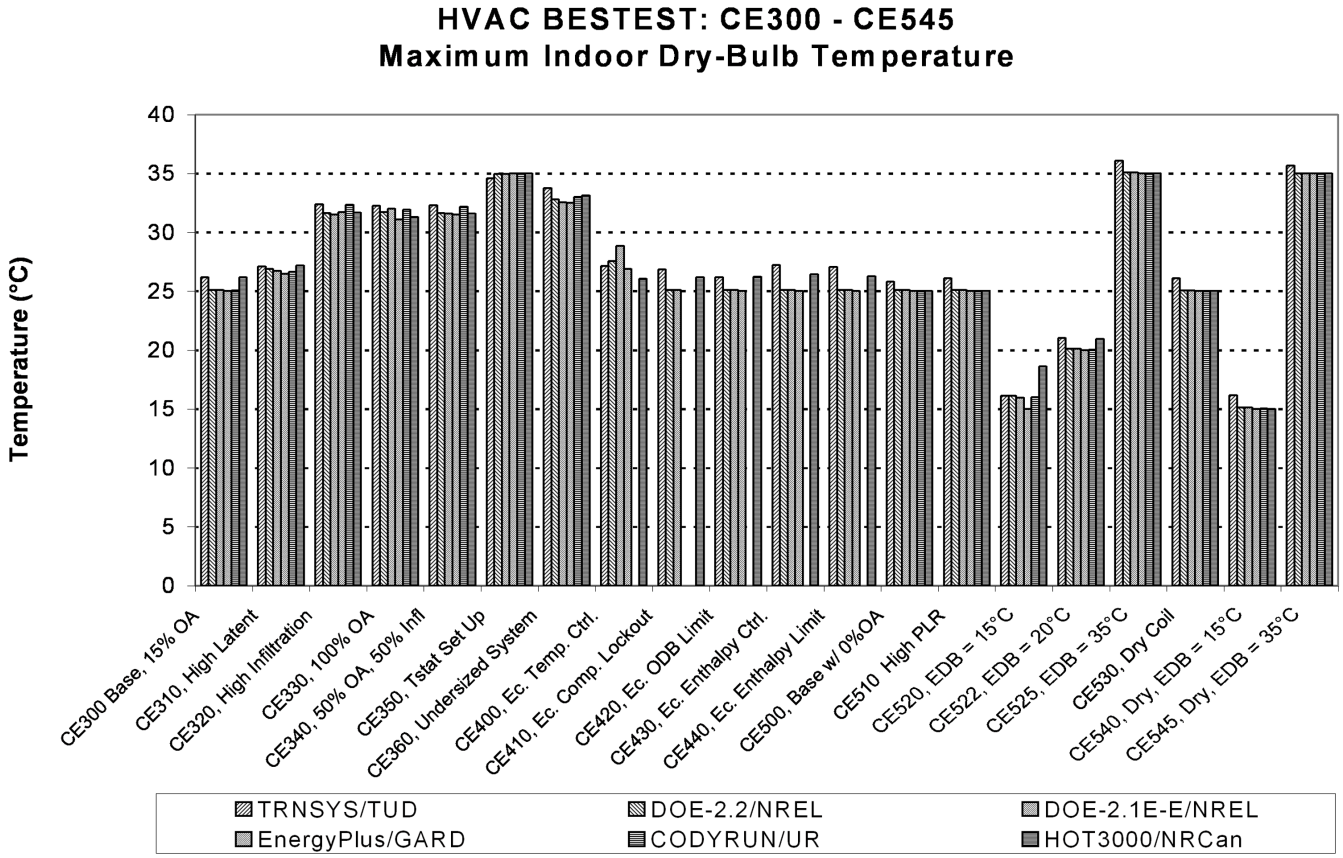

HVAC BESTEST: CE300 - CE545
Hourly Maximum COP2 Sensitivities
COP2
4
3
2
1
0
-1
-2
-3
-4
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/Inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

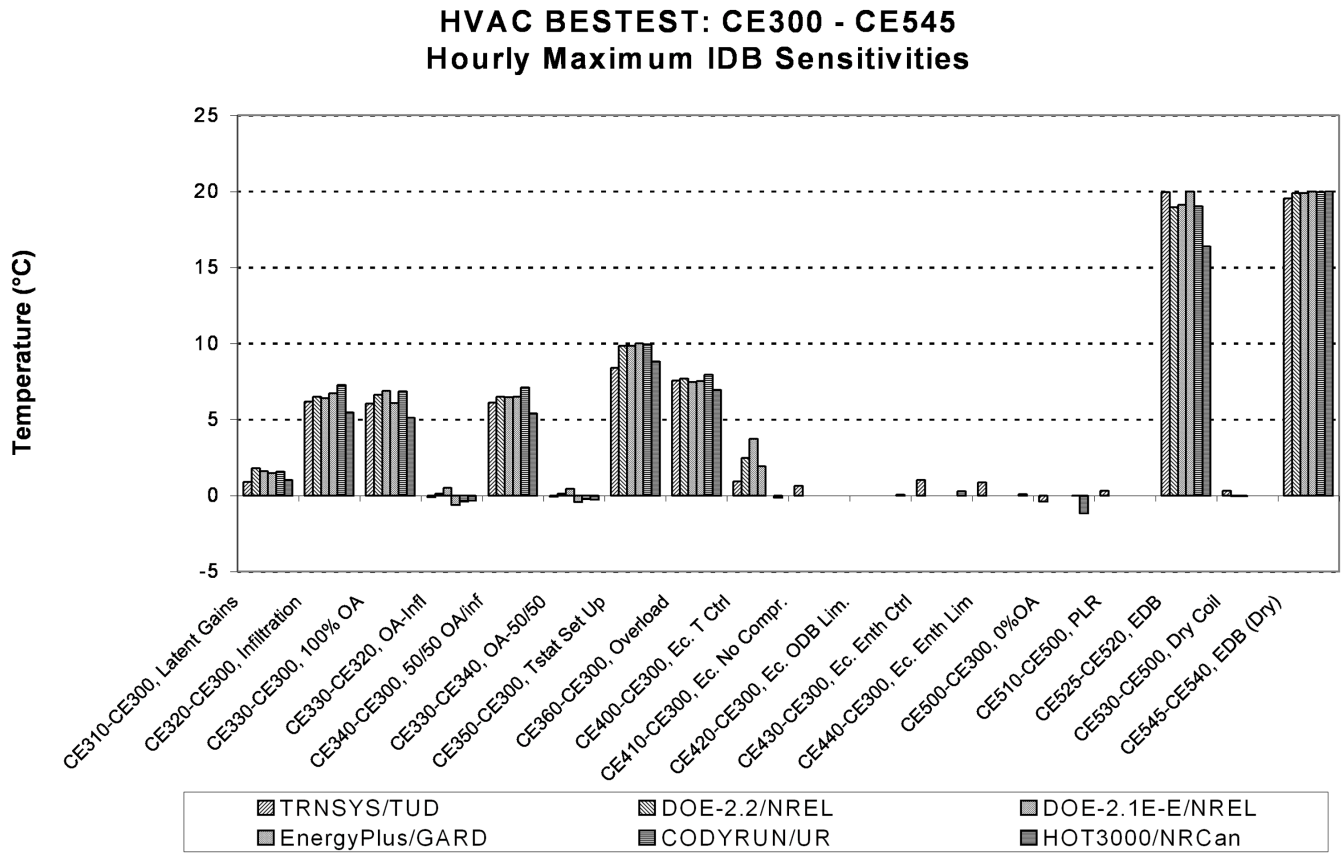

HVAC BESTEST: CE300 - CE545
Minimum COP2
COP2
3.5
3
2.5
2
1.5
1
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

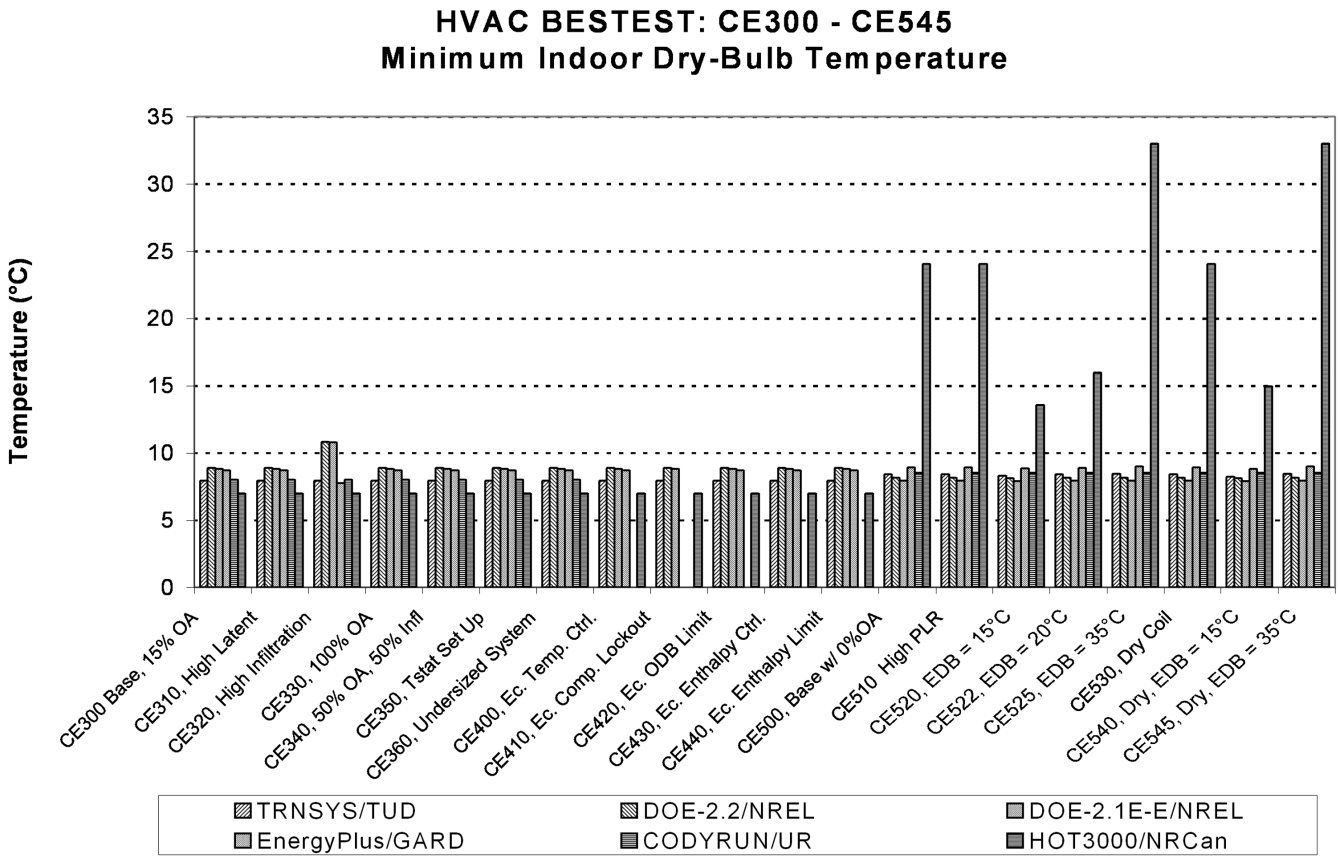

HVAC BESTEST: CE300 - CE545
Hourly Minimum COP2 Sensitivities
COP2
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/Inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

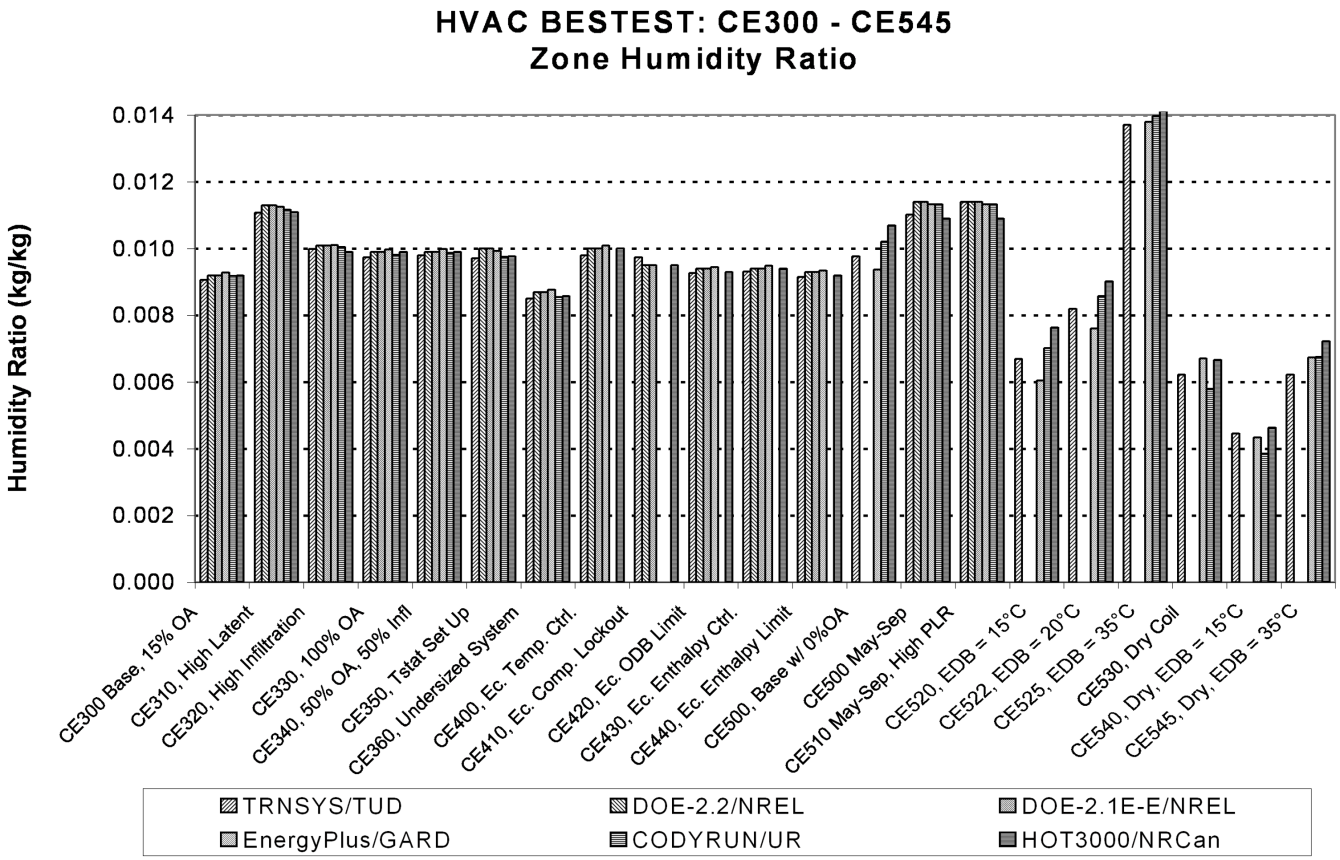

HVAC BESTEST: CE300 - CE545
Indoor Dry-Bulb Temperature
Temperature (°C)
35
30
25
20
15
10
5
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE500 May-Sep
CE510 May-Sep, High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

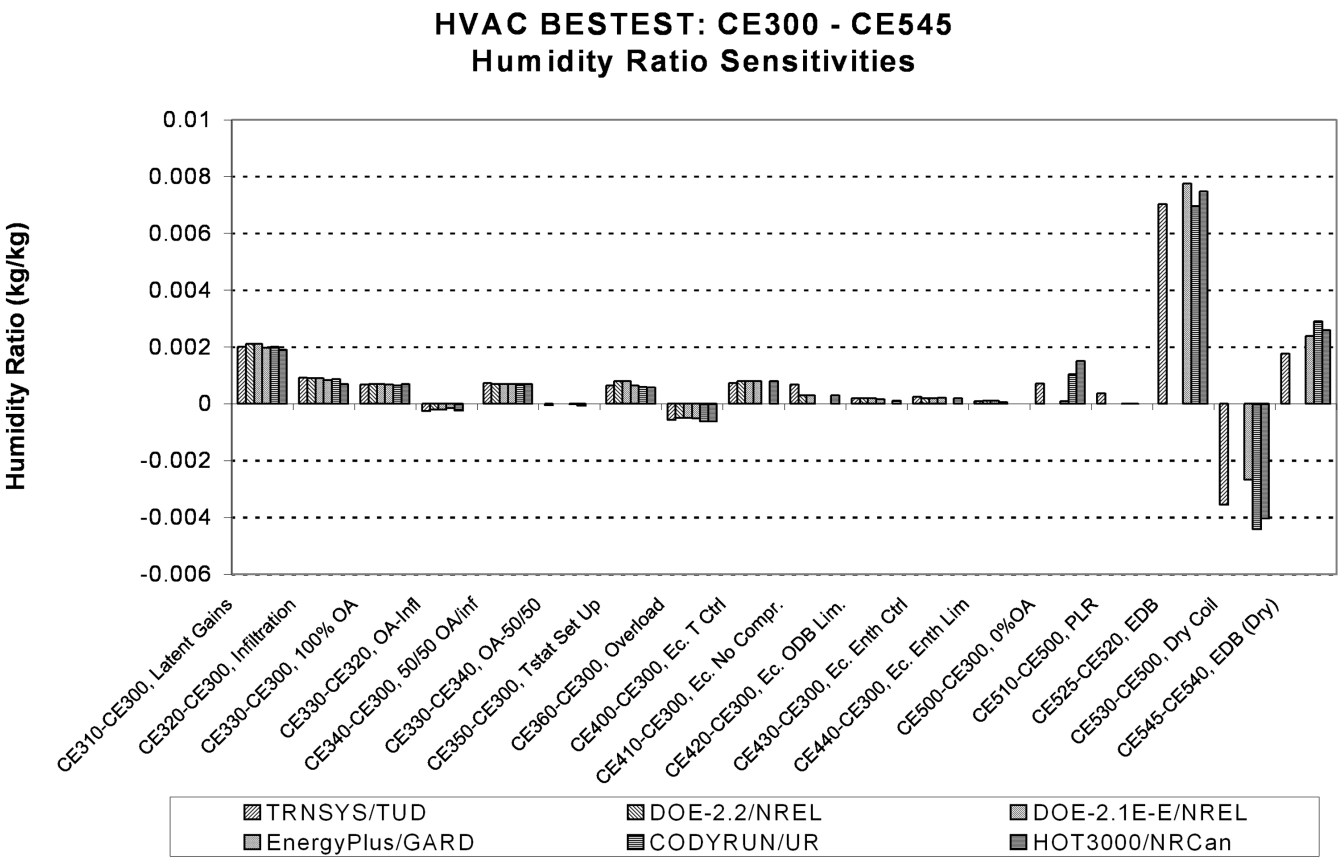

HVAC BESTEST: CE300 - CE545
IDB Sensitivities
Temperature (°C)
20
15
10
5
0
-5
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/Inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

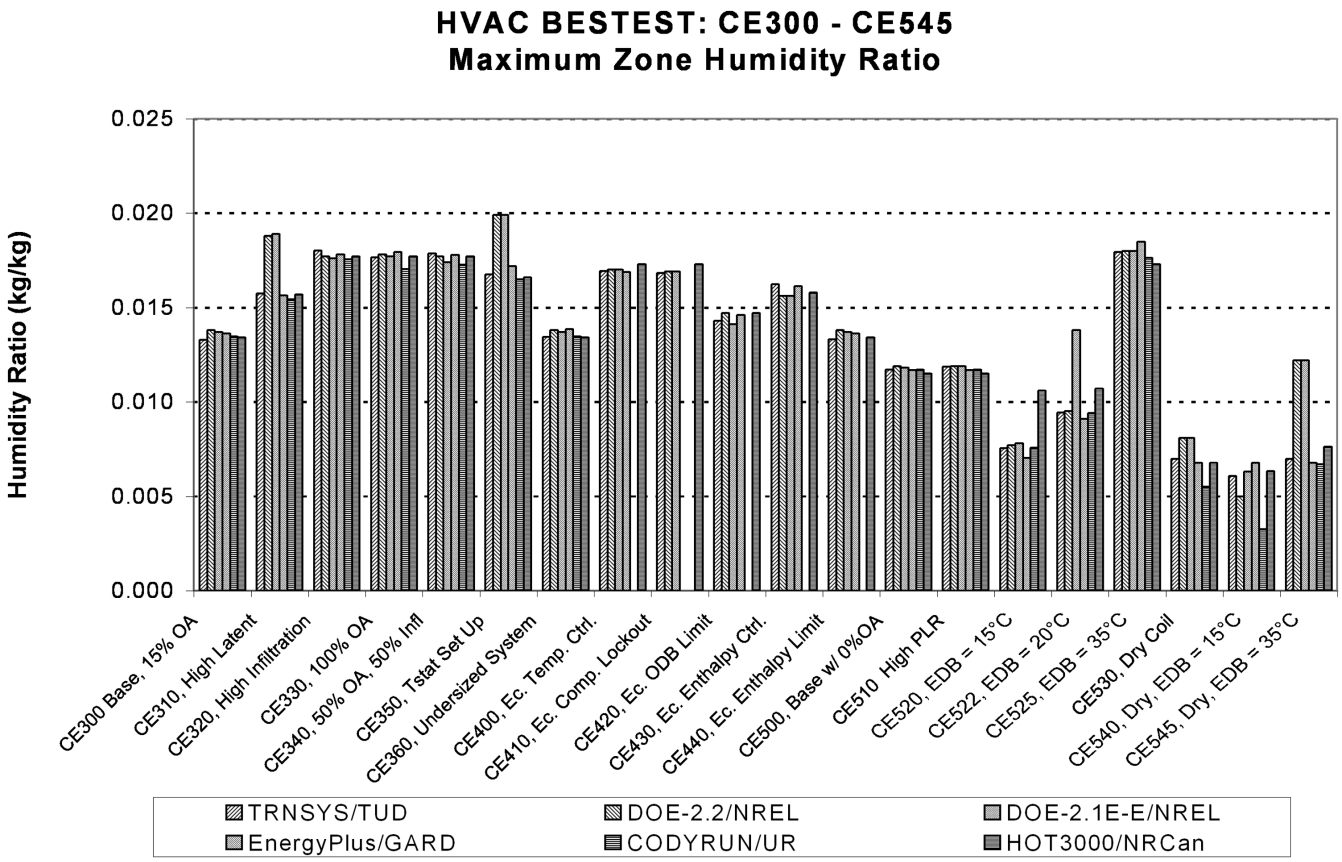

HVAC BESTEST: CE300 - CE545
Maximum Indoor Dry-Bulb Temperature
Temperature (°C)
40
35
30
25
20
15
10
5
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

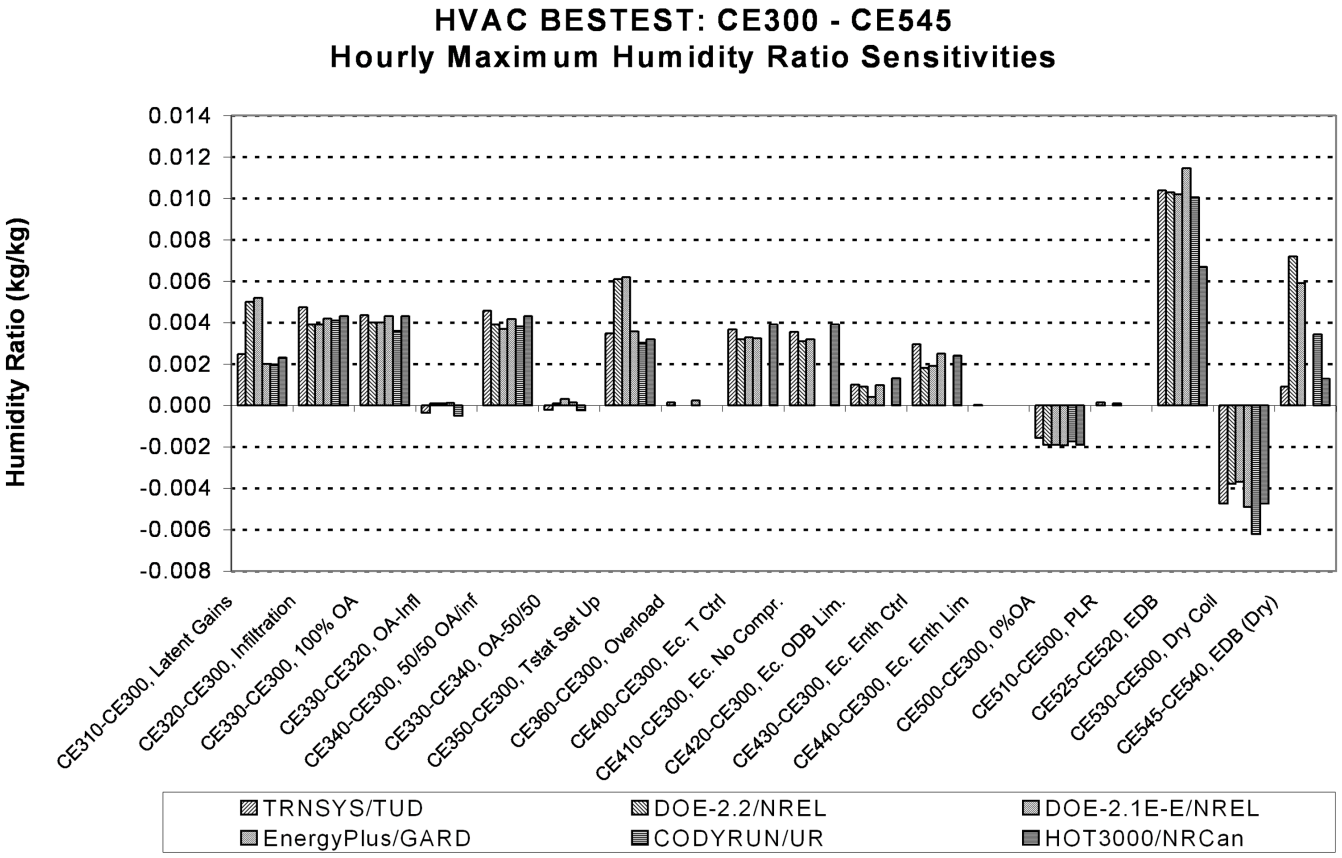

HVAC BESTEST: CE300 - CE545
Hourly Maximum IDB Sensitivities
Temperature (°C)
25
20
15
10
5
0
-5
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

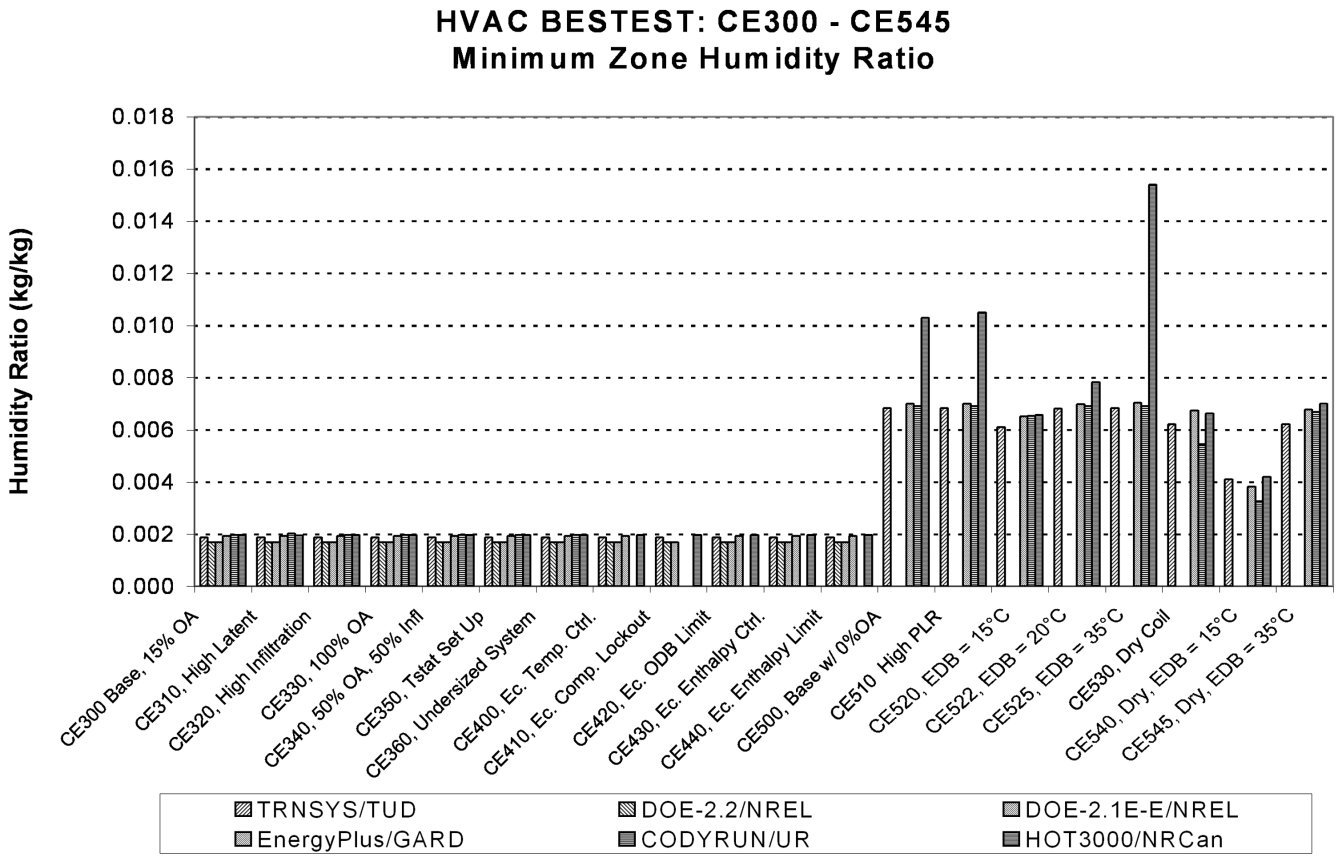

HVAC BESTEST: CE300 - CE545
Minimum Indoor Dry-Bulb Temperature
Temperature (°C)
35
30
25
20
15
10
5
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

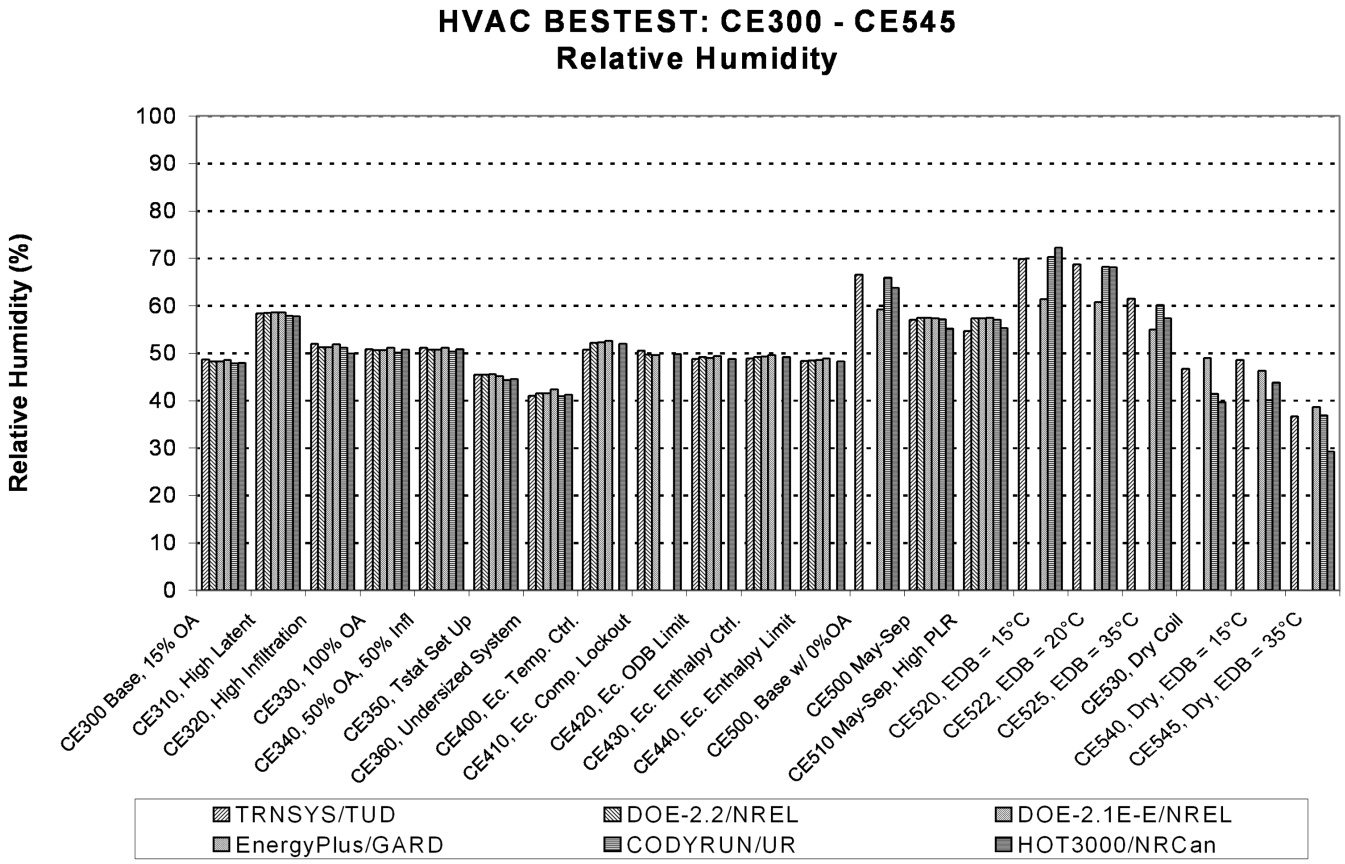

HVAC BESTEST: CE300 - CE545
Zone Humidity Ratio
Humidity Ratio (kg/kg)
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE500 May-Sep
CE510 May-Sep, High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

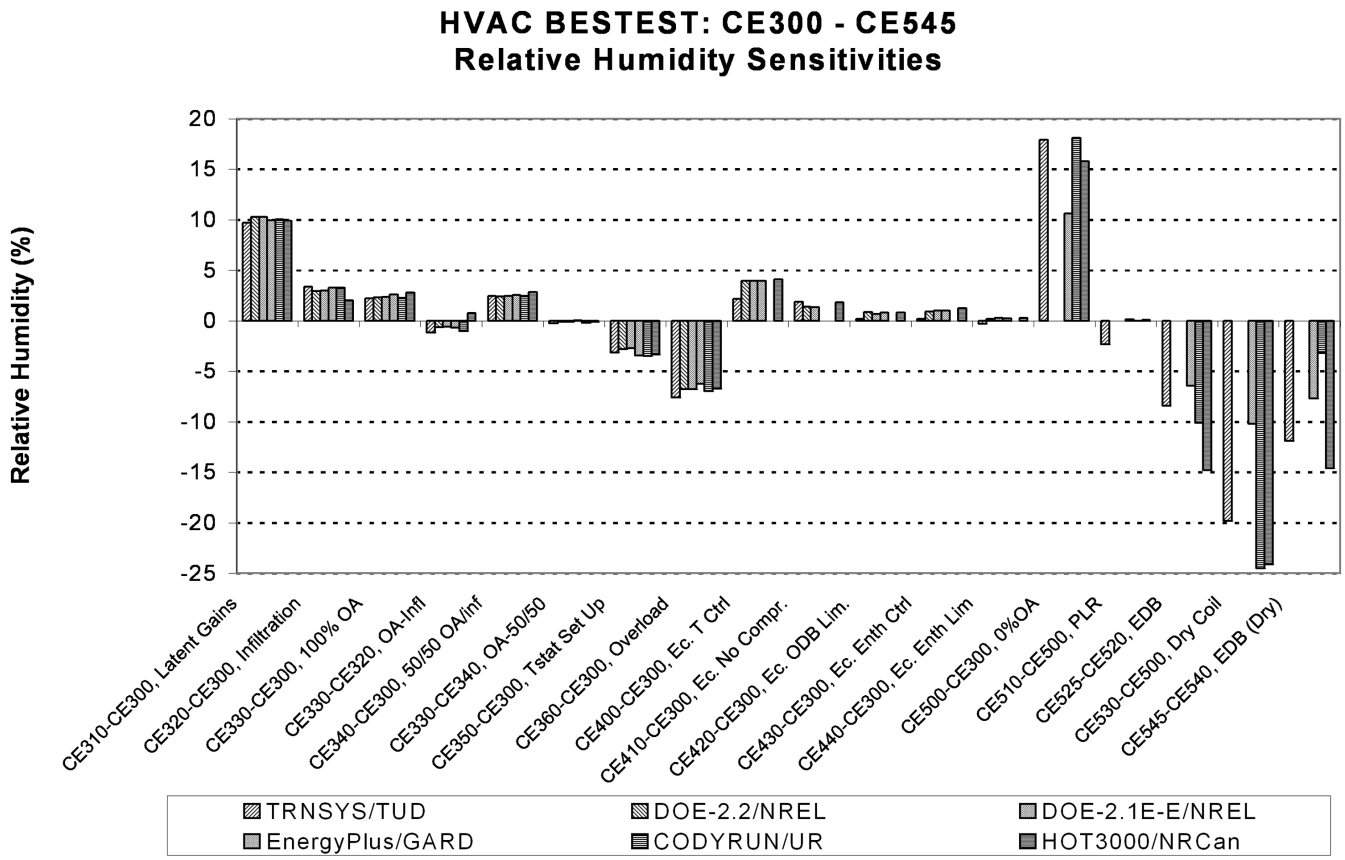

HVAC BESTEST: CE300 - CE545
Humidity Ratio Sensitivities
Humidity Ratio (kg/kg)
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/Inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

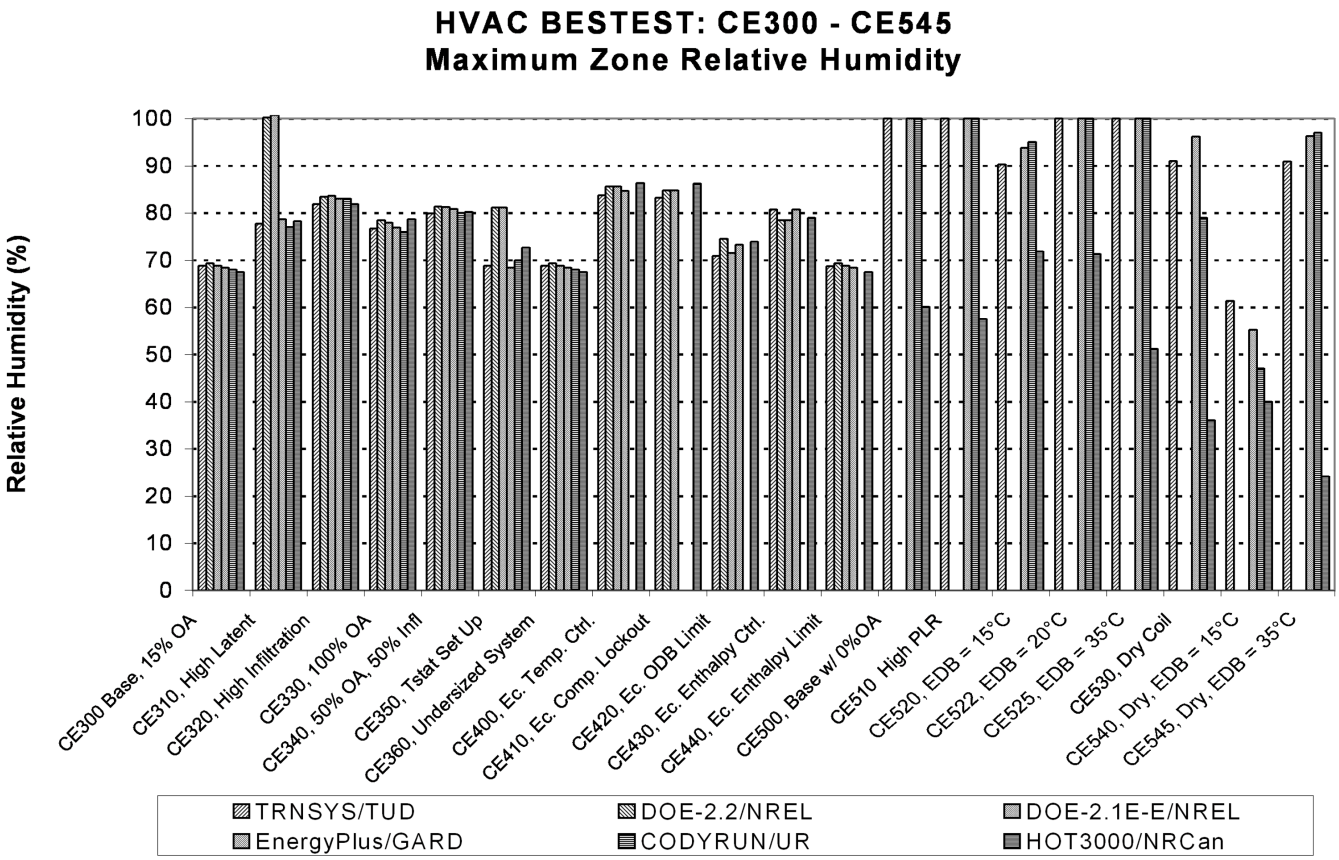

HVAC BESTEST: CE300 - CE545
Maximum Zone Humidity Ratio
Humidity Ratio (kg/kg)
0.025
0.020
0.015
0.010
0.005
0.000
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

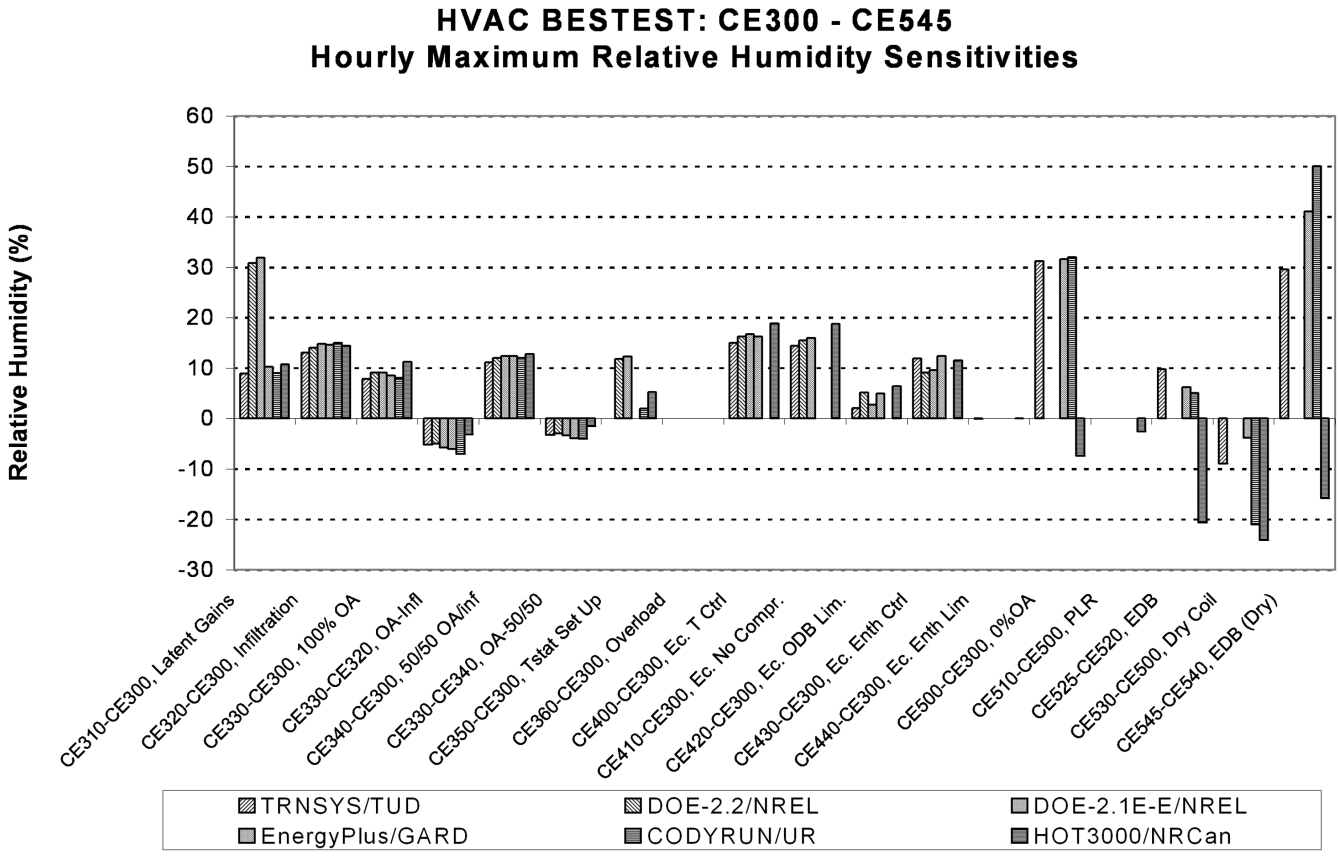

HVAC BESTEST: CE300 - CE545
Hourly Maximum Humidity Ratio Sensitivities
Humidity Ratio (kg/kg)
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/Inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

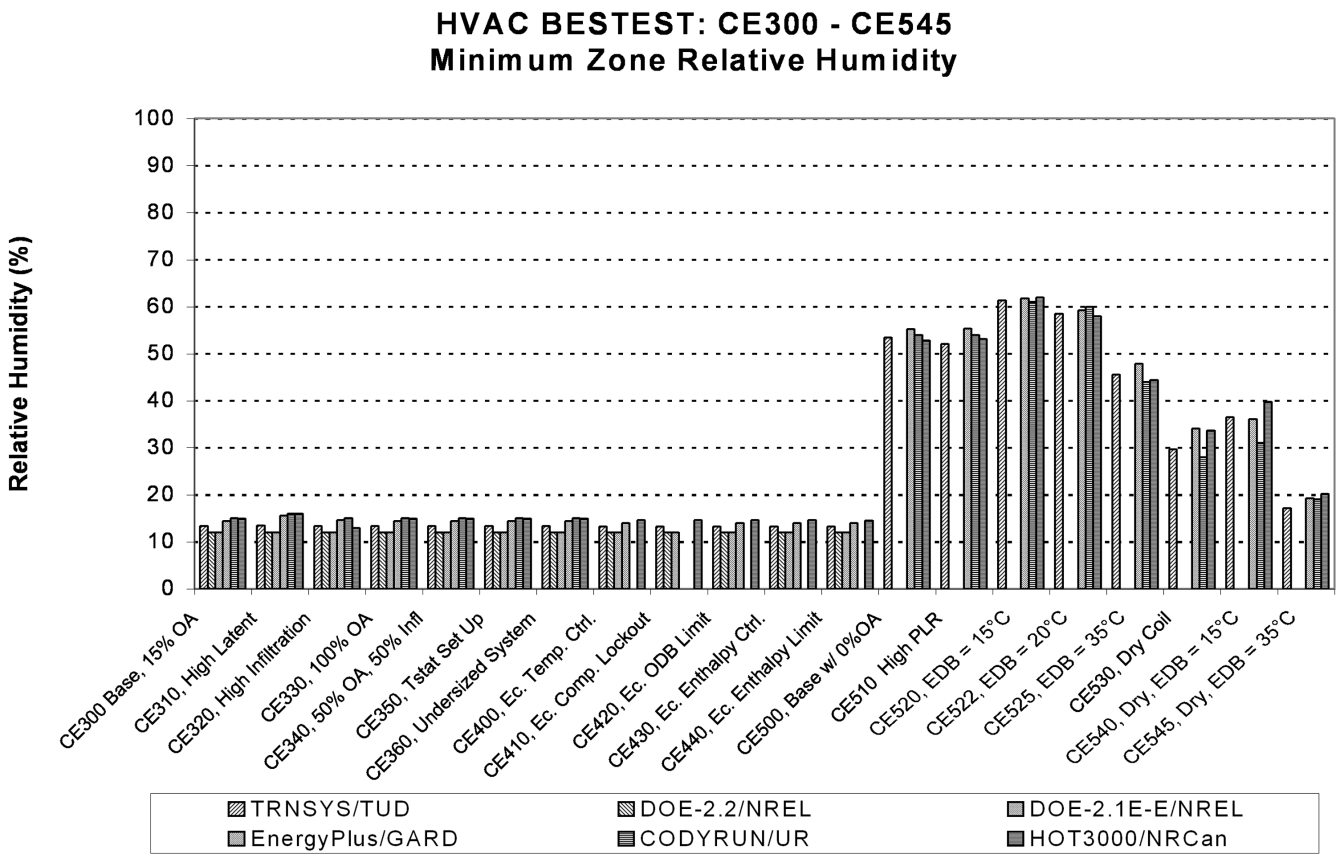

HVAC BESTEST: CE300 - CE545
Minimum Zone Humidity Ratio
Humidity Ratio (kg/kg)
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

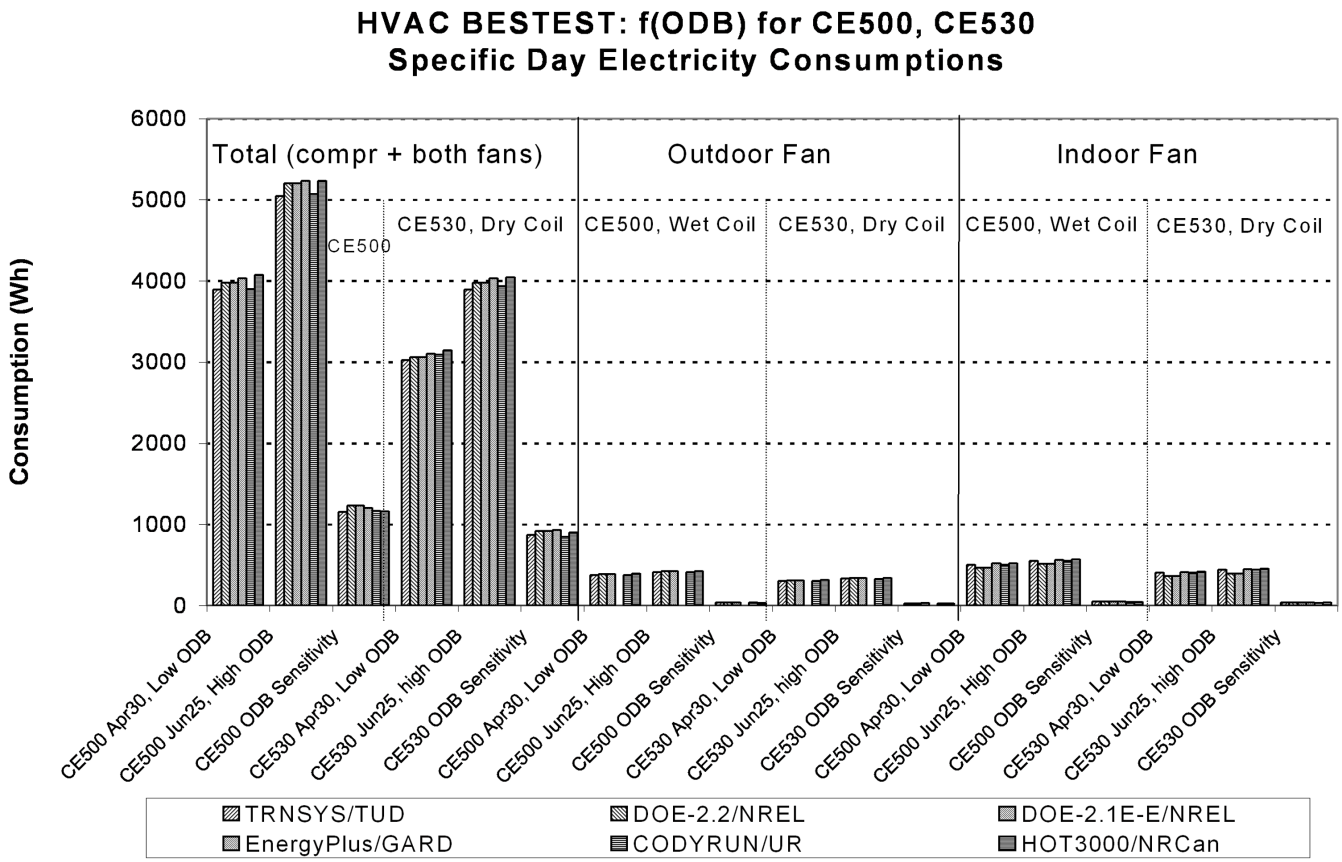

HVAC BESTEST: CE300 - CE545
Relative Humidity
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE500 May-Sep
CE510 May-Sep, High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

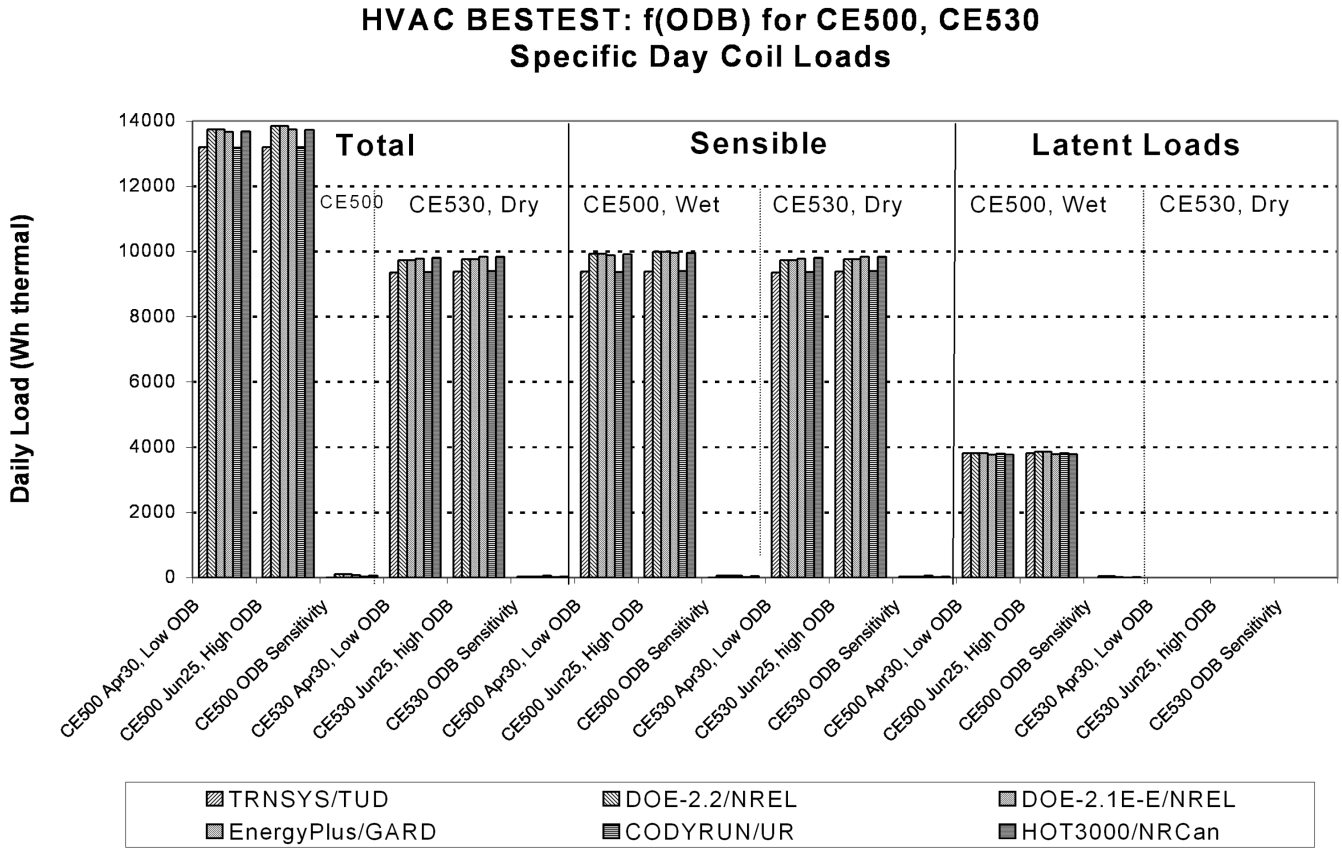

HVAC BESTEST: CE300 - CE545
Relative Humidity Sensitivities
Relative Humidity (%)
20
15
10
5
0
-5
-10
-15
-20
-25
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

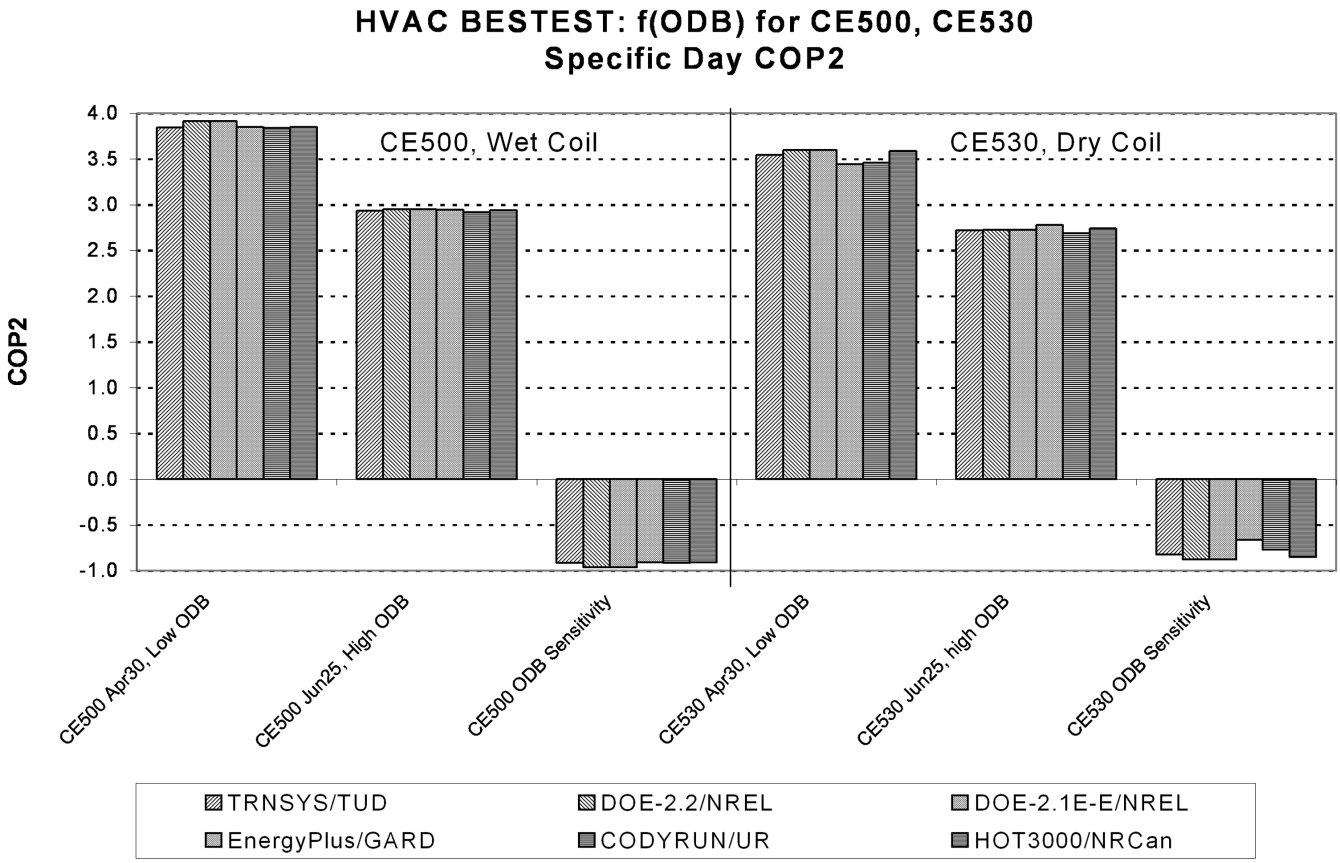

HVAC BESTEST: CE300 - CE545
Maximum Zone Relative Humidity
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

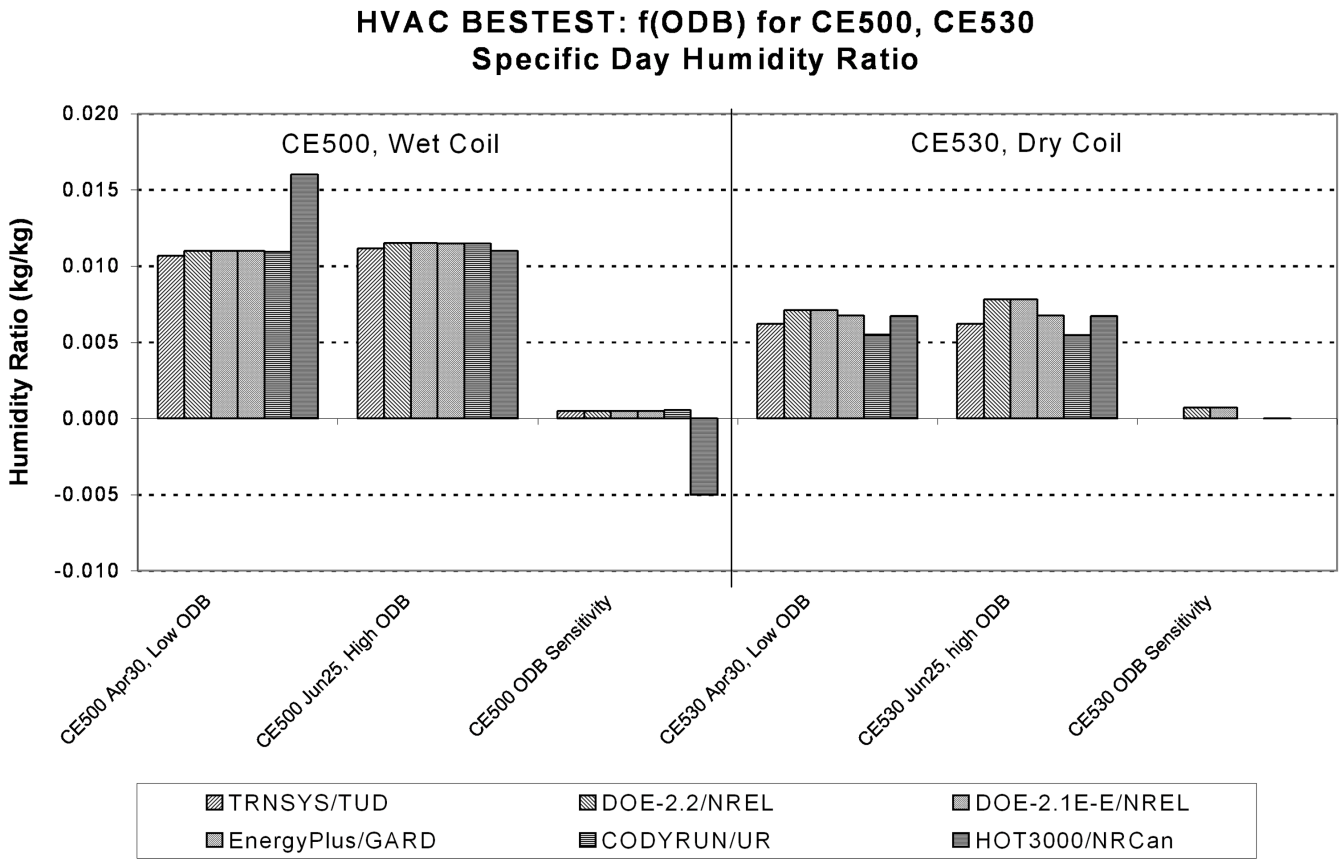

HVAC BESTEST: CE300 - CE545
Hourly Maximum Relative Humidity Sensitivities
Relative Humidity (%)
60
50
40
30
20
10
0
-10
-20
-30
CE310-CE300, Latent Gains
CE320-CE300, Infiltration
CE330-CE300, 100% OA
CE330-CE320, OA-Infl
CE340-CE300, 50/50 OA/inf
CE330-CE340, OA-50/50
CE350-CE300, Tstat Set Up
CE360-CE300, Overload
CE400-CE300, Ec. T Ctrl
CE410-CE300, Ec. No Compr.
CE420-CE300, Ec. ODB Lim.
CE430-CE300, Ec. Enth Ctrl
CE440-CE300, Ec. Enth Lim
CE500-CE300, 0%OA
CE510-CE500, PLR
CE525-CE520, EDB
CE530-CE500, Dry Coil
CE545-CE540, EDB (Dry)
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

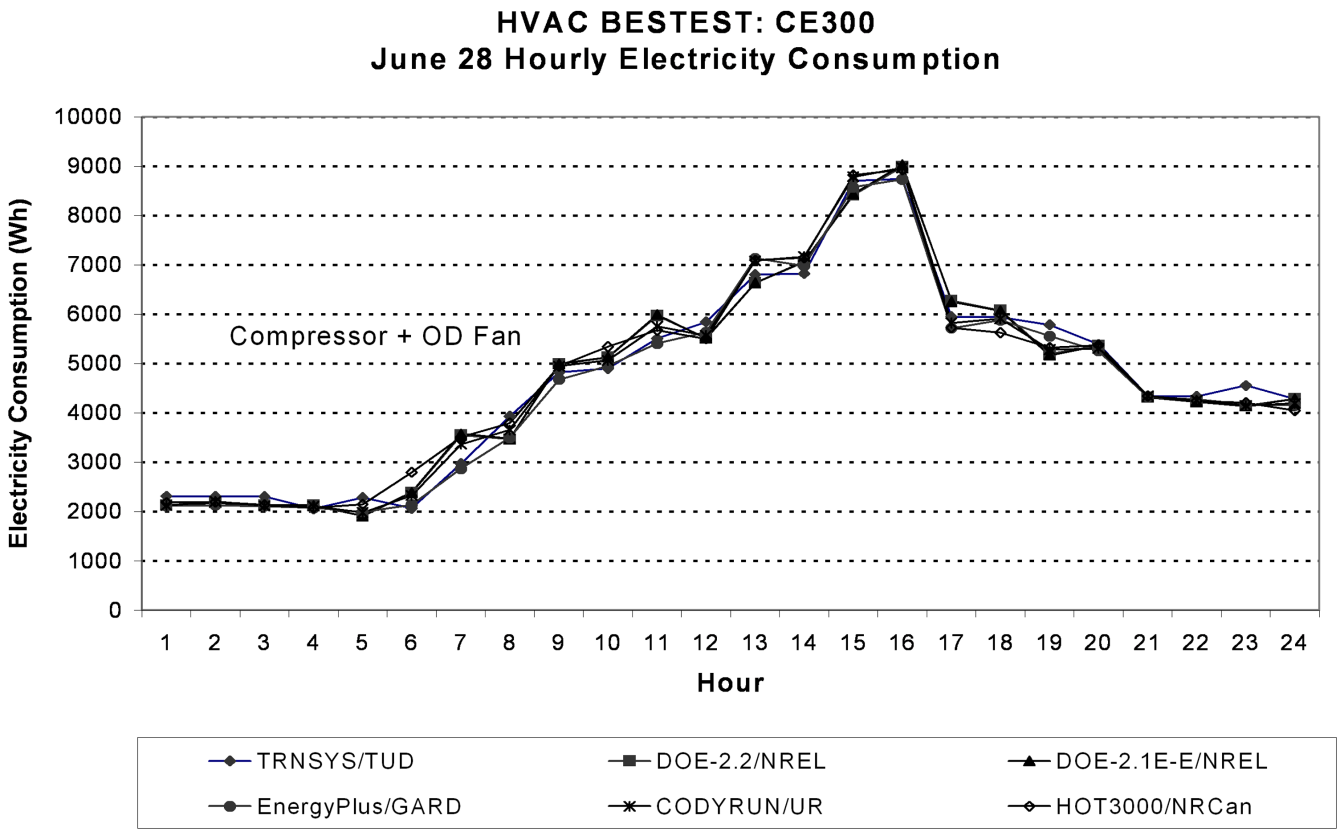

HVAC BESTEST: CE300 - CE545
Minimum Zone Relative Humidity
Relative Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
CE300 Base, 15% OA
CE310, High Latent
CE320, High Infiltration
CE330, 100% OA
CE340, 50% OA, 50% Infl
CE350, Tstat Set Up
CE360, Undersized System
CE400, Ec. Temp. Ctrl.
CE410, Ec. Comp. Lockout
CE420, Ec. ODB Limit
CE430, Ec. Enthalpy Ctrl.
CE440, Ec. Enthalpy Limit
CE500, Base w/ 0%OA
CE510 High PLR
CE520, EDB = 15°C
CE522, EDB = 20°C
CE525, EDB = 35°C
CE530, Dry Coil
CE540, Dry, EDB = 15°C
CE545, Dry, EDB = 35°C
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

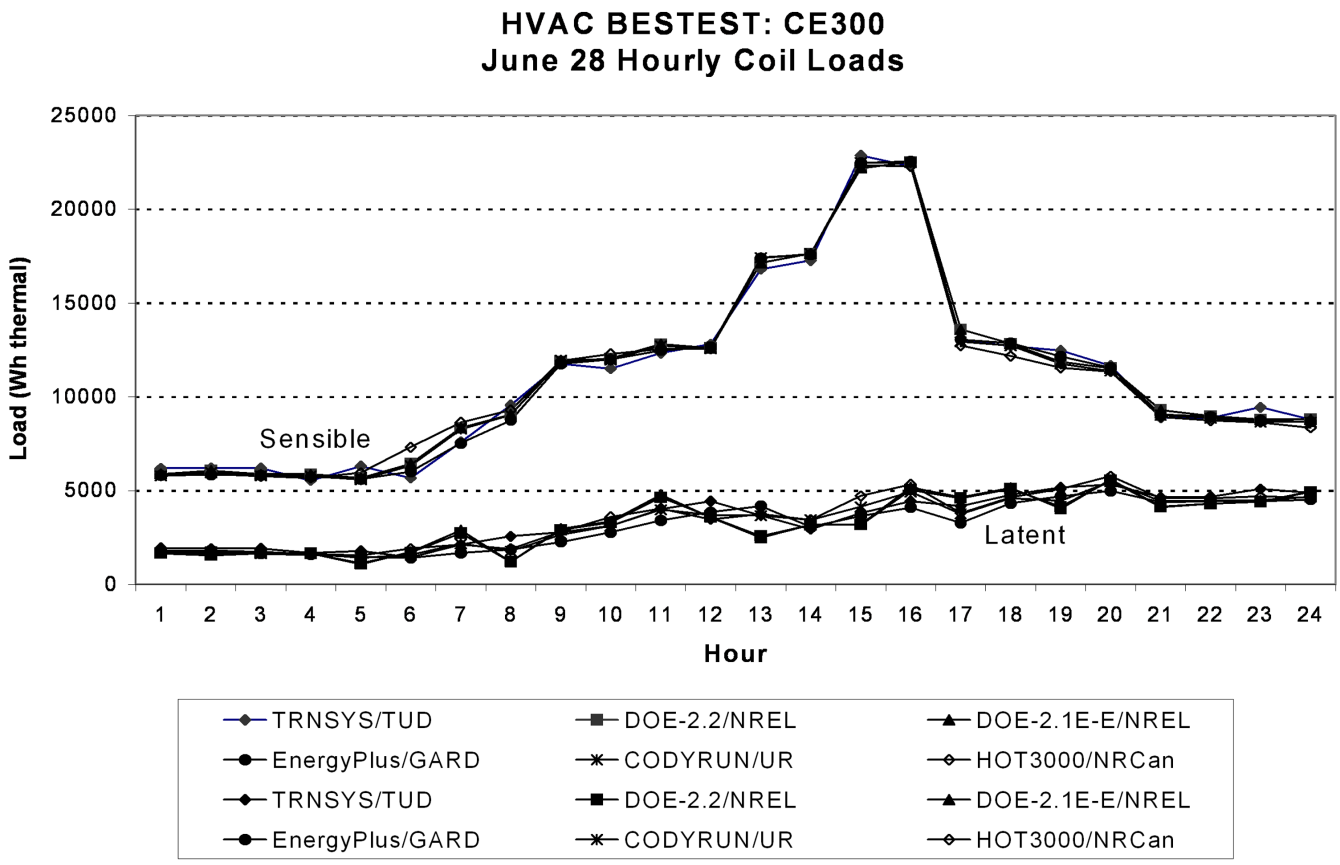

HVAC BESTEST: f(ODB) for CE500, CE530
Specific Day Electricity Consumptions
Consumption (Wh)
6000
5000
4000
3000
2000
1000
0
Total (compr + both fans)
Outdoor Fan
Indoor Fan
CE500
CE530, Dry Coil
CE500, Wet Coil
CE530, Dry Coil
CE500, Wet Coil
CE530, Dry Coil
CE500 Apr30, Low ODB
CE500 Jun25, High ODB
CE500 ODB Sensitivity
CE530 Apr30, Low ODB
CE530 Jun25, high ODB
CE530 ODB Sensitivity
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

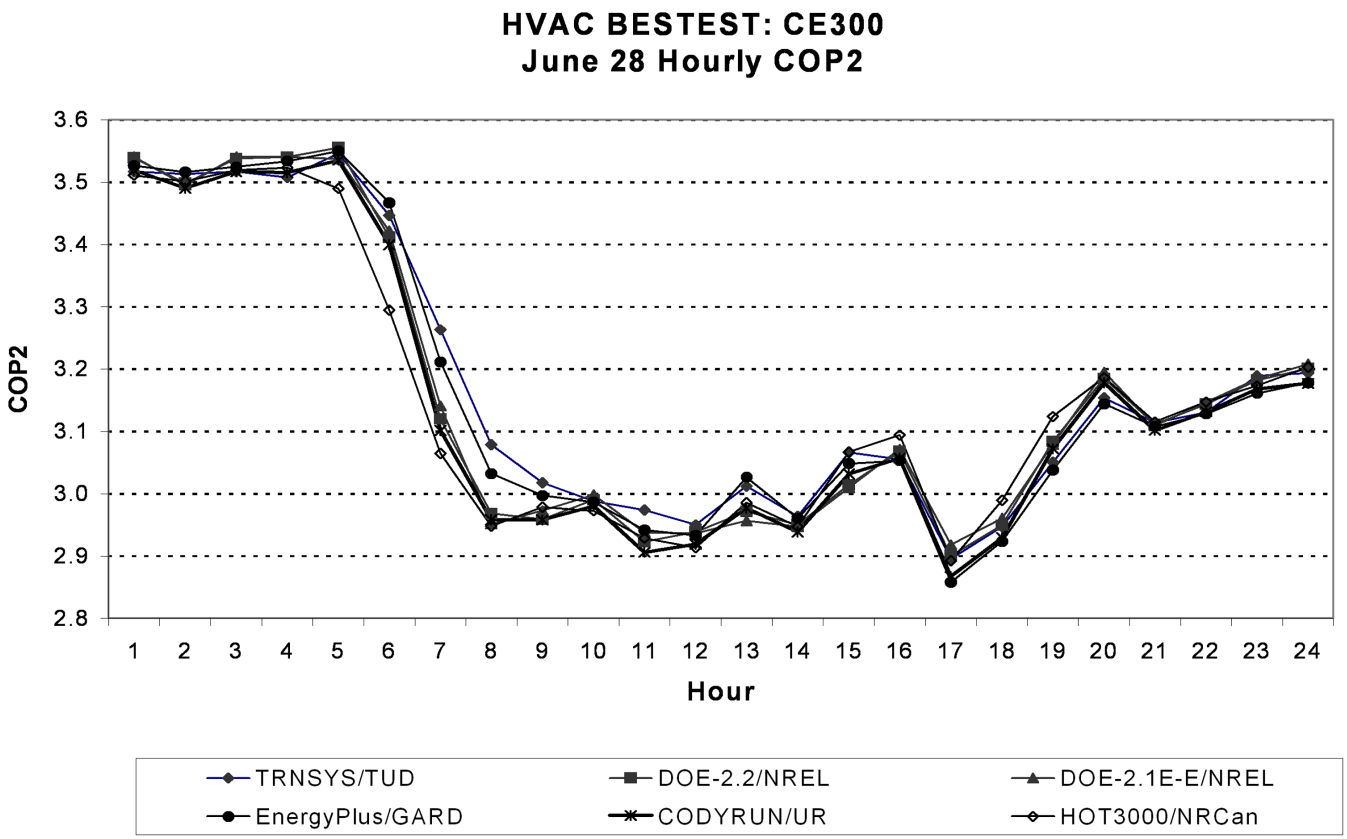

HVAC BESTEST: f(ODB) for CE500, CE530
Specific Day Coil Loads
Daily Load (Wh thermal)
14000
12000
10000
8000
6000
4000
2000
0
Total
Sensible
Latent Loads
CE500
CE530, Dry
CE500, Wet
CE530, Dry
CE500, Wet
CE530, Dry
CE500 Apr30, Low ODB
CE500 Jun25, High ODB
CE500 ODB Sensitivity
CE530 Apr30, Low ODB
CE530 Jun25, high ODB
CE530 ODB Sensitivity
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

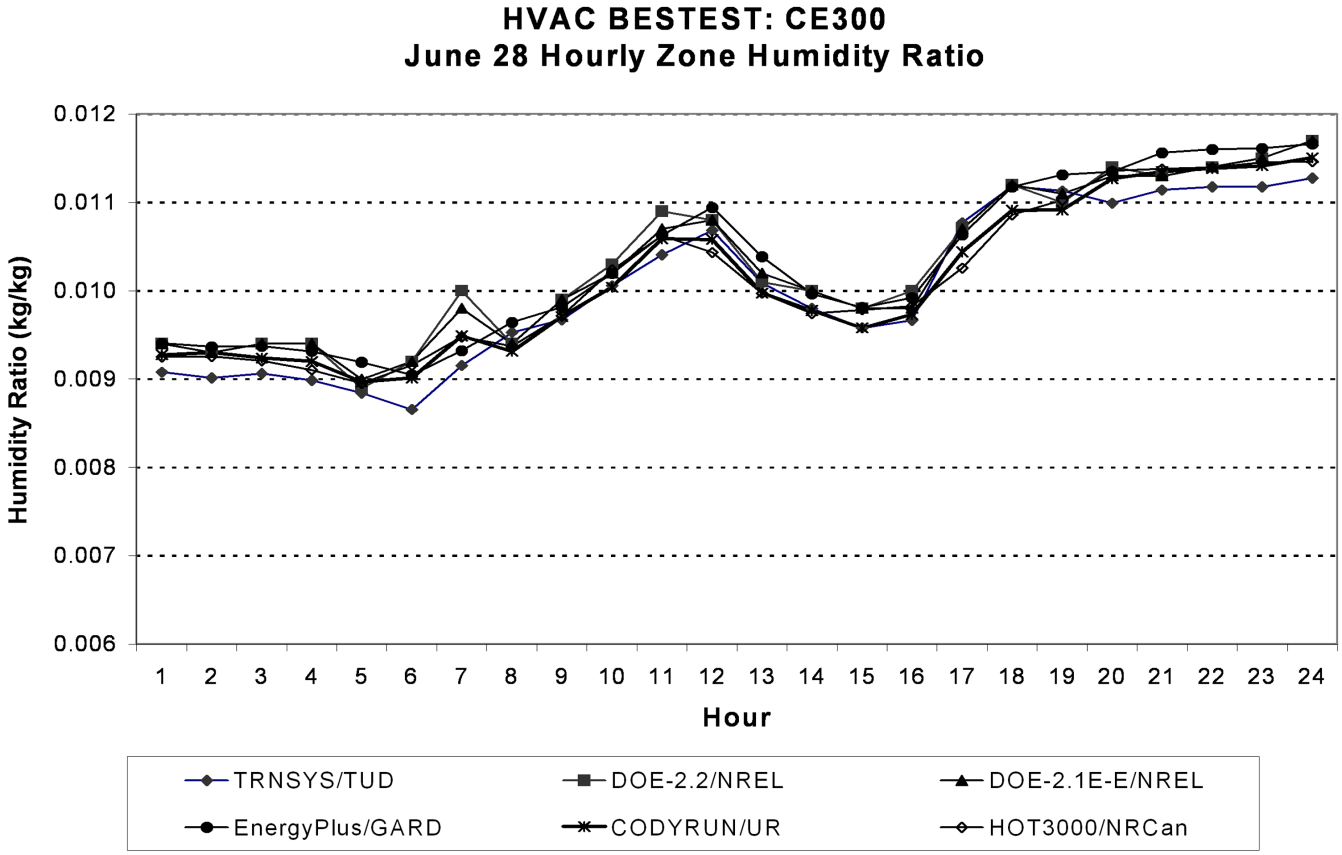

HVAC BESTEST: f(ODB) for CE500, CE530
Specific Day COP2
COP2
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
CE500, Wet Coil
CE530, Dry Coil
CE500 Apr30, Low ODB
CE500 Jun25, High ODB
CE500 ODB Sensitivity
CE530 Apr30, Low ODB
CE530 Jun25, high ODB
CE530 ODB Sensitivity
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

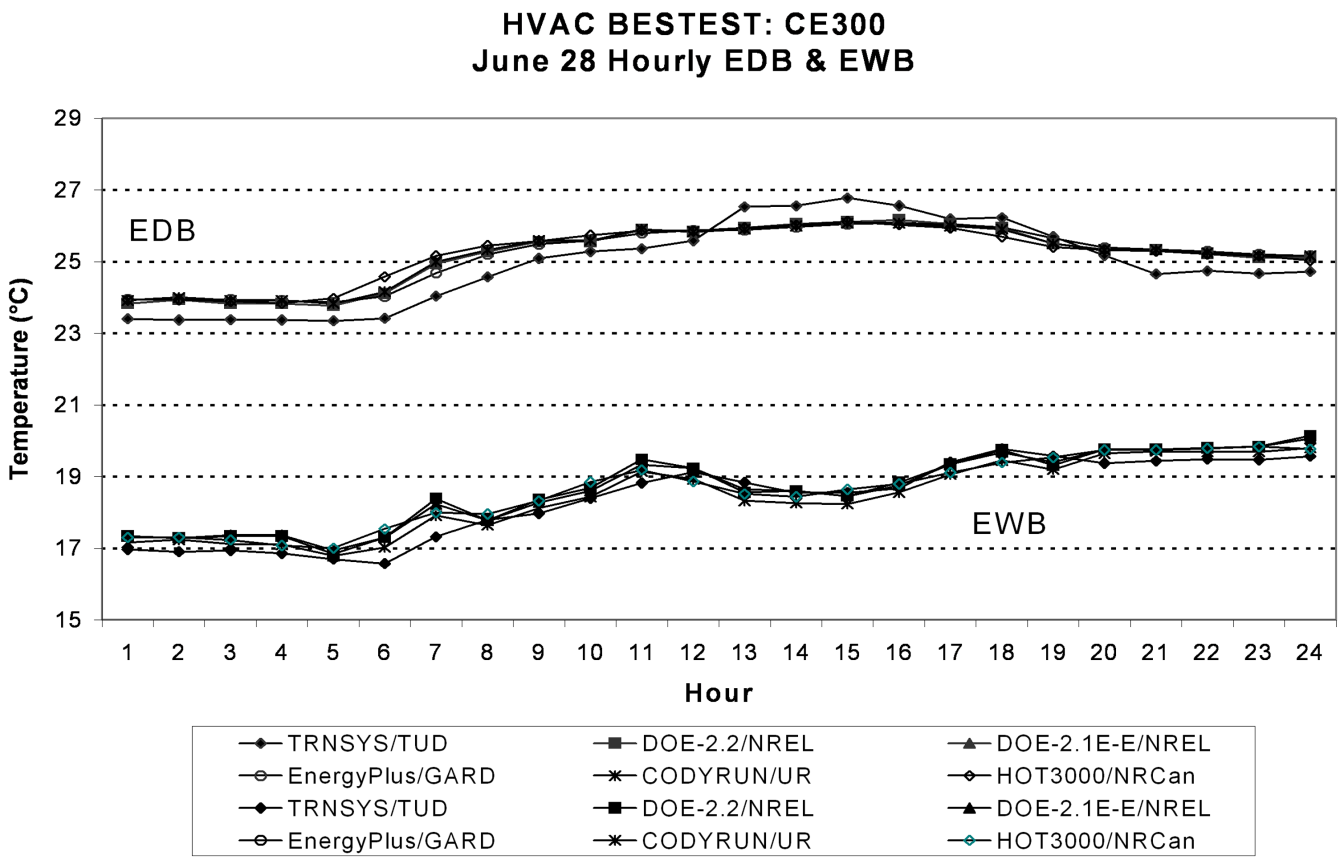

HVAC BESTEST: f(ODB) for CE500, CE530
Specific Day Humidity Ratio
Humidity Ratio (kg/kg)
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
CE500, Wet Coil
CE530, Dry Coil
CE500 Apr30, Low ODB
CE500 Jun25, High ODB
CE500 ODB Sensitivity
CE530 Apr30, Low ODB
CE530 Jun25, high ODB
CE530 ODB Sensitivity
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

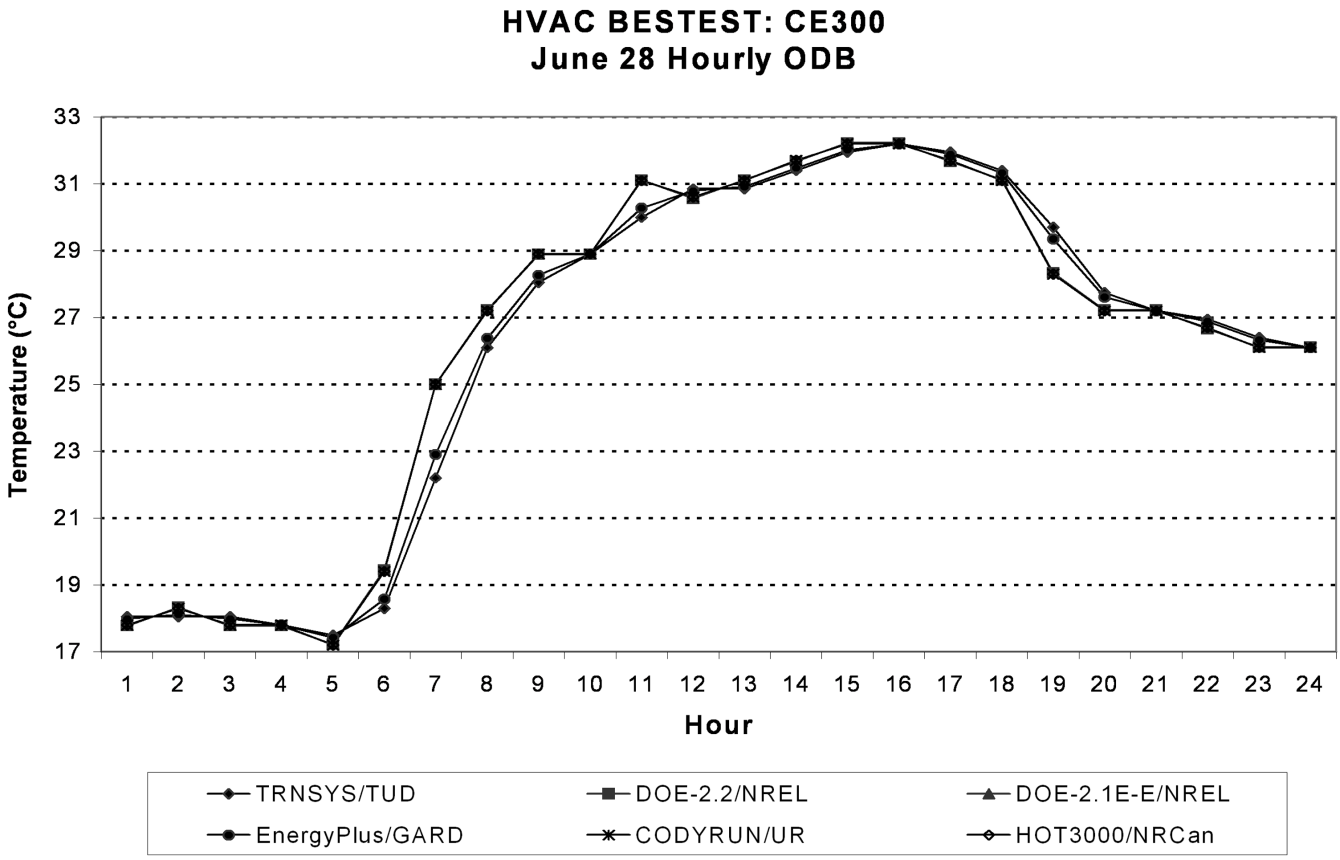

HVAC BESTEST: CE300
June 28 Hourly Electricity Consumption
Electricity Consumption (Wh)
Compressor + OD Fan
Hour
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

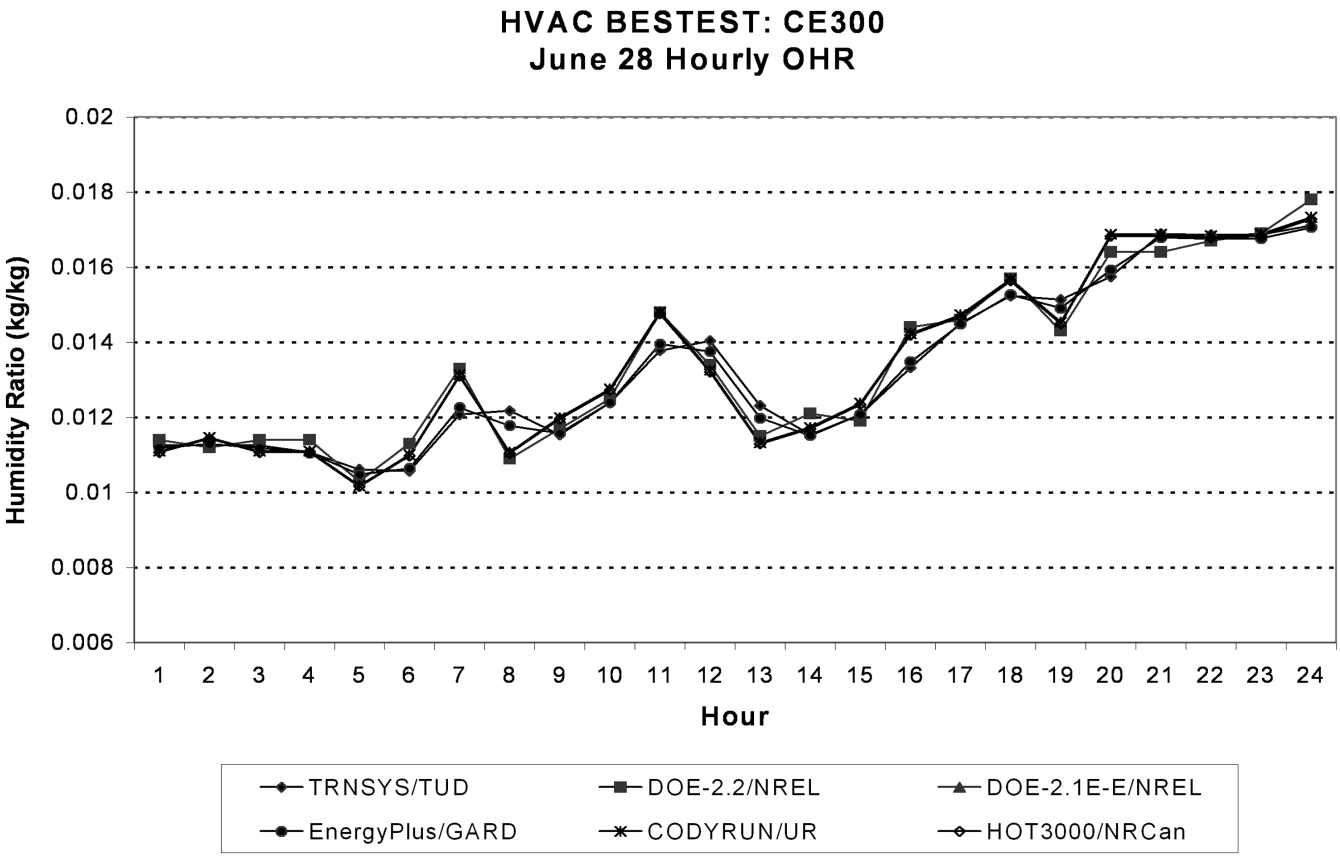

HVAC BESTEST: CE300
June 28 Hourly Coil Loads
Load (Wh thermal)
Sensible
Latent
Hour
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan


HVAC BESTEST: CE300
June 28 Hourly COP2
COP2
3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan


HVAC BESTEST: CE300
June 28 Hourly Zone Humidity Ratio
Humidity Ratio (kg/kg)
0.012
0.011
0.010
0.009
0.008
0.007
0.006
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan


HVAC BESTEST: CE300
June 28 Hourly EDB & EWB
Temperature (°C)
29
27
25
23
21
19
17
15
EDB
EWB
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan


HVAC BESTEST: CE300
June 28 Hourly ODB
Temperature (°C)
33
31
29
27
25
23
21
19
17
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan


HVAC BESTEST: CE300
June 28 Hourly OHR
Humidity Ratio (kg/kg)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
TRNSYS/TUD
DOE-2.2/NREL
DOE-2.1E-E/NREL
EnergyPlus/GARD
CODYRUN/UR
HOT3000/NRCan

Space Cooling Electricity Consumption

Energy Consumption, Total (kWh,e)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE300	35634	34750	34755	34746	34976	35070	34746	35634	2.5%
CE310	39973	39379	39384	39290	39520	39608	39290	39973	1.7%
CE320	40060	38745	38792	39079	39401	39457	38745	40060	3.3%
CE330	40963	39708	39438	40143	40535	40330	39438	40963	3.8%
CE340	40619	39358	39265	39783	40065	39947	39265	40619	3.4%
CE350	32237	30547	30548	31145	31587	31742	30547	32237	5.4%
CE360	55299	54064	54016	54705	54843	55068	54016	55299	2.3%
CE400	32045	30846	30876	31013		31413	30846	32045	3.8%
CE410	32078	31668	31699			31503	31503	32078	1.8%
CE420	33387	32530	32910	32736		33208	32530	33387	2.6%
CE430	32538	31932	31811	31772		31818	31772	32538	2.4%
CE440	33691	33032	32973	33032		33248	32973	33691	2.2%
CE500	22338	22817	22822	23035	22323	23138	22323	23138	3.6%
CE500 May-Sep	17391	17872	17870	17996	17435	18051	17391	18051	3.7%
CE510 May-Sep	34609	35971	35970	35732	34849	35845	34609	35971	3.8%
CE520	24987	25389	25390	25017	25131	25781	24987	25781	3.1%
CE522	23544	24293	24307	24078	23620	24360	23544	24360	3.4%
CE525	20321	20408	20421	20702	20242	21323	20242	21323	5.3%
CE530	17281	17540	17537	17742	17442	17875	17281	17875	3.4%
CE540	19430	19878	19874	19061	19537	20164	19061	20164	5.6%
CE545	15687	15802	15791	16636	15791	16339	15687	16636	5.9%

Energy Consumption, Compressor (kWh,e)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE300	22354	21569	21573		21770	21876	21569	22354	3.6%
CE310	26340	25813	25817		25937	26053	25813	26340	2.0%
CE320	26433	25250	25294		25846	25912	25250	26433	4.6%
CE330	27300	26172	25925		26928	26775	25925	27300	5.2%
CE340	26963	25829	25745		26473	26400	25745	26963	4.6%
CE350	19317	17802	17801		18738	18891	17801	19317	8.2%
CE360	40106	38999	38955		39697	39941	38955	40106	2.9%
CE400	19179	18106	18131			18629	18106	19179	5.8%
CE410	19204	18823	18850			18685	18685	19204	2.8%
CE420	20359	19596	19934			20214	19596	20359	3.8%
CE430	19599	19059	18951			18966	18951	19599	3.4%
CE440	20629	20042	19989			20249	19989	20629	3.2%
CE500	17854	18473	18478		17858	18522	17854	18522	3.7%
CE500 May-Sep	13942	14508	14506		13989	14491	13942	14508	4.0%
CE510 May-Sep	27748	28811	28810		27902	28721	27748	28811	3.7%
CE520	19521	20121	20126		19655	20185	19521	20185	3.3%
CE522	18620	19407	19418		18690	19281	18620	19418	4.2%
CE525	16558	16880	16893		16507	17443	16507	17443	5.6%
CE530	13657	14127	14124		13856	14172	13657	14172	3.7%
CE540	15021	15680	15677		15164	15664	15021	15680	4.3%
CE545	12622	12967	12957		12751	13215	12622	13215	4.6%

RESULTS5-3B.xls q:a06..m55; 02/09/06

Space Cooling Electricity Consumption

Energy Consumption, Supply Fan (kWh,e)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE300	10880	10880	10880	10862	10880	10880	10862	10880	0.2%
CE310	10880	10880	10880	10862	10880	10880	10862	10880	0.2%
CE320	10880	10880	10880	10862	10880	10880	10862	10880	0.2%
CE330	10880	10880	10880	10862	10880	10880	10862	10880	0.2%
CE340	10880	10880	10880	10862	10880	10880	10862	10880	0.2%
CE350	10880	10880	10880	10862	10880	10880	10862	10880	0.2%
CE360	10880	10880	10880	10862	10880	10880	10862	10880	0.2%
CE400	10880	10880	10880	10862		10880	10862	10880	0.2%
CE410	10880	10880	10880			10880	10880	10880	0.0%
CE420	10880	10880	10880	10862		10880	10862	10880	0.2%
CE430	10880	10880	10880	10862		10880	10862	10880	0.2%
CE440	10880	10880	10880	10862		10880	10862	10880	0.2%
CE500	2564	2369	2369	2628	2553	2639	2369	2639	10.7%
CE500 May-Sep	1972	1837	1837	2029	1970	2035	1837	2035	10.2%
CE510 May-Sep	3923	4099	4099	4063	3972	4073	3923	4099	4.4%
CE520	3125	2874	2871	3019	3131	3200	2871	3200	10.8%
CE522	2816	2704	2707	2843	2819	2904	2704	2904	7.1%
CE525	2152	1886	1885	2180	2136	2221	1885	2221	16.2%
CE530	2072	1833	1833	2090	2051	2117	1833	2117	14.2%
CE540	2522	2258	2258	2309	2500	2573	2258	2573	13.1%
CE545	1753	1501	1501	1871	1739	1786	1501	1871	21.9%

Energy Consumption, Condenser Fan (kWh,e)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE300	2400	2301	2302		2326	2323	2301	2400	4.3%
CE310	2754	2686	2687		2703	2691	2686	2754	2.5%
CE320	2747	2615	2618		2675	2681	2615	2747	4.9%
CE330	2784	2656	2633		2727	2693	2633	2784	5.6%
CE340	2776	2649	2640		2713	2684	2640	2776	5.1%
CE350	2040	1865	1867		1969	1970	1865	2040	9.0%
CE360	4313	4185	4181		4266	4272	4181	4313	3.1%
CE400	1986	1860	1865			1902	1860	1986	6.6%
CE410	1994	1965	1969			1936	1936	1994	3.0%
CE420	2149	2054	2096			2115	2054	2149	4.5%
CE430	2059	1993	1980			1970	1970	2059	4.5%
CE440	2182	2110	2104			2120	2104	2182	3.7%
CE500	1920	1975	1975		1912	1976	1912	1976	3.3%
CE500 May-Sep	1477	1527	1527		1476	1524	1476	1527	3.4%
CE510 May-Sep	2938	3061	3061		2974	3050	2938	3061	4.1%
CE520	2340	2394	2393		2345	2396	2340	2396	2.4%
CE522	2108	2182	2182		2111	2174	2108	2182	3.4%
CE525	1611	1642	1643		1599	1663	1599	1663	3.9%
CE530	1552	1580	1580		1536	1585	1536	1585	3.1%
CE540	1888	1940	1939		1872	1926	1872	1940	3.5%
CE545	1312	1334	1333		1302	1337	1302	1337	2.7%

RESULTS5-3B.xls q:a56..m105; 02/09/06

Weather Data Checks, CE300 Only

	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
Annual Mean Output									
ODB	19.91	19.89	19.89	19.91	19.91	19.91	20	20	0.1%
OHR	0.01164	0.01160	0.01160	0.01159	0.01165	0.01160	0.01159	0.01165	0.5%
Annual Hourly Integrated Maxima									
ODB	34.70	35.00	35.00	34.78	35.00	35.00	35	35	0.9%
OHR	0.02188	0.02250	0.02250	0.02184	0.02241	0.02230	0.02184	0.02250	3.0%

RESULTS5-3B.xls q:a109..m119; 02/09/06

Space Cooling Coil Loads

Total Sensible + Latent (kWh,th)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE300	80427	77283	77292	77318	77745	78257	77283	80427	4.0%
CE310	99342	97395	97412	96448	97296	97261	96448	99342	3.0%
CE320	99792	96356	96493	96084	97141	96957	96084	99792	3.8%
CE330	105013	100730	100993	102211	103713	102008	100730	105013	4.2%
CE340	102728	99028	99223	99709	100676	99753	99028	102728	3.7%
CE350	69388	63736	63635	65790	66860	67389	63635	69388	8.7%
CE360	162974	159807	159854	161248	161200	162168	159807	162974	2.0%
CE400	68793	64918	65025	65414		66898	64918	68793	5.9%
CE410	68673	66780	66844			66175	66175	68673	3.7%
CE420	72609	69611	70882	70349		71803	69611	72609	4.2%
CE430	69756	67641	67219	67141		67200	67141	69756	3.9%
CE440	73711	71380	71181	71417		72029	71181	73711	3.5%
CE500	63357	65996	65992	65571	63105	65614	63105	65996	4.5%
CE500 May-Sep	48443	50693	50690	50354	48440	50357	48440	50693	4.5%
CE510 May-Sep	108974	114018	114015	112793	108979	112781	108974	114018	4.5%
CE520	63422	66571	66565	66088	63212	66146	63212	66571	5.1%
CE522	63389	66373	66372	65851	63157	65900	63157	66373	4.9%
CE525	63293	65399	65395	64973	63002	65155	63002	65399	3.7%
CE530	45046	46634	46631	46944	44875	47002	44875	47002	4.6%
CE540	45113	47130	47126	47297	44980	47462	44980	47462	5.3%
CE545	44981	46240	46236	46612	44775	46668	44775	46668	4.1%

Sensible Coil Load (kWh,th)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE300	56662	55797	55805	55252	55209	55191	55191	56662	2.6%
CE310	56256	56301	56313	55225	55185	55083	55083	56313	2.2%
CE320	62859	62697	62747	62043	62009	62734	62009	62859	1.4%
CE330	63083	63311	63328	63779	62649	61822	61822	63779	3.1%
CE340	63033	63053	63111	62886	62381	61406	61406	63111	2.7%
CE350	50371	47684	47677	48545	48589	48768	47677	50371	5.5%
CE360	134977	134920	134940	135287	134206	134697	134206	135287	0.8%
CE400	41952	41419	41437	40688		41181	40688	41952	3.1%
CE410	45677	47659	47660			45585	45585	47660	4.4%
CE420	50390	49666	50612	49524		49984	49524	50612	2.2%
CE430	47863	47731	47454	46739		46143	46143	47863	3.6%
CE440	50876	50593	50492	50060		49785	49785	50876	2.2%
CE500	45044	47650	47646	47491	44874	47530	44874	47650	5.9%
CE500 May-Sep	34443	36596	36593	36476	34448	36480	34443	36596	6.0%
CE510 May-Sep	77489	82306	82303	81566	77499	81563	77489	82306	6.0%
CE520	45110	48102	48096	47986	44977	48059	44977	48102	6.6%
CE522	45076	47962	47961	47758	44924	47795	44924	47962	6.5%
CE525	44979	47218	47213	46930	44775	47110	44775	47218	5.3%
CE530	45046	46574	46570	46944	44874	47002	44874	47002	4.6%
CE540	45112	47023	47019	47288	44977	47460	44977	47460	5.3%
CE545	44981	46214	46210	46612	44775	46668	44775	46668	4.1%

Latent Coil Load(kWh,th)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE300	23765	21487	21487	22066	22535	23067	21487	23765	10.2%
CE310	43086	41094	41099	41222	42111	42178	41094	43086	4.8%
CE320	36932	33659	33746	34040	35133	34224	33659	36932	9.5%
CE330	41929	37419	37666	38433	41063	40186	37419	41929	11.4%
CE340	39695	35974	36113	36823	38296	38346	35974	39695	9.9%
CE350	19017	16052	15958	17245	18271	18621	15958	19017	17.5%
CE360	27997	24887	24914	25961	26994	27470	24887	27997	11.8%
CE400	26840	23498	23588	24726		25717	23498	26840	13.4%
CE410	22996	19121	19184			20590	19121	22996	18.9%
CE420	22219	19945	20270	20826		21855	19945	22219	10.8%
CE430	21893	19909	19765	20403		21057	19765	21893	10.3%
CE440	22835	20788	20689	21357		22244	20689	22835	9.9%
CE500	18313	18346	18346	18080	18231	18084	18080	18346	1.5%
CE500 May-Sep	14000	14097	14097	13879	13991	13877	13877	14097	1.6%
CE510 May-Sep	31485	31712	31712	31226	31480	31217	31217	31712	1.6%
CE520	18312	18470	18470	18101	18235	18087	18087	18470	2.1%
CE522	18313	18411	18410	18093	18233	18104	18093	18411	1.7%
CE525	18314	18182	18182	18044	18227	18045	18044	18314	1.5%
CE530	0	61	61	0	1	0	0	61	297.1%
CE540	1	107	107	9	3	2	1	107	278.2%
CE545	0	25	25	0	0	0	0	25	300.0%

RESULTS5-3B.xls q:a125..m198; 02/09/06

Various Annual Means (COP2, IDB)

COP2	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE300	3.249	3.238	3.237	3.237	3.226	3.230	3.226	3.249	0.7%
CE310	3.415	3.417	3.417	3.393	3.397	3.380	3.380	3.417	1.1%
CE320	3.420	3.458	3.457	3.405	3.406	3.390	3.390	3.458	2.0%
CE330	3.491	3.494	3.536	3.491	3.497	3.460	3.460	3.536	2.2%
CE340	3.454	3.477	3.496	3.448	3.450	3.420	3.420	3.496	2.2%
CE350	3.249	3.241	3.235	3.244	3.229	3.230	3.229	3.249	0.6%
CE360	3.669	3.701	3.706	3.678	3.667	3.660	3.660	3.706	1.2%
CE400	3.250	3.251	3.252	3.246		3.260	3.246	3.260	0.4%
CE410	3.240	3.212	3.211			3.210	3.210	3.240	0.9%
CE420	3.226	3.215	3.218	3.216		3.210	3.210	3.226	0.5%
CE430	3.221	3.213	3.211	3.211		3.210	3.210	3.221	0.3%
CE440	3.231	3.222	3.222	3.221		3.220	3.220	3.231	0.4%
CE500	3.204	3.227	3.227	3.213	3.192	3.200	3.192	3.227	1.1%
CE500 May-Sep	3.142	3.161	3.162	3.154	3.132	3.140	3.132	3.162	0.9%
CE510 May-Sep	3.551	3.577	3.577	3.562	3.530	3.550	3.530	3.577	1.3%
CE520	2.901	2.957	2.956	3.004	2.873	2.920	2.873	3.004	4.5%
CE522	3.058	3.074	3.073	3.101	3.036	3.070	3.036	3.101	2.1%
CE525	3.484	3.531	3.528	3.508	3.480	3.410	3.410	3.531	3.5%
CE530	2.962	2.969	2.969	2.999	2.916	2.980	2.916	2.999	2.8%
CE540	2.668	2.675	2.675	2.823	2.640	2.690	2.640	2.823	6.8%
CE545	3.228	3.233	3.236	3.157	3.186	3.200	3.157	3.236	2.5%

IDB (°C)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE300	23.62	24.06	24.06	24.09	24.08	23.99	23.62	24.09	1.9%
CE310	23.76	24.11	24.06	24.09	24.09	24.01	23.76	24.11	1.5%
CE320	23.90	24.39	24.39	24.25	24.33	24.53	23.90	24.53	2.6%
CE330	23.88	24.28	24.28	24.27	24.30	24.18	23.88	24.30	1.7%
CE340	23.88	24.28	24.28	24.30	24.31	24.21	23.88	24.31	1.8%
CE350	25.66	26.17	26.17	26.24	26.27	26.15	25.66	26.27	2.3%
CE360	25.36	25.61	25.56	25.32	25.48	25.37	25.32	25.61	1.1%
CE400	24.13	24.06	24.06	24.09		23.99	23.99	24.13	0.6%
CE410	24.12	24.06	24.06			23.99	23.99	24.12	0.5%
CE420	23.93	24.06	24.06	24.09		23.99	23.93	24.09	0.7%
CE430	23.99	24.06	24.06	24.09		23.99	23.99	24.09	0.4%
CE440	23.91	24.06	24.06	24.09		23.99	23.91	24.09	0.7%
CE500	20.23	20.67	20.56	20.38	21.10	22.86	20.23	22.86	12.5%
CE500 May-Sep	24.57	25.00	25.00	24.98	25.00	25.00	24.57	25.00	1.7%
CE510 May-Sep	25.82	25.11	25.11	24.96	25.00	25.00	24.96	25.82	3.4%
CE520	13.52	13.78	13.72	13.58	14.14	14.89	13.52	14.89	9.9%
CE522	16.95	17.28	17.22	17.00	17.73	18.70	16.95	18.70	10.0%
CE525	26.84	27.39	27.28	27.10	27.77	30.69	26.84	30.69	13.8%
CE530	20.03	20.61	20.56	20.59	21.10	22.86	20.03	22.86	13.5%
CE540	13.29	13.78	13.72	13.79	14.14	14.98	13.29	14.98	12.1%
CE545	26.61	27.33	27.28	27.31	27.72	30.69	26.61	30.69	14.7%

RESULTS5-3B.xls q:a205..m254; 02/09/06

Various Annual Means (Humidity Ratio, Zone Relative Humidity)

Humidity Ratio (kg/kg)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE300	0.0091	0.0092	0.0092	0.0093	0.0092	0.0092	0.0091	0.0093	2.4%
CE310	0.0111	0.0113	0.0113	0.0113	0.0112	0.0111	0.0111	0.0113	2.0%
CE320	0.0100	0.0101	0.0101	0.0101	0.0100	0.0099	0.0099	0.0101	2.1%
CE330	0.0097	0.0099	0.0099	0.0100	0.0098	0.0099	0.0097	0.0100	2.3%
CE340	0.0098	0.0099	0.0099	0.0100	0.0099	0.0099	0.0098	0.0100	1.9%
CE350	0.0097	0.0100	0.0100	0.0099	0.0098	0.0098	0.0097	0.0100	3.0%
CE360	0.0085	0.0087	0.0087	0.0088	0.0086	0.0086	0.0085	0.0088	3.1%
CE400	0.0098	0.0100	0.0100	0.0101		0.0100	0.0098	0.0101	2.9%
CE410	0.0097	0.0095	0.0095			0.0095	0.0095	0.0097	2.5%
CE420	0.0093	0.0094	0.0094	0.0094		0.0093	0.0093	0.0094	2.0%
CE430	0.0093	0.0094	0.0094	0.0095		0.0094	0.0093	0.0095	1.9%
CE440	0.0092	0.0093	0.0093	0.0093		0.0092	0.0092	0.0093	1.9%
CE500	0.0098			0.0094	0.0102	0.0107	0.0094	0.0107	13.2%
CE500 May-Sep	0.0110	0.0114	0.0114	0.0113	0.0113	0.0109	0.0109	0.0114	4.5%
CE510 May-Sep	0.0114	0.0114	0.0114	0.0113	0.0113	0.0109	0.0109	0.0114	4.4%
CE520	0.0067			0.0060	0.0070	0.0076	0.0060	0.0076	23.1%
CE522	0.0082			0.0076	0.0086	0.0090	0.0076	0.0090	16.8%
CE525	0.0137			0.0138	0.0140	0.0151	0.0137	0.0151	9.8%
CE530	0.0062			0.0067	0.0058	0.0067	0.0058	0.0067	14.4%
CE540	0.0045			0.0043	0.0039	0.0046	0.0039	0.0046	17.9%
CE545	0.0062			0.0067	0.0067	0.0072	0.0062	0.0072	14.8%

Relative Humidity (%)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE300	48.61	48.26	48.28	48.59	47.83	47.93	47.83	48.61	1.6%
CE310	58.33	58.51	58.53	58.55	57.84	57.80	57.80	58.55	1.3%
CE320	52.01	51.21	51.25	51.84	51.10	49.94	49.94	52.01	4.0%
CE330	50.84	50.58	50.65	51.18	50.08	50.70	50.08	51.18	2.2%
CE340	51.09	50.69	50.73	51.15	50.30	50.78	50.30	51.15	1.7%
CE350	45.48	45.45	45.55	45.17	44.32	44.56	44.32	45.55	2.7%
CE360	41.03	41.49	41.49	42.37	40.87	41.21	40.87	42.37	3.6%
CE400	50.77	52.21	52.25	52.55		52.01	50.77	52.55	3.4%
CE410	50.50	49.65	49.63			49.75	49.63	50.50	1.7%
CE420	48.78	49.14	48.97	49.40		48.76	48.76	49.40	1.3%
CE430	48.82	49.17	49.30	49.60		49.17	48.82	49.60	1.6%
CE440	48.33	48.46	48.57	48.83		48.23	48.23	48.83	1.2%
CE500	66.53			59.20	65.94	63.73	59.20	66.53	11.5%
CE500 May-Sep	57.05	57.47	57.47	57.32	57.07	55.13	55.13	57.47	4.1%
CE510 May-Sep	54.70	57.36	57.36	57.44	57.06	55.24	54.70	57.44	4.8%
CE520	69.87			61.40	70.23	72.17	61.40	72.17	15.7%
CE522	68.68			60.75	68.23	68.11	60.75	68.68	11.9%
CE525	61.47			54.99	60.14	57.37	54.99	61.47	11.1%
CE530	46.73			48.97	41.45	39.60	39.60	48.97	21.2%
CE540	48.52			46.31	40.05	43.82	40.05	48.52	19.0%
CE545	36.62			38.63	36.87	29.20	29.20	38.63	26.7%

RESULTS5-3B.xls q:a255..m304; 02/09/06

f(ODB) Sensitivity CE500 and CE530, April 30 and June 25

	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
Energy Consumption, Compr. + Both Fans (Wh,e)									
CE500Apr30	3893	3975	3975	4029	3901	4073	3893	4073	4.5%
CE500Jun25	5045	5204	5204	5229	5067	5230	5045	5230	3.6%
Del CE500	1152	1229	1229	1200	1165	1157	1152	1229	6.5%
CE530Apr30	3023	3062	3062	3101	3092	3144	3023	3144	3.9%
CE530Jun25	3894	3978	3978	4029	3935	4043	3894	4043	3.7%
Del CE530	871	916	916	927	843	899	843	927	9.4%
Energy Consumption, Compressor (Wh,e)									
CE500Apr30	3015	3120	3120		3020	3159	3015	3159	4.7%
CE500Jun25	4084	4264	4263		4106	4239	4084	4264	4.3%
Del CE500	1069	1144	1144		1086	1080	1069	1144	6.7%
CE530Apr30	2311	2390	2390		2378	2411	2311	2411	4.2%
CE530Jun25	3118	3243	3243		3166	3248	3118	3248	4.1%
Del CE530	807	853	853		787	837	787	853	8.0%
Energy Consumption, Condenser Fan (Wh,e)									
CE500Apr30	376	389	389		377	391	376	391	3.9%
CE500Jun25	411	426	426		411	424	411	426	3.6%
Del CE500	35	37	37		34	33	33	37	12.0%
CE530Apr30	305	311	311		305	314	305	314	3.1%
CE530Jun25	332	340	340		329	340	329	340	3.2%
Del CE530	28	28	29		24	26	24	29	17.0%
Energy Consumption, Supply Fan (Wh,e)									
CE500Apr30	502	467	466	519	504	522	466	522	11.2%
CE500Jun25	550	514	514	566	549	566	514	566	9.5%
Del CE500	47	48	48	47	45	44	44	48	8.5%
CE530Apr30	407	361	361	412	408	419	361	419	14.8%
CE530Jun25	444	396	396	450	440	454	396	454	13.6%
Del CE530	37	35	35	38	32	35	32	38	16.0%
Sensible + Latent Coil Load (Wh,th)									
CE500Apr30	13186	13733	13733	13655	13170	13673	13170	13733	4.2%
CE500Jun25	13188	13838	13837	13733	13198	13727	13188	13838	4.8%
Del CE500	2	105	104	78	29	54	2	105	165.3%
CE530Apr30	9353	9721	9721	9775	9365	9798	9353	9798	4.6%
CE530Jun25	9376	9761	9761	9835	9388	9834	9376	9835	4.8%
Del CE530	23	40	39	60	22	36	22	60	102.8%
Sensible Coil Load (Wh,th)									
CE500Apr30	9375	9925	9925	9884	9365	9902	9365	9925	5.8%
CE500Jun25	9378	9981	9981	9953	9388	9946	9378	9981	6.2%
Del CE500	3	56	56	69	22	44	3	69	158.2%
CE530Apr30	9353	9721	9721	9775	9365	9798	9353	9798	4.6%
CE530Jun25	9376	9761	9761	9835	9388	9834	9376	9835	4.8%
Del CE530	23	40	39	60	22	36	22	60	102.9%
Latent Coil Load (Wh,th)									
CE500Apr30	3811	3808	3808	3772	3804	3770	3770	3811	1.1%
CE500Jun25	3810	3856	3856	3781	3810	3780	3780	3856	2.0%
Del CE500	-1	48	48	9	6	10	-1	48	242.3%
CE530Apr30	0	0	0	0	0	0	0	0	28464.8%
CE530Jun25	0	0	0	0	0	0	0	0	300.0%
Del CE530	0	0	0	0	0	0	0	0	300.0%

RESULTS5-3B.xls q:a316..m69; 02/09/06

f(ODB) Sensitivity CE500 and CE530, April 30 and June 25

	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
Humidity Ratio (kg/kg)									
CE500Apr30	0.0107	0.0110	0.0110	0.0110	0.0109	0.0160	0.011	0.016	45.3%
CE500Jun25	0.0112	0.0115	0.0115	0.0115	0.0115	0.0110	0.011	0.012	4.4%
Del CE500	0.0005	0.0005	0.0005	0.0005	0.0005	-0.0050	-0.005	0.001	-1334.8%
CE530Apr30	0.0062	0.0071	0.0071	0.0068	0.0055	0.0067	0.005	0.007	24.6%
CE530Jun25	0.0062	0.0078	0.0078	0.0068	0.0055	0.0067	0.005	0.008	34.2%
Del CE530	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.000	0.001	304.5%
COP2									
CE500Apr30	3.845	3.914	3.914	3.850	3.837	3.850	3.837	3.914	2.0%
CE500Jun25	2.931	2.951	2.951	2.943	2.921	2.940	2.921	2.951	1.0%
Del CE500	-0.914	-0.963	-0.963	-0.907	-0.916	-0.910	-0.963	-0.907	-6.1%
CE530Apr30	3.543	3.599	3.599	3.441	3.460	3.590	3.441	3.599	4.5%
CE530Jun25	2.720	2.724	2.724	2.780	2.690	2.740	2.690	2.780	3.3%
Del CE530	-0.823	-0.874	-0.875	-0.662	-0.770	-0.850	-0.875	-0.662	-26.3%
ODB (°C)									
CE500Apr30	16.79	16.83	16.83	16.81	16.88	16.96	16.79	16.96	1.0%
CE500Jun25	29.52	29.50	29.50	29.52	29.52	29.50	29.50	29.52	0.1%
Del CE500	12.73	12.67	12.67	12.70	12.63	12.54	12.54	12.73	1.5%
CE530Apr30	16.79	16.83	16.83	16.81	16.88	16.96	16.79	16.96	1.0%
CE530Jun25	29.52	29.50	29.50	29.52	29.52	29.50	29.50	29.52	0.1%
Del CE530	12.73	12.67	12.67	12.70	12.63	12.54	12.54	12.73	1.5%
EDB (°C)									
CE500Apr30	24.64	24.94	24.94	24.98	25.00	25.00	24.64	25.00	1.4%
CE500Jun25	24.55	25.00	25.00	24.98	25.00	25.00	24.55	25.00	1.8%
Del CE500	-0.09	0.06	0.06	0.00	0.00	0.00	-0.09	0.06	4740.8%
CE530Apr30	24.37	24.94	24.67	25.00	25.00	25.00	24.37	25.00	2.6%
CE530Jun25	24.35	24.94	24.94	25.00	25.00	25.00	24.35	25.00	2.6%
Del CE530	-0.01	0.00	0.28	0.00	0.00	0.00	-0.01	0.28	651.2%

RESULTS5-3B.xls q:a370..m402; 02/09/06

Hourly Integrated Maxima (Total Cooling System Energy Consumption and Total Coil Load)

Energy Consumption, Compressor + Both Fans (Wh,e)	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour	NREL	Date	Hour	NREL	Date	Hour	GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	11626	20-Jul	15	11564	20-Jul	15	11602	20-Jul	15	11900	07/20	15:00	11932	20-Jul	15	11548	20-Jul	15	11548	11932	3.3%
CE310	12594	20-Jul	15	12583	20-Jul	15	12595	20-Jul	15	12541	07/20	15:00	12653	20-Jul	15	12162	16-Aug	16	12162	12653	3.9%
CE320	13028	20-Jul	15	12916	20-Jul	15	12981	20-Jul	15	12954	07/20	15:00	13104	20-Jul	15	12875	20-Jul	14	12875	13104	1.8%
CE330	13347	20-Jul	15	13212	20-Jul	15	13407	20-Jul	15	13314	07/20	15:00	13467	20-Jul	15	13335	20-Jul	15	13212	13467	1.9%
CE340	13181	20-Jul	15	13158	20-Jul	15	13190	20-Jul	15	13134	07/20	15:00	13277	20-Jul	15	13101	20-Jul	14	13101	13277	1.3%
CE350	11627	20-Jul	15	11654	20-Jul	15	11602	20-Jul	15	11900	07/20	15:00	11932	20-Jul	15	11546	20-Jul	15	11546	11932	3.3%
CE360	12770	20-Jul	15	12736	20-Jul	15	12726	20-Jul	15	12744	07/20	15:00	12863	20-Jul	15	12762	20-Jul	14	12726	12863	1.1%
CE400	11628	20-Jul	15	11564	20-Jul	15	11677	18-Sep	15	11900	07/20	15:00				11519	20-Jul	15	11519	11900	3.3%
CE410	11628	20-Jul	15	11564	20-Jul	15	11602	20-Jul	15							11549	20-Jul	15	11549	11628	0.7%
CE420	11626	20-Jul	15	11564	20-Jul	15	11602	20-Jul	15	11900	07/20	15:00				11548	20-Jul	15	11548	11900	3.0%
CE430	11626	20-Jul	15	11564	20-Jul	15	11602	20-Jul	15	11900	07/20	15:00				11548	20-Jul	15	11548	11900	3.0%
CE440	11626	20-Jul	15	11564	20-Jul	15	11602	20-Jul	15	11900	07/20	15:00				11461	16-Aug	16	11461	11900	3.8%
CE500	10166	20-Jul	15	10431	20-Jul	15	10425	20-Jul	15	10399	07/20	15:00	10177	20-Jul	15	10274	4-Jun	15	10166	10431	2.6%
CE510	11205	20-Jul	15	11590	20-Jul	15	11587	20-Jul	15	11410	07/20	15:00	11186	20-Jul	15	11344	20-Jul	14	11186	11590	3.5%
CE520	11035	20-Jul	15	10989	20-Jul	15	11014	20-Jul	15	11101	07/20	15:00	11044	20-Jul	15	10684	4-Jun	15	10684	11101	3.8%
CE522	10431	20-Jul	15	10972	20-Jul	15	10966	20-Jul	15	10762	07/20	15:00	10639	20-Jul	15	10747	16-Aug	15	10431	10972	5.0%
CE525	9367	20-Jul	15	9538	20-Jul	15	9531	20-Jul	15	9570	07/20	15:00	9419	20-Jul	15	9585	16-Aug	15	9367	9585	2.3%
CE530	8028	20-Jul	15	8059	20-Jul	15	8055	20-Jul	15	8171	07/20	15:00	7992	20-Jul	15	8089	16-Aug	15	7992	8171	2.2%
CE540	8699	20-Jul	15	8943	20-Jul	15	8939	20-Jul	15	8677	07/20	15:00	8846	20-Jul	15	8985	16-Aug	15	8677	8985	3.5%
CE545	7205	20-Jul	15	7350	20-Jul	15	7346	20-Jul	15	7763	07/20	15:00	7351	20-Jul	15	7471	4-Jun	15	7205	7763	7.5%

Senstible + Latent Coil Load (Wh,th)	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour	NREL	Date	Hour	NREL	Date	Hour	GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	32174	08-Jul	15	31401	20-Jul	15	31455	20-Jul	15	32733	07/20	15:00	32502	20-Jul	15	32072	20-Jul	15	31401	32733	4.2%
CE310	37328	03-Sep	15	36750	3-Sep	16	37033	3-Sep	16	37126	09/17	15:00	37261	3-Sep	15	36991	3-Sep	16	36750	37328	1.6%
CE320	40318	03-Sep	16	53813	2-Oct	9	53823	2-Oct	9	39765	09/03	16:00	39904	3-Sep	16	39920	3-Sep	16	39765	53823	31.5%
CE330	43492	02-Oct	9	43628	2-Oct	9	64572	2-Oct	9	43445	10/02	09:00	43978	2-Oct	9	42415	10-Jul	11	42415	64572	47.2%
CE340	41652	02-Oct	10	50819	2-Oct	9	59549	2-Oct	9	41328	10/02	10:00	41366	3-Sep	15	41132	3-Sep	16	41132	59549	40.1%
CE350	32092	08-Jul	15	31401	20-Jul	15	31454	20-Jul	15	32733	07/20	15:00	32502	20-Jul	15	32077	20-Jul	15	31401	32733	4.2%
CE360	38857	02-Oct	10	40613	2-Oct	9	41019	2-Oct	9	38460	10/02	11:00	38322	2-Oct	10	38451	2-Oct	10	38322	41019	6.9%
CE400	41179	16-Sep	15	40543	18-Sep	14	49838	18-Sep	15	40728	09/16	15:00				40774	16-Sep	14	40543	49838	21.8%
CE410	32092	08-Jul	15	31401	20-Jul	15	31455	20-Jul	15							32073	20-Jul	15	31401	32092	2.2%
CE420	32174	08-Jul	15	31401	20-Jul	15	31455	20-Jul	15	32733	07/20	15:00				32072	20-Jul	15	31401	32733	4.2%
CE430	32174	08-Jul	15	31401	20-Jul	15	31455	20-Jul	15	32733	07/20	15:00				32072	20-Jul	15	31401	32733	4.2%
CE440	32174	08-Jul	15	31401	20-Jul	15	31455	20-Jul	15	32733	07/20	15:00				31777	8-Jul	16	31401	32733	4.2%
CE500	27486	28-Oct	15	27707	16-Aug	16	27706	16-Aug	16	27646	06/29	16:00	26567	29-Jun	16	27555	29-Jun	15	26567	27707	4.2%
CE510	30593	29-Apr	19	31188	20-Jul	15	31188	20-Jul	15	31178	06/17	14:00	29948	17-Jun	14	31097	17-Jun	13	29948	31188	4.0%
CE520	27330	28-Sep	15	27878	14-Aug	16	27878	23-Jul	16	27653	06/29	16:00	26675	20-Jul	16	28343	23-May	15	26675	28343	6.0%
CE522	27384	12-Mai	15	27868	16-Aug	16	27866	16-Aug	16	27659	06/29	16:00	26514	29-Jun	16	27636	29-Jun	15	26514	27868	4.9%
CE525	27740	26-Jul	16	27466	8-Jul	16	27466	8-Jul	16	27577	06/29	16:00	26683	29-Jun	16	27462	29-Jun	15	26683	27740	3.9%
CE530	19834	29-Mai	15	19576	24-Apr	16	19575	24-Apr	16	19639	07/20	15:00	18776	4-Jun	15	19626	8-Jul	15	18776	19834	5.4%
CE540	19575	30-Aug	16	19766	24-Apr	16	19766	24-Apr	16	19726	07/20	15:00	18794	4-Jun	15	19799	16-Aug	15	18794	19799	5.1%
CE545	20075	17-Jun	16	19475	24-Apr	16	19474	24-Apr	16	19540	07/20	15:00	18764	20-Jul	15	19497	4-Jun	15	18764	20075	6.7%

Hourly Integrated Maxima (Sensible Coil Load and Latent Coil Load)

Sensible Coil Load (Wh,th)	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour	NREL	Date	Hour	NREL	Date	Hour	GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	23277	20-Jul	16	23203	20-Jul	15	23205	20-Jul	15	23531	07/20	15:00	23457	20-Jul	15	22908	4-Jun	15	22908	23531	2.7%
CE310	23094	10-Sep	15	23080	10-Sep	16	23119	4-Jun	16	23276	07/11	16:00	23078	10-Sep	15	22649	13-Jun	16	22649	23276	2.7%
CE320	31316	24-Apr	16	31119	24-Apr	16	31072	24-Apr	16	31972	04/24	15:00	31134	3-Jun	16	30967	24-Apr	15	30967	31972	3.2%
CE330	33226	14-Jun	14	33410	14-Jun	14	34490	14-Jun	15	34765	06/14	15:00	33997	24-Apr	16	33421	9-Sep	14	33226	34765	4.5%
CE340	32829	24-Apr	15	32086	16-May	16	32086	16-May	16	32888	04/24	15:00	32940	24-Apr	16	32180	24-Apr	15	32086	32940	2.6%
CE350	23278	29-Jul	15	23203	20-Jul	15	23205	20-Jul	15	23531	07/20	15:00	23457	20-Jul	15	22876	10-Jul	15	22876	23531	2.8%
CE360	32061	24-Apr	16	32111	24-Apr	16	32065	24-Apr	16	32621	04/24	16:00	31981	24-Apr	16	32179	24-Apr	15	31981	32621	2.0%
CE400	23278	29-Jul	15	23203	20-Jul	15	23205	20-Jul	15	23531	07/20	15:00				22877	8-Jul	16	22877	23531	2.8%
CE410	23266	10-Sep	16	23203	20-Jul	15	23205	20-Jul	15							22893	29-Jul	15	22893	23266	1.6%
CE420	23277	20-Jul	16	23203	20-Jul	15	23205	20-Jul	15	23531	07/20	15:00				22893	29-Jul	15	22893	23531	2.7%
CE430	23277	20-Jul	16	23203	20-Jul	15	23205	20-Jul	15	23531	07/20	15:00				22893	29-Jul	15	22893	23531	2.7%
CE440	23277	20-Jul	16	23203	20-Jul	15	23205	20-Jul	15	23531	07/20	15:00				22875	16-Aug	16	22875	23531	2.8%
CE500	19549	28-Oct	15	20009	4-Jun	16	20008	10-Sep	16	19849	07/20	15:00	18776	4-Jun	15	19818	29-Jul	15	18776	20009	6.3%
CE510	21729	29-Apr	19	22513	11-Jul	15	22513	11-Jul	15	22290	07/20	15:00	21121	4-Jun	13	22269	20-Jul	14	21121	22513	6.3%
CE520	19416	28-Sep	15	20159	26-May	16	20154	26-May	16	19999	07/20	15:00	18969	20-Jul	16	20378	23-May	15	18969	20378	7.1%
CE522	19489	12-Mai	15	20137	11-Jul	16	20135	11-Jul	16	19934	07/20	15:00	18785	4-Jun	15	19920	16-Aug	15	18785	20137	6.9%
CE525	19703	26-Jul	16	19850	24-Apr	16	19850	24-Apr	16	19664	07/20	15:00	18759	4-Jun	15	19661	4-Jun	15	18759	19850	5.6%
CE530	19834	29-Mai	15	19576	24-Apr	16	19575	24-Apr	16	19639	07/20	15:00	18776	4-Jun	15	19626	8-Jul	15	18776	19834	5.4%
CE540	19575	30-Aug	16	19766	24-Apr	16	19766	24-Apr	16	19726	07/20	15:00	18794	4-Jun	15	19799	16-Aug	15	18794	19799	5.1%
CE545	20075	17-Jun	16	19475	24-Apr	16	19474	24-Apr	16	19540	07/20	15:00	18759	4-Jun	15	19497	4-Jun	15	18759	20075	6.8%

Latent Coil Load (Wh,th)	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour	NREL	Date	Hour	NREL	Date	Hour	GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	9636	03-Sep	16	9304	3-Sep	15	9394	3-Sep	15	10235	07/10	13:00	10375	3-Sep	15	10392	3-Sep	15	9304	10392	11.0%
CE310	15907	03-Sep	15	15139	3-Sep	15	15270	3-Sep	15	16275	08/04	15:00	16112	4-Aug	15	16077	3-Sep	16	15139	16275	7.2%
CE320	23147	02-Oct	10	31497	2-Oct	9	31503	2-Oct	9	22195	10/02	10:00	21697	17-Sep	12	21929	1-Oct	20	21697	31503	38.7%
CE330	27825	18-Sep	16	26941	18-Sep	15	40809	2-Oct	9	27134	09/18	16:00	28184	18-Sep	15	27488	18-Sep	15	26941	40809	46.6%
CE340	24848	02-Oct	9	30451	2-Oct	9	36011	2-Oct	9	23911	10/02	10:00	24225	3-Sep	17	23794	1-Oct	20	23794	36011	44.9%
CE350	9751	01-Oct	13	9303	3-Sep	15	9393	3-Sep	15	10235	07/10	13:00	10755	2-Oct	8	11603	3-Aug	7	9303	11603	22.6%
CE360	9275	02-Oct	10	10026	2-Oct	9	10336	2-Oct	9	8520	10/02	11:00	8859	3-Sep	17	8934	3-Sep	17	8520	10336	19.5%
CE400	27075	16-Sep	15	25578	18-Sep	14	32396	18-Sep	15	26317	09/16	14:00				26645	16-Sep	14	25578	32396	24.7%
CE410	11139	16-Sep	15	9304	3-Sep	15	9391	3-Sep	15							10377	9-Sep	15	9304	11139	18.3%
CE420	9751	01-Oct	13	9304	3-Sep	15	9394	3-Sep	15	10235	07/10	13:00				10394	3-Sep	15	9304	10394	11.1%
CE430	9636	03-Sep	16	11105	24-Oct	14	11101	21-May	15	11074	10/24	13:00				10394	3-Sep	15	9636	11105	13.8%
CE440	9636	03-Sep	16	9304	3-Sep	15	9391	3-Sep	15	10235	07/10	13:00				10139	3-Sep	15	9304	10235	9.6%
CE500	7965	06-Oct	15	7733	3-Sep	15	7733	3-Sep	15	7839	06/29	16:00	7805	29-Jun	16	7762	29-Jun	15	7733	7965	3.0%
CE510	8893	15-Sep	11	8723	2-Oct	9	8723	2-Oct	9	8955	06/17	14:00	8850	17-Jun	14	8874	17-Jun	13	8723	8955	2.6%
CE520	7914	28-Sep	15	7785	3-Sep	15	7785	3-Sep	15	7699	06/29	16:00	7726	30-Jun	16	7964	23-May	15	7699	7964	3.4%
CE522	7907	02-Mai	15	7760	3-Sep	15	7760	3-Sep	15	7770	06/29	16:00	7743	29-Jun	16	7745	29-Jun	15	7743	7907	2.1%
CE525	8037	26-Jul	16	7663	3-Sep	15	7663	3-Sep	15	7947	06/29	16:00	7938	29-Jun	16	7820	29-Jun	15	7663	8037	4.8%
CE530	0	18-Jun	16	0	0-Jan	0	0	0-Jan	0	1	03/16	10:00	179	11-Mar	11	36	1-Nov	20	0	179	497.3%
CE540	627	11-Mar	10	0	0-Jan	0	0	0-Jan	0	1655	03/11	10:00	845	11-Mar	10	1181	11-Mar	10	0	1655	230.5%
CE545	0	01-Jul	16	0	0-Jan	0	0	0-Jan	0	0	05/23	15:00	4	20-Jul	15	0	1-Jan	1	0	4	600.0%

RESULTS5-3B.xls r:a07..w102; 02/09/06

Hourly Integrated Maxima and Minima (COP2)

Maximum COP2	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour	NREL	Date	Hour	NREL	Date	Hour	GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	4.168	16-Apr	3	3.869	30-Apr	16	3.857	30-Apr	16	3.925	04/30	15:00	3.871	30-Apr	16	3.880	30-Apr	16	3.857	4.168	7.9%
CE310	4.143	30-Apr	15	4.141	30-Apr	16	4.128	30-Apr	16	4.173	04/30	15:00	4.128	30-Apr	15	4.120	30-Apr	15	4.120	4.173	1.3%
CE320	4.168	16-Apr	3	5.143	2-Oct	9	4.967	2-Oct	9	3.940	09/16	15:00	3.943	16-Sep	15	4.380	18-Dec	3	3.940	5.143	27.2%
CE330	4.168	16-Apr	3	4.109	17-Jun	16	5.595	2-Oct	9	4.071	09/16	14:00	4.122	17-Jun	16	4.050	17-Jun	16	4.050	5.595	35.5%
CE340	4.168	16-Apr	3	4.621	2-Oct	9	5.339	2-Oct	9	3.987	09/16	15:00	4.017	16-Sep	16	3.950	16-Sep	16	3.950	5.339	32.0%
CE350	4.168	16-Apr	3	3.889	27-Apr	5	3.863	5-Oct	3	4.555	10/13	01:00	3.932	4-Oct	24	3.880	30-Apr	16	3.863	4.555	17.1%
CE360	4.401	05-Oct	1	4.428	4-Oct	24	4.427	4-Oct	24	4.455	10/04	24:00	4.432	4-Oct	24	4.440	4-Oct	24	4.401	4.455	1.2%
CE400	4.077	16-Sep	15	4.088	17-Jun	16	4.776	18-Sep	15	4.071	09/16	14:00				4.050	17-Jun	16	4.050	4.776	17.2%
CE410	3.888	30-Apr	15	3.903	30-Apr	15	3.855	30-Apr	16							3.840	21-May	15	3.840	3.903	1.6%
CE420	3.781	27-Sep	16	3.807	21-May	15	3.759	27-Sep	15	3.821	05/21	15:00				3.940	21-May	13	3.759	3.940	4.7%
CE430	3.781	27-Sep	16	3.805	24-Oct	15	3.759	27-Sep	15	3.793	05/21	16:00				3.930	30-Apr	13	3.759	3.930	4.5%
CE440	3.883	12-Dez	7	3.774	27-Sep	15	3.759	27-Sep	15	3.802	05/21	15:00				3.810	30-Apr	15	3.759	3.883	3.3%
CE500	4.275	13-Oct	1	7.367	11-Mar	10	5.301	13-Oct	9	4.198	03/16	10:00	4.185	16-Mar	10	4.140	30-Apr	16	4.140	7.367	65.7%
CE510	4.693	05-Oct	1	7.367	11-Mar	10	5.301	13-Oct	9	4.685	10/05	01:00	4.690	4-Oct	24	4.530	4-May	3	4.530	7.367	54.4%
CE520	3.814	30-Apr	15	4.896	16-Mar	10	4.652	16-Mar	10	3.938	04/30	15:00	3.802	30-Apr	16	3.840	30-Apr	16	3.802	4.896	26.3%
CE522	3.986	16-Mar	10	6.233	11-Mar	10	5.678	11-Mar	10	4.042	04/30	15:00	3.986	30-Apr	16	4.000	30-Apr	16	3.986	6.233	48.3%
CE525	4.718	13-Oct	1	6.325	12-Apr	9	6.031	16-Mar	10	4.704	03/16	10:00	4.638	16-Mar	10	4.400	16-Mar	10	4.400	6.325	37.5%
CE530	4.006	02-Nov	1	3.981	11-Mar	10	3.850	13-Oct	9	3.925	03/16	10:00	3.840	16-Mar	10	3.880	16-Mar	10	3.840	4.006	4.2%
CE540	3.456	30-Apr	15	3.456	30-Apr	16	3.455	30-Apr	16	3.696	03/16	10:00	3.667	11-Mar	22	3.690	17-Oct	5	3.455	3.696	6.7%
CE545	4.250	16-Mar	10	4.275	16-Mar	10	4.428	16-Mar	10	4.166	03/16	10:00	4.156	16-Mar	10	4.170	16-Mar	10	4.156	4.428	6.4%

Minimum COP2	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour	NREL	Date	Hour	NREL	Date	Hour	GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	2.793	24-Apr	17	2.798	1-Dec	14	2.801	1-Dec	12	2.782	06/13	17:00	2.786	13-Jun	17	2.810	14-Jun	12	2.782	2.810	1.0%
CE310	2.865	01-Dec	15	2.850	1-Dec	14	2.851	1-Dec	12	2.893	12/01	15:00	2.873	1-Dec	15	2.870	1-Dec	14	2.850	2.893	1.5%
CE320	2.825	31-Mar	14	2.801	1-Dec	14	2.805	1-Dec	15	2.842	03/31	15:00	2.815	31-Mar	15	2.830	31-Mar	14	2.801	2.842	1.4%
CE330	2.825	31-Mar	14	2.798	1-Dec	14	2.801	1-Dec	12	2.844	03/31	15:00	2.823	31-Mar	15	2.840	31-Mar	14	2.798	2.844	1.6%
CE340	2.825	31-Mar	14	2.798	1-Dec	14	2.801	1-Dec	12	2.844	03/31	15:00	2.823	31-Mar	15	2.840	31-Mar	14	2.798	2.844	1.6%
CE350	2.790	24-Apr	17	2.798	1-Dec	14	2.801	1-Dec	12	2.782	06/13	17:00	2.786	13-Jun	17	2.810	14-Jun	12	2.782	2.810	1.0%
CE360	2.825	31-Mar	14	2.799	1-Dec	14	2.801	1-Dec	12	2.844	03/31	15:00	2.823	31-Mar	15	2.840	31-Mar	14	2.799	2.844	1.6%
CE400	2.782	31-Mar	19	2.734	3-Dec	15	2.735	3-Dec	13	2.782	06/13	17:00				2.810	14-Jun	12	2.734	2.810	2.7%
CE410	2.786	24-Apr	17	2.798	1-Dec	14	2.801	1-Dec	12							2.810	14-Jun	12	2.786	2.810	0.9%
CE420	2.793	24-Apr	17	2.798	1-Dec	14	2.801	1-Dec	12	2.782	06/13	17:00				2.810	14-Jun	12	2.782	2.810	1.0%
CE430	2.771	30-Mar	19	2.734	3-Dec	13	2.735	3-Dec	13	2.782	06/13	17:00				2.810	14-Jun	12	2.734	2.810	2.7%
CE440	2.782	31-Mar	19	2.734	3-Dec	13	2.735	3-Dec	13	2.782	06/13	17:00				2.810	8-Apr	13	2.734	2.810	2.7%
CE500	2.685	30-Jul	12	2.693	29-Jul	12	2.652	30-Mar	17	2.705	07/30	12:00	2.666	30-Jul	12	2.710	29-Jul	12	2.652	2.710	2.2%
CE510	2.888	31-Mar	15	2.817	5-Apr	17	2.652	30-Mar	17	2.865	03/31	18:00	2.882	31-Mar	15	2.900	31-Mar	14	2.652	2.900	8.8%
CE520	2.442	30-Jul	12	2.463	5-Apr	17	2.394	5-Apr	17	2.532	07/30	12:00	2.333	29-Jan	10	2.470	30-Jul	12	2.333	2.532	8.1%
CE522	2.569	08-Jul	17	2.572	29-Jul	12	2.562	31-Mar	17	2.613	07/30	12:00	2.429	30-Mar	17	2.590	29-Jul	12	2.429	2.613	7.2%
CE525	2.911	14-Jul	17	2.939	30-Jul	12	2.814	31-Mar	17	2.940	07/30	12:00	2.894	29-Jul	12	2.900	29-Jul	12	2.814	2.940	4.3%
CE530	2.501	30-Jul	12	2.495	29-Jul	12	2.498	29-Jul	12	2.532	07/30	12:00	2.473	29-Jul	12	2.520	29-Jul	12	2.473	2.532	2.3%
CE540	2.253	30-Jul	12	2.261	29-Jul	12	2.262	30-Jul	12	2.383	07/30	12:00	2.143	5-Apr	20	2.280	29-Jul	12	2.143	2.383	10.6%
CE545	2.733	14-Jul	17	2.720	29-Jul	12	2.722	30-Jul	12	2.660	07/30	12:00	2.692	29-Jul	12	2.720	29-Jul	12	2.660	2.733	2.7%

Hourly Integrated Maxima and Minima (IDB)

Maximum IDB (°C)	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour	NREL	Date	Hour	NREL	Date	Hour	GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	26.20	07-Jul	15	25.11	22-Apr	15	25.11	22-Apr	15	25.00	09/23	08:00	25.05	21-Feb	17	26.19	3-Nov	15	25.00	26.20	4.7%
CE310	27.08	20-Jul	15	26.89	20-Jul	16	26.72	20-Jul	16	26.47	07/20	16:00	26.62	20-Jul	15	27.19	8-Jul	15	26.47	27.19	2.7%
CE320	32.36	20-Jul	15	31.61	8-Jul	16	31.50	8-Jul	16	31.71	07/20	15:00	32.32	20-Jul	15	31.65	8-Jul	15	31.50	32.36	2.7%
CE330	32.23	20-Jul	15	31.72	8-Jul	16	32.00	20-Jul	16	31.07	07/08	16:00	31.90	20-Jul	15	31.30	8-Jul	15	31.07	32.23	3.7%
CE340	32.31	20-Jul	15	31.61	8-Jul	16	31.56	8-Jul	16	31.50	07/20	15:00	32.15	20-Jul	15	31.58	8-Jul	15	31.50	32.31	2.5%
CE350	34.58	01-Oct	24	34.94	23-Jun	24	34.94	24-Jun	24	35.00	10/01	02:00	35.00	21-Apr	1	35.00	21-Apr	2	34.58	35.00	1.2%
CE360	33.76	10-Jul	13	32.78	20-Jul	15	32.56	20-Jul	16	32.51	07/10	13:00	33.00	20-Jul	15	33.13	10-Jul	12	32.51	33.76	3.8%
CE400	27.11	16-Sep	15	27.56	16-Sep	16	28.83	18-Sep	16	26.91	09/16	16:00				26.04	15-Aug	15	26.04	28.83	10.2%
CE410	26.83	23-Oct	15	25.11	22-Apr	15	25.11	22-Apr	15							26.19	3-Nov	15	25.11	26.83	6.6%
CE420	26.20	07-Jul	15	25.11	22-Apr	15	25.11	22-Apr	15	25.00	09/23	08:00				26.23	20-Oct	15	25.00	26.23	4.8%
CE430	27.20	01-Nov	16	25.11	22-Apr	15	25.11	22-Apr	15	25.00	05/18	19:00				26.45	23-Oct	15	25.00	27.20	8.5%
CE440	27.05	28-Apr	15	25.11	22-Apr	15	25.11	22-Apr	15	25.00	04/24	19:00				26.26	23-Oct	15	25.00	27.05	7.9%
CE500	25.81	30-Apr	15	25.11	21-Apr	16	25.11	21-Apr	16	25.00	03/31	18:00	25.02	30-Mar	17	25.00	11-Mar	11	25.00	25.81	3.2%
CE510	26.10	09-Jul	15	25.11	21-Apr	3	25.11	21-Apr	3	25.00	03/31	18:00	25.02	30-Mar	17	25.00	24-Apr	12	25.00	26.10	4.4%
CE520	16.12	15-Aug	15	16.11	16-Aug	16	15.94	10-Jul	16	15.00	04/16	01:00	15.98	20-Jul	15	18.62	4-Jun	16	15.00	18.62	22.2%
CE522	21.01	16-Jul	15	20.11	21-Apr	15	20.11	21-Apr	15	20.00	04/16	20:00	20.05	13-Mar	22	20.93	21-Apr	15	20.00	21.01	5.0%
CE525	36.08	10-Mai	16	35.06	21-Apr	16	35.06	21-Apr	16	35.00	03/11	12:00	35.00	11-Mar	10	35.00	11-Mar	11	35.00	36.08	3.1%
CE530	26.12	04-Jun	15	25.06	21-Apr	16	25.06	21-Apr	16	25.00	03/30	17:00	25.02	30-Mar	17	25.00	11-Mar	11	25.00	26.12	4.4%
CE540	16.15	21-Sep	16	15.11	31-May	16	15.11	31-May	16	15.00	03/25	08:00	15.05	28-Jan	20	15.00	11-Mar	10	15.00	16.15	7.5%
CE545	35.67	20-Jul	15	35.00	21-Apr	15	35.00	21-Apr	15	35.00	07/09	22:00	35.00	11-Mar	10	35.00	11-Mar	11	35.00	35.67	1.9%

Minimum IDB (°C)	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour	NREL	Date	Hour	NREL	Date	Hour	GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	7.93	06-Jan	6	8.89	6-Jan	6	8.83	6-Jan	6	8.72	01/06	06:00	8.00	6-Jan	5	6.99	6-Jan	5	6.99	8.89	23.1%
CE310	7.93	06-Jan	6	8.89	6-Jan	6	8.83	6-Jan	6	8.72	01/06	06:00	8.00	6-Jan	5	6.99	6-Jan	5	6.99	8.89	23.1%
CE320	7.93	06-Jan	6	10.83	6-Jan	7	10.78	6-Jan	7	7.75	01/06	06:00	8.00	6-Jan	5	6.99	6-Jan	5	6.99	10.83	44.1%
CE330	7.93	06-Jan	6	8.89	6-Jan	6	8.83	6-Jan	6	8.72	01/06	06:00	8.00	6-Jan	5	6.99	6-Jan	5	6.99	8.89	23.1%
CE340	7.93	06-Jan	6	8.89	6-Jan	6	8.83	6-Jan	6	8.72	01/06	06:00	8.00	6-Jan	5	6.99	6-Jan	5	6.99	8.89	23.1%
CE350	7.93	06-Jan	6	8.89	6-Jan	6	8.83	6-Jan	6	8.72	01/06	06:00	8.00	6-Jan	5	6.99	6-Jan	5	6.99	8.89	23.1%
CE360	7.93	06-Jan	6	8.89	6-Jan	6	8.83	6-Jan	6	8.72	01/06	06:00	8.00	6-Jan	5	6.99	6-Jan	5	6.99	8.89	23.1%
CE400	7.93	06-Jan	6	8.89	6-Jan	6	8.83	6-Jan	6	8.72	01/06	06:00				6.99	6-Jan	5	6.99	8.89	23.0%
CE410	7.93	06-Jan	6	8.89	6-Jan	6	8.83	6-Jan	6							6.99	6-Jan	5	6.99	8.89	23.3%
CE420	7.93	06-Jan	6	8.89	6-Jan	6	8.83	6-Jan	6	8.72	01/06	06:00				6.99	6-Jan	5	6.99	8.89	23.0%
CE430	7.93	06-Jan	6	8.89	6-Jan	6	8.83	6-Jan	6	8.72	01/06	06:00				6.99	6-Jan	5	6.99	8.89	23.0%
CE440	7.93	06-Jan	6	8.89	6-Jan	6	8.83	6-Jan	6	8.72	01/06	06:00				7.00	6-Jan	5	7.00	8.89	22.8%
CE500	8.43	20-Dec	22	8.17	20-Dec	12	7.94	20-Dec	11	8.94	12/21	02:00	8.54	20-Dec	20	24.04	15-Apr	5	7.94	24.04	146.2%
CE510	8.43	20-Dec	22	8.17	20-Dec	12	7.94	20-Dec	11	8.94	12/21	02:00	8.54	20-Dec	20	24.04	15-Apr	5	7.94	24.04	146.2%
CE520	8.31	20-Dec	22	8.11	20-Dec	12	7.89	20-Dec	12	8.83	12/21	01:00	8.51	20-Dec	20	13.57	1-Nov	7	7.89	13.57	61.7%
CE522	8.41	20-Dec	22	8.17	20-Dec	12	7.94	20-Dec	11	8.90	12/21	01:00	8.54	20-Dec	20	15.98	12-Apr	19	7.94	15.98	83.3%
CE525	8.44	20-Dec	22	8.17	20-Dec	13	7.94	20-Dec	12	9.01	12/21	02:00	8.54	20-Dec	20	33.01	1-Apr	8	7.94	33.01	200.2%
CE530	8.42	20-Dec	22	8.17	20-Dec	12	7.94	20-Dec	11	8.94	12/21	02:00	8.54	20-Dec	20	24.04	15-Apr	5	7.94	24.04	146.3%
CE540	8.23	20-Dec	22	8.11	20-Dec	12	7.89	20-Dec	12	8.83	12/21	01:00	8.51	20-Dec	20	14.95	19-Dec	1	7.89	14.95	74.9%
CE545	8.45	20-Dec	22	8.17	20-Dec	13	7.94	20-Dec	12	9.01	12/21	02:00	8.54	20-Dec	20	33.01	1-Apr	8	7.94	33.01	200.2%

RESULTS5-3B.xls r:a111..aa204; 02/09/06

Hourly Integrated Maxima and Minima (Zone Humidity Ratio)

Maximum Humidity Ratio	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour	NREL	Date	Hour	NREL	Date	Hour	GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	0.0133	16-Nov	17	0.0138	16-Nov	16	0.0137	16-Nov	16	0.0136	11/16	17:00	0.0135	16-Nov	16	0.0134	16-Nov	16	0.0133	0.0138	3.8%
CE310	0.0158	01-Oct	23	0.0188	15-Oct	9	0.0189	15-Oct	9	0.0156	10/01	08:00	0.0154	2-Oct	8	0.0157	2-Oct	8	0.0154	0.0189	20.8%
CE320	0.0180	10-Jul	13	0.0177	10-Jul	12	0.0176	10-Jul	12	0.0178	07/10	13:00	0.0175	10-Jul	12	0.0177	10-Jul	12	0.0175	0.0180	2.7%
CE330	0.0177	10-Jul	12	0.0178	2-Oct	9	0.0177	10-Jul	13	0.0179	07/10	12:00	0.0170	10-Jul	13	0.0177	10-Jul	12	0.0170	0.0179	5.0%
CE340	0.0179	10-Jul	13	0.0177	10-Jul	12	0.0174	10-Jul	12	0.0178	07/10	12:00	0.0173	10-Jul	13	0.0177	10-Jul	12	0.0173	0.0179	3.4%
CE350	0.0168	01-Oct	24	0.0199	2-Aug	22	0.0199	2-Aug	22	0.0172	10/02	01:00	0.0165	2-Oct	2	0.0166	2-Oct	1	0.0165	0.0199	19.2%
CE360	0.0134	10-Jul	13	0.0138	16-Nov	16	0.0137	16-Nov	16	0.0139	07/10	13:00	0.0135	16-Nov	16	0.0134	16-Nov	16	0.0134	0.0139	3.4%
CE400	0.0169	05-Apr	22	0.0170	5-Apr	21	0.0170	5-Apr	21	0.0169	04/05	22:00				0.0173	22-Apr	6	0.0169	0.0173	2.5%
CE410	0.0168	05-Apr	22	0.0169	2-Apr	5	0.0169	2-Apr	5							0.0173	22-Apr	6	0.0168	0.0173	2.7%
CE420	0.0143	02-Apr	10	0.0147	1-Apr	21	0.0141	17-Apr	3	0.0146	04/02	18:00				0.0147	2-Apr	18	0.0141	0.0147	4.1%
CE430	0.0162	02-Apr	5	0.0156	2-Apr	4	0.0156	2-Apr	4	0.0161	04/02	05:00				0.0158	2-Apr	5	0.0156	0.0162	4.0%
CE440	0.0133	16-Nov	17	0.0138	16-Nov	16	0.0137	16-Nov	16	0.0136	11/16	17:00				0.0134	16-Nov	16	0.0133	0.0138	3.6%
CE500	0.0117	11-Jul	15	0.0119	20-Jul	15	0.0118	6-Apr	10	0.0117	07/20	15:00	0.0117	20-Jul	15	0.0115	11-Mar	10	0.0115	0.0119	3.4%
CE510	0.0119	07-Sep	15	0.0119	20-Jul	15	0.0119	20-Jul	15	0.0117	07/20	15:00	0.0117	20-Jul	15	0.0115	11-Mar	10	0.0115	0.0119	3.4%
CE520	0.0075	07-Sep	15	0.0077	10-Jul	16	0.0078	29-Mar	10	0.0070	07/20	15:00	0.0076	20-Jul	15	0.0106	5-Jan	16	0.0070	0.0106	44.5%
CE522	0.0094	20-Jul	16	0.0095	4-Jun	15	0.0138	6-Apr	10	0.0091	07/20	15:00	0.0094	20-Jul	15	0.0107	1-Jan	2	0.0091	0.0138	45.4%
CE525	0.0179	10-Mai	16	0.0180	20-Jul	15	0.0180	20-Jul	15	0.0185	07/20	15:00	0.0176	20-Jul	15	0.0173	20-Jul	15	0.0173	0.0185	6.6%
CE530	0.0070	01-Jan	1	0.0081	20-Jul	15	0.0081	20-Jul	15	0.0068	03/11	01:00	0.0055	1-Apr	1	0.0068	26-Oct	9	0.0055	0.0081	37.1%
CE540	0.0061	01-Jan	1	0.0050	4-Jun	13	0.0063	8-Apr	8	0.0068	03/11	01:00	0.0033	1-Apr	1	0.0063	11-Mar	9	0.0033	0.0068	62.6%
CE545	0.0070	01-Jan	1	0.0122	20-Jul	15	0.0122	20-Jul	15	0.0068	12/31	07:00	0.0067	1-Apr	1	0.0076	5-Nov	9	0.0067	0.0122	63.0%

Minimum Humidity Ratio	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour	NREL	Date	Hour	NREL	Date	Hour	GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24	0.0019	01/11	03:00	0.0020	11-Jan	3	0.0020	5-Jan	6	0.0017	0.0020	14.5%
CE310	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24	0.0019	01/05	07:00	0.0020	5-Jan	7	0.0020	5-Jan	7	0.0017	0.0020	17.1%
CE320	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24	0.0019	01/11	03:00	0.0020	11-Jan	3	0.0020	5-Jan	6	0.0017	0.0020	14.5%
CE330	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24	0.0019	01/11	03:00	0.0020	11-Jan	3	0.0020	5-Jan	6	0.0017	0.0020	14.5%
CE340	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24	0.0019	01/11	03:00	0.0020	11-Jan	3	0.0020	5-Jan	6	0.0017	0.0020	14.5%
CE350	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24	0.0019	01/11	03:00	0.0020	11-Jan	3	0.0020	5-Jan	6	0.0017	0.0020	14.5%
CE360	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24	0.0019	01/11	03:00	0.0020	11-Jan	3	0.0020	5-Jan	6	0.0017	0.0020	14.5%
CE400	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24	0.0019	01/11	03:00				0.0020	5-Jan	6	0.0017	0.0020	14.7%
CE410	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24							0.0020	5-Jan	6	0.0017	0.0020	14.9%
CE420	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24	0.0019	01/11	03:00				0.0020	5-Jan	6	0.0017	0.0020	14.7%
CE430	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24	0.0019	01/11	03:00				0.0020	5-Jan	6	0.0017	0.0020	14.7%
CE440	0.0019	11-Jan	3	0.0017	4-Jan	24	0.0017	4-Jan	24	0.0019	01/11	03:00				0.0020	5-Jan	7	0.0017	0.0020	14.7%
CE500	0.0068	20-Dec	22							0.0070	12/20	12:00	0.0069	20-Dec	20	0.0103	2-Nov	2	0.0068	0.0103	44.7%
CE510	0.0068	20-Dec	22							0.0070	12/20	12:00	0.0069	20-Dec	20	0.0105	2-Apr	22	0.0068	0.0105	47.0%
CE520	0.0061	26-Nov	2							0.0065	11/10	09:00	0.0065	27-Nov	23	0.0066	1-Nov	7	0.0061	0.0066	7.3%
CE522	0.0068	20-Dec	22							0.0070	12/20	12:00	0.0069	20-Dec	20	0.0078	2-Apr	21	0.0068	0.0078	14.1%
CE525	0.0068	20-Dec	22							0.0070	12/20	12:00	0.0069	20-Dec	20	0.0154	2-Nov	2	0.0068	0.0154	94.7%
CE530	0.0062	01-Apr	1							0.0067	10/18	12:00	0.0055	1-Nov	21	0.0066	1-Apr	5	0.0055	0.0067	20.5%
CE540	0.0041	05-Oct	3							0.0038	10/18	09:00	0.0033	29-Apr	23	0.0042	15-Oct	5	0.0033	0.0042	24.6%
CE545	0.0062	01-Apr	1							0.0068	04/01	02:00	0.0067	20-Jul	15	0.0070	1-Apr	8	0.0062	0.0070	11.9%

Hourly Integrated Maxima and Minima (Relative Humidity)

Maximum Relative Humidity	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour	NREL	Date	Hour	NREL	Date	Hour	GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	68.79	16-Nov	17	69.35	16-Nov	16	68.85	16-Nov	16	68.37	11/16	17:00	68.00	16-Nov	16	67.44	16-Nov	16	67.44	69.3500	2.8%
CE310	77.70	02-Oct	4	100.18	15-Oct	9	100.70	15-Oct	9	78.64	10/02	08:00	77.00	12-Jun	8	78.19	2-Oct	8	77.00	100.7000	27.8%
CE320	81.84	18-Sep	10	83.41	2-Oct	9	83.67	22-Apr	18	82.97	09/18	10:00	83.00	3-Sep	17	81.88	16-Sep	20	81.84	83.6700	2.2%
CE330	76.66	22-Sep	20	78.46	2-Oct	9	77.94	18-Sep	9	76.88	09/03	10:00	76.00	10-Jun	18	78.70	2-Sep	12	76.00	78.7000	3.5%
CE340	79.93	18-Sep	10	81.37	18-Sep	9	81.26	22-Apr	18	80.80	09/18	10:00	80.00	3-Sep	17	80.25	16-Sep	20	79.93	81.3700	1.8%
CE350	68.79	16-Nov	17	81.12	7-Aug	21	81.12	7-Aug	21	68.37	11/16	17:00	70.00	2-Oct	8	72.65	3-Aug	7	68.37	81.1200	17.3%
CE360	68.79	16-Nov	17	69.35	16-Nov	16	68.85	16-Nov	16	68.37	11/16	17:00	68.00	16-Nov	16	67.44	16-Nov	16	67.44	69.3500	2.8%
CE400	83.75	05-Apr	22	85.57	5-Apr	21	85.57	5-Apr	21	84.64	04/05	22:00				86.31	22-Apr	6	83.75	86.3100	3.0%
CE410	83.22	05-Apr	22	84.79	2-Apr	5	84.79	2-Apr	5							86.18	22-Apr	6	83.22	86.1800	3.5%
CE420	70.84	02-Apr	10	74.51	17-Apr	7	71.53	17-Apr	3	73.28	04/02	18:00				73.85	2-Apr	18	70.84	74.5100	5.0%
CE430	80.71	02-Apr	5	78.43	2-Apr	4	78.43	2-Apr	4	80.74	04/02	05:00				78.94	2-Apr	5	78.43	80.7427	2.9%
CE440	68.72	16-Nov	17	69.35	16-Nov	16	68.85	16-Nov	16	68.37	11/16	17:00				67.51	16-Nov	16	67.51	69.3500	2.7%
CE500	100.00	21-Nov	24							100.00	11/21	09:00	100.00	14-Nov	5	60.08	1-Apr	5	60.08	100.0000	44.3%
CE510	100.00	21-Nov	24							100.00	11/21	09:00	100.00	14-Nov	5	57.51	1-Apr	5	57.51	100.0000	47.5%
CE520	90.23	20-Dec	22							93.81	12/20	11:00	95.00	20-Dec	17	71.77	16-Aug	17	71.77	95.0000	26.5%
CE522	100.00	18-Dec	8							100.00	12/15	22:00	100.00	15-Dec	1	71.32	5-Apr	17	71.32	100.0000	30.9%
CE525	100.00	12-Nov	20							100.00	11/12	19:00	100.00	11-Nov	23	51.12	1-Apr	8	51.12	100.0000	55.7%
CE530	91.04	20-Dec	22							96.16	12/20	11:00	79.00	20-Dec	8	36.01	20-Apr	21	36.01	96.1602	79.6%
CE540	61.28	20-Dec	22							55.18	12/20	11:00	47.00	20-Dec	6	39.96	18-Apr	18	39.96	61.2750	41.9%
CE545	90.88	20-Dec	22							96.23	12/20	11:00	97.00	20-Dec	4	24.14	24-Dec	1	24.14	97.0000	94.5%

Minimum Relative Humidity	TRNSYS			DOE-2.2			DOE21E-E			EnergyPlus			CODYRUN			HOT3000			Statistics, All Results		
	TUD	Date	Hour							GARD	Date	Hour	UR	Date	Hour	NRCan	Date	Hour	Min	Max	(Max-Min) /Mean
CE300	13.33	06-Nov	5	11.97	6-Nov	4	11.97	6-Nov	4	14.40	11/06	06:00	15.00	6-Nov	5	14.94	6-Nov	8	11.97	15.0000	22.3%
CE310	13.39	06-Nov	6	11.97	6-Nov	4	11.97	6-Nov	4	15.50	11/06	08:00	16.00	6-Nov	8	15.93	6-Nov	8	11.97	16.0000	28.5%
CE320	13.33	06-Nov	5	11.97	6-Nov	4	11.97	6-Nov	4	14.64	11/06	06:00	15.00	6-Nov	5	12.92	20-Dec	5	11.97	15.0000	22.8%
CE330	13.33	06-Nov	5	11.97	6-Nov	4	11.97	6-Nov	4	14.40	11/06	06:00	15.00	6-Nov	5	14.94	6-Nov	8	11.97	15.0000	22.3%
CE340	13.33	06-Nov	5	11.97	6-Nov	4	11.97	6-Nov	4	14.40	11/06	06:00	15.00	6-Nov	5	14.94	6-Nov	8	11.97	15.0000	22.3%
CE350	13.33	06-Nov	5	11.97	6-Nov	4	11.97	6-Nov	4	14.40	11/06	06:00	15.00	6-Nov	5	14.94	6-Nov	8	11.97	15.0000	22.3%
CE360	13.33	06-Nov	5	11.97	6-Nov	4	11.97	6-Nov	4	14.40	11/06	06:00	15.00	6-Nov	5	14.94	6-Nov	8	11.97	15.0000	22.3%
CE400	13.21	06-Nov	5	11.97	6-Nov	4	11.97	6-Nov	4	13.93	11/06	06:00				14.57	6-Nov	5	11.97	14.5700	19.8%
CE410	13.21	06-Nov	5	11.97	6-Nov	4	11.97	6-Nov	4							14.58	6-Nov	5	11.97	14.5800	20.2%
CE420	13.21	06-Nov	5	11.97	6-Nov	4	11.97	6-Nov	4	13.93	11/06	06:00				14.59	6-Nov	5	11.97	14.5900	19.9%
CE430	13.21	06-Nov	5	11.97	6-Nov	4	11.97	6-Nov	4	13.93	11/06	06:00				14.58	6-Nov	5	11.97	14.5800	19.9%
CE440	13.21	06-Nov	5	11.97	6-Nov	4	11.97	6-Nov	4	13.93	11/06	06:00				14.54	6-Nov	5	11.97	14.5400	19.6%
CE500	53.41	30-Apr	15							55.17	04/30	04:00	54.00	4-Oct	24	52.83	5-Oct	1	52.83	55.1668	4.3%
CE510	52.09	04-Oct	23							55.29	05/04	03:00	54.00	4-Oct	23	53.15	4-May	4	52.09	55.2884	6.0%
CE520	61.27	25-Nov	24							61.73	11/27	24:00	61.00	27-Nov	22	61.90	20-Jul	15	61.00	61.9000	1.5%
CE522	58.51	30-Apr	15							59.18	04/30	04:00	60.00	4-Oct	23	57.97	5-Oct	1	57.97	60.0000	3.4%
CE525	45.53	30-Apr	15							47.85	10/05	02:00	44.00	4-May	4	44.40	5-Oct	1	44.00	47.8518	8.5%
CE530	29.59	04-Jun	15							34.03	04/18	18:00	28.00	1-Apr	10	33.68	1-Apr	13	28.00	34.0277	19.2%
CE540	36.47	21-Sep	16							36.00	09/28	16:00	31.00	1-Apr	1	39.74	5-Oct	1	31.00	39.7400	24.4%
CE545	17.12	20-Jul	15							19.23	04/18	17:00	19.00	1-Apr	10	20.14	1-Apr	12	17.12	20.1400	16.0%

RESULTS5-3B.xls r:a215..aa308; 02/09/06

June 28 Hourly Output - Case CE300

TRNSYS-TUD	Energy Consumption		Evaporator Coil **Load**			Zone Hum.					
	Compressor	Cond Fan	Total	Sensible	Latent	Ratio	COP2	ODB	EDB	EWB	OHR
Hour	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(kg/kg)		(°C)	(°C)	(°C)	(kg/kg)
1	2056	257	8132	6189	1942	0.0091	3.517	18.05	23.41	16.96	0.0113
2	2054	257	8116	6202	1914	0.0090	3.513	18.05	23.37	16.90	0.0113
3	2054	257	8128	6194	1934	0.0091	3.517	18.05	23.38	16.94	0.0113
4	1830	230	7224	5549	1676	0.0090	3.507	17.80	23.37	16.86	0.0111
5	2029	256	8105	6319	1786	0.0088	3.546	17.50	23.35	16.70	0.0106
6	1839	230	7131	5686	1445	0.0087	3.447	18.30	23.42	16.57	0.0106
7	2667	309	9711	7597	2115	0.0092	3.263	22.20	24.04	17.32	0.0121
8	3553	384	12121	9558	2563	0.0095	3.079	26.10	24.57	17.79	0.0122
9	4365	458	14556	11758	2798	0.0097	3.018	28.05	25.09	17.97	0.0115
10	4441	458	14639	11506	3133	0.0101	2.988	28.90	25.28	18.40	0.0124
11	5000	506	16374	12342	4032	0.0104	2.974	30.00	25.36	18.82	0.0138
12	5317	529	17248	12810	4438	0.0107	2.950	30.85	25.59	19.12	0.0140
13	6189	617	20498	16816	3682	0.0101	3.012	30.85	26.53	18.84	0.0123
14	6211	616	20234	17284	2951	0.0098	2.964	31.40	26.56	18.55	0.0115
15	7922	781	26687	22882	3805	0.0096	3.066	31.95	26.78	18.55	0.0121
16	7965	781	26723	22285	4438	0.0097	3.055	32.20	26.56	18.67	0.0133
17	5421	529	17231	13048	4183	0.0108	2.896	31.95	26.20	19.40	0.0145
18	5410	529	17506	12721	4785	0.0112	2.947	31.40	26.23	19.77	0.0152
19	5260	529	17662	12491	5171	0.0111	3.051	29.70	25.70	19.58	0.0151
20	4880	506	16990	11655	5335	0.0110	3.154	27.75	25.17	19.37	0.0157
21	3939	409	13540	8882	4658	0.0111	3.114	27.20	24.65	19.44	0.0169
22	3924	410	13565	8880	4684	0.0112	3.130	26.95	24.74	19.48	0.0169
23	4123	434	14531	9449	5082	0.0112	3.189	26.40	24.67	19.47	0.0169
24	3877	410	13692	8807	4885	0.0113	3.194	26.10	24.73	19.57	0.0171

DOE-2.2	Energy Consumption		Evaporator Coil **Load**			Zone Hum.					
	Compressor	Cond Fan	Total	Sensible	Latent	Ratio	COP2	ODB	EDB	EWB	OHR
Hour	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(kg/kg)		(°C)	(°C)	(°C)	(kg/kg)
1	1897	237	7552	5889	1663	0.0094	3.539	17.78	23.83	17.34	0.0114
2	1941	240	7630	6070	1560	0.0093	3.499	18.33	23.94	17.29	0.0112
3	1897	237	7550	5881	1669	0.0094	3.538	17.78	23.83	17.34	0.0114
4	1891	237	7534	5878	1656	0.0094	3.540	17.78	23.83	17.34	0.0114
5	1697	215	6798	5675	1123	0.0089	3.555	17.22	23.78	16.85	0.0103
6	2126	259	8136	6439	1698	0.0092	3.411	19.44	24.11	17.30	0.0113
7	3198	352	11076	8342	2734	0.0100	3.120	25.00	24.94	18.39	0.0133
8	3135	332	10291	9070	1221	0.0094	2.968	27.22	25.28	17.78	0.0109
9	4528	469	14786	11873	2913	0.0099	2.959	28.89	25.56	18.36	0.0117
10	4651	479	15340	12039	3301	0.0103	2.990	28.89	25.56	18.68	0.0125
11	5434	537	17455	12812	4643	0.0109	2.923	31.11	25.89	19.48	0.0148
12	5019	498	16215	12612	3603	0.0108	2.939	30.56	25.83	19.23	0.0134
13	6040	597	19723	17139	2584	0.0101	2.972	31.11	25.94	18.56	0.0115
14	6420	633	20808	17638	3170	0.0100	2.950	31.67	26.06	18.60	0.0121
15	7671	751	25387	22196	3191	0.0098	3.014	32.22	26.11	18.46	0.0119
16	8190	800	27581	22528	5053	0.0100	3.068	32.22	26.17	18.84	0.0144
17	5715	561	18205	13599	4605	0.0107	2.901	31.67	26.06	19.35	0.0146
18	5536	544	17933	12830	5103	0.0112	2.950	31.11	25.94	19.75	0.0157
19	4711	481	16012	11876	4137	0.0110	3.084	28.33	25.50	19.32	0.0143
20	4859	504	17082	11532	5550	0.0114	3.185	27.22	25.33	19.76	0.0164
21	3913	405	13435	9302	4133	0.0113	3.111	27.22	25.33	19.76	0.0164
22	3825	399	13280	8974	4307	0.0114	3.144	26.67	25.22	19.80	0.0167
23	3750	395	13192	8787	4404	0.0115	3.183	26.11	25.11	19.84	0.0169
24	3880	407	13724	8799	4925	0.0117	3.201	26.11	25.11	20.14	0.0178

RESULTS5-3B.xlss:a03..n62; 02/09/06

June 28 Hourly Output(Ctd.) - Case CE300

DOE-2.1E-E	Energy Consumption		Evaporator Coil Load			Zone Hum.					
	Compressor	Cond Fan	Total	Sensible	Latent	Ratio	COP2	ODB	EDB	EWB	OHR
Hour	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(kg/kg)		(°C)	(°C)	(°C)	(kg/kg)
1	1894	237	7545	5887	1658	0.0094	3.541	17.78	23.83	17.34	0.0114
2	1941	241	7627	6067	1560	0.0093	3.495	18.33	23.94	17.29	0.0112
3	1894	237	7546	5878	1668	0.0094	3.541	17.78	23.83	17.37	0.0114
4	1890	236	7528	5873	1655	0.0094	3.541	17.78	23.83	17.37	0.0114
5	1694	215	6753	5672	1081	0.0090	3.537	17.22	23.78	16.94	0.0103
6	2133	259	8185	6439	1747	0.0092	3.422	19.44	24.11	17.30	0.0113
7	3223	353	11233	8348	2885	0.0098	3.141	25.00	24.94	18.23	0.0133
8	3145	335	10272	9069	1203	0.0094	2.952	27.22	25.28	17.78	0.0109
9	4526	467	14844	11875	2969	0.0099	2.973	28.89	25.56	18.28	0.0117
10	4655	478	15393	12041	3352	0.0102	2.999	28.89	25.56	18.60	0.0125
11	5456	536	17605	12818	4787	0.0107	2.938	31.11	25.89	19.33	0.0148
12	5015	498	16188	12611	3577	0.0108	2.936	30.56	25.83	19.23	0.0134
13	6036	600	19621	17135	2486	0.0102	2.957	31.11	25.94	18.64	0.0115
14	6429	635	20819	17639	3180	0.0100	2.947	31.67	26.06	18.60	0.0121
15	7683	754	25393	22197	3196	0.0098	3.010	32.22	26.11	18.46	0.0119
16	8222	803	27721	22533	5188	0.0098	3.072	32.22	26.17	18.76	0.0144
17	5696	556	18245	13600	4644	0.0107	2.918	31.67	26.06	19.35	0.0146
18	5531	541	17978	12832	5146	0.0112	2.961	31.11	25.94	19.68	0.0157
19	4689	479	15914	11871	4043	0.0111	3.079	28.33	25.50	19.40	0.0143
20	4855	503	17120	11534	5586	0.0113	3.195	27.22	25.33	19.76	0.0164
21	3918	406	13445	9303	4142	0.0113	3.109	27.22	25.33	19.76	0.0164
22	3823	399	13285	8974	4311	0.0114	3.147	26.67	25.22	19.80	0.0167
23	3748	394	13192	8787	4405	0.0115	3.185	26.11	25.11	19.84	0.0169
24	3880	407	13754	8800	4955	0.0117	3.208	26.11	25.11	20.06	0.0178

EnergyPlus	Energy Consumption		Evaporator Coil Load			Zone Hum.					
	Compressor	Cond Fan	Total	Sensible	Latent	Ratio	COP2	ODB	EDB	EWB	OHR
Hour	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(kg/kg)		(°C)	(°C)	(°C)	(kg/kg)
1	2119	Note 1	7472	5811	1661	0.0094	3.527	17.99	23.95	0.00	0.0112
2	2131	Note 1	7494	5853	1641	0.0094	3.516	18.11	23.96	0.00	0.0113
3	2113	Note 1	7447	5809	1637	0.0094	3.525	17.99	23.95	0.00	0.0112
4	2075	Note 1	7332	5744	1588	0.0093	3.534	17.80	23.92	0.00	0.0111
5	1997	Note 1	7091	5614	1477	0.0092	3.550	17.43	23.86	0.00	0.0105
6	2142	Note 1	7425	6015	1410	0.0090	3.467	18.58	24.03	0.00	0.0106
7	2870	Note 1	9216	7532	1684	0.0093	3.212	22.90	24.68	0.00	0.0123
8	3499	Note 1	10609	8757	1853	0.0096	3.033	26.38	25.21	0.00	0.0118
9	4682	Note 1	14032	11767	2265	0.0098	2.997	28.26	25.49	0.00	0.0116
10	4948	Note 1	14778	11996	2781	0.0102	2.987	28.90	25.59	0.00	0.0124
11	5407	Note 1	15905	12488	3417	0.0106	2.942	30.28	25.79	0.00	0.0140
12	5632	Note 1	16522	12671	3851	0.0109	2.933	30.79	25.87	0.00	0.0138
13	7133	Note 1	21588	17401	4187	0.0104	3.027	30.91	25.88	0.00	0.0120
14	6983	Note 1	20678	17592	3086	0.0100	2.961	31.48	25.97	0.00	0.0115
15	8572	Note 1	26133	22481	3652	0.0098	3.049	32.01	26.05	0.00	0.0121
16	8733	Note 1	26665	22557	4107	0.0099	3.053	32.20	26.08	0.00	0.0135
17	5718	Note 1	16345	13061	3283	0.0106	2.858	31.89	26.04	0.00	0.0145
18	5881	Note 1	17193	12870	4324	0.0112	2.924	31.33	25.95	0.00	0.0153
19	5555	Note 1	16878	12170	4708	0.0113	3.038	29.35	25.65	0.00	0.0149
20	5259	Note 1	16536	11556	4981	0.0113	3.144	27.61	25.39	0.00	0.0159
21	4326	Note 1	13445	9063	4383	0.0116	3.108	27.20	25.33	0.00	0.0168
22	4279	Note 1	13387	8953	4434	0.0116	3.129	26.89	25.29	0.00	0.0168
23	4173	Note 1	13191	8753	4437	0.0116	3.161	26.33	25.20	0.00	0.0168
24	4152	Note 1	13196	8674	4522	0.0117	3.178	26.10	25.17	0.00	0.0171

RESULTS5-3B.xls s:a66..n125; 02/09/06

June 28 Hourly Output(Ctd.) - Case CE300

CODYRUN	Energy Consumption		Evaporator Coil Load			Zone Hum.					
	Compressor	Cond Fan	Total	Sensible	Latent	Ratio	COP2	ODB	EDB	EWB	OHR
Hour	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(kg/kg)		(°C)	(°C)	(°C)	(kg/kg)
1	1886	237	7472	5788	1684	0.0093	3.520	17.80	23.92	17.16	0.0111
2	1964	244	7707	5961	1747	0.0093	3.490	18.30	24.00	17.24	0.0115
3	1881	236	7445	5788	1657	0.0092	3.517	17.80	23.92	17.12	0.0111
4	1878	236	7432	5788	1644	0.0092	3.516	17.80	23.92	17.10	0.0111
5	1756	224	7000	5580	1420	0.0090	3.535	17.20	23.83	16.79	0.0102
6	2075	253	7915	6341	1574	0.0090	3.400	19.40	24.16	17.03	0.0110
7	3035	334	10450	8277	2173	0.0095	3.102	25.00	25.00	17.91	0.0131
8	3303	352	10813	9038	1775	0.0093	2.958	27.20	25.33	17.65	0.0111
9	4483	463	14631	11971	2660	0.0097	2.958	28.90	25.59	18.12	0.0120
10	4594	472	15099	11971	3128	0.0100	2.980	28.90	25.59	18.44	0.0128
11	5238	516	16722	12731	3991	0.0106	2.906	31.10	25.91	19.14	0.0148
12	5066	504	16258	12559	3699	0.0106	2.919	30.60	25.84	18.94	0.0133
13	6442	642	21090	17422	3669	0.0100	2.977	31.10	25.91	18.33	0.0113
14	6523	645	21067	17629	3438	0.0098	2.939	31.70	26.00	18.27	0.0117
15	8000	785	26636	22491	4145	0.0096	3.032	32.20	26.08	18.24	0.0124
16	8169	799	27416	22491	4925	0.0097	3.057	32.20	26.08	18.56	0.0142
17	5306	519	16702	12939	3763	0.0104	2.867	31.70	26.00	19.06	0.0147
18	5381	528	17312	12729	4582	0.0109	2.930	31.10	25.91	19.46	0.0157
19	4791	492	16232	11761	4470	0.0109	3.072	28.30	25.50	19.20	0.0145
20	4809	498	16867	11381	5486	0.0113	3.178	27.20	25.33	19.65	0.0169
21	3939	408	13484	9036	4447	0.0113	3.102	27.20	25.33	19.71	0.0169
22	3852	402	13322	8864	4459	0.0114	3.132	26.70	25.25	19.70	0.0168
23	3752	395	13139	8656	4482	0.0114	3.168	26.10	25.16	19.69	0.0169
24	3794	399	13323	8656	4666	0.0115	3.177	26.10	25.16	19.81	0.0173

HOT3000	Energy Consumption		Evaporator Coil Load			Zone Hum.					
	Compressor	Cond Fan	Total	Sensible	Latent	Ratio	COP2	ODB	EDB	EWB	OHR
Hour	(Wh)	(Wh)	(Wh)	(Wh)	(Wh)	(kg/kg)		(°C)	(°C)	(°C)	(kg/kg)
1	1943	241	7668	5870	1798	0.0093	3.511	17.80	23.94	17.30	0.0111
2	1951	241	7674	5872	1803	0.0093	3.502	18.30	23.94	17.31	0.0114
3	1902	237	7528	5783	1745	0.0092	3.519	17.80	23.90	17.24	0.0111
4	1845	231	7317	5683	1634	0.0091	3.524	17.80	23.84	17.08	0.0111
5	1914	239	7514	5955	1559	0.0090	3.490	17.20	23.98	17.01	0.0102
6	2507	293	9223	7312	1911	0.0092	3.295	19.40	24.58	17.54	0.0110
7	3171	343	10770	8647	2123	0.0095	3.065	25.00	25.16	17.99	0.0131
8	3434	361	11186	9299	1888	0.0094	2.948	27.20	25.45	17.96	0.0110
9	4489	461	14744	11923	2821	0.0097	2.979	28.90	25.58	18.33	0.0120
10	4853	489	15882	12287	3595	0.0102	2.973	28.90	25.74	18.85	0.0127
11	5164	508	16615	12562	4053	0.0106	2.929	31.10	25.86	19.19	0.0148
12	5005	497	16030	12561	3468	0.0104	2.914	30.60	25.86	18.87	0.0132
13	6455	639	21180	17431	3749	0.0100	2.986	31.10	25.94	18.52	0.0113
14	6503	640	21055	17609	3447	0.0097	2.948	31.70	26.02	18.44	0.0117
15	8041	785	27070	22350	4719	0.0098	3.067	32.20	26.13	18.65	0.0123
16	8134	794	27623	22292	5331	0.0098	3.094	32.20	26.03	18.80	0.0142
17	5212	510	16551	12739	3812	0.0103	2.893	31.70	25.94	19.11	0.0147
18	5122	507	16830	12181	4649	0.0109	2.990	31.10	25.70	19.39	0.0156
19	4832	493	16635	11541	5095	0.0110	3.124	28.30	25.41	19.53	0.0145
20	4875	501	17131	11359	5772	0.0114	3.187	27.20	25.33	19.74	0.0168
21	3936	406	13525	8931	4593	0.0114	3.115	27.20	25.29	19.74	0.0168
22	3844	399	13356	8747	4609	0.0114	3.148	26.70	25.21	19.79	0.0168
23	3807	397	13343	8647	4697	0.0114	3.173	26.10	25.16	19.84	0.0168
24	3664	386	12973	8360	4613	0.0115	3.203	26.10	25.04	19.77	0.0173

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Delta Annual Space Cooling Electricity Consumptions

Total (kWh,e)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	4340	4629	4629	4545	4543	4538	4340	4629	6.4%
CE320-CE300	4426	3995	4037	4333	4424	4387	3995	4426	10.1%
CE330-CE300	5330	4958	4683	5398	5559	5260	4683	5559	16.8%
CE330-CE320	904	963	646	1064	1134	873	646	1134	52.5%
CE340-CE300	4986	4608	4510	5037	5089	4877	4510	5089	11.9%
CE330-CE340	344	350	173	360	470	383	173	470	85.6%
CE350-CE300	-3397	-4203	-4207	-3601	-3390	-3328	-4207	-3328	-23.8%
CE360-CE300	19665	19314	19261	19959	19867	19998	19261	19998	3.7%
CE400-CE300	-3589	-3904	-3879	-3733		-3657	-3904	-3589	-8.4%
CE410-CE300	-3555	-3082	-3056			-3567	-3567	-3056	-15.4%
CE420-CE300	-2247	-2220	-1845	-2010		-1862	-2247	-1845	-19.7%
CE430-CE300	-3096	-2818	-2944	-2973		-3252	-3252	-2818	-14.4%
CE440-CE300	-1942	-1718	-1782	-1714		-1822	-1942	-1714	-12.7%
CE500-CE300	-13296	-11933	-11933	-11711	-12653	-11932	-13296	-11711	-12.9%
CE510-CE500	17218	18099	18100	17736	17414	17794	17218	18100	5.0%
CE525-CE520	-4666	-4981	-4969	-4316	-4889	-4458	-4981	-4316	-14.1%
CE530-CE500	-5057	-5277	-5285	-5293	-4880	-5263	-5293	-4880	-8.0%
CE545-CE540	-3743	-4076	-4083	-2425	-3745	-3825	-4083	-2425	-45.4%

Compressor (kWh,e)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	3986	4244	4244		4167	4177	3986	4244	6.2%
CE320-CE300	4080	3681	3721		4076	4036	3681	4080	10.2%
CE330-CE300	4946	4603	4352		5158	4899	4352	5158	16.8%
CE330-CE320	867	922	631		1082	863	631	1082	51.6%
CE340-CE300	4609	4260	4172		4703	4524	4172	4703	11.9%
CE330-CE340	337	343	180		455	375	180	455	81.4%
CE350-CE300	-3037	-3767	-3772		-3032	-2985	-3772	-2985	-23.7%
CE360-CE300	17752	17430	17382		17927	18065	17382	18065	3.9%
CE400-CE300	-3175	-3463	-3442			-3247	-3463	-3175	-8.7%
CE410-CE300	-3149	-2746	-2723			-3191	-3191	-2723	-15.9%
CE420-CE300	-1995	-1973	-1639			-1662	-1995	-1639	-19.6%
CE430-CE300	-2755	-2510	-2622			-2910	-2910	-2510	-14.8%
CE440-CE300	-1724	-1527	-1584			-1627	-1724	-1527	-12.2%
CE500-CE300	-4499	-3096	-3095		-3912	-3354	-4499	-3095	-39.1%
CE510-CE500	13806	14303	14304		13913	14230	13806	14304	3.5%
CE525-CE520	-2963	-3241	-3233		-3148	-2742	-3241	-2742	-16.3%
CE530-CE500	-4197	-4346	-4354		-4002	-4350	-4354	-4002	-8.3%
CE545-CE540	-2399	-2713	-2720		-2413	-2449	-2720	-2399	-12.6%

RESULTS5-3B.xls t:a06..m49; 02/09/06

Delta Annual Space Cooling Electricity Consumptions (ctd.)

Supply Fan (kWh,e)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	0	0	0	0	0	0	0	0	#DIV/0!
CE320-CE300	0	0	0	0	0	0	0	0	#DIV/0!
CE330-CE300	0	0	0	0	0	0	0	0	#DIV/0!
CE330-CE320	0	0	0	0	0	0	0	0	#DIV/0!
CE340-CE300	0	0	0	0	0	0	0	0	#DIV/0!
CE330-CE340	0	0	0	0	0	0	0	0	#DIV/0!
CE350-CE300	0	0	0	0	0	0	0	0	#DIV/0!
CE360-CE300	0	0	0	0	0	0	0	0	#DIV/0!
CE400-CE300	0	0	0	0		0	0	0	#DIV/0!
CE410-CE300	0	0	0			0	0	0	#DIV/0!
CE420-CE300	0	0	0	0		0	0	0	#DIV/0!
CE430-CE300	0	0	0	0		0	0	0	#DIV/0!
CE440-CE300	0	0	0	0		0	0	0	#DIV/0!
CE500-CE300	-8316	-8511	-8511	-8234	-8327	-8241	-8511	-8234	-3.3%
CE510-CE500	1951	2262	2262	2034	2002	2038	1951	2262	14.9%
CE525-CE520	-973	-988	-986	-839	-996	-979	-996	-839	-16.3%
CE530-CE500	-491	-536	-536	-538	-502	-522	-538	-491	-9.0%
CE545-CE540	-769	-757	-757	-438	-762	-787	-787	-438	-49.0%

Condenser Fan (kWh,e)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	354	385	385		376	368	354	385	8.4%
CE320-CE300	346	314	316		348	358	314	358	13.1%
CE330-CE300	383	355	331		401	370	331	401	19.0%
CE330-CE320	37	41	15		53	12	12	53	128.8%
CE340-CE300	376	348	338		386	361	338	386	13.3%
CE330-CE340	7	7	-7		15	9	-7	15	352.1%
CE350-CE300	-360	-436	-435		-358	-353	-436	-353	-21.4%
CE360-CE300	1913	1884	1879		1940	1949	1879	1949	3.7%
CE400-CE300	-414	-441	-437			-421	-441	-414	-6.3%
CE410-CE300	-406	-336	-333			-387	-406	-333	-20.1%
CE420-CE300	-252	-247	-206			-208	-252	-206	-20.1%
CE430-CE300	-341	-308	-322			-353	-353	-308	-13.6%
CE440-CE300	-218	-191	-198			-203	-218	-191	-13.4%
CE500-CE300	-481	-326	-327		-415	-347	-481	-326	-40.8%
CE510-CE500	1461	1534	1534		1499	1526	1461	1534	4.8%
CE525-CE520	-729	-752	-750		-746	-733	-752	-729	-3.1%
CE530-CE500	-368	-395	-395		-376	-391	-395	-368	-7.0%
CE545-CE540	-576	-606	-606		-571	-589	-606	-571	-6.0%

RESULTS5-3B.xls t:a51..m94; 02/09/06

Delta Cooling Coil Loads

Sensible Coil Load (kWh,th)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	-405	504	508	-27	-24	-108	-405	508	1224.5%
CE320-CE300	6197	6900	6942	6791	6799	7543	6197	7543	19.6%
CE330-CE300	6422	7514	7523	8527	7440	6631	6422	8527	28.7%
CE330-CE320	224	614	581	1735	641	-912	-912	1735	550.9%
CE340-CE300	6371	7257	7306	7634	7171	6215	6215	7634	20.3%
CE330-CE340	51	258	217	893	269	416	51	893	240.2%
CE350-CE300	-6291	-8112	-8128	-6707	-6621	-6423	-8128	-6291	-26.1%
CE360-CE300	78315	79123	79135	80035	78996	79506	78315	80035	2.2%
CE400-CE300	-14709	-14378	-14368	-14564		-14010	-14709	-14010	-4.9%
CE410-CE300	-10985	-8138	-8145			-9606	-10985	-8138	-30.9%
CE420-CE300	-6272	-6131	-5193	-5728		-5207	-6272	-5193	-18.9%
CE430-CE300	-8798	-8066	-8351	-8513		-9048	-9048	-8066	-11.5%
CE440-CE300	-5786	-5204	-5313	-5192		-5406	-5786	-5192	-11.0%
CE500-CE300	-11618	-8147	-8159	-7761	-10335	-7661	-11618	-7661	-44.2%
CE510-CE500	43046	45710	45710	45091	43051	45083	43046	45710	6.0%
CE525-CE520	-131	-884	-882	-1057	-202	-949	-1057	-131	-135.4%
CE530-CE500	2	-1076	-1076	-547	0	-528	-1076	2	-200.6%
CE545-CE540	-130	-809	-809	-676	-202	-792	-809	-130	-119.1%

Latent Coil Load(kWh,th)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	19321	19607	19612	19156	19576	19111	19111	19612	2.6%
CE320-CE300	13167	12173	12259	11974	12597	11157	11157	13167	16.4%
CE330-CE300	18164	15932	16179	16367	18528	17119	15932	18528	15.2%
CE330-CE320	4997	3760	3919	4393	5931	5962	3760	5962	45.6%
CE340-CE300	15930	14488	14625	14757	15760	15279	14488	15930	9.5%
CE330-CE340	2234	1445	1553	1610	2768	1840	1445	2768	69.3%
CE350-CE300	-4748	-5435	-5529	-4821	-4264	-4446	-5529	-4264	-26.0%
CE360-CE300	4232	3401	3427	3895	4459	4403	3401	4459	26.7%
CE400-CE300	3075	2012	2101	2660		2650	2012	3075	42.5%
CE410-CE300	-769	-2366	-2303			-2477	-2477	-769	-86.3%
CE420-CE300	-1546	-1542	-1217	-1240		-1212	-1546	-1212	-24.7%
CE430-CE300	-1872	-1577	-1722	-1663		-2010	-2010	-1577	-24.5%
CE440-CE300	-930	-699	-798	-709		-823	-930	-699	-29.1%
CE500-CE300	-5452	-3141	-3141	-3986	-4304	-4983	-5452	-3141	-55.5%
CE510-CE500	17485	17615	17615	17348	17488	17340	17340	17615	1.6%
CE525-CE520	2	-288	-288	-58	-9	-42	-288	2	-255.0%
CE530-CE500	-18313	-18285	-18286	-18080	-18230	-18084	-18313	-18080	-1.3%
CE545-CE540	-1	-81	-81	-9	-3	-2	-81	-1	-272.0%

RESULTS5-3B.xlst:a99..m142; 02/09/06

Delta Various Annual Means (COP2, IDB)

COP2	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	0.166	0.180	0.180	0.155	0.171	0.150	0.150	0.180	18.0%
CE320-CE300	0.171	0.220	0.220	0.168	0.180	0.160	0.160	0.220	32.3%
CE330-CE300	0.242	0.256	0.299	0.253	0.271	0.230	0.230	0.299	26.7%
CE330-CE320	0.071	0.036	0.079	0.086	0.091	0.070	0.036	0.091	76.3%
CE340-CE300	0.205	0.240	0.258	0.210	0.223	0.190	0.190	0.258	30.9%
CE330-CE340	0.036	0.017	0.041	0.043	0.048	0.040	0.017	0.048	82.5%
CE350-CE300	0.000	0.003	-0.002	0.006	0.003	0.000	-0.002	0.006	498.6%
CE360-CE300	0.420	0.463	0.468	0.441	0.440	0.430	0.420	0.468	10.9%
CE400-CE300	0.001	0.014	0.015	0.009		0.030	0.001	0.030	210.3%
CE410-CE300	-0.010	-0.025	-0.027			-0.020	-0.027	-0.010	-84.0%
CE420-CE300	-0.023	-0.022	-0.020	-0.021		-0.020	-0.023	-0.020	-14.9%
CE430-CE300	-0.028	-0.025	-0.026	-0.026		-0.020	-0.028	-0.020	-33.0%
CE440-CE300	-0.018	-0.015	-0.015	-0.016		-0.010	-0.018	-0.010	-51.9%
CE500-CE300	-0.045	-0.010	-0.011	-0.024	-0.034	-0.030	-0.045	-0.010	-135.4%
CE510-CE500	0.409	0.416	0.416	0.408	0.397	0.410	0.397	0.416	4.6%
CE525-CE520	0.582	0.574	0.572	0.504	0.606	0.490	0.490	0.606	21.0%
CE530-CE500	-0.242	-0.258	-0.257	-0.214	-0.276	-0.220	-0.276	-0.214	-25.5%
CE545-CE540	0.560	0.559	0.560	0.334	0.546	0.510	0.334	0.560	44.3%

IDB (°C)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	0.13	0.06	0.00	0.00	0.01	0.02	0.00	0.13	364.3%
CE320-CE300	0.28	0.33	0.33	0.16	0.25	0.54	0.16	0.54	119.3%
CE330-CE300	0.26	0.22	0.22	0.18	0.21	0.19	0.18	0.26	34.0%
CE330-CE320	-0.02	-0.11	-0.11	0.02	-0.03	-0.35	-0.35	0.02	-365.4%
CE340-CE300	0.25	0.22	0.22	0.21	0.23	0.22	0.21	0.25	19.5%
CE330-CE340	0.00	0.00	0.00	-0.02	-0.01	-0.03	-0.03	0.00	-319.0%
CE350-CE300	2.04	2.11	2.11	2.15	2.19	2.16	2.04	2.19	7.1%
CE360-CE300	1.74	1.56	1.50	1.23	1.40	1.38	1.23	1.74	34.6%
CE400-CE300	0.50	0.00	0.00	0.00		0.00	0.00	0.50	498.8%
CE410-CE300	0.50	0.00	0.00			0.00	0.00	0.50	400.0%
CE420-CE300	0.30	0.00	0.00	0.00		0.00	0.00	0.30	500.3%
CE430-CE300	0.37	0.00	0.00	0.00		0.00	0.00	0.37	500.3%
CE440-CE300	0.29	0.00	0.00	0.00		0.00	0.00	0.29	500.2%
CE500-CE300	-3.39	-3.39	-3.50	-3.71	-2.98	-1.13	-3.71	-1.13	-85.5%
CE510-CE500	1.24	0.11	0.11	-0.02	0.00	0.00	-0.02	1.24	526.6%
CE525-CE520	13.33	13.61	13.56	13.53	13.63	15.80	13.33	15.80	17.8%
CE530-CE500	-0.21	-0.06	0.00	0.21	0.00	0.00	-0.21	0.21	-4302.5%
CE545-CE540	13.32	13.56	13.56	13.52	13.58	15.71	13.32	15.71	17.3%

RESULTS5-3B.xls t:a145..m188; 02/09/06

Delta Various Annual Means (Zone Humidity)

Humidity Ratio (kg/kg)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	0.0020	0.0021	0.0021	0.0020	0.0020	0.0019	0.0019	0.0021	9.9%
CE320-CE300	0.0009	0.0009	0.0009	0.0008	0.0009	0.0007	0.0007	0.0009	25.7%
CE330-CE300	0.0007	0.0007	0.0007	0.0007	0.0006	0.0007	0.0006	0.0007	9.3%
CE330-CE320	-0.0002	-0.0002	-0.0002	-0.0001	-0.0002	0.0000	-0.0002	0.0000	-143.9%
CE340-CE300	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	4.1%
CE330-CE340	-0.0001	0.0000	0.0000	0.0000	-0.0001	0.0000	-0.0001	0.0000	-277.9%
CE350-CE300	0.0006	0.0008	0.0008	0.0006	0.0006	0.0006	0.0006	0.0008	34.2%
CE360-CE300	-0.0006	-0.0005	-0.0005	-0.0005	-0.0006	-0.0006	-0.0006	-0.0005	-22.0%
CE400-CE300	0.0007	0.0008	0.0008	0.0008		0.0008	0.0007	0.0008	8.7%
CE410-CE300	0.0007	0.0003	0.0003			0.0003	0.0003	0.0007	94.5%
CE420-CE300	0.0002	0.0002	0.0002	0.0002		0.0001	0.0001	0.0002	58.3%
CE430-CE300	0.0002	0.0002	0.0002	0.0002		0.0002	0.0002	0.0002	19.7%
CE440-CE300	0.0001	0.0001	0.0001	0.0000		0.0000	0.0000	0.0001	148.5%
CE500-CE300	0.0007			0.0001	0.0010	0.0015	0.0001	0.0015	169.4%
CE510-CE500	0.0004			0.0000	0.0000	0.0000	0.0000	0.0004	394.2%
CE525-CE520	0.0070			0.0078	0.0070	0.0075	0.0070	0.0078	10.9%
CE530-CE500	-0.0035			-0.0027	-0.0044	-0.0040	-0.0044	-0.0027	-48.0%
CE545-CE540	0.0018			0.0024	0.0029	0.0026	0.0018	0.0029	46.8%

Relative Humidity (%)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	9.72	10.25	10.25	9.96	10.01	9.87	9.72	10.25	5.3%
CE320-CE300	3.39	2.95	2.97	3.25	3.28	2.01	2.01	3.39	46.4%
CE330-CE300	2.23	2.32	2.37	2.59	2.26	2.77	2.23	2.77	22.3%
CE330-CE320	-1.16	-0.63	-0.60	-0.66	-1.02	0.76	-1.16	0.76	-347.8%
CE340-CE300	2.47	2.43	2.45	2.56	2.47	2.85	2.43	2.85	16.5%
CE330-CE340	-0.24	-0.11	-0.08	0.03	-0.21	-0.08	-0.24	0.03	-232.7%
CE350-CE300	-3.13	-2.81	-2.73	-3.42	-3.51	-3.37	-3.51	-2.73	-24.7%
CE360-CE300	-7.58	-6.77	-6.79	-6.22	-6.96	-6.72	-7.58	-6.22	-19.9%
CE400-CE300	2.16	3.95	3.97	3.96		4.08	2.16	4.08	53.1%
CE410-CE300	1.88	1.39	1.35			1.82	1.35	1.88	33.0%
CE420-CE300	0.16	0.88	0.69	0.81		0.83	0.16	0.88	106.1%
CE430-CE300	0.21	0.91	1.02	1.01		1.24	0.21	1.24	117.8%
CE440-CE300	-0.29	0.20	0.29	0.24		0.30	-0.29	0.30	394.1%
CE500-CE300	17.91			10.61	18.12	15.80	10.61	18.12	48.1%
CE510-CE500	-2.35			0.11	-0.01	0.11	-2.35	0.11	-461.4%
CE525-CE520	-8.41			-6.41	-10.09	-14.80	-14.80	-6.41	-84.5%
CE530-CE500	-19.80			-10.22	-24.49	-24.13	-24.49	-10.22	-72.6%
CE545-CE540	-11.90			-7.68	-3.18	-14.62	-14.62	-3.18	-122.5%

RESULTS5-3B.xlsx:a191..m234; 02/09/06

Delta Hourly Integrated Maximum Total Consumptions

Total Consumption (Wh,e)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	968	1019	993	641	721	614	614	1019	49.0%
CE320-CE300	1402	1352	1379	1055	1172	1327	1055	1402	27.1%
CE330-CE300	1721	1648	1805	1414	1535	1787	1414	1805	23.7%
CE330-CE320	319	296	426	360	363	460	296	460	44.3%
CE340-CE300	1555	1594	1588	1234	1345	1553	1234	1594	24.3%
CE330-CE340	166	54	217	180	190	234	54	234	103.8%
CE350-CE300	1	90	0	0	0	-2	-2	90	621.2%
CE360-CE300	1143	1172	1124	844	931	1214	844	1214	34.5%
CE400-CE300	2	0	75	0		-29	-29	75	1087.2%
CE410-CE300	2	0	0			1	0	2	258.7%
CE420-CE300	0	0	0	0		0	0	0	#DIV/0!
CE430-CE300	0	0	0	0		0	0	0	-500.0%
CE440-CE300	0	0	0	0		-87	-87	0	-500.0%
CE500-CE300	-1460	-1133	-1177	-1501	-1755	-1274	-1755	-1133	-45.0%
CE510-CE500	1038	1159	1162	1011	1009	1070	1009	1162	14.2%
CE525-CE520	-1669	-1451	-1483	-1531	-1625	-1099	-1669	-1099	-38.6%
CE530-CE500	-2138	-2372	-2370	-2228	-2185	-2185	-2372	-2138	-10.4%
CE545-CE540	-1494	-1593	-1593	-915	-1495	-1514	-1593	-915	-47.3%

RESULTS5-3B.xls t:a242..m264; 02/09/06

Delta Hourly Integrated Maximum Coil Loads

Sensible + Latent Coil Load (Wh,th)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	5154	5349	5578	4393	4759	4919	4393	5578	23.6%
CE320-CE300	8144	22412	22368	7032	7402	7848	7032	22412	122.7%
CE330-CE300	11318	12227	33117	10712	11476	10343	10343	33117	153.2%
CE330-CE320	3174	-10185	10749	3680	4074	2495	-10185	10749	898.0%
CE340-CE300	9478	19418	28094	8595	8864	9060	8595	28094	140.1%
CE330-CE340	1840	-7191	5023	2117	2612	1283	-7191	5023	1289.3%
CE350-CE300	-82	0	-1	0	0	5	-82	5	-669.0%
CE360-CE300	6683	9212	9564	5726	5820	6379	5726	9564	53.1%
CE400-CE300	9005	9142	18383	7995		8702	7995	18383	97.6%
CE410-CE300	-82	0	0			1	-82	1	-409.8%
CE420-CE300	0	0	0	0		0	0	0	#DIV/0!
CE430-CE300	0	0	0	0		0	0	0	-500.0%
CE440-CE300	0	0	0	0		-295	-295	0	-500.0%
CE500-CE300	-4689	-3694	-3749	-5087	-5935	-4517	-5935	-3694	-48.6%
CE510-CE500	3108	3481	3482	3531	3381	3542	3108	3542	12.7%
CE525-CE520	410	-412	-412	-76	8	-881	-881	410	-568.4%
CE530-CE500	-7651	-8131	-8131	-8008	-7791	-7929	-8131	-7651	-6.0%
CE545-CE540	500	-291	-292	-187	-30	-302	-302	500	-800.3%

Sensible Coil Load (Wh,th)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	-183	-123	-86	-254	-379	-259	-379	-86	-136.9%
CE320-CE300	8038	7916	7867	8441	7677	8059	7677	8441	9.6%
CE330-CE300	9949	10207	11285	11234	10540	10513	9949	11285	12.6%
CE330-CE320	1911	2291	3418	2793	2863	2454	1911	3418	57.5%
CE340-CE300	9552	8883	8881	9357	9483	9272	8881	9552	7.3%
CE330-CE340	397	1324	2404	1877	1057	1241	397	2404	145.1%
CE350-CE300	0	0	0	0	0	-32	-32	0	-603.8%
CE360-CE300	8783	8908	8860	9090	8524	9271	8524	9271	8.4%
CE400-CE300	0	0	0	0		-31	-31	0	-503.2%
CE410-CE300	-12	0	0			-15	-15	0	-224.7%
CE420-CE300	0	0	0	0		-15	-15	0	-500.0%
CE430-CE300	0	0	0	0		-15	-15	0	-500.0%
CE440-CE300	0	0	0	0		-33	-33	0	-500.0%
CE500-CE300	-3728	-3194	-3197	-3682	-4681	-3090	-4681	-3090	-44.3%
CE510-CE500	2180	2504	2505	2441	2345	2451	2180	2505	13.5%
CE525-CE520	287	-309	-304	-336	-210	-717	-717	287	-379.1%
CE530-CE500	285	-433	-433	-211	0	-192	-433	285	-437.9%
CE545-CE540	500	-291	-292	-187	-35	-302	-302	500	-793.7%

Latent Coil Load (Wh,th)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	6271	5835	5876	6040	5737	5685	5685	6271	9.9%
CE320-CE300	13512	22193	22109	11961	11322	11537	11322	22193	70.4%
CE330-CE300	18190	17637	31415	16899	17809	17096	16899	31415	73.2%
CE330-CE320	4678	-4556	9306	4939	6487	5559	-4556	9306	314.9%
CE340-CE300	15213	21147	26617	13676	13850	13402	13402	26617	76.3%
CE330-CE340	2977	-3510	4798	3223	3959	3694	-3510	4798	329.2%
CE350-CE300	116	-1	-1	1	380	1211	-1	1211	426.5%
CE360-CE300	-361	722	942	-1715	-1516	-1458	-1715	942	-470.9%
CE400-CE300	17440	16274	23002	16082		16253	16082	23002	38.9%
CE410-CE300	1503	0	-3			-15	-15	1503	408.9%
CE420-CE300	115	0	0	0		2	0	115	491.5%
CE430-CE300	0	1801	1707	839		2	0	1801	207.1%
CE440-CE300	0	0	-3	0		-253	-253	0	-494.1%
CE500-CE300	-1670	-1571	-1661	-2396	-2570	-2630	-2630	-1571	-50.8%
CE510-CE500	927	990	990	1116	1045	1112	927	1116	18.3%
CE525-CE520	123	-122	-122	249	212	-144	-144	249	1201.2%
CE530-CE500	-7965	-7733	-7733	-7838	-7626	-7726	-7965	-7626	-4.4%
CE545-CE540	-627	0	0	-1655	-841	-1181	-1655	0	-230.7%

RESULTS5-3B.xls t:a266..m330; 02/09/06

Delta Hourly Integrated Maximum and Minimum COP2

Maximum COP2	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	-0.025	0.272	0.271	0.248	0.257	0.240	-0.025	0.272	141.1%
CE320-CE300	0.000	1.274	1.110	0.014	0.073	0.500	0.000	1.274	257.3%
CE330-CE300	0.000	0.240	1.738	0.146	0.251	0.170	0.000	1.738	409.6%
CE330-CE320	0.000	-1.034	0.628	0.132	0.179	-0.330	-1.034	0.628	-2344.2%
CE340-CE300	0.000	0.752	1.482	0.061	0.147	0.070	0.000	1.482	354.0%
CE330-CE340	0.000	-0.512	0.256	0.085	0.105	0.100	-0.512	0.256	13685.7%
CE350-CE300	0.000	0.020	0.006	0.630	0.061	0.000	0.000	0.630	526.8%
CE360-CE300	0.233	0.559	0.570	0.530	0.561	0.560	0.233	0.570	67.2%
CE400-CE300	-0.091	0.219	0.919	0.146		0.170	-0.091	0.919	370.7%
CE410-CE300	-0.280	0.034	-0.002			-0.040	-0.280	0.034	-436.1%
CE420-CE300	-0.387	-0.062	-0.098	-0.104		0.060	-0.387	0.060	-378.3%
CE430-CE300	-0.387	-0.064	-0.098	-0.133		0.050	-0.387	0.050	-346.0%
CE440-CE300	-0.285	-0.095	-0.098	-0.123		-0.070	-0.285	-0.070	-160.0%
CE500-CE300	0.107	3.498	1.444	0.273	0.314	0.260	0.107	3.498	345.1%
CE510-CE500	0.417	0.000	0.000	0.487	0.505	0.390	0.000	0.505	168.4%
CE525-CE520	0.904	1.429	1.379	0.766	0.836	0.560	0.560	1.429	88.8%
CE530-CE500	-0.269	-3.386	-1.451	-0.273	-0.345	-0.260	-3.386	-0.260	-313.5%
CE545-CE540	0.794	0.819	0.973	0.470	0.490	0.480	0.470	0.973	74.9%

Minimum COP2	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	0.072	0.052	0.050	0.111	0.087	0.060	0.050	0.111	84.8%
CE320-CE300	0.032	0.003	0.004	0.060	0.029	0.020	0.003	0.060	231.0%
CE330-CE300	0.032	0.000	0.000	0.063	0.038	0.030	0.000	0.063	231.1%
CE330-CE320	0.000	-0.003	-0.004	0.003	0.009	0.010	-0.004	0.010	584.2%
CE340-CE300	0.032	0.000	0.000	0.063	0.038	0.030	0.000	0.063	231.1%
CE330-CE340	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	#DIV/0!
CE350-CE300	-0.003	0.000	0.000	0.000	0.000	0.000	-0.003	0.000	-742.2%
CE360-CE300	0.032	0.001	0.000	0.063	0.038	0.030	0.000	0.063	229.7%
CE400-CE300	-0.011	-0.064	-0.066	0.000		0.000	-0.066	0.000	-233.8%
CE410-CE300	-0.007	0.000	0.000			0.000	-0.007	0.000	-400.0%
CE420-CE300	0.000	0.000	0.000	0.000		0.000	0.000	0.000	#DIV/0!
CE430-CE300	-0.022	-0.064	-0.066	0.000		0.000	-0.066	0.000	-217.2%
CE440-CE300	-0.011	-0.064	-0.066	0.000		0.000	-0.066	0.000	-234.7%
CE500-CE300	-0.108	-0.105	-0.149	-0.076	-0.119	-0.100	-0.149	-0.076	-66.6%
CE510-CE500	0.203	0.124	0.000	0.160	0.215	0.190	0.000	0.215	144.8%
CE525-CE520	0.469	0.476	0.420	0.408	0.561	0.430	0.408	0.561	33.2%
CE530-CE500	-0.184	-0.198	-0.154	-0.173	-0.193	-0.190	-0.198	-0.154	-24.2%
CE545-CE540	0.479	0.459	0.460	0.277	0.549	0.440	0.277	0.549	61.2%

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Delta Hourly Integrated Maximum and Minimum IDB

Maximum IDB (°C)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	0.88	1.78	1.61	1.47	1.57	1.00	0.88	1.78	65.1%
CE320-CE300	6.16	6.50	6.39	6.71	7.27	5.46	5.46	7.27	28.2%
CE330-CE300	6.03	6.61	6.89	6.07	6.85	5.11	5.11	6.89	28.4%
CE330-CE320	-0.13	0.11	0.50	-0.64	-0.42	-0.35	-0.64	0.50	-736.8%
CE340-CE300	6.11	6.50	6.45	6.50	7.10	5.39	5.39	7.10	27.0%
CE330-CE340	-0.07	0.11	0.44	-0.43	-0.25	-0.28	-0.43	0.44	-1078.3%
CE350-CE300	8.38	9.83	9.83	10.00	9.95	8.81	8.38	10.00	17.1%
CE360-CE300	7.56	7.67	7.45	7.51	7.95	6.94	6.94	7.95	13.4%
CE400-CE300	0.91	2.45	3.72	1.91		-0.15	-0.15	3.72	218.8%
CE410-CE300	0.63	0.00	0.00			0.00	0.00	0.63	400.0%
CE420-CE300	0.00	0.00	0.00	0.00		0.04	0.00	0.04	500.0%
CE430-CE300	1.00	0.00	0.00	0.00		0.26	0.00	1.00	396.6%
CE440-CE300	0.85	0.00	0.00	0.00		0.07	0.00	0.85	461.5%
CE500-CE300	-0.39	0.00	0.00	0.00	-0.03	-1.19	-1.19	0.00	-441.5%
CE510-CE500	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.29	600.0%
CE525-CE520	19.96	18.95	19.12	20.00	19.02	16.38	16.38	20.00	19.1%
CE530-CE500	0.31	-0.05	-0.05	0.00	0.00	0.00	-0.05	0.31	1025.2%
CE545-CE540	19.53	19.89	19.89	20.00	19.95	20.00	19.53	20.00	2.4%

Minimum IDB (°C)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-600.0%
CE320-CE300	0.00	1.94	1.95	-0.96	0.00	0.00	-0.96	1.95	597.5%
CE330-CE300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-600.0%
CE330-CE320	0.00	-1.94	-1.95	0.96	0.00	0.00	-1.95	0.96	-596.8%
CE340-CE300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-600.0%
CE330-CE340	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
CE350-CE300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
CE360-CE300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	600.0%
CE400-CE300	0.00	0.00	0.00	0.00		0.00	0.00	0.00	-500.0%
CE410-CE300	0.00	0.00	0.00			0.00	0.00	0.00	#DIV/0!
CE420-CE300	0.00	0.00	0.00	0.00		0.00	0.00	0.00	-500.0%
CE430-CE300	0.00	0.00	0.00	0.00		0.00	0.00	0.00	-500.0%
CE440-CE300	0.00	0.00	0.00	0.00		0.01	0.00	0.01	500.0%
CE500-CE300	0.50	-0.72	-0.89	0.22	0.54	17.05	-0.89	17.05	644.6%
CE510-CE500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	600.0%
CE525-CE520	0.14	0.06	0.05	0.18	0.03	19.44	0.03	19.44	585.3%
CE530-CE500	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	-533.6%
CE545-CE540	0.22	0.06	0.05	0.18	0.03	18.06	0.03	18.06	581.6%

RESULTS5-3B.xlst:a386..m429; 02/09/06

Delta Hourly Integrated Maximum and Minimum Zone Humidity Ratio

Maximum Humidity Ratio (kg/kg)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	0.0025	0.0050	0.0052	0.0020	0.0020	0.0023	0.0020	0.0052	102.1%
CE320-CE300	0.0047	0.0039	0.0039	0.0042	0.0041	0.0043	0.0039	0.0047	19.9%
CE330-CE300	0.0044	0.0040	0.0040	0.0043	0.0036	0.0043	0.0036	0.0044	19.0%
CE330-CE320	-0.0004	0.0001	0.0001	0.0001	-0.0005	0.0000	-0.0005	0.0001	-696.5%
CE340-CE300	0.0046	0.0039	0.0037	0.0042	0.0038	0.0043	0.0037	0.0046	21.8%
CE330-CE340	-0.0002	0.0001	0.0003	0.0001	-0.0002	0.0000	-0.0002	0.0003	3174.2%
CE350-CE300	0.0035	0.0061	0.0062	0.0036	0.0030	0.0032	0.0030	0.0062	74.6%
CE360-CE300	0.0001	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0002	366.5%
CE400-CE300	0.0037	0.0032	0.0033	0.0033		0.0039	0.0032	0.0039	20.2%
CE410-CE300	0.0036	0.0031	0.0032			0.0039	0.0031	0.0039	23.3%
CE420-CE300	0.0010	0.0009	0.0004	0.0010		0.0013	0.0004	0.0013	98.3%
CE430-CE300	0.0029	0.0018	0.0019	0.0025		0.0024	0.0018	0.0029	49.6%
CE440-CE300	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	500.0%
CE500-CE300	-0.0016	-0.0019	-0.0019	-0.0019	-0.0017	-0.0019	-0.0019	-0.0016	-20.6%
CE510-CE500	0.0002	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0002	352.6%
CE525-CE520	0.0104	0.0103	0.0102	0.0115	0.0101	0.0067	0.0067	0.0115	48.3%
CE530-CE500	-0.0047	-0.0038	-0.0037	-0.0049	-0.0062	-0.0047	-0.0062	-0.0037	-53.9%
CE545-CE540	0.0009	0.0072	0.0059	0.0000	0.0034	0.0013	0.0000	0.0072	230.7%

Minimum Humidity Ratio (kg/kg)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	646.4%
CE320-CE300	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	600.0%
CE330-CE300	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-600.0%
CE330-CE320	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-600.0%
CE340-CE300	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-600.0%
CE330-CE340	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	#DIV/0!
CE350-CE300	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	#DIV/0!
CE360-CE300	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-600.0%
CE400-CE300	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	500.0%
CE410-CE300	0.0000	0.0000	0.0000			0.0000	0.0000	0.0000	#DIV/0!
CE420-CE300	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	-500.0%
CE430-CE300	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	500.0%
CE440-CE300	0.0000	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	-500.0%
CE500-CE300	0.0050			0.0051	0.0049	0.0083	0.0049	0.0083	58.2%
CE510-CE500	0.0000			0.0000	0.0000	0.0002	0.0000	0.0002	400.0%
CE525-CE520	0.0007			0.0005	0.0004	0.0088	0.0004	0.0088	322.8%
CE530-CE500	-0.0006			-0.0003	-0.0015	-0.0037	-0.0037	-0.0003	-226.1%
CE545-CE540	0.0021			0.0030	0.0034	0.0028	0.0021	0.0034	47.3%

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Delta Hourly Integrated Maximum and Minimum Zone Relative Humidity

Maximum Relative Humidity (%)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	8.91	30.83	31.85	10.28	9.00	10.75	8.91	31.85	135.4%
CE320-CE300	13.05	14.06	14.82	14.60	15.00	14.44	13.05	15.00	13.6%
CE330-CE300	7.87	9.11	9.09	8.51	8.00	11.26	7.87	11.26	37.8%
CE330-CE320	-5.18	-4.95	-5.73	-6.09	-7.00	-3.18	-7	-3	-71.3%
CE340-CE300	11.14	12.02	12.41	12.43	12.00	12.81	11	13	13.8%
CE330-CE340	-3.27	-2.91	-3.32	-3.92	-4.00	-1.55	-4	-2	-77.5%
CE350-CE300	0.00	11.77	12.27	0.00	2.00	5.21	0.00	12.27	235.6%
CE360-CE300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-600.0%
CE400-CE300	14.96	16.22	16.72	16.27		18.87	14.96	18.87	23.5%
CE410-CE300	14.44	15.44	15.94			18.74	14.44	18.74	26.7%
CE420-CE300	2.05	5.16	2.68	4.92		6.41	2.05	6.41	102.7%
CE430-CE300	11.92	9.08	9.58	12.38		11.50	9.08	12.38	30.3%
CE440-CE300	-0.06	0.00	0.00	0.00		0.07	-0.06	0.07	13500.0%
CE500-CE300	31.21			31.63	32.00	-7.36	-7.36	32.00	180.0%
CE510-CE500	0.00			0.00	0.00	-2.57	-2.57	0.00	-400.0%
CE525-CE520	9.77			6.19	5.00	-20.65	-20.65	9.77	39706.5%
CE530-CE500	-8.96			-3.84	-21.00	-24.07	-24.07	-3.84	-139.8%
CE545-CE540	29.60			41.06	50.00	-15.82	-15.82	50.00	251.1%

Minimum Relative Humidity (%)	TRNSYS TUD	DOE-2.2 NREL	DOE21E-E NREL	EnergyPlus GARD	CODYRUN UR	HOT3000 NRCan	Statistics, All Results Min	Max	(Max-Min) /Mean
CE310-CE300	0.06	0.00	0.00	1.10	1.00	0.99	0.00	1.10	209.6%
CE320-CE300	0.00	0.00	0.00	0.24	0.00	-2.02	-2.02	0.24	-761.2%
CE330-CE300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	600.0%
CE330-CE320	0.00	0.00	0.00	-0.24	0.00	2.02	-0.24	2.02	761.1%
CE340-CE300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	600.0%
CE330-CE340	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
CE350-CE300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
CE360-CE300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-600.0%
CE400-CE300	-0.12	0.00	0.00	-0.48		-0.37	-0.48	0.00	-246.0%
CE410-CE300	-0.12	0.00	0.00			-0.36	-0.36	0.00	-298.7%
CE420-CE300	-0.12	0.00	0.00	-0.48		-0.35	-0.48	0.00	-251.4%
CE430-CE300	-0.12	0.00	0.00	-0.48		-0.36	-0.48	0.00	-248.3%
CE440-CE300	-0.12	0.00	0.00	-0.48		-0.40	-0.48	0.00	-238.1%
CE500-CE300	40.07			40.76	39.00	37.89	37.89	40.76	7.3%
CE510-CE500	-1.32			0.12	0.00	0.32	-1.32	0.32	-747.8%
CE525-CE520	-15.74			-13.87	-17.00	-17.50	-17.50	-13.87	-22.6%
CE530-CE500	-23.81			-21.14	-26.00	-19.15	-26.00	-19.15	-30.4%
CE545-CE540	-19.35			-16.77	-12.00	-19.60	-19.60	-12.00	-44.9%

RESULTS5-3B.xlsx t:a476..m519; 02/09/06

[Informative Note. Correct the title of B16.6 as shown. The tables and graphs of Section B16.6 are the same as the furnace test cases of 140-2004 Addendum a and have no further changes in this addendum.]

B16.6 Tables and Graphs of Results For Space Heating Equipment Cases HE100-HE170 and HE210-HE230

The following tables provide a comparison of the results calculated from the methods outlined in Section B17.2 with the results obtained from the test cases using three different software simulation tools: ESP-r/HOT3000,[A-2] EnergyPlus,[A-1] and DOE2.1E. [A-7]

(This annex is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

ANNEX B17
PRODUCTION OF QUASI-ANALYTICAL SOLUTION RESULTS AND EXAMPLE SIMULATION RESULTS FOR HVAC EQUIPMENT PERFORMANCE TESTS

[Informative Note: Renumber Section B17.1 to facilitate cross-referencing in later sections, and make editorial revisions as shown.]

B17.1 FOR SPACE COOLING EQUIPMENT CASES ~~(e100-e200)~~

B17.1.1 Analytical Verification Tests, Cases E100-E200

B17.1.1.1 Introduction

B17.1.1.1.1 The full discussion regarding production of quasi-analytical solution results and example simulation results is included in *HVAC BESTEST*.[8] Portions of that discussion have been included here. The quasi-analytical solutions and programs used to generate the example simulation results are described in Table B17-1.

B17.1.1.1.2 The first column of Table B17-1 ("Model") indicates the proper program name and version number or indicates a quasi-analytical solution. The second column ("Authoring Organization") indicates the national research facility or university with expertise in building science that wrote the simulation software or did the quasi-analytical solutions. The third column ("Implemented By") indicates the national research facility or university with expertise in building science that performed the simulations or did the quasi-analytical solutions. The entries in the fourth column are the abbreviations for the simulations and quasi-analytical solutions generally used in Annex B16 and elsewhere in the informative annexes. The majority of participating organizations that performed simulations ran software that their organization either authored or coauthored.

B17.1.1.1.3 The availability of quasi-analytical solutions (see Section B17.1.1.2) greatly helped to identify and correct errors in the simulations such that errors are minimized in the final simulation results. Also, to minimize the potential for user error in the simulations, when feasible, more than one modeler developed input files for each program. This was done for DOE-2.1E and where disagreement in the inputs or results was found, the modelers worked to resolve the differences. Additionally, one of the participants (TUD) developed quasi-analytical solutions and ran separate controller models within TRNSYS; this allowed for greater understanding of the test specification and of their simulation model. Where only a single modeler was involved, we strongly recommended that another modeler familiar with the program check the inputs carefully.

B17.1.1.1.4 Where improvements to simulation programs or simulation inputs were made as a result of running the tests, such improvements must have mathematical and physical bases and must be applied consistently across tests. Also, all improvements were required to be documented in modeler reports. Arbitrary modification of a simulation program's input or internal code just for the purpose of more closely matching a given set of results was not allowed.

B17.1.1.1.5 Input decks used to generate the simulation results are provided in the files accompanying this standard; see the README*.DOC file. International Energy Agency participants that ran simulations for CA-SIS and CLIM2000 did not supply input decks with their results.

[Informative Note: Revise title of Table B17-1 as shown]

TABLE B17-1
Participating Organizations and Computer Programs, Analytical Verification Cases E100-E200

[Informative Note: Renumber Section B17.1.2, with editorial revision as shown]

B17.1.1.2 Quasi-Analytical Solution Results

The quasi-analytical solution results given in Annex B16, Section B16.5.1 were developed as part of …

[Informative Note: Add entirely new Section B17.1.2 as shown.]

B17.1.2 Comparative Tests, Cases CE300-CE545

B17.1.2.1 Introduction. Programs used to generate the example simulation results are described in Table B17-2, which is organized similarly to Table B17-1. See Section B17.1.1.1.2 for description of information included in the table. Rules for improvements to simulations were in accord with Section B17.1.1.1.4. Input decks used to generate the simulation results are provided on the accompanying CD; see the README*.DOC file.

B17.1.2.2 Disagreements Related to TMY2 Data Time Convention. According to the TMY2 weather data documentation included in Annex A1, Section A1.5, solar radiation data represent energy received during the 60 minutes preceding the hour indicated. For meteorological elements, such as dry-bulb temperature, dew-point temperature, relative humidity, and atmospheric pressure, data are spot measurements made at the hour indicated.[11] During the field trials of cases CE300-CE545, it was observed that some simulation tools have adapted the meteorological element data to a preceding hour convention by averaging the listed point measurements for each hour. Other simulation tools have applied the meteorological element data as listed directly to their preceding hour time convention. These different applications give similar annual energy use results but can cause variations among hourly and peak-hour load and consumption results. Either of these applications is a reasonable interpretation for the tests in this Standard for simulations that use preceding hour time conventions; such different adaptations of the mixed conventions of TMY2 data cause legitimate disagreement among simulation results.

[Informative Note: Revise Section B17.1.3. as shown.]

B17.1.3 Selection of Programs for Producing Example Simulation Results. The criteria for selection of programs used for producing example results required that

a. the program be a true simulation based on hourly weather data and calculational time increments of one hour or less and
b. the program be representative of the state of the art in whole-building energy simulation as defined by the IEA country making the selection.

The programs used to generate example results have been subjected to extensive prior validation testing. Such testing includes the preliminary trials of *HVAC BESTEST Volume 1* [8] that ran from 1997 through 2001 and *HVAC BESTEST Volume 2*[B-1] that ran from 2001 through 2004. The programs (to various extents) were also subjected to other comparative, empirical validation and/or analytical verification tests such as those referenced in *HVAC BESTEST, IEA BESTEST*, and in International Building Performance Simulation Association (IBPSA) proceedings.[8, 14, 27, 28]

[Informative Note: Renumber Tables B17.2 through B17.6 as B17-3 through B17-7 as shown.]

B17.2 FOR SPACE HEATING EQUIPMENT CASES (HE100-HE170)

B17.2.2.1 Case HE140. The calculation of the heating load on the furnace and the fuel consumption over a 24-hour period is required to examine the impact of the varying outdoor dry-bulb temperature. Table ~~B17.2~~B17-3 shows the calculated sensible heat load to be delivered by the furnace, $Q_{delivered}$, the part-load efficiency, $\eta_{part\ load}$, the rate of fuel consumption of the furnace, Q_{fuel}, and the resulting fuel consumption over a 24-hour period. A description of the semi-analytical calculation method is presented in Section B17.2.2.

The average hourly calculated heat delivered by the furnace is **4998.45 W** and the rate of fuel consumption is **0.000132 m^3/s**.

Table ~~B17.2~~B17-3 Heat Load, Efficiency, and Fuel Consumption for the Complex Part-Load Test

B17.2.2.2 Case HE150. As the circulation fan runs constantly, 200 W of fan heat is continuously added to the heated airstream. This reduces the energy required from fuel combustion while maintaining the constant zone temperature. This has the impact of affecting the part load factor and fuel consumption.

The average-hourly value calculated for the heat to be delivered by the furnace is **4759.67 W** and the rate of fuel consumption is **0.0001253 m^3/s**. The total electricity consumption is calculated to be 432 kWh or **1.56GJ** for the three-month period. Table ~~B17.3~~B17-4 gives the results for a 24-hour period.

Table ~~B17.3~~B17-4 Heat Load, Efficiency, Fuel and Electricity Consumption for the Circulating Fan Test

B17.2.2.3 Case HE160. This calculated solution assumes that the PLR_f is equal to the fraction of time during which the fan operates for a given time-step. In addition, it assumes that there are no effects from fan start-up or shutdown, i.e., when the fan is on it draws 200 W. It is recognized that some building simulation programs may apply different assumptions in the modeling of circulation fans. In this case, results would be expected to disagree with these calculated results by a small degree.

As the circulating fan cycles with the burner operation, its hourly energy varies based on the load on the furnace. It can be calculated as

$$\text{Energy}_{circ,fan} = \Delta t \cdot \text{Power}_{circ,fan} \cdot \text{PLR}_f, \qquad \text{(B17.15)}$$

where Δt is the time step, $Power_{circ,fan}$ is the rated circulation fan power (200 W in this case), and PLR_f is

$$\text{PLR}_f = \frac{\text{load placed on furnace}}{\text{furnace capacity}}, \qquad \text{(B17.8)}$$

where the available *Furnace Capacity* includes the fan power.

The average-hourly value calculated for the heat to be delivered by the furnace is **4898.48 W** and the rate of fuel consumption is **0.0001289 m^3/s**. These values are higher than the previous case where the circulating fan ran constantly.

The total electricity consumption is 172.76 kWh or **0.62 GJ** for the three-month period, which is lower than in the previous case. Table ~~B17.4~~B17-5 gives the results for a 24-hour period.

Table ~~B17.4~~B17-5 Heat Load, Efficiency, Fan Power, Fuel and Electricity Consumption for Cycling Fan Case

B17.2.2.4 Case HE170 The circulating fan operates continuously at 200 W whereas the draft fan cycles with the burner operation. Implicit in this calculation is that the PLR_f is equal to the fraction of time during which the draft fan operates for a given time-step. In addition, it is assumed that there are no effects from fan start-up or shutdown, i.e., when the draft fan is on it draws 50 W. The draft fan's hourly energy varies based on the load on the furnace and can be calculated as

$$\text{Energy}_{draft,fan} = \Delta t \cdot \text{Power}_{draft,fan} \cdot \text{PLR}_f, \qquad \text{(B17.16)}$$

where Δt is the time step, $Power_{draft,fan}$ is the rated draft fan power (50 W in this case), and PLR_f is

$$\text{PLR}_f = \frac{\text{hourly load}}{\text{available capacity}}. \qquad \text{(B17.8)}$$

The heat output of the draft fan should not be added to the zone energy balance; therefore, there should be no impact on the energy balance of the zone. The average hourly value calculated for the heat to be delivered by the furnace is **4759.67 W** and the rate of fuel consumption is **0.0001253 m^3/s**.

The electrical consumption of the furnace system should increase with an additional load of the draft fan. The total electricity consumption is calculated as 473.18 kWh or 1.70 GJ for the three-month period of this test. Table ~~B17.5~~B17-6 gives the results for a 24-hour period.

Table ~~B17.5~~B17-6: Heat Load, Efficiency, Fan Power, Fuel and Electricity Consumption for Draft Fan Case

B17.2.3 Analytical Solution For Alternate Cases. These alternate test cases, described in section 5.4.1.9, are designed for those simulation programs that do not allow the definition of convective heat transfer coefficients. In this approach, the heating loads are driven by infiltration of outdoor air into the zone.

The rate of energy consumption due to the required sensible heating of the incoming outdoor air, Q_{total}, can be defined as

$$Q_{total} = \dot{m} \cdot c_p \cdot \Delta T \,. \tag{15}$$

where

$\dot{m}$ = air mass flow rate, kg/s,

c_p = specific heat of the air, J/(kg·K), and

ΔT = temperature difference between the indoor and outdoor air, K.

Using the values defined in the previous sections and Equation 9, the heat transfer rate required to maintain the interior setpoint temperature is $\mathbf{Q_{total}}$ **= 9997 W**. The rate of energy transfer from the furnace to the zone air required to meet this load is $\mathbf{Q_{delivered}}$ **= 9997 W**.

As the furnace is 100% efficient, the heat delivered by the furnace is equal to the rate at which the furnace consumed fuel, as calculated with Equation 11, i.e., $\mathbf{Q_{delivered} = Q_{fuel}}$ **= 9997 W**. Using Equation 10, the rate of fuel consumption is **0.000263 m^3/s**.

The remaining test cases differ from the originals only in the analytical/calculated solutions. Table ~~B5.1~~B17-7 describes the numerical results calculated for the infiltration cases.

Table ~~B17.6~~B17-7 Energy Delivered and Consumed by Fuel-Fired Furnace for alternate tests, in GJ

TABLE B17-2 Participating Organizations and Computer Programs, Comparative Test Cases CE300-CE545

Model	Authoring Organization	Implemented by	Abbreviation
CODYRUN/LGIMAT	Université de la Reunion Island, France	Université de la Reunion Island, France	CODYRUN/UR
DOE-2.1E version 120 (ESTSC release)	LANL/LBNL/ESTSC/JJH,[a,b,c,d] United States	NREL/JNA,[e] United States	DOE-2.1E-E/NREL DOE21E-E
DOE-2.2 NT42j	LBNL/JJH,[b,d] United States	NREL/JNA,[e] United States	DOE-2.2/NREL
EnergyPlus 1.1.0.020	LBNL/UIUC/CERL/OSU/GARD Analytics/ FSEC/DOE-BT,[b,f,g,h,i,j] United States	GARD Analytics, United States	EnergyPlus/GARD
HOT3000/ESP-r	CETC/ESRU,[k,l] Canada/United Kingdom	CETC,[k] Canada	HOT3000/NRCan
TRNSYS 14.2-TUD with real controller model	University of Wisconsin, United States; Technische Universität Dresden, Germany	Technische Universität Dresden, Germany	TRNSYS-TUD/TUD

[a] LANL: Los Alamos National Laboratory, United States
[b] LBNL: Lawrence Berkeley National Laboratory, United States
[c] ESTSC: Energy Science and Technology Software Center (at Oak Ridge National Laboratory, United States
[d] JJH: James J. Hirsch & Associates, United States
[e] NREL/JNA: National Renewable Energy Laboratory/J. Neymark & Associates, United Sates
[f] UIUC: University of Illinois Urbana/Champaign, United States
[g] CERL: US Army Corps of Engineers, Construction Engineering Research Laboratories, United States
[h] OSU: Oklahoma State University, United States
[i] FSEC: University of Central Florida, Florida Solar Energy Center, United States
[j] DOE-BT: US Department of Energy, Office of Building Technologies, Energy Efficiency and Renewable Energy, United States
[k] CETC: CANMET Energy Technology Centre, Natural Resources Canada, Canada
[l] ESRU: Energy Systems Research Unit, University of Strathclyde, Scotland, United Kingdom

(This annex is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

ANNEX B18
VALIDATION METHODOLOGIES AND OTHER RESEARCH RELEVANT TO STANDARD 140

[Informative Note: Revise Section B18.1 as shown to include updates contained in the new 2005 Handbook of Fundamentals validation section.]

B18.1 Overall Validation Methodology. An overall validation methodology consists of three parts:

a. Comparative Testing—in which a program is compared to itself or to other programs
b. Analytical Verification—in which ~~the~~ outputs from a program, subroutine, algorithm, or software object ~~is~~are compared to ~~the~~ results from a known analytical or quasi-analytical solution or a generally accepted numerical method for isolated heat transfer ~~mechanisms~~ under very simple, ~~and~~ highly constrained boundary conditions
c. Empirical Validation—in which calculated results from a program, subroutine, algorithm, or software object are compared to monitored data from a real building, test cell, or laboratory experiment.

Table B18-1 ~~shows the advantages and disadvantages of~~compares these ~~three~~ techniques.[37, 38, 8] ~~Defining two terms is useful in interpreting Table 1. Here a~~In this table the term "model" is the representation of reality for a given physical behavior. For example, heat transfer may be simulated with one-, two-, or three-dimensional conduction models. ~~one way to model heat transfer through a wall is by using a simplifying assumption of one-dimensional conduction. An alternative (more detailed) model for wall heat transfer could employ two-dimensional conduction.~~ The term "solution process" ~~is a term that~~ encompasses the mathematics and computer coding to solve a given model. ~~(e.g., a finite difference approximation to solve a differential equation) and the technique for integrating individual models and boundary conditions into an overall solution methodology—such as an iterative energy balance through layers of a single wall, over all the surfaces of a given zone, or between a zone(s) and its related mechanical system(s).~~ The solution process for a model can be perfect while the model remains ~~faulty or~~ inappropriate for a given physical situation, ~~or purpose; for example,~~ such as using a one-dimensional conduction model where two-dimensional conduction dominates. The term "truth standard" represents the standard of accuracy for predicting real behavior. An analytical solution is a "mathematical truth standard" but only tests the solution process for a model, not the appropriateness of the model. An approximate truth standard from an experiment tests both the solution process and appropriateness of the model within experimental uncertainty. The ultimate (or "absolute") validation truth standard would be comparison of simulation results with a perfectly performed empirical experiment, with all simulation inputs perfectly defined.

The methodologies may be further subdivided within each category as building envelope tests and mechanical equipment tests, creating a matrix of six areas for testing including:

a. Comparative Tests— Building Envelope
b. Comparative Tests—Mechanical Equipment and On-Site Energy Generation Equipment
c. Analytical Verification—Building Envelope
d. Analytical Verification—Mechanical Equipment and On-Site Energy Generation Equipment
e. Empirical Validation—Building Envelope
f. Empirical Validation—Mechanical Equipment and On-Site Energy Generation Equipment.

[Informative Note. Delete HVAC BESTEST Volume 2 (item d and Section 18.2.4); Addendum b is proposing to add it to Standard 140. Renumber following sections accordingly, and add a new reference for "ETNA BESTEST".]

B18.2 Other Relevant Research. There are a number of other simulation test suites in various stages of completion that could eventually be included in Standard 140. These include, among others:

a. ASHRAE RP-1052, "Development of an Analytical Verification Test Suite for Whole Building energy Simulation Programs – Building Fabric"[39]
b. "Home Energy Rating System Building Energy Simulation Test (HERS BESTEST)"[40]
c. ASHRAE RP-865, "Development of Accuracy Tests for Mechanical System Simulation"[41]
~~d. "International Energy Agency Building Energy Simulation Test and Diagnostic Method for Heating, Ventilating, and Air-Conditioning Equipment Models (HVAC BESTEST), Volume 2: Cases E300-E545" [A-5]~~
d. ~~e.~~ "RADTEST Radiant Heating and Cooling Test Cases"[43]
e. ~~f.~~ "Proposed IEA BESTEST Ground-Coupled Cases"
f. ~~g.~~ ETNA BESTEST Empirical Validation Test Specification[B-3]
g. ~~h.~~ "Daylighting – HVAC Interaction Tests for the Empirical Validation of Building Energy Analysis Tools"[44]
h. ~~i.~~ "Economizer Control Tests for the Empirical Validation of Building Energy Analysis Tools"[A-4]
i. ~~j.~~ A number of test suites that are being developed by National Renewable Energy Laboratory and researchers in International Energy Agency (IEA) member nations under auspices of IEA Solar Heating and Cooling Programme Task 34 and IEA Energy Conservation in Buildings and Community Systems Programme Annex 43 (IEA SHC 34/ECBCS 43).[45]

(**Note:** ~~Since items f and g are~~Because item e is a work~~s~~ in progress, no reference~~s~~ can yet be cited for it~~them~~.)

B18.2.1 ASHRAE RP-1052[39] These tests are analytical verification tests that focus on the ability to model thermal physics related to the building fabric. The tests were developed by Oklahoma State University as an ASHRAE research project. Cases allow the comparison of analytical solutions to program results for the purpose of testing the ability of programs to model steady-state convection and conduction, exterior and interior infrared radiation, exterior solar radiation, transient conduction, infiltration, convective and radiant internal gains, ground coupling, solar transmission through windows, internal (transmitted) solar radiation distribution, and external shading.

B18.2.2 HERS BESTEST HERS BESTEST[40] is similar to the current test included in Section 5.2 of Standard 140 in that it is a comparative test that focuses on the building envelope. However, HERS BESTEST was designed for testing more simplified building energy analysis tools commonly used for residential modeling and specifically for home energy rating systems. As such, it goes into less detail in testing specific building physics algorithms than Standard 140 and uses more realistic test cases.

B18.2.3 ASHRAE RP-865[41] These tests are analytical verification tests that focus on the ability to model thermal physics related to the air side of mechanical equipment. The tests were developed by Pennsylvania State University and Texas A&M University as an ASHRAE research project. Cases allow the comparison of quasi-analytical solutions to program results for the purpose of testing the ability of programs to model air-side mechanical equipment and systems. These tests are subdivided by system type, for example, constant-volume dual duct or variable-volume single duct with reheat.

~~**B18.2.4 HVAC BESTEST Cases E300-E545**[A-5] is a comparative test being developed by the National Renewable Energy Laboratory in conjunction with the International Energy Agency Solar Heating and Cooling Programme Task 22. This test suite extends the unitary space cooling equipment tests of Section 5.3. The cases are more realistic (including more dynamic loading and weather conditions) and cannot be solved analytically or quasi-analytically. Cases include variation of PLR, ODB, and EDB for both dry-coil and wet-coil conditions. Also tested in the dynamic context is the ability of programs to model equipment performance with outside air mixing, infiltration loading, thermostat set-up, undersized equipment, and economizers with various temperature and enthalpy controls.~~

B18.2.4~~5~~ RADTEST[43] is a comparative test developed by Hochschule fur Technik + Architektur Luzern in conjunction with the IEA Solar Heating and Cooling Task 22. Cases allow the comparison of program results to each other for the purpose of testing the ability of programs to model radiant heating or cooling hydronic loop systems embedded in the building shell (e.g., floor, ceiling, etc.).

B18.2.5~~6~~ Proposed IEA BESTEST Ground-Coupled Cases is a comparative test being developed by the National Renewable Energy Laboratory in conjunction with the IEA Solar Heating and Cooling (SHC) Programme Task 22 and IEA SHC Programme Task 34/Energy Conservation in Buildings and Community Systems (BCS) Programme Annex 43. These cases focus on the ability to model ground-coupled heat transfer and could directly append the building fabric cases of Section 5.2. Cases allow the comparison of program results to each other for the purpose of testing the ability of programs to model interaction of the building with the atmosphere through the ground, effects of solar radiation on ground-coupled surfaces, effects of calculated film coefficients versus constant film coefficients, slab-on-grade geometries with and without insulation, basement geometries with and without insulation, interaction of the building with the deep ground conditions including heat sinks such as water tables, and walkout basement construction. Additional in-depth cases are being developed to determine the causes for disagreements among detailed model results found in the preceding test cases. The new test cases compare ground models integrated with whole-building simulations to independent detailed models. There is also an analytical verification test case for checking the independent detailed models and for checking that such models are properly applied by users. Parametric variations versus a steady-state slab-on-grade base case include periodic ground surface temperature variation (versus steady-state), floor slab aspect ratio, slab size, deep ground temperature depth, and interior and exterior convective coefficients (realistic versus high values to test the effect of surface temperature uniformity).

B18.2.6~~7~~ ETNA BESTEST[B-3] is an empirical validation test being developed by Electricité de France in conjunction with J. Neymark & Associates and the National Renewable Energy Laboratory. Cases allow the comparison of empirical data to program results, allowing for validation of models within the uncertainty of the experiments. Test cases focus on the ability to model thermal loads associated with the building fabric in artificial and natural climatic configurations. Parametric variations in a natural climate configuration include dynamic thermal diffusion (with windows insulated and covered), solar gains (windows uncovered), thermostat setback, variation of interior surface convective coefficient (by varying mixing fan flow rate), variation of heater type, variation of thermal mass (insulation over the floor slab), and interactions of these. Parametric variations in an artificial climate configuration include tests for the ability to model outside air ventilation/infiltration, internal gains, and typical wall mounted "convective" and "radiant" heaters versus a heater designed for ideal pure convective output with uniform mixing of zone air (commonly assumed by simulations). Data were gathered in the artificial climate configuration to empirically characterize steady-state overall building heat loss coefficient; steady-state thermal conductance of individual walls, floor, ceiling, and windows; and internal thermal capacitance. Measurements were also made with the objectives of estimating interior convective surface coefficients and empirically characterizing incidence-angle-dependent window optical transmittance.

B18.2.7~~8~~ Daylighting—HVAC Interaction Tests for the Empirical Validation of Building Energy Analysis Tools[44] were developed by Iowa State University and Iowa Energy Resource Station in conjunction with IEA SHC Task 22. Cases

allow the comparison of empirical data to program results, allowing for validation of models within the uncertainty of the experiments. The tests focus on the ability to model daylighting/HVAC interaction. Identical rooms connected to separate mechanical systems are used with the difference that one room has dimmable ballasts; interior illuminance, solar irradiance, and heating loads were measured in both rooms.

B18.2.8~~9~~ Economizer Control Tests for the Empirical Validation of Building Energy Analysis Tools[A-4] are being developed by Iowa State University and Iowa Energy Resource Station in conjunction with IEA SHC Task 22. Cases allow the comparison of empirical data to program results, allowing for validation of models within the uncertainty of the experiments. The test cases focus on the ability to model economizer control and outdoor air in VAV Systems. Parametric variations of economizer control tests include outside air versus return air temperature comparison, with parametric variations for 0% and 20% minimum outside air, and outside air versus return air enthalpy comparison with 0% minimum outside air.

TABLE B18-1 Advantages and Disadvantages of Various Validation Techniques

Technique	Advantages	Disadvantages
Empirical Test of model and solution process	• Approximate truth standard within experimental accuracy • Any level of complexity	• Experimental uncertainties: - Instrument calibration, spatial/ temporal discretization - Imperfect knowledge/specification of the experimental object (building) being simulated • High quality, ~~D~~detailed measurements ~~of high quality~~ are expensive and time consuming • Only a limited number of test conditions are practical
Analytical Test of solution process	• No input uncertainty • Exact mathematical truth standard for the given model • Inexpensive	• No test of model validity • Limited to highly constrained cases for which analytical solutions can be derived
Comparative Relative test of model and solution process	• No input uncertainty • Any level of complexity • Many diagnostic comparisons possible • Inexpensive and quick	• No absolute truth standard (only statistically based acceptance ranges are possible)

(This annex is not part of the standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

ANNEX B19
INFORMATIVE REFERENCES

[Informative Note: Current 140-2004 references that are re-cited in the addendum are included here for convenience, with editorial revision as shown; see published version of 140-2004 for full listing of references 1 through 44, and Addendum a for full listing of references A-1 through A-8.]

[7]Brandemuehl, M. (1993). *HVAC 2 Toolkit*. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers. See pp. 4-82, 4–83.

[8]Neymark, J., and R. Judkoff. (2002). *International Energy Agency Building Energy Simulation Test and Diagnostic Method for Heating, Ventilating, and Air-Conditioning Equipment Models (HVAC BESTEST) Volume 1: Cases E100-E200.* NREL/TP-550-30152. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy02osti/30152.pdf.

[11]Marion, W.; Urban, K. (1995). *User's Manual for TMY2s Typical Meteorological Years*. Golden, CO: National Renewable Energy Laboratory.

[14]Judkoff, R., and J. Neymark. (1995). *International Energy Agency Building Energy Simulation Test (BESTEST) and Diagnostic Method*. NREL/TP-472-6231. Golden, CO: National Renewable Energy Laboratory. www.nrel.gov/docs/legosti/old/6231.pdf.

[27]Bloomfield D., Y. Candau, P. Dalicieux, S. Delille, S. Hammond, K.J. Lomas, C. Martin, F. Parand, J. Patronis, and N. Ramdani. (1995). "New Techniques for Validating Building Energy Simulation Programs." *Proc. Building Simulation '95* (Madison, Wisconsin, USA), IBPSA.

[28]Jensen, S.O. (1993). "Empirical Whole Model Validation Case Study: the PASSYS Reference Wall." Proc. *Building Simulation '93* (Adelaide, Australia), IBPSA.

[29]Henderson, H., Y.J. Huang, and D. Parker. (1999). *Residential Equipment Part Load Curves for Use in DOE-2.* LBNL-42175. Berkeley, CA: Lawrence Berkeley National Laboratory.

[31]Howell, R.H.; Sauer, H.J.; Coad, W.J. (1998). *Principles of Heating, Ventilating, and Air Conditioning*. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers. See pp. 3.4–3.5.

[33]ANSI/AMCA 210-85, ANSI/ASHRAE 51-1985. (1985). *Laboratory Methods of Testing Fans for Rating*. Jointly published by: Air Movement and Control Association Inc., Arlington Heights, IL; and American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA. See pp. 4, 40, 46-48.

[37]Judkoff, R., D. Wortman, R. O'Doherty, and J. Burch. 1983. *A Methodology for Validating Building Energy Analysis Simulations*. SERI/TR-254-1508 (190 p.). Golden, CO: National Renewable Energy Laboratory (formerly Solar Energy Research Institute).

[38]Judkoff, R. (1988). *Validation of Building Energy Analysis Simulation Programs at the Solar Energy Research Institute*. Energy and Buildings, Vol. 10, No. 3, p. 235. Lausanne, Switzerland: Elsevier Sequoia.

[Informative Note: Rename Addendum a Section B19.2 (Addendum a furnace tests references) as B19.1 as shown; neither 140-2004 nor its Addendum a contained a Section B19.1.]

B19.1~~2~~ References for Addendum a to ANSI/ASHRAE Standard 140-2004

[Informative Note: A partial listing of Addendum a references cited in this document (even if not as part of new language for Addendum b) are listed here for convenience. Also note that this Addendum b deleted citation of reference "A-5" from Annex B18, but then cites it elsewhere, see Section B19.2.]

[A-1]Crawley, Drury B., Linda K. Lawrie, Curtis O. Pedersen, Richard K. Strand, Richard J. Liesen, Frederick C. Winkelmann, W. F. Buhl, Y. Joe Huang, A.Ender Erdem, Daniel E. Fisher, Michael J Witte, and Jason Glazer. (2001), Creating a New-Generation Building Energy Simulation Program, *Energy & Buildings*, Vol. 33, No. 4 (April), pp. 319-331.

[A-2]ESRU (2000), The ESP-r System for Building Energy Simulations: User Guide Version 9 Series, ESRU Manual U00/1, University of Strathclyde, Glasgow UK

[A-4]Maxwell, G.; Loutzenhiser P.; Klaassen C. (2004). *Economizer Control Tests for the Empirical Validation of Building Energy Analysis Tools*. Ames Iowa: Iowa State University, Department of Mechanical Engineering. Ankeny, Iowa: Iowa Energy Center.

~~[A-5]Neymark, J., and R. Judkoff. (2004). *International Energy Agency Building Energy Simulation Test and Diagnostic Method for Heating, Ventilating, and Air-Conditioning Equipment Models (HVAC BESTEST)*, Volume 2: Cases E300-E545. NREL/TP/550-36754. Golden, Colorado: National Renewable Energy Laboratory. http://www.nrel.gov.docs/fy05osti/36754.pdf~~

[A-6]Purdy, J. and I.Beausoleil-Morrison. 2002. Building Energy Simulation Test for Heating, Ventilating, and Air-*Conditioning Equipment Models (HVAC BESTEST), IEA Fuel-Fired Furnace.* Ottawa, Energy Technology Centre.

[A-7]Winkelmann F., Birdsall B., Buhl W., Ellington K., Erdem A., Hirsch J., and Gates S. (1994), *DOE-2 Supplement: Version 2.1E*, U. California, Berkeley USA.

[Informative Note: Add section B19.2 references, new for Addendum b as shown.]

B19.2 References for Addendum b to ANSI/ASHRAE Standard 140-2004

B-1 Neymark, J.; Judkoff, R. (2004). *International Energy Agency Building Energy Simulation Test and Diagnostic Method for Heating, Ventilating, and Air-Conditioning Equipment Models (HVAC BESTEST), Volume 2: Cases E300-E545*. NREL/TP-550-36754. Golden, Colorado, US: National Renewable Energy Laboratory. Available from http://www.nrel.gov/docs/fy05osti/36754.pdf (PDF 15.4 MB).

B-2 McQuiston, F.; Parker, J. (1994). *HVAC Analysis and Design*. 4th ed. New York, New York, US: John Wiley & Sons. See p. 463.

B-3 Neymark, J.; Girault, P.; Guyon, G., Judkoff, R.; LeBerre, R.; Ojalvo, J.; Reimer, P. (2005). *The "ETNA BESTEST Empirical Validation Data Set.* Building Simulation 2005, Ninth International IBPSA Conference, Montréal, Canada, August 15-18, 2005. International Building Performance Simulation Assocation.

[Informative Note: In the 2007 edition of ANSI/ASHRAE Standard 140, the following editorial revisions will be made for consistency:

- ***all occurences of "air stream" will be changed to "air-stream"***
- ***all alpha-lists that are in outline form will be standardized to have the same style.***
- ***use parentheses in denominatiors as needed to group units. For example, change "W/m^2·K" to "W/(m^2·K)."]***

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the standards and guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive technical committee structure, continue to generate up-to-date standards and guidelines where appropriate and adopt, recommend, and promote those new and revised standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating standards and guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.