

# ANSI/ASHRAE Addendum *a* to ANSI/ASHRAE Standard 140-2001



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

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(Note: Additions are shown in this addendum by <u>underlining</u> and deletions are shown by <u>strikethrough</u> except when an informative note makes it clear that the entire material that follows is to be added or deleted as a whole.)

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(This foreword 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.)

[Informative Note: This new foreword replaces the previous foreword.]

# 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

• 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 HVAC 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 these steady-state cases, 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 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 test results of Annex B8, 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 results presented in the informative Annex B8 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 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 results for the HVAC equipment performance tests include both quasi-analytical solutions and simulation results. 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 Section 5.3 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 accept the given underlying physical assumptions while recognizing that these assumptions represent a simplification of physical reality. The ultimate or "absolute" validation 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).

The minor disagreements among the two sets of quasianalytical solution results presented in Annex B16 are small enough to allow 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 in Annex B16 is to allow simulationists to compare their relative agreement (or disagreement) versus the quasi-analytical solution results to that for other simulation results. Perfect agreement among simulations and quasi-analytical solutions is not necessarily expected. The results give an indication of the sort of agreement that is possible between simulation results and the quasi-analytical solution results. Because the physical assumptions of a simulation may be different from those for the quasi-analytical solutions, a tested program may disagree with the quasi-analytical 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: Add the following new definitions to Section 3.1.]

*adjusted net sensible capacity:* the gross sensible capacity less the actual fan power. (Also see *gross sensible capacity*.)

*adjusted net total capacity:* the gross total capacity less the actual fan power. (Also see *gross total capacity*.)

*analytical solution:* mathematical solution of a model of reality that has a deterministic result for a given set of parameters and boundary conditions.

*apparatus dew point (ADP):* the effective coil surface temperature when there is dehumidification; this is the temperature to which all the supply air would be cooled if 100% of the supply air contacted the coil. On the psychrometric chart, this is the intersection of the condition line and the saturation curve, where the condition line is the line going through entering air conditions with slope defined by the sensible heat ratio ([gross sensible capacity]/[gross total capacity]). (Also see *gross sensible capacity* and *gross total capacity*.)

*building thermal envelope and fabric*: includes the building thermal envelope as defined in ASHRAE Terminology, <sup>A-1</sup> as well as internal thermal capacitance and heat and mass transfer between internal zones.

*bypass factor (BF):* can be thought of as the percentage of the distribution air that does not come into contact with the cooling coil; the remaining air is assumed to exit the coil at the average coil temperature (apparatus dew point). (See also apparatus dew point.)

*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 cooling energy consumption. (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, condenser fan, and related auxiliaries.

*COP*<sub>SEER</sub>: the seasonal energy efficiency ratio (dimension-less).

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

*degradation coefficient:* measure of efficiency loss due to cycling of equipment.

*energy efficiency ratio (EER):* the ratio of net refrigeration effect (in Btu per hour) to cooling energy consumption (in watts) so that EER is stated in units of (Btu/h)/W. (Also see *net refrigeration effect* and *cooling energy consumption*.)

*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, EDB equals the indoor 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, this would also be the zone 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). (Also see *sensible heat* and *latent heat*.)

gross sensible capacity: the rate of sensible heat removal by the cooling coil for a given set of operating conditions. This

value varies as a function of performance parameters such as EWB, ODB, EDB, and airflow rate. (Also see *sensible heat*.)

*gross total capacity:* the total rate of both sensible heat and latent heat removal by the cooling coil for a given set of operating conditions. This value varies as a function of performance parameters such as EWB, ODB, EDB, and airflow rate. (Also see *sensible heat* and *latent heat*.)

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

*humidity ratio:* the ratio of the mass of water vapor to the mass of dry air in a moist air sample.

*indoor dry-bulb temperature (IDB):* the temperature that a thermometer would measure if exposed to indoor air.

*latent heat:* the change in enthalpy associated with a change in humidity ratio, caused by the addition or removal of moisture. (Also see *humidity ratio*.)

*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*.)

*net sensible capacity:* the gross sensible capacity less the default rate of fan heat assumed by the manufacturer; this rate of fan heat is not necessarily the same as for the actual installed fan (see *adjusted net sensible capacity*). (Also see *gross sensible capacity*.)

*net total capacity:* the gross total capacity less the default rate of fan heat assumed by the manufacturer; this rate of fan heat is not necessarily the same as for the actual installed fan (see *adjusted net total capacity*). (Also see *gross total capacity*.)

*outdoor dry-bulb temperature (ODB):* the temperature that a thermometer would measure if exposed to outdoor air. This is the temperature of air entering the condenser coil.

*part-load ratio (PLR):* the ratio of the net refrigeration effect to the adjusted net total capacity for the cooling coil. (Also see *net refrigeration effect* and *adjusted net total capacity*.)

*quasi-analytical solution:* mathematical solution of a model of reality for a given set of parameters and boundary conditions; such a result may be computed by generally accepted numerical method calculations, provided that such calculations occur outside the environment of a whole-building energy simulation program and can be scrutinized.

seasonal energy efficiency ratio (SEER): the ratio of net refrigeration effect in Btu to the cooling energy consumption

in watt-hours for a refrigerating device over its normal annual usage period as determined using ANSI/ARI Standard 210/240-89.<sup>A-2</sup> This parameter is commonly used for simplified estimates of energy consumption based on a given load and is not generally useful for detailed simulations of mechanical systems. (Also see *net refrigeration effect* and *cooling energy consumption*.)

*sensible heat:* the change in enthalpy associated with a change in dry-bulb temperature caused by the addition or removal of heat.

*sensible heat ratio (SHR):* also known as sensible heat factor (SHF), the ratio of sensible heat transfer to total (sensible + latent) heat transfer for a process. (Also see *sensible heat* and *latent heat*.)

*zone cooling loads:* sensible heat and latent heat loads associated with heat and moisture exchange between the building envelope and its surroundings as well as internal heat and moisture gains within the building. These loads do not include internal gains associated with operating the mechanical system (e.g., air distribution fan heat).

## 3.2 Abbreviations and Acronyms Used in This Standard

[Informative	Note:	Add	the	following	acronyms	to	Section
3.2.]							

0.2.	
ADP	apparatus dew point
ANSI	American National Standards Institute
ARI	Air Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BF	bypass factor
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
EDB	entering dry-bulb temperature
EER	energy efficiency ratio
EWB	entering wet-bulb temperature
HVAC	heating, ventilating, and air-conditioning
I.D.	inside diameter
IDB	indoor dry-bulb temperature
NOAA	National Oceanic and Atmospheric Administration
NSRDB	National Solar Radiation Database
O.D.	outside diameter
ODB	outdoor dry-bulb temperature
PLR	part-load ratio
SEER	seasonal energy efficiency ratio
SHR	sensible heat ratio
SI	Système Internationale
TMY2	Typical Meteorological Year 2

TUD	Technische Universität Dresden
WBAN	Weather Bureau Army Navy
wg	water gauge

# [Informative Note: Make the following revisions in Sections 4.1—4.4.]

# 4.1 Applicability of Test Method

The method of test is provided for analyzing and diagnosing building energy simulation software using software-tosoftware <u>and software-to-quasi-analytical-solution</u> comparisons. This is a comparative test that 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 programs to the example <u>simulation</u> results provided in the informative Annex B8<u>, to the example quasi-analyti-</u> cal solution and simulation results in the informative <u>Annex B16</u>, and/or to other results (<u>simulations or</u> <u>quasi-analytical solutions</u>) 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; and
- diagnosing the algorithmic sources of prediction differences (diagnostic logic flow diagrams are included in the informative Annex B9).

# 4.2 Organization of Test Cases

The specifications for determining input values are provided case by case in Section 5.-2. Weather data required for use with the test cases are provided in Annex A1. Annex B1 provides an informative 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 informative Annex B9 on diagnostic logic. In some instances (e.g., Case 620, Section 5.2.2.1.2), a case developed from modifications to Case 600 (Section 5.2.1) will also serve as the base case for other cases. The cases are grouped as:

- (a) <u>Building Thermal Envelope and Fabric Load</u> Base Case (see 4.2.1)
- (b) <u>Building Thermal Envelope and Fabric Load</u> Basic Tests (see 4.2.2)
  - Low Mass (see 4.2.2.1)
    High Mass (see 4.2.2.2)
    Free Float (see 4.2.2.3)
- (c) <u>Building Thermal Envelope and Fabric Load</u> In-Depth Tests (see 4.2.3)
- (d) HVAC Equipment Performance Base Case (see 4.2.4)
- (e) <u>HVAC Equipment Performance Parameter Variation Tests</u> (see 4.2.5)

**4.2.1** <u>Building Thermal Envelope and Fabric Load</u> **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** <u>Building Thermal Envelope and Fabric Load</u> **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** <u>Building Thermal Envelope and Fabric Load In-</u> **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 non-deadband 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, infiltration, 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 HVAC Equipment Performance 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 HVAC Equipment Performance Parameter Variation 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.

## 4.3 **Reporting Results**

The Standard Output Reports provided in the files that accompany this standard (available at http://www.ashrae.org/template/PDFDetail?assetID=34505) 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 using <u>S140OUT2''S140outNotes</u>.TXT'' in the accompanying files, and
- (c) results for simulated cases using <u>S140OUT2.WK3-the</u> <u>following files</u> (available at http://www.ashrae.org/template/PDFDetail?assetID=34505):-
  - <u>Sec5-2out.XLS for the building thermal envelope</u> and fabric load tests of Section 5.2,
  - <u>Sec5-3out.XLS for the HVAC equipment perfor-</u> mance tests of Section 5.3.

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

# 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 as informative Annex B11 and Annex B17. For the convenience of users who wish to plot or tabulate their results along with the example results, an electronic versions of the example results hashave been included with the accompanying files RESULTS5-2.XLSWK3 (for Annex B8) and RESULTS5-3.XLS (for Annex B16). Documentation regarding RESULTS5-2.XLSWK3 and RESULTS5-3.XLS have has been included with the files 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:

(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) <u>availability of analytical or quasi-analytical solution</u> results (i.e., mathematical truth standard as described in informative Annex B16, Section B16.2),
- (f) for the HVAC equipment performance tests of Section 5.3, the degree of disagreement that occurred for other simulation results in Annex B16 versus the quasi-analytical solution results.

**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 informative Annex B9.

# 5. TEST PROCEDURES

[Informative Note: Make revisions to sections 5.1 and 5.2 as noted.]

# 5.1 Modeling Approach

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

**5.1.1 Time Convention.** All references to time in this specification are to local standard time and assume that: *hour* l = the interval from midnight to 1 a.m. Do not use daylight savings time or holidays for scheduling. The required TMY weather data are in hourly bins corresponding to solar time as described in Annex A1. TMY2 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 ( $6 \text{ m} \times 8 \text{ m} \times 2.7 \text{ m} = 129.6 \text{ m}^3$ ). Make the thicknesses extend exterior to the currently defined internal volume.

**5.1.3** Non-Applicable 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 non-applicable 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** Simulation Initialization and Preconditioning. If your software allows, begin the simulation initialization process with zone air conditions that equal the outdoor air conditions. If your program allows for preconditioning (iterative

simulation of an initial time period until temperatures or fluxes, or both, stabilize at initial values), use that capability.

# 5.1.6 Simulation Duration

**5.1.6.1** Results for the tests of Section 5.2 are to be taken from a full annual simulation.

**5.1.6.2** For the tests of Section 5.3, 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. The first month of the simulation period (January) serves as an initialization period.

# 5.2 Input Specifications <u>for Building Thermal Envelope</u> and Fabric Load Tests

# 5.2.1 Case 600: Base Case

Begin with Case 600. Case 600 shall be modeled as detailed in this section and its subsections.

The bulk of the work for implementing this the Section 5.2 tests is assembling an accurate base building model. It is recommended that base building inputs be double checked and results disagreements be diagnosed before going on to the other cases.

**5.2.1.1 Weather Data.** Use weather data provided on the files accompanying this standard (available at http://www.ashrae.org/template/PDFDetail?assetID=34505) as described in Annex A1<u>. Section A1.1</u>. These weather data shall be used for all cases described in Section 5.2.

**5.2.1.6** Infiltration. Infiltration rate = 0.5 ACH, continuously (24 hours per day for the full year).

The weather data file provided in Annex A1 (Section A1.1) represents a high-altitude site (1609 m above sea level) with an air density roughly 80% of that at sea level. If the program being tested does not use barometric pressure from the weather data, or otherwise automatically correct for the change in air density due to altitude, then adjust the specified infiltration rates to yield mass flows equivalent to what would occur at the 1609 m altitude as shown in Table 2. The listed infiltration rate is independent of wind speed, indoor/outdoor temperature difference, etc. The calculation technique used to develop Table 2 is provided as background information in informative Annex B3.

**5.2.3.1.4 High Conductance Wall/Opaque Window**. An element, which may be thought of as a highly conductive wall or an opaque window, replaces the  $12 \text{ m}^2$  of transparent window on the south wall.

The properties of the high-conductance wall are as follows:

- (a) Shortwave transmittance = 0.
- (b) Infrared emittances and solar absorptances are as listed in Table 15.
- (c) The exterior surface coefficient is in accordance with Section 5.2.1.9 (Case 600); if combined coefficients are applied, use 21.0 W/m<sup>2</sup>K<sub>2</sub> The surface texture for the high-conductance wall is very smooth, same as glass.
- (d) The interior surface coefficient is in accordance with Section 5.2.1.10 (Case 600).
- (e) Conductance, density, specific heat, and surface texture (very smooth) are the same as for the transparent window listed in Table 16.

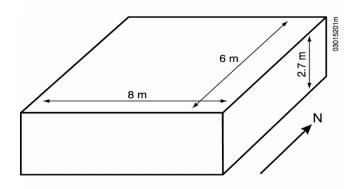


Figure 8 HVAC-BESTEST: Near-adiabatic envelope geometry.

# 5.3 Input Specifications for HVAC Equipment Performance Tests

#### [Informative Note: Add entirely new Section 5.3.]

# 5.3.1 Case E100: Base Case Building and Mechanical System

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 is assembling an accurate base building model. It is recommended that base building inputs be double-checked and results disagreements be diagnosed before going on to the other cases.

**5.3.1.1 Weather Data.** This case requires either HVBT461.TMY or HVBT461A.TM2 data provided on the files accompanying this standard (available at http://www.ashrae.org/template/PDFDetail?assetID=34505) as described in Annex A1. *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. *Note:* All of the Section 5.3 tests have the same output requirements.

**5.3.1.3 Building Geometry.** The base building plan is a 48 m<sup>2</sup> floor area, single-story, low-mass building with rectangular-prism geometry as shown in Figure 8. Zone air volume is  $129.6 \text{ m}^3$ .

**5.3.1.4 Building Envelope Thermal Properties**. The base building zone is intended as a near-adiabatic test cell with cooling load driven by user-specified internal gains. Tables 23a and 23b list material properties in Système Internationale (SI) and inch-pound units, respectively.

**5.3.1.4.1** The building insulation has been made very thick to effectively thermally decouple the zone from ambient conditions. If your software does not allow this much insulation, use the thickest insulation your program will permit and reduce the floor, roof, and wall areas to achieve the thermal conductance (UA) values listed in Tables 23a or 23b. The zone air volume must remain at 129.6 m<sup>3</sup>.

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

**5.3.1.4.3** Air density at sea level is  $1.201 \text{ kg/m}^3$ .

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

**5.3.1.4.5** 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
Soil density	=	1500 kg/m <sup>3</sup>
Soil specific heat	=	800 J/kg·K
Deep ground temperature	=	10°C

# TABLE 23a Material Specifications Base Case (SI Units)

					mspec4.xls; May 20, 2004									
EXTERIOR WALL (inside to outside)														
	k	Thickness	U	R										
ELEMENT	(W/(m*K))	(m)	(W/(m <sup>2</sup> *K))	(m <sup>2</sup> *K/W)										
Int Surf Coef			8.290	0.121										
Insulation (Note 1)	0.010	1.000	0.010	100.000										
Ext Surf Coef			29.300	0.034										
Total air - air			0.010	100.155										
Total surf - surf			0.010	100.000										
FLOOR (inside to outsi	•													
	k	Thickness	U	R										
ELEMENT	(W/(m*K))	(m)	(W/(m <sup>2</sup> *K))	(m <sup>2</sup> *K/W)										
Int Surf Coef (Note 2)			8.290	0.121										
Insulation (Note 1)	0.010	1.000	0.010	100.000										
Ext Surf Coef			29.300	0.034										
Total air - air			0.010	100.155										
Total surf - surf			0.010	100.000										
ROOF (inside to outsid	•													
	k	Thickness	U	R										
ELEMENT	(W/(m*K))	(m)	(W/(m <sup>2</sup> *K))	(m <sup>2</sup> *K/W)										
Int Surf Coef (Note 2)			8.290	0.121										
Insulation (Note 1)	0.010	1.000	0.010	100.000										
Ext Surf Coef			29.300	0.034										
Total air - air			0.010	100.155										
Total surf - surf			0.010	100.000										
SUMMARY														
	AREA	UA												
COMPONENT	(m²)	(W/K)												
Wall	75.600	0.755												
Floor	48.000	0.479												
Roof	48.000	0.479												
Infiltration (Note 3)		0.000												
Total UA		1.713												
	ACH	VOLUME	ALTITUDE											
		(m <sup>3</sup> )	(m)											
	0.00	129.6	2.0											
Note 1: This level of ins			diabatic cond	ition such t	hat conduction gains									
					much insulation, then									
reduce the floor, roof	-	-												
	Note 2: The interior film coefficient for floors and ceilings is a compromise between upward													
				•	and downward heat flow for summer and winter									

and downward heat flow for summer and winter.

Note 3: Infiltration derived from:

ACH\*Volume\*(specific heat of air)\*(density of air at specified altitude)

# TABLE 23b Material Specifications Base Case (English Units)

					mspec4.xls; May 20, 2004
EXTERIOR WALL (ins				_	
		Thickness	U	R	
ELEMENT	(Btu/(h*ft*F))	(ft)	(Btu/(h*ft <sup>2</sup> *F))	<u>.</u>	
Int Surf Coef			1.461	0.684	
Insulation (Note 1)	0.00578	3.281	0.002	567.447	
Ext Surf Coef			5.163	0.194	
Total air - air			0.00176	E60 22E	
Total surf - surf				568.325	
	· · · · ·		0.00176	567.447	
FLOOR (inside to outs		<b>-</b>		_	
		Thickness	U	R	
ELEMENT	(Btu/(h*ft*F))	(ft)	(Btu/(h*ft <sup>2</sup> *F))		
Int Surf Coef (Note 2)			1.461	0.684	
Insulation (Note 1)	0.00578	3.281	0.002	567.447	
Ext Surf Coef			5.163	0.194	
Total air - air			0.00176	568.325	
Total surf - surf			0.00176	567.447	
			0.00170	507.447	
ROOF (inside to outside	•	<b>-</b>		-	
		Thickness	U	R	
ELEMENT	(Btu/(h*ft*F))	(ft)	(Btu/(h*ft <sup>2</sup> *F))		
Int Surf Coef (Note 2)			1.461	0.684	
Insulation (Note 1)	0.00578	3.281	0.002	567.447	
Ext Surf Coef			5.163	0.194	
Total air - air			0.00176	568.325	
Total surf - surf			0.00176	567.447	
			0.00170	307.447	
SUMMARY	AREA	UA			
	2				
	<u>(π)</u> 813.752	(Btu/(h*F))			
Wall		1.432			
Floor	516.668	0.909			
Roof	516.668	0.909			
Infiltration		0.000			
Total UA		3.250			
	ACH	VOLUME	ALTITUDE U	JAinf (Note 3	)
		(ft <sup>3</sup> )	(ft)	(Btu/(h*F))	/
	0.000	4577	6.56	0.000	-
Note 1: This level of in					conduction gains
are < 1% of the total					•
reduce the floor, roo					
Note 2: The interior filr					etween unward
and downward heat				ompronnse b	erween upwaru
Note 3: Infiltration deri					
		(donaity of	air at chaoifiad	Latituda)	
ACH*Volume*(speci	ne near of alf)"	(density of	air at specified	i aililude)	

# 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 <sup>2</sup> K (1.46 Btu/(hft <sup>2</sup> F))						
Upward heat transfer on horizontal surfaces	9.26 W/m <sup>2</sup> K (1.63 Btu/(hft <sup>2</sup> F))						
Downward heat transfer on horizontal surfaces	6.13 W/m <sup>2</sup> K (1.08 Btu/(hft <sup>2</sup> F))						

#### 5.3.1.5 Infiltration.

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

#### 5.3.1.6 Internal Heat Gains.

Sensible internal gains = 5400 W (18430 Btu/h), continuously (24 hours per day for the full simulation period).

Latent internal gains = 0 W (0 Btu/h), continuously (24 hours per day for the full simulation period).

Sensible internal gains are 100% convective.

Zone sensible and latent internal gains are assumed to be distributed evenly throughout the zone air. These are internally generated sources of heat (from equipment, lights, people, etc.) that are not related to the operation of the mechanical cooling system or its air distribution fan.

**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<sup>2</sup>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  $5.13 \text{ W/m}^2\text{K}$  [0.90 Btu/(hft<sup>2</sup>F)] for an interior infrared emissivity of 0.9.

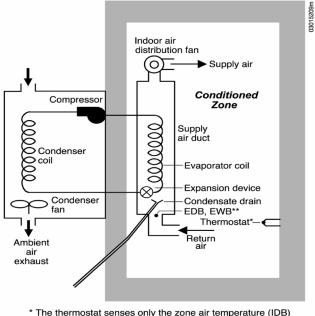
If the program being tested does not allow you to schedule these coefficients, then use  $8.29 \text{ W/m}^2\text{K}$  [1.46 Btu/(hft<sup>2</sup>F)] for all horizontal surfaces. If different values can be justified, then use different values.

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

**5.3.1.10 Mechanical System.** The mechanical system represents a simple vapor compression cooling system, or more precisely, a unitary split air-conditioning system consisting of an air-cooled condensing unit and indoor evaporator coil. Figure 9 is a schematic diagram of this system. See Section 3 for definitions of terminology used in this section.

# 5.3.1.10.1 General Information.

- 100% convective air system
- Zone air is perfectly mixed
- No outside air; no exhaust air
- Single-speed, draw-through air distribution fan
- Indoor and outdoor fans cycle on and off together with compressor
- Air-cooled condenser



\*\* Location of entering dry bulb and wet bulb temperatures

Figure 9 Unitary split air-conditioning system consisting of an air-cooled condensing unit and indoor evaporator coil.

- 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 zone air moisture that condenses on the evaporator coil (latent load) leaves the system through a condensate drain
- Crankcase heater and other auxiliary energy = 0

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 this by specifying minimum outside air =  $0.000001 \text{ ft}^3/\text{min}$ . We recommend doing a sensitivity test to check that using 0 for both these inputs does not cause a problem.

# 5.3.1.10.2 Thermostat Control Strategy.

Heat = off

Cool = on if zone air temperature >  $22.2^{\circ}C$  (72.0°F); otherwise cool = off.

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.

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

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 +  $x^{\circ}C$  or OFF at setpoint -  $y^{\circ}C$ ). If your software requires input for these, use the minimum values your software allows.

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.

**5.3.1.10.3 Full-Load Cooling System Performance Data.** Equipment full-load capacity and full-load performance data <sup>A-3</sup> are given in six formats in Tables 26a through 26f. Before using these tables, read all of the discussion in this section (5.3.1.10.3) and its subsections (5.3.1.10.3.1 through 5.3.1.10.3.6). Use the table that most closely matches the input requirements of the software being tested. The tables contain similar information with the following differences:

- Table 26a lists net capacities (SI units)
- Table 26b lists net capacities (I-P units)
- Table 26c lists gross capacities (SI units)
- Table 26d lists gross capacities (I-P units)
- Table 26e lists adjusted net capacities (SI units)
- Table 26f lists adjusted net capacities (I-P units).

**5.3.1.10.3.1** For convenience, an electronic file (PERFMAP140.XLS) that contains these tables is included in the files accompanying this standard (available at http://www.ashrae.org/template/PDFDetail?assetID=34505).

**5.3.1.10.3.2** The meaning of the various ways to represent system capacity is discussed below; specific terms are also defined in Section 3. These tables use outdoor drybulb temperature (ODB), entering dry-bulb temperature (EDB), and entering wet-bulb temperature (EWB) as independent variables for performance data; the location of EDB and EWB is shown in Figure 9.

Listed capacities of Tables 26a and 26b are net values after subtracting manufacturer default fan heat based on 365 W per 1,000 cubic feet per minute (CFM), so the default fan heat for the 900 CFM fan is 329 W. For example, in Table 26a the listed net total capacity at Air-Conditioning and Refrigeration Institute (ARI) rating conditions (EDB =  $26.7^{\circ}$ C, outdoor dry-bulb temperature [ODB] =  $35.0^{\circ}$ C, EWB =  $19.4^{\circ}$ C) is 7852 W, and the assumed fan heat is 329 W. Therefore, the gross total capacity (see Table 26c) of the system at ARI rating conditions—including both the net total capacity and the distribution system fan heat—is 7,852 + 329 = 8,181 W. Similarly, the gross sensible capacity—including both the net sensible capacity and air distribution system fan heat—is 6,040 + 329 = 6,369 W.

The unit as described actually uses a 230 W fan. Therefore, the "real" net capacity is actually an adjusted net capacity, (net cap)<sub>adj</sub>, which is determined by

 $(net cap)_{adj} = (net cap)_{listed} + (default fan heat) - (actual fan power),$ 

so for the adjusted net total (sensible + latent) capacity at ARI conditions and 900 CFM,

 $(net cap)_{adj} = 7852 W + 329 W - 230 W = 7951 W.$ 

The technique for determining adjusted net sensible capacities (see Table 26e) is similar.

**5.3.1.10.3.3 Validity of Listed Data (VERY IMPORTANT).** Compressor kW (kilowatts) and apparatus dew point, along with net total, gross total, and adjusted net total capacities given in Tables 26a through 26f, are valid

# TABLE 26a Equipment Full-Load Performance<sup>1</sup> (SI Units)

		Net Total	Net	Sensible	Capacity <sup>2</sup>	<sup>2,3</sup> (kW) at		Compressor	Apparatus		
ODB	EWB	Capacity <sup>2,3,4</sup>						Power <sup>4</sup>	Dew Point <sup>4</sup>		
۵۵۵ (°C)	(°C)	(kW)	22.2	23.3	24.4	25.6	26.7	(kW)	(°C)		
( •)	15.0	7.09	6.21	6.77	7.18	7.38	7.56	1.62	8.9		
	17.2	7.68	5.16	5.71	6.27	6.80	7.35	1.66	11.1		
29.4	19.4	8.32	4.01	4.57	5.13	5.65	6.21	1.71	13.4		
	21.7	8.97	2.87	3.40	3.96	4.48	5.04	1.76	15.8		
	15.0	6.91	6.12	6.68	7.03	7.21	7.41	1.69	9.1		
	17.2	7.47	5.10	5.63	6.18	6.71	7.27	1.74	11.3		
32.2	19.4	8.09	3.93	4.48	5.04	5.57	6.12	1.79	13.6		
	21.7	8.70	2.75	3.31	3.87	4.39	4.95	1.84	15.9		
	15.0	6.71	6.07	6.59	6.89	7.06	7.24	1.77	9.3		
	17.2	7.27	5.01	5.54	6.09	6.62	7.18	1.81	11.4		
35.0	19.4	7.85	3.84	4.39	4.95	5.48	6.04	1.86	13.8		
	21.7	8.47	2.67	3.22	3.75	4.31	4.86	1.91	16.2		
	15.0	6.53	5.98	6.53	6.71	6.89	7.06	1.85	9.4		
	17.2	7.06	4.92	5.45	6.01	6.53	7.06	1.89	11.6		
37.8	19.4	7.62	3.75	4.31	4.83	5.39	5.95	1.94	13.9		
	21.7	8.17	2.58	3.14	3.66	4.22	4.75	1.98	16.3		
	15.0	6.33	5.89	6.39	6.53	6.71	6.89	1.94	9.6		
	17.2	6.83	4.83	5.36	5.92	6.45	6.89	1.98	11.8		
40.6	19.4	7.35	3.66	4.22	4.75	5.30	5.83	2.02	14.2		
	21.7	7.91	2.49	3.02	3.57	4.13	4.66	2.06	16.6		
	15.0	5.92	5.71	6.04	6.21	6.36	6.50	2.11	10.0		
	17.2	6.39	4.66	5.19	5.74	6.27	6.50	2.14	12.2		
46.1	19.4	6.89	3.49	4.04	4.57	5.13	5.65	2.18	14.6		
	21.7	7.38	2.31	2.84	3.40	3.93	4.48	2.21	16.9		
Values a	t ARI Rat	ing Condition	s (EDB =	26.7°C,	EWB = 19	.4°C, OD	B = 35.	0°C)			
	Net Tota	I Capacity	7852	W							
	Airflow		0.425	m <sup>3</sup> / s							
	Apparati	us Dew Point	13.8	°C							
	Compres	ssor Power	1858	W							
	Indoor F	an Power	230	W							
	Outdoor	Fan Power	108	W							
	COP		3.62								
Seasona	l Efficien	cy Rating									
	COP		3.78								
		DB = outdoor	drvbulb t	emperati	re: EWB	= enterin	a wetbu	ılb temperatur	e:		
								ration Institute			
	-	ent of perform					<b>3</b> -		- 1		
		ensionless Sea		erav Effic	iencv Rat	tio.					
Notes:				0.9,	noney nu						
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					111993.	Performa	ance ra	ted with 25 fe	el		
		and 5/16" liq									
			•		-	-		sible capacitie	es		
	-	th manufactu				-					
	•	e Capacity) >	•	• • •		dry coil co	ndition	.,			
	•	otal Capacity)	•	•	• •						
<sup>₄</sup> Compi	ressor kV	V, Apparatus D	Dew Point	t, and Ne	t Total Ca	apacity va	lid only	for wet coil.			
	Compressor kW, Apparatus Dew Point, and Net Total Capacity valid only for wet coil.										

perfmap140.xls, b:a4..j55; Oct 08, 2002

 TABLE 26b

 Equipment Full-Load Performance<sup>1</sup> (I-P Units)

		Net Total	Net Se	nsible Ca	pacitv <sup>2,3</sup>	(kBtu/h)	at	Compressor	Apparatus
ODB	EWB	Capacity <sup>2,3,4</sup>	entering					Power <sup>4</sup>	
(°F)	(°F)	(kBtu/ h)	72 r	74 74	76	78 (100,	80	(kW)	(°F)
	59	24.2	21.2	23.1	24.5	25.2	25.8	1.62	48.1
	63	26.2	17.6	19.5	21.4	23.2	25.1	1.66	52.0
85	67	28.4	13.7	15.6	17.5	19.3	21.2	1.71	56.1
	71	30.6	9.8	11.6	13.5	15.3	17.2	1.76	60.4
	59	23.6	20.9	22.8	24.0	24.6	25.3	1.69	48.4
	63	25.5	17.4	19.2	21.1	22.9	24.8	1.74	52.3
90	67	27.6	13.4	15.3	17.2	19.0	20.9	1.79	56.5
	71	29.7	9.4	11.3	13.2	15. <b>0</b>	16.9	1.84	60.7
	59	22.9	20.7	22.5	23.5	24.1	24.7	1.77	48.7
	63	24.8	17.1	18.9	20.8	22.6	24.5	1.81	52.6
95	67	26.8	13.1	15.0	16.9	18.7	20.6	1.86	56.8
	71	28.9	9.1	11.0	12.8	14.7	16.6	1.91	61.1
	59	22.3	20.4	22.3	22.9	23.5	24.1	1.85	49.0
100	63	24.1	16.8	18.6	20.5	22.3	24.1	1.89	52.9
100	67 71	26.0 27.9	12.8 8.8	14.7	16.5	18.4 14.4	20.3 16.2	1.94 1.98	57.1 61.4
	59	27.9	20.1	10.7 21.8	12.5 22.3	22.9	23.5	1.96	49.3
	63	21.0	16.5	18.3	20.2	22.0	23.5	1.94	53.2
105	67	25.1	12.5	14.4	16.2	18.1	19.9	2.02	57.5
	71	27.0	8.5	10.3	12.2	14.1	15.9	2.06	61.8
	59	20.2	19.5	20.6	21.2	21.7	22.2	2.11	50.0
	63	21.8	15.9	17.7	19.6	21.4	22.2	2.14	53.9
115	67	23.5	11.9	13.8	15.6	17.5	19.3	2.18	58.2
	71	25.2	7.9	9.7	11.6	13.4	15.3	2.21	62.5
Values at	ARI Rat	ing Condition	s (EDB =	80°F, EW	B = 67°F	, ODB = 9	95°F)		
	Net Tota	l Capacity	26800	Btu/ h			-		
	Airflow		900 (	CFM					
	Apparatu	us Dew Pt	56.8	°F					
	Compres	sor Power	1858						
		an Power	230						
		Fan Power	108						
	EER		12.36	(Btu/ h)/ <b>\</b>	N				
		cy Rating	40.00	(D) ())))					
	SEER			(Btu/ h)/ \					
			•	•	-		-	Ib temperatur	
	-	fficiency ratio				-	-	ration Institute	3,
Notes:	energy e	Inciency ratio	I, SEEK -	Seasona	renergy	entciency	ratio.		
	d norfor	manaa data .	ourtoov T	rana Ca	Tulor T			is for "TTDO?	40
	-		-		-			is for "TTP02 ted with 25 fe	
		and 5/16" liq		апеч Ар	11 1993.	renorma	ancera		51
I_									_
			•		-	-		sible capacitie	25
	-	th manufactur			-				
	•	e Capacity) >	•			iry coll co	ndition	,	
1.	-	otal Capacity)	-	-			lial c l	<b></b>	
Compr	essor KV	V, Apparatus [	ew Point	, and Net		pacity va	-		

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# TABLE 26c Equipment Full-Load Performance with Gross Capacities<sup>1</sup> (SI Units)

		Gross Total	Gross	Sensible	Capacity	<sup>2,3</sup> (kW) at		Compressor	Apparatus		
ODB	EWB	Capacity <sup>2,3,4</sup>				ure (EDB,		Power⁴	Dew Point <sup>4</sup>		
(°C)	(°C)	(kW)	22.2	23.3	24.4	25.6	- <i>,</i> 26.7	(kW)	(°C)		
	15.0	7.42	6.54	7.10	7.51	7.71	7.89	1.62	8.9		
	17.2	8.01	5.49	6.04	6.60	7.13	7.68	1.66	11.1		
29.4	19.4	8.65	4.34	4.90	5.46	5.98	6.54	1.71	13.4		
	21.7	9.29	3.20	3.73	4.28	4.81	5.37	1.76	15.8		
	15.0	7.24	6.45	7.01	7.36	7.54	7.74	1.69	9.1		
	17.2	7.80	5.43	5.95	6.51	7.04	7.60	1.74	11.3		
32.2	19.4	8.42	4.26	4.81	5.37	5.90	6.45	1.79	13.6		
	21.7	9.03	3.08	3.64	4.20	4.72	5.28	1.84	15.9		
	15.0	7.04	6.39	6.92	7.21	7.39	7.57	1.77	9.3		
	17.2	7.60	5.34	5.87	6.42	6.95	7.51	1.81	11.4		
35.0	19.4	8.18	4.17	4.72	5.28	5.81	6.36	1.86	13.8		
	21.7	8.80	3.00	3.55	4.08	4.64	5.19	1.91	16.2		
	15.0	6.86	6.31	6.86	7.04	7.21	7.39	1.85	9.4		
	17.2	7.39	5.25	5.78	6.34	6.86	7.39	1.89	11.6		
37.8	19.4	7.95	4.08	4.64	5.16	5.72	6.28	1.94	13.9		
	21.7	8.50	2.91	3.46	3.99	4.55	5.08	1.98	16.3		
	15.0	6.66	6.22	6.72	6.86	7.04	7.21	1.94	9.6		
	17.2	7.16	5.16	5.69	6.25	6.77	7.21	1.98	11.8		
40.6	19.4	7.68	3.99	4.55	5.08	5.63	6.16	2.02	14.2		
	21.7	8.24	2.82	3.35	3.90	4.46	4.99	2.06	16.6		
	15.0	6.25	6.04	6.36	6.54	6.69	6.83	2.11	10.0		
	17.2	6.72	4.99	5.52	6.07	6.60	6.83	2.14	12.2		
46.1	19.4	7.21	3.82	4.37	4.90	5.46	5.98	2.18	14.6		
	21.7	7.71	2.64	3.17	3.73	4.26	4.81	2.21	16.9		
Values a		ing Condition	•		EWB = 19	0.4°C, OD	B = 35.	.0°C)			
	Gross To	otal Capacity	8181								
	Airflow		0.425	m³/s							
	Apparat	us Dew Point	13.8	°C							
	Compres	ssor Power	1858	W							
	Indoor F	an Power	230								
		Fan Power	108	W							
	COP		3.62								
Seasona		cy Rating									
	COPSEER		3.78								
Abbrevia	tions: Ol	DB = outdoor (	drybulb t	emperatu	ıre; EWB	= enterin	g wetbu	ılb temperatur	e;		
EDB =	entering	ı drybulb temp	erature;	ARI = Air	-Conditio	ning and	Refrige	ration Institute	e;		
COP =	coefficie	ent of performa	ance;								
COPSE	<sub>FR</sub> = dime	ensionless Sea	sonal En	ergy Effic	iency Rat	io.					
Notes:					-						
	on full-lo	oad performan	ce data,	courtesy	Trane Co	., Tyler, T	exas, l	JSA. Data is fo	or		
		TWH039P15- suction and 5		-	blished A	pril 1993	. Perfo	ormance rated	with		
-			-		s include	manufact	urer de	fault fan heat	of		
329 W		<b>o</b>		.,	<b>.</b> .						
	-	e Capacity) > otal Capacity)	-			Iry coil co	ndition	;			
	-		-	-		Canacity	valid o	nly for wet coil			
	Compressor kW, Apparatus Dew Point, and Gross Total Capacity valid only for wet coil.										

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# TABLE 26dEquipment Full-Load Performance with Gross Capacities<sup>1</sup> (I-P Units)

		Gross Total	Gross Se	ensible Ca	apacity <sup>2,3</sup>	(kBtu/h)	) at	Compressor	Apparatus		
ODB	EWB	Capacity <sup>2,3,4</sup>		entering drybulb temperature (EDB, °F) Power <sup>4</sup> Dew F							
(°F)	(°F)	(kBtu/h)	72	74	76	78	80	(kW)	(°F)		
	59	25.3	22.3	24.2	25.6	26.3	26.9	1.62	48.1		
	63	27.3	18.7	20.6	22.5	24.3	26.2	1.66	52.0		
85	67	29.5	14.8	16.7	18.6	20.4	22.3	1.71	56.1		
	71	31.7	10.9	12.7	14.6	16.4	18.3	1.76	60.4		
	59	24.7	22.0	23.9	25.1	25.7	26.4	1.69	48.4		
	63	26.6	18.5	20.3	22.2	24.0	25.9	1.74	52.3		
90	67	28.7	14.5	16.4	18.3	20.1	22.0	1.79	56.5		
	71	30.8	10.5	12.4	14.3	16.1	18.0	1.84	60.7		
	59	24.0	21.8	23.6	24.6	25.2	25.8	1.77	48.7		
	63	25.9	18.2	20.0	21.9	23.7	25.6	1.81	52.6		
95	67	27.9	14.2	16.1	18.0	19.8	21.7	1.86	56.8		
	71	30.0	10.2	12.1	13.9	15.8	17.7	1.91	61.1		
	59	23.4	21.5	23.4	24.0	24.6	25.2	1.85	49.0		
100	63	25.2	17.9	19.7	21.6	23.4	25.2	1.89	52.9		
100	67	27.1	13.9	15.8	17.6	19.5	21.4	1.94	57.1		
	71 59	29.0 22.7	9.9 21.2	11.8 22.9	13.6 23.4	15.5 24.0	17.3 24.6	1.98 1.94	61.4 49.3		
	63	22.7	21.2 17.6	22.9 19.4	23.4 21.3	24.0 23.1	24.6 24.6	1.94	49.3 53.2		
105	67	24.4 26.2	13.6	15.5	17.3	23.1 19.2	24.0	2.02	57.5		
103	71	28.2	9.6	11.4	13.3	15.2	17.0	2.02	61.8		
	59	21.3	20.6	21.7	22.3	22.8	23.3	2.00	50.0		
	63	22.9	17.0	18.8	20.7	22.5	23.3	2.14	53.9		
115	67	24.6	13.0	14.9	16.7	18.6	20.4	2.18	58.2		
	71	26.3	9.0	10.8	12.7	14.5	16.4	2.21	62.5		
Values at		ing Conditions									
		tal Capacity	27920			,	,				
	Airflow		900 (								
	Apparatu	is Dew Pt	56.8 '	'F							
	Compres	sor Power	1858 \	N							
	Indoor F	an Power	230 \	N							
	Outdoor	Fan Power	108 \	N							
	EER		12.36 (	(Btu/ h)/ <b>V</b>	N						
Seasonal	Efficien	cy Rating									
	SEER			(Btu/ h)/ <b>\</b>							
			-	•			-	Ib temperatur			
	-					-	-	ration Institute	e;		
	energy e	fficiency ratio	n; SEER =	seasona	l energy	efficiency	ratio.				
Notes:											
		•		-		-		ISA. Data is fo			
					blished A	pril 1993	8. Perfo	rmance rated	with		
		suction and 5	-								
	<sup>2</sup> Listed gross total and gross sensible capacities include manufacturer default fan heat of 1.12 kBtu/h.										
-		e Capacity) >	(Total Car	nacity) in	dicates d	ry coil or	ndition				
		otal Capacity) >					mailion	,			
	-		-	-		Capacitv	valid or	nly for wet coil			
	Compressor kW, Apparatus Dew Point, and Gross Total Capacity valid only for wet coil.										

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# TABLE 26e Equipment Full-Load Performance with Adjusted Net Capacities<sup>1</sup> (SI Units)

ODB         EWB         Capacity <sup>2,3,4</sup> entering drubub temperature (EDB, °C)         Power <sup>4</sup> Dew Point           (°C)         (°C)         (kW)         22.2         23.3         24.4         25.6         26.7         (kW)         (°C)           15.0         7.19         6.31         6.87         7.28         7.48         7.66         1.62         8.9           17.2         7.78         5.26         5.81         6.37         6.90         7.45         1.66         11.1           29.4         19.4         8.42         4.11         4.67         5.23         5.75         6.31         1.71         13.4           21.7         9.06         2.97         3.50         4.05         4.58         5.14         1.76         15.8           17.2         7.01         6.22         6.78         7.13         7.31         7.51         1.69         9.1           32.2         19.4         8.19         4.03         4.58         5.14         5.67         6.22         1.79         13.6           32.2         19.4         8.19         4.03         4.58         5.14         5.67         6.22         1.79         13.6 <td< th=""><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th>_</th><th></th></td<>									_	
(*C)       (*W)       22.2       23.3       24.4       25.6       26.7       (WW)       (*C)         15.0       7.19       6.31       6.87       7.28       7.48       7.66       1.62       8.9         17.2       7.76       5.26       5.81       6.37       6.80       7.45       1.66       11.1         29.4       19.4       8.42       4.11       4.67       5.23       5.75       6.31       1.71       13.4         21.7       9.06       2.97       3.50       4.05       4.58       5.14       5.67       6.22       1.78       13.6         21.7       8.80       2.85       3.41       3.97       4.49       5.05       1.84       11.4         35.0       19.4       7.95       3.94       4.49       5.05       1.86       1.86       1.88       1.14         35.0       19.4       7.95       3.94       4.49       5.05       5.58       6.13       1.86       1.88       11.6         21.7       8.57       2.77       3.23       3.54       4.41       4.96       1.91       16.2         21.7       8.57       2.71       5.28       6.13       6.38				-		-		-	Compressor	Apparatus
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$				-	•	•	•			
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	(°C)		. ,						. ,	
29.4       19.4       8.42       4.11       4.67       5.23       5.75       6.31       1.71       13.4         15.0       7.01       6.22       6.78       7.13       7.51       1.69       9.1         17.2       7.57       5.20       5.72       6.28       6.81       7.37       1.74       11.3         32.2       19.4       8.19       4.03       4.58       5.14       5.05       1.84       15.9         17.2       7.57       5.20       5.72       6.28       6.81       7.37       1.74       11.3         32.2       19.4       8.19       4.03       4.58       5.14       5.05       1.84       15.9         15.0       6.81       6.16       6.69       6.98       7.16       7.34       1.77       9.3         17.2       7.37       5.11       5.64       6.19       6.97       7.16       1.85       9.4         17.2       7.16       5.02       5.55       6.11       6.63       6.18       6.98       1.94       1.62         17.7       6.33       5.39       6.44       4.33       5.46       9.8       1.88       1.18         17.2 <td></td>										
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$									1.66	
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	29.4	19.4	8.42	4.11	4.67		5.75	6.31	1.71	13.4
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		21.7	9.06	2.97	3.50	4.05	4.58	5.14	1.76	15.8
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		15.0	7.01	6.22	6.78	7.13	7.31		1.69	9.1
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		17.2	7.57	5.20	5.72	6.28	6.81	7.37	1.74	11.3
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	32.2	19.4	8.19	4.03	4.58	5.14	5.67	6.22	1.79	13.6
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		21.7	8.80	2.85	3.41	3.97	4.49	5.05	1.84	15.9
$\begin{array}{c c c c c c c c c c c c c c c c c c c $		15.0	6.81	6.16	6.69	6.98	7.16	7.34	1.77	9.3
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		17.2	7.37	5.11	5.64	6.19	6.72	7.28	1.81	11.4
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	35.0	19.4	7.95	3.94	4.49	5.05	5.58	6.13	1.86	13.8
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		21.7	8.57	2.77	3.32	3.85	4.41	4.96	1.91	16.2
37.8       19.4       7.72       3.85       4.41       4.93       5.49       6.05       1.94       13.9         21.7       8.27       2.68       3.23       3.76       4.32       4.85       1.98       16.3         15.0       6.43       5.99       6.49       6.63       6.81       6.98       1.94       9.6         40.6       19.4       7.45       3.76       4.32       4.85       5.40       5.93       2.02       14.2         21.7       8.01       2.59       3.12       3.67       4.23       4.76       2.06       16.6         15.0       6.02       5.81       6.13       6.46       6.60       2.11       10.0         17.2       6.49       4.76       5.29       5.84       6.37       6.60       2.14       12.2         46.1       19.4       6.98       3.59       4.14       4.67       5.23       5.75       2.18       14.6         21.7       7.48       2.41       2.94       3.50       4.03       4.58       2.21       16.9         alues at ARI Rating Conditions (EDB = 26.7°C, EWB = 19.4°C, ODB = 35.0°C       Adj Net Total Capacity       7951 W       Airflow       0.4248 m³/s </td <td></td> <td>15.0</td> <td>6.63</td> <td>6.08</td> <td>6.63</td> <td>6.81</td> <td>6.98</td> <td>7.16</td> <td>1.85</td> <td>9.4</td>		15.0	6.63	6.08	6.63	6.81	6.98	7.16	1.85	9.4
$ \begin{array}{ c c c c c c } \hline 21.7 & 8.27 & 2.68 & 3.23 & 3.76 & 4.32 & 4.85 & 1.98 & 16.3 \\ \hline 15.0 & 6.43 & 5.99 & 6.49 & 6.63 & 6.81 & 6.98 & 1.94 & 9.6 \\ \hline 17.2 & 6.93 & 4.93 & 5.46 & 6.02 & 6.54 & 6.98 & 1.98 & 11.8 \\ \hline 40.6 & 19.4 & 7.45 & 3.76 & 4.32 & 4.85 & 5.40 & 5.93 & 2.02 & 14.2 \\ \hline 21.7 & 8.01 & 2.59 & 3.12 & 3.67 & 4.23 & 4.76 & 2.06 & 16.6 \\ \hline 15.0 & 6.02 & 5.81 & 6.13 & 6.31 & 6.46 & 6.60 & 2.11 & 10.0 \\ \hline 17.2 & 6.49 & 4.76 & 5.29 & 5.84 & 6.37 & 6.60 & 2.14 & 12.2 \\ \hline 46.1 & 19.4 & 6.98 & 3.59 & 4.14 & 4.67 & 5.23 & 5.75 & 2.18 & 14.6 \\ \hline 21.7 & 7.48 & 2.41 & 2.94 & 3.50 & 4.03 & 4.58 & 2.21 & 16.9 \\ \hline alues at AR Rating Conditions (EDB = 26.7°C, EWB = 19.4°C, ODB = 35.0°C) \\ Adj Net Total Capacity & 7951 W \\ \hline Airflow & 0.4248 m^3/s & \\ Apparatus Dew Point & 13.8 °C \\ \hline Compressor Power & 1858 W \\ Indoor Fan Power & 230 W \\ \hline COP & 3.62 \\ \hline easonal Efficiency Rating \\ \hline COP_{SEER} & 3.78 \\ \hline bereviations: ODB = outdoor drybulb temperature; EWB = entering wetbulb temperature; \\ EDB = entering drybulb temperature; ARI = Air-Conditioning and Refrigeration Institute; \\ COP = coefficient of performance; COP_{SEER} & 3.78 \\ \hline bereviations: ODB = outdoor drybulb temperature; Tane Co., Tyler, Texas, USA. Data is for  "TTPO24C with TWH039P15-C" at 900 CFM, published April 1993. Performance rated with 25 feet of 3/4" suction and 5/16" liquid lines. \\ \ Listed adjusted net total and adjusted net sensible capacities are gross capacities with actual fan heat (230 W) subtracted. \\ \hline Where (Sensible Capacity) > (Total Capacity) indicates dry coil condition; in such case (Total Capacity) = (Sensible Capacity). \\ \hline Compressor kW, Apparatus Dew Point, and Adjusted Net Total Capacity valid only for wet coil. \\ \hline \end{array}$		17.2	7.16	5.02	5.55	6.11	6.63	7.16	1.89	11.6
$ \begin{array}{ c c c c c c } \hline 21.7 & 8.27 & 2.68 & 3.23 & 3.76 & 4.32 & 4.85 & 1.98 & 16.3 \\ \hline 15.0 & 6.43 & 5.99 & 6.49 & 6.63 & 6.81 & 6.98 & 1.94 & 9.6 \\ \hline 17.2 & 6.93 & 4.93 & 5.46 & 6.02 & 6.54 & 6.98 & 1.98 & 11.8 \\ \hline 40.6 & 19.4 & 7.45 & 3.76 & 4.32 & 4.85 & 5.40 & 5.93 & 2.02 & 14.2 \\ \hline 21.7 & 8.01 & 2.59 & 3.12 & 3.67 & 4.23 & 4.76 & 2.06 & 16.6 \\ \hline 15.0 & 6.02 & 5.81 & 6.13 & 6.31 & 6.46 & 6.60 & 2.11 & 10.0 \\ \hline 17.2 & 6.49 & 4.76 & 5.29 & 5.84 & 6.37 & 6.60 & 2.14 & 12.2 \\ \hline 46.1 & 19.4 & 6.98 & 3.59 & 4.14 & 4.67 & 5.23 & 5.75 & 2.18 & 14.6 \\ \hline 21.7 & 7.48 & 2.41 & 2.94 & 3.50 & 4.03 & 4.58 & 2.21 & 16.9 \\ \hline alues at AR Rating Conditions (EDB = 26.7°C, EWB = 19.4°C, ODB = 35.0°C) \\ Adj Net Total Capacity & 7951 W \\ \hline Airflow & 0.4248 m^3/s \\ Apparatus Dew Point & 13.8 °C \\ Compressor Power & 1858 W \\ Indoor Fan Power & 230 W \\ COP & 3.62 \\ \hline easonal Efficiency Rating \\ \hline COP_{SEER} & 3.78 \\ \hline bereviations: ODB = outdoor drybulb temperature; EWB = entering wetbulb temperature; \\ EDB = entering drybulb temperature; ARI = Air-Conditioning and Refrigeration Institute; \\ COP = coefficient of performance; COP_{SEER} & 3.78 \\ \hline bereviations: ODB = outdoor drybulb temperature; Tane Co., Tyler, Texas, USA. Data is for TTTPO24C with TW-1039P15-C' at 900 CFM, published April 1993. Performance rated with 25 feet of 3/4" suction and 5/16" liquid lines. \\ \ Listed adjusted net total and adjusted net sensible capacities are gross capacities with actual fan heat (230 W) subtracted. \\ \hline Where (Sensible Capacity) > (Total Capacity) indicates dry coil condition; in such case (Total Capacity) = (Sensible Capacity). \\ \hline Compressor kW, Apparatus Dew Point, and Adjusted Net Total Capacity valid only for wet coil. \\ \hline \end{array}$	37.8	19.4	7.72	3.85	4.41	4.93	5.49	6.05	1.94	13.9
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		21.7		2.68	3.23	3.76	4.32			
$ \begin{array}{ c c c c c c } 17.2 & 6.93 & 4.93 & 5.46 & 6.02 & 6.54 & 6.98 & 1.98 & 11.8 \\ 19.4 & 7.45 & 3.76 & 4.32 & 4.85 & 5.40 & 5.93 & 2.02 & 14.2 \\ 21.7 & 8.01 & 2.59 & 3.12 & 3.67 & 4.23 & 4.76 & 2.06 & 16.6 \\ 15.0 & 6.02 & 5.81 & 6.13 & 6.31 & 6.46 & 6.60 & 2.11 & 10.0 \\ 17.2 & 6.49 & 4.76 & 5.29 & 5.84 & 6.37 & 6.60 & 2.14 & 12.2 \\ 46.1 & 19.4 & 6.98 & 3.59 & 4.14 & 4.67 & 5.23 & 5.75 & 2.18 & 14.6 \\ 21.7 & 7.48 & 2.41 & 2.94 & 3.50 & 4.03 & 4.58 & 2.21 & 16.9 \\ alues at ARI Rating Conditions (EDB = 26.7°C, EWB = 19.4°C, ODB = 35.0°C) \\ Adj Net Total Capacity & 7951 W \\ Airflow & 0.4248 m^3/s \\ Apparatus Dew Point & 13.8 °C \\ Compressor Power & 1858 W \\ Indoor Fan Power & 108 W \\ COP & 3.62 \\ easonal Efficiency Rating \\ \hline COP_{SEER} & 3.78 \\ \hline Derivations: ODB = outdoor drybulb temperature; EWB = entering wetbulb temperature; EDB = entering drybulb temperature; ARI = Air-Conditioning and Refrigeration Institute; COP = coefficient of performance; \\ \hline COP_{SEER} & 3.78 \\ \hline Dereviations (DDB = 0.000 CFM, published April 1993. Performance rated with 25 feet of 3/4" suction and 5/16" liquid lines. \\ Listed adjusted net total and adjusted net sensible capacities are gross capacities with actual fan heat (230 W) subtracted. \\ \hline Where (Sensible Capacity) = (Sensible Capacity). \\ \hline Compressor KW, Apparatus Dew Point, and Adjusted Net Total Capacity valid only for wet coil. \\ \hline \ \end{tabular}$										
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21.7         8.01         2.59         3.12         3.67         4.23         4.76         2.06         16.6           15.0         6.02         5.81         6.13         6.31         6.46         6.60         2.11         10.0           17.2         6.49         4.76         5.29         5.84         6.37         6.60         2.14         12.2           46.1         19.4         6.98         3.59         4.14         4.67         5.23         5.75         2.18         14.6           21.7         7.48         2.41         2.94         3.50         4.03         4.58         2.21         16.9           alues at ARI Rating Conditions (EDB = 26.7°C, EWB = 19.4°C, ODB = 35.0°C)         Adj Net Total Capacity         7951 W         7951 W         7951 W         7951 W         7000000000000000000000000000000000000	40.6									
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EDB = entering drybulb temperature; ARI = Air-Conditioning and Refrigeration Institute; COP = coefficient of performance; COP <sub>SEER</sub> = dimensionless Seasonal Energy Efficiency Ratio. otes: Based on full-load performance data, courtesy Trane Co., Tyler, Texas, USA. Data is for "TTP024C with TWH039P15-C" at 900 CFM, published April 1993. Performance rated with 25 feet of 3/4" suction and 5/16" liquid lines. Listed adjusted net total and adjusted net sensible capacities are gross capacities with actual fan heat (230 W) subtracted. Where (Sensible Capacity) > (Total Capacity) indicates dry coil condition; in such case (Total Capacity) = (Sensible Capacity). Compressor kW, Apparatus Dew Point, and Adjusted Net Total Capacity valid only for wet coil.			<u> </u>				4			
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COP <sub>SEER</sub> = dimensionless Seasonal Energy Efficiency Ratio. otes: Based on full-load performance data, courtesy Trane Co., Tyler, Texas, USA. Data is for "TTP024C with TWH039P15-C" at 900 CFM, published April 1993. Performance rated with 25 feet of 3/ 4" suction and 5/ 16" liquid lines. Listed adjusted net total and adjusted net sensible capacities are gross capacities with actual fan heat (230 W) subtracted. Where (Sensible Capacity) > (Total Capacity) indicates dry coil condition; in such case (Total Capacity) = (Sensible Capacity). Compressor kW, Apparatus Dew Point, and Adjusted Net Total Capacity valid only for wet coil.		-			= Air-Coi	altioning	and Ref	rigeratio	on institute;	
otes: Based on full-load performance data, courtesy Trane Co., Tyler, Texas, USA. Data is for "TTP024C with TWH039P15-C" at 900 CFM, published April 1993. Performance rated with 25 feet of 3/4" suction and 5/16" liquid lines. Listed adjusted net total and adjusted net sensible capacities are gross capacities with actual fan heat (230 W) subtracted. Where (Sensible Capacity) > (Total Capacity) indicates dry coil condition; in such case (Total Capacity) = (Sensible Capacity). Compressor kW, Apparatus Dew Point, and Adjusted Net Total Capacity valid only for wet coil.			-			- ··				
Based on full-load performance data, courtesy Trane Co., Tyler, Texas, USA. Data is for "TTP024C with TWH039P15-C" at 900 CFM, published April 1993. Performance rated with 25 feet of 3/4" suction and 5/16" liquid lines. Listed adjusted net total and adjusted net sensible capacities are gross capacities with actual fan heat (230 W) subtracted. Where (Sensible Capacity) > (Total Capacity) indicates dry coil condition; in such case (Total Capacity) = (Sensible Capacity). Compressor kW, Apparatus Dew Point, and Adjusted Net Total Capacity valid only for wet coil.		$_{\rm ER}$ = aime	ensioniess Seas	onal Energy	Efficienc	cy Ratio.				
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Compressor kW, Apparatus Dew Point, and Adjusted Net Total Capacity valid only for wet coil.							oli condi	ition;		
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 TABLE 26f

 Equipment Full-Load Performance with Adjusted Net Capacities<sup>1</sup> (I-P Units)

		Adj Net Total	Adjusted Ne	t Sensib	le Capaci	ty <sup>2,3</sup> (kBt	tu/h)	Compressor	Apparatus
ODB	EWB		at entering					Power⁴	Dew Point⁴
(°F)	(°F)	(kBtu/ h)	72	74	76	78	, , , 80	(kW)	(°F)
	59	24.5	21.5	23.4	24.8	25.5	26.1	1.62	48.1
	63	26.5	17.9	19.8	21.7	23.5	25.4	1.66	52.0
85	67	28.7	14.0	15.9	17.8	19.6	21.5	1.71	56.1
	71	30.9	10.1	11.9	13.8	15.6	17.5	1.76	60.4
	59	23.9	21.2	23.1	24.3	24.9	25.6	1.69	48.4
	63	25.8	17.7	19.5	21.4	23.2	25.1	1.74	52.3
90	67	27.9	13.7	15.6	17.5	19.3	21.2	1.79	56.5
	71	30.0	9.7	11.6	13.5	15.3	17.2	1.84	60.7
	59	23.2	21.0	22.8	23.8	24.4	25.0	1.77	48.7
	63	25.1	17.4	19.2	21.1	22.9	24.8	1.81	52.6
95	67	27.1	13.4	15.3	17.2	19.0	20.9	1.86	56.8
	71	29.2	9.4	11.3	13.1	15.0	16.9	1.91	61.1
	59	22.6	20.7	22.6	23.2	23.8	24.4	1.85	49.0
	63	24.4	17.1	18.9	20.8	22.6	24.4	1.89	52.9
100	67	26.3	13.1	15. <b>0</b>	16.8	18.7	20.6	1.94	57.1
	71	28.2	9.1	11.0	12.8	14.7	16.5	1.98	61.4
	59	21.9	20.4	22.1	22.6	23.2	23.8	1.94	49.3
	63	23.6	16.8	18.6	20.5	22.3	23.8	1.98	53.2
105	67	25.4	12.8	14.7	16.5	18.4	20.2	2.02	57.5
	71	27.3	8.8	10.6	12.5	14.4	16.2	2.06	61.8
	59	20.5	19.8	20.9	21.5	22.0	22.5	2.11	50.0
	63	22.1	16.2	18.0	19.9	21.7	22.5	2.14	53.9
115	67	23.8	12.2	14.1	15.9	17.8	19.6	2.18	58.2
	71	25.5	8.2	10.0	11.9	13.7	15.6	2.21	62.5
		ing Conditions	•		= 67°F, OD	)B = 95°	F)		
	-	Total Capacity	27140						
	Airflow		900 (						
		us Dew Pt	56.8 '						
		sor Power	1858						
		an Power	230						
		Fan Power	108 \						
	EER		12.36 (	(Btu/ h)/	W				
		cy Rating		· <b>-</b> · ·· · ·					
	SEER			(Btu/ h)/					
		DB = outdoor di	• •			-		•	
	-	drybulb tempe			-		-	on Institute;	
	energy e	fficiency ration	SEER = sea	isonal er	nergy effic	ency rat	10.		
Notes:									
		ad performanc							
		TWH039P15-C		•	hed April	1993. F	Performa	nce rated with	ו
1_		suction and 5/	-						
<sup>2</sup> Listed	adjusted	net total and a	djusted net	sensible	capacitie	es are gro	oss capa	cities with	
I_		(785 Btu/h) su							
		e Capacity) > (				oil condi	tion;		
		otal Capacity) =					-:	1 h - <b>F</b> '	1
Compr	essor kV	V, Apparatus De	w Point, and	a Adjust	ed Net To	tal Capa	city valio	a only for wet a	coll.

perfmap140.xls, e:a4..j54; oct 08, 2002

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 26a through 26f, the dry-coil condition is evident from a given table for conditions where the listed sensible capacity is greater than the corresponding total capacity. For such a dry-coil condition, set total capacity equal to sensible capacity.

For a given EDB and ODB, the compressor power, total capacity, sensible capacity, and apparatus dew point for wet coils change only with varying EWB. Once the coil becomes dry—which is apparent for a given EDB and ODB from the maximum EWB where total and sensible capacities are equal— for a given EDB, compressor power and capacities remain constant with decreasing EWB.<sup>A-4</sup>

To evaluate equipment performance for a dry-coil condition, establish the performance at the maximum EWB where total and sensible capacities are equal. Make this determination by interpolating or extrapolating with EWB for a given EDB and ODB. For example, to determine the dry-coil compressor power for ODB/EDB =  $29.4^{\circ}$ C/26.7°C, find the "maximum EWB" dry-coil condition (net sensible capacity = net total capacity) using the data shown in Table 27 (extracted from Table 26e):

At the dry-coil condition:

Adjusted net total capacity = adjusted net sensible capacity = 7.66 kW

Linear interpolation based on adjusted net total capacity gives

Maximum EWB for the dry-coil condition =  $16.75^{\circ}$ C

#### Compressor power = 1.652 kW

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 B17.2, regarding analytical solution results.

**5.3.1.10.3.4 Extrapolation of Performance Data.** For Cases E100–E200, allow your software to perform the necessary extrapolations of the performance data as may be required by these cases, if it has that capability. Cases E100, E110, E130, and E140 require some extrapolation of data for EWB <15.0°C (<59°F). Additionally, Case E180 may require (depending on the model) a small amount of extrapolation of data for EWB >21.7°C (>71°F). Case E200 may require (depending on the model) some extrapolation of data for EDB >26.7°C (>80°F).

In cases where the maximum-EWB dry-coil condition occurs at EWB <15.0°C, extrapolate the total capacity and sensible capacity to the intersection point where they are both equal. For example, use the data shown in Table 28 (extracted from Table 26e) to find the maximum EWB dry-coil condition for ODB/EDB =  $29.4^{\circ}$ C/22.2°C:

Linear extrapolation of the total and sensible capacities to the point where they are equal gives:

Adjusted net total capacity = adjusted net sensible capacity = 6.87 kW

Maximum dry-coil EWB =  $13.8^{\circ}$ C

Resulting compressor power = 1.598 kW.

EWB (°C)	Adjusted Net Total Capacity (kW)	Adjusted Net Sensible Capacity (kW)	Compressor Power (kW)
15.0	7.19	7.66	1.62
Maximum dry EWB 16.75*	7.66*	7.66*	1.652*
17.2	7.78	7.45	1.66

TABLE 27 Determination of Maximum Dry-Coil EWB Using Interpolation

\* Italicized values are not specifically listed with Table 26e; they are determined based on the accompanying discussion. Other data in this table are from Table 26e.

TABLE 28
Determination of Maximum Dry-Coil EWB Using Extrapolation

EWB (°C)	Adjusted Net Total Capacity (kW)	Adjusted Net Sensible Capacity (kW)	Compressor Power (kW)
Maximum dry EWB 13.8*	6.87*	6.87*	1.598*
15.0	7.19	6.31	1.62
17.2	7.78	5.26	1.66

\* Italicized values are not specifically listed with Table 26e; they are determined based on the accompanying discussion. Other data in this table are from Table 26e.

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 B17.2, regarding analytical solution results.

**5.3.1.10.3.5 Apparatus Dew Point.** Apparatus dew point (ADP) is defined in Section 3. Listed values of ADP may vary somewhat from those calculated using the other listed performance parameters. For more discussion of this, see informative Annex B14 (Cooling Coil Bypass Factor).

**5.3.1.10.3.6** Values at ARI Rating Conditions. In Tables 26a through 26f, nominal values at ARI rating conditions are useful to system designers for comparing the capabilities of one system to those of another. Some detailed simulation programs utilize inputs for ARI rating conditions in conjunction with the full performance maps of Tables 26a through 26f. For simplified simulation programs and other programs that do not allow performance maps of certain parameters, appropriate values at ARI conditions may be used and assumed constant.

**5.3.1.10.3.7 SEER.** In Tables 26a through 26f, seasonal energy efficiency ratio (SEER), which is a generalized seasonal efficiency rating, is not generally a useful input for detailed simulation of mechanical systems. SEER (or "COP<sub>SEER</sub>" in the metric versions) is useful to system designers for comparing one system to another. SEER is further discussed in Section 3 and informative Annex B13.

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

BF at ARI rating conditions is *approximately*  $0.049 \le BF \le 0.080$ .

Calculation techniques and uncertainty about this range of values are discussed in informative Annex B14. Annex B14 is provided for illustrative purposes; some models may perform the calculation with minor differences in technique or assumptions or both. If your software requires this input, calculate the BF in a manner consistent with the assumptions of your specific model. If the assumptions of your model are not apparent from its documentation, use a value consistent with the above range and Annex B14.

Calculations based on the listed performance data indicate that BF varies as a function of EDB, EWB, and ODB. Incorporate this aspect of equipment performance into your model if your software allows it, using a consistent method for developing all points of the BF variation map.

**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 software requires an input for minimum allowable supply air temperature, use

Minimum supply air temperature  $\leq 7.7^{\circ}C$  (45.9°F).

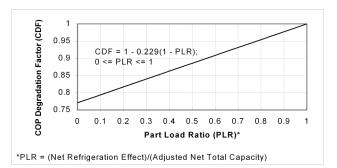


Figure 10 Cooling equipment part load performance (COP degradation factor versus PLR).

This value is the lowest value of ADP that occurs in the Section 5.3 test cases based on the quasi-analytical solutions for Case E110 presented in HVAC BESTEST.<sup>A-5</sup>

If your software does not require this input, ignore this information.

**5.3.1.10.4 Part-Load Operation.** The system COP 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 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. Then, because the controller is ideal ON/OFF cycling (see Section 5.3.1.10.2),

Hourly fractional run time = PLR/CDF.

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.

Simplifying assumptions in Figure 10 are:

- 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.

Annex B13 includes additional details about how Figure 10 was derived.

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

**5.3.1.10.5 Evaporator Coil.** Geometry of the evaporator coil is included in Figures 11 and 12. Evaporator coil fins are actually contoured to enhance heat transfer, but further design details about fin geometry are proprietary and therefore unavailable.

# 5.3.1.10.5.1 Frontal Dimensions (also see Figure 11).

- Height = 68.6 cm (27 in.)
- Width = 61.0 cm (24 in.)
- Frontal area =  $0.418 \text{ m}^2 (4.50 \text{ ft}^2)$
- Depth = 9.53 cm (3.75 in.)

## 5.3.1.10.5.2 Tubes.

- 130 tubes total
- (5 tubes per row, 26 rows)
- Tube outside diameter = 9.53 mm (0.375 in.)
- Tube inside diameter = 8.81 mm (0.347 in.)
- Exposed tube surface area =  $2.229 \text{ m}^2 (23.99 \text{ ft}^2)$ .

# 5.3.1.10.5.3 Fins.

- 12 fins per inch
- Fin thickness = 0.13 mm (0.005 in.)
- 288 fins total
- Exposed fin surface area =  $32.085 \text{ m}^2 (345.36 \text{ ft}^2)$ .

# 5.3.1.10.6 Fans.

# 5.3.1.10.6.1 Indoor Air Distribution Fan.

- Indoor fan power = 230 W
- Airflow rate =  $0.425 \text{ m}^3/\text{s} = 1529 \text{ m}^3/\text{h} = 900 \text{ CFM}$
- 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.

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**.

5.3.1.10.6.2 Outdoor Condenser Fan.

• Outdoor fan power = 108 W.

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

5.3.2 HVAC Equipment Performance Parameter Variation Tests

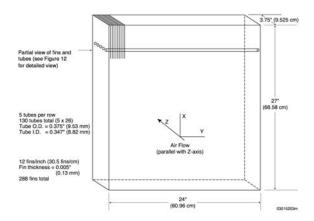


Figure 11 Evaporator coil overall dimensions.

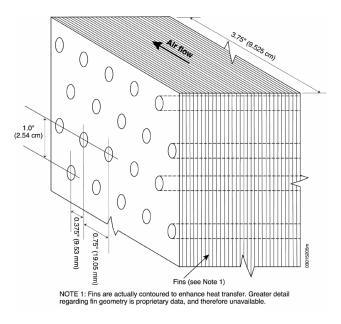


Figure 12 Evaporator coil detail, tube and fin geometry.

#### 5.3.2.1 Additional Dry Coil Test Cases

It is recommended to double check the Case E100 base case inputs and to diagnose Case E100 results disagreements before going on to the other test cases.

This section describes sequential revisions to the base case required to model additional dry-coil cases. The dry-coil cases have no latent load in the zone. In many instances the base case for a given case is not Case E100; appropriate base cases for a given dry-coil case are:

Case	<b>Basis for That Case</b>
E110	E100
E120	E110
E130	E100
E140	E130

**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 in the files accompanying this standard (available at http://www.ashrae.org/template/PDFDetail?assetID=34505) as described in Annex A1, Section A1.2.

**5.3.2.1.2 Case E120: Increased Thermostat Setpoint**. Case E120 is exactly the same as Case E110 except the thermostat control strategy is:

$$Heat = off$$

Cool = on if zone air temperature >26.7°C (80.0°F); otherwise cool = off

All other features of the thermostat remain as before.

**5.3.2.1.3 Case E130: Low Part-Load Ratio.** Case E130 is exactly the same as Case E100 except the internal heat gains are:

Sensible internal gains = 270 W (922 Btu/h), continuously (24 hours per day for the full simulation period)

Latent internal gains = 0 W (0 Btu/h), continuously (24 hours per day for the full simulation period)

Sensible internal gains remain as 100% convective.

Zone sensible internal gains are assumed to be distributed evenly throughout the zone air. These are internally generated sources of heat (from equipment, lights, people, etc.) that are not related to the operation of the mechanical cooling system or its air distribution fan.

**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 weather 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.

**5.3.2.2 Humid Zone Test Cases.** In this section, the sequential revisions required to model humid zone cases are described. The humid zone cases have latent load in the zone and, therefore, have moisture removed by the evaporator coil. All condensed moisture is assumed to leave the system through a condensate drain. The appropriate base cases for a given case are:

Case	Basis for That Case
E150	E110
E160	E150
E165	E160
E170	E150
E180	E170
E185	E180
E190	E180
E195	E190
E200	E150

**5.3.2.2.1 Case E150: Latent Load at High Sensible Heat Ratio.** Case E150 is exactly as Case E110 except the internal heat gains are:

Sensible internal gains = 5400 W (18430 Btu/h), continuously (24 hours per day for the full simulation period)

Latent internal gains = 1100 W (3754 Btu/h), continuously (24 hours per day for the full simulation period)

Sensible gains remain as 100% convective.

Zone sensible and latent internal gains are assumed to be distributed evenly throughout the zone air. These are internally generated sources of heat (from equipment, lights, people, etc.) that are not related to operation of the mechanical cooling system or its air distribution fan.

If the software being tested requires input of water vapor mass flow rate rather than latent internal gains, then to convert the listed latent internal gains to water vapor mass flow rate, use a heat of vaporization  $(h_{fg})$  that approximates the value of  $h_{fg}$  for condensation at the coil used by the software being tested.

If the software being tested requires input of total internal gains, then use the sum of listed sensible + latent internal gains.

**5.3.2.2.2 Case E160: Increased Thermostat Setpoint at High Sensible Heat Ratio.** Case E160 is exactly the same as Case E150 except the thermostat control strategy is:

$$Heat = off$$

Cool = on if zone air temperature >26.7°C ( $80.0^{\circ}F$ ); otherwise cool = off

All other features of the thermostat remain as before.

**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.

#### 5.3.2.2.3.2 Thermostat control strategy

$$Heat = off$$

Cool = on if zone air temperature >23.3°C (74.0°F); otherwise cool = off

All other features of the thermostat remain as before.

**5.3.2.2.4 Case E170: Reduced Sensible Load.** Case E170 is exactly the same as Case E150 except the internal heat gains are:

Sensible internal gains = 2100 W (7166 Btu/h), continuously (24 hours per day for the full simulation period)

Latent internal gains = 1100 W (3754 Btu/h), continuously (24 hours per day for the full simulation period)

Sensible gains remain as 100% convective.

Zone sensible and latent internal gains are assumed to be distributed evenly throughout the zone air. These are internally generated sources of heat (from equipment, lights, people, etc.) that are not related to operation of the mechanical cooling system or its air distribution fan.

If the software being tested requires input of water vapor mass flow rate rather than latent internal gains, then to convert the listed latent internal gains to water vapor mass flow rate, use a heat of vaporization  $(h_{fg})$  that approximates the value of  $h_{fg}$  for condensation at the coil used by the software being tested.

If the software being tested requires input of total internal gains, then use the sum of listed sensible + latent internal gains.

**5.3.2.2.5 Case E180: Increased Latent Load.** Case E180 is exactly the same as Case E170 except the internal heat gains are:

Sensible internal gains = 2100 W (7166 Btu/h), continuously (24 hours per day for the full simulation period)

Latent internal gains = 4400 W (15018 Btu/h), continuously (24 hours per day for the full simulation period).

Sensible gains remain as 100% convective.

Zone sensible and latent internal gains are assumed to be distributed evenly throughout the zone air. These are internally generated sources of heat (from equipment, lights, people, etc.) that are not related to operation of the mechanical cooling system or its air distribution fan.

If the software being tested requires input of water vapor mass flow rate rather than latent internal gains, then to convert the listed latent internal gains to water vapor mass flow rate, use a heat of vaporization  $(h_{fg})$  that approximates the value of  $h_{fg}$  for condensation at the coil used by the software being tested.

If the software being tested requires input of total internal gains, then use the sum of listed sensible + latent internal gains.

**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 weather applicable weather data file is

#### HVBT461.TMY or HVBT461A.TM2.

These data are provided in the files accompanying this standard (available at http://www.ashrae.org/template/PDFDetail?assetID=34505) as described in Annex A1, Section A1.2.

**5.3.2.2.7** Case E190: Low Part-Load Ratio at Low Sensible Heat Ratio. Case E190 is exactly the same as Case E180 except the internal heat gains are:

Sensible internal gains = 270 W (922 Btu/h), continuously (24 hours per day for the full simulation period)

Latent internal gains = 550 W (1877 Btu/h), continuously (24 hours per day for the full simulation period)

Sensible gains remain as 100% convective.

Zone sensible and latent internal gains are assumed to be distributed evenly throughout the zone air. These are internally generated sources of heat (from equipment, lights, people, etc.) that are not related to operation of the mechanical cooling system or its air distribution fan.

If the software being tested requires input of water vapor mass flow rate rather than latent internal gains, then to convert the listed latent internal gains to water vapor mass flow rate, use a heat of vaporization  $(h_{fg})$  that approximates the value of  $h_{fg}$  for condensation at the coil used by the software being tested.

If the software being tested requires input of total internal gains, then use the sum of listed sensible + latent internal gains.

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.

**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.

#### 5.3.2.2.9.2 Internal heat gains

Sensible internal gains = 6120 W (20890 Btu/h), continuously (24 hours per day for the full simulation period)

Latent internal gains = 1817 W (6200 Btu/h), continuously (24 hours per day for the full simulation period).

Sensible gains remain as 100% convective.

Zone sensible and latent internal gains are assumed to be distributed evenly throughout the zone air. These are internally generated sources of heat (from equipment, lights, people, etc.) that are not related to operation of the mechanical cooling system or its air distribution fan.

If the software being tested requires input of water vapor mass flow rate rather than latent internal gains, then to convert the listed latent internal gains to water vapor mass flow rate, use a heat of vaporization  $(h_{fg})$  that approximates the value of  $h_{fg}$  for condensation at the coil used by the software being tested.

If the software being tested requires input of total internal gains, then use the sum of listed sensible + latent internal gains.

# 5.3.2.2.9.3 Thermostat Control Strategy

# Heat = off.

 $Cool = on if zone air temperature > 26.7^{\circ}C (80.0^{\circ}F); otherwise cool = off.$ 

All other features of the thermostat remain as before.

# 6. OUTPUT REQUIREMENTS

[Informative Note: Make the following revisions to Section 6.]

# 6.1 Annual Outputs <u>for Building Thermal Envelope and</u> <u>Fabric Load Tests of Section 5.2</u>

**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 <u>described in Section 5.2</u> (Annex B1 includes an informative summary listing of all the cases). Required outputs for the non-free-float cases are:

**<u>6.1.1.5</u>** All heating and cooling loads listed in 6.1.1.1 through 6.1.1.4 shall be entered into the appropriate standard output report (see Annex A2) as positive values ( $\geq 0$ ).

# 6.2 Daily Hourly Output <u>for Building Thermal Envelope</u> 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 2<u>9</u>-3.

Table 2<u>9</u>3

## Daily Hourly Output Requirements <u>for Building Thermal</u> <u>Envelope and Fabric Load Tests of Section 5.2</u>

# 6.3 Output Requirements for HVAC Equipment Performance Tests of Section 5.3

**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.

**6.3.2** 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 ( $^{\circ}C$ )

(c) Zone humidity ratio (kg moisture/kg dry air).

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

#### ANNEX A1

#### WEATHER DATA

[Informative Note: Create new Section A1.1 by combining the first paragraph of Annex A1 and the first sentence of the second paragraph and revising as follows.]

# A1.1 Weather Data for Building Thermal Envelope and Fabric Load Tests

The <u>full-year</u> weather data (DRYCOLD.TMY) in the files accompanying this standard method of test (available at http:/ /www.ashrae.org/template/PDFDetail?assetID=34505) shall be used for performing the tests <u>called out in Section 5.2</u>. Site and weather characteristics are summarized in Table A1-1.

## A1.2 Weather Data for HVAC Equipment Performance Tests

The weather data listed in Table A1-2 shall be used as called out in Section 5.3. 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 TMYformat data are three-month-long data files used in the original field trials of the test procedure; the TMY2-format data are vear-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 A1.3 and A1.4 respectively.

[Informative Note: Revise the title of Table A1-1 as follows.]

# TABLE A1-1 Site and Weather Summary for DRYCOLD.TMY Weather Data Used with Building Thermal Envelope and Fabric Load Tests

TABLE A1-2
Weather Data for HVAC Equipment Performance Tests

Data Files	Applicable Cases	Applicable Cases' Sections
HVBT294.TMY or HVBT294A.TM2		5.3.2.1.1; 5.3.2.1.2; 5.3.2.1.4; 5.3.2.2.1; 5.3.2.2.2; 5.3.2.2.4; 5.3.2.2.5; 5.3.2.2.7
HVBT350.TMY or HVBT350A.TM2	E200	5.3.2.2.9
HVBT406.TMY or HVBT406A.TM2	E165	5.3.2.2.3
HVBT461.TMY or HVBT461A.TM2	E100, E130, E185, E195	5.3.1; 5.3.2.1.3; 5.3.2.2.6; 5.3.2.2.8

# TABLE A1-3a Site and Weather Summary for HVAC Equipment Performance Tests—TMY Data

Weather Type		Artificial Conditions
Weather Format		TMY
Latitude		25.8° North
Longitude (local site)		80.3° West
Altitude		2 m (6.6 ft)
Time Zone (Standard Meridian Longitude	2)	5 (75° West)
Ground Reflectivity		0.2
Site		Flat, unobstructed, located exactly at weather station
Dew Point Temperature (constant)		14.0°C (57.2°F)
Humidity Ratio		0.010 kg moisture/kg dry air (0.010 lb moisture/lb dry air)
Mean 3-Month Wind Speed		4.4 m/s (9.8 miles/h)
Maximum 3-Month Wind Speed		12.4 m/s (27.7 miles/h)
Global Horizontal Solar Radiation 3-Mon	th Total	1354 MJ/m <sup>2</sup> (119.2 kBtu/ft <sup>2</sup> )
Direct Normal Solar Radiation 3-Month	Total	1350 MJ/m <sup>2</sup> (118.8 kBtu/ft <sup>2</sup> )
Direct Horizontal Solar Radiation 3-Mon	h Total	817 MJ/m <sup>2</sup> (71.9 kBtu/ft <sup>2</sup> )
Diffuse Horizontal Solar Radiation 3-Mon	nth Total	536 MJ/m <sup>2</sup> (47.2 kBtu/ft <sup>2</sup> )
Quantities That Vary Between Data Sets	Ambient Dry Bulb Temperature (constant)	Ambient Relative Humidity
HVBT294.TMY	29.4°C (85.0°F)	39%
HVBT350.TMY	35.0°C (95.0°F)	28%
HVBT406.TMY	40.6°C (105.0°F)	21%
HVBT461.TMY	46.1°C (115.0°F)	16%

TABLE A1-3b Site and Weather Summary for HVAC Equipment Performance Tests—TMY2 Data

Weather Type		Artificial Conditions
Weather Format		TMY2
Latitude		25.8° North
Longitude (local site)		80.3° West
Altitude		2 m (6.6 ft)
Time Zone (Standard Meridian Longitude	e)	5 (75° West)
Ground Reflectivity		0.2
Site		Flat, unobstructed, located exactly at weather station
Dew Point Temperature (constant)		14.0°C (57.2°F)
Humidity Ratio		0.010 kg moisture/kg dry air (0.010 lb moisture/lb dry air)
Mean Annual Wind Speed		4.3 m/s (9.7 miles/h)
Maximum Annual Wind Speed		13.9 m/s (31.1 miles/h)
Global Horizontal Solar Radiation Annua	l Total	6453 MJ/m <sup>2</sup> (568 kBtu/ft <sup>2</sup> )
Direct Normal Solar Radiation Annual To	otal	5418 MJ/m <sup>2</sup> (477 kBtu/ft <sup>2</sup> )
Diffuse Horizontal Solar Radiation Annua	al Total	2914 MJ/m <sup>2</sup> (257 kBtu/ft <sup>2</sup> )
Quantities That Vary Between Data Sets	Ambient Dry Bulb Temperature (constant)	Ambient Relative Humidity
HVBT294A.TM2 29.4°C (85.0°F)		39%
HVBT350A.TM2	35.0°C (95.0°F)	28%
HVBT406A.TM2 40.6°C (105.0°F)		21%
HVBT461A.TM2 46.1°C (115.0°F)		16%

[Informative Note: Revise Section A1.3 as follows.]

# A1.3 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-<u>42</u>. 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<sup>8</sup> can be obtained from the National Climatic Data Center (NCDC) in Asheville, North Carolina. The address is Federal Building, Asheville, NC 28801-2733; telephone 828-271-4800. Informative Annex B2 contains additional background information regarding TMY weather data.

The hourly time convention for TMY weather data is solar time, where

Solar Time = Standard Time + (4 minutes / degree) x (Lst -Lloc) + E

and where

Lst = standard meridian longitude (degrees)

 $Lloc \equiv local site longitude (degrees)$ 

 $E = \frac{-9.87 \sin 2B}{0.001868 \cos(B)} - \frac{7.53 \cos B}{0.032077 \sin(B)} - \frac{1.5 \sin B229.2(0.000075 + 0.001868 \cos(2B) - 0.032077 \sin(B) - 0.014615 \cos(2B) - 0.014615 \cos(2B) - 0.04089 \sin(2B)}{0.04089 \sin(2B)}$  (minutes)

where

B = 360(n - 81)/364365 (degrees)

 $n \equiv day of the year, 1 \le n \le 365$ 

E varies roughly  $\pm$  15 minutes throughout the year because of cosmology. Additional background information on the equation of time may be found in the references.<sup>4</sup>

Additional background regarding the difference between solar time and standard time is included in informative Annex B11 (Section B11.3).

#### [Informative Note: Add entirely new Section A1.4 as below.]

#### A1.4 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<sup>A-6</sup> can be obtained at http://rredc.nrel.gov/solar/pubs/tmy2.

**A1.4.1 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 A1-5, along with sample FOR-TRAN and C formats for reading the header. A sample of a file header and data for January 1 is shown in Figure A1-1.

**A1.4.2** 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 A1-6 provides field positions, element definitions, and sample FORTRAN and C formats for reading the hourly records.

Each hourly record begins with the year (field positions 2-3) from which the typical month was chosen, followed by the month, day, and hour information in field positions 4-9. *The times are in local standard time (previous TMYs based on SOLMET/ERSATZ data are in solar time).* 

For solar radiation and illuminance elements, the data values represent the energy received during the 60 minutes *preceding the hour indicated*. For meteorological elements (with a few exceptions), observations or measurements were

made *at the hour indicated*. A few of the meteorological elements had observations, measurements, or estimates made at daily, instead of hourly, intervals. Consequently, the data values for broadband aerosol optical depth, snow depth, and days since last snowfall represent the values available for the day indicated.

[Informative Note: Add Figure A1-1. Change the designation of Table A1-2, Typical Meteorological Year Data Format, to Table A1-4 on all pages on which the table appears. Add tables A1-5 and A1-6.]

14944 SIOUX FALLS SD -6 N 43 34 W 96 44 435

850101130562141503876408066400676504071407671401011501391500870087-15687-244870478709788732087067870193877777777770999999999999999990387050F80008700E7850101150436141502776407166400566502891406451400881501111500870037-13947-2394704337097887330870528701938777777777770999999999999999990387056780008700E7

Ч Ч Ч

(for field position identification only)

# Figure A1-1 Sample file header and data in the TMY2 format for January 1

TABLE A1-5
Header Elements in the TMY2 Format (For First Record of Each File)

Field Position	Element	Definition			
002 - 006	WBAN Number	Station's Weather Bureau Army Navy number (see Table 2-1 of Marion and Urban [1995]) <sup>A-6</sup>			
008 - 029	City	City where the station is located (maximum of 22 characters)			
031 - 032	State	State where the station is located (abbreviated to two letters)			
034 - 036	Time Zone	Time zone is the number of hours by which the local standard time is ahead of or behind Universal Time. For example, Mountain Standard Time is designated -7 because it is 7 hours behind Universal Time.			
<b>038 - 044</b> 038 040 - 041 043 - 044	Latitude	Latitude of the station N = North of equator Degrees Minutes			
<b>046 - 053</b> 046 048 - 050 052 - 053	Longitude	Longitude of the station W = West, E = East Degrees Minutes			
056 - 059	Elevation	Elevation of station in meters above sea level			
FORTRAN Sample Format: (1X,A5,1X,A22,1X,A2,1X,I3,1X,A1,1X,I2,1X,I2,1X,A1,1X,I3,1X,I2,2X,I4) C Sample Format: (%s %s %s %d %s %d %d %s %d %d %d)					

 TABLE A1-6

 Data Elements in the TMY2 Format (For All Except the First Record)

Field Position	Element	Values	Definition
<b>002 - 009</b> 002 - 003 004 - 005 006 - 007 008 - 009	Local Standard Time Year Month Day Hour	61 - 90 1 - 12 1 - 31 1 - 24	Year, 1961-1990 Month Day of month Hour of day in local standard time
010 - 013	Extraterrestrial Horizontal Radiation	0 - 1415	Amount of solar radiation in Wh/m <sup>2</sup> received on a horizontal surface at the top of the atmosphere during the 60 minutes preceding the hour indicated
014 - 017	Extraterrestrial Direct Normal Radiation	0 - 1415	Amount of solar radiation in Wh/m <sup>2</sup> received on a surface nor- mal to the sun at the top of the atmosphere during the 60 min- utes preceding the hour indicated
<b>018 - 023</b> 018 - 021 022 023	Global Horizontal Radiation Data Value Flag for Data Source Flag for Data Uncertainty	0 - 1200 A - H, ? 0 - 9	Total amount of direct and diffuse solar radiation in Wh/m <sup>2</sup> received on a horizontal surface during the 60 minutes preceding the hour indicated
<b>024 - 029</b> 024 - 027 028 029	Direct Normal Radiation Data Value Flag for Data Source Flag for Data Uncertainty	0 - 1100 A - H, ? 0 - 9	Amount of solar radiation in Wh/m <sup>2</sup> received within a 5.7° field of view centered on the sun, during the 60 minutes preceding the hour indicated
<b>030 - 035</b> 030 - 033 034 035	Diffuse Horizontal Radiation Data Value Flag for Data Source Flag for Data Uncertainty	0 - 700 A - H, ? 0 - 9	Amount of solar radiation in Wh/m <sup>2</sup> received from the sky (excluding the solar disk) on a horizontal surface during the 60 minutes preceding the hour indicated
<b>036 - 041</b> 036 - 039 040 041	Global Horiz. Illuminance Data Value Flag for Data Source Flag for Data Uncertainty	0 - 1,300 I, ? 0 - 9	Average total amount of direct and diffuse illuminance in hundreds of lux received on a horizontal surface during the 60 minutes preceding the hour indicated. 0 to $1,300 = 0$ to $130,000$ lux
<b>042 - 047</b> 042 - 045 046 047	Direct Normal Illuminance Data Value Flag for Data Source Flag for Data Uncertainty	0 - 1,100 I, ? 0 - 9	Average amount of direct normal illuminance in hundreds of lux received within a 5.7 degree field of view centered on the sun during the 60 minutes preceding the hour indicated. 0 to $1,100 = 0$ to $110,000$ lux
<b>048 - 053</b> 048 - 051 052 053	Diffuse Horiz. Illuminance Data Value Flag for Data Source Flag for Data Uncertainty	0 - 800 I, ? 0 - 9	Average amount of illuminance in hundreds of lux received from the sky (excluding the solar disk) on a horizontal surface during the 60 minutes preceding the hour indicated. 0 to $800 = 0$ to $80,000$ lux
<b>054 - 059</b> 054 - 057 058 059	Zenith Luminance Data Value Flag for Data Source Flag for Data Uncertainty	0 - 7,000 I, ? 0 - 9	Average amount of luminance at the sky's zenith in tens of Cd/m <sup>2</sup> during the 60 minutes preceding the hour indicated. 0 to 7,000 = 0 to 70,000 Cd/m <sup>2</sup>
<b>060 - 063</b> 060 - 061 062 063	Total Sky Cover Data Value Flag for Data Source Flag for Data Uncertainty	0 - 10 A - F, ? 0 - 9	Amount of sky dome in tenths covered by clouds or obscuring phenomena at the hour indicated
<b>064 - 067</b> 064 - 065 066 067	Opaque Sky Cover Data Value Flag for Data Source Flag for Data Uncertainty	0 - 10 A - F 0 - 9	Amount of sky dome in tenths covered by clouds or obscuring phenomena that prevent observing the sky or higher cloud lay- ers at the hour indicated
<b>068 - 073</b> 068 - 071 072 073	Dry Bulb Temperature Data Value Flag for Data Source Flag for Data Uncertainty	-500 to 500 A - F 0 - 9	Dry bulb temperature in tenths of °C at the hour indicated. -500 to 500 = -50.0 to 50.0 degrees C
<b>074 - 079</b> 074 - 077 078 079	Dew Point Temperature Data Value Flag for Data Source Flag for Data Uncertainty	-600 to 300 A - F 0 - 9	Dew point temperature in tenths of $^{\circ}$ C at the hour indicated. -600 to 300 = -60.0 to 30.0 $^{\circ}$ C

# TABLE A1-6 (Continued)Data Elements in the TMY2 Format (For All Except the First Record)

Field Position	Element	Values	Definition				
080 - 084	Relative Humidity		Relative humidity in percent at the hour indicated				
080 - 082 083	Data Value Flag for Data Source	0 - 100 A - F					
083	Flag for Data Source Flag for Data Uncertainty	A - F 0 - 9					
		0-9					
085 - 090	Atmospheric Pressure	700 1100	Atmospheric pressure at station in millibars at the hour indi-				
085 - 088 089	Data Value Flag for Data Source	700 - 1100 A - F	cated				
090	Flag for Data Uncertainty	0 - 9					
<b>091 - 095</b> 091 - 093	Wind Direction Data Value	0 - 360	Wind direction in degrees at the hour indicated. (N = 0 or 360, $E = 90$ , S = 180, W = 270). For calm winds, wind direction				
094	Flag for Data Source	A - F	E = 90, $S = 180$ , $W = 270$ ). For each which, which direction equals zero.				
095	Flag for Data Uncertainty	0 - 9					
096 - 100	Wind Speed		Wind speed in tenths of meters per second at the hour indi-				
096 - 98	Data Value	0 - 400	cated.				
99	Flag for Data Source	A - F	0  to  400 = 0  to  40.0  m/s				
100	Flag for Data Uncertainty	0 - 9					
101 - 106	Visibility		Horizontal visibility in tenths of kilometers at the hour indi-				
101 - 104	Data Value	0 - 1609	cated.				
105	Flag for Data Source	A - F, ?	7777 = unlimited visibility				
106	Flag for Data Uncertainty	0 - 9	0 to 1609 = 0.0 to 160.9 km				
			9999 = missing data				
107 - 113	Ceiling Height		Ceiling height in meters at the hour indicated.				
107 - 111	Data Value	0 - 30450	77777 = unlimited ceiling height				
112	Flag for Data Source	A - F, ?	88888 = cirroform				
113	Flag for Data Uncertainty	0 - 9	99999 = missing data				
114 - 123	Present Weather	See	Present weather conditions denoted by a 10-digit number. See				
		Appendix B of Mar-	Appendix B of Marion and Urban (1995) <sup>A-6</sup> for key to present				
		ion and Urban (1995) <sup>A-6</sup>	weather elements.				
		(1995)					
124 - 128	Precipitable Water		Precipitable water in millimeters at the hour indicated				
124 - 126	Data Value	0 - 100					
127 128	Flag for Data Source     A - F       Flag for Data Uncertainty     0 - 9						
	Flag for Data Uncertainty	0-9					
129 - 133	Aerosol Optical Depth		Broadband aerosol optical depth (broad-band turbidity) in				
129 - 131 132	Data Value $0 - 240$ thousandths on the day indicated.Flag for Data SourceA - F0 to $240 = 0.0$ to $0.240$						
132	Flag for Data Uncertainty	0 - 9	0 to 240 = 0.0 to 0.240				
<b>134 - 138</b> 134 - 136	Snow Depth Snow depth in centimeters on the day indicated.						
134 - 130	Data Value $0 - 150$ $999 = missing data$						
138	Flag for Data Source     A - F, ?       Flag for Data Uncertainty     0 - 9						
139 - 142							
139 - 140	Days Since Last SnowfallNumber of days since last snowfallData Value0 - 88Flag for Data SourceA - F, ?99 = missing data						
141							
142	Flag for Data Uncertainty   0 - 9						
FORTRAN Sampl	e Format:						
(1X,4I2,2I4,7(I4,A1,I1),2(I2,A1,I1),2(I4,A1,I1),1(I3,A1,I1),							
1(I4,A1,I1),2(I3,A1,I1),1(I4,A1,I1),1(I5,A1,I1),10I1,3(I3,A1,I1),							
1(I2,A1,I1))							
(%2d%2d%2d%2d%4d%4d%1s%1d%4d%1s%1d%4d%1s%1d%4d%1s%1d%4d%1s%1d%4d%1s							
%1d%4d%1s%1d%2d%1s%1d%2d%1s%1d%4d%1s%1d%3d%1s%1d%4d%1s%1d%4d%1s%1d%3d %1s%1d%3d%1s%1d%4d%1s%1d%51d%1d%1d%1d%1d%1d%1d%1d%1d%1d%1d%1d%1d%3d%1s							
	%1d%3d%1s%1d%3d%1s%1d%2d%1s%1d)						
	Note: For ceiling height data, integer variable should accept data values as large as 99999.						

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

# **ANNEX A2**

## STANDARD OUTPUT REPORTS

[Informative Note: Replace item (b) in alphabetized list below with new item (b), change old item (b) to item (c), and revise items (a) and (c) as shown.]

The standard output report consists of two-three forms provided in the files accompanying this standard (available at http://www.ashrae.org/template/PDFDetail?assetID=34505):

- (a) Output Results for Section 5.2 Cases (S140OUT2Sec5-2out.XLSWK3, spreadsheet file)
- (b) <u>Output Results for Section 5.3 Cases (Sec5-3out.XLS,</u> spreadsheet file)
- (c) Modeling Notes (S140OUT2S140outNotes.TXT, text file reprinted as Attachment A2.3A2.1)

For entering output results into <u>S140OUT2Sec5-</u> <u>2out.XLSWK3</u> and <u>Sec5-2out.XLS</u>, follow the instructions provided at the top of the <u>appropriate</u> electronic spreadsheet files. These instructions are reprinted as Attachment<u>s</u> <u>A2.1</u> and <u>A2.2</u> respectively<u>A2.2</u> within this section.

For entering modeling notes into <u>S140OUT2S140outNotes</u>.TXT, use the format of the following examples given as Attachments <u>A2.3 and A2.4 and A2.5</u> within this section.

[Informative Note: Change Attachment A2.2 to A2.1 and revise heading as follows. Move it ahead of the former A2.1.]

## Attachment <u>A2.2A2.1</u> Instructions for Entering Results into <u>S140OUT2Sec5-2out.XLSWK3</u>

#### [Informative Note: Revise results as follows.]

STANDARD 140 OUTPUT FORM - RESULTS 17 DEC 1997; S140OUT2Sec5-2out.XLSWK3

# [Informative Note: Delete the following paragraph in A2.2 (formerly A2.1).]

When dates are input in this format, they are converted to a 5-digit date code (04-Jan = 33607) which appears in the data cell. To convert this five-digit code back into a date, the cell must have an appropriate format. Thus, for S140OUT2.WK3 the format command "/ Worksheet Range Format Date 2" is already applied to the cells that require the entry of dates.

## [Informative Note: Add entirely new Attachment A2.2.]

#### <u>Attachment A2.2 Instructions for Entering Results into</u> Sec5-3out.XLS

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

#### Instructions:

1. Use specified units.

- 2. Data entry is restricted to columns B through T and rows 25 through 38. The protection option has been employed to help ensure that data are input in the correct cells.
- 3. February totals are consumptions and loads just for the month of February. Similarly, February means and maxima are those values just for the month of February.
- 4. Cooling energy consumption, evaporator coil load, zone load, and COP are defined in Section 3.

[Informative Note: Change Section A2.1 to A2.3 and move it to the correct sequence (heading change only).]

Attachment <u>A2.1A2.3</u> Standard 140 Output Form - Modeling Notes

[Informative Note: Change Section A2.3 to A2.4 (heading change only).]

Attachment <u>A2.3A2.4</u> Example of Modeling Notes for BLAST 3.0<sup>3</sup>

[Informative Note: Change Section A2.4 to A2.5 (heading change only).]

Attachment A2.4<u>A2.5</u> Example of Modeling Notes for DOE-2.1E<sup>5</sup>

(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.)

## **ANNEX B1**

# TABULAR SUMMARY OF TEST CASES

[Informative Note: Revise the introductory paragraph for Annex B1 as follows.]

Tables B1-1A and B1-1B include a tabular summary of the <u>building thermal envelope and fabric load</u> test cases described in Section 5.2, in SI units only. Tables B1-2A and B1-2B include a tabular summary of the HVAC Equipment Performance test cases described in Section 5.3, in SI and I-P units respectively.

#### NOMENCLATURE

# [Informative Note: Add the following abbreviations to the nomenclature used in Tables B1-1A and B1-1B.]

- ARI Air Conditioning and Refrigeration Institute
- EDB entering dry-bulb temperature
- **ODB** outdoor dry-bulb temperature
- PLR part-load ratio
- SHR sensible heat ratio

	Zone			Weather			
	Internal Gains*		Setpoint				
	Sensible	Latent	EDB	ODB			
Case #	(W)	(W)	(°C)	(°C)	Comments		
dry zone series							
E100	5400	0	22.2	46.1	Base case, dry coil. High PLR.		
E110	5400	0	22.2	29.4	High PLR. Tests low ODB versus E100.		
E120	5400	0	26.7	29.4			
EIZU	5400	U	20.7	29.4	High PLR. Tests high EDB versus E110. Tests ODB & EDB interaction versus E100.		
E130	270	0	22.2	46.1	Low PLR test versus E100.		
E140	270	0	22.2	29.4			
					Tests PLR at low ODB vs E110.		
humid zor		=					
E150	5400	1100	22.2	29.4	5 5		
54.00	5 400	4400	00.7	00.4	Tests latent load versus E110.		
E160	5400	1100	26.7	29.4			
E165	5400	1100	23.3	40.6	Tests EDB versus E150.		
EI65	5400	1100	23.3	40.6	High PLR. High SHR. Tests ODB & EDB interaction with latent load versus E160.		
E170	2100	1100	22.2	29.4	Mid PLR. Mid SHR.		
					Tests low sensible load versus E150.		
E180	2100	4400	22.2	29.4	High PLR. Low SHR.		
					Tests SHR versus E150.		
					Tests high latent load versus E170.		
E185	2100	4400	22.2	46.1	High PLR. Low SHR.		
					Tests ODB versus E180.		
E190	270	550	22.2	29.4			
					Tests low PLR at constant SHR vs E180.		
-	070				Tests latent load at low PLR versus E140.		
E195	270	550	22.2	46.1	Low PLR. Low SHR		
					Tests ODB at low PLR & SHR versus E190.		
					Tests low PLR at constant SHR vs E185.		
	Tests latent load at low PLR versus E130.						
	full load test at ARI conditions						
E200	6120	1817	26.7	35.0	Tests for ARI indoor wetbulb temperature at full sensible and latent loads.		
Abbreviations: PLR = Part Load Ratio; ODB = outdoor drybulb temperature; EDB = entering drybulb temperature; vs = versus;							
	SHR = Sensible Heat Ratio; ARI = Air Conditioning and Refrigeration Institute.						
ont – censiste rical natio, Ant – An conditioning and heingeration institute.							
*Internal Gains are internally generated sources of heat and humidity that are not related to							
internal Gains are internally generated sources of near and numberly that are not related to							

operation of the mechanical cooling system or its air distribution fan.

# TABLE B1-2a HVAC BESTEST Case Descriptions (SI Units).

i22case4.xls, a:a1..h48; May 30, 2000

# TABLE B1-2b HVAC BESTEST Case Descriptions (I-P Units).

	Zone		Weather		
	Internal Gains*		Setpoint		
	Sensible	Latent	EDB	ODB	
Case #	(Btu/h)				Comments
dry zone series					
E100	18430	0	72.0	115.0	Base case, dry coil. High PLR.
E110	18430	0	72.0	85.0	High PLR. Tests low ODB versus E100.
E120	18430	0	80.0	85.0	High PLR. Tests high EDB versus E110. Tests ODB & EDB interaction versus E100.
E130	922	0	72.0	115.0	Low PLR test versus E100.
E140	922	0	72.0	85.0	Tests ODB at low PLR vs E130. Tests PLR at low ODB vs E110.
humid zor	ne series				
E150	18430	3754	72.0	85.0	High PLR. High SHR. Tests latent load versus E110.
E160	18430	3754	80.0	85.0	High PLR. High SHR.
E165	18430	3754	74.0	105.0	Tests EDB versus E150. High PLR. High SHR. Tests ODB & EDB interaction with latent load versus E160.
E170	7166	3754	72.0	85.0	Mid PLR. Mid SHR.
E180	7166	15018	72.0	85.0	Tests low sensible load versus E150. High PLR. Low SHR. Tests SHR versus E150.
E185	7166	15018	72.0	115.0	Tests high latent load versus E170. High PLR. Low SHR. Tests ODB versus E180.
E190	922	1877	72.0	85.0	Low PLR. Low SHR
E195	922	1877	72.0	115.0	Tests low PLR at constant SHR vs E180. Tests latent load at low PLR versus E140. Low PLR. Low SHR Tests ODB at low PLR & SHR versus E190. Tests low PLR at constant SHR vs E185.
					Tests latent load at low PLR versus E130.
full load te					
E200	20890	6200	80.0	95.0	Tests for ARI indoor wetbulb temperature at full sensible and latent loads.
Abbreviations: PLR = Part Load Ratio; ODB = outdoor drybulb temperature;					
EDB = entering drybulb temperature; vs = versus; SHR = Sensible Heat Ratio; ARI = Air Conditioning and Refrigeration Institute.					
*Internal Gains are internally generated sources of heat and humidity that are not related to operation of the mechanical cooling system or its air distribution fan.					
i22case4 xls h:a1 h48: May 10 2001					

i22case4.xls, b:a1..h48; May 10, 2001

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## **ANNEX B2**

# ABOUT TYPICAL METEOROLOGICAL YEAR (TMY) WEATHER DATA

#### [Informative Note: Revise Annex B2 as follows.]

TMY data are used in Standard 140, <u>Section 5.2</u> for the following reasons:

- The original research that is the foundation of Standard 140, IEA BESTEST, was performed by the International Energy Agency.<sup>14</sup> -(Judkoff and Neymark, 1995) The underlying research used in this standard began in 1990 and was completed in 1993. At that time TMY data represented the state of the art regarding hourly weather data.
- During the process of converting the original IEA work into a Standard Method of Test, SPC 140 considered changing the weather data file and format. The problems with this were that:
  - Some parts of the test specification are based on the specific TMY data file provided with Standard 140. For example, the convective portion of annual average exterior combined surface coefficients – provided for those programs that do not calculate exterior convection hourly – are related to the average annual wind speed from the original weather data file. This means that some inputs in the test specification would need to be changed.
  - 2. The example results of informative Annex B8 would not be consistent with user-generated results if new weather data were used—unless the test cases were rerun for all the programs shown. For many users of Standard 140, the evaluation of results will be facilitated by being able to compare the results for their program with the example results presented in Annex B8, which requires using consistent testing methods and weather data.

For these reasons, SPC 140 decided to keep the original TMY weather data and the detailed documentation of the TMY weather data format. For Section 5.3, either TMY-format data or TMY2-format data may be used as described in Annex A1, Section A1.2.

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## **ANNEX B8**

## EXAMPLE RESULTS FOR BUILDING THERMAL ENVELOPE AND FABRIC LOAD TESTS

#### [Informative Note: Revise Annex B8 as noted.]

The example results from various detailed building energy simulation programs that applied the tests of Section <u>5.2</u> 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 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. Section B9.4.

The building energy simulation computer programs used to generate example results are described in informative Annex B11. These computer programs 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 results presented, to the extent possible, input errors or differences have been eliminated. Thus, for a given case the range of differences between results presented in the informative Annex B8 represents 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:

- (a) user input error, where the user misinterpreted or mis-entered 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.

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

For the convenience to users who wish to plot or tabulate their results along with the example results, an electronic version of the example results has been included with the file RESULTS<u>5-2.XLSWK3</u> in the files accompanying this standard. Documentation regarding RESULTS<u>5-2.XLSWK3</u> has been included with the file and is printed out in informative Annex B10. Section B10.1, for convenience.

For generating these results, along with using consistent modeling methods, simulationists were requested to use the most detailed modeling methods their software allows. For a summary of how example results were developed see informative Annex B11. For more detailed information about the example results see *IEA BESTEST*<sup>14</sup>.

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## **ANNEX B9**

# DIAGNOSING THE RESULTS USING THE FLOW DIAGRAMS

#### [Informative Note: Revise Sections B9.1 – B9.4 as noted.]

**B9.1** General Description. Figures B9-1 through <u>B9-5B9-</u>4 contain a set of flow diagrams that serve as a guide for diagnosing the cause of disagreeing results that may arise from using this <u>method of</u> 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) <u>availability of analytical or quasi-analytical solution</u> results (i.e., mathematical truth standard as described in informative Annex B16, Section B16.2),
- (f) for the HVAC equipment performance tests of Section 5.3, the degree of disagreement that occurred for other simulation results in Annex B16 versus the quasi-analytical solution results.

**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. For the tests of Section 5.2, **T**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, <u>using Figure B9-1</u>, 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 recheck 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 judgment of the user, the disagreement is due to 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).

**B9.5**<u>B9.4.2</u> **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.

**B9.6B9.4.3** 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 B9-3) 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.

#### [Informative Note: Add new Section B9.5.]

# **B9.5** Diagnostic Logic Flow Diagram for HVAC Equipment Performance Tests (Section 5.3)

**B9.5.1 General Description.** 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. 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.

**B9.5.2** Consideration of Quasi-Analytical Solution Results. As a minimum, the user should compare output with the quasi-analytical solution results found in Annex B16. The user may also choose to compare output with the example simulation results in Annex B16 or with other results that were generated using Section 5.3 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 RESULTS5-3.XLS on the accompanying electronic media (available at http://www.ashrae.org/ template/PDFDetail?assetID=34505). Regarding determination of agreement of results discussed in B9.2.2, in making this determination for the HVAC equipment performance tests of Section 5.3, the user should consider that the quasi-analytical solution results given in Annex B16 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). 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.

# [Informative Note: Renumber current Section B9.7 as B9.6 and revise as follows.]

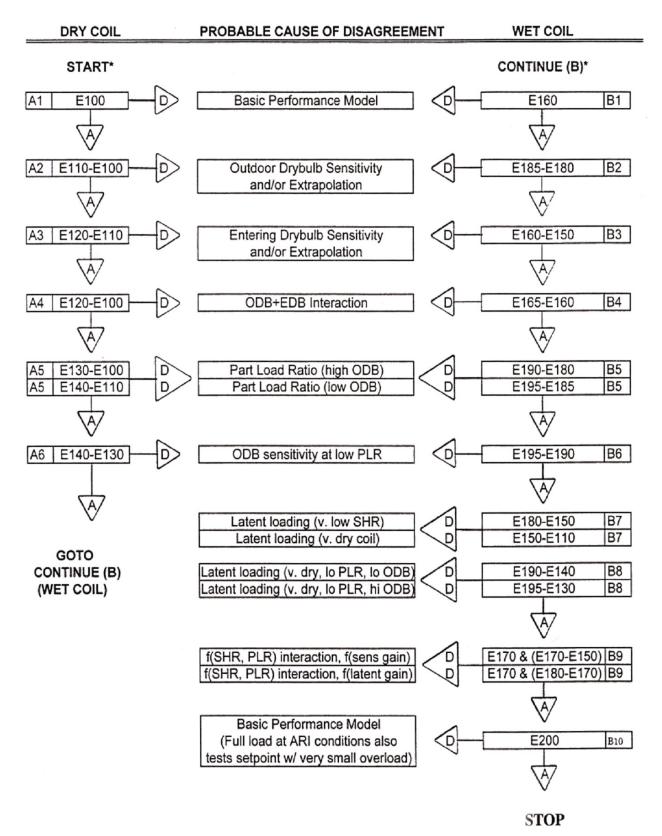
#### B9.76 Examples

**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*<sup>14</sup> gives examples of how the tests were used to trace and correct specific algorithmic and input errors in the programs used to produce example results of informative Annex B8.

**B9.6.2 Example using Flow Diagrams for HVAC Equipment Performance Tests (Section 5.3).** 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.

<u>HVAC BESTEST<sup>A-5</sup> gives examples of how the tests were</u> 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.



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

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

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## **ANNEX B10**

# INSTRUCTIONS FOR WORKING WITH RESULTS SPREADSHEETS PROVIDED ON CD WITH THE STANDARD

# [Informative Note: Revise introductory paragraph and Section B10.1 as follows.]

For the convenience of users, a printout of documentation included with for navigating the example results files on the CD (RESULTS2.WK3) is included below.

# B10.1 Documentation for RESULTS<u>5-</u>2.XLS<del>WK3</del> 21 APR 1998

This spreadsheet contains the IEA 12B/21C participant results that are presented in informative Annex B8. These data are provided for the convenience of users who wish to plot or tabulate their results along with the example results. This spreadsheet was <u>originally</u> created with Lotus 1-2-3 version 3.1 for DOS.

The spreadsheet contains only values and text (no formulas).

The Standard Output Report spreadsheet (S140OUT2Sec5-2out.XLSWK3) has been designed such that values input to Column B of S140OUT2Sec5-2out.XLSWK3 can be directly transferred to Column J of this spreadsheet.

#### [Informative Note: Add new Section B10.2.]

# B10.2 Documentation for RESULTS5-3.XLS (given in RESULTS5-3.DOC)

Import data so that Cell A1 of Sec5-3out.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.

# **Contents of Sheets:**

Sheet	Description
ʻA'	Raw data compilation.
'YD'	For inputting new results (your data); see above for instructions.
'B' – 'G', 'L'	Results from each simulation program. 'E' is blank.
'H' – 'J'	Results from the quasi-analytical solutions.
'Q'	Formatted summary results tables including quasi-analytical solutions, simulations and statistics. "Your data" auto- matically appears on the right side of each table. See below for Sheet Q table locations.
'R'	Formatted summary results tables and statistics for quasi-analytical solutions only. See below for Sheet 'R' table locations. (Sheet 'R' is not reproduced in the hardcopy.)
'COP' thru 'QCL- QZL' (26 sheets)	26 summary charts (one per sheet). Import of "your data" into these charts is not automated. However the data does automatically appear on the right side of the tables used for making the charts. See below.
"Data"-x' (last 5 sheets)	5 data sheets that the 26 data charts are linked to. "Your data" automatically appears on the right side of each data table.

# Contents of Sheet Q:

Description	Cell Range
Space Cooling Electricity Consumption (Total, Compressor, Supply Fan, Condenser Fan)	A6 – P75
COP including (Max-Min)/Mean	A185 – P220
Coil Loads: Total, Sensible, Latent, and (Sensible Coil)-(Sensible Zone)	BC77 – BR147
Zone Loads: Total, Sensible, Latent, and (Latent Coil)-(Latent Zone)	BT77 – CI147
Sensitivities for Space Cooling Electricity Consumption (Total, Compressor, ID fan, OD fan)	CK491 – CZ580
Sensitivities for COP and Coil Loads (Total, Sensible, and Latent)	DB491 – DQ580
Zone IDB and Humidity Ratio including (Max-Min)/Mean	BC233 – BR304

# **Contents of Sheet R:**

Description	Cell Range
COP, IDB and Humidity Ratio including (Max-Min)/Mean	A85 – K141
Space Cooling Electricity Consumption, Coil Loads, Zone Loads, Fan Heat and Latent Loads Check	AM06 – BE81
Sensitivities for Space Cooling Electricity Consumption, COP and Coil Loads	\$145 – AK192

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#### ANNEX B11

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

# [Informative Note: Revise selected paragraphs in Annex B11 as follows.]

To minimize the potential for user error, when feasible, more than one modeler developed input files for each program. This was done for BLAST, SERIRES, and TRNSYS. Where disagreement in the inputs or results was found, the modelers were requested to resolve the differences. Where only a single modeler was involved, it was strongly recommended that inputs be carefully checked by another modeler familiar with the program.

Input decks used to generate the results are provided in the files accompanying this standard (available at http://www.ashrae.org/template/PDFDetail?assetID=34505); see the README.DOCTXT file. 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.

#### **B11.3** Hourly Time Convention

Details of differences in modeling methods utilized by various software are given in Part II of *IEA BESTEST*<sup>14</sup>. 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<u>. Section A1.3</u>, for discussion of the difference between solar time and standard time). The time convention is therefore most correctly modeled by software which re-bins 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 re-binning 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<u>, Section A1.3</u>) because the building site has been located within 0.1° 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. (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.)

#### **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),

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.

		Total Ca	apacities			
	ODB	Qnetcap,list	Qnetcap,adj	Qcomp	Qfans	EER
	(°F)	(kBtu/h)	(kBtu/ h)	(kW)	(kW)	
	90	27.6	27.9	1.79	0.34	13.13
	85	28.4	28.7	1.71	0.34	14.03
						extrap
	82					14.57
[	Egn (2) i	mplies 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 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.<sup>A-7</sup> However, real equipment that cycles ON/OFF has controls that prevent operation at PLR less than or equal to approximately 0.05. For the purpose of testing simulation software 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 based on guidance from the equipment manufacturer as

$$PLR1 = Qnet / CAPnet$$

where

Qnet = net refrigeration effect,

CAPnet = adjusted net total capacity.

We wish to check the equivalence of defining PLR as

$$PLR2 = Qgtc / CAPgtc$$

where

Qgtc = gross total coil load,

CAPgtc = gross total capacity.

The net refrigeration effect = Qgtc - Qfanwhere Qfan is the air distribution fan heat.

The adjusted net capacity = CAPgtc - Pfanwhere Pfan = fan rated power.

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.

For cases E100-E200, because the indoor fan cycles on/ off with the compressor, we originally defined the net refrigeration effect 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, it is useful to think of

However, this relation implies

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

with the theoretical result that  $PLR1 \neq PLR2$ .

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 table. This analysis applies values of coil capacity and fan power for the equipment at ARI rating conditions. From this analysis we observe (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 <0.05%, which is negligible. Thus, we conclude that for the purpose of calculating CDF, either PLR1 or PLR2 may be used.

PLR2									PLR1=				
	CAPgtc	Ogto	Pfan		Qfan	Qfan/	Qnet	CAPnet	Qnet/	PLR2/	PLR2 -		CDF2/
	(Btu/h)	(Btu/h)	(Btu/h)	CDF2	(Btu/h)	Pfan	(Btu/h)	(Btu/h)	CAPnet	PLR1	PLR1	CDF1	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

Note regarding the above spreadsheet table: 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), the additional run time (fan heat) for mid-PLR Case E170 is 0.5% greater if this effect is taken into account. Since 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.

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#### **ANNEX B14**

## **COOLING COIL BYPASS FACTOR**

#### **B14.1** Introduction

Calculation techniques provided here are for illustrative purposes. Some models may have slight variations in the calculation, including the use of enthalpy ratios rather than dry-bulb temperature ratios in Equation B14-1 (below), or different specific heat assumptions for leaving air conditions in Equation B14-3 (below), among others.

Cooling coil BF can be thought of as the fraction of the distribution air that does not come into contact with the cooling coil; the remaining air is assumed to exit the coil at the average coil surface temperature (ADP). BF at ARI rating conditions is *approximately* 

$$0.049 \le BF \le 0.080.$$

The uncertainty surrounding this value is illustrated in the two examples for calculating BF from given manufacturer data that are included in the rest of this annex, as well as from separate calculation results by Technische Universität Dresden (TUD). The uncertainty can be traced to the calculated ADP (56.2°F) being different from the ADP listed by the manufacturer (56.8°F). Because we have been unable to acquire the manufacturer's specific method for determining ADP, we have not been able to determine which ADP number is better. However, the manufacturer has indicated that performance data are only good to within 5% of real equipment performance. So we can hypothesize that the listed versus calculated ADP disagreements could be a consequence of the development of separate correlation equations for each performance parameter within the range of experimental uncertainty. Based on simulation sensitivity tests with DOE-2.1E, the above range of BF inputs causes total electricity consumption to vary by  $\pm 1\%$ .

Calculations based on the listed performance data indicate that BF varies as a function of EDB, EWB, and ODB. Incorporate this aspect of equipment performance into your model if your software allows it, using a consistent method for developing all points of the BF variation map. (Note that sensitivity tests for cases E100–E200 using DOE-2.1E indicate that assuming a constant value of BF—versus allowing BF to vary as a function of EWB and ODB—adds an additional  $\pm 1\%$ uncertainty to the total energy consumption results for Case E185 and less for the other cases.)

The equipment manufacturer recommends modeling the BF as independent of (*not* varying with) the PLR. This is because the airflow rate over the cooling coil is assumed constant when the compressor is operating (fan cycles on/off with compressor).

#### B14.2 Calculation of Coil Bypass Factor

## B14.2.1 Nomenclature

	annext a land a sint (OE)
ADP	apparatus dew point (°F)
BF	bypass factor (dimensionless)
cp <sub>a</sub>	specific heat of dry air (Btu/lb°F)
cpw	specific heat of water vapor (Btu/lb°F)
h <sub>1</sub>	enthalpy of air entering cooling coil (Btu/lb dry air)
h <sub>2</sub>	enthalpy of air leaving cooling coil (Btu/lb dry air)
q <sub>s</sub>	gross sensible capacity (Btu/h)
$q_{\mathrm{T}}$	gross total capacity (Btu/h)
Q	indoor fan airflow rate (ft <sup>3</sup> /min)
T <sub>db1</sub>	entering dry-bulb temperature (°F)
T <sub>db2</sub>	leaving dry-bulb temperature (°F)
T <sub>wb1</sub>	entering wet-bulb temperature (°F)
W	humidity ratio (lb water vapor/lb dry air)
$ ho_r$	density of standard dry air at fan rating conditions (0.075 lb/ft <sup>3</sup> )

#### B14.2.2 Known Information

Air-Conditioning and Refrigeration Institute (ARI) Conditions:

- $T_{db1} = 80^{\circ}F$
- $T_{wb1} = 67^{\circ}F.$

From Table 26d at ARI conditions:

- $Q = 900 \text{ ft}^3/\text{min}$
- $q_s = 21700 \text{ Btu/h}$  (gross sensible capacity)
- $q_T = 27900$  Btu/h (gross total capacity)
- ADP =  $56.8^{\circ}$ F.

## B14.2.3 Governing Equations

$$BF = (T_{db2} - ADP)/(T_{db1} - ADP)$$
 (Eq. B14-1)<sup>A-8</sup>

The following equations and related properties are commonly used approximations for working with volumetric flow rates.<sup>A-9</sup>

$$q_T = \rho_r Q (60 \text{ min/h}) (h_1 - h_2)$$
 (Eq. B14-2)

 $q_s = \rho_r Q (60 \min/h) (cp_a + cp_w(w)) (T_{db1} - T_{db2})$  (Eq. B14-3)

$$\label{eq:rho} \begin{split} \rho_r &= 0.075 \ lb/ft^3 \\ cp_a &= 0.24 \ Btu/lb^\circ F \\ cp_w &= 0.45 \ Btu/lb^\circ F \end{split}$$

#### $w \approx 0.01$ lb water vapor/lb dry air.

So for these English units, Equations (B14-2) and (B14-3) become:

$$q_T = 4.5 \text{ Q} (h_1 - h_2)$$
 (Eq. B14-2a)  
 $q_s = 1.10 \text{ Q} (T_{db1} - T_{db2})$  (Eq. B14-3a)

# **B14.2.4** Solution Technique Using ADP Calculated by Extending the Condition Line to the Saturation Curve.

To find ADP, extend the condition line of the system through the saturation curve on the psychrometric chart.<sup>A-10</sup> The condition line is the line going through coil entering conditions with slope determined by sensible heat ratio for the given operating conditions.<sup>A-8</sup> This example is illustrated on the psychrometric chart in Figure B14-2. To draw the condition line, State 2 must be determined; State 1 is ARI conditions (T<sub>db1</sub> = 80.0°F, T<sub>wb1</sub> = 67°F). Defining State 2 requires two independent properties that can be identified from Equations (B14-2) and (B14-3).

Solve for  $h_2$  using Equation (B14-2) with  $q_T = 27,900$ Btu/h and Q = 900 ft<sup>3</sup>/min. From ideal gas equations commonly used for psychrometrics,<sup>1</sup> at ARI conditions  $h_1 =$ 31.45 Btu/lb dry air. These values applied to Equation (B14-2) give:

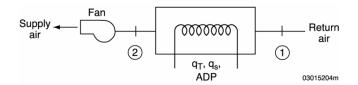
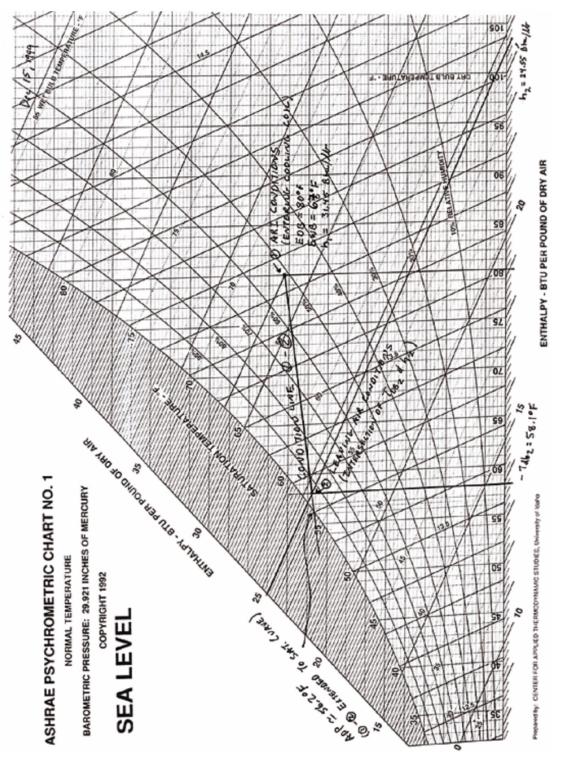


Figure B14-1 System schematic.





# $h_2 = 24.55$ Btu/lb dry air.

Solving for  $T_{db2}$  using Equation (B14-3) with  $T_{db1} = 80^{\circ}$ F,  $q_s = 21700$  Btu/h, and Q = 900 ft<sup>3</sup>/min gives:

 $T_{db2} = 58.1^{\circ}F.$ 

On the psychrometric chart, drawing a line through these two states and extending it to the saturation curve gives:

$$ADP = 56.2^{\circ}F.$$

Solving Equation (B14-1) using  $T_{db1} = 80^{\circ}F$ ,  $T_{db2} = 58.1^{\circ}F$ , and ADP = 56.2°F gives:

#### BF = 0.080

**B14.2.5** Solution Technique Using ADP Listed in Performance Data

Solving Equation (B14-1) using  $T_{db1} = 80^{\circ}F$ ,  $T_{db2} = 58.1^{\circ}F$ , and  $ADP = 56.8^{\circ}F$  gives:

$$BF = 0.055$$

#### B14.2.6 Solution by TUD

The TRNSYS-TUD modeler report in Part III of HVAC BESTEST<sup>A-5</sup> indicates that:

$$\mathbf{BF} = \mathbf{0.049}$$

This solution is based on manufacturer-listed values of ADP.

#### B14.3 Conclusions

The BF for this system at ARI conditions is *approximately* in the range of:

$$0.049 \leq BF \leq 0.080$$

Some uncertainty is associated with the governing equations and related properties commonly used for calculating leaving air conditions; these equations are approximations. In addition, some uncertainty is associated with using the psychrometric chart to find the ADP (56.2°F) in the first solution. Finally, there may be additional uncertainty related to the methodology for developing ADP. For example, the results of Equation B14-1 can be slightly different if enthalpy ratios are used in place of dry bulb temperature ratios. Also, documentation of how the manufacturer calculated its listed ADP was unavailable, and the source code for manufacturer software used to develop catalog data is proprietary.

Based on sensitivity tests with DOE-2.1E:

- The above range of BF inputs causes total electricity consumption to vary by ±1%.
- Assuming a constant value of BF versus allowing BF to vary as a function of EWB and ODB adds an additional ±1% uncertainty to the total energy consumption results for Case E185, and less for the other cases.

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### **ANNEX B15**

## **INDOOR FAN DATA EQUIVALENCE**

Fan performance data for indoor fan power (230 W) and airflow rate (900 CFM =  $0.425 \text{ m}^3/\text{s}$ ) 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<sup>3</sup> (1.204 kg/m<sup>3</sup>).<sup>A-9</sup>

The fan efficiency of 0.5 is based on a discussion with the unitary system manufacturer.

The total fan pressure is based on:<sup>A-11</sup>

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

where

 $Q \equiv indoor fan airflow rate (m<sup>3</sup>/s)$ 

 $\Delta P \equiv \text{total fan pressure (Pa)}$ 

 $W \equiv fan \ electric \ power \ input \ (W)$ 

Eff  $\equiv$  total fan plus motor and drive efficiency (motor/drive in air stream).

Solving for  $\Delta P$ ,

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

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

The supply air temperature rise from fan heat is based on

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

where

 $q_{fan} \equiv fan heat (Btu/h or W),$ 

$$=$$
 standard air density = 0.075 lb/ft<sup>3</sup> (1.204 kg/m<sup>3</sup>),

 $c_p \equiv \text{specific heat of air (Btu/(lb°F) or kJ/(kgK))},$ 

 $Q \equiv \text{indoor fan airflow rate (ft^3/min or m^3/s),}$ 

$$\Delta T \equiv \text{supply air temperature rise from fan heat (°F or °C)},$$

 $C \equiv units conversion constant.$ 

Solving for  $\Delta T$ ,

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

where

$$q_{\text{fan}} = 230 \text{ W} = 785 \text{ Btu/h}; \text{ Q} = 900 \text{ CFM} = 0.425 \text{ m}^3/\text{s},$$

 $c_p = 0.24$  Btu/lb F for dry air, or

$$c_{\rm p} = 0.2445$$
 Btu/lb F when humidity ratio = 0.01.<sup>A-9</sup>

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

$$\Delta T = 0.793^{\circ}F (0.441 \ ^{\circ}C)$$

or

for 
$$cp = 0.24 \text{ Btu}/(lb^{\circ}F)$$
,  $\Delta T = 0.808^{\circ}F (0.449^{\circ}C)$ .

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#### ANNEX B16

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

## **B16.1** Introduction

The results from quasi-analytical solutions and various detailed building energy simulation programs applied to the tests of Section 5.3 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 quasi-analytical solution results and example simulation results has been included with the spreadsheet file RESULTS5-3.XLS in the accompanying files (available at http://www.ashrae.org/template/PDFDetail?assetID=34505). Spreadsheet navigation instructions are included in RESULTS5-3.DOC and have been printed out in informative Annex B10, Section B10.2 for convenience.

## **B16.2** Importance of 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 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 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 accept the given underlying physical assumptions while recognizing that these assumptions represent a simplification of physical reality. The ultimate or "absolute" validation standard would be comparison of simulation results with a *perfectly performed* empirical experiment, the inputs for which are *perfectly 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 quasianalytical solution results presented in Annex B16 are small enough to allow 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 solutions were developed is included in Annex B17.

#### **B16.3** Example Simulation Results

Because the quasi-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 cases in Annex B16 is to allow simulationists to compare their relative agreement (or disagreement) versus the quasi-analytical solution results to that for other simulation results. Perfect agreement among simulations and quasi-analytical solutions is not necessarily expected. The results give an indication of what sort of agreement is possible between simulation results and the quasi-analytical solution results.

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

- (a) user input error, where the user misinterpreted or mis-entered 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.

For generating simulation results, 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 specification, simulation input deck corrections, and simulation software improvements. 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*.<sup>A-5</sup>

#### **B16.4** Nomenclature

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
ARI	Air-Conditioning & Refrigeration Institute
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)
СОР	coefficient of performance
Delta	sensitivity between listed cases

DOE21E	DOE-2.1E-088 or DOE-2.1E-133 (see Table B17-1)	ODB PL	outdoor dry-bulb temperature part-load ratio
dry	dry coil	PLR	part-load ratio
EDF	Electricité de France	Qcoil,lat	latent coil load
Energy+	EnergyPlus 1.0.0.023 (see Table B17-1)	Qcoil,s	sensible coil load
Hi	high	Qcoil,t	total sensible + latent coil load
HTAL1	quasi-analytical solution with ideal controller	Qcomp	compressor electric energy
	by Hochschule Technik & Architektur Luzern	Q ID fan	indoor fan electric energy
HTAL2	quasi-analytical solution with realistic	Q OD fan	outdoor fan electric energy
	controller model by Hochschule Technik & Architektur Luzern	Qtot	total electric energy of compressor + both fans
IDB	indoor dry-bulb temperature	sens	sensible internal gains
kWh	kilowatt hours	SH	sensible heat ratio
kWh,e	kilowatt hours, electrical	SHR	sensible heat ratio
lat	latent internal gains	TRN-id	TRNSYS-TUD with ideal controller (see Table
	·		B17-1)
lo	low	TRN-re	TRNSYS-TUD with realistic controller (see
m	mid-range		Table B17-1)
Max	maximum	TUD	Technische Universitat Dresden
Min	minimum	<b>v.</b>	versus
GARD	GARD Analytics	x	multiplied by
NREL	National Renewable Energy Laboratory	@	at

	Space Cooling Electricity Consumption Energy Consumption, Total (kWh,e) Statistics, All Results												
Energy					<b>F</b>			Statistic	s, All Res				
	CA-SIS EDF	CLM2000 EDF	DOE21E	DOE21E		TRN-id	TRN-re	Min	May	(Max-Min)	TUD	Analytical	LITALO
E100	1531	1530	CIEMAT 1521	NREL 1519	GARD 1520	TUD 1522	TUD 1512	Min 1512	1531	/Analytical 1.2%	1531	HTAL1 1531	HTAL2 1531
E100	1077	1089	1061	1065	1069	1067	1062	1061	1089	2.6%	1076	1077	1077
E120	1012	1012	1011	1003	1005	1007	1002	1001	1012	1.0%	1013	1011	1011
E130	110	109	105	106	109	109	110	105	110	4.2%	111	110	110
E140	68	69	65	66	68	68	69	65	69	5.8%	69	69	68
E150	1208	1207	1202	1183	1197	1199	1192	1183	1208	2.1%	1206	1207	1207
E160	1140	1139	1138	1107	1132	1137	1133	1107	1140	2.9%	1140	1139	1139
E165	1502	1501	1499	1470	1491	1500	1490	1470	1502	2.1%	1498	1500	1500
E170	638	638	629	620	635	636	636	620	638	2.8%	641	638	638
E180	1083	1082	1077	1080	1082	1081	1080	1077	1083	0.5%	1083	1082	1082
E185	1544	1543	1541	1547	1540	1542	1538	1538	1547	0.6%	1545	1543	1543
E190	164	164	160	160	164	164	165	160	165	3.1%	165	164	164
E195	250	250	245	246	250	250	252	245	252	2.6%	252	250	250
E200	1477	1464	1468	1440	1465	1480	1480	1440	1480	2.7%	1476	1477	1477
Energy	Consumpt	ion, Compre	essor (kWh					Statistic	s, All Res	sults			
	CA-SIS	CLM2000	DOE21E	DOE21E	Energy+	TRN-id	TRN-re			(Max-Min)	ļ	Analytical	
	EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	Min		/ Analytical	TUD	HTAL1	HTAL2
E100	1319	1318	1307	1311		1311	1303	1303	1319	1.2%	1319	1319	1319
E110	889	899	866	883		879	876	866	899	3.7%	888	889	889
E120	840	840	850	838		836	832	832	850	2.2%	841	839	839
E130	95	94	93	93		94	95	93	95	2.1%	95	94	94
E140	57	57	55	56		56	57	55	57	3.9%	57	57	56
E150	1000	999	1007	982		992	987	982	1007	2.5%	999	999	999
E160	950	949	963	926		947	944	926	963	3.9%	950	949	949
E165	1283	1281	1291	1256		1280	1272	1256	1291	2.8%	1279	1280	1280
E170	531	530	539	523		528	529	523	539	3.0%	533	530	530
E180	909	908	914	912		907	906	906	914	0.9%	908	908	908
E185	1340	1339	1343	1344		1337	1334	1334	1344	0.7%	1340	1339	1338
E190	138	138	139	138		138	138	138	139	1.4%	138	138	138
E195	217	217	219	217		216	218	216	219	1.1% 2.8%	219	217	217
E200	1250	1239 ion, Supply	1249	1218		1253	1253	1218 Statistic	1253 s, All Res		1249	1250	1250
Energy	CA-SIS		DOE21E	DOE21E	Energy+	TRN-id	TRN-re	Statistic	s, All Net	(Max-Min)		Analytical	
	EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	Min	Max	/ Analytical	םטד (	HTAL1	HTAL2
E100	144	144	145	141	144	144	142	141	145	2.9%	144	144	144
E110	128	129	133	122	128	128	127	122	133	8.5%	128	128	128
E120	117	117	110	110	116	117	115	110	117	6.3%	117	117	117
E130	10	10	8	8	10	10	10	8	10	23.0%	10	10	10
E140	8	8	7	6	8	8	8	6	8	26.9%	8	8	8
E150	141	141	133	136	140	141	139	133	141	5.7%	141	141	141
E160	129	129	119	121	128	129	128	119	129	7.8%	129	129	129
E165	149	150	142	145	149	149	148	142	150	5.6%	149	149	149
E170	73	73	61	63	73	73	73						
E180	118						10 1	61	73	16.1%	74	73	73
E185		119	111	112	118	118	118	61 111	73 119	16.1% 6.9%	74 119	73 119	73 119
	139	119 139	111 135		118 139								
E190	18	139 18	135 14	112	139 18	118 139 18	118 139 18	111 135 14	119 139 18	6.9% 3.0% 22.8%	119 139 18	119 139 18	119 139 18
E190 E195	18 23	139 18 23	135 14 18	112 137	139	118 139	118 139 18 23	111 135 14 18	119 139	6.9% 3.0% 22.8% 23.1%	119 139 18 23	119 139	119 139 18 23
E190 E195 E200	18 23 154	139 18 23 153	135 14 18 149	112 137 14 18 151	139 18	118 139 18	118 139 18	111 135 14 18 149	119 139 18 23 155	6.9% 3.0% 22.8% 23.1% 3.5%	119 139 18	119 139 18	119 139 18
E190 E195 E200	18 23 154 Consumpt	139 18 23 <u>153</u> ion, Conder	135 14 18 <u>149</u> Iser Fan (k <sup>1</sup>	112 137 14 18 <u>151</u> <b>Wh,e)</b>	139 18 23 153	118 139 18 23 155	118 139 18 23 155	111 135 14 18 149	119 139 18 23	6.9% 3.0% 22.8% 23.1% <u>3.5%</u> sults	119 139 18 23 154	119 139 18 23 155	119 139 18 23
E190 E195 E200	18 23 154 Consumpt CA-SIS	139 18 23 <u>153</u> ion, Conder CLM2000	135 14 18 149 Iser Fan (k <sup>i</sup> DOE21E	112 137 14 18 <u>151</u> <b>Wh,e)</b> DOE21E	139 18 23 153 Energy+	118 139 18 23 155 TRN-id	118 139 18 23 155 TRN-re	111 135 14 18 <u>149</u> Statistic	119 139 18 23 <u>155</u> s, All Res	6.9% 3.0% 22.8% 23.1% <u>3.5%</u> sults (Max-Min)	119 139 18 23 154	119 139 18 23 155 Analytical	119 139 18 23 155
E190 E195 E200 Energy	18 23 154 Consumpt CA-SIS EDF	139 18 23 153 ion, Conder CLM2000 EDF	135 14 18 <u>149</u> Iser Fan (k <sup>t</sup> DOE21E CIEMAT	112 137 14 18 <u>151</u> Wh,e) DOE21E NREL	139 18 23 153	118 139 18 23 155 TRN-id TUD	118 139 18 23 155 TRN-re TUD	111 135 14 18 <u>149</u> Statistic Min	119 139 18 23 155 s, All Res Max	6.9% 3.0% 22.8% 23.1% <u>3.5%</u> sults (Max-Min) / Analytical	119 139 18 23 154 / TUD	119 139 18 23 <u>155</u> Analytical HTAL1	119 139 18 23 155 HTAL2
E190 E195 E200 Energy E100	18 23 154 Consumpt CA-SIS EDF 68	139 18 23 153 ion, Conder CLM2000 EDF 68	135 14 18 149 Iser Fan (k DOE21E CIEMAT 68	112 137 14 18 <u>151</u> Wh,e) DOE21E <u>NREL</u> 67	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67	118 139 18 23 155 TRN-re TUD 67	111 135 14 18 <u>149</u> Statistic <u>Min</u> 67	119 139 18 23 <u>155</u> s, All Res <u>Max</u> 68	6.9% 3.0% 22.8% 23.1% 3.5% sults (Max-Min) / Analytical 2.0%	119 139 18 23 154 TUD 68	119 139 18 23 155 Analytical HTAL1 68	119 139 18 23 155 HTAL2 68
E190 E195 E200 Energy E100 E110	18 23 154 Consumpt CA-SIS EDF 68 60	139 18 23 153 ion, Conder CLM2000 EDF 68 61	135 14 18 149 Iser Fan (k DOE21E CIEMAT 68 62	112 137 14 18 <u>151</u> Wh,e) DOE21E NREL 67 60	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60	118 139 18 23 155 TRN-re TUD 67 59	111 135 14 18 <u>149</u> Statistic <u>Min</u> 67 59	119 139 18 23 <u>155</u> s, All Res <u>Max</u> 68 62	6.9% 3.0% 22.8% 23.1% 3.5% sults (Max-Min) / Analytical 2.0% 4.9%	119 139 18 23 154 <i>FUD</i> 68 60	119 139 18 23 155 Analytical HTAL1 68 60	119 139 18 23 155 HTAL2 68 60
E190 E195 E200 Energy E100 E110 E120	18 23 154 Consumpt CA-SIS EDF 68 60 55	139 18 23 153 ion, Conder CLM2000 EDF 68 61 55	135 14 18 149 Iser Fan (k' DOE21E CIEMAT 68 62 51	112 137 14 18 <u>151</u> Wh,e) DOE21E NREL 67 60 55	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60 55	118 139 18 23 155 TRN-re TUD 67 59 54	111 135 14 18 <u>149</u> Statistic <u>Min</u> 67 59 51	119 139 18 23 <u>155</u> s, All Res <u>Max</u> 68 62 55	6.9% 3.0% 22.8% 23.1% 3.5% (Max-Min) / Analytical 2.0% 4.9% 6.5%	119 139 18 23 154 <i>TUD</i> 68 60 55	119 139 18 23 155 Analytical HTAL1 68 60 55	119 139 18 23 <u>155</u> HTAL2 68 60 55
E190 E195 E200 Energy E100 E110 E120 E130	18 23 154 Consumpt CA-SIS EDF 68 60 55 55	139 18 23 153 ion, Conder CLM2000 EDF 68 68 61 55 5	135 14 18 149 Iser Fan (k' DOE21E CIEMAT 68 62 51 4	112 137 14 18 151 DOE21E NREL 67 60 55 5	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60 55 5 5	118 139 18 23 155 TRN-re TUD 67 59 54 5	111 135 14 18 <u>149</u> Statistic Min 67 59 51 4	119 139 18 23 <u>155</u> s, All Res <u>Max</u> 68 62 55 5	6.9% 3.0% 22.8% 23.1% 3.5% (Max-Min) / Analytical 2.0% 4.9% 6.5% 22.4%	119 139 18 23 154 TUD 68 60 55 5	119 139 18 23 155 Analytical HTAL1 68 60 55 5	119 139 18 23 155 HTAL2 68 60 55 55 5
E190 E195 E200 Energy E100 E110 E120 E130 E140	18 23 154 Consumpt CA-SIS EDF 68 60 55 5 5 4	139 18 23 153 ion, Conder CLM2000 EDF 68 61 55 55 5 4	135 14 18 149 Iser Fan (k' DOE21E CIEMAT 68 62 51 4 3	112 137 14 18 151 DOE21E NREL 67 60 55 5 4	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60 55 5 5 4	118 139 18 23 155 TRN-re TUD 67 59 54 5 5 4	111 135 14 18 149 Statistic Min 67 59 51 4 3	119 139 18 23 <u>155</u> s, All Res <u>Max</u> 68 62 55 5 5 4	6.9% 3.0% 22.8% 23.1% 3.5% (Max-Min) / Analytical 2.0% 4.9% 6.5% 22.4% 19.1%	119 139 18 23 154 TUD 68 60 55 5 5 4	119 139 18 23 155 Analytical HTAL1 68 60 55 5 4	119 139 18 23 155 HTAL2 68 60 55 55 5 4
E190 E195 E200 Energy E100 E110 E120 E130 E140 E150	18 23 154 Consumpt CA-SIS EDF 68 60 55 5 4 66	139 18 23 153 ion, Conder CLM2000 EDF 68 61 55 55 4 61	135 14 18 149 Iser Fan (k' DOE21E CIEMAT 68 62 51 4 3 62	112 137 14 18 151 DOE21E NREL 67 60 55 5 4 65	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60 55 5 4 66	118 139 18 23 155 TRN-re TUD 67 59 54 54 5 4 65	111 135 14 18 149 Statistic Min 67 59 51 4 3 62	119 139 18 23 155 s, All Res 68 62 55 5 4 66	6.9% 3.0% 22.8% 23.1% 3.5% (Max-Min) / Analytical 2.0% 4.9% 6.5% 22.4% 19.1% 5.6%	119 139 18 23 154 TUD 68 60 55 5 4 66	119 139 18 23 155 Analytical HTAL1 68 60 55 5 4 66	119 139 18 23 155 HTAL2 68 60 55 5 5 4 66
E190 E195 E200 Energy E100 E110 E120 E120 E130 E140 E150 E160	18 23 154 Consumpt CA-SIS EDF 68 60 55 55 5 4 66 61	139 18 23 153 ion, Conder CLM2000 EDF 68 61 55 5 4 66 61	135 14 18 149 Iser Fan (k' DOE21E CIEMAT 68 62 51 4 3 62 51 4 3 62 55	112 137 14 18 151 DOE21E NREL 67 60 55 5 4 65 60	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60 55 5 4 66 61	118 139 18 23 155 TRN-re TUD 67 59 54 5 5 4 4 65 60	111 135 14 18 <u>149</u> Statistic <u>Min</u> 67 59 51 4 3 62 56	119 139 18 23 155 s, All Res 68 62 55 55 5 4 66 61	6.9% 3.0% 22.8% 23.1% 3.5% (Max-Min) / Analytical 2.0% 4.9% 6.5% 22.4% 19.1% 5.6% 8.4%	119 139 18 23 154 TUD 68 60 55 5 4 66 61	119 139 18 23 155 Analytical HTAL1 68 60 55 5 5 4 4 66 61	119 139 18 23 155 HTAL2 68 60 55 5 5 5 5 5 5 4 66 61
E190 E195 E200 Energy E100 E110 E120 E120 E130 E140 E150 E160 E165	18 23 154 Consumpt CA-SIS EDF 68 60 55 5 5 4 66 61 70	139 18 23 153 ion, Conder CLM2000 EDF 68 61 55 5 4 66 61 70	135 14 18 149 DOE21E CIEMAT 68 62 51 4 3 62 51 4 3 62 56 67	112 137 14 18 151 DOE21E NREL 67 60 55 5 4 65 60 65 60 69	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60 55 5 5 4 66 61 70	118 139 18 23 155 TRN-re TUD 67 59 54 5 4 4 65 60 69	111 135 14 18 <u>149</u> Statistic <u>Min</u> 67 59 51 4 3 62 56 67	119 139 18 23 155 s, All Res 68 62 55 5 4 66 61 70	6.9% 3.0% 22.8% 23.1% 3.5% sults (Max-Min) / Analytical 2.0% 4.9% 6.5% 22.4% 19.1% 5.6% 8.4% 5.2%	119 139 18 23 154 TUD 68 60 55 5 4 66 61 70	119 139 18 23 155 Analytical HTAL1 68 60 55 5 4 66 61 70	119 139 18 23 155 HTAL2 68 60 55 5 4 66 61 70
E190 E195 E200 Energy E100 E110 E120 E130 E140 E150 E160 E165 E170	18 23 154 Consumpt CA-SIS EDF 68 60 55 5 4 66 66 61 70 34	139 18 23 153 ion, Conder CLM2000 EDF 68 61 55 5 4 66 66 61 70 34	135 14 18 149 DOE21E CIEMAT 68 62 51 4 3 62 51 4 3 62 56 67 29	112 137 14 18 151 DOE21E NREL 67 60 55 5 4 65 60 65 60 69 34	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60 55 5 4 66 61 70 34	118 139 18 23 155 TRN-re TUD 67 59 54 5 4 65 60 69 34	111 135 14 18 149 Statistic Min 67 59 51 4 3 62 56 67 29	119 139 18 23 155 s, All Res 68 62 55 5 4 66 61 70 34	6.9% 3.0% 22.8% 23.1% 3.5% (Max-Min) / Analytical 2.0% 4.9% 6.5% 22.4% 19.1% 5.6% 8.4% 5.2% 16.1%	119 139 18 23 154 TUD 68 60 55 5 4 66 61 70 35	119 139 18 23 155 Analytical HTAL1 68 60 55 5 4 66 61 70 34	119 139 18 23 155 HTAL2 68 60 55 5 4 66 61 70 34
E190 E195 E200 Energy E100 E110 E120 E120 E130 E140 E140 E165 E165 E170 E180	18 23 154 Consum pt CA-SIS EDF 68 60 55 5 4 66 61 70 34 56	139 18 23 153 ion, Conder CLM2000 EDF 68 61 55 5 4 66 61 70 34 56	135 14 18 149 DOE21E CIEMAT CIEMAT 68 62 51 4 3 62 51 4 3 62 51 6 6 6 7 29 52	112 137 14 18 151 DOE21E NREL 67 60 55 5 4 60 65 60 69 34 56	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60 55 5 4 66 66 61 70 34 56	118 139 18 23 155 TRN-re TUD 67 59 54 5 4 65 65 60 69 34 55	111 135 14 18 149 Statistic Min 67 59 51 4 3 62 56 67 29 52	119 139 18 23 <u>155</u> s, All Res 68 62 55 5 4 66 61 70 34 56	6.9% 3.0% 22.8% 23.1% 3.5% (Max-Min) / Analytical 2.0% 4.9% 6.5% 22.4% 19.1% 5.6% 8.4% 5.2% 16.1% 7.1%	119 139 18 23 154 TUD 68 60 55 5 4 66 61 70 35 56	119 139 18 23 155 Analytical HTAL1 68 60 55 5 4 66 61 61 70 34 55	119 139 18 23 155 HTAL2 68 60 55 5 4 66 61 70 34 56
E190 E195 E200 Energy E100 E110 E120 E120 E130 E140 E150 E165 E170 E180 E185	18 23 154 Consumpt CA-SIS EDF 68 60 55 5 4 66 61 70 34 56 65	139 18 23 153 ion, Conder CLM2000 EDF 68 61 55 5 4 66 61 70 34 56 65	135 14 18 149 DOE21E CIEMAT CIEMAT 68 62 51 4 3 62 51 4 3 62 51 4 3 62 51 4 3 62 51 4 3 62 52 56 67 29 52 63	112 137 14 18 151 DOE21E NREL 67 60 55 5 4 60 65 60 69 34 56 60	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60 55 5 4 66 61 70 34 56 65	118 139 18 23 155 TRN-re TUD 67 59 54 5 4 65 60 69 34 55 65	111 135 14 18 149 Statistic Min 67 59 51 4 3 62 56 67 29 52 63	119 139 18 23 <u>155</u> 5, All Res 68 62 55 5 5 4 66 61 70 34 56 66	6.9% 3.0% 22.8% 23.1% 3.5% (Max-Min) / Analytical 2.0% 4.9% 6.5% 22.4% 19.1% 5.6% 8.4% 5.2% 16.1% 7.1% 3.9%	119 139 18 23 154 TUD 68 60 55 5 4 66 61 70 35 56 65	119 139 18 23 155 4 hTAL1 68 60 55 5 4 66 61 70 34 56 65	119 139 18 23 155 HTAL2 68 60 55 5 4 66 61 70 34 56 65
E190 E195 E200 Energy E100 E110 E120 E130 E140 E140 E140 E165 E170 E180 E185 E190	18 23 154 Consumpt CA-SIS EDF 68 60 55 5 4 66 61 70 34 56 65 8	139 18 23 153 ion, Conder CLM2000 EDF 68 61 55 5 4 66 61 70 34 56 65 9	135 14 18 149 DOE21E CIEMAT 68 62 51 4 3 62 51 4 3 62 56 67 29 52 63 7	112 137 14 18 151 DOE21E NREL 67 60 55 5 4 60 55 5 4 60 69 34 56 60 34 56 66 8	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60 55 5 4 66 61 70 34 56 65 8	118 139 18 23 155 TRN-re TUD 67 59 54 5 4 65 60 69 34 55 65 9	111 135 14 18 149 Statistic Min 67 59 51 4 3 62 56 67 29 52 63 7	119 139 18 23 <u>155</u> 5, All Res 68 62 55 5 4 66 61 70 34 56 66 9	6.9% 3.0% 22.8% 23.1% 3.5% (Max-Min) / Analytical 2.0% 4.9% 6.5% 22.4% 19.1% 5.6% 8.4% 5.2% 16.1% 7.1% 3.9% 27.6%	119 139 18 23 154 TUD 68 60 55 5 4 66 61 70 35 56 65 9	119 139 18 23 155 4nalytical HTAL1 68 60 55 5 4 66 61 70 34 56 65 9	119 139 18 23 155 HTAL2 68 60 55 5 4 66 61 70 34 56 65 9
E190 E195 E200 Energy E100 E110 E120 E130 E140 E150 E165 E165 E170 E180 E185	18 23 154 Consumpt CA-SIS EDF 68 60 55 5 4 66 61 70 34 56 65	139 18 23 153 ion, Conder CLM2000 EDF 68 61 55 5 4 66 61 70 34 56 65	135 14 18 149 DOE21E CIEMAT CIEMAT 68 62 51 4 3 62 51 4 3 62 51 4 3 62 51 4 3 62 51 4 3 62 52 56 67 29 52 63	112 137 14 18 151 DOE21E NREL 67 60 55 5 4 60 65 60 69 34 56 60	139 18 23 153 Energy+	118 139 18 23 155 TRN-id TUD 67 60 55 5 4 66 61 70 34 56 65	118 139 18 23 155 TRN-re TUD 67 59 54 5 4 65 60 69 34 55 65	111 135 14 18 149 Statistic Min 67 59 51 4 3 62 56 67 29 52 63	119 139 18 23 <u>155</u> 5, All Res 68 62 55 5 4 66 61 70 34 56 66	6.9% 3.0% 22.8% 23.1% 3.5% (Max-Min) / Analytical 2.0% 4.9% 6.5% 22.4% 19.1% 5.6% 8.4% 5.2% 16.1% 7.1% 3.9%	119 139 18 23 154 TUD 68 60 55 5 4 66 61 70 35 56 65	119 139 18 23 155 4 hTAL1 68 60 55 5 4 66 61 70 34 56 65	119 139 18 23 155 HTAL2 68 60 55 5 4 66 61 70 34 56 65

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COP: Mean, and (Max-Min)/ Mean

Mean C	OP						1	Statistic	cs, All Res	sults			
	CA-SIS	CLM2000	DOE21E	DOE21E	Energy+	TRN-id	TRN-re			(Max-Min)		Analytical	
	EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	Min	Max	/ Analytical	TUD	HTAL1	HTAL2
E100	2.39	2.39	2.43	2.41	2.40	2.40	2.42	2.39	2.43	1.7%	2.39	2.39	2.39
E110	3.38	3.34	3.46	3.41	3.40	3.41	3.43	3.34	3.46	3.5%	3.38	3.38	3.38
E120	3.59	3.59	3.61	3.62	3.61	3.61	3.63	3.59	3.63	1.2%	3.59	3.59	3.59
E130	1.91	1.91	1.98	1.95	1.90	1.92	1.92	1.90	1.98	3.8%	1.89	1.91	1.91
E140	2.77	2.73	2.92	2.85	2.77	2.80	2.80	2.73	2.92	6.6%	2.75	2.77	2.77
E150	3.62	3.63	3.67	3.70	3.65	3.65	3.67	3.62	3.70	2.2%	3.63	3.63	3.63
E160	3.84	3.84	3.87	3.95	3.86	3.85	3.86	3.84	3.95	2.9%	3.83	3.84	3.84
E165	2.92	2.92	2.95	2.99	2.94	2.93	2.94	2.92	2.99	2.2%	2.93	2.93	2.93
E170	3.38	3.39	3.44	3.48	3.40	3.39	3.40	3.38	3.48	2.9%	3.37	3.39	3.39
E180	4.04	4.04	4.08	4.03	4.04	4.05	4.06	4.03	4.08	1.4%	4.04	4.04	4.04
E185	2.85	2.85	2.87	2.82	2.85	2.85	2.86	2.82	2.87	1.8%	2.85	2.85	2.85
E190	3.41	3.41	3.49	3.46	3.39	3.41	3.40	3.39	3.49	2.7%	3.39	3.41	3.41
E195	2.31	2.31	2.36	2.34	2.30	2.32	2.31	2.30	2.36	2.5%	2.29	2.31	2.31
E200	3.62	3.61	3.67	3.71	3.65	3.61	3.61	3.61	3.71	2.7%	3.62	3.62	3.62
(Max - M	Min)/ Mean	COP			5-0				cs, All Res	sults			
	CA-SIS	CLM2000	DOE21E	DOE21E	Energy+	TRN-id	TRN-re			(Max-Min)		Analytical	
	EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	Min		/ Analytical	TUD	HTAL1	HTAL2
E100	0.000	0.001	0.002	0.001	0.003	0.000	0.000	0.000	0.003		0.000	0.000	0.000
E110	0.000	0.010	0.002	0.001	0.003	0.000	0.011	0.000	0.011		0.000	0.000	0.000
E120	0.000	0.004	0.001	0.001	0.003	0.000	0.012	0.000	0.012		0.000	0.000	0.000
E130	0.000	0.038	0.013	0.009	0.004	0.000	0.172	0.000	0.172		0.000	0.000	0.000
E140	0.000	0.056	0.011	0.019	0.004	0.000	0.204	0.000	0.204		0.000	0.000	0.000
E150	0.003	0.003	0.001	0.005	0.011	0.000	0.009	0.000	0.011		0.000	0.000	0.001
E160	0.003	0.005	0.001	0.003	0.011	0.000	0.010	0.000	0.011		0.000	0.000	0.000
E165	0.010	0.003	0.001	0.003	0.012	0.000	0.008	0.000	0.012		0.000	0.000	0.000
E170	0.000	0.006	0.002	0.004	0.015	0.000	0.043	0.000	0.043		0.000	0.000	0.000
E180	0.005	0.002	0.002	0.010	0.029	0.000	0.012	0.000	0.029		0.000	0.000	0.000
E185	0.007	0.004	0.002	0.010	0.034	0.000	0.009	0.000	0.034		0.000	0.000	0.000
E190	0.000	0.023	0.007	0.019	0.040	0.000	0.101	0.000	0.101		0.000	0.000	0.000
E195	0.000	0.017	0.008	0.017	0.043	0.000	0.086	0.000	0.086		0.000	0.000	0.000
E200	0.006	0.000	0.000	0.005	0.012	0.000	0.000	0.000	0.012		0.000	0.000	0.000

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Coil Loads:	Total,	Sensible,	and	Latent
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	Loads: Total	, <u> </u>											
Coil L	oad, Total (kWh,tl							Statistics	, All Result:				
	CA-SIS	CLM2000	DOE21E	DOE21E	Energy+	TRN-id	TRN-re		(	Max-Min)	A	nalytical	
	EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	Min	Max /	Analytical	TUD	HTAL1	HTAL2
E100	3800	3800	3841	3794	3798	3800	3798	3794	3841	1.3%	3800	3800	3800
E110	3765	3766	3804	3756	3763	3765		3756	3804	1.3%	3765	3765	
							3763						3765
E120	3749	3749	3763	3739	3747	3748	3747	3739	3763	0.6%	3749	3749	3749
E130	219	219	216	215	217	219	220	215	220	2.1%	219	219	219
E140	198	198	196	195	196	198	199	195	199	2.0%	198	198	197
E150	4517	4517	4543	4528	4509	4517	4515	4509	4543	0.8%	4518	4517	4518
E160	4501	4500	4516	4508	4491	4500	4499	4491	4516	0.6%	4501	4500	4500
E165	4538	4538	4567	4549	4529	4537	4535	4529	4567	0.9%	4537	4537	4538
E170	2233	2232	2226	2237	2225	2232	2232	2225	2237	0.5%	2232	2232	2233
E180	4495	4495	4510	4535	4481	4495	4494	4481	4535	1.2%	4495	4495	4494
E185													
	4507	4535	4565	4583	4523	4535	4534	4507	4583	1.7%	4535	4535	4534
E190	578	577	573	579	574	577	578	573	579	1.0%	578	577	578
E195	602	601	595	602	598	601	601	595	602	1.1%	601	601	601
E200	5498	5436	5534	5522	5484	5498	5498	5436	5534	1.8%	5498	5498	5498
			0001	UULL	0101	0100			All Results		0100	0100	
	oad, Sensible (kW				_			Statistics	•				
1		CLM2000	DOE21E	DOE21E	Energy+	TRN-id	TRN-re			Max-Min)		nalytical	
	EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	Min	Max /	Analytical	TUD	HTAL1	HTAL2
E100	3800	3800	3841	3794	3798	3800	3798	3794	3841	1.3%	3800	3800	3800
E110	3765	3766	3804	3756	3763	3765	3763	3756	3804	1.3%	3765	3765	3765
E120	3749	3749	3763	3739	3747	3748	3747	3739	3763	0.6%	3749	3749	3749
E130	219	219	216	215	217	219	220	215	220	2.1%	219	219	219
E140	198	198	196	195	196	198	199	195	199	2.0%	198	198	197
E150	3778	3778	3804	3786	3776	3778	3776	3776	3804	0.7%	3778	3778	3779
E160	3761	3761	3777	3769	3759	3761	3760	3759	3777	0.5%	3761	3761	3761
E165	3798	3798	3828	3809	3795	3798	3796	3795	3828	0.9%	3798	3798	3799
E170	1493	1493	1487	1498	1491	1492	1492	1487	1498	0.7%	1493	1493	1493
E180	1537	1538	1553	1607	1537	1538	1537	1537	1607	4.5%	1538	1538	1538
E185	1548	1578	1608	1653	1577	1578	1577	1548	1653	6.6%	1578	1578	1578
E190	208	208	203	212	206	208	208	203	212	4.4%	208	208	208
E195	232	232	226	235	230	231	232	226	235	4.1%	232	232	232
E200	4276	4215	4313	4303	4274	4277	4277	4215	4313	2.3%	4277	4277	4277
Coil L													
Coil L	oad, Latent (kWh,	thermal)							, All Results	5			
Coil L	oad, Latent (kWh, CA-SIS	thermal) CLM2000	DOE21E	DOE21E	Energy+	TRN-id	TRN-re	Statistics	, All Result: (	s Max-Min)	A	nalytical	
	oad, Latent (kWh,	thermal)							, All Result: (	5			HTAL2
Coil Lo	oad, Latent (kWh, CA-SIS	thermal) CLM2000	DOE21E	DOE21E	Energy+	TRN-id	TRN-re	Statistics	, All Result: (	s Max-Min)	A	nalytical	
E100	oad, Latent (kWh, CA-SIS EDF 0	thermal) CLM2000 EDF 0	DOE21E CIEMAT 0	DOE21E NREL 0	Energy+ GARD 0	TRN-id TUD 0	TRN-re TUD 0	Statistics Min 0	, All Results ( Max / 0	s Max-Min)	A TUD 0	nalytical HTAL1 0	HTAL2 0
E100 E110	oad, Latent (kWh, CA-SIS EDF 0 0	thermal) CLM2000 EDF 0 0	DOE21E CIEMAT 0 0	DOE21E NREL 0 0	Energy+ GARD 0 0	TRN-id TUD 0 0	TRN-re TUD 0 0	Statistics Min 0 0	, All Results ( Max / 0 0	s Max-Min)	A TUD 0 0	nalytical HTAL1 0 0	HTAL2 0 0
E100 E110 E120	oad, Latent (kWh, CA-SIS EDF 0 0 0	thermal) CLM2000 EDF 0 0 0	DOE21E CIEMAT 0 0	DOE21E NREL 0 0 0	Energy+ GARD 0 0	TRN-id TUD 0 0 0	TRN-re TUD 0 0	Statistics Min 0 0 0	, All Result: ( Max / / 0 0 0	s Max-Min)	A TUD 0 0 0	nalytical HTAL1 0 0 0	HTAL2 0 0 0
E100 E110	oad, Latent (kWh, CA-SIS EDF 0 0 0 0	thermal) CLM2000 EDF 0 0 0 0	DOE21E CIEMAT 0 0	DOE21E NREL 0 0 0 0 0	Energy+ GARD 0 0	TRN-id TUD 0 0 0 0	TRN-re TUD 0 0	Statistics Min 0 0 0 0	, All Result: ( Max / 0 0 0 0 0	s Max-Min)	A TUD 0 0	nalytical HTAL1 0 0	HTAL2 0 0
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E100 E110 E120 E130 E140 E150	oad, Latent (KWh, CA-SIS EDF 0 0 0 0 0 0 0 739	thermal) CLM2000 EDF 0 0 0 0 0 739	DOE21E CIEMAT 0 0 0 0 0 739	DOE21E NREL 0 0 0 0 0 0 742	Energy+ GARD 0 0 0 0 0 733	TRN-id TUD 0 0 0 0 0 739	TRN-re TUD 0 0 0 0 0 739	Statistics Min 0 0 0 0 733	All Result: ( Max // 0 0 0 0 742	s Max-Min) Analytical 1.2%	A TUD 0 0 0 0 0 739	nalytical HTAL1 0 0 0 0 0 739	HTAL2 0 0 0 0 0 739
E100 E110 E120 E130 E140 E150 E160	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 0 0 739 740	thermal) CLM2000 EDF 0 0 0 0 0 739 739	DOE21E CIEMAT 0 0 0 0 0 739 739	DOE21E NREL 0 0 0 0 0 0 742 739	Energy+ GARD 0 0 0 0 0 733 732	TRN-id TUD 0 0 0 0 739 739	TRN-re TUD 0 0 0 0 0 739 739	Statistics Min 0 0 0 0 733 732	; Al Result: ( Max // 0 0 0 0 742 740	s Max-Min) Analytical 1.2% 1.1%	A TUD 0 0 0 0 739 739 739	nalytical HTAL1 0 0 0 0 739 739	HTAL2 0 0 0 0 0 739 739
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E100 E110 E120 E130 E140 E150 E160	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 0 0 739 740	thermal) CLM2000 EDF 0 0 0 0 0 739 739	DOE21E CIEMAT 0 0 0 0 0 739 739	DOE21E NREL 0 0 0 0 0 0 742 739	Energy+ GARD 0 0 0 0 0 733 732	TRN-id TUD 0 0 0 0 739 739	TRN-re TUD 0 0 0 0 0 739 739	Statistics Min 0 0 0 0 733 732	; Al Result: ( Max // 0 0 0 0 742 740	s Max-Min) Analytical 1.2% 1.1%	A TUD 0 0 0 0 739 739 739	nalytical HTAL1 0 0 0 0 739 739	HTAL2 0 0 0 0 739 739
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E100 E110 E120 E130 E140 E150 E160 E165 E170 E180	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 0 739 740 740 740 740 2958	thermal) CLM2000 EDF 0 0 0 0 0 0 739 739 739 739 739 2957	DOE21E CIEMAT 0 0 0 0 0 739 739 739 739 739 2957	DOE21 E NREL 0 0 0 0 0 742 739 740 739 2928	Energy+ GARD 0 0 0 0 0 733 732 733 734 2944	TRN-id TUD 0 0 0 0 739 739 739 739 2957	TRN-re TUD 0 0 0 0 739 739 739 739 739 2957	Statistics Min 0 0 0 0 0 733 733 732 733 734 2928	, All Result: ( Max / 0 0 0 0 0 0 742 740 740 740 740 2958	s Max-Min) Analytical 1.2% 1.1% 1.0% 0.9% 1.0%	A TUD 0 0 0 0 0 739 739 739 739 739 2957	nalytical HTAL1 0 0 0 0 739 739 739 739 2957	HTAL2 0 0 0 739 739 739 739 2956
E100 E110 E120 E130 E140 E150 E160 E165 E170 E180 E185	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 0 739 740 740 740 2958 2959	thermal) CLM2000 EDF 0 0 0 0 739 739 739 739 739 739 2957	DOE21E CIEMAT 0 0 0 0 739 739 739 739 739 2957	DOE21 E NREL 0 0 0 0 0 742 739 740 739 2928 2930	Energy+ GARD 0 0 0 733 732 733 734 2944 2946	TRN-id TUD 0 0 0 0 739 739 739 739 739 2957 2957	TRN-re TUD 0 0 0 0 739 739 739 739 739 2957 2957	Statistics Min 0 0 0 733 733 733 734 2928 2930	, All Result: ( Max / 0 0 0 0 0 742 740 740 740 2958 2959	s Max-Min) Analytical 1.2% 1.1% 1.0% 0.9% 1.0%	A TUD 0 0 0 739 739 739 739 739 2957 2958	nalytical HTAL1 0 0 0 0 739 739 739 739 739 2957 2957	HTAL2 0 0 0 739 739 739 739 2956 2956
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E100 E110 E120 E130 E140 E150 E160 E165 E170 E180 E185 E190 E195	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 0 739 740 740 740 2958 2959	thermal) CLM2000 EDF 0 0 0 0 0 739 739 739 739 739 739 2957 2957 370 370	DOE21E CIEMAT 0 0 0 0 739 739 739 739 739 739 739 739 739 739	DOE21E NREL 0 0 0 0 742 739 740 739 740 739 2928 2930 366 367	Energy+ GARD 0 0 0 0 733 733 733 734 2944 2946 368 368	TRN-id TUD 0 0 0 739 739 739 739 739 739 2957 2957 370 370	TRN-re TUD 0 0 0 739 739 739 739 739 2957 370 370 370	Statistics Min 0 0 0 733 733 733 733 734 2928 2930	, All Result: ( Max / 0 0 0 0 0 742 740 740 740 2958 2959	s Max-Min) Analytical 1.2% 1.1% 1.0% 1.0% 1.0% 1.0% 0.9%	A TUD 0 0 0 739 739 739 739 739 2957 2958	nalytical HTAL1 0 0 0 739 739 739 739 739 739 2957 2957 370 370	HTAL2 0 0 0 739 739 739 2956 2956 370 370
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E100 E110 E120 E130 E140 E150 E160 E165 E170 E165 E170 E185 E190 E195 E200	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 0 0 739 740 740 740 740 740 2958 2959 370 370 370 1222	thermal) CLM2000 EDF 0 0 0 0 0 0 0 739 739 739 739 739 739 2957 2957 370 370 1221 results5-3.xl	DOE21E CIEMAT 0 0 0 0 0 739 739 739 739 739 2957 2957 2957 370 370 370 1221	DOE21 E NREL 0 0 0 0 742 739 740 739 2928 2930 366 367 1219	Energy+ GARD 0 0 0 0 733 732 733 734 2944 2946 368 368 368	TRN-id TUD 0 0 0 739 739 739 739 739 739 2957 2957 370 370	TRN-re TUD 0 0 0 739 739 739 739 739 2957 370 370 370	Statistics Min 0 0 0 733 732 733 734 2928 2930 366 367 1210	i, All Result: ( Max / 0 0 0 0 0 742 740 740 740 740 740 2958 2959 370 370 370 1222	s Max-Min) Analytical 1.2% 1.1% 1.0% 1.0% 1.0% 1.0% 0.9% 1.0%	A TUD 0 0 0 0 739 739 739 739 739 739 739 739 739 739	nalytical HTAL1 0 0 0 739 739 739 739 739 739 2957 2957 370 370	HTAL2 0 0 0 739 739 739 739 2956 2956 370 370
E100 E110 E120 E130 E140 E150 E160 E165 E170 E165 E170 E185 E190 E195 E200	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 739 740 740 740 740 740 740 2958 2959 370 370 370 370 370	thermal) CLM2000 EDF 0 0 0 0 739 739 739 739 739 739 739 739	DOE21E CIEMAT 0 0 0 0 739 739 739 739 739 739 739 2957 370 370 370 370 1221 Is q:bc77br	DOE21E NREL 0 0 0 0 742 739 740 739 740 739 2928 2930 366 367 367 367 367 367 367 371 219	Energy+ GARD 0 0 0 733 732 733 734 2944 2946 368 368 368 368 1210	TRN-id TUD 0 0 0 739 739 739 739 739 2957 2957 370 370 370 1221	TRN-re TUD 0 0 0 0 739 739 739 739 739 2957 370 2957 370 370 1221	Statistics Min 0 0 0 733 732 733 734 2928 2930 366 367 1210	<ul> <li>All Result:</li> <li>Max / 0</li> <li>0</li> <li>0</li> <li>0</li> <li>0</li> <li>0</li> <li>742</li> <li>740</li> <li>740</li> <li>740</li> <li>2958</li> <li>2959</li> <li>370</li> <li>370</li> <li>1222</li> </ul>	s Max-Min) Analytical 1.2% 1.1% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0%	A TUD 0 0 0 739 739 739 739 739 739 2957 2958 370 370 370 1221	nalytical HTAL1 0 0 0 739 739 739 739 739 739 2957 2957 370 370 370 370	HTAL2 0 0 0 739 739 739 739 2956 2956 370 370
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E100 E110 E120 E130 E140 E150 E160 E165 E170 E185 E190 E195 E200 <b>Sensit</b> E100 E110	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 0 739 740 740 740 740 740 2958 2959 370 370 1222 0 1222 1222 1222 1222 1222 1222	thermal) CLM2000 EDF 0 0 0 0 0 739 739 739 739 739 739 739 739	DOE21E CIEMAT 0 0 0 739 739 739 739 739 739 739 739 739 739	DOE21E NREL 0 0 0 0 742 739 740 739 2928 2930 366 367 1219 147; 10/15 rrmal) DOE21E NREL NREL 139 119	Energy+ GARD 0 0 0 733 732 733 734 2944 2946 368 368 368 3210 5/02 Energy+ GARD 144 128	TRN-id TUD 0 0 0 739 739 739 739 739 2957 2957 370 370 370 1221 TRN-id TUD 144 128	TRN-re TUD 0 0 739 739 739 739 2957 370 2957 370 370 1221 TRN-re TRN-re TUD 142 127	Statistics           Min           0           0           0           0           0           0           0           0           0           0           0           0           0           0           733           734           2928           2930           366           367           1210           Statistics           Min           139           119	<ul> <li>All Result: (/ Max // 0 0 0</li></ul>	Max-Min) Analytical 1.2% 1.1% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0	A TUD 0 0 0 739 739 739 739 739 739 2957 2958 370 370 1221 4 4 TUD 144 128	nalytical HTAL1 0 0 0 739 739 739 739 2957 2957 370 370 370 370 1221 nalytical HTAL1 144 128	HTAL2 0 0 739 739 739 739 2956 370 370 1221 HTAL2 HTAL2 144 128
E100 E110 E120 E130 E150 E165 E165 E170 E185 E190 E195 E200 <b>Sensit</b> E100 E1100 E120	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 739 740 740 740 740 740 740 740 740 740 740	thermal) CLM2000 EDF 0 0 0 0 739 739 739 739 739 739 739 739	DOE21E CIEMAT 0 0 0 739 739 739 739 739 739 739 739 739 739	DOE21E NREL 0 0 0 0 742 739 740 739 740 739 740 739 740 739 740 739 740 739 740 739 740 739 740 739 740 739 740 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 742 739 740 739 740 739 721 740 739 721 740 739 721 721 721 721 721 721 721 721 721 721	Energy+ GARD 0 0 0 0 733 732 733 734 2944 2946 368 368 368 368 368 368 368 368 368 36	TRN-id TUD 0 0 0 0 739 739 739 739 739 739 2957 2957 370 370 370 1221 TRN-id TUD 144 128 117	TRN-re TUD 0 0 0 0 0 0 0 0 0 0 739 739 739 739 739 739 739 739 739 739	Statistics           Min           0           0           0           0           0           0           0           0           0           0           0           0           0           0           0           733           734           7928           2930           366           367           1210           Statistics           Min           139           119           108	, All Result: ( Max / 0 0 0 0 0 0 0 0 742 740 740 740 740 740 740 2958 2959 370 370 370 370 370 370 370 370 370 370	s Max-Min) Analytical 1.2% 1.1% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0	A TUD 0 0 0 739 739 739 739 739 739 739 739 739 739	nalytical HTAL1 0 0 0 739 739 739 739 739 739 739 739 739 739	HTAL2 0 0 0 739 739 739 739 2956 2956 370 370 1221 HTAL2 144 128 117
E100 E110 E120 E130 E140 E165 E165 E165 E170 E185 E190 E195 E200 <b>Sensit</b> E100 E110 E1100 E120 E130	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 739 740 740 740 740 740 740 740 740 740 740	thermal) CLM2000 EDF 0 0 0 0 0 0 739 739 739 739 739 739 739 739	DOE21E CIEMAT 0 0 0 739 739 739 739 739 739 739 739 739 739	DOE21 E NREL 0 0 0 742 739 740 739 2928 2930 366 367 1219 147, 10/15 DOE21 E NREL 139 119 108 8	Energy+ GARD 0 0 0 0 733 732 733 734 2944 2944 368 368 368 1210 5/02 Energy+ GARD 144 128 116 10	TRN-id TUD 0 0 0 0 739 739 739 739 739 739 739 739 739 739	TRN-re TUD 0 0 0 739 739 739 739 739 739 2957 370 370 1221 TRN-re TUD 142 127 115 10	Statistics           Min           0           0           0           0           0           0           0           0           0           0           0           0           0           0           0           733           734           2928           2930           366           367           1210           Statistics           Min           139           108           8	, All Result: ( Max / 0 0 0 0 0 0 0 740 740 740 740 740 740 7	5 Max-Min) Analytical 1.2% 1.1% 1.0% 0.9% 1.0% 1.0% 1.0% 0.9% 1.0% 1.0% 3.6% 38.2% 21.8% 21.8% 26.7%	A TUD 0 0 0 0 739 739 739 739 739 739 739 739 739 739	nalytical HTAL1 0 0 0 739 739 739 739 739 739 739 739 739 739	HTAL2 0 0 0 739 739 739 739 2956 2956 370 370 1221 HTAL2 144 128 117 10
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E100 E110 E120 E130 E140 E165 E170 E185 E170 E185 E190 E195 E200 Sensit E100 E110 E120 E120 E140 E150 E140 E150 E165 E165 E170 E180	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 739 740 740 740 740 740 740 740 740 740 740	thermal) CLM2000 EDF 0 0 0 0 0 739 739 739 739 739 739 739 739	DOE21E CIEMAT 0 0 0 739 739 739 739 739 739 739 739 739 739	DOE21E NREL 0 0 0 742 739 740 739 2928 2930 366 367 1219 2930 366 367 1219 DOE21E NREL 139 119 108 8 6 149 137 161 79 188	Energy+ GARD 0 0 0 0 733 732 733 734 2944 368 368 1210 5/02 Energy+ GARD 144 128 116 10 8 140 129 149 73 119	TRN-id TUD 0 0 0 739 739 739 739 739 739 739 739 739 739	TRN-re TUD 0 0 0 739 739 739 739 739 739 739 739 739 739	Statistics           Min           0           0           0           0           0           0           0           0           0           0           0           0           0           0           0           0           0           733           734           2928           2930           366           367           1210           Statistics           Min           139           119           108           8           6           139           128           148           69           117	, All Result: ( <u>Max</u> / 0 0 0 0 740 740 740 740 740 740 740 740	Max-Min) Analytical 1.2% 1.1% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0	A TUD 0 0 0 0 0 739 739 739 739 739 739 739 739 739 739	nalytical HTAL1 0 0 0 739 739 739 739 739 739 739 739 739 739	HTAL2 0 0 0 7399 739 739 29566 29566 3700 3700 1221 HTAL2 1444 128 117 100 8 142 1299 1500 74 118
E100 E110 E120 E130 E140 E165 E170 E185 E195 E200 <b>Sensit</b> E100 E110 E120 E110 E120 E140 E150 E160 E165 E170 E165 E170 E185	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 0 0 740 740 740 740 740 740 7	thermal) CLM2000 EDF 0 0 0 0 739 739 739 739 739 739 739 739	DOE21E CIEMAT 0 0 0 739 739 739 739 739 739 739 739 739 739	DOE21E NREL 0 0 0 742 739 740 739 2928 2930 366 367 1219 147;10/15 rrmal) DOE21E NREL 139 119 108 8 6 149 137 161 79 188 215	Energy+ GARD 0 0 0 733 732 733 734 2944 2946 368 368 368 3210 5/02 Energy+ GARD 144 128 116 10 8 140 129 149 73 119 140	TRN-id TUD 0 0 0 739 739 739 739 739 2957 2957 370 370 370 320 1221 TRN-id TUD 144 128 117 10 8 141 129 149 73 3118 139	TRN-re TUD 0 0 0 739 739 739 739 739 2957 370 370 1221 125 10 142 127 115 10 8 3 139 128 148 73 118 139	Statistics           Min           0           0           0           0           0           0           0           0           0           0           0           0           733           734           2928           2930           366           367           1210           Statistics           Min           139           119           108           8           6           139           128           148           69           117           109	, All Result: (Max // 0 0 0 0 742 740 740 740 740 740 2958 2959 370 1222 (Max // 187 168 133 10 8 168 147 181 79 188 215	Max-Min) Analytical 1.2% 1.1% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0	A TUD 0 0 0 739 739 739 739 739 2957 2958 370 370 1221 1221 1221 144 128 117 10 8 141 129 149 74 118 139	nalytical HTAL1 0 0 0 739 739 739 739 2957 2957 370 370 370 370 370 1221 HTAL1 1221 HTAL1 144 128 117 10 8 141 129 149 73 319 139	HTAL2 0 0 0 739 739 739 739 2956 370 1221 HTAL2 144 128 117 10 8 8 142 129 150 744 118 139
E100 E110 E120 E130 E150 E165 E170 E165 E190 E195 E200 E195 E200 E100 E120 E1100 E120 E130 E140 E150 E165 E165 E165 E165 E170 E188 E190	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 0 739 740 740 740 740 740 740 740 740 740 740	thermal) CLM2000 EDF 0 0 0 0 739 739 739 739 739 739 739 739	DOE21E CIEMAT 0 0 0 739 739 739 739 739 739 739 739 739 739	DOE21 E NREL 0 0 0 742 739 740 739 2928 2930 366 367 367 367 367 367 367 367 367 367	Energy+ GARD 0 0 0 733 732 733 734 2944 2946 368 368 368 368 368 368 368 368 1210 5/02 Energy+ GARD 144 128 116 10 8 440 129 149 73 119 140 18	TRN-id TUD 0 0 0 739 739 739 739 739 739 2957 2957 370 370 1221 TRN-id TUD 144 128 117 10 8 141 129 149 73 118 139 18	TRN-re TUD 0 0 0 739 739 739 739 739 739 739 739 739 739	Statistics           Min           0           0           0           0           0           0           0           0           0           0           0           0           733           734           2928           2930           366           367           1210           Statistics           Min           139           119           108           8           6           139           128           148           69           117           109           15	, All Result: ( Max / 0 0 0 0 0 742 740 740 740 740 2958 2959 370 370 370 370 370 370 370 370 370 370	Max-Min) Analytical 1.2% 1.1% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0	A TUD 0 0 0 739 739 739 739 739 739 739 739 739 739	nalytical HTAL1 0 0 0 739 739 739 739 739 739 739 739 739 739	HTAL2 0 0 0 0 739 739 739 739 2956 2956 370 370 1221 HTAL2 144 128 117 10 8 142 129 150 74 118 139 8 8
E100 E110 E120 E130 E140 E165 E170 E185 E195 E200 <b>Sensit</b> E100 E110 E120 E140 E140 E150 E140 E150 E165 E170 E185	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 0 0 740 740 740 740 740 740 7	thermal) CLM2000 EDF 0 0 0 0 739 739 739 739 739 739 739 739	DOE21E CIEMAT 0 0 0 739 739 739 739 739 739 739 739 739 739	DOE21E NREL 0 0 0 742 739 740 739 2928 2930 366 367 1219 147;10/15 rrmal) DOE21E NREL 139 119 108 8 6 149 137 161 79 188 215	Energy+ GARD 0 0 0 733 732 733 734 2944 2946 368 368 368 3210 5/02 Energy+ GARD 144 128 116 10 8 140 129 149 73 119 140	TRN-id TUD 0 0 0 739 739 739 739 739 2957 2957 370 370 370 320 1221 TRN-id TUD 144 128 117 10 8 141 129 149 73 3118 139	TRN-re TUD 0 0 0 739 739 739 739 739 2957 370 370 1221 125 10 142 127 115 10 8 3 139 128 148 73 118 139	Statistics           Min           0           0           0           0           0           0           0           0           0           0           0           0           733           734           2928           2930           366           367           1210           Statistics           Min           139           119           108           8           6           139           128           148           69           117           109	, All Result: (Max // 0 0 0 0 742 740 740 740 740 2958 2959 370 320 370 1222 (Max // 187 168 133 10 8 168 147 181 79 188 215	Max-Min) Analytical 1.2% 1.1% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0	A TUD 0 0 0 739 739 739 739 739 2957 2958 370 370 1221 1221 1221 144 128 117 10 8 141 129 149 74 118 139	nalytical HTAL1 0 0 0 739 739 739 739 2957 2957 370 370 370 370 370 1221 HTAL1 1221 HTAL1 144 128 117 10 8 141 129 149 139	HTAL2 0 0 0 0 0 0 0 0 0 0 739 739 739 2956 370 1221 HTAL2 144 128 117 10 8 142 129 150 748 148 139
E100 E110 E120 E130 E150 E165 E165 E170 E185 E190 E195 E200 <b>Sensit</b> E100 E120 E1100 E120 E130 E140 E150 E165 E165 E165 E170 E185 E190	oad, Latent (kWh, CA-SIS EDF 0 0 0 0 0 0 739 740 740 740 740 740 740 740 740 740 740	thermal) CLM2000 EDF 0 0 0 0 739 739 739 739 739 739 739 739	DOE21E CIEMAT 0 0 0 739 739 739 739 739 739 739 739 739 739	DOE21 E NREL 0 0 0 742 739 740 739 2928 2930 366 367 367 367 367 367 367 367 367 367	Energy+ GARD 0 0 0 733 732 733 734 2944 2946 368 368 368 368 368 368 368 368 1210 5/02 Energy+ GARD 144 128 116 10 8 440 129 149 73 119 140 18	TRN-id TUD 0 0 0 739 739 739 739 739 739 2957 2957 370 370 1221 TRN-id TUD 144 128 117 10 8 141 129 149 73 118 139 18	TRN-re TUD 0 0 0 739 739 739 739 739 739 739 739 739 739	Statistics           Min           0           0           0           0           0           0           0           0           0           0           0           0           733           734           2928           2930           366           367           1210           Statistics           Min           139           119           108           8           6           139           128           148           69           117           109           15	, All Result: ( Max / 0 0 0 0 742 740 740 740 740 2958 2959 370 370 370 370 370 370 370 370 370 370	Max-Min) Analytical 1.2% 1.1% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0% 1.0	A TUD 0 0 0 739 739 739 739 739 739 739 739 739 739	nalytical HTAL1 0 0 0 739 739 739 739 739 739 739 739 739 739	HTAL2 0 0 0 0 739 739 739 2956 2956 370 370 1221 HTAL2 124 124 128 117 10 8 117 10 8 142 2129 150 74 118 139 38

$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Zone	Loads: Tota	i, Sensidie,	and Laten	L									
	Zone	Load, Total (k	Wh,therma	l)					Statistics, A	All Results	5			
EDP         EDP         CIEMAT         NREL         CARD         TUD         TUD         Min         Max         Available           2100         3654         3656         3556         3556         3556         3556         3556         3557         3577         3527         3537         3					DOE21E	Energy+	TRN-id	TRN-re				A	nalvtical	
						• • • •			Min	Max				HTAL2
E110         3637         3636         3637         3636         3637         20.87         3636         3637         20.87         20.87         20.9	<b>E100</b>										<i>.</i>			
E120         3632         3632         3631         3632         0.071         3630         3632         0.071         209         229         2207         208         1.3%         209     <														3656
E130         209         207         208         207         209         1.79         209         1.79         209         207         209         1.79 <th1.79< th=""> <th1.79< th=""> <th1.79< th=""></th1.79<></th1.79<></th1.79<>	E110	3637	3637	3636	3637	3636	3637	3637	3636	3637	0.0%	3637	3637	3637
E130         209         207         208         207         209         1.79         209         1.79         209         207         209         1.79 <th1.79< th=""> <th1.79< th=""> <th1.79< th=""></th1.79<></th1.79<></th1.79<>	E120	3632	3632	3630	3632	3631	3632	3631	3630	3632	0.0%	3632	3632	3632
ElA0         190         189         188         188         190         188         190         188         190         190         188         190         110         110         110         110         110         110         110         110         110         110         110         110         110         110         110         110         110         110 </td <td></td> <td>209</td>														209
E150         4376         4377         4371         4370         4371         4376 <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>														
E160         4371         4370         4371         4370         4371         4370         4371         4370         4371         4370         4371         4370         4371         4370         4371         4371         4370         4371         4370         4371         4376 <t< td=""><td>E140</td><td>190</td><td>190</td><td></td><td>188</td><td>188</td><td></td><td>190</td><td>188</td><td></td><td>1.1%</td><td>190</td><td></td><td>190</td></t<>	E140	190	190		188	188		190	188		1.1%	190		190
E160         4371         4370         4371         4370         4371         4370         4371         4370         4371         4370         4371         4370         4371         4370         4371         4371         4370         4371         4370         4371         4376 <t< td=""><td>E150</td><td>4376</td><td>4376</td><td>4375</td><td>4376</td><td>4375</td><td>4376</td><td>4376</td><td>4375</td><td>4376</td><td>0.0%</td><td>4376</td><td>4376</td><td>4376</td></t<>	E150	4376	4376	4375	4376	4375	4376	4376	4375	4376	0.0%	4376	4376	4376
El65         4388         4386         4387         4386         4387         4386         4386         4386         4388         4386         4388         4386         4388         4386         4388         4386         4388         4386         4388         4386         4386         4388         4386         4376 <t< td=""><td>F160</td><td>4371</td><td>4371</td><td>4370</td><td>4371</td><td>4370</td><td>4371</td><td>4371</td><td>4370</td><td>4371</td><td>0.0%</td><td>4371</td><td>4371</td><td>4371</td></t<>	F160	4371	4371	4370	4371	4370	4371	4371	4370	4371	0.0%	4371	4371	4371
E170         2159         2169         2169         2169 <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>														
E180         4176         4175         4175         4175         4175         4175         4175         4175         4176 <th< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>4388</td></th<>														4388
EIRS         4396         4396         4396         4397         4393         4393         4396         4396         4396         4396         559         557         559         0.1%         559         557         559         0.1%         559         557         559         557         559         0.5%         557         559         0.5%         557         559         0.5%         557         559         0.5%         557         559         0.5%         557         559         0.5%         557         559         0.5%         557         559         0.5%         557         559         557 <td>E170</td> <td>2159</td> <td>2159</td> <td>2157</td> <td>2158</td> <td>2157</td> <td>2159</td> <td>2159</td> <td>2157</td> <td>2159</td> <td>0.1%</td> <td>2159</td> <td>2159</td> <td>2159</td>	E170	2159	2159	2157	2158	2157	2159	2159	2157	2159	0.1%	2159	2159	2159
EIRS         4396         4395         4393         4393         4393         4393         4396         0.1%         4396         4396         559         557         559         0.1%         559         559         557         559         0.1%         559         557         559         0.5%         557         559         0.5%         557         559         0.5%         557         559         0.5%         557         559         0.5%         557         559         0.5%         557	E180	4376	4376	4375	4376	4375	4376	4376	4375	4376	0.0%	4376	4376	4376
El90         557         559         558         558         558         557         557         559         559         559         559         559         559         559         559         559         559         559         559         577         576         577         576         579         576         579         576         579         576         579         576         579         576         579         576         579         576         579         576         579         576         579         576         577         576         577         576         577         576         577         576         577         576         577         576         577         576         577         576         577         576         577         576         576         578         577         576         576         578         577         576         578         558 </td <td></td> <td>4396</td>														4396
E195         576         579         576         576         578         579         576         579         578         574         574         574         574         574         574         574         574         578         579         579         579         579         570         578         576         576         578         576         576         576         576         578         576 <td></td>														
12:00         54:3         53:42         53:42         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:43         53:45         53:56         73:56:56         73:56:56         73:56:56         73:56:56         73:56:56         73:56:56         73:56:75         73:57:7         73:56:56         73:57:7         73:56:7         73:57:7														559
	E195	576	579	577	577	576	578	579	576	579	0.5%	579	579	579
Zone Land, Sensible (AW), therema)         EVE         Statistics, All Results         \(MaxAm)/(rel)         \(TUD)         TUD         Min         Max /Analytical         TUD         HTXLi         III           EI00         3656         3655         3654         3656         3655         3654         3656         3656         3656         3656         3657         3638         3637         3636         3637         3637         3638         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3638         3647 <td< td=""><td>E200</td><td>5343</td><td>5283</td><td>5342</td><td>5343</td><td>5342</td><td>5343</td><td>5343</td><td>5283</td><td>5343</td><td>11%</td><td>5343</td><td>5343</td><td>5343</td></td<>	E200	5343	5283	5342	5343	5342	5343	5343	5283	5343	11%	5343	5343	5343
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Lone					-			Statistics, F	an Result				
		EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	Min	Max	/Analytical	TUD	HTAL1	HTAL2
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	E100													3656
E120         3632         3632         3630         3632         3632         3632         3632         3632         3632         3632         3632         3632         3632         3632         3632         3632         3632         3632         3632         3632         3632         3633         3633         3636         3637         3636         3637         3636         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3636         3637         3637         3636         3637         3636         3637         3636         3637         3637         3637         3637         3637         3637         3637         3637         3637         3636         3637         3637         3637         3637 <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>														
E130         209         209         209         209         209         209         1.3%         203         203         203         203         203         203         203         203         203         203         203         203         203         203         203         203         203         1420         <														3637
E140         190         190         188         190         188         190         1.1%         190         190           E150         3637         3636         3637         3636         3636         3637         0.0%         3637         3637         3636         3637														3632
E140         190         190         188         190         188         190         1.1%         190         190           E150         3637         3636         3637         3636         3636         3637         0.0%         3637         3637         3636         3637	E130	209	209	207	208	207	209	209	207	209	1.3%	209	209	209
E150         3637         3636         3636         3637         3636         3636         3637         0.0%         3637 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>190</td></t<>														190
E160         3632         3632         3630         3632         3631         3632         3632         0.0%         3632         3643         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647         3649         3647 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>														
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $														3637
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	E160	3632	3632	3630	3632	3631	3632	3631	3630	3632	0.0%	3632	3632	3632
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	E165	3649	3649	3647	3648	3647	3649	3648	3647	3649	0.1%	3649	3649	3649
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $														1420
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $														
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $														1420
E195         209         209         207         209         207         209         1.1%         209         2102           CA-SIS         CLM2000         DOE21E         Energy+         TRN+re         TRN+re         TRN+re         (Max-Min)         Max Analytical         TUD         HTA1         HT         Energy+         TRN+re         (Max Analytical         TUD         HTA1         HT         Energy+         TRN+re         (Max Analytical         TUD         HTA1         HT         Energy+         TRN +re         TRN	E185	1439	1439	1437	1437	1437	1438	1438	1437	1439	0.2%	1439	1439	1439
E195         209         209         207         209         207         209         1.1%         209         2102           CA-SIS         CLM2000         DOE21E         Energy+         TRN+re         TRN+re         TRN+re         (Max-Min)         Max Analytical         TUD         HTA1         HT         Energy+         TRN+re         (Max Analytical         TUD         HTA1         HT         Energy+         TRN+re         (Max Analytical         TUD         HTA1         HT         Energy+         TRN +re         TRN	E190	190	190	188	188	188	190	190	188	190	1.0%	190	190	190
E200         4122         4062         4121         4122         4123 <th< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>209</td></th<>														209
Zone Load, Latert (WPL, thermal)         Statistics, All Results         (Max-Min)         Analytical           CA-SIS         CLM2000         DOE21E         DOE21E         GRAD         TUD         Min         Max-Min)         Analytical           E100         0 <td></td>														
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $					4122	4121	4122	4122				4122	4122	4122
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Zone	Load, Latent	(kWh,therm	ial)					Statistics, A	All Results	5			
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$		CA-SIS	CLM2000	DOE21E	DOE21E	Energy+	TRN-id	TRN-re			(Max-Min)	A	nalvtical	
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $									Min	Max				HTAL2
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	<b>E100</b>										7711al yilloai			
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $				-			-		-					0
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	E110	0	0	0	0	0	0	0	0	0		0	0	0
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	E120	Û.	0	0	0	0	0	0	0	0		0	0	0
$\begin{array}{c c c c c c c c c c c c c c c c c c c $														0
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $									-					
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $		0	0	0	0	0		U	0	0		0		0
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	E150	739	739	739	739	739	739	739	739	739	0.1%	739	739	739
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	E160	739	739	739	739	739	739	739	739	739	0.1%	739	739	739
$\begin{array}{c c c c c c c c c c c c c c c c c c c $														
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $														739
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $			739		739	739		739	739		0.1%	739		739
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	E180	2957	2957	2957	2958	2957	2957	2957	2957	2958	0.0%	2957	2957	2957
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$														2957
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $														
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $														370
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	E195		370	370	370	370						370		370
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	<u>E2</u> 00	1221	1221	1221	1221	1221	1221	1221	1221	1221	0.0%	1221	1221	1221
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $														
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $									Statistics	11 Decult	, 1			
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	Lat-			1a de U) (KW		-				m results	5			
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Laten	t Coil - Zone l			DOF21F	Energy+	TRN-id					A	nalytical	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Laten	t Coil - Zone l		DOE21E	DOLLID	a · P P	TUD	TUD	Min	Max	/Analytical	TUD	HTALI	HTAL2
E110       0	Laten	<b>it Coil - Zone</b> I CA-SIS	CLM2000			GARD								0
E120       0		<b>it Coil - Zone</b> I CA-SIS EDF	CLM2000 EDF	CIEMAT	NREL						· · · ·	0	0	
E130       0	E100	tt Coil - Zone I CA-SIS EDF 0	CLM2000 EDF 0	CIEMAT 0	NREL 0	0	0	0	0	0				-
E130       0	E100 E110	t Coil - Zone I CA-SIS EDF 0 0	CLM2000 EDF 0 0	CIEMAT 0 0	<u>NREL</u> 0 0	0 0	0 0	0 0	0	0 0		0	0	0
E140       0	E100 E110	t Coil - Zone I CA-SIS EDF 0 0	CLM2000 EDF 0 0	CIEMAT 0 0	<u>NREL</u> 0 0	0 0	0 0	0 0	0	0 0		0	0	
E150       0       0       0       2       -7       0       0       -7       2       0       0         E160       1       0       0       -7       0       0       -7       1       0       0         E165       1       0       0       1       -6       0       0       -6       1       0       0         E170       1       0       0       -1       -6       0       0       -6       1       0       0         E180       1       0       0       -30       -13       0       0       -30       1       1       0         E185       2       0       0       -3       -2       0       0       -3       3       0       0         E190       3       0       0       -3       -3       3       0       0       0         E195       3       0       0       -3       -1       0       0       -3       3       0       0	E100 E110 E120	tt Coil - Zone I CA-SIS EDF 0 0 0	CLM2000 EDF 0 0 0	CIEMAT 0 0 0	<u>NREL</u> 0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0		0 0	0 0	0
E160       1       0       0       -7       0       0       -7       1       0       0         E165       1       0       0       1       -6       0       0       -6       1       0       0         E170       1       0       0       -1       -6       0       0       -6       1       0       0         E180       1       0       0       -30       -13       0       0       -30       1       1       0         E185       2       0       0       -28       -11       0       0       -28       2       1       0         E190       3       0       0       -3       -2       0       0       -3       3       0       0         E195       3       0       0       -3       -1       0       0       -3       3       0       0	E100 E110 E120 E130	tt Coil - Zone I CA-SIS EDF 0 0 0 0 0	CLM2000 EDF 0 0 0 0	CIEMAT 0 0 0 0	NREL 0 0 0 0	0 0 0 0	0 0 0 0	0 0 0	0 0 0 0	0 0 0		0 0 0	0 0 0	0 0 0
E165       1       0       0       1       -6       0       0       -6       1       0       0         E170       1       0       0       -1       -6       0       0       -6       1       0       0       0         E180       1       0       0       -30       -13       0       0       -30       1       1       0         E185       2       0       0       -28       -11       0       0       -28       2       1       0         E190       3       0       0       -3       -2       0       0       -3       3       0       0       0         E195       3       0       0       -3       -1       0       0       -3       3       0       0       0	E100 E110 E120 E130 E140	tt Coil - Zone   CA-SIS EDF 0 0 0 0 0 0 0	CLM2000 EDF 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0	NREL 0 0 0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0		0 0 0	0 0 0 0	0 0 0 0
E165       1       0       0       1       -6       0       0       -6       1       0       0         E170       1       0       0       -1       -6       0       0       -6       1       0       0       0         E180       1       0       0       -30       -13       0       0       -30       1       1       0         E185       2       0       0       -28       -11       0       0       -28       2       1       0         E190       3       0       0       -3       -2       0       0       -3       3       0       0       0         E195       3       0       0       -3       -1       0       0       -3       3       0       0       0	E100 E110 E120 E130 E140 E150	tt Coil - Zone   CA-SIS EDF 0 0 0 0 0 0 0	CLM2000 EDF 0 0 0 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0 0 0 0	NREL 0 0 0 0 0 0 2	0 0 0 0 -7	0 0 0 0 0	0 0 0 0 0 0	0 0 0 0 -7	0 0 0 0		0 0 0	0 0 0 0	0 0 0 0 0
E170       1       0       0       -1       -6       0       0       -6       1       0       0         E180       1       0       0       -30       -13       0       0       -30       1       1       0         E185       2       0       0       -28       -11       0       0       -28       2       1       0         E190       3       0       0       -3       -2       0       0       -3       3       0       0         E195       3       0       0       -3       -1       0       0       -3       3       0       0	E100 E110 E120 E130 E140 E150	tt Coil - Zone   CA-SIS EDF 0 0 0 0 0 0 0 0 0 0 0	CLM2000 EDF 0 0 0 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0 0 0 0	NREL 0 0 0 0 0 0 2	0 0 0 0 -7	0 0 0 0 0	0 0 0 0 0 0	0 0 0 0 -7	0 0 0 0 0 2		0 0 0 0	0 0 0 0	0 0 0 0
E180       1       0       0       -30       -13       0       0       -30       1       1       0         E185       2       0       0       -28       -11       0       0       -28       2       1       0         E190       3       0       0       -3       -2       0       0       -3       3       0       0         E195       3       0       0       -3       -1       0       0       -3       3       0       0	E100 E110 E120 E130 E140 E150 E160	tt Coil - Zone   CA-SIS EDF 0 0 0 0 0 0 0 0 0 0 0	CLM2000 EDF 0 0 0 0 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0 0 0 0 0 0	NREL 0 0 0 0 0 2 0	0 0 0 0 -7 -7	0 0 0 0 0 0 0	0 0 0 0 0 0 0	0 0 0 0 -7 -7	0 0 0 0 2 1		0 0 0 0 0	0 0 0 0 0	0 0 0 0 0 0
E185       2       0       0       -28       -11       0       0       -28       2       1       0         E190       3       0       0       -3       -2       0       0       -3       3       0       0       0         E195       3       0       0       -3       -1       0       0       -3       3       0       0       0	E100 E110 E120 E130 E140 E150 E160 E165	nt Coil - Zone I CA-SIS EDF 0 0 0 0 0 0 0 0 1 1	CLM2000 EDF 0 0 0 0 0 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0 0 0 0 0 0	NREL 0 0 0 0 2 0 1	0 0 0 0 -7 -7 -7 -6	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 -7 -7 -7 -6	0 0 0 0 0 2 1 1		0 0 0 0 0	0 0 0 0 0 0	0 0 0 0 0 0 0
E190       3       0       0       -3       2       0       0       -3       3       0       0         E195       3       0       0       -3       3       0 <t< td=""><td>E100 E110 E120 E130 E140 E150 E160 E165 E170</td><td>tt Coil - Zone I CA-SIS EDF 0 0 0 0 0 0 0 1 1 1 1</td><td>CLM2000 EDF 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>CIEMAT 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>NREL 0 0 0 0 0 2 0 1 1 -1</td><td>0 0 0 -7 -7 -6 -6</td><td>0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0</td><td>0 0 0 -7 -7 -7 -6 -6</td><td>0 0 0 0 2 1 1 1</td><td></td><td>0 0 0 0 0</td><td>0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0 0</td></t<>	E100 E110 E120 E130 E140 E150 E160 E165 E170	tt Coil - Zone I CA-SIS EDF 0 0 0 0 0 0 0 1 1 1 1	CLM2000 EDF 0 0 0 0 0 0 0 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0 0 0 0 0 0 0 0	NREL 0 0 0 0 0 2 0 1 1 -1	0 0 0 -7 -7 -6 -6	0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0	0 0 0 -7 -7 -7 -6 -6	0 0 0 0 2 1 1 1		0 0 0 0 0	0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0
E190       3       0       0       -3       2       0       0       -3       3       0       0         E195       3       0       0       -3       3       0 <t< td=""><td>E100 E110 E120 E130 E140 E150 E160 E165 E170</td><td>tt Coil - Zone I CA-SIS EDF 0 0 0 0 0 0 0 1 1 1 1</td><td>CLM2000 EDF 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>CIEMAT 0 0 0 0 0 0 0 0 0 0 0 0 0</td><td>NREL 0 0 0 0 0 2 0 1 1 -1</td><td>0 0 0 -7 -7 -6 -6</td><td>0 0 0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0 0 0</td><td>0 0 0 -7 -7 -7 -6 -6</td><td>0 0 0 0 2 1 1 1</td><td></td><td>0 0 0 0 0</td><td>0 0 0 0 0 0 0</td><td>0 0 0 0 0 0 0</td></t<>	E100 E110 E120 E130 E140 E150 E160 E165 E170	tt Coil - Zone I CA-SIS EDF 0 0 0 0 0 0 0 1 1 1 1	CLM2000 EDF 0 0 0 0 0 0 0 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0 0 0 0 0 0 0 0	NREL 0 0 0 0 0 2 0 1 1 -1	0 0 0 -7 -7 -6 -6	0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0	0 0 0 -7 -7 -7 -6 -6	0 0 0 0 2 1 1 1		0 0 0 0 0	0 0 0 0 0 0 0	0 0 0 0 0 0 0
E195 3 0 0 -3 -1 0 0 -3 3 0 0	E100 E110 E120 E130 E140 E150 E165 E165 E170 E180	tt Coil - Zone I CA-SIS EDF 0 0 0 0 0 0 0 1 1 1 1 1	CLM2000 EDF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	NREL 0 0 0 0 2 0 1 -1 -30	0 0 0 0 -7 -7 -6 -6 -13	0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 -7 -7 -6 -6 -6 -30	0 0 0 2 1 1 1 1		0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 1
	E100 E110 E120 E130 E140 E150 E160 E165 E170 E180 E185	tt Coil - Zone I CA-SIS EDF 0 0 0 0 0 0 0 1 1 1 1 1 2	CLM2000 EDF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	NREL 0 0 0 0 2 0 1 -1 -30 -28	0 0 0 0 -7 -7 -6 -6 -13 -11	0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 -7 -7 -6 -6 -30 -28	0 0 0 2 1 1 1 1 1 2		0 0 0 0 0 0 0 1 1	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
	E100 E110 E120 E130 E140 E150 E160 E165 E170 E180 E185 E190	t Coil - Zone I CA-SIS EDF 0 0 0 0 0 0 0 1 1 1 1 1 1 2 3	CLM2000 EDF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	NREL 0 0 0 0 2 0 1 -1 -1 -30 -28 -3	0 0 0 0 -7 -7 -6 -6 -13 -11 -2	0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 -7 -7 -7 -6 -6 -30 -28 -3	0 0 0 2 1 1 1 1 2 3		0 0 0 0 0 0 0 1 1	0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
	E100 E110 E120 E130 E140 E150 E160 E165 E170 E180 E185 E190 E195	t Coil - Zone I CA-SIS EDF 0 0 0 0 0 0 0 1 1 1 1 1 1 2 3	CLM2000 EDF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	NREL 0 0 0 0 2 0 1 -1 -30 -28 -3 -3 -3	0 0 0 -7 -7 -6 -6 -13 -11 -2 -1	0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 -7 -7 -7 -6 -6 -30 -28 -3 -3 -3	0 0 0 2 1 1 1 1 2 3		0 0 0 0 0 0 0 1 1 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 -1 -1 -1 0 0
	E100 E110 E120 E130 E140 E150 E160 E165 E170 E180 E185 E190 E195	t Coil - Zone I CA-SIS EDF 0 0 0 0 0 0 0 1 1 1 1 1 1 2 3	CLM2000 EDF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	CIEMAT 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	NREL 0 0 0 0 2 0 1 -1 -30 -28 -3 -3 -3	0 0 0 -7 -7 -6 -6 -13 -11 -2 -1	0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 -7 -7 -7 -6 -6 -30 -28 -3 -3 -3	0 0 0 2 1 1 1 1 2 3		0 0 0 0 0 0 0 1 1 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Sensitivities for Space Cooling Electricity Consumption
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Sensitivit													
Delta Qtot (k)		CI M2000	DODALE	DOESIE	Enours	TDM 4	TDN -	Statistics,	All Result		A	a bati cal	
	CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	Energy+ GARD	TRN-id TUD	TRN-re TUD	Min	Max	Abs(Max- Min)/Analy.	An TUD	alytical HTAL1	HTAL2
E110-E100	-454	-441	-460	-454	-451	-455	-450	-460	-441	4.1%	-454	-454	-453
E120-E110	-65	-77	-50	-62	-63	-60	-60	-77	-50	42.3%	-64	-66	-66
E120-E100	-519	-518	-510	-516	-514	-515	-510	-519	-510	1.8%	-518	-520	-520
E130-E100	-1421	-1421	-1415	-1413	-1411	-1414	-1402	-1421	-1402	1.4%	-1420	-1421	-1421
E140-E130	-42	-40	-40	-40	-41	-41	-41	-42	-40	4.8%	-42	-41	-41
E140-E110	-1009	-1020	-996	-999	-1001	-999	-993	-1020	-993	2.6%	-1007	-1009	-1009
E150-E110	131	118	141	118	128	132	130	118	141	17.8%	130	129	129
E160-E150	-68	-68	-65	-76	-65	-62	-59	-76	-59	26.1%	-66	-67	-68
E165-E160	362	362	362	363	359	363	357	357	363	1.7%	357	360	361
E170-E150	-570	-569	-573	-563	-562	-563	-556	-573	-556	3.1%	-565	-569	-569
E180-E150	-125	-125	-125	-103	-115	-118	-112	-125	-103	18.0%	-124	-124	-125
E180-E170	445	444	448	460	447	445	444	444	460	3.6%	442	445	444
E185-E180	461	461	464	467	458	460	458	458	467	1.9%	462	461	461
E190-E180	-919	-918	-917	-920	-918	-917	-915	-920	-915	0.6%	-917	-918	-918
E190-E140	96	95	95	<del>9</del> 4	96	96	96	94	96	2.6%	96	96	96
E195-E190	86	86	85	86	86	86	86	85	86	2.0%	87	86	86
E195-E185	-1294	-1293	-1296	-1301	-1290	-1292	-1287	-1301	-1287	1.1%	-1292	-1293	-1293
E195-E130	140	141	140	140	142	141	141	140	142	1.5%	142	141	141
E200-E100	-54	-66	-53	-79	-55	-42	-32	-79	-32	86.0%	-55	-53	-54
Del Qcomp (k								Statistics,	All Result				
	CA-SIS	CLM2000	DOE21E	DOE21E	Energy+	TRN-id	TRN-re			Abs(Max-		alytical	
	EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	Min	Max	Min)/Analy.	TUD	HTALI	HTAL2
E110-E100	-430	-419	-442	-428		-432	-427	-442	-419	5.2%	-431	-430	-430
E120-E110	-49	-59	-16	-45		-43	-44	-59	-16	91.8%	-47	-50	-50
E120-E100	-479	-478	-457	-473		-475	-471	-479	-457	4.5%	-478	-480	-480
E130-E100	-1224	-1224	-1214	-1218		-1218	-1208	-1224	-1208	1.3%	-1224	-1225	-1225
E140-E130	-38	-37	-38	-37		-38	-38	-38	-37	3.6%	-38	-38	-38
E140-E110	-832	-842	-811	-827		-823	-819	-842	-811	3.7%	-831	-833	-833
E150-E110	111	100	141	99		113	111	99	141	38.0%	111	110	110
E160-E150	-50	-50	-44	-56		-45	-42	-56	-42	28.0%	-49	-50	-50
E165-E160	333	332	329	330		333	328	328	333	1.6%	328	331	331
E170-E150	-469	-469	-468	-459		-464	-458	-469	-458	2.3%	-466	-469	-469
E180-E150	-91 279	-91 279	-93 275	-70		-85	-80	-93 275	-70	25.1%	-91 275	-91 279	-92 279
E180-E170	378	378	375	389		379	378	375	389	3.7%	375	378	378
E185-E180 E190-E180	431 -771	431 -770	428 -775	432 -774		430 -770	428 -768	428 -775	432 -768	0.9% 0.9%	432 -770	431 -770	431 -770
E190-E180 E190-E140	-//1 81	-//0 81	-775 85	- / /4 82		-770	- / 08 82	-775 81	- / 08 85	0.9% 4.4%	- / /0 82	-770 81	-770 81
E190-E140 E195-E190	81 79	79	85 79	82 79		82 79	82 80	79	80 80	4.4% 0.8%	82 80	81 79	81 79
E195-E190	-1123	-1122	-1124	-1127		-1120	-1116	-1127	-1116	1.0%	-1121	-1122	-1121
E195-E130	122	123	126	124		123	123	122	126	3.0%	123	122	123
	144	145	120	144		125		144	120		145	144	145
		-70	-58	-03		-58		-03	-50		-70	-60	-60
E200-E100	-69	-79	-58	-93		-58	-50	-93 Statistics	-50	61.6%	-70	-69	-69
Del Q IDfan (	-69 kWh,e)				Enerov+		-50		-50 All Result	61.6% s			-69
	-69 <b>kWh,e)</b> CA-SIS	CLM2000	DOE21E	DOE21E	Energy+ GARD	TRN-id	-50 TRN-re	Statistics,	All Result	61.6% s Abs(Max-	An	alytical	
Del Q IDfan (1	-69 kWh,e) CA-SIS EDF	CLM2000 EDF	DOE21E CIEMAT	DOE21E NREL	GARD	TRN-id TUD	-50 TRN-re TUD	Statistics, Min	All Result Max	61.6% s Abs(Max- Min)/Analy.	An TUD	alytical HTAL1	HTAL2
Del Q IDfan () E110-E100	-69 kWh,e) CA-SIS EDF -16	CLM2000 EDF -15	DOE21E CIEMAT -12	DOE21E NREL -19	GARD -16	TRN-id TUD -16	-50 TRN-re TUD -16	Statistics, Min -19	All Result Max -12	61.6% s Abs(Max- Min)/Analy. 42.3%	An TUD -16	alytical HTAL1 -16	HTAL2 -16
Del Q IDfan () E110-E100 E120-E110	-69 <b>kWh,e)</b> CA-SIS EDF -16 -11	CLM2000 EDF -15 -12	DOE21E CIEMAT -12 -23	DOE21E NREL -19 -12	GARD -16 -11	TRN-id TUD -16 -11	-50 TRN-re TUD -16 -11	Statistics, Min -19 -23	All Result Max -12 -11	61.6% s Abs(Max- <u>Min)/Analy</u> 42.3% 110.0%	An TUD -16 -11	alytical HTAL1 -16 -11	HTAL2 -16 -11
Del Q IDfan () E110-E100 E120-E110 E120-E100	-69 kWh,e) CA-SIS EDF -16	CLM2000 EDF -15	DOE21E CIEMAT -12	DOE21E NREL -19	GARD -16	TRN-id TUD -16	-50 TRN-re TUD -16	Statistics, Min -19	All Result Max -12	61.6% s Abs(Max- Min)/Analy. 42.3%	An TUD -16	alytical HTAL1 -16	HTAL2 -16
Del Q IDfan () E110-E100 E120-E110	-69 <b>kWh,e)</b> CA-SIS EDF -16 -11 -27	CLM2000 EDF -15 -12 -27	DOE21E CIEMAT -12 -23 -36	DOE21E NREL -19 -12 -31	GARD -16 -11 -27	TRN-id TUD -16 -11 -27	-50 TRN-re TUD -16 -11 -27	Statistics, Min -19 -23 -36	All Result <u>Max</u> -12 -11 -27	61.6% s Abs(Max- Min)/Analy. 42.3% 110.0% 32.2%	An TUD -16 -11 -27	alytical <u>HTAL1</u> -16 -11 -27	HTAL2 -16 -11 -27 -134
Del Q IDfan () E110-E100 E120-E110 E120-E100 E130-E100 E140-E130	-69 <b>kWh,e)</b> CA-SIS EDF -16 -11 -27 -134	CLM2000 EDF -15 -12 -27 -134	DOE21E CIEMAT -12 -23 -36 -137	DOE21E NREL -19 -12 -31 -133	GARD -16 -11 -27 -133	TRN-id TUD -16 -11 -27 -133	-50 TRN-re TUD -16 -11 -27 -132	Statistics, <u>Min</u> -19 -23 -36 -137	All Result -12 -11 -27 -132	61.6% s Abs(Max- Min)/Analy. 42.3% 110.0% 32.2% 3.7%	An TUD -16 -11 -27 -134	alytical HTAL1 -16 -11 -27 -134	HTAL2 -16 -11 -27 -134 -2
Del Q IDfan () E110-E100 E120-E110 E120-E100 E130-E100 E140-E130 E140-E110	-69 kWh,e) CA-SIS EDF -16 -11 -27 -134 -2 -120	CLM2000 EDF -15 -12 -27 -134 -2	DOE21E CIEMAT -12 -23 -36 -137 -1	DOE21E NREL -19 -12 -31 -133 -2	GARD -16 -11 -27 -133 -2	TRN-id TUD -16 -11 -27 -133 -2	-50 TRN-re TUD -16 -11 -27 -132 -2	Statistics, <u>Min</u> -19 -23 -36 -137 -2	All Result -12 -11 -27 -132 -1	61.6% s Abs(Max- Min)/Analy. 42.3% 110.0% 32.2% 3.7% 36.8%	An TUD -16 -11 -27 -134 -2	alytical HTAL1 -16 -11 -27 -134 -2	HTAL2 -16 -11 -27 -134 -2 -120
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Del Q IDfan ( E110-E100 E120-E110 E120-E100 E130-E100 E140-E100 E140-E10 E150-E10 E150-E10 E160-E150 E180-E150 E180-E170 E180-E170 E190-E180 E190-E180 E195-E190 E195-E130 E200-E100 Del Q ODfan E110-E100 E140-E110 E140-E110 E150-E10 E150-E10 E150-E10 E165-E160 E170-E150 E180-E150 E180-E150 E180-E150 E180-E150 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180	-69 kWh,e) CA-SIS EDF -16 -11 -27 -134 -2 -20 13 -12 20 -68 -23 45 21 -100 10 5 -116 13 10 (kWh,e) CA-SIS EDF -8 -3 -63 -11 -100 10 5 -116 -13 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0	CLM2000 EDF -15 -12 -27 -134 -2 -121 12 -12 -12 -12 -12 -12 -12 -12	DOE21E CIEMAT -12 -23 -36 -137 -1 -126 0 -14 23 -72 -22 -22 -22 -22 -22 -22 -22 -22 -49 24 -97 7 7 4 -117 7 7 4 -117 -9 4 24 -97 7 7 4 -11 -126 0 -14 -23 -72 -22 -22 -22 -22 -22 -22 -22 -22 -22	DOE21E NREL -19 -12 -31 -133 -2 -116 14 -15 24 -73 -24 49 25 -98 8 4 -119 10 10 10 10 DOE21E NREL -7 -5 -12 -62 -1 -5 9 9 -31 -9 22 10 -48 4	GARD -16 -11 -27 -133 -2 -119 13 -12 20 -67 -22 45 21 -100 10 5 -116 12 10 Energy+	TRN-id TUD -16 -11 -27 -133 -2 -120 -120 -68 -22 45 21 -100 -68 -22 45 21 -100 5 -117 12 11 TRN-id TUD -7 -5 -13 -63 -13 -56 -6 -6 -6 -6 -6 -6 -6 -10 -12 21 -100 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7	-50 TRN-re TUD -16 -11 -27 -32 -2 -118 -11 20 -66 -62 -21 45 21 -100 -00 10 5 5 5 5 5 -116 12 12 12 -100 -77 -7 -13 -62 -11 -13 -62 -13 -62 -13 -62 -13 -13 -54	Statistics, Min -19 -23 -36 -137 -2 -126 0 -15 20 -15 20 -73 -24 45 20 -101 7 4 -119 9 4 Statistics, Min -8 -11 -17 -64 -11 -19 -9 -34 -119 9 4 -119 9 4 -119 -24 -126 0 -101 7 4 -119 9 -24 -126 0 -101 7 4 -119 9 -24 -126 0 -101 7 4 -119 9 -24 -126 0 -101 7 4 -119 9 -24 -126 0 -101 7 -24 -15 200 -101 7 -24 -15 200 -101 7 4 -119 9 -8 -117 -64 -11 -117 -64 -11 -119 -9 -34 -11 -117 -64 -11 -119 -9 -34 -119 -8 -8 -11 -117 -64 -11 -119 -9 -34 -11 -127 -64 -11 -12 -126 -126 -119 -8 -11 -117 -64 -11 -11 -11 -12 -29 -34 -11 -12 -59 0 -7 -7 -24 -11 -11 -11 -11 -11 -25 -3 -24 -3 -25 -3 -3 -25 -55 -55	All Result Max -12 -11 -27 -132 -1 -16 14 -11 24 -66 -5 -12 -62 -1 -12 -62 -1 -56 -5 11 -31 -99 23 -1 -54 -54	61.6% * Abs(Max- Min)/Analy. 42.3% 110.0% 32.2% 3.7% 36.8% 8.3% 9.7% 12.1% 9.9% 24.3% 24.3% 24.3% 24.3% 24.3% 28.1% 30.6% 2.6% 28.9% 79.1% * Abs(Max- Min)/Analy. 29.9% 113.1% 37.0% 3.7% 4.3% 9.7% 113.1% 37.0% 3.7% 4.3% 100.8% 27.0% 17.5% 8.2% 14.3% 9.6% 17.5% 8.2% 14.3% 9.6% 2.0% 14.3% 1.0% 1	Ann TUD -16 -11 -27 -134 -2 -120 -68 -22 45 21 -101 10 5 -117 12 10 -107 -7 -5 -117 12 10 -7 -7 -5 -13 -63 -11 -13 -63 -11 -15 -6 6 -6 9 -32 -11 21 00 -47 5 5 -55	alytical HTAL1 -16 -11 -27 -120 -34 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -10 10 5 -117 -10 10 5 -117 -12 21 -12 -10 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 -10 -10 -10 -10 -10 -10 -10 -10 -10 -10	HTAL2 -16 -11 -27 -134 -22 -120 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -134 -12 20 -6 -134 -12 20 -6 -134 -12 20 -134 -12 20 -6 -134 -12 20 -6 -134 -12 20 -6 -134 -12 20 -6 -134 -12 20 -6 -13 -12 20 -6 -13 -12 20 -6 -13 -12 20 -6 -6 -12 -12 -12 -12 -12 -12 -12 -12
Del Q IDfan ( E110-E100 E120-E110 E120-E100 E130-E100 E140-E130 E140-E110 E160-E150 E160-E150 E180-E150 E180-E170 E180-E170 E190-E180 E190-E180 E195-E190 Del Q ODfan E120-E100 E120-E100 E120-E100 E140-E130 E140-E130 E140-E150 E160-E150 E160-E150 E180-E170 E180-E170 E180-E170 E180-E170 E180-E170 E180-E150 E180-E150 E180-E150 E180-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180	-69 kWh,e) CA-SIS EDF -16 -11 -27 -134 -22 -120 13 -12 20 -68 -23 45 21 -100 10 5 -116 13 10 (kWh,e) CA-SIS EDF -8 -5 -13 -63 -5 9 -32 -10 22 9 -48 4 3	CLM2000 EDF -15 -12 -27 -134 -2 -121 12 -12 -12 21 -68 -22 46 20 -101 -101 10 5 -116 13 9 9 CLM2000 EDF -7 -6 -13 -63 -13 -63 -13 -57 9 9 -32 -10 22 9 9 -32 -10 22 -54 6 6	DOE21E CIEMAT -12 -23 -36 (-137 -1 -126 0 -14 23 -72 -22 49 24 -97 -7 4 -117 -6 -11 -17 -64 -11 -17 -64 -11 -17 -64 -11 -17 -64 -11 -17 -64 -11 -17 -59 -0 -7 23 -7 24 -7 25 -7 24 -7 25 -7 24 -7 25 -7 24 -7 25 -7 25 -7 25 -7 26 -7 27 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7 -7	DOE21E NREL -19 -12 -31 -133 -2 -116 14 -15 24 -73 -24 49 25 -98 8 4 -119 10 10 10 DOE21E NREL -77 -5 -12 -62 -11 -56 5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -5 -	GARD -16 -11 -27 -133 -2 -119 13 -12 20 -67 -22 45 21 -100 10 5 -116 12 10 Energy+	TRN-id TUD -16 -11 -27 -133 -2 -120 -12 20 -68 -22 45 21 -100 10 5 -117 12 11 TRN-id TUD -7 -5 -13 -63 -1 -56 6 6 -6 10 -32 -11 21 10 -5 2	-50 TRN-re TUD -16 -11 -12 -2 -2 -118 -11 20 -2 -2 -118 -11 20 -21 -2 -2 -2 -118 -21 -2 -2 -2 -11 -20 -21 -2 -2 -2 -2 -2 -118 -21 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2	Statistics, Min -19 -23 -36 -137 -2 -126 0 -15 20 -73 -24 45 20 -101 7 4 -119 9 4 Statistics, Min -8 -11 -17 -64 -1 -17 -64 -1 -17 -64 -1 -19 -36 -36 -36 -137 -24 45 20 -101 7 4 -119 9 4 -126 -101 7 -73 -24 45 20 -101 7 -73 -24 45 20 -101 7 -73 -24 45 20 -101 7 -73 -24 45 20 -101 7 -73 -24 45 20 -101 7 -73 -24 45 20 -101 7 -73 -24 45 20 -101 7 -73 -24 45 20 -101 7 -73 -24 45 20 -101 7 -15 20 -101 -73 -24 -119 9 -4 -119 9 -4 -119 -8 -11 -73 -24 -126 -01 -73 -24 -119 9 -4 -11 -17 -64 -11 -17 -59 0 -7 -7 9 -34 -34 -11 -17 -64 -11 21 9 -34 -11 -17 -59 0 -7 -7 -7 -34 -11 -17 -59 0 -7 -7 -34 -11 21 -59 -7 -7 -34 -11 -17 -59 -34 -11 -11 -17 -55 -34 -11 -11 -55 -34 -11 -11 -12 -55 -7 -7 -34 -11 -11 -55 -55 -4 -11 -15 -55 -55 -55 -55 -55 -55	All Result Max -12 -11 -27 -132 -1 -116 14 -11 24 -6 -21 49 25 -97 10 5 -116 13 12 Max -6 -5 -12 -1 -66 -5 -11 -62 -1 -1 -62 -1 -1 -5 -1 -1 -62 -1 -1 -5 -1 -1 -5 -1 -1 -5 -1 -1 -5 -1 -1 -5 -1 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2	61.6% * Abs(Max- Min)/Analy. 42.3% 110.0% 32.2% 3.7% 36.8% 8.3% 9.7% 107.0% 32.6% 21.8% 9.7% 24.3% 24.3% 24.3% 24.3% 2.8% 28.1% 30.6% 28.9% 79.1% * * Abs(Max- Min)/Analy. 29.9% 113.1% 37.0% 37.0% 3.7% 6.3%	Ann TUD -16 -11 -27 -134 -2 -120 -68 -22 45 21 -101 10 5 -117 12 10 -7 -7 -5 -13 -63 -11 -13 -63 -11 -13 -63 -11 -13 -63 -11 -13 -55 6 -6 9 -32 -11 21 10 -7 -55 6	alytical HTAL1 -16 -11 -27 -120 13 -12 20 -68 -23 -12 20 -68 -23 -12 20 -63 -101 10 5 -117 2 11 10 5 -117 2 11 -101 10 5 -117 -23 -45 21 -101 -10 -63 -11 -7 -5 -5 6 6 6 6 6 6 6 6 -6 9 9 -32 -11 -27 -12 -20 -28 -28 -28 -28 -28 -28 -28 -28 -28 -28	HTAL2 -16 -11 -27 -134 -2 -120 13 -12 20 -68 -23 -23 -23 -13 -10 -05 -117 12 11 -101 5 -117 -13 -13 -13 -13 -68 -23 -23 -11 11 -10 -5 -117 -134 -2 -2 -120 -68 -23 -2 -2 -2 -120 -68 -23 -2 -2 -120 -68 -23 -2 -2 -120 -68 -23 -2 -2 -120 -68 -23 -2 -2 -2 -120 -68 -22 -2 -120 -68 -22 -20 -68 -22 -20 -68 -21 -110 -15 -14 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2
Del Q IDfan ( E110-E100 E120-E110 E120-E100 E130-E100 E140-E100 E140-E10 E150-E10 E150-E10 E160-E150 E180-E150 E180-E170 E180-E170 E190-E180 E190-E180 E195-E190 E195-E130 E200-E100 Del Q ODfan E110-E100 E120-E10 E120-E10 E120-E10 E140-E110 E150-E10 E165-E160 E170-E150 E180-E150 E180-E150 E180-E150 E180-E150 E180-E150 E180-E150 E180-E150 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180 E190-E180	-69 kWh,e) CA-SIS EDF -16 -11 -27 -134 -22 -120 13 -12 20 -68 -23 45 21 -100 10 5 -116 13 10 (kWh,e) CA-SIS EDF -8 -5 -13 -63 -63 -5 -13 -63 -63 -5 -9 -32 -10 -5 -5 -13 -63 -5 -5 -13 -63 -5 -5 -13 -63 -5 -5 -13 -12 -5 -16 -5 -5 -12 -12 -12 -12 -12 -12 -12 -12	CLM2000 EDF -15 -12 -27 -134 -2 -121 12 -12 21 -68 -22 46 20 -12 21 -12 -12 -12 -12 -12 -12 -12 -12	DOE21E CIEMAT -12 -23 -36 -137 -1 -126 0 -14 23 -72 -22 -22 49 24 -97 7 7 4 -117 7 4 -117 9 4 -97 7 7 4 -117 -7 9 4 -97 7 7 4 -117 -22 -22 -22 -22 -22 -22 -22 -22 -22 -2	DOE21E NREL -19 -12 -31 -133 -2 -116 14 -15 24 -73 -24 49 25 -98 8 4 -119 10 10 10 DOE21E NREL -7 -5 -12 -7 -5 -12 -62 -1 -56 5 -5 9 9 -31 -9 22 10 -48 4 3 3 -55 6 4	GARD -16 -11 -27 -133 -2 -119 13 -12 20 -67 -22 45 21 -100 10 5 -116 12 10 Energy+ GARD	TRN-id TUD -16 -11 -27 -13 -2 -120 13 -12 20 -68 -22 45 21 -100 10 5 -117 12 11 TRN-id TUD -7 -5 -13 -63 -1 -13 -63 -1 -13 -63 -1 -13 -63 -1 -13 -56 6 -6 -6 10 -7 -7 -55 6 6	-50 TRN-re TUD -16 -11 -27 -32 -2 -118 -11 20 -66 -62 -21 45 21 -100 -00 10 5 5 5 5 5 -116 12 12 12 -100 -77 -7 -13 -62 -11 -13 -62 -13 -62 -13 -62 -13 -13 -54	Statistics, Min -19 -23 -36 -137 -2 -126 0 -15 20 -15 20 -73 -24 45 20 -101 7 4 -119 9 4 Statistics, Min -8 -11 -17 -64 -11 -19 -9 -34 -119 9 4 -119 9 4 -119 -24 -126 0 -101 7 4 -119 9 -24 -126 0 -101 7 4 -119 9 -24 -126 0 -101 7 4 -119 9 -24 -126 0 -101 7 4 -119 9 -24 -126 0 -101 7 -24 -15 200 -101 7 -24 -15 200 -101 7 4 -119 9 -8 -117 -64 -11 -117 -64 -11 -119 -9 -34 -11 -117 -64 -11 -119 -9 -34 -119 -8 -8 -11 -117 -64 -11 -119 -9 -34 -11 -127 -64 -11 -12 -126 -126 -119 -8 -11 -117 -64 -11 -11 -11 -12 -29 -34 -11 -12 -59 0 -7 -7 -24 -11 -11 -11 -11 -11 -25 -3 -24 -3 -25 -3 -3 -25 -55 -55	All Result Max -12 -11 -27 -132 -1 -16 14 -11 24 -66 -5 -12 -62 -1 -12 -62 -1 -56 -5 11 -31 -99 23 -1 -54 -54	61.6% 8 Abs(Max- Min)/Analy. 42.3% 110.0% 32.2% 3.7% 36.8% 8.3% 9.7% 12.1% 9.9% 24.3% 24.3% 24.3% 24.3% 24.3% 28.1% 30.6% 2.6% 28.9% 79.1% 8 Abs(Max- Min)/Analy. 29.9% 113.1% 37.0% 3.7% 4.3% 9.7% 113.1% 37.0% 3.7% 3.6.8% 100.8% 27.0% 17.5% 8.8% 100.8% 27.0% 17.5% 8.8% 100.8% 27.0% 17.5% 8.2% 1.0.9% 1.0.9% 1.0.5% 1	Ann TUD -16 -11 -27 -134 -2 -120 -68 -22 45 21 -101 10 5 -117 12 10 -107 -7 -5 -117 12 10 -7 -7 -5 -13 -63 -13 -63 -11 -156 6 -6 6 -6 9 -32 -11 21 00 -75 5 -35 -55	alytical HTAL1 -16 -11 -27 -120 -34 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -10 10 5 -117 -10 10 5 -117 -12 21 -12 -10 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 20 -68 -23 -12 -10 -10 -10 -10 -10 -10 -10 -10 -10 -10	HTAL2 -16 -11 -27 -134 -22 -120 20 -68 -23 45 21 -101 10 5 -117 -101 10 5 -117 -134 HTAL2 -7 -5 -13 -13 -13 -134 -2 -2 -12 -12 -12 -12 -12 -12

# Sensitivities for COP and Coil Loads

BERDEN         0.48 <th0.48< th="">         0.48         0.48         <t< th=""><th></th><th>AND IN</th><th></th><th></th><th></th><th></th><th></th><th>1</th><th>Chatistics.</th><th>All Description</th><th>-</th><th></th><th></th><th></th></t<></th0.48<>		AND IN						1	Chatistics.	All Description	-			
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			01 1/2000	DODUE	DODDIE	En avage l	TIDAT : J	TDM	Statistics,			A	alutical	
BIRCHOM         0.99         0.90         0.45									3.6					TTLATA
Electric de la construction de la construcción de l														
BIRGENIO         1.20														
BELBER         0.48         0.44         <	E120-E110	0.21	0.25	0.16	0.21	0.21	0.20	0.20	0.16	0.25	44.9%	0.21	0.21	0.21
Elabelia         0.86         0.87         0.98         0.98         0.88	E120-E100	1.20	1.20	1.18	1.22	1.20	1.20	1.21	1.18	1.22	2.8%	1.20	1.20	1.20
Elabelia         0.86         0.87         0.98         0.98         0.88		-0.48	-0.48	-0.46	-045	-0.50	-0.48	-0.50	-0.50	-0.45	9.8%	-0.50		
Birds-Elilo         0.61         0.54         0.55         0.61         0.68         0.64         0.64         0.54         13.6%         0.63         0.61														
Bilb Billo         0.24         0.23         0.21         0.29         3.20*         0.23														
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$														
Bits 5:116         0.92         0.93	E150-E110	0.24	0.29	0.21	0.29	0.25	0.24	0.25	0.21	0.29		0.25	0.25	0.25
Bits 5:116         0.92         0.93	E160-E150	0.22	0.21	0.20	0.25	0.21	0.20	0.19	0.19	0.25	30.9%	0.21	0.21	0.21
BITO-E.150         0.424         0.24         0.23         0.425         0.25         0.27         0.427         0.22         B1814         0.425         0.34         0.04         0.35         0.42         0.35         0.42         0.35         0.42         0.35         0.42         0.35         0.42         0.35         0.42         0.35         0.42         0.43         0.44         0.44         0.44         0.44         0.44         0.44         0.44         0.44         0.44         0.44         0.44         0.44         0.44         0.44         0.44         0.45														
Bible I:10         0.42         0.41         0.42         0.43         0.43         0.42         2.2 drs         0.46         0.45 <th0.45< th="">         0.45         0.45</th0.45<>														
Bible Time         0.66         0.65         0.65         0.65         0.65         0.65         0.65         0.66         1.64         0.68         0.65         0.65         0.65         0.66         1.64         0.68         0.65         0.65         0.65         0.65         0.65         0.66         1.05         1.13         1.12         1.12         1.13         1.12         1.13         1.12         1.13         1.12         1.13         1.12         1.13         1.13         1.13         1.13         1.13         1.13         1.13         1.13         1.13         1.13         1.13         1.13         1.13         1.13         1.13         1.05         0.05														
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$														
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	E180-E170	0.66	0.65	0.64	0.55	0.65	0.65	0.65	0.55	0.66	16.4%	0.68	0.65	0.65
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	E185-E180	-1.19	-1.19	-1.21	-1.20	-1.19	-1.20	-1.20	-1.21	-1.19	1.7%	-1.20	-1.19	-1.19
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	E190-E180	-0.63	-0.63	-0.60	-0.57	-0.65			-0.65	-0.57	12.4%		-0.63	-0.63
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$														
Bits 5:15         0.49         0.54         0.40         0.40         0.45         0.45         0.45         0.45         0.45         0.45         0.45         0.45         0.44         0.40         0.40         0.45         0.44         0.40         0.45         0.44         0.40         0.45         0.44         0.45         0.45         0.44         0.44         0.40         0.40         0.45         0.44         0.44         0.44         0.40         0.45         0.40														
Bits-5:13:0         0.40         0.40         0.48         0.43         0.40														
E320-E100         1.23         1.24														
DH O GALR RAWN.J)         Concernment         First-id         TRN-id	E195-E130	0.40	0.40	0.38	0.38	0.40	0.40	0.39	0.38	0.40	4.2%	0.40	0.40	0.40
DH O GALR RAWN.J)         Concernment         First-id         TRN-id	E200-E100	1 23	1 22	1 24	1 30	1 24	1 21	1 19	1 19	1 30	8 9%	1 23	1 23	1 23
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			1.22	1.21	1.50	1.2.	1.21					1.25	1.40	1.25
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			CT 3 (2000	DOFUE	DOPUE	Transa l		TDN				•	-1-4-1-1	
Ello-Lillo -35 -34 -38 -38 -38 -35 -35 -35 -35 -35 -35 -35 -35 -35 -35														
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$														
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	E110-E100	-35	-34	-38	-38	-35	-35	-35	-38	-34	12.5%	-35	-35	-35
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	E120-E110	-16	-17	-40	-16	-16	-16	-16	-40	-16	147.5%	-16	-16	-17
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$														
Elde.Elia0         -21         -21         -21         -21         -21         -21         -20         -21         -23         -23         -23         -23         -23         -22         -23         -23         -22         -23         -23         -22         -23         -23         -22         -23         -23         -22         -23         -23         -22         -23         -23         -23         -23         -23         -23         -23         -23         -23         -23         -22														
$ \begin{split} &                                   $														
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$\begin{split} &   160-1150 \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$	E140-E110	-3567	-3568	-3608	-3561	-3567	-3567	-3565	-3608	-3561		-3567	-3567	-3568
$\begin{split} &   160-1150 \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$	E150-E110	752	751	739	772	746	752		739		4.4%	752		
Els65_El66       37       38       51       40       38       37       36       37       286       238       1288       228       228       17       228       17       228       17       228       17       228       17       228       17       228       17       228       238       39														
Bit Po.E150         -2284         -2284         -2285         -2385         -338 <td></td>														
bitsR0=bits0         -22         -22         -33         7         -28         -22         -21         -33         7         78         -28         -23         -23         -25         -236         226         226         226         226         228         226         226         228         226         228         226         228         226         228         226         228         226         228         226         228         228         228         228         228         228         228         228         228         228         228         228         228         228         228         228         228         2307         38         1.8%         383         393         363         193         128         128         128         128         1														
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made bigourb remperature, mean and (max-ming mean	Indoor Drybulb	<b>Temperature: Mean</b>	and (Max-Min)/ Mean
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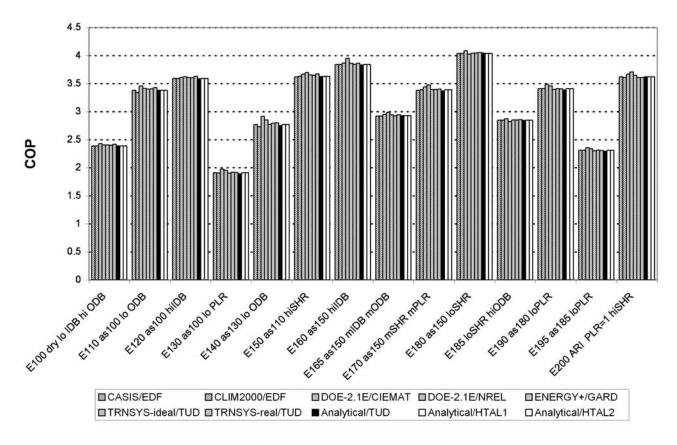
E110       22.2       22.2       22.3       22.3       22.2       22.2       22.5       1.5%       22.2       22.2       22.2         E120       26.7       26.7       26.7       26.7       26.7       26.7       26.7       26.7       26.7       26.7       26.7       26.7       26.7       26.7       22.2       22.2       22.2       22.2       22.5       1.5%       22.2       22.2       22.2       22.2       22.5       1.6%       22.2       22.2       22.2       22.2       22.5       1.5%       22.2	Mean IDB (°C	;)							Statistics	, All Results				
E100         22.2         22.2         22.3         22.3         22.2         22.2         22.6         22.2         22.6         2.0         22.2		CASIS	CLM2000	DOE21E	DOE21 E	Energy+	TRN-id	TRN-re		()	/lax-Min)	A	nalytical	
E110       22.2       22.2       22.3       22.3       22.2       22.5       1.5%       22.2		EDF		CIEMAT			TUD			Max / A	nalytical	TUD		
E120       26.7       26.7       26.8       26.7       26.7       27.1       1.4.%       26.7       26.7       26.7       26.7         E130       22.2       22.2       22.1       22.1       22.1       22.2       22.2       21.6       21.6       22.2       2.5.%       22.2	E100	22.2	22.2	22.3	22.3	22.2	22.2	22.6	22.2	22.6	2.0%	22.2	22.2	
E130       22.2       22.2       22.1       22.1       22.2       22.2       21.6       21.6       22.2       2.5       4       22.2 <td< td=""><td>E110</td><td>22.2</td><td>22.2</td><td>22.3</td><td>22.3</td><td>22.2</td><td>22.2</td><td>22.5</td><td>22.2</td><td>22.5</td><td>1.5%</td><td>22.2</td><td>22.2</td><td>22.2</td></td<>	E110	22.2	22.2	22.3	22.3	22.2	22.2	22.5	22.2	22.5	1.5%	22.2	22.2	22.2
E140       22.2       22.2       22.1       22.1       22.2       22.2       21.5       22.2       2.2.7       2.1.%       22.2	E120	26.7	26.7	26.8	26.7	26.7	26.7	27.1	26.7	27.1		26.7		26.7
E150       22.2       22.2       22.3       22.3       22.2       22.2       22.7       2.1%       22.2       22.2       22.2       22.2         E160       26.7       26.7       26.8       26.7       26.7       27.0       1.1%       26.7       26.7       26.7       27.0       1.1%       26.7       26.7       26.7       27.0       1.1%       26.7       26.7       26.7       27.0       1.1%       28.3       23.2       22.2	E130	22.2	22.2	22.1	22.1	22.2	22.2		21.6	22.2	2.5%	22.2	22.2	22.2
E160         26.7         26.7         26.8         26.7         26.7         27.0         1.1%         26.7         26.7         27.0         1.1%         26.7         26.7         27.0         1.1%         26.7         26.7         27.0         1.1%         26.7         26.7         27.0         1.1%         26.7         26.7         27.0         1.1%         26.7         26.7         27.0         1.1%         26.7         26.7         27.0         1.1%         23.3         23.3         23.3         23.3         23.3         23.3         23.3         23.3         23.3         23.3         23.3         23.3         23.3         23.3         23.3         23.3         23.2         22.2 <th< td=""><td>E140</td><td>22.2</td><td>22.2</td><td>22.1</td><td>22.1</td><td>22.2</td><td>22.2</td><td>21.5</td><td>21.5</td><td></td><td>3.1%</td><td>22.2</td><td>22.2</td><td>22.2</td></th<>	E140	22.2	22.2	22.1	22.1	22.2	22.2	21.5	21.5		3.1%	22.2	22.2	22.2
E165         23.3         23.3         23.4         23.3 <th< td=""><td>E150</td><td>22.2</td><td>22.2</td><td>22.3</td><td></td><td></td><td>22.2</td><td>22.7</td><td></td><td></td><td>2.1%</td><td>22.2</td><td></td><td></td></th<>	E150	22.2	22.2	22.3			22.2	22.7			2.1%	22.2		
E170         22.2         22.2         22.2         22.2         22.2         22.1         22.1         22.2         0.5%         22.2         22.2         22.2           E180         22.2         22.2         22.3         22.2         22.2         22.3         0.6%         22.2         22	E160													
E180         22.2         22.2         22.3         22.2         22.2         22.3         0.6%         22.2 <th< td=""><td>E165</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th<>	E165													
E185         22.2         22.2         22.3         22.2         22.2         22.4         0.8%         22.2 <th< td=""><td>E170</td><td>22.2</td><td>22.2</td><td>22.2</td><td>22.2</td><td></td><td>22.2</td><td>22.1</td><td>22.1</td><td></td><td>0.5%</td><td>22.2</td><td></td><td>22.2</td></th<>	E170	22.2	22.2	22.2	22.2		22.2	22.1	22.1		0.5%	22.2		22.2
E190         22.2         22.2         22.1         22.1         22.2         22.2         21.9         21.9         22.2         1.1%         22.2 <th< td=""><td>E180</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th<>	E180													
E195         22.2         22.1         22.1         22.1         22.2         22.2         22.0         22.0         22.0         22.2         0.9%         22.2         26.7 <th< td=""><td>E185</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th<>	E185													
E200         26.7         26.7         26.8         26.8         26.7         26.7         26.7         26.8         0.4%         26.7         26.7         26.7           (Max - Min)/ Mean TDB (°C) EDF         EDF         DDE21E         DDE21E         Energy+         TRN-id         TRN-re         (Max-Min)/ Min         Analytical         TUD         HTAL1         HTAL2           E100         0.0	E190	22.2					22.2	21.9	21.9					22.2
Statistics, Al Results           CA-SIS CLM2000 DOE21E DOE21E Energy+ TRN-id         TRN-id         TRN-id         TRN-id         Statistics, Al Results           CA-SIS CLM2000 DOE21E DOE21E Energy+ TRN-id         TRN-id         TRN-id         TRN-id         TRN-id         TRN-id         Min         Max-Min)         Analytical           TUD         TUD         TUD         TUD         Min         Max-Min)           EDF CIEMAT NREL GARD TUD         TUD         Min         Max-Min)         Analytical           TUD         OU00         0.000         0.000         0.000         OU00          OU000 <th< td=""><td>E195</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th<>	E195													
CA-SIS         CLM2000         DOE21E         DOE21E         Energy+         TRN-id         TRN-re         (Max-Min)         Analytical           EDF         EDF         CIEMAT         NREL         GARD         TUD         TUD         Min         Max / Analytical         TUD         HTAL1         HTAL2           E100         0.000				26.8	26.8	26.7	26.7	26.7				26.7	26.7	26.7
EDF         EDF         CIEMAT         NREL         GARD         TUD         TUD         Min         Max / Analytical         TUD         HTAL1         HTAL2           E100         0.000<	(Max - Min)/ N								Statistics					
E100         0.000										•	11		-	
E110         0.000											nalytical			
E120         0.000														
E130         0.000         0.000         0.000         0.000         0.000         0.000         0.000         0.000         0.000         0.000         0.001           E140         0.000														
E140         0.000														
E150         0.000														
E160         0.000														
E165         0.000														
E170         0.000         0.000         0.000         0.000         0.000         0.000         0.000         0.000         0.000         0.001           E180         0.000         0.000         0.000         0.000         0.000         0.000         0.000         0.001           E185         0.000         0.000         0.000         0.000         0.000         0.001         0.000         0.001           E190         0.000         0.000         0.000         0.000         0.000         0.023         0.000         0.000         0.001           E195         0.000         0.000         0.000         0.000         0.023         0.000         0.000         0.001														
E180         0.000         0.000         0.000         0.000         0.000         0.000         0.000         0.001           E185         0.000         0.000         0.000         0.000         0.000         0.001         0.000         0.000         0.001           E185         0.000         0.000         0.000         0.000         0.001         0.001         0.000         0.001           E190         0.000         0.000         0.000         0.000         0.002         0.000         0.028         0.000         0.000         0.001           E195         0.000         0.000         0.000         0.000         0.000         0.001         0.000         0.001														
E185         0.000         0.000         0.000         0.000         0.000         0.001         0.001         0.000         0.000         0.001           E190         0.000         0.000         0.000         0.000         0.000         0.000         0.000         0.001           E195         0.000         0.000         0.000         0.000         0.000         0.001         0.000         0.001														
E190         0.000         0.000         0.000         0.000         0.000         0.000         0.028         0.000         0.028         0.000         0.000         0.001           E195         0.000         0.000         0.000         0.000         0.000         0.023         0.000         0.000         0.001														
E195 0.000 0.000 0.000 0.000 0.000 0.000 0.023 0.000 0.023 0.000 0.000 0.001														
	E190													
E200 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000														
	E200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000

# Humidity Ratio: Mean and (Max-Min)/ Mean

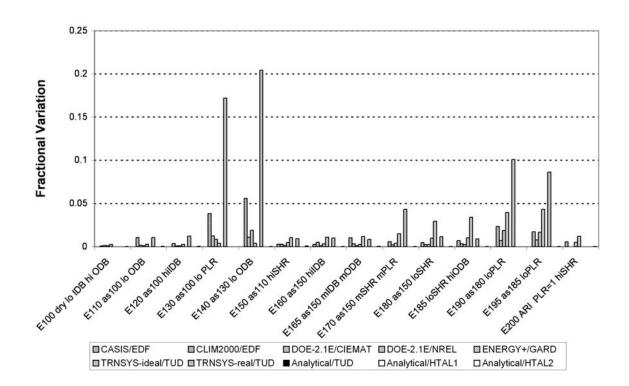
Mean Humid	ity Ratio							Statistic	s, All Result	S			
	CASIS	CLM2000	DOE21E	DOE21E	Energy+	TRN-id	TRN-re			(Max-Min)	, All All All All All All All All All Al	Analytical	
	EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	Min		Analytical	TUD	HTAL1	HTAL2
E100	0.0075	0.0069	0.0076	0.0074	0.0075	0.0075	0.0075	0.0069	0.0076	9.3%	0.0074	0.0073	0.0073
E110	0.0066	0.0069	0.0070	0.0064	0.0066	0.0066	0.0066	0.0064	0.0070	9.7%	0.0065	0.0064	0.0064
E120	0.0080	0.0070	0.0078	0.0078	0.0080	0.0080	0.0080	0.0070	0.0080	13.2%	0.0079	0.0079	0.0079
E130	0.0075	0.0069	0.0076	0.0073	0.0075	0.0075	0.0075	0.0069	0.0076	9.3%	0.0074	0.0073	0.0073
E140	0.0065	0.0069	0.0071	0.0064	0.0066	0.0066	0.0066	0.0064	0.0071	10.1%	0.0065	0.0064	0.0064
E150	0.0083	0.0085	0.0082	0.0083	0.0084	0.0083	0.0085	0.0082	0.0085	4.0%	0.0082	0.0082	0.0082
E160	0.0102	0.0101	0.0097	0.0099	0.0103	0.0101	0.0102	0.0097	0.0103	5.8%	0.0100	0.0099	0.0099
E165	0.0093	0.0099	0.0090	0.0092	0.0094	0.0093	0.0095	0.0090	0.0099	9.1%	0.0093	0.0092	0.0092
E170	0.0106	0.0107	0.0105	0.0105	0.0106	0.0105	0.0105	0.0105	0.0107	2.2%	0.0104	0.0105	0.0105
E180	0.0164	0.0164	0.0166	0.0164	0.0162	0.0163	0.0164	0.0162	0.0166	2.6%	0.0162	0.0162	0.0162
E185	0.0162	0.0171	0.0164	0.0162	0.0161	0.0162	0.0163	0.0161	0.0171	6.4%	0.0161	0.0161	0.0161
E190	0.0160	0.0161	0.0163	0.0159	0.0159	0.0159	0.0157	0.0157	0.0163	3.5%	0.0158	0.0159	0.0159
E195	0.0156	0.0164	0.0158	0.0155	0.0154	0.0155	0.0153	0.0153	0.0164	7.0%	0.0154	0.0154	0.0154
E200	0.0114	0.0115	0.0109	0.0111	0.0115	0.0113	0.0113	0.0109	0.0115	5.1%	0.0111	0.0111	0.0111
(Max - Min)/							Ì	Statistic	s, All Result				
		CLM2000	DOE21E	DOE21E	Energy+	TRN-id	TRN-re			(Max-Min)		Analytical	
	EDF	EDF	CIEMAT	NREL	GARD	TUD	TUD	Min		Analytical	TUD	HTAL1	HTAL2
E100	0.000	0.022	0.000	0.000	0.001	0.000	0.000	0.0000	0.0217		0.000	0.000	0.000
E110	0.000	0.022	0.014	0.000	0.000	0.000	0.000	0.0000	0.0217		0.000	0.000	0.000
E120	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.0000	0.0005		0.000	0.000	0.000
E130	0.000	0.010	0.000	0.000	0.001	0.000	0.000	0.0000	0.0101		0.000	0.000	0.000
E140	0.000	0.012	0.014	0.000	0.001	0.000	0.000	0.0000	0.0142		0.000	0.000	0.000
E150	0.012	0.000	0.000	0.000	0.013	0.000	0.013	0.0000	0.0132		0.000	0.000	0.000
E160	0.020	0.000	0.010	0.010	0.013	0.000	0.011	0.0000	0.0196		0.000	0.000	0.000
E165	0.011	0.001	0.011	0.000	0.013	0.000	0.013	0.0000	0.0131		0.000	0.000	0.000
E170	0.000	0.000	0.010	0.000	0.011	0.000	0.024	0.0000	0.0238		0.000	0.000	0.001
E180	0.018	0.000	0.012	0.012	0.010	0.000	0.040	0.0000	0.0402		0.000	0.000	0.001
E185	0.012	0.006	0.018	0.012	0.011	0.000	0.025	0.0000	0.0246		0.000	0.000	0.001
E190	0.000	0.000	0.018	0.019	0.014	0.000	0.031	0.0000	0.0312		0.000	0.000	0.001
E195	0.000	0.006	0.019	0.019	0.014	0.000	0.024	0.0000	0.0241		0.000	0.000	0.001
E200	0.018	0.000	0.009	0.009	0.013	0.000	0.000	0.0000	0.0175		0.000	0.000	0.000

results5-3.xls q:bc233..br304; 10/15/02

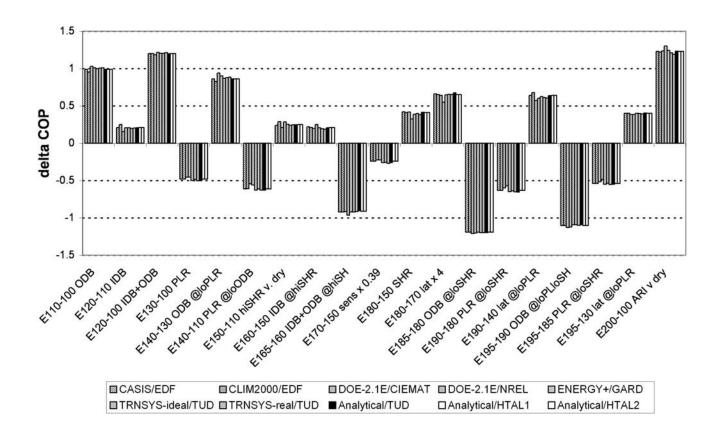


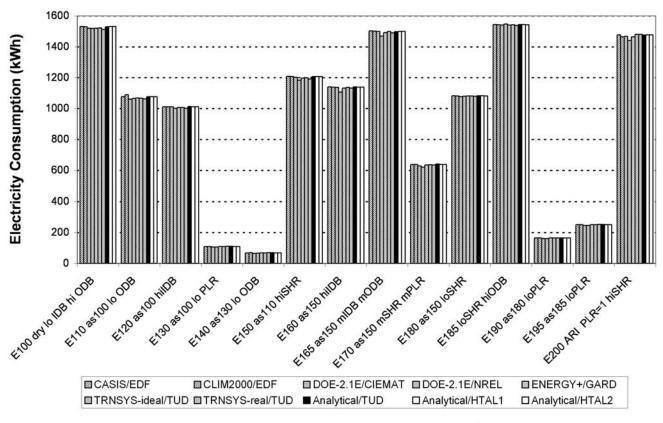


HVAC BESTEST: (Maximum - Minimum)/Mean COP



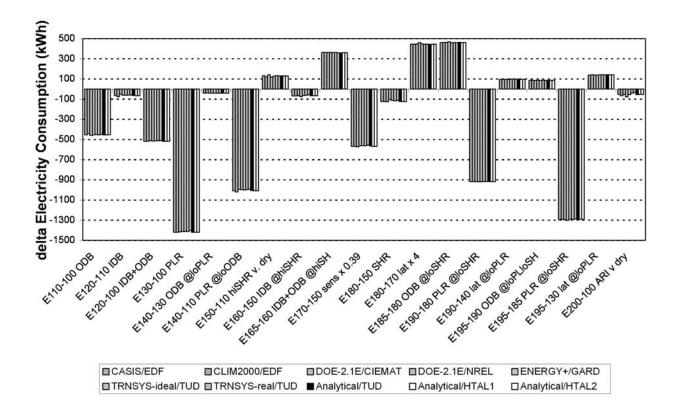
# **HVAC BESTEST: Mean COP Sensitivities**

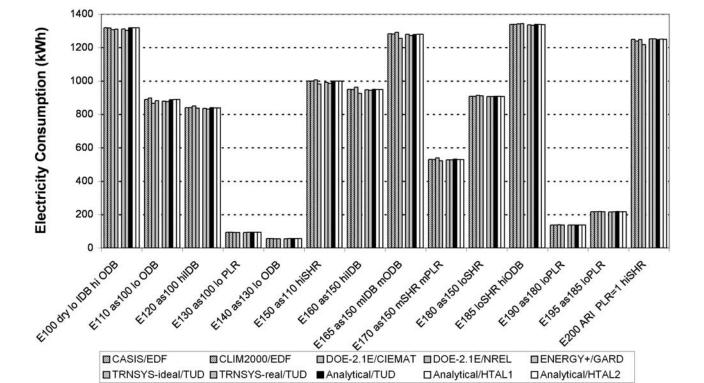




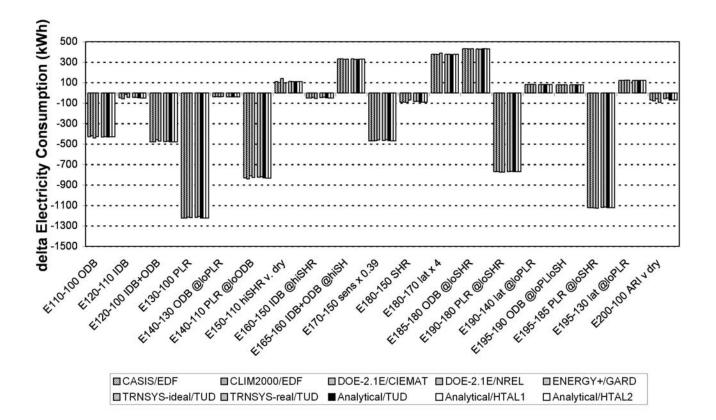
# **HVAC BESTEST: Total Space Cooling Electricity Consumption**

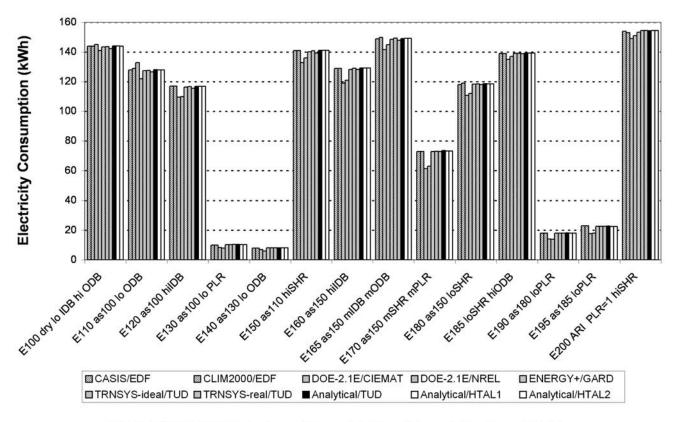
HVAC BESTEST: Total Space Cooling Electricity Sensitivities





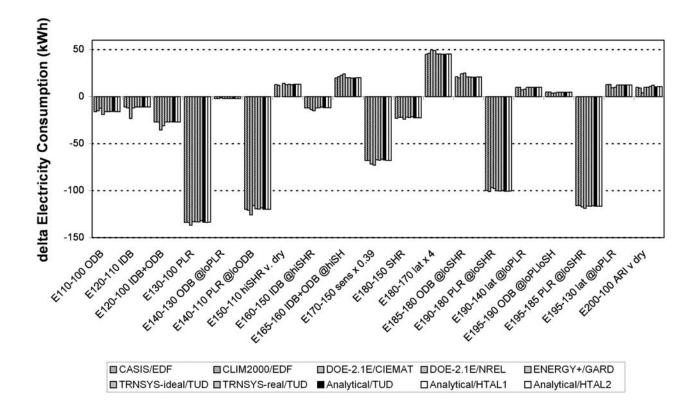
**HVAC BESTEST: Total Compressor Electricity Sensitivities** 

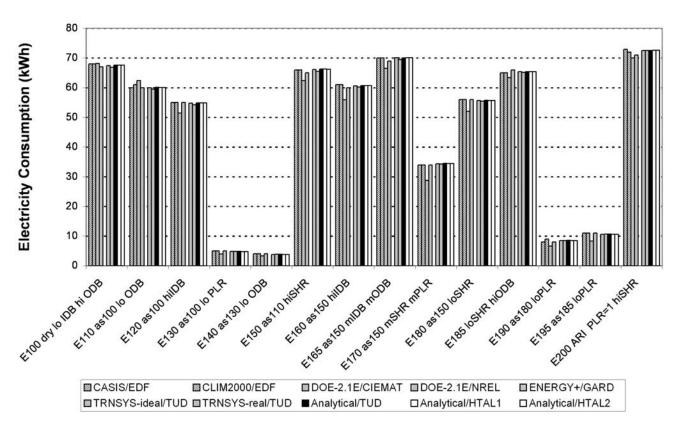




# HVAC BESTEST: Total Indoor (Supply) Fan Electricity Consumption

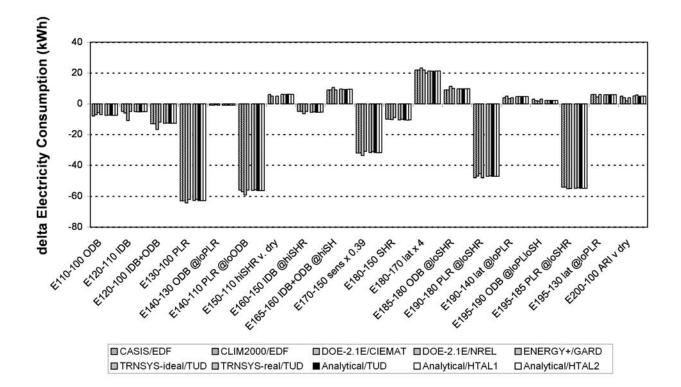
HVAC BESTEST: Indoor (Supply) Fan Electricity Sensitivities

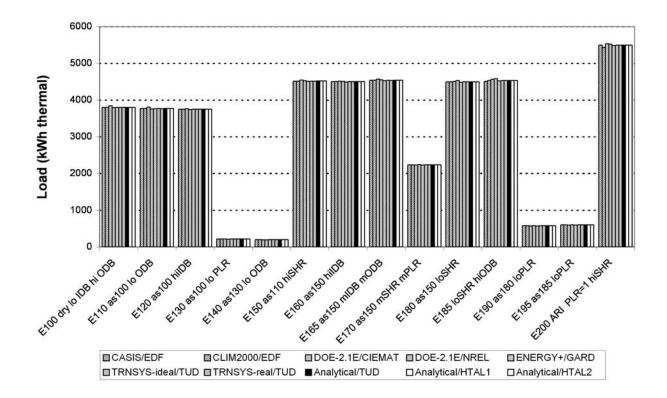




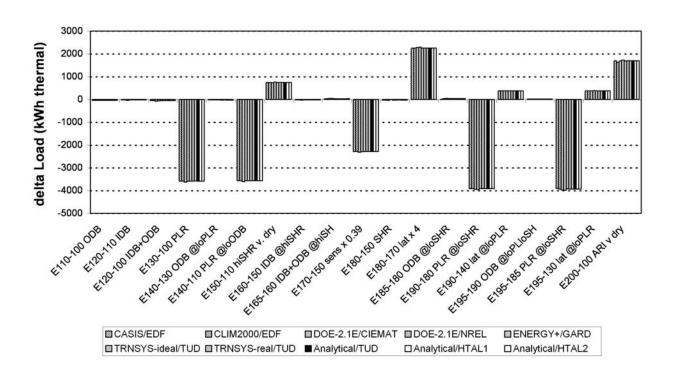
# HVAC BESTEST: Outdoor (Condenser) Fan Electricity Consumption

HVAC BESTEST: Outdoor (Condenser) Fan Electricity Sensitivities





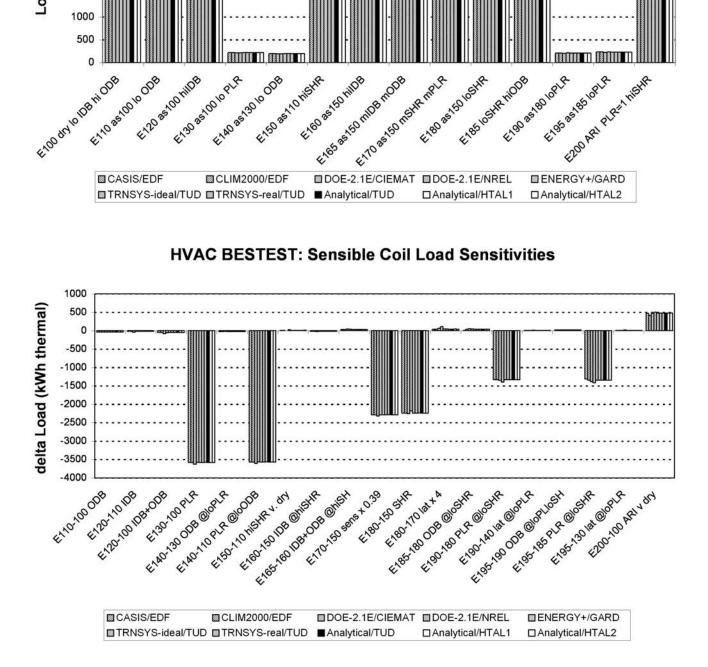
# **HVAC BESTEST: Total Coil Load Sensitivities**



EIME STADIATIR

EIBBIOSHEMODE

E1808215005HR



**HVAC BESTEST: Sensible Coil Load** 

5000 4500 4000

1000

500 0

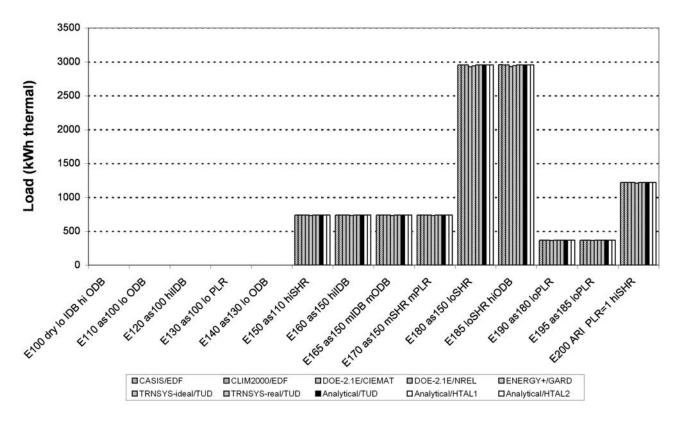
E120 28 10 HIDE

El 39 as 1010 PLR

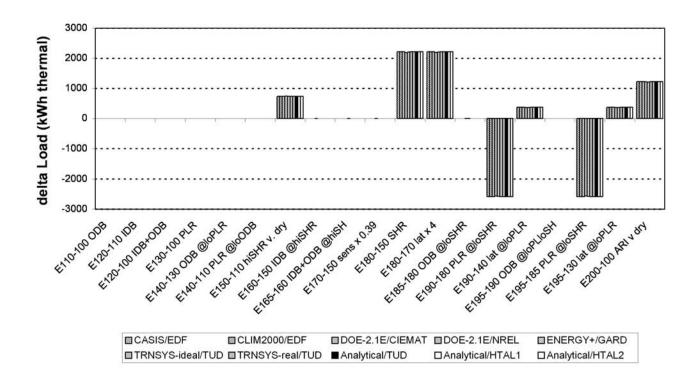
ELMAS 3910 DDB

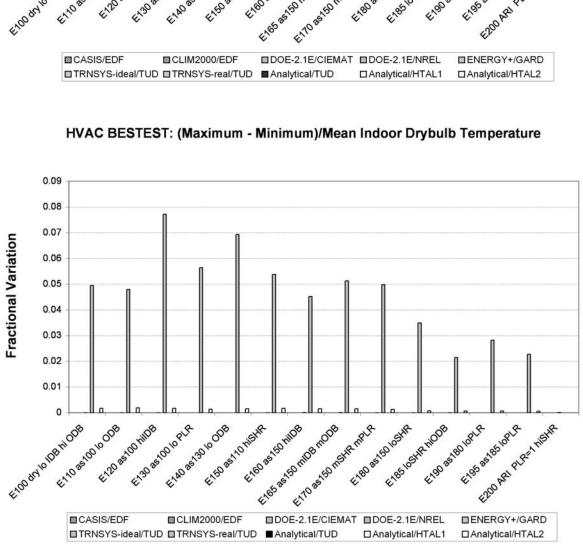
E1898510118HR

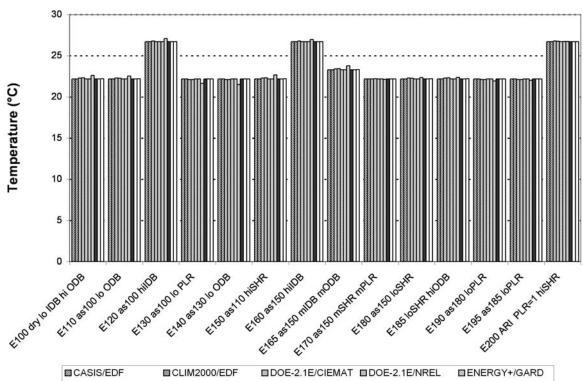
Load (kWh thermal)



**HVAC BESTEST: Latent Coil Load Sensitivities** 

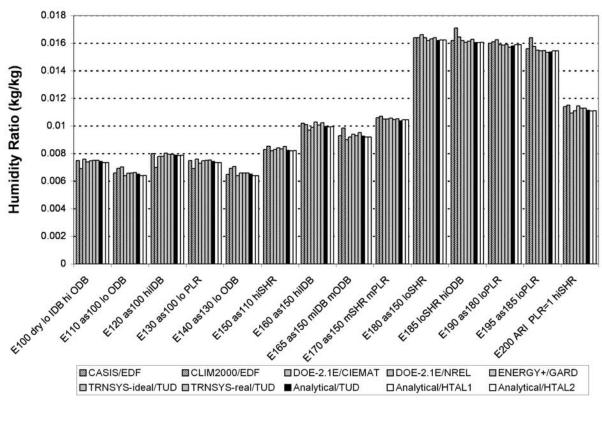






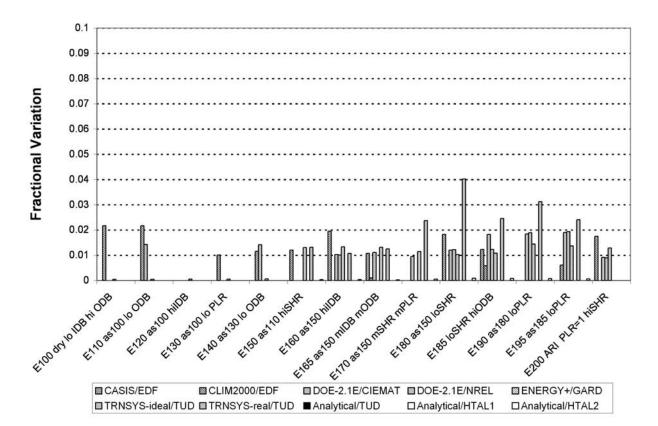
HVAC BESTEST: Mean Indoor Drybulb Temperature

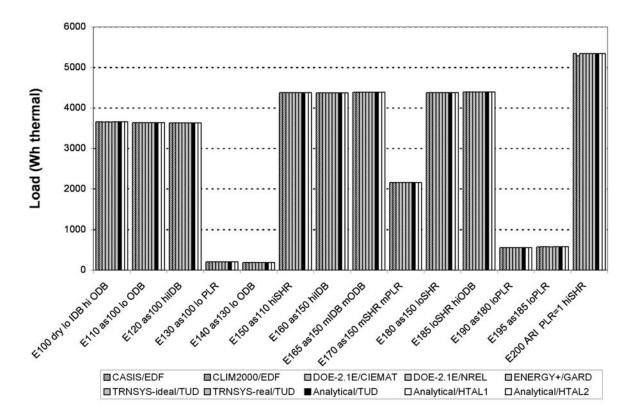
64



**HVAC BESTEST: Mean Indoor Humidity Ratio** 

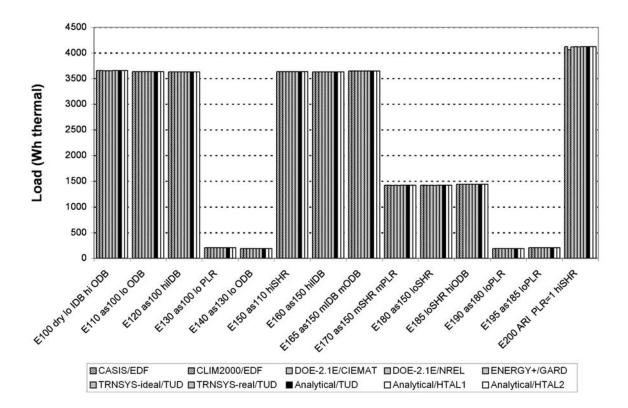
# HVAC BESTEST: (Maximum - Minimum)/Mean Indoor Humidity Ratio



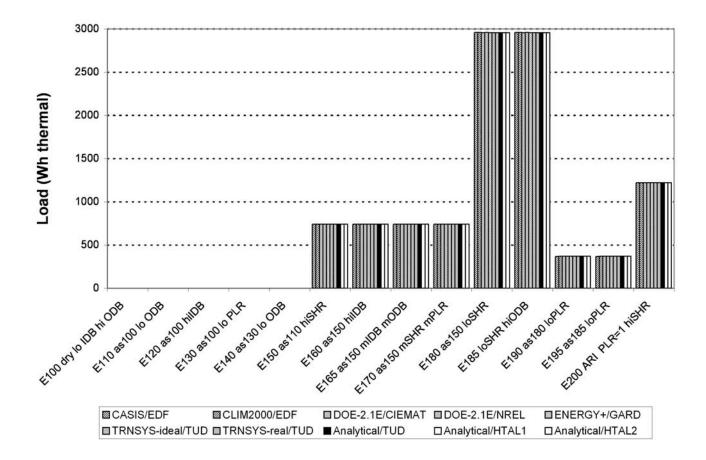


HVAC BESTEST: Total Zone Load

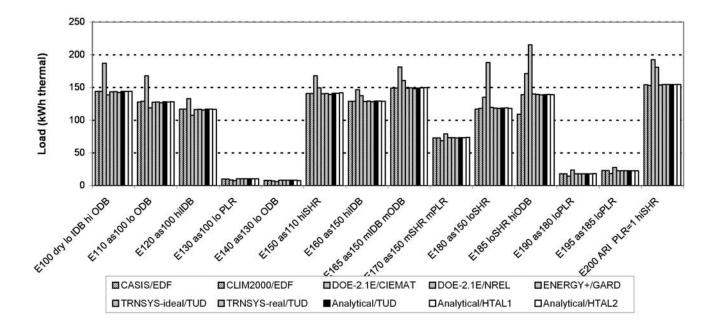
HVAC BESTEST: Sensible Zone Load



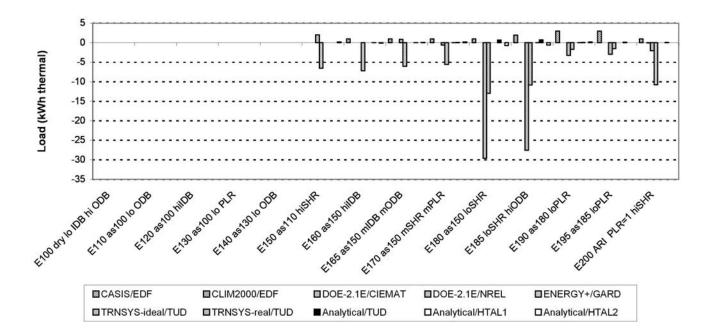
# HVAC BESTEST: Latent Zone Load







HVAC BESTEST: Latent Coil Load - Latent Zone Load (Should = 0)



(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.)

#### ANNEX B17

# PRODUCTION OF QUASI-ANALYTICAL SOLUTION RESULTS AND EXAMPLE SIMULATION RESULTS

#### **B17.1** Introduction

The full discussion regarding production of quasi-analytical solution results and example simulation results is included in *HVAC BESTEST*.<sup>A-5</sup> 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.

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.

The availability of quasi-analytical solutions (see Section B17.2) 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

Model	Authoring Organization	Implemented By	Abbreviation
Quasi-analytical solution with ideal controller model	Hochschule Technik & Architektur Luzern, Switzerland (HTAL)	Hochschule Technik & Architektur Luzern, Switzerland	HTAL1
Quasi-analytical solution with realistic controller model	Hochschule Technik & Architektur Luzern, Switzerland	Hochschule Technik & Architektur Luzern, Switzerland	HTAL2
Quasi-analytical solution with ideal controller model	Technische Universität Dresden, Germany (TUD)	Technische Universität Dresden, Germany	TUD
CA-SIS V1	Electricité de France, France (EDF)	Electricité de France, France	CA-SIS
CLIM2000 2.1.6	Electricité de France, France	Electricité de France, France	CLM2000
DOE-2.1E-088	LANL/LBNL/ESTSC, <sup>a,b,c</sup> USA	CIEMAT, <sup>d</sup> Spain	DOE21E/CIEMAT
DOE-2.1E-133	LANL/LBNL/JJH, <sup>a,b,e</sup> USA	NREL/JNA, <sup>f</sup> USA	DOE21E/NREL
ENERGYPLUS 1.0.0.023	LBNL/UIUC/CERL/OSU/GARD Analytics/ FSEC/DOE-OBT, <sup>a,g,h,i,j,k</sup>	GARD Analytics, USA	Energy+
TRNSYS 14.2-TUD with ideal controller model	University of Wisconsin, USA; Technische Universität Dresden, Ger.	Technische Universität Dresden, Germany	TRN-id TRNSYS-ideal
TRNSYS 14.2-TUD with real controller model	University of Wisconsin, USA; Technische Universität Dresden, Ger.	Technische Universität Dresden, Germany	TRN-re TRNSYS-real

TABLE B17-1 Participating Organizations and Computer Programs

<sup>a</sup>LANL: Los Alamos National Laboratory

<sup>b</sup>LBNL: Lawrence Berkeley National Laboratory

<sup>c</sup>ESTSC: Energy Science and Technology Software Center (at Oak Ridge National Laboratory, USA)

<sup>d</sup>CIEMAT: Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas

<sup>e</sup>JJH: James J. Hirsch & Associates

<sup>f</sup>NREL/JNA: National Renewable Energy Laboratory/J. Neymark & Associates

<sup>g</sup>UIUC: University of Illinois Urbana/Champaign

<sup>h</sup>CERL: U.S. Army Corps of Engineers, Construction Engineering Research Laboratories

<sup>i</sup>OSU: Oklahoma State University

<sup>j</sup>FSEC: University of Central Florida, Florida Solar Energy Center

<sup>k</sup>DOE-OBT: U.S. Department of Energy, Office of Building Technology, State and Community Programs, Energy Efficiency and Renewable Energy found, the modelers worked to resolve the differences. Additionally, one of the participants (TUD) developed quasianalytical 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.

Input decks used to generate the simulation results are provided in the files accompanying this standard (available at http:// www.ashrae.org/template/PDFDetail?assetID=34505); 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.

### B17.2 Quasi-Analytical Solution Results

The quasi-analytical solution results given in Annex B16 were developed as part of International Energy Agency (IEA) Solar Heating and Cooling Programme Task 22. The importance of having analytical or quasi-analytical solution results is discussed in Annex B16 (Section B16.2). Two of the IEA participating organizations independently developed quasianalytical solutions that were submitted to a third party for review.<sup>A-12, A-13, A-14</sup> Comparing the results indicated some disagreements, which were then resolved by allowing the solvers to review the third-party reviewers' comments and to review and critique each others' solution techniques. This process resulted in both solvers making logical and non-arbitrary changes to their solutions such that their final results are mostly well within a <1% range of disagreement. Remaining differences in the quasi-analytical solutions are due in part to the difficulty of completely describing boundary conditions. In this case the boundary conditions are a compromise between full reality and some simplification of the real physical system that is mathematically solvable. Therefore, the quasi-analytical solutions have some element of interpretation of the exact nature of the boundary conditions that causes minor differences in the results. For example, in the modeling of the controller, one group derived a quasi-analytical solution for an "ideal" controller (that maintains zone temperature exactly at the thermostat setpoint) while another group developed a numerical solution for a "realistic" controller (that allows a small degree of zone temperature variation over very short simulation time steps). As another example, for the purpose of determining the "maximum EWB" dry-coil condition, one group used linear interpolation or extrapolation in conjunction with local intervals of given performance data, while another group used a similar but more generalized solution technique and incorporated the extremes of performance data. Each quasi-analytical solution yields slightly different results, but all are correct in the context of this exercise. This may be less than perfect from a mathematician's viewpoint but quite acceptable from an engineering perspective. A fully detailed presentation of the quasi-analytical solutions, including specific examples of remaining minor differences in the solutions, are discussed in Part II of HVAC BESTEST.<sup>A-5</sup>

# B17.3 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*<sup>A-5</sup> that ran from 1997 through 2001. 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.<sup>14,21,22, A-5</sup>

(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.)

# **ANNEX B18**

# VALIDATION METHODOLOGIES AND OTHER RESEARCH RELEVANT TO STANDARD 140

[Informative Note: Delete Annex B13 and replace with new Annex B18 as follows.]

# **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 output from a program, subroutine, algorithm, or software object is compared to the result from a known analytical or quasianalytical solution 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 these three techniques.<sup>A-15, A-5</sup> Defining two terms is useful in interpreting Table 1. Here a "model" is the representation of reality for a given physical behavior. For example, 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 "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 cone, or between a zone(s) and its related mechanical system(s). The solution process for a model can be perfect, while the model

TABLE B18-1 Advantages and Disadvantages of Various Validation Techniques

Technique	Advantages	Disadvantages
<i>Empirical</i> Test of model and solution process	<ul> <li>Approximate truth standard within experimental accuracy</li> <li>Any level of complexity</li> </ul>	<ul> <li>Experimental uncertainties:         <ul> <li>Instrument calibration, spatial/ temporal discretization</li> <li>Imperfect knowledge/specification of the experimental object (building) being simulated</li> </ul> </li> <li>Detailed measurements of high quality are expensive and time consuming</li> <li>Only a limited number of test conditions are practical</li> </ul>
Analytical Test of solution process	<ul> <li>No input uncertainty</li> <li>Exact mathematical truth standard for the given model</li> <li>Inexpensive</li> </ul>	<ul> <li>No test of model validity</li> <li>Limited to highly constrained cases for which analytical solutions can be derived</li> </ul>
<i>Comparative</i> Relative test of model and solution process	<ul> <li>No input uncertainty</li> <li>Any level of complexity</li> <li>Many diagnostic comparisons possible</li> <li>Inexpensive and quick</li> </ul>	• No truth standard

remains faulty or inappropriate for a given physical situation or purpose; for example, using a one-dimensional conduction model where two-dimensional conduction dominates.

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
- (c) Analytical Verification Building Envelope
- (d) Analytical Verification Mechanical Equipment
- (e) Empirical Validation Building Envelope
- (f) Empirical Validation Mechanical Equipment.

### **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"<sup>A-16</sup>
- (b) "Home Energy Rating System Building Energy Simulation Test (HERS BESTEST)"<sup>23</sup>
- (c) ASHRAE RP-865, "Development of Accuracy Tests for Mechanical System Simulation"<sup>A-17</sup>
- (d) "Building Energy Simulation Test and Diagnostic Method for Heating, Ventilating, and Air-Conditioning Equipment Models (HVAC BESTEST), Fuel-Fired Furnace Test Suite"<sup>A-18</sup>
- (e) "International Energy Agency Building Energy Simulation Test and Diagnostic Method for Heating, Ventilating, and Air-Conditioning Equipment Models (HVAC BEST-EST), Volume 2: Cases E300-E545"
- (f) "RADTEST Radiant Heating and Cooling Test Cases"<sup>A-19</sup>
- (g) "Proposed IEA BESTEST Ground-Coupled Cases"
- (h) ETNA BESTEST Empirical Validation Test Specification

- "Daylighting HVAC Interaction Tests for the Empirical Validation of Building Energy Analysis Tools"<sup>A-20</sup>
- (j) "Economizer Control Tests for the Empirical Validation of Building Energy Analysis Tools"
- (k) 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 Task 34 and IEA Energy Conservation in Buildings and Community Systems Annex 43 (IEA SHC 34/ECBCS 43).<sup>A-21</sup>

(Note: Since items e, g, h, and j are works in progress, no references can yet be cited for them.)

**B18.2.1 ASHRAE RP-1052**<sup>A-16</sup> 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<sup>23</sup> 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**<sup>A-17</sup> 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 Fuel-Fired Furnace Test Suite**<sup>A-18</sup> is an analytical verification test that also has some comparative test components, developed by the CANMET Energy Technology Centre of Natural Resources Canada in conjunction with the International Energy Agency (IEA) Solar Heating and Cooling (SHC) Programme Task 22. This test focuses on the ability to model residential fuel-fired furnace mechanical equipment and could directly append the unitary mechanical equipment cases of Section 5.3. Cases allow the comparison of quasi-analytical solutions to program results for the purpose of testing the ability of programs to model steady-state efficiency, fuel consumption, variation of furnace performance with part-load ratio, air-distribution fan operation, and combustion-air fan operation.

**B18.2.5 HVAC BESTEST Cases E300-E545** 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.

**B18.2.6 RADTEST**<sup>A-19</sup> is a comparative test developed by Hochschule fur Technik + Architektur Luzern in conjunction with the IEA SHC 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.).

**B18.2.7 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 Programme. 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 steadystate 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).

B18.2.8 ETNA BESTEST 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.

**B18.2.9 Daylighting – HVAC Interaction Tests for the Empirical Validation of Building Energy Analysis Tools**<sup>A-20</sup> 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.

B18.2.10 Economizer Control Tests for the Empirical Validation of Building Energy Analysis Tools 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.

**B18.3 Recommended Additional Research.** The additional tests listed in B18.2 do not cover the following areas:

- (a) Comparative Tests Mechanical Equipment (Additional tests beyond those in HVAC BESTEST unitary cooling and heating equipment cases)
- (b) Analytical Verification Mechanical Equipment (Additional tests beyond those in RP-865 and HVAC BEST-EST unitary cooling and heating equipment cases)
- (c) Empirical Validation Mechanical Equipment (Additional tests beyond those in IEA SHC Task 22 described above).

More work to develop such Methods of Test is recommended.

Informative Note: Renumber Section B14, References, as Section B19 and divide it into two parts, Section B19.1, which contains the references in the current standard, and Section B19.2, which adds the new references for Addendum a.

(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.)

## ANNEX B194

#### REFERENCES

## **B19.1 References for ANSI/ASHRAE Standard 140-**2001

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# **B19.2** References for Addendum a to ANSI/ASHRAE Standard 140-2001

The following references are cited in this Addendum a to ANSI ASHRAE Standard 140-2001. Each reference begins with the letter "A," and all are informative. When Standard 140 is next republished, these references will be integrated with those in ANSI/ASHRAE Standard 140 and renumbered consecutively.

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# 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.