3.4.1. Standard for Performance Rating Of Electrically Operated Dehumidifying Equipment (DRAFT); adapted from AHRI Standard 210/240

PERFORMANCE RATING OF ELECTRICALLY OPERATED DEHUMIDIFYING EQUIPMENT

Commenter suggestion to re-title to: METHOD OF TEST FOR ELECTRICALLY OPERATED DEHUMIDIFYING EQUIPMENT. The MOT would describe how to make the measurements but not set a performance standard. [The ARI Standard 210/240 from which this draft was modeled uses the "performance rating" terminology but does not specify the DOE minimum performance level.] Commenter also suggests looking at referencing ASHRAE Standard 37 (Methods of testing for rating electrically driven unitary air conditioning and heat pump equipment) in order to reduce text here.

1. Purpose

1.1 Purpose.
The purpose of this standard is to establish, for dehumidifying equipment: definitions; classifications; test requirements; rating requirements; minimum data requirements for Published Ratings; operating requirements; marking and nameplate data; and conformance conditions.

1.1.1 Intent.
This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors and users.

1.1.2 Review and Amendment.
This standard is subject to review and amendment as technology advances.

2. Scope

2.1 Scope.
This standard applies to the following factory-made vapor compression refrigeration dehumidifying equipment as defined in Section 3:

a) Unitary Cooling Unit;
b) Unitary Cooling and Dehumidification Unit;
~~b)~~c) Unitary Dehumidification Unit; and
~~c)~~d) Unitary Air-Source Unitary Heat Pump Unit.

Commenter suggestion to simplify this to systems that remove moisture by cooling air below its dew-point. That would eliminate desiccant systems [but not heat activated absorption systems].

2.1.1 Energy Source
This standard applies only to electrically operated vapor compression refrigeration dehumidifying systems.

2.2 Exclusions

2.2.1 This standard does not apply to the rating and testing of individual assemblies, such as condensing units or coils, for separate use.

2.2.2 This standard does not apply to heat operated cooling/heat pump equipment.

2.2.3 This standard does not apply to equipment with capacities of 65,000 Btu/h [19,000 W] or greater.

2.2.4 This standard does not apply to: water-source heat pumps, ground water-source heat pumps, and ground source closed-loop heat pumps.

3. Definitions
All terms in this document shall follow the standard industry definitions in the current edition of ASHRAE Terminology of Heating, Ventilation, Air- Conditioning and Refrigeration, unless otherwise defined in this section.

3.4 Moisture Removal Efficiency (MRE).
A ratio of the water removal rate in liters/h to the power input value obtained at any given Rating Condition expressed in l/(kW-h).

3.4.1 Standard Moisture Removal Efficiency
A ratio of the water removal rate in liters/h to power input value obtained at Standard Rating Conditions expressed in l/(kW-h).

3.5 Dehumidification Efficiency Ratio (DER)
A ratio of the latent cooling rate in Btu/h to the power input value in watts at any given set of Rating Conditions expressed in Btu/(W·h).

3.5.1 Standard Dehumidification Efficiency Ratio
A ratio of the latent cooling rate in Btu/h to the power input value in watts at Standard Rating Conditions expressed in Btu/(W·h).

3.6 Energy Efficiency Ratio
A ratio of the total (combined sensible and latent) cooling rate in Btu/h to the power input value in watts at any given set of Rating conditions expressed in Btu/(W-h).

[alternate: Energy efficiency ratio (EER) means the ratio of the average rate of space cooling delivered to the average rate of electrical energy consumed by the air conditioner or heat pump. These rate quantities must be determined from a single test or, if derived via interpolation, must be tied to a single set of operating conditions. EER is expressed in units of Btu/W-h. When determined for a ducted unit tested without an indoor fan installed, EER must include the section 3.3 and 3.5.1 default values for the heat output and power input of a fan motor.]

3.7 Published Rating
A statement of the assigned values of those performance characteristics, under stated Rating Conditions, by which a unit may be chosen to fit its application. These values apply to all units of like nominal capacity and type (identification) produced by the same manufacturer. As used herein, the term Published Rating includes the rating of all performance characteristics shown on the unit or published in specifications, advertising, or other literature controlled by the manufacturer, at stated Rating Conditions.

3.7.1 Application Rating
A rating based on tests performed at Application Rating Conditions (other than Standard Rating Conditions).

3.7.2 Standard Rating
A rating based on tests performed at Standard Rating Conditions.

3.8 Rating Conditions (commenter suggestion to delete this definition)
Any set of operating conditions under which a single level of performance results and which causes only that level of performance to occur.

3.8.1 Standard Rating Conditions. (commenter suggestion to delete this definition))
-Rating Conditions used as the basis of comparison for performance characteristics.

3.10 "Shall" or "Should" (commenter suggestion to delete this definition)
."Shall" or "should" shall be interpreted as follows:

3.10.1 Shall (commenter suggestion to delete this definition)
.Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.10.2 Should (commenter suggestion to delete this definition)
."Should" is used to indicate provisions which are not mandatory but which are desirable as good practice.

3.13 Standard Air
Dry Aair weighingwith a density of 0.075 lb/ft3 [1.2 kg/m3] which approximates dry air at 70°F [21°C] and at a barometric pressure of 29.92 in Hg [101.3 kPa].

3.16 Unitary Cooling Unit (Commenter suggests deleting all the following definitions)
One or more factory-made assemblies which normally include an air distribution fan, evaporator or cooling coil(s), compressor(s), ~~-~~and condenser(s). Where such equipment is provided in more than one assembly, the separated assemblies are to be designed to be used together, and the requirements of rating outlined in this standard are based upon the use of these assemblies in operation together.

3.16.1 Functions
Either alone or in combination with a heating plant, the function is to provide cooling and dehumidification.

3.17 Unitary Cooling and Dehumidification Unit.
One or more factory-made assemblies which normally include an air distribution fan, evaporator or cooling coil(s), compressor(s), condenser(s), and may include a condenser reheat coil. Where such equipment is provided in more than one assembly, the separated assemblies are to be designed to be used together, and the requirements of rating outlined in this standard are based upon the use of these assemblies in operation together.

3.17.1 Functions
Either alone or in combination with a heating plant, the function is to provide dehumidification or cooling and dehumidification.

3.18 Air-Source Unitary Heat Pump
One or more factory-made assemblies which normally include an air distribution fan, indoor conditioning coil(s), compressor(s), and outdoor coil(s), including means to provide a heating function. When such equipment is provided in more than one assembly, the separated assemblies shall be designed to be used together, and the requirements of rating outlined in the standard are based upon the use of matched assemblies.

3.18.1 Functions
The function is to provide heating, cooling, and dehumidifying.

4. Classifications
Equipment covered within the scope of this standard shall be classified as shown in Table ~~???~~xx (to be created).

5. Test Requirements (commenter suggestion to more explicitly state that the actual measurment/step-by-step procedures are in Std. 37)
All Standard Ratings shall be verified by tests conducted in accordance with the test methods and procedures as described in this standard and its appendices. Air-cooled units shall be tested in accordance with ANSI/ASHRAE Standard 37 and with Appendices C and D. Water-cooled and

evaporative-cooled condensing units shall be tested in accordance with ANSI/ASHRAE Standard 37.

6. Rating Requirements

6.1 Standard Ratings.
Standard Ratings shall be established at the Standard Rating Conditions specified in 6.1.3. Standard Ratings relating to cooling or moisture removal rates shall be net values, including the effects of circulating-fan heat. Power input shall be the total power input to the compressor(s) and fan(s), plus controls and other items required as part of the system for normal operation.

Standard Ratings of units which do not have indoor air-circulating fans furnished as part of the model, i.e., split systems with indoor coil alone, shall be established by subtracting from the total cooling rate 1,250 Btu/h per 1,000 cfm (0.366 W/cfm) [775 W/m3/s]. Total power input for both heating and cooling shall be increased by 0.366 W/cfm [226 W/m3/s] of indoor air circulated. (commenter suggestion to change to: …1500 Btu/h per 1,000 cfm (0.44 W/cfm) [925 W/m3/s]. Total power input for both heating and cooling shall be increased by 0.5 W/cfm [238 W/m3/s] of indoor air circulated.

6.1.1 Values of Standard Ratings
These ratings shall be expressed only in terms of:

a) airflow through the indoor coil reported in cubic feet per minute (cfm) to a resolution of 10 cfm;
b) sensible cooling capacity reported in British thermal unit per hour (Btu/h) to a resolution of 10 Btu/h (sensible cooling capacity will be negative if the outlet air is warmer than the inlet air);
c) latent cooling capacity reported in Btu/h to a resolution of 20 Btu/h;
d) latent cooling capacity reported in liter per hour (l/h) to a resolution of 0.01 l/h;
e) total power reported in watts (W) to a resolution of 3 W;
f) Moisture Removal Efficiency (MRE) reported in liter per kilowatt-hour (l/kW·h) to a resolution of 0.01;
g) Dehumidification Efficiency Ratio (DER) reported in British thermal unit per watt-hour (Btu/W-h) to a resolution of 0.05; and
h) Energy Efficiency Ratio (EER) reported in British thermal unit per watt-hour (Btu/W-h) to a resolution of 0.05.

6.1.3 Standard Rating Tests
Table 6-1 shows the test conditions which are required to determine values of standard ratings.

Table 6.1 Test conditions to determine values of standard ratings for units with both indoor and outdoor heat transfer components

	Outdoor T/RH/Tdp (F/%/F)	Inlet T/RH/Tdp (F/%/F)
Test 1a	95/58/78	80/60/65
Test 1b	""	78/55/61
Test 1c	""	75/50/55
Test 2a	80/85/75	80/60/65
Test 2b	""	78/55/61
Test 2c	""	75/50/55
Test 3a	75/85/70	78/60/63
Test 3b	""	78/55/61
Test 3c	""	75/50/55
Test 4a	65/90/62	72/60/57
Test 4b	""	70/52/52
Test 4c	""	68/45/46

[1] Negative cooling capacity denotes net heat added from inlet to outlet
[2] Same units as the USDOE and USEPA Energy Factor for dehumidifiers
[3] All tests with steady wet coil

Commentor suggestions:
Use ARI outdoor condition of 67 Tdp

Table 6.2 Test conditions to determine values of standard ratings for units with only indoor heat transfer components

	Inlet T/RH/Tdp (F/%/F)
Test 1	80/60/65
Test 2	78/60/63
Test 3	78/55/61
Test 4	75/50/55
Test 5	72/60/57
Test 6	70/52/52
Test 7	68/45/46

[1] Negative cooling capacity denotes net heat added from inlet to outlet
[2] Same units as the USDOE and USEPA Energy Factor for dehumidifiers
[3] All tests with steady wet coil

Table 6.3 Test conditions to determine values of standard ratings for basement units

	Inlet T/RH/Tdp (F/%/F)
Test 1	65/50/46
Test 2	65/60/51
Test 3	70/50/51
Test 4	70/60/56

[1] Negative cooling capacity denotes net heat added from inlet to outlet
[2] Same units as the USDOE and USEPA Energy Factor for dehumidifiers
[3] All tests with steady wet coil

6.1.3.2 Electrical Conditions

Standard Rating tests shall be performed at the nameplate rated voltage(s) and frequency. For air-cooled equipment which is rated with 208-230 V dual nameplate voltages, Standard Rating tests shall be performed at 230 V. For all other dual nameplate voltage equipment covered by this standard, the Standard Rating tests shall be performed at both voltages or at the lower of the two voltages if only a single Standard Rating is to be published.

6.1.3.3.1 Cooling and Dehumidification Air Volume Rate

6.1.3.3.1.1 Cooling and Dehumidification Air Volume Rate for Ducted Units (commenter suggestion to define Ducted Units)

The manufacturer must specify the cooling air volume rate and the external static pressure.

a. For ducted units that are tested with a fixed-speed, multi-speed, or variable speed variable-air-volume-rate indoor fan installed, the measured external static pressure must be equal to or greater than 0.5 inch w.c. (125 Pa).

6.1.3.3.1.2 Cooling Air Volume Rate for Non-ducted Units

For non-ducted units, the cooling air volume rate is the air volume rate that results during each test when the unit is operated with all of its normal grilles and air filter components in place.

6.1.3.4 Outdoor-Coil Airflow Rate

All Standard Ratings for systems with an outdoor coil shall be determined at the outdoor-coil airflow rate specified by the manufacturer where the fan drive is adjustable. Where the fan drive is non-adjustable, they shall be determined at the outdoor-coil airflow rate inherent in the equipment when operated with all of the resistance elements associated with inlets, louvers, and any ductwork and attachments considered by the manufacturer as normal installation practice. Once established, the outdoor coil air circuit of the equipment shall remain unchanged throughout all tests prescribed herein.

6.1.3.5 Requirements For Separated Assemblies

All Standard Ratings for equipment in which the outdoor section is separated from the indoor section shall be determined with at least 25 ft [7.6 m] of interconnection tubing on each line of the size recommended by the manufacturer. Such equipment in which the interconnection tubing is furnished as an integral part of the machine not recommended for cutting to length shall be tested with the complete length of tubing furnished, or with 25 ft [7.6] of tubing, whichever is greater. At least 10 ft [3.0 m] of the interconnection tubing shall be exposed to the outside conditions. The line sizes, insulation, and details of installation shall be in accordance with the manufacturer's published recommendation.

6.3 Application Ratings.

Ratings at conditions of temperature or airflow rate other than those specified in Table 6.1 may be published as Application Ratings, and shall be based on data determined by the prescribed methods.

6.4 Publication Of Ratings.
Wherever Application Ratings are published or printed, they shall include, or be accompanied by the Standard Ratings, clearly designated as such, including a statement of the conditions at which the ratings apply.

6.4.1 Capacity Designation
The capacity designation used in published specifications, literature or advertising, controlled by the manufacturer, for equipment rated under this standard, shall be expressed only in Btu/h [W] at the Standard Rating Conditions.

6.5 Tolerances (commenter suggestion that this section may not be needed or is confusing)
To comply with this standard, measured test results shall not be less than 95% of Published Ratings for performance ratios and capacities.

7. Minimum Data Requirements for Published Ratings

7.1 Minimum Data Requirements for Published Ratings.
As a minimum, Published Ratings shall consist of the following information:

Table 7-1. Minimum Data Requirements for Published Ratings for units with both indoor and outdoor heat transfer components

	Outdoor T/RH/Tdp (F/%/F)	Inlet T/RH/Tdp (F/%/F)	Outlet T/RH/Tdp (F/%/F)	Indoor Wet-coil Airflow (cfm)	Sensible Cooling Capacity[1] (Btu/h)	Latent Cooling Capacity (Btu/h)	Moisture Removal Capacity (L/h)	Total Power (kW)	Moisture Removal Efficiency[2] (L/kW-h)
Test 1a	95/58/78	80/60/65							
Test 1b	""	78/55/61							
Test 1c	""	75/50/55							
Test 2a	80/85/75	80/60/65							
Test 2b	""	78/55/61							
Test 2c	""	75/50/55							
Test 3a	75/85/70	78/60/63							
Test 3b	""	78/55/61							
Test 3c	""	75/50/55							
Test 4a	65/90/62	72/60/57							
Test 4b	""	70/52/52							
Test 4c	""	68/45/46							

[1] Negative cooling capacity denotes net heat added from inlet to outlet

[2] Same units as the USDOE and USEPA Energy Factor for dehumidifiers

[3] All tests with steady wet coil

Table 7-2. Minimum Data Requirements for Published Ratings for units with only indoor heat transfer components

	Inlet T/RH/Tdp (F/%/F)	Outlet T/RH/Tdp (F/%/F)	Indoor Wet-coil Airflow (cfm)	Sensible Cooling Capacity (Btu/h)	Latent Cooling Capacity[1] (Btu/h)	Moisture Removal Capacity (L/h)	Total Power (kW)	Moisture Removal Efficiency[2] (L/kW-h)
Test 1	80/60/65							
Test 2	78/60/63							
Test 3	78/55/61							
Test 4	75/50/55							
Test 5	72/60/57							
Test 6	70/52/52							
Test 7	68/45/46							

[1] Negative cooling capacity denotes net heat added from inlet to outlet
[2] Same units as the USDOE and USEPA Energy Factor for dehumidifiers
[3] All tests with steady wet coil

Table 7-3. Minimum Data Requirements for Published Ratings for basement units

	Inlet T/RH/Tdp (F/%/F)	Outlet T/RH/Tdp (F/%/F)	Indoor Wet-coil Airflow (cfm)	Sensible Cooling Capacity[1] (Btu/h)	Latent Cooling Capacity (Btu/h)	Moisture Removal Capacity (L/h)	Total Power (kW)	Moisture Removal Efficiency[2] (L/kW-h)
Test 1	65/50/46							
Test 2	65/60/51							
Test 3	70/50/51							
Test 4	70/60/56							

[1] Negative cooling capacity denotes net heat added from inlet to outlet
[2] Same units as the USDOE and USEPA Energy Factor for dehumidifiers
[3] All tests with steady wet coil

Commenter suggestions:
Check with EPA and DOE on use of Energy Factor (EF) instead of MRE.
What about water heating by desuperheating? Could add column for hot water heating capacity, with text footnote for applicability.

7.2 Capacity and Efficiency Designations
All minimum data designations shall be published in the manufacturer's specifications and literature.

7.2.1 Indoor Airflow
The airflow of the indoor supply air fan shall be reported for all test conditions in units of cfm.

7.2.2 Sensible Cooling Capacity
The sensible cooling capacity shall be reported in Btu/h at all test conditions regardless of whether the capacity is positive, negative, or zero, for all test conditions. Dehumidification equipment that supplies air that is warmer than the equipment inlet air will report a negative cooling capacity.

7.2.3 Latent Capacity
The latent (moisture) removal capacity shall be reported for all test conditions in units of Btu/h and l/h for all test conditions.

7.2.4 Total Power
The total system power (indoor and outdoor units as applicable) shall be reported in units of kW for all test conditions.

7.2.6 Moisture Removal Efficiency
The Moisture Removal Efficiency shall be reported in units of l/(kW-h) for all test conditions.

7.2.7 Dehumidification Efficiency Ratio
The dehumidification efficiency ratio, as a ratio of latent capacity to latent power, shall be reported in units of Btu/W-h for all test conditions.

7.2.8 Energy Efficiency Ratio
The energy efficiency ratio, as a ratio of total capacity to total power, shall be reported in units of Btu/W-h for all test conditions.

7.3 Rating Claims. All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with Standard ??? ". All claims to ratings outside the scope of this standard shall include the statement: "Outside the scope of Standard ???". Wherever Application Ratings are published or printed, they shall include a statement of the conditions at which the ratings apply.

8. Operating Requirements

8.1 Operating Requirements
Unitary equipment shall comply with the provisions of this section such that any production unit will meet the requirements detailed herein.

8.2 Maximum Operating Conditions Test

Unitary equipment shall pass the following maximum operating conditions test with an indoor-coil airflow rate as determined under ??? (need to complete this).

8.2.1 Temperature Conditions
Temperature conditions shall be maintained as shown in Tables ??? (need to complete this).

8.2.2 Voltages
The test shall be run at the minimum utilization voltage based upon the unit's nameplate rated voltage(s). This voltage shall be supplied at the unit's service connection and at rated frequency.

8.2.3 Procedure
The equipment shall be operated for one hour at the temperature conditions and voltage specified.

8.2.4 Requirements
The equipment shall operate continuously without interruption for any reason for one hour.

8.3.2.2 The power supplied to single phase equipment shall be adjusted just prior to the shut-down period (8.3.3.2) so that the resulting voltage at the unit's service connection is 86% of nameplate rated voltage when the compressor motor is on locked-rotor. (For 200V or 208V nameplate rated equipment the restart voltage shall be set at 180V when the compressor motor is on locked rotor). Open circuit voltage for threephase equipment shall not be greater than 90% of nameplate rated voltage.
8.3.2.3 Within one minute after the equipment has resumed continuous operation (8.3.4.3), the voltage shall be restored to the values specified in 8.3.2.1.

8.3.3 Procedure.

8.3.3.1 The equipment shall be operated for one hour at the temperature conditions and voltage(s) specified.

8.3.3.2 All power to the equipment shall be shut off for a period sufficient to cause the compressor to stop (not to exceed five seconds) and then restored.

8.3.4 Requirements.

8.3.4.1 During both tests, the equipment shall operate without failure of any of its parts.

8.3.4.2 The equipment shall operate continuously without interruption for any reason for the one hour period preceding the power interruption.

8.3.4.3 The unit shall resume continuous operation within two hours of restoration of power and shall then operate continuously for one half hour. Operation and resetting of safety devices prior to establishment of continuous operation is permitted.

8.4 Low-Temperature Operation Test (commenter suggestion to delete all of sections 8.4 and 8.5)
Unitary equipment shall pass the following low-temperature operation test when operating with initial airflow rates as determined in Table 6.1 and with controls and dampers set to produce the maximum tendency to frost or ice the evaporator, provided such settings are not contrary to the manufacturer's instructions to the user.

8.4.1 Temperature Conditions
Temperature Conditions shall be maintained as shown in Table ??? (need to complete this).

8.4.2 Procedure
The test shall be continuous with the unit on the cooling cycle, for not less than four hours after establishment of the specified temperature conditions. The unit will be permitted to start and stop under control of an automatic limit device, if provided.

8.4.3 Requirements.

8.4.3.1 During the entire test, the equipment shall operate without damage or failure of any of its parts.

8.4.3.2 During the entire test, the air quantity shall not drop more than 25% from that determined under the Standard Rating test.

8.4.3.3 During the test and during the defrosting period after the completion of the test, all ice or meltage must be caught and removed by the drain provisions.

8.5 Insulation Effectiveness Test
Unitary equipment shall pass the following insulation effectiveness test when operating with airflow rates as determined in 6.1.3.3 and 6.1.3.4 with controls, fans, dampers, and grilles set to produce the maximum tendency to sweat, provided such settings are not contrary to the manufacturer's instructions to the user.

8.5.1 Temperature and Moisture Conditions
Temperature and moisture conditions shall be maintained as shown in Table 6-1.

8.5.2 Procedure
After establishment of the specified temperature and moisture conditions, the unit shall be operated continuously for a period of four hours.

8.5.3 Requirements.
During the test, no condensed water shall drop, run, or blow off from the unit casing.

8.6 Tolerances.
The conditions for the tests outlined in Section 8 are average values subject to tolerances of ± 1.0°F [± 0.6°C] for air dry-bulb and dew-point temperatures, ±2% for air relative humidity, and ± 1.0% of the reading for voltages.

9. Marking and Nameplate Data

9.1 Marking and Nameplate Data
As a minimum, the nameplate shall display the manufacturer's name, model designation, and electrical characteristics. Nameplate voltages for 60 Hertz systems shall include one or more of the equipment nameplate voltage ratings shown in Table 1 of ARI Standard 110. Nameplate voltages for 50 Hertz systems shall include one or more of the utilization voltages shown in Table 1 of IEC Standard 60038.

10. Conformance Conditions

10.1 Conformance
While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within the standard’s Purpose (Section 1) and Scope (Section 2) unless such product claims meet all of the requirements of the standard and all of the testing and rating requirements are measured and reported in complete compliance with the standard. Any product that has not met all the requirements of the standard shall not reference, state, or acknowledge the standard in any written, oral, or electronic communication.

3.4.2. Method of Testing for Residential Dehumidifiers for Moisture Removal (DRAFT); adapted from ASHRAE Standard 37

Draft product of Building America Dehumidification Working Group, Armin Rudd—lead.
For internal use only

Method of Testing for ~~Rating~~ Residential Dehumidifiers for Moisture Removal ~~Capacity and Moisture Removal Efficiency~~

FORWARD

…

1. PURPOSE

1.1. This standard establishes an ASHRAE standard method of determining the moisture removal capacity and moisture removal ~~efficiency~~efficacy of residential dehumidifiers at a range of specified test conditions.

2. SCOPE

2.1 This Standard applies to residential dehumidifying equipment that removes moisture ~~by cooling air below its dew-point or by desiccant adsorption~~ from process air that can be measured by the air enthalpy method. The equipment may consist of one or more separate assemblies located indoors or outdoors. Where more than one separate assembly is used, they shall be designed to be used together.

2.2 For purposes of this standard, a residential dehumidifier provides air dehumidification and may also provide ~~additional functions of:~~ air cooling, air heating, air circulation, air filtration, air-to-air heat recovery, ~~and~~ water heating.

3.1 DEFINITIONS

3.1 Definitions are given in ASHRAE Standard 37-2005, ARI Standard 210/240, and additionally as follows below:

moisture removal ~~efficiency~~efficacy (MRE): a ratio of the water removal rate in liters/h to the power input value obtained at any given Rating Condition expressed in l/(kW-h). Dehumidification Efficacy (DHE)?

~~***dehumidification efficiency ratio (DER):*** a ratio of the latent cooling rate in Btu/h to the power input value in watts at any given set of Rating Conditions expressed in Btu/(W·h).~~

energy efficiency ratio: a ratio of the combined sensible plus latent) cooling rate in Btu/h to the power input value in watts at any given set of Rating conditions expressed in Btu/(W-h).

standard air: dry air with a density of 0.075 lb/ft3 [1.2 kg/m3] at 70°F [21°C] and at a barometric pressure of 29.92 in Hg [101.3 kPa].

Possibly add heat added per lb of water removed, kind of a new consumer rating value

4. CLASSIFICATIONS

4.1 Component Arrangement:

4.2 Method of Outdoor Coil Heat Exchange:

5. INSTRUMENTS

5.1 Instruments for measuring temperature, pressure, differential pressure, air flow, electrical power, voltage, volatile refrigerant flow, liquid flow, rotational speed, time, mass, and volatile refrigerant mass composition shall be as specified in Section 5 of ASHRAE Standard 37-2005*.*

6. AIRFLOW AND AIR DIFFERENTIAL PRESSURE MEASUREMENT APPARATUS

6.1 Airflow and air differential pressure measurement apparatus shall be as specified in Section 6 of ASHRAE Standard 37-2005.

7. METHOD OF TESTING AND CALCULATION

7.1 Standard Test Methods. The methods of testing and calculation shall be as specified in Section 7 of ASHRAE Standard 37-2005, except as otherwise specified here.

7.1.1

7.2 Applicability of Test Methods.

7.2.1

7.2.2

7.2.3 The methods described in this standard may be used to test dehumidifying equipment with heat rejection to at least one of, or a combination of: outdoor air heat rejection; indoor air reheating, and water heating. The air-enthalpy method shall be used for both the indoor and outdoor equipment sections. Condensate flow measurement is required in all cases.

7.3.4 Net-Air Reheating Calculations*.*

7.4.5 Moisture Removal Capacity Calculations.

7.2 Water Heating Calculations. Calculate water heating capacity according to Equation 1.

$$q_w = c_w w_w (t_{w.in} - t_{w.out}) \quad (1)$$

8. TEST PROCEDURES

The test procedures will be as specified in Section 8 of ASHRAE Standard 37-2005 and as otherwise specified herein.

9. DATA TO BE RECORDED

Data to be recorded shall be as specified in Section 9 of ASHRAE Standard 37-2005 and as otherwise specified in Table 2.

9.2 Test Tolerances. All test observations shall be within the tolerances specified in Section 9.2 of ASHRAE Standard 37-2005 and as specified in Table 3, as appropriate to the test methods, type of equipment, and type of test.

Table 2. Data to be recorded in addition to data recorded as specified in Section 9.1 of ASHRAE Standard 37-2005

Item	Units		Comment
	English	SI	
Date			
Observer			

10. TEST RESULTS

10.1 Test Requirements.

10.1.1 The results of a test shall express quantitatively the effects produced upon air by the equipment tested. For given test conditions, the capacity test results shall include each of the following quantities that are applicable to cooling, dehumidifying, air heating or water heating and to the type of equipment tested:

(1) Moisture removal capacity (condensate), pint/h [L/h]

(2) Air-reheating capacity, Btu/h [W]
(3) Water heating capacity, Btu/h [W]

a) airflow through the indoor coil reported in cubic feet per minute (cfm) to a resolution of 10 cfm;
b) sensible cooling capacity reported in British thermal unit per hour (Btu/h) to a resolution of 10 Btu/h (sensible cooling capacity will be negative if the outlet air is warmer than the inlet air);
c) latent cooling capacity reported in Btu/h to a resolution of 20 Btu/h;
d) latent cooling capacity reported in liter per hour (l/h) to a resolution of 0.01 l/h;
e) total power reported in watts (W) to a resolution of 3 W;
f) Moisture Removal Efficiency (MRE) reported in liter per kilowatt-hour (l/kW·h) to a resolution of 0.01;
g) Dehumidification Efficiency Ratio (DER) reported in British thermal unit per watt-hour (Btu/W-h) to a resolution of 0.05; and
h) Energy Efficiency Ratio (EER) reported in British thermal unit per watt-hour (Btu/W-h) to a resolution of 0.05.

	Outdoor T/RH/Tdp (F/%/F)	Indoor Return T/RH/Tdp (F/%/F)	Indoor Supply T/RH/Tdp (F/%/F)	Indoor Wet-coil Airflow (cfm)	Sensible Cooling Capacity (Btu/h)	Latent Cooling Capacity (Btu/h)	Heating Added In Dehum (Btu/h)	Moisture Removal Capacity (L/h)	Total Power (kW)	Moisture Removal Efficiency[1] (MRE) (L/kW-h)	Dehum Efficiency Ratio (DER) (Btu/W-h)	Energy Efficiency Ratio (EER) (Btu/W-h)
Test 1	95/58/78	80/60/65 78/55/61 75/50/55										
Test 2	80/85/75	80/60/65 78/55/61 75/50/55										
Test 3	75/85/70	78/60/63 78/55/61 75/50/55										
Test 4	65/90/62	72/60/57 70/52/52 68/45/46										
Test 5 (opt)		65/55/49										

[1] Same as the Energy Factor used for dehumidifiers by Energy Star

10.2 Calculations of Results.

10.2.1 Moisture Removal Capacity shall be determined by the volume of moisture collected by the condensate measurement method.

10.2.2 Moisture Removal Efficiency shall be calculated by dividing the Moisture Removal Capacity divided by the total input power.

11. TEST CONDITIONS

Table 11.1 Standard test conditions

	Outdoor T/RH/Tdp (F/%/F)	Indoor T/RH/Tdp (F/%/F)	
Test 1	95/58/78	80/60/65 78/55/61 75/50/55	cooling design conditions
Test 2	80/85/75	80/60/65 78/55/61 75/50/55	cooling part-load: summer nights/rainy periods
Test 3	75/85/70	78/60/63 78/55/61 75/50/55	cooling part-load: spring/fall
Test 4	65/90/62	72/60/57 70/52/52 68/45/46	no cooling: spring/fall/winter
Test 5 (opt)		65/55/49[1]	cold climate basement conditions

[1] Single unit basement dehumdifier condition

May be able to combine Test 2 and Test 3.
If the equipment cannot operate at any standard test condition, then note that in reporting the results.
May be run at additional non-standard test conditions.

10. LETTER SYMBOLS USED IN EQUATIONS

10.1 Symbols used in this appendix **are in ASHRAE Standard 37-2005 or are defined as follows:**

11. REFERENCE PROPERTIES AND DATA

11.1 Thermodynamic Properties of Air.

11.1.1 The thermodynamic properties of air-water vapor mixture shall be obtained from the equations in the Psychrometric chapter in *2009 ASHRAE Handbook, Fundamentals*.

11.2 Thermodynamic Properties of Water and Steam.

11.2.1 The thermodynamic properties of water and steam shall be obtained from the *2009 ASHRAE Handbook, Fundamentals*.

11.3 Thermodynamic Properties of Volatile Refrigerants.

11.3.1 The thermodynamic properties of volatile refrigerants may be obtained from the *2009 ASHRAE Handbook, Fundamentals* or from an established refrigerant property database.

13. REFERENCES

Copy references from ASHRAE Standard 37-2005

3.4.3. Final Report on the Expert Meeting for "Residential Dehumidifier Performance: Modeling, Lab Testing, And Method Of Test Development"

Final Report on the Expert Meeting for RESIDENTIAL DEHUMIDIFIER PERFORMANCE: MODELING, LAB TESTING, AND METHOD OF TEST DEVELOPMENT

Building Science Corporation Industry Team

23 August 2009

Work Performed Under Funding Opportunity Number:
DE-FC26-08NT00601

Submitted By:
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National Energy Technology Laboratory
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EXECUTIVE SUMMARY

1. Title: Final Report on the Expert Meeting for RESIDENTIAL DEHUMIDIFIER PERFORMANCE: MODELING, LAB TESTING, AND METHOD OF TEST DEVELOPMENT (Gate 1B)

2. Overview: The Building Science Consortium held an Expert Meeting on Residential Dehumidifier Performance: Modeling, Lab Testing, And Method Of Test Development on 19 June 2009 at the Galt House hotel in Louisville, Kentucky. To make it easier for key industry personnel to participate, the expert meeting was held the morning immediately before the afternoon ASHRAE SSPC 62.2 meetings in advance of the ASHRAE technical program. Planned speakers included Hugh Henderson, Jr. of CDH Energy Corp., Dane Christensen of the National Renewable Energy Laboratory, and Armin Rudd of Building Science Corporation.

3. Key Results: Key results from this meeting were: 1) a greater understanding of the availability of and need for tools and methods to evaluate indoor humidity control systems in building energy simulations; 2) a greater understanding of laboratory testing capabilities that both exist and are needed to develop more detailed dehumidification equipment performance maps and to supplement field testing; and 3) more buy-in and assistance from ASHRAE and AHRI industry participants in moving forward with approaches for developing a dehumidification equipment method of test standard and a performance rating standard.

4. Gate Status: This project meets the “must meet” and “should meet” criteria for Gate 1B. The project provides source energy and whole building performance benefits by allowing building efficiency improvements that further reduce the sensible cooling requirement while providing a sure means to properly handle the unchanged moisture removal requirement, thereby reducing the source energy needed to condition the house. The project also meets the performance-based safety, health, and building code requirements for use in new homes, as it directly attempts to improve the indoor air quality, comfort, and durability of residential buildings. For the same reason, this project meets the prescriptive-based code requirements. The project will be cost-neutral for new homes, as builders will still be free to choose from a variety of dehumidification systems. The project will increase reliability by increasing the likelihood of proper indoor moisture control. Finally, the project does not require any new products to be manufactured, and suppliers, manufactures, and builders will continue responding to market forces as they always do. As part of the effort in responding to market forces, the project continues to work with industry partners to improve product features and capabilities.

5. Conclusions: The key gaps that remain are obtaining enough detailed performance data to adequately compare the dehumidification performance of different systems as they will typically operate in residential buildings, standardizing test methods and performance ratings, and pushing the limits of equipment efficiency, system integration, and cost reduction. Expected benefits include energy savings (due to lower cooling requirements without creating a moisture control problem especially in humid climates), reliability (due to improved indoor humidity control), durability (due to lower chances of moisture damage), and expected value to builders, contractors, and homeowners (due to improved occupant satisfaction).

INTRODUCTION

The Building Science Consortium held an Expert Meeting on Residential Dehumidifier Performance: Modeling, Lab Testing, And Method Of Test Development on 19 June 2009 at the Galt House hotel in Louisville, Kentucky. To make it easier for key industry personnel to participate, the expert meeting was held the morning immediately before the afternoon ASHRAE SSPC 62.2 meetings in advance of the ASHRAE technical program. There were 25 in attendance. Invited speakers gave presentations in their particular area of expertise. The presentations were followed by discussion with the expert audience.

A summary of the individual presentations and major discussion points is provided in the sections below.

The final agenda for the meeting is listed in Appendix A. A list of attendees for the meeting is given in Appendix B. The presentations are included in Appendices C through E.

PRESENTATIONS

Speaker 1: Hugh Henderson, Jr., P.E., CDH Energy Corp.

Presenter bio: Hugh is a founding principal of CDH Energy Corp., an energy consulting firm Cazenovia, NY. With a master's degree in mechanical engineering from Cornell University, Hugh has been working in the building space conditioning field for over 20 years. Prior to CDH Energy, Hugh worked for Carrier Corporation, the Florida Solar Energy Center, and the Fleming Group. Hugh has developed and published widely recognized algorithms for modeling part load latent capacity of DX cooling systems.

Presentation Title: *Data Needs for Modeling Dehumidification and Cooling Systems.*

Presentation Summary:

Mr. Henderson presented how the TRNSYS based ResDH program that he has developed over several years incorporates the control algorithms and performance data of various dehumidification systems into a whole-building energy simulation.

To develop a building simulation model for any HVAC system, a performance map must created from either measured data or a more detailed equipment model. Regression analysis or lookup tables are generally the most common approach to accomplish this task. In addition, many HVAC systems inherently include control algorithms that describe how the system responds to the building loads and operating conditions. The presentation described the different data needs for simulating various systems: 1) stand alone dehumidifiers, 2) spilt system dehumidifiers, 3) air conditioners with enhanced dehumidification features, and 4) dedicated outdoor air systems that pre-treat ventilation air. The specific needs for laboratory measured data were discussed including the range of data needed and how these needs could fit into a standard method of test.

Mr. Henderson made the following key points during his presentation:

- Data sources for creating performance maps can be measured or simulated, or a combination of the two, yielding semi-empirical, which generally works better.
- Regression models or other means then generate the maps using the best independent variables (Tdb, Tdp, Twb, RH) to represent dependent variables such as outlet temperature, power draw, total capacity, sensible capacity, and latent capacity.
- Changes in operating state caused by equipment controls need to be characterized with individual performance maps. Dehumidification examples of different control states are: compressor staging, airflow reduction, refrigerant reheat systems (spanning from subcooling reheat to partial condensing reheat to full condensing reheat with and without hot gas modulation) and hybrid desiccant units.
- Part load effects need to be accounted for such as: startup efficiency, shut-down latent degradation (evaporation from coil), and thermostat "droop" as the space temperature changes with loading.
- Multiple equipment configurations need to be addressed also (i.e. ventilation or recirculation mode, integrated or not-integrated with central system fans, interactions with other equipment or building components, etc).
- Currently we have focused on recirculation dehumidification systems for residential buildings, but we should consider establishing test conditions for systems that may bring in 100% outdoor air. In very low load houses, conditioning the outside air may be the primary means of space conditioning.
- Testing for too many conditions may be overly burdensome. Testing for two or three conditions may be enough. Currently, manufacturers test only at the single rating condition then simulate performance from there to provide extended performance data. Although there is no standard for doing this, it has generally worked pretty well. However, the best approach might be a blend laboratory tests and simulated data, using the model to fill in testing gaps.
- Perhaps developing a better standard for creating performance maps through modeling (using a model like the ORNL heat pump design model) would reduce the need for testing at off-rating conditions.
- In 1992, Hugh published a semi-empirical air conditioner model that is now in USDOE's EnergyPlus. The model uses the apparatus dew point (ADP) and bypass factor (BF) approach. From knowing one operating condition you get the BF. From knowing the bypass factor you get the ADP and the performance at all other operating conditions. However, you need a different performance map for each control state. The simulation switches between the different maps depending on the control state.
- When using a short simulation time step (<15 min), the traditional degradation coefficient (C_d) used in the current rating standard is not applicable anymore. You need to calculate the time constant from C_d and use that to obtain performance at part load operation using a short time step. Also, using a short time step (<= 2 min) allows more accurate calculation of evaporation rates from wet coils.

<u>Participant questions and discussion:</u>

Questions, comments and answers were as follows:

- Q: Does the ResDH model iterate between the building load and the HVAC system? A: Yes.
- Q: Does the EnergyPlus building simulation program do that also? A: Pretty sure the answer is yes but should ask Don Shirey at the Florida Solar Energy Center.

Speaker 2: Dane Christensen, National Renewable Energy Laboratory

Presenter bio: Dane joined NREL in 2008. His expertise is in equipment testing and integration, and is currently focused on performance of emerging technologies in HVAC and Dehumidification across varied loading conditions. He supports technical efforts for the Building America Program and conducts finite element modeling for building energy simulation. Prior to joining NREL, Dane worked at Atec, Inc., designing test and support equipment for turboshaft engines. He has 18 publications and has earned 2 patents.

Presentation Title: *Laboratory Testing of Dehumidification Equipment*

Presentation Summary:

Mr. Christensen began with an overview of the USDOE Building America including the research being conducted to achieve zero net energy homes by the target year 2020. During the rest of his presentation, he gave details of the setup and capability of the HVAC testing laboratory at NREL, and recent results from testing the Thermastor Ultra-Aire dehumidifier in a standalone configuration.

Current HVAC equipment EER & SEER test methods do not include accurate evaluations of dehumidification performance. This motivates laboratory evaluation at a wider range of test conditions to develop performance maps. NREL has begun a program of laboratory performance testing the dehumidification performance of residential HVAC equipment. The data will illuminate energy simulations and allow better comparisons between divergent technologies for Net-Zero Energy Homes. Recent experimental results were presented to show laboratory capabilities and difficulties in obtaining test data at the proposed matrix of test conditions.

Mr. Christensen made the following key points during his presentation:

- A key net zero energy technology gap is very high performance AC systems which control humidity and provide 30% reduction in annual energy use, with an incremental cost of $1000 or less, relative to a current SEER 18/EER 13.4 system with ducts located in conditioned space.
- A Building America home with 50% savings over Benchmark will have significantly reduced sensible loads and roughly equivalent latent loads. Right-sizing leads to reduced equipment size. The equipment can’t keep up with dehumidification requirements, humidity builds, causing high-RH excursions. Thus, these houses need equipment with on-demand dehumidification or at least enhanced dehumidification options/controls.
- The Thermastor Ultra-Aire dehumidifier was the first dehumidifier tested in the NREL HVAC lab. The test protocol was designed to obtain performance data for a wide range of operating conditions as opposed to the single state point (80^{o}F dry-bulb, 69.6^{o}F wet-bulb, converts to 60% RH) specified by the American Home Appliance Manufacturers (AHAM) standard (ANSI/AHAM DH-1-1992). The wider range of dehumidifier test conditions has been proposed by the Building America working group on dehumidification led by Building Science Corporation.
- The laboratory setup consisted of a system to continuously condition the inlet airstream to the dehumidifier. This allowed relatively quick changes from one test condition to another, compared to a traditional environmental chamber with slow response time.

- The equipment performance was measured at twelve test conditions, and checked by computing an air mass balance, a moisture balance, and a total energy balance.
- A six coefficient regression model was used to create the equipment performance map (in terms of power, efficiency, total load removal, sensible load removal, and latent load removal) as a function of inlet dry-bulb temperature and inlet dew-point temperature.
- Typically, a good HVAC lab will achieve accuracy within 5%. The NREL lab has been able to achieve a repeatable 2% accuracy. The performance map shows excellent fit to the measured data.
- The dehumidifier model/performance map is being put into Energy Plus.
- In general, what is needed for appropriate modeling of dehumidification equipment is: extensive ratings tables at a broad range of temperature and humidity, time constants derived from cycling data, evaluation at all control states (i.e. fan cycling, delays, steps, and capacity staging).

Questions, comments, and answers were as follows:

Mr. Christensen considered the following questions and comments after his presentation:

- Question: Will adding more "boxes," such as separate dehumidifiers, ultimately be successful due to owner maintenance costs? Answer: Proper maintenance of the additional air filter will be the primary requirement in this case.
- Question: Much more complicated systems are emerging that will need testing. Will the NREL lab be capable of testing those systems also? Answer: In time, yes. The current system can be used effectively to test standalone dehumidifiers, but an outdoor section chamber will be necessary to test split systems.
- Comment: A dialogue should be opened with existing testing labs regarding the greatly increased number of test conditions. There will be a learning curve to increase accuracy for humidity measurements and energy balances, and to reduce the testing time through process air treatment versus the room/environmental chamber method.

Speaker 3: Armin Rudd, Building Science Corporation

Presenter bio: Armin Rudd is a Principal at Building Science Corporation where he joined in 1999. Prior to that he worked at the Florida Solar Energy Center, a research institute of the University of Central Florida. He has worked in the field of buildings research and consulting for over 20 years. Armin has a wide range of experience in residential and commercial buildings, and has been especially focused on space conditioning systems, ventilation, and product development. He has authored many technical publications, is a regular presenter at national conferences.

Presentation Title: *Development of a Standard Method of Test for Residential Dehumidification Equipment*

Presentation Summary:

Mr. Rudd presented an overview of residential dehumidification systems typically being installed in current high-performance homes, then he summarized on-going work being conducted within the USDOE Building America program to develop a standard method of test for residential dehumidification equipment. Such a standard method of test (MOT) is needed to better evaluate and compare the performance of residential dehumidification equipment, and to eventually allow more detailed modeling toward a standard rating. Testing dehumidification equipment at a number of environmental conditions is critical to characterize actual performance for proper space conditioning system design and evaluation. Ongoing work has produced a preliminary draft MOT. ASHRAE TC 8.10 may be willing to sponsor a new SPC to pursue this formally. With an industry consensus MOT in place, resultant test data would feed into detailed modeling to allow development of a new rating standard.

Mr. Rudd made the following key points during his presentation:

- High-performance homes have low sensible heat gain but latent gain remains mostly unchanged. This causes periods of high indoor relative humidity unless supplemental humidity control is employed, separate from sensible cooling operation.
- A number of supplemental dehumidification systems have been successfully employed in high-performance homes. These have ranged from:
    - Unducted standalone dehumidifiers in interior mechanical closets, either in or near the central system return air path; to
    - Ducted standalone dehumidifiers integrated with the central duct system, to;
    - Supplemental dehumidification integrated into a central split heat pump system utilizing modulating hot gas for condenser reheat.
- Those systems have been field monitored, but more controlled and accurate laboratory testing would enhance our understanding of their performance, and in less time.
- Moving forward, we are working to create a framework in which to evaluate the performance of a range of supplemental dehumidification systems as they are applied to high-performance homes. This will entail developing engineering criteria for obtaining standardized extended performance data in laboratories, and conducting field evaluations that will also serve as a reality check for modeling efforts towards a new rating standard.
- Planned process steps to achieve that include:
    - Settle on an approach to establish performance and testing requirements for humidity control equipment in high performance homes in hot-humid climates, which includes defining the minimum whole house performance goal. The initial performance goal in Building America is to limit the duration of indoor RH greater than 60% to 4 hours or less, while meeting Energy Star dehumidification efficiency requirements for latent cooling.
    - Define a test method and rating method that that provides a consistent basis of comparison of performance between different types of equipment.
    - Demonstrate that the method works based on lab tests and field tests in high performance homes.
    - Hold meetings with stakeholders to build consensus for performance goals and test methods.
    - Integrate equipment performance maps into annual energy simulations which would support the rating procedures
    - Publish test methods, rating procedures, and test/analysis results.
- It is critical that designers specifying dehumidification equipment have the performance data necessary to properly apply the equipment for the way it will be used. A range of test conditions should be representative of climate, season-of-year, interior temperature and humidity set-points, and the sensible and latent loads.
- A draft method of test has been developed. A series of test conditions includes those that would cover: design cooling conditions; part-load cooling conditions representing

summer nights and rainy periods; part-load conditions representing spring and fall shoulder seasons; dehumidification-only conditions in spring/fall; and basement dehumidification conditions.

- At each test condition, test results for rating purposes would include:
    - Dry-bulb temperature, dew-point temperature, and relative humidity of the air leaving the dehumidification equipment
    - Indoor unit airflow. Measured with coil fully wet if using equipment that cools air to its dew-point temperature to condense water on a heat exchange coil.
    - Latent, sensible, and total cooling capacity.
    - Heat added if the air leaving the equipment is warmer than the air entering the equipment.
    - Volumetric moisture removal capacity
    - Total equipment power draw
    - Moisture removal efficiency (same units as Energy Factor)
    - Dehumidification efficiency ratio

<u>Questions, comments, and answers were as follows:</u>

Mr. Rudd considered the following questions and comments after his presentation:

- Comment: Moisture Removal Efficiency should be Moisture Removal Efficacy since it is not dimensionless.
- Comment: There is either a need to define “residential” since it is used in the title. Consider definitions used in ASHRAE 90.2 and codes, etc.
- Q: Should there be a need for a capacity limit, say single-phase electrical connection and less than 65 kBtu/h? A: My preference would be to not have a limitation on capacity but to state that any dehumidification equipment applied in residential use should be tested according to the standard.

- Comment: There is a need to test at 100% outside air conditions for equipment that will be applied in ventilation mode.
- Comment: When writing the scope, only specifically include equipment functions that are covered by the standard, then add a generic statement such as, “…and may provide other functions like filtration…”
- Comment: The “heat added” test result could be normalized by mass of water removed.
- Comment: The table of test conditions is large and more confusing than it needs to be. For example, if there is no outdoor unit, then outdoor conditions don’t matter. So, use different tables in different sections for:
    - No outdoor unit, not designed for low temperature basement use;
    - No outdoor unit, designed for low temperature basement use;
    - Outdoor unit plus indoor unit; and
    - Any unit designed for 100% outside air.
- For desiccant dehumidification equipment, there should be another inlet test condition at 78 F dry-bulb, 55 F dew-point, 45% relative humidity.
- Comment: A method of test should not specify a range of test conditions but should only define the test. A range of test conditions should be left to a performance rating standard. The draft we are working with today is a combination of both and should be separated.

FOLLOW-UP WORK

BSC will have meetings during the ASHRAE conference in Louisville with technical committees TC 8.12 (Desiccant Dehumidification Equipment and Components) and TC 8.10 (Mechanical Dehumidification Equipment and Heat Pipes) to generate interest concerning starting an SPC for the standard method of test development. AHRI will be contacted concerning the development of a new performance rating standard for residential dehumidifiers.

Appendix A: Expert Meeting Agenda

INVITATION and AGENDA

Building America Expert Meeting

RESIDENTIAL DEHUMIDIFIER PERFORMANCE: MODELING, LAB TESTING, AND METHOD OF TEST DEVELOPMENT

Meeting Manager: Armin Rudd, Building Science Corp.
Date/Time: **Friday, 19 June 2009, 8:00 am to 12 pm**
(light breakfast refreshments after 7:45 am)
Location: Louisville, ASHRAE Summer Annual Meeting
The Galt House Hotel, Ballroom B

Featured Speakers:

- Hugh Henderson, Jr., CDH Energy Corp.
- Dane Christensen, National Renewable Energy Laboratory
- Armin Rudd, Building Science Corp.

The objective of this session is to present and discuss recent developments in modeling and lab testing of residential dehumidification equipment, as well as ongoing efforts to develop a standard method of test. TRNSYS will be the primary modeling platform presented. The goal is to provide Building America teams with necessary tools and performance information to make informed choices in the design and application of net-zero energy homes.

Key points regarding this meeting:

1. To develop a building simulation model for any HVAC system, a performance map must created from either measured data or a more detailed equipment model. Regression analysis or lookup tables are generally the most common approach to accomplish this task. In addition, many HVAC systems inherently include control algorithms that describe how the system responds to the building loads and operating conditions.

This presentation will describe the different data needs for simulating various systems: 1) stand alone dehumidifiers, 2) spilt system dehumidifiers, 3) air conditioners with enhanced dehumidification features, and 4) dedicated outdoor air systems that pre-treat ventilation air. The specific needs for laboratory measured data will be discussed including the range of data needed and how these needs could fit into a method of test (MOT).

2. Current HVAC equipment EER & SEER test methods do not include accurate evaluations of dehumidification performance. This motivates laboratory evaluation at a wider range of test conditions to develop performance maps. NREL has begun a program of laboratory performance testing the dehumidification performance of residential HVAC equipment. The data will illuminate energy simulations and allow better comparisons between divergent technologies for Net-Zero Energy Homes. Recent experimental results will be presented to show laboratory capabilities and difficulties in obtaining test data at the proposed matrix of test conditions.

3. A standard method of test (MOT) is needed to better evaluate and compare the performance of residential dehumidification equipment, and to eventually allow more detailed modeling toward a standard rating. Testing dehumidification equipment at a number of environmental conditions is critical. Ongoing work has produced a preliminary draft MOT. ASHRAE TC 8.10 may be willing to sponsor a new SPC to pursue this formally. With an industry consensus MOT in place, resultant test data would feed into detailed modeling to allow development of a new rating standard.

Invitees:

Participants will be key people working in the indoor air quality, comfort, and space conditioning fields. Participants are invited from the following groups: Building America teams, ASHRAE and AHRI standards and technical committee members and participants, residential HVAC and construction industry, national and state government laboratories and agencies, university researchers, energy efficiency organizations, and building consultants.

Meeting Agenda:

- 8:00 am to 8:05 am, Welcome and Meeting Introduction
- Presentations
    - 8:05 to 8:45, (40 min) Hugh Henderson, *Data Needs for Modeling Dehumidification and Cooling Systems*.
    - 8:45 to 8:55, (10 min) Questions and discussion
    - 8:55 to 9:35, (40 min) Dane Christensen, *Laboratory Testing of Dehumidification Performance*.
    - 9:35 to 9:45, (10 min) Questions and discussion
    - 9:45 to 10:00, (15 min) Break
    - 10:00 to 10:30 (30 min) Armin Rudd, *Development of a Standard Method of Test for Residential Dehumidification Equipment*.

- Group discussion and advancement of the draft MOT, 10:30 to 11:45
- Wrap up, action items, and follow-up plan, 11:45 to 12:00

Bios

Hugh Henderson: Hugh is a founding principal of CDH Energy Corp., an energy consulting firm Cazenovia, NY. With a master's degree in mechanical engineering from Cornell University, Hugh has been working in the building space conditioning field for over 20 years. Prior to CDH Energy, Hugh worked for Carrier Corporation, the Florida Solar Energy Center, and the Fleming Group. Hugh has developed and published widely recognized algorithms for modeling part load latent capacity of DX cooling systems.

Dane Christensen: Dane joined NREL in 2008. His expertise is in equipment testing and integration, and is currently focused on performance of emerging technologies in HVAC and Dehumidification across varied loading conditions. He supports technical efforts for the Building America Program and conducts finite element modeling for building energy simulation. Prior to joining NREL, Dane worked at Atec, Inc., designing test and support equipment for turboshaft engines. He has 18 publications and has earned 2 patents.

Armin Rudd: Armin Rudd is a Principal at Building Science Corporation where he joined in 1999. For 12 years prior to that, he was at the Florida Solar Energy Center, a research institute of the University of Central Florida. He has worked in the field of buildings research and consulting for over 20 years. Armin has a wide range of experience in residential and commercial buildings, and has been especially focused on space conditioning systems, ventilation, and product development. He has authored many technical publications, is a regular presenter at national conferences, and holds 10 patents.

Appendix B: Expert Meeting Attendee List (based on sign-in sheet)

Last name	First name	Company
Baxter	Van	ORNL
Crawford	Roy	Trane
Domanski	Piotr	NIST
Drumheller	Craig	NAHB RC
Emmerich	Steve	NIST
Fairey	Philip	FSEC
Ferguson	Julie	Applied Dehumdification, Inc.
Harriman	Lew	Mason Grant
Henderson	Hugh	CDH Energy
Hoeschele	Marc	Davis Energy Group
Kosar	Douglas	Gas Technology Institute
Logee	Terry	USDOE
Payne	Vance	NIST
Raymer	Paul	Heyoka Solutions
Rudd	Armin	Building Science Corp.
Sherman	Max	LBNL
Stevens	Don	Panasonic
Uselton	Dutch	Lennox
Walker	Iain	LBNL
Werling	Eric	USEPA
Wilcox	Bruce	
Williamson	Jennifer	PNNL

Appendix C: Presentation 1

Data Needs for Modeling Dehumidification and Cooling Systems

Building America Expert Meeting

June 19, 2009

Hugh I Henderson, Jr., P.E.

CDH Energy Corp.

Cazenovia, NY

www.cdhenergy.com

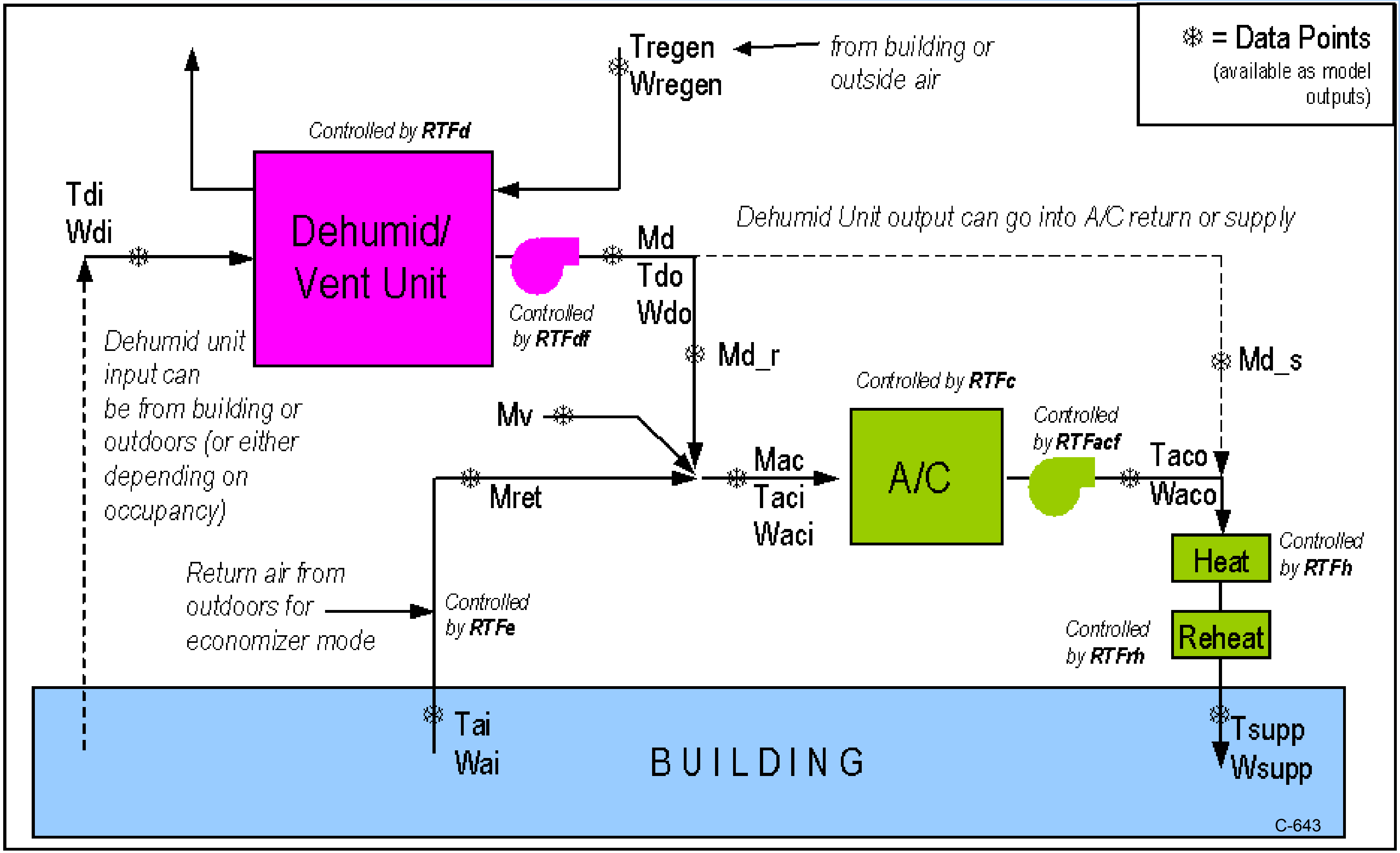
CDH ENERGY

Overview

- Performance Maps for Components
  - Measured vs. simulated data sources
  - Regression maps vs. other means
  - Empirical vs. semi-empirical
- Representing Different Types of Systems
  - Best independent variable (RH, DPT, WB, etc)
- Equipment Controls and Configuration
  - Change state in response to environment, loading, or state of other equipment
  - Arrangement of multiple components in system
  - Equipment-building interactions

Simulation Framework

model from Henderson and Sand (2003)

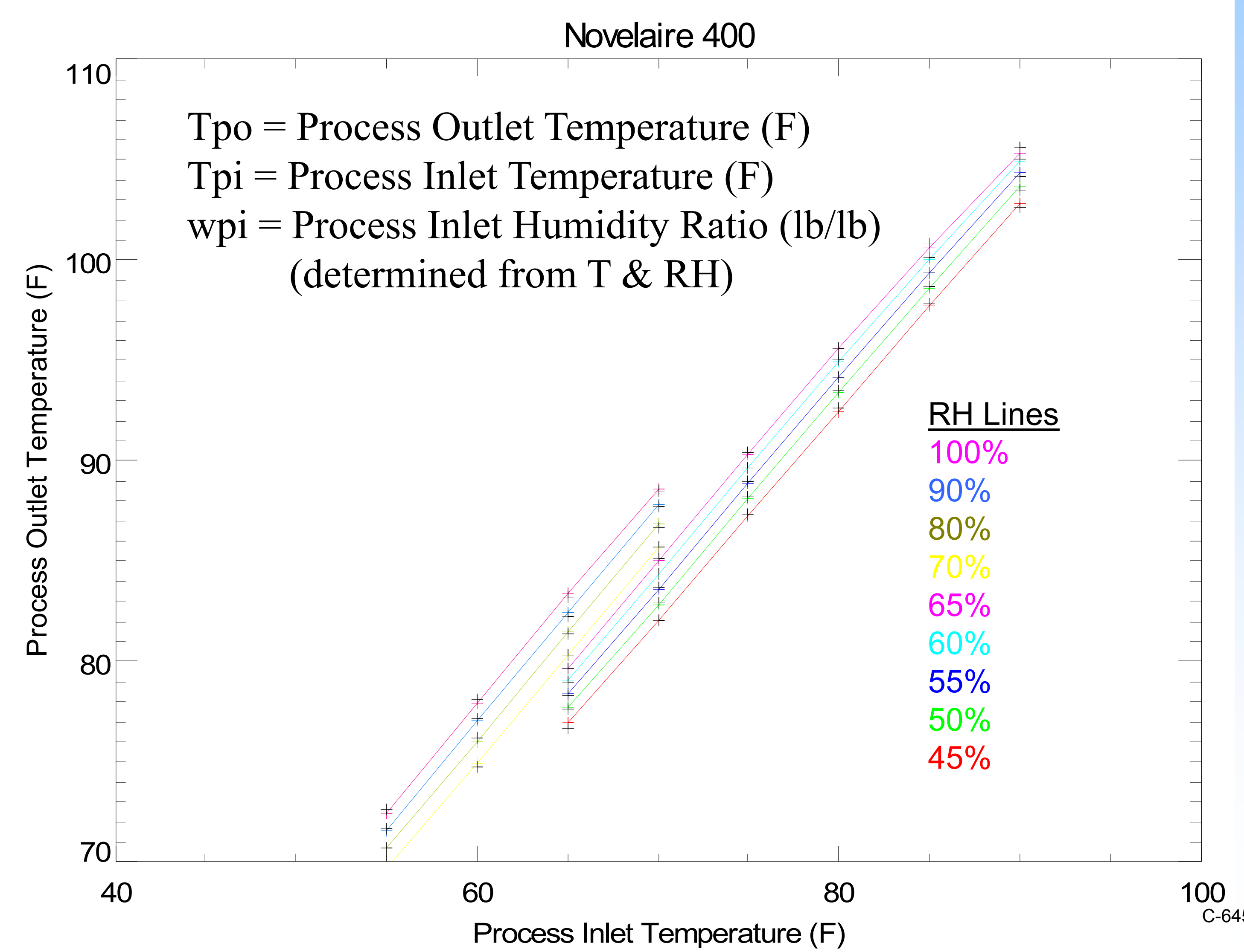


Developing Performance Maps

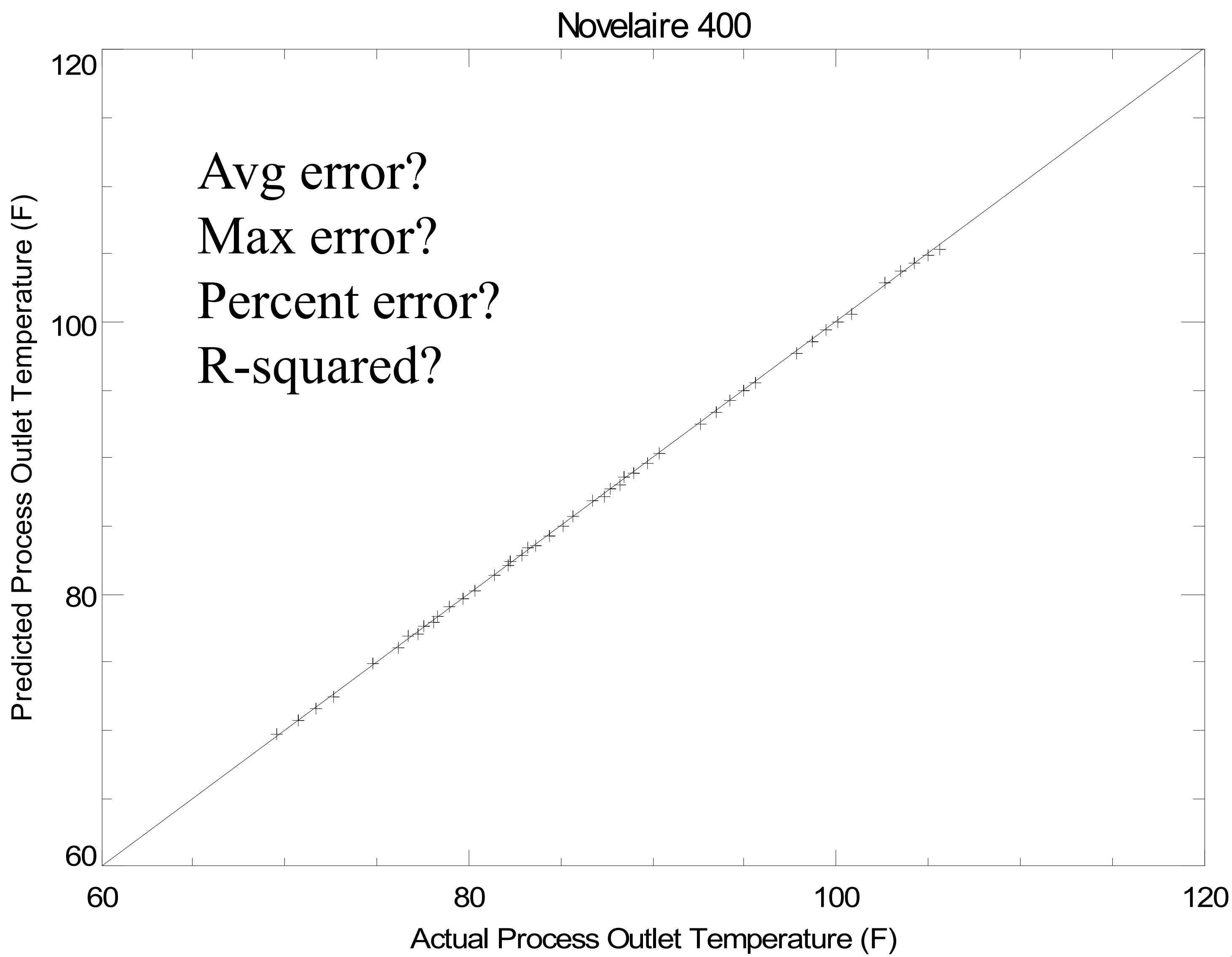
- Choose best dependent variables
  - Leaving conditions (T & w)
  - Total, Latent and sensible capacity
  - Usually need 3 variables to fully describe a AC or DH capacity & efficiency
- Choose best independent variables
  - Humidity: dew pt, RH, humidity ratio, WB
  - What provides the best fit
  - Physical performance expectations
    - E.g., Total Capacity = F(WB) ≠ F(DB, WB)

Typical Performance Map

$$Tpo = c_0 + c_1 * Tpi + c_2 * wpi + c_3 * Tpi^2 + c_4 * wpi^2$$

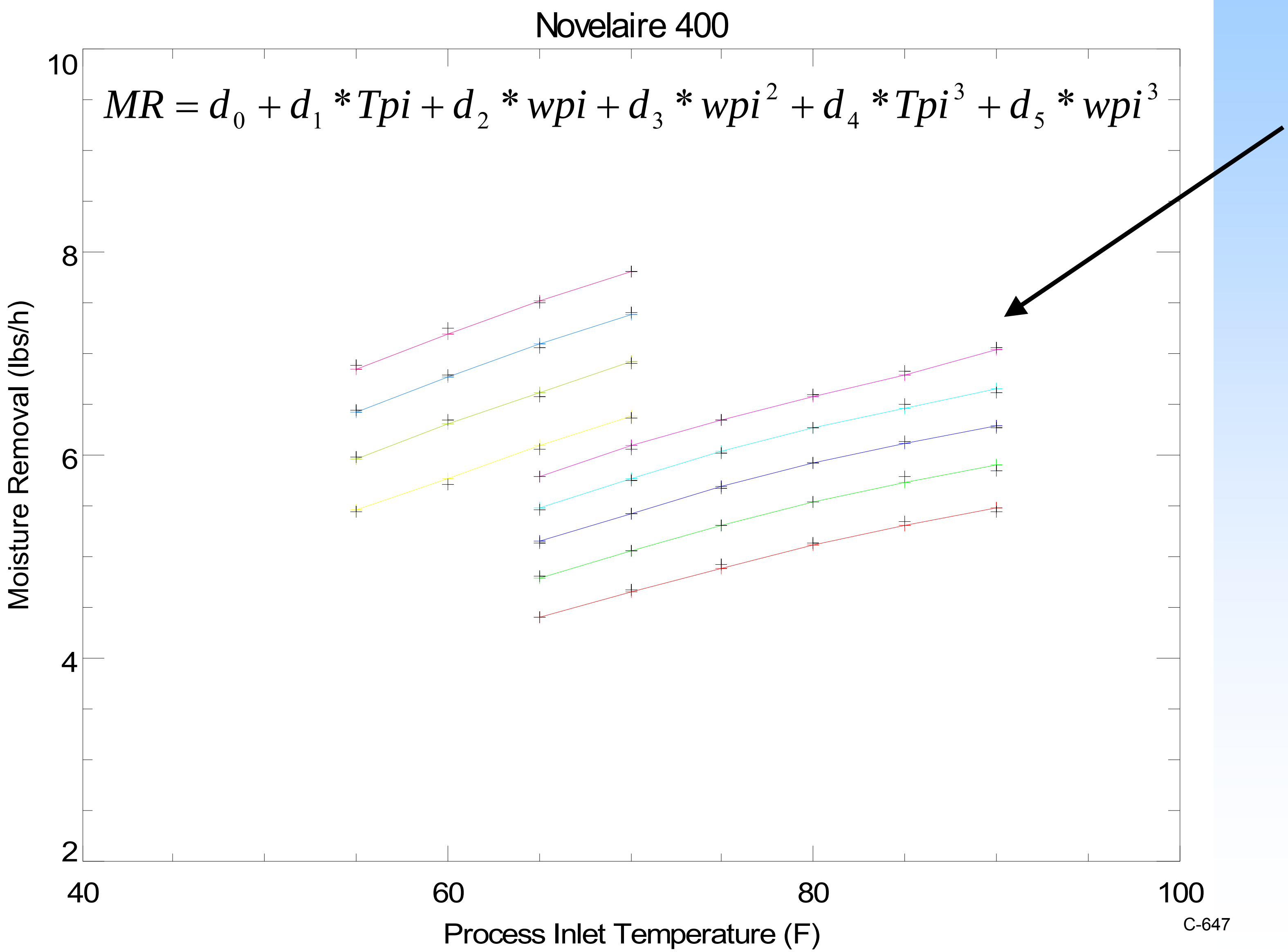


How Good is the Resulting Model?



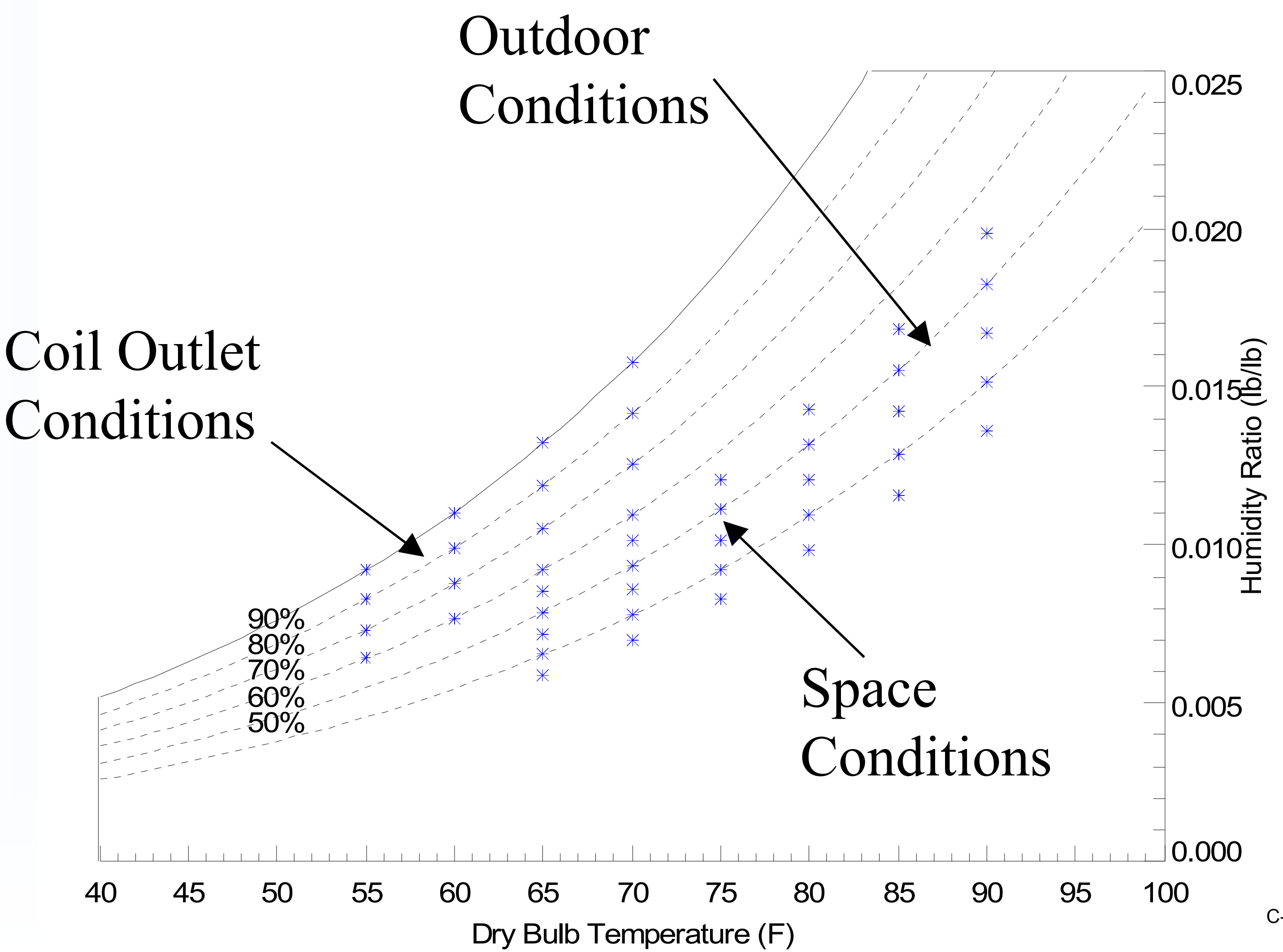
C-646

Slightly Non-Physical Behavior



Range of Inlet Conditions

How will the Component Be Applied?



C-648

How Comprehensive is The Performance Map?

- Apply to all configurations?
  - inlet from space, from outdoors, from coil outlet
- Various airflows and hardware options
  - different air flows, imbalanced flows, regeneration temperatures, wheel thicknesses
- Can it be normalized to represent different sizes?
  - same model applies for 1, 5, or 50 tons?

Different Products – Different Needs

- Easy: Stand-alone Dehumidifier
  - Ductless = constant air flow, operates at space conditions
  - Few possibilities, easy to make a map
- Harder: Commercial Desiccant Unit
  - Could pull air from space or from outdoors
  - Could operate at different airflow rates
  - Could have imbalanced flows
  - Regeneration temperatures might be fixed or vary with ambient or loading
  - Controls maintain constant supply air temperature

Manufacturer's Performance Data

Typically Generated with Algorithm

48TF004 (3 TONS)

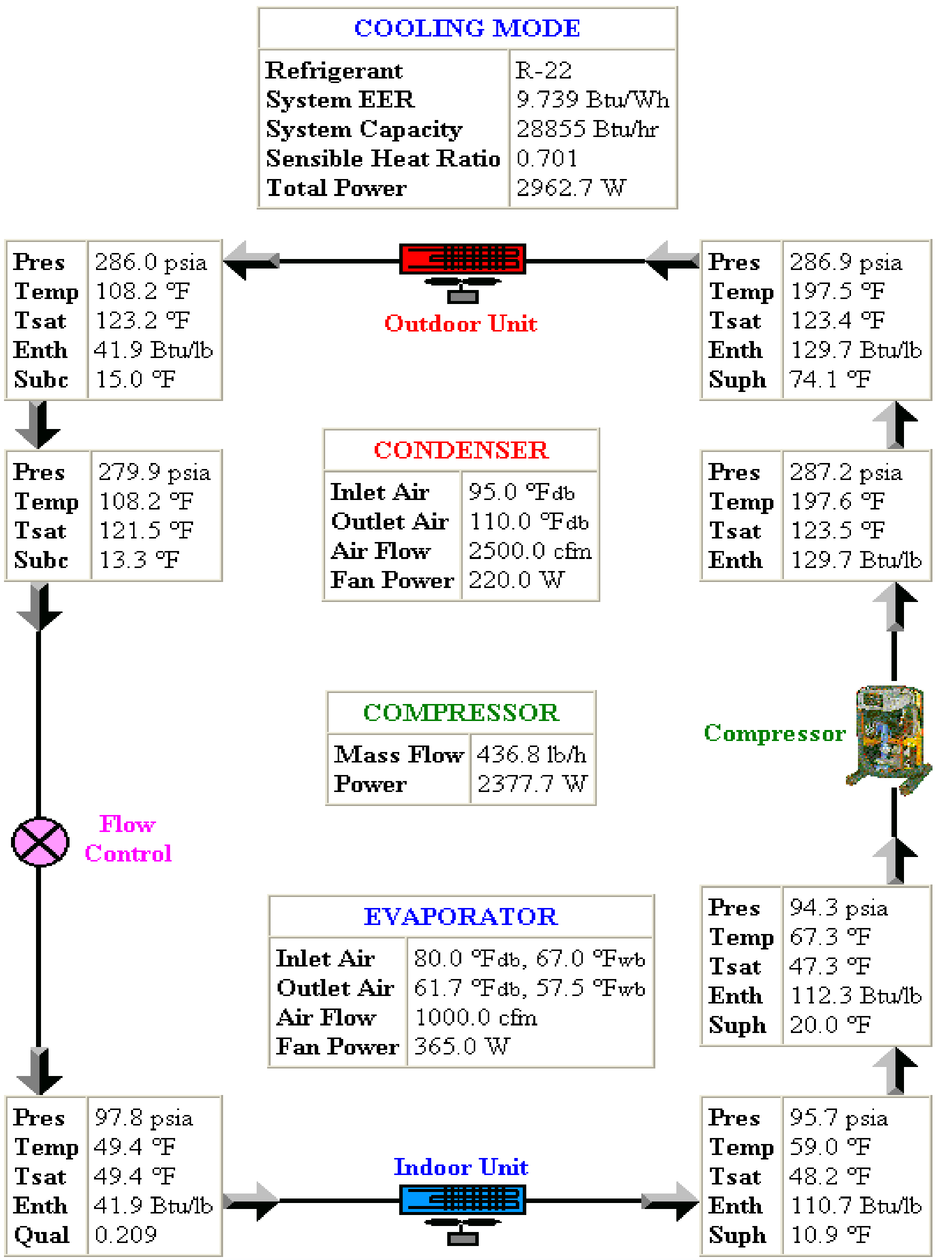
Temp (F) Air Entering Condenser (Edb)		Air Entering Evaporator — Cfm/BF								
		900/0.11			1200/0.14			1500/0.17		
		Air Entering Evaporator — Ewb (F)								
		72	67	62	72	67	62	72	67	62
75	TC	42.8	38.9	35.0	44.8	40.8	37.0	45.8	41.9	38.2
	SHC	20.0	24.5	28.7	21.8	27.5	32.8	23.0	30.0	36.0
	kW	2.91	2.81	2.70	2.99	2.88	2.78	3.02	2.92	2.82
85	TC	40.8	36.9	33.3	42.5	38.7	35.0	43.6	39.9	36.1
	SHC	19.4	23.7	27.9	21.0	26.8	31.8	22.6	29.7	35.1
	kW	3.14	3.01	2.90	3.20	3.08	2.97	3.24	3.14	3.02
95	TC	38.7	34.9	31.4	40.4	36.6	33.0	41.4	37.6	34.1
	SHC	18.6	22.9	27.0	20.3	26.0	30.9	22.0	28.8	34.0
	kW	3.35	3.21	3.09	3.42	3.29	3.16	3.47	3.35	3.22
105	TC	36.5	32.8	29.2	38.1	34.3	30.9	39.0	35.2	32.4
	SHC	17.8	22.1	25.9	19.6	25.2	29.8	21.2	28.0	32.3
	kW	3.55	3.41	3.27	3.63	3.49	3.35	3.68	3.54	3.43
115	TC	34.3	30.7	26.9	35.7	32.1	28.8	36.5	32.9	30.6
	SHC	17.0	21.3	24.8	19.0	24.4	28.8	20.5	27.1	30.6
	kW	3.76	3.60	3.45	3.84	3.68	3.54	3.88	3.74	3.64

Source of Data

- Virtually all manufacturers publish "simulated" performance data
  - There is no rating standard for how to present this data
- Only rating points are fully based on measured data
- Is this a bad thing?
  - Mature, well understood products may not need measured data for every point in a performance table or map
  - There is a difference between certified data, published data, and "just" data

ORNL AC Model

- Best approach might blend a mix of laboratory tests and simulated data
- Use model to fill in gaps



C-653

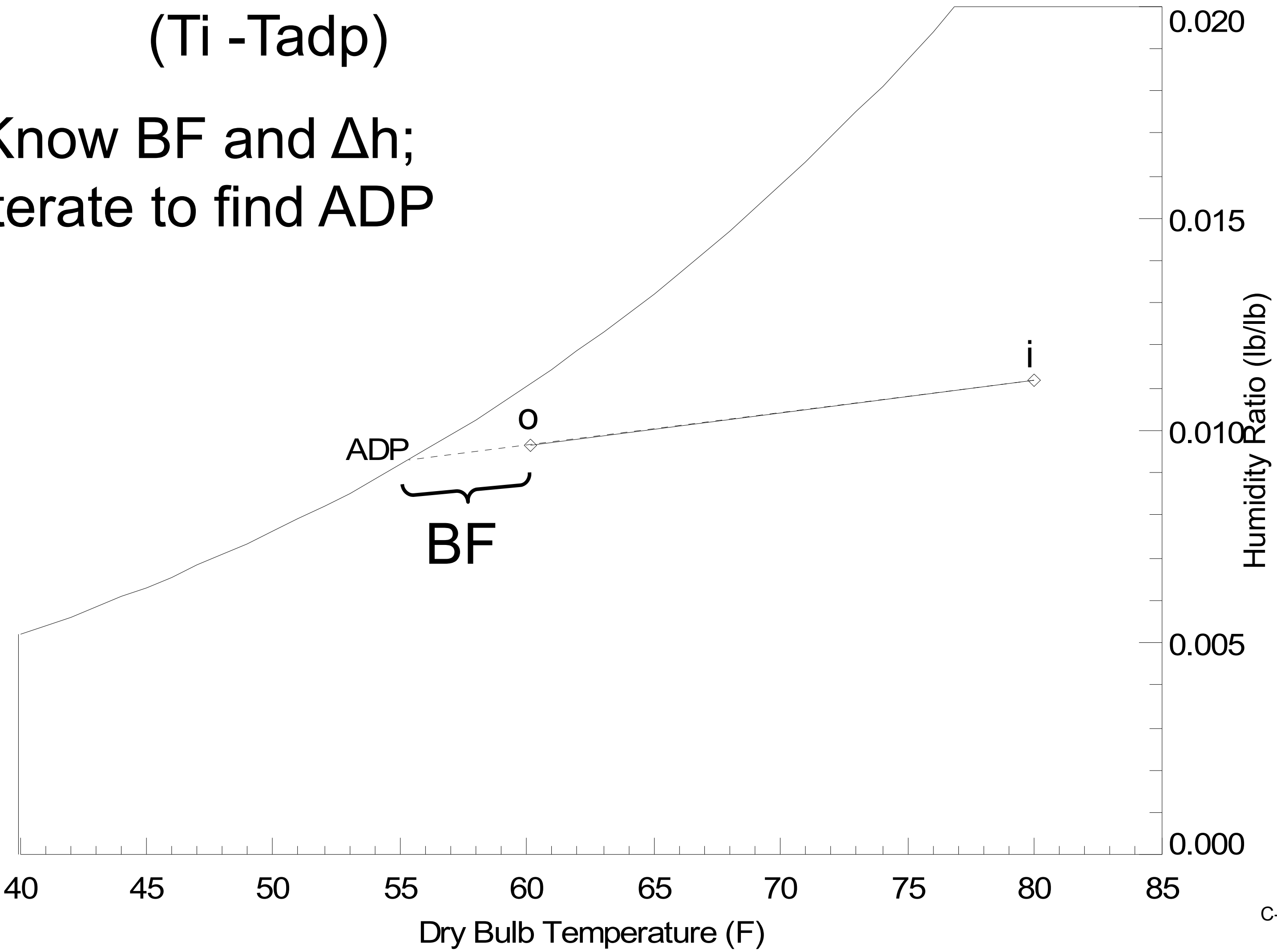
Semi-Empirical Model: AC

- Empirical
  - $QT/QT_{rated} = F(DBO, WBI, CFM_{ton})$
  - $kW/kW_{rated} = F(DBO, WBI, CFM_{ton})$
- Find sensible and latent breakout with physical model
  - Use apparatus dew point and bypass factor (ADP/BF) method; predicts coil dryout
  - Use rated SHR to find "rated" BF
- Then build entire performance map from one rating point

ADP/BF Approach

$$BF = \frac{(To - Tadp)}{(Ti - Tadp)} = F(cfm)$$

Know BF and Δh;
iterate to find ADP



C-655

Equipment with Different States

Integrating control issues

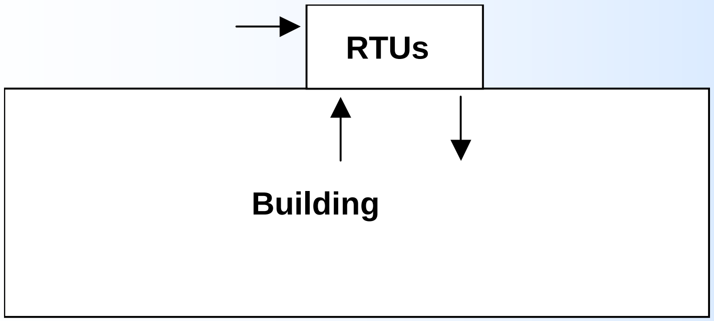
- Examples
  - Subcool/reheat systems, hybrid desiccant units, condenser reheat systems
- Component changes "state"
  - Switch between multiple performance maps
- What drives "state" change
  - Ambient temperature (easy)
  - Space conditions (when space is "overcooled")
  - State of other components (change state when AC is on)

Iterations required (applies to the last two items above)

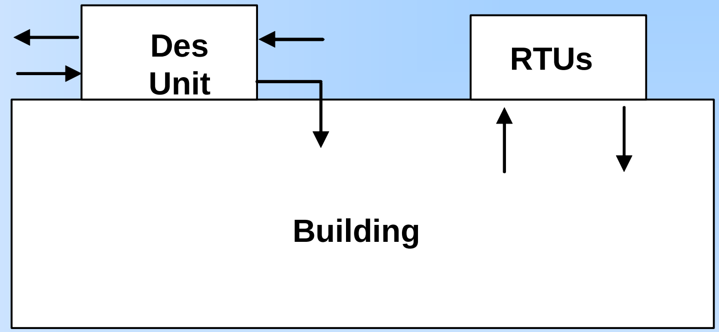
Easy or Hard: Condenser Reheat

- Simple Way (desuperheating reheat):
  - Use AC performance map
  - Some condenser heat is added into air stream
  - Probably works for small amounts of reheat
    - Reheat does not change AC coil performance
- Hard Way (full condensing):
  - As more reheat is used, AC performance changes (condensing temperature changes)
  - More complicated with modulating
    - Continuous function or 2-3 state maps?

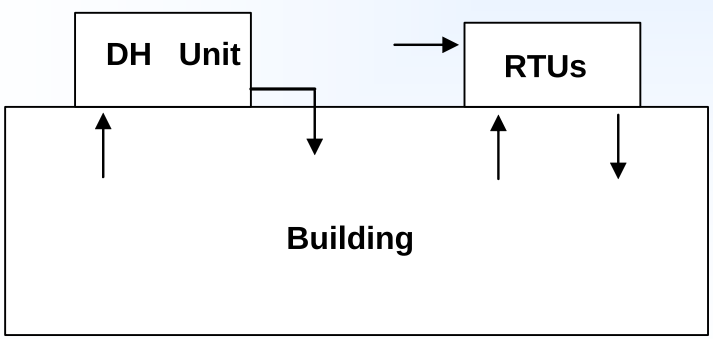
Possible Configurations



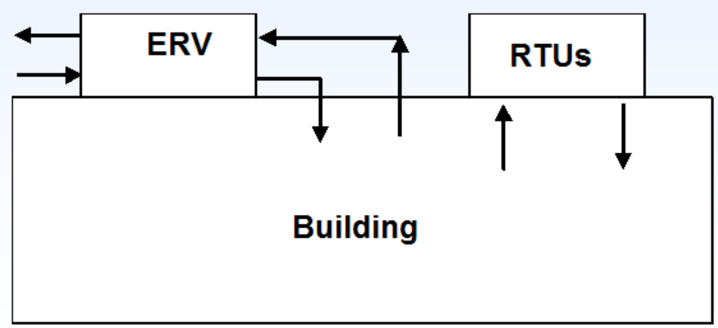
AC Only



AC w/ DH venting



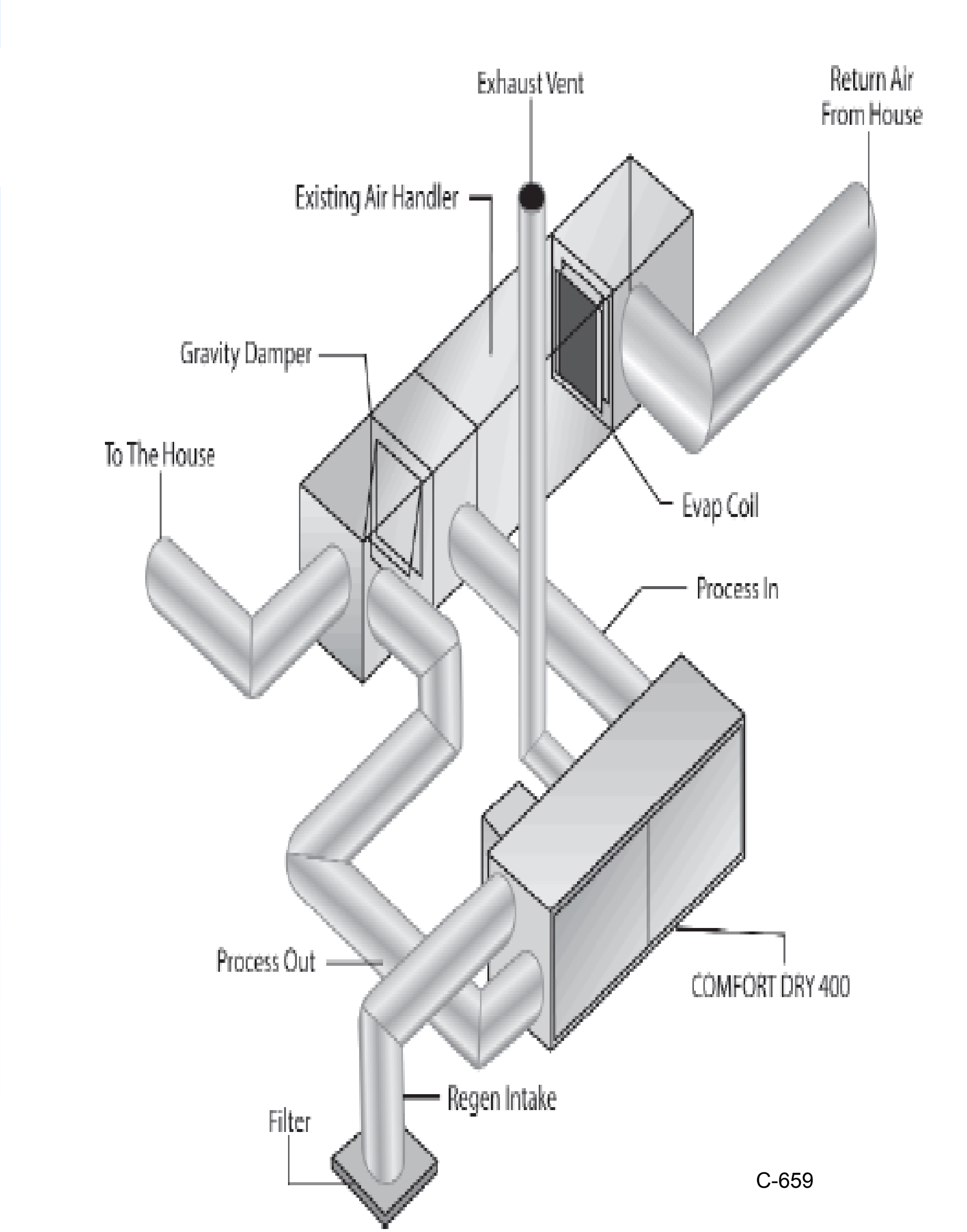
AC w/ DH



AC w/ ERV

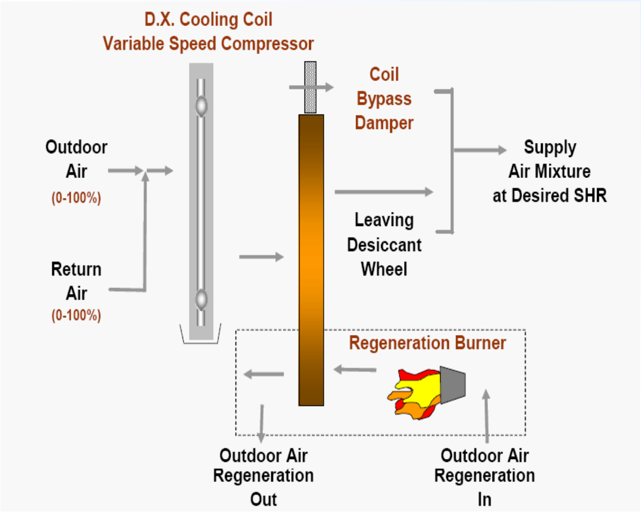
Component Configuration Issues

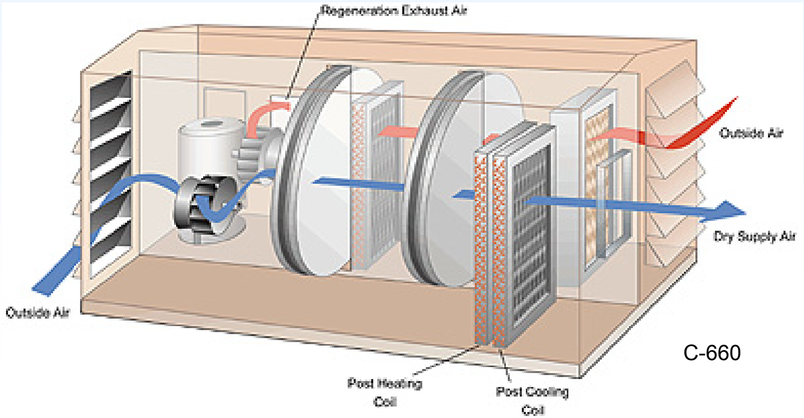
- Novelaire suggests putting desiccant unit in AC supply stream
  - Desiccant likes cold, high RH air
- DH Runs independently
  - DH might see return or supply air conditions…. or in between



Commercial Hybrid Units

- Can combine multiple components (desiccant, HX, DX coil) into one bigger component
- Integrate some controls into component:
  - Constant supply air set point
  - Hot gas bypass
  - Changes of state (based on no-iterative conditions, e.g., outdoor temperature)

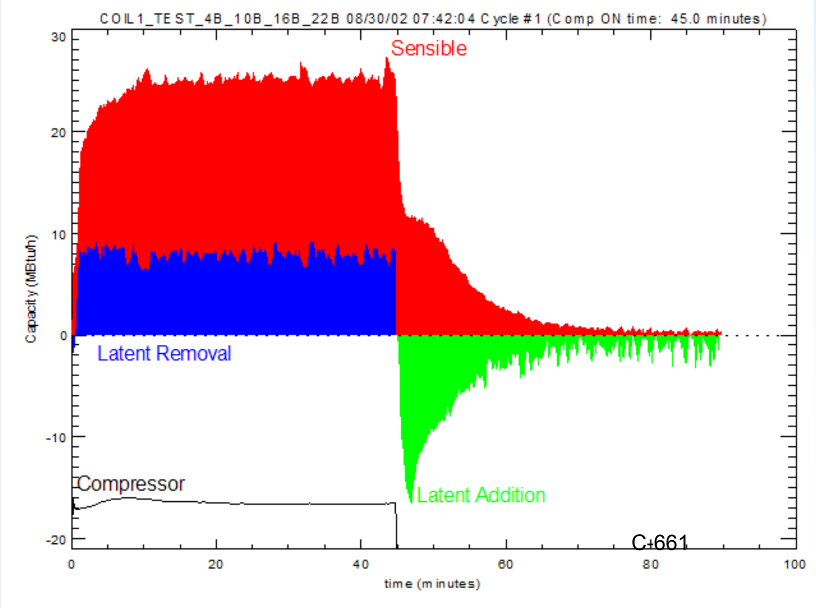




C-660

Part-load Load Effects

- Part load efficiency degradation
- Part load latent degradation (i.e., off-cycle moisture evaporation)
- Thermostat "droop"; space temperature changes with loading
- Independent ventilation controls (recycler)
- Hot gas bypass controls



Summary

- Performance for the Component
  - Need data to represent range of expected operating conditions (maybe a mix of measured and simulated)
  - Choose good independent and dependent variables
  - semi-empirical models are better
  - Normalize models where possible
- Integration, Configuration and Control
  - Often the hardest part
  - How component works with other components and within building system

Appendix D: Presentation 2

Not available at this time, pending approval by NREL.

Appendix E: Presentation 3

Residential Dehumidifier Performance: Field Testing and Method Of Test Development

By:
Armin Rudd
Building Science Corp.
www.buildingscience.com

For:
Building America Expert Meeting
Louisville
19 June 2009

Stand-alone dehumidifier
Installed in mechanical closet, in central system return air path

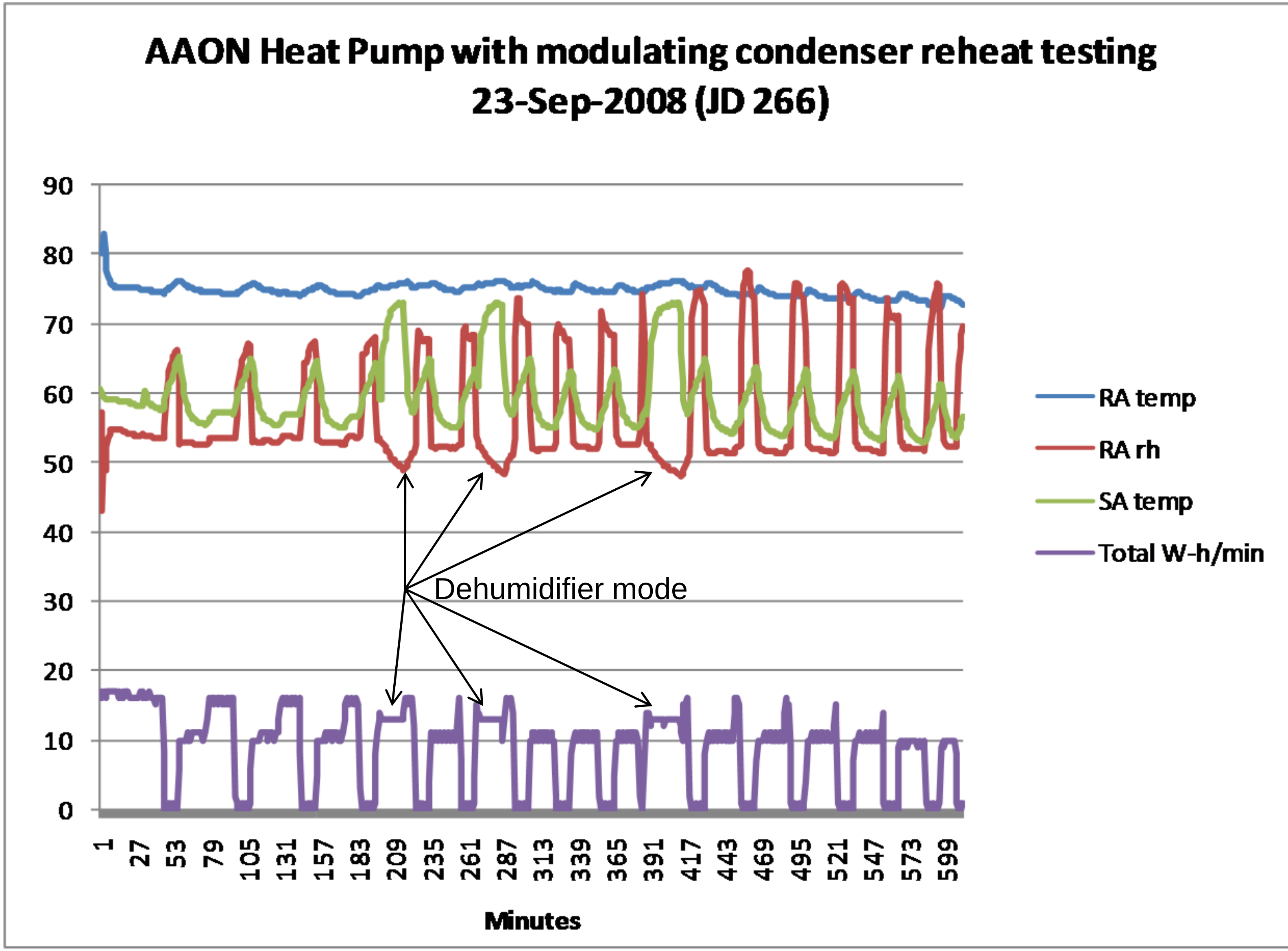
Stand-alone dehumidifier, installed in attic
Ducted to living space and central system supply

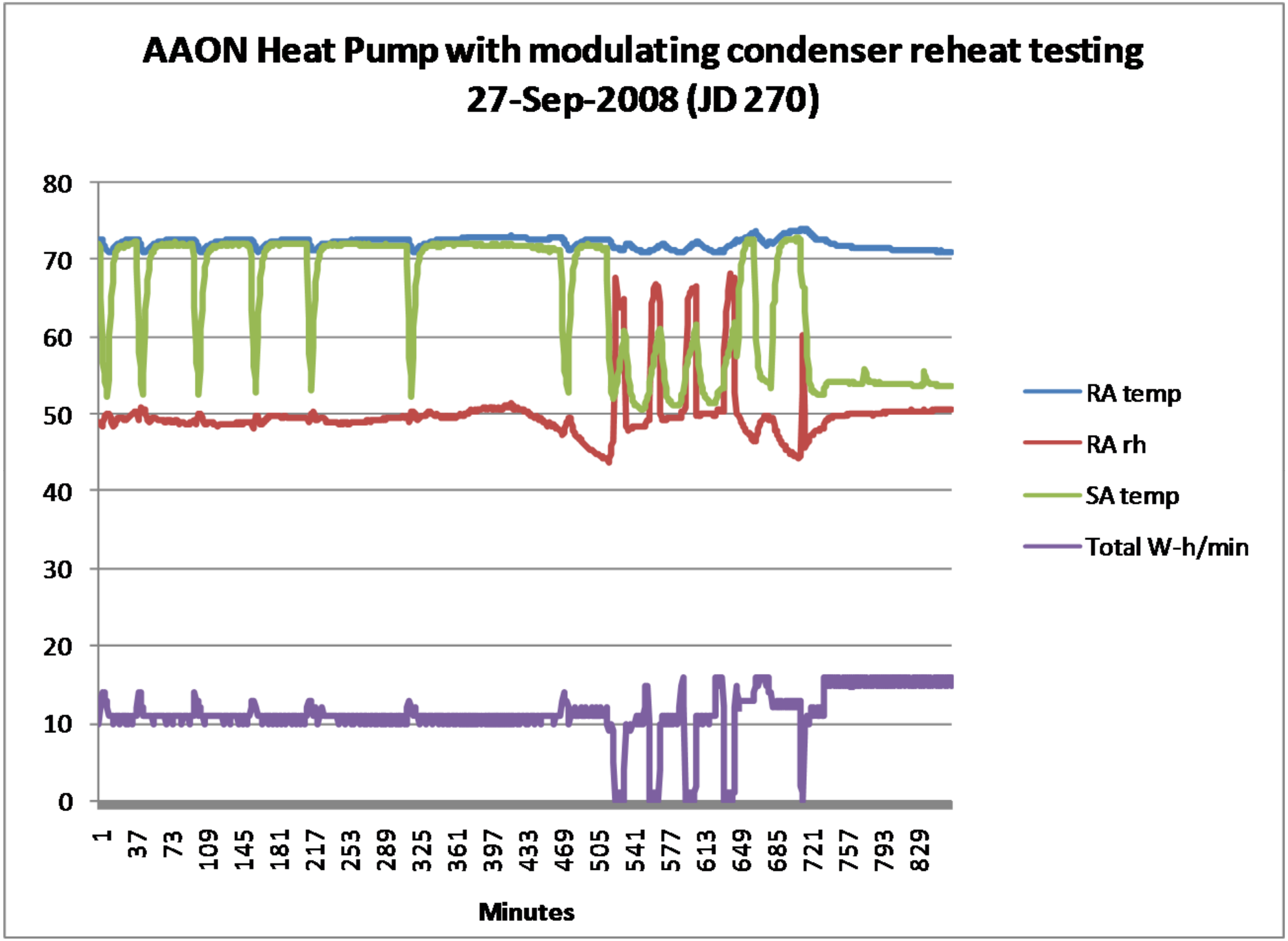
Stand-alone dehumidifier, installed in conditioned space
Ducted and integrated with central system

DX cooling system with modulating hot gas condenser reheat for dedicated dehumidification mode

3-pipe system

FSEC Manufactured Housing LAB
Cocoa, FL


AAON Heat Pump with modulating condenser reheat testing
23-Sep-2008 (JD 266)
90
80
70
60
50
40
30
20
10
0
1
27
53
79
105
131
157
183
209
235
261
287
313
339
365
391
417
443
469
495
521
547
573
599
Minutes
RA temp
RA rh
SA temp
Total W-h/min
Dehumidifier mode



AAON Heat Pump with modulating condenser reheat testing
27-Sep-2008 (JD 270)
80
70
60
50
40
30
20
10
0
1
37
73
109
145
181
217
253
289
325
361
397
433
469
505
541
577
613
649
685
721
757
793
829
Minutes
RA temp
RA rh
SA temp
Total W-h/min

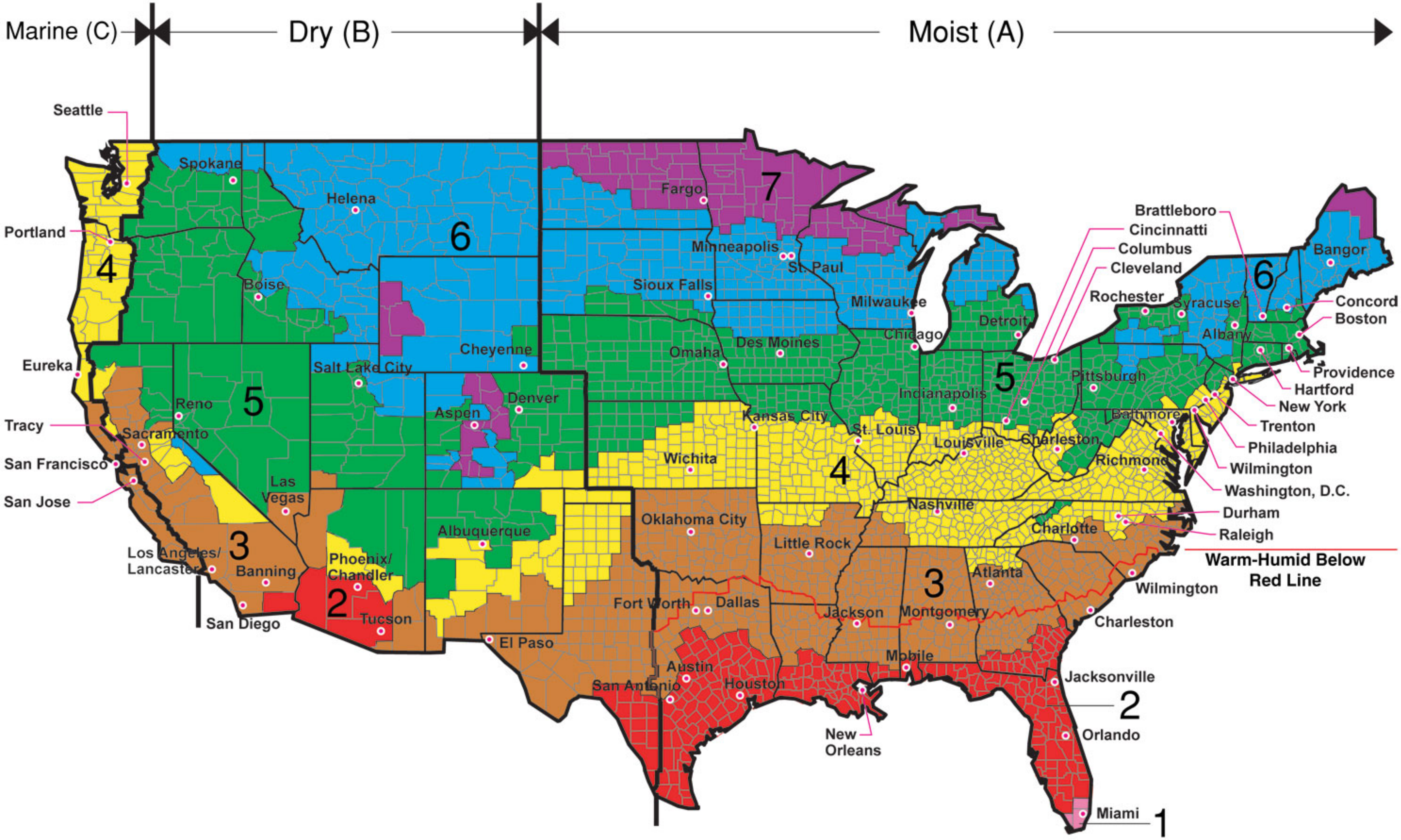
Summary to this point

- **Where we have been** is to demonstrate that there is a certain need for dehumidification separate from cooling in high-performance, low sensible gain houses in humid climates. We have also worked with manufacturers providing stand-alone dehumidifier solutions, and have developed and tested our own integrated system.
- **Where we are right now** is: existing packaged dehumidifier equipment, and single-system integrated approach.
- **Where we are going** is to create a framework in which to evaluate the performance of a range of supplemental dehumidification systems as they are applied to high-performance homes. This will entail developing engineering criteria for obtaining standardized extended performance data in laboratories (MOT), and conducting field evaluations that will also serve as a reality check for modeling efforts towards a new rating standard.

Approach to establish performance and testing requirements for humidity control equipment in high performance homes in hot-humid climates

- Define the minimum whole house performance goal
  - for example: Limit duration of indoor RH >60% to 4 hours or less, while meeting Energy Star dehumidification efficiency requirements for latent cooling and SEER 13 efficiency requirement for total cooling.
- Define a test method that that provides a consistent basis of comparison of performance between different types of equipment
- Demonstrate that the method works based on lab tests and field tests in high performance homes
- Hold meetings with stakeholders to build consensus for performance goals and test methods
- Begin to adapt the field test data to models to provide basis for equipment rating (further testing may be needed)
- Integrate equipment performance maps into annual energy simulations which would support the rating procedures
- Publish test methods, rating procedures, and test/analysis results

Regional ratings may be important



All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands

Method of Testing for Rating Residential Dehumidifiers for Moisture Removal Capacity and Moisture Removal Efficiency

FORWARD

...

1. PURPOSE

1.1. The purpose of this standard is to prescribe test methods for determining the moisture removal capacity and moisture removal efficiency for residential dehumidifiers.

2. SCOPE

2.1 This Standard applies to residential dehumidifying equipment that removes moisture by cooling air below its dew-point. The equipment may consist of one or more separate assemblies located indoors or outdoors. Where more than one separate assembly is used, they shall be designed to be used together.

2.2 For purposes of this standard, residential dehumidifiers provides air dehumidification and may provide additional functions of: air cooling, air heating, air circulation, air filtration, air-to-air heat recovery, and water heating.

3.1 DEFINITIONS

ARI Standard 210/240 test conditions

Table 3. Cooling Mode Test Conditions for Units Having a Single-Speed Compressor and a Fixed-Speed Indoor Fan, a Constant Air Volume Rate Indoor Fan, or No Indoor Fan

Test Description	Air Entering Indoor Unit				Air Entering Outdoor Unit			
	Dry-Bulb		Wet-Bulb		Dry-Bulb		Wet-Bulb	
	F	C	F	C	F	C	F	C
A Test - required (steady, wet coil)	80	26.7	67	19.4	95	35	75.0(1)	23.9(1)
B Test - required (steady, wet coil)	80	26.7	67	19.4	82	27.8	65.0(1)	18.3(1)
C Test - optional (steady, dry coil)	80	26.7			82	27.8		
D Test - optional (cyclic, dry coil)	80	26.7			82	27.8		

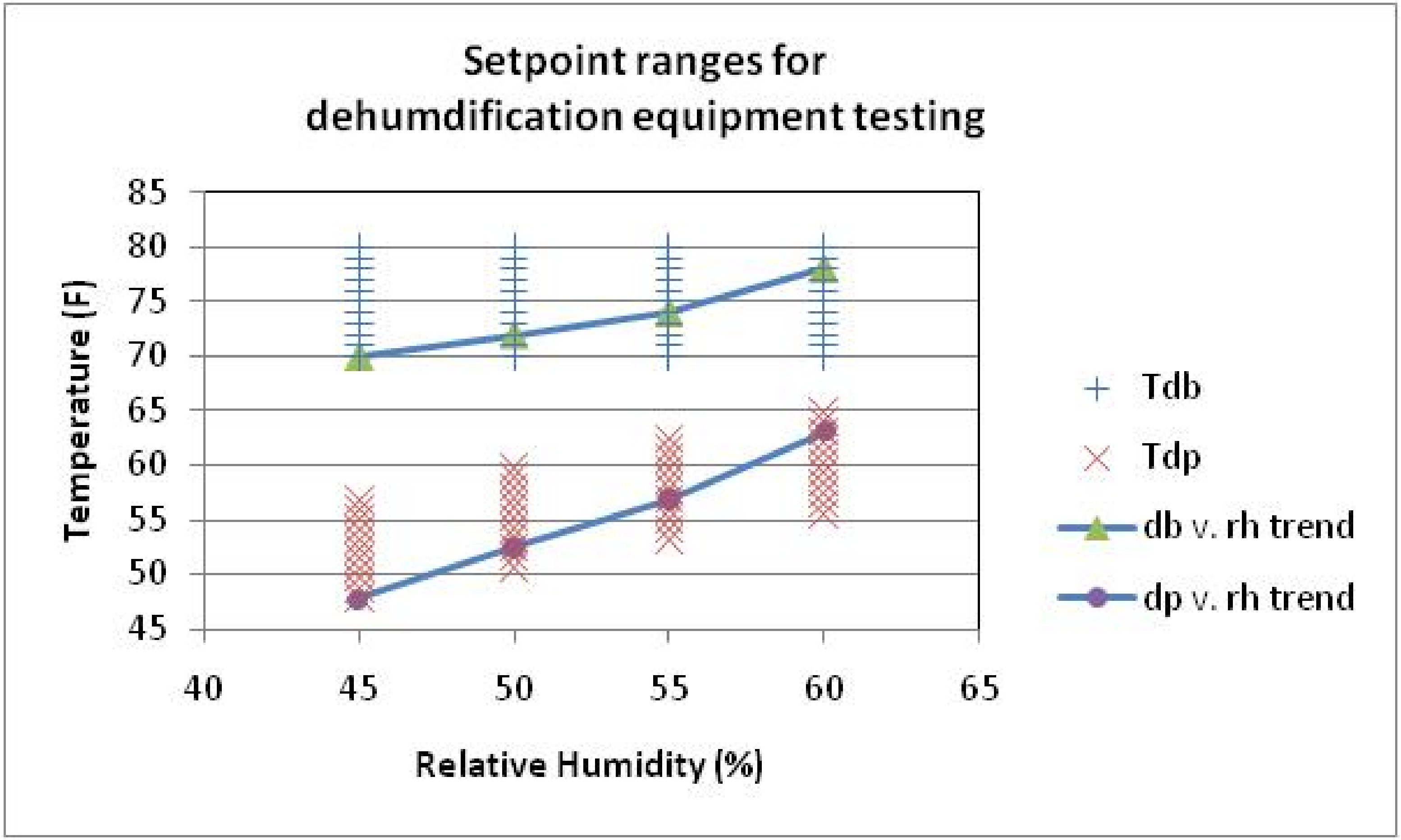
Notes: (1) The specified test condition only applies if the unit rejects condensate to the outdoor coil.

Cd = degradation coefficient, you want that to be low, default=0.25
PLF = part load factor (at 50% load), you want that to be high

PLF = 1 - 0.5(Cd)

SEER = PLF * EER

Humidity control setpoints for testing



Humidity control setpoints for testing

	Outdoor T/RH/Tdp (F/%/F)	Indoor T/RH/Tdp (F/%/F)	
Test 1	95/58/78	80/60/65 78/55/61 75/50/55	cooling design conditions
Test 2	80/85/75	80/60/65 78/55/61 75/50/55	cooling part-load: summer nights/rainy periods
Test 3	75/85/70	78/60/63 78/55/61 75/50/55	cooling part-load: spring/fall
Test 4	65/90/62	72/60/57 70/52/52 68/45/46	no cooling: spring/fall/winter
Test 5 (opt)		65/55/49[1]	cold climate basement conditions

[1] Single unit basement dehumdifier condition

Dehumidification equipment test results

	Outdoor T/RH/Tdp (F/%/F)	Indoor Return T/RH/Tdp (F/%/F)	Indoor Supply T/RH/Tdp (F/%/F)	Indoor Wet-coil Airflow (cfm)	Sensible Cooling Capacity (Btu/h)	Latent Cooling Capacity (Btu/h)	Heat Added In Dehum (Btu/h)	Moisture Removal Capacity (L/h)	Total Power (kW)	Moisture Removal Efficiency[1] (MRE) (L/kW-h)	Dehum Efficiency Ratio (DER) (Btu/W-h)	Energy Efficiency Ratio (EER) (Btu/W-h)
Test 1	95/58/78	80/60/65 78/55/61 75/50/55										
Test 2	80/85/75	80/60/65 78/55/61 75/50/55										
Test 3	75/85/70	78/60/63 78/55/61 75/50/55										
Test 4	65/90/62	72/60/57 70/52/52 68/45/46										
Test 5 (opt)		65/55/49										

[1] Same as the Energy Factor used for dehumidifiers by Energy Star