Dehumidification and Humidity Control in Humid Climate U.S. Residences

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

For:
Affordable Comfort Conference
Kansas City
28 April 2009

Introduction

- Started looking at humidity control in hot-humid climate homes in the early 90's
- Some Southeast US production builders began routinely installing supplemental dehumidification in the late 90's
- Started an extensive field research project on cost and performance of dehumidification options in early 2001
- Continued gathering indoor temperature and relative humidity data during the course of additional projects involving dehumidification, ventilation, unvented-cathedralized attics, and cooling system sizing
- Questions from some industry members about the extent of the humidity control problem prompted analysis of the combined data from all of these projects, presented at ASHRAE in Jan-2007

Why do we want to control indoor humidity?

1. Comfort and IAQ
   - Control indoor humidity year-around, just like we do temperature
   - Important to the homeowner and therefore the builder

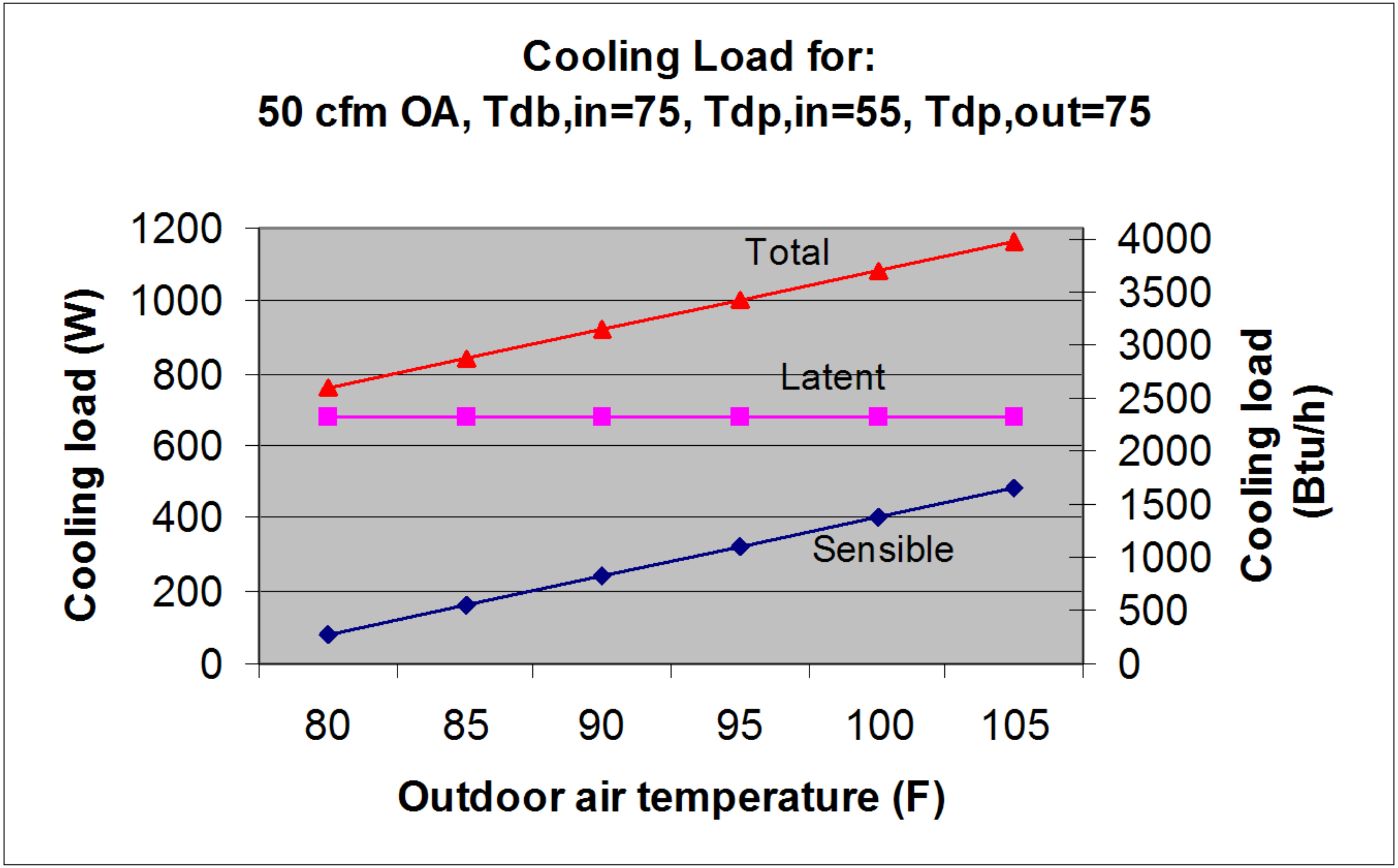
2. Durability
   - Important to the builder but mostly hidden to the homeowner until a problem becomes evident

Why isn't moisture removal by the cooling system adequate?

1. There will always be times of the year when there is little cooling load but humidity remains high, and thermostats control primarily on temperature
   - Thermostats and blower speed controls that modify operation based on humidity are still limited in how much they can over-cool
2. More energy efficient construction has a lower sensible heat load but the latent load remains mostly the same
   - Low glazing heat gain, or shading of glazing
   - Ducts in conditioned space
   - More insulation
3. More energy efficient (Energy Star®) appliances give off less waste heat

Why isn't moisture removal by the cooling system adequate?

4. More energy efficient cooling equipment often has a higher evaporator coil temperature yielding less moisture removal
   - Larger evaporator coil by manufacturer design, or up-sized air handler unit or airflow by installer choice
5. Cooling systems are sized on peak load, which is mostly sensible load, the system normally operates at far less than peak load
6. Conventional over-sizing to cover for lack of design or execution causes short-cycling yielding less moisture removal


Cooling Load for:
50 cfm OA, Tdb,in=75, Tdp,in=55, Tdp,out=75
Cooling load (W)
1200
1000
800
600
400
200
0
Total
Latent
Sensible
4000
3500
3000
2500
2000
1500
1000
500
0
Cooling load (Btu/h)
80
85
90
95
100
105
Outdoor air temperature (F)

Dehumidifier and ventilation duct in interior mechanical closet with louvered door Jacksonville, FL

Systems Tested – Houston, TX

STAND-ALONE IN CLOSET	
19803 Ash.,	2 story, 2386 ft^2
19902 Ash.,	2 story, 2397 ft^2
STAND-ALONE IN ATTIC	
19950 Ash.,	2 story, 2397 ft^2
2731 Sun.,	2 story, 2448 ft^2
ULTRA-AIRE	
19915 Ash.,	1 story, 2100 ft^2
19938 Ash.,	2 story, 2448 ft^2
19923 Ash.,	2 story, 2397 ft^2
FILTER-VENT + STAND-ALONE	
19934 Ash.,	1 story, 1830 ft^2
19922 Ash.,	1 story, 2100 ft^2
19954 Ash.,	2 story, 2386 ft^2
ERV	
19926 Ash.,	1 story, 1830 ft^2
19942 Ash.,	1 story, 2197 ft^2
19930 Ash.,	2 story, 2448 ft^2
2-STAGE + ECM AHU	
19422 Col.,	1 story, 2197 ft^2
ENERGY EFFICIENT REFERENCE	
2802 Sun.,	2 story, 2386 ft^2
2814 Sun.,	1 story, 2197 ft^2
19906 Ash.,	2 story, 2386 ft^2
STANDARD REFERENCE	
19622 Her.,	2 story, 2448 ft^2
4818 Cot.,	1 story, 2197 ft^2
6263 Clear.,	2 story, 3300 ft^2

© buildingscience.com

Ducted dehumidifier attic installation

Ducted dehumidifier basement installation

Introduction

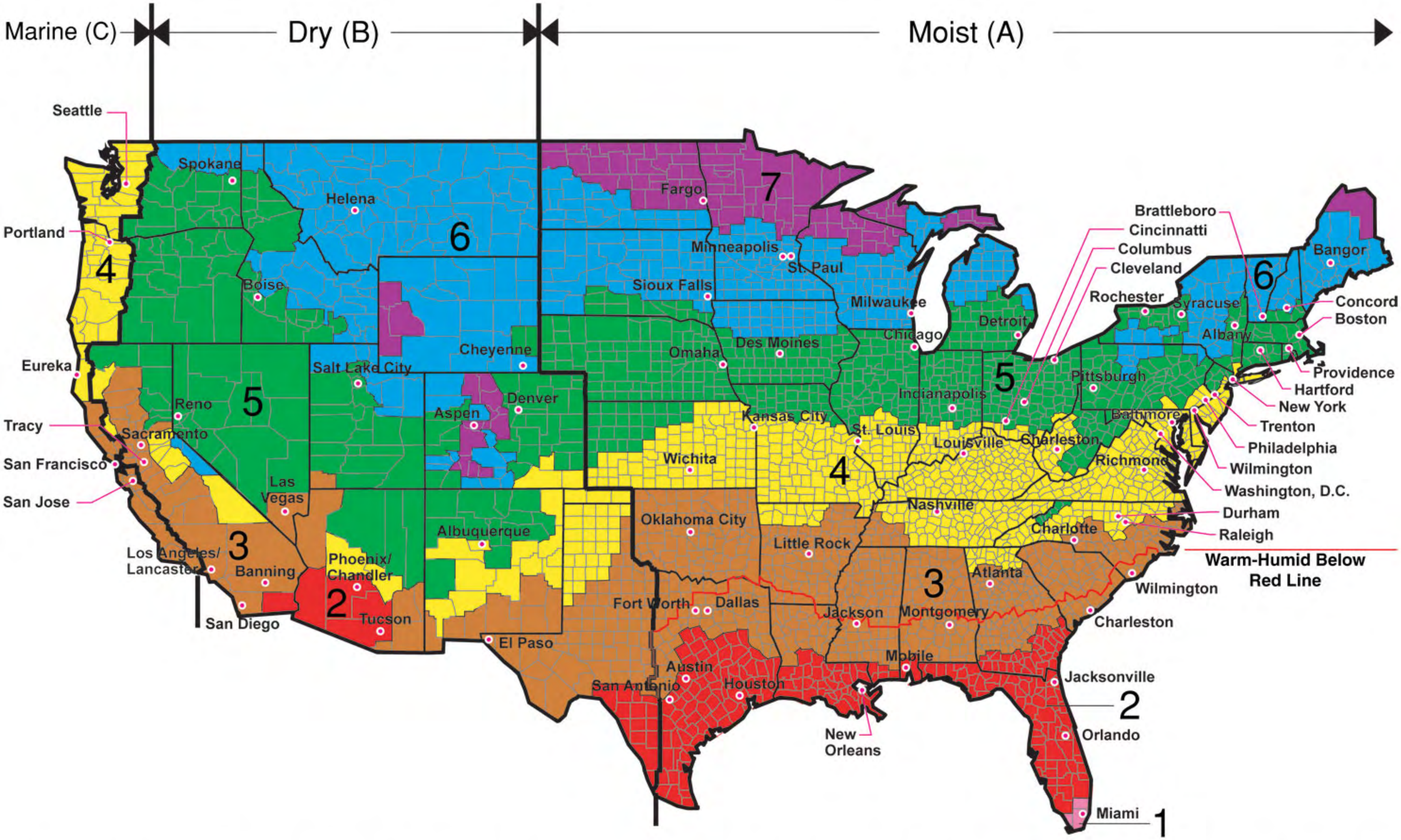
- Data set
  - 43 homes, each with one to four T/RH space measurements
  - Data recorded hourly
  - 27 homes also had equipment runtime measurements (cool, heat, fan, dehumidifier)








Houston (29), Austin (3), Dallas (3), Jacksonville (2), Ft. Myers (2), Orlando (1), OK City (3)



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

© buildingscience.com

Observations from the Data

- The average cooling set points were generally several degrees lower than the commonly assumed value of 78°F. The data provided no clear indication that either lower or higher cooling set points caused high humidity events.
- There was little clear difference in space humidity between Standard houses with and without ventilation. They both had multi-day excursions above 60% RH, but not as much as Medium- or High-Performance houses.
- Most Medium-Performance houses and all High-Performance houses with ventilation showed a marked increase in space humidity compared to Standard houses with ventilation.

Observations (cont.)

- Cooling system enhancements showed little effect on space humidity for Standard houses or High-Performance houses with ventilation
- Three of the five Standard houses with ventilation and supplemental dehumidification exhibited superior humidity control throughout the year.
- Most High-Performance houses with ventilation and supplemental dehumidification had space humidity controlled below 60% RH year round. Some did not due to occupant manipulation of the humidistat setpoint.

Conclusions for Standard houses

- Conventional cooling systems in Standard houses usually provide humidity control below 60% RH.
- Some space humidity excursions above 60% RH occur during the spring and fall, and summer nights, and rainy periods when sensible cooling loads are modest or non-existent.
- The effect of adding mechanical ventilation to Standard houses in humid climates was not a consistently clear or strong signal
  – Space humidity is maintained in swing seasons by occasional cooling operation driven by higher sensible gain in Standard houses
  – Differences in occupancy and occupant behavior seem to have a larger impact than ventilation (i.e. large houses with few occupants, thermostat setup and manual manipulation, extreme temperature setpoints).

Conclusions for High-Performance houses

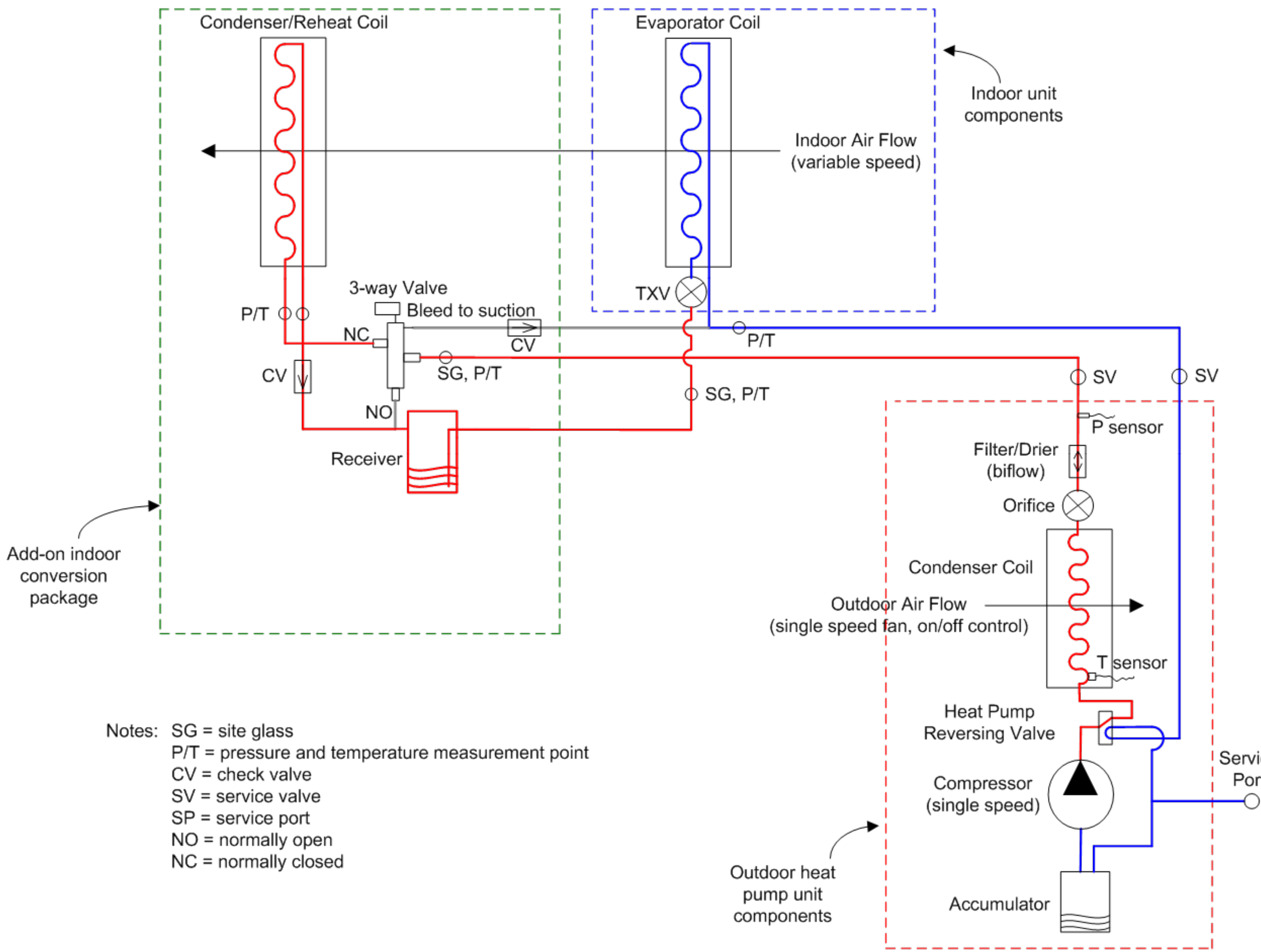
- The combination of High-Performance low sensible heat gain buildings and mechanical ventilation significantly increases the number of hours that require dehumidification without sensible cooling.
  - Higher cooling balance point temperature than for conventional Standard houses
  - High space humidity occurs during spring and fall swing seasons, and summer nights, and rainy periods
- The effect of reducing the latent ventilation load through energy recovery was insufficient to avoid high humidity at part-load and no-load conditions.
- Humidity loads in High-Performance homes cannot always be met by conventional or enhanced cooling systems, but instead require separate dehumidification.

The addition of supplemental dehumidification to High-Performance homes in humid climates enables continued improvements in energy efficiency while ensuring against elevated indoor humidity.

Advanced Cooling with Dehumidifier Mode ACDM Goals

- Provide year-around relative humidity control in high-performance (low-sensible gain) houses
- Avoid over-cooling the space
- Make standard DX cooling equipment switchable between normal or enhanced cooling and dehumidification only (requires air reheating)
- Lower installed cost than high efficiency whole-house integrated dehumidifier

Advanced Cooling with Dehumidification Mode (ACDM) prototype schematic
(cooling-only system, DEH mode active)

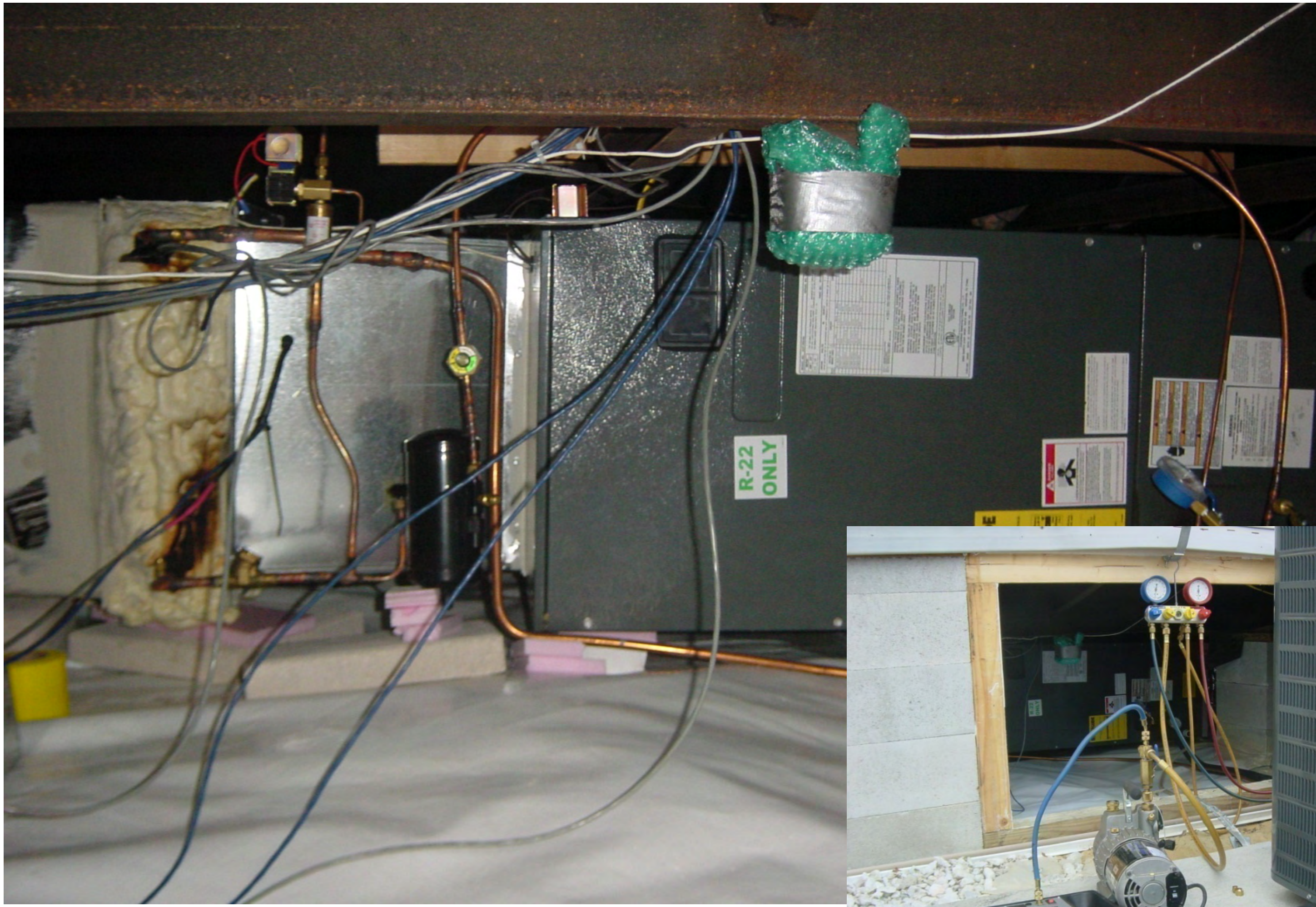


Notes: SG = site glass
P/T = pressure and temperature measurement point
CV = check valve
SV = service valve
SP = service port
NO = normally open
NC = normally closed

A.Rudd, Building Science Corp.

Advanced Cooling with Dehumidifier Mode (ACDM) Benchtop Testing

Field testing at the FSEC MH lab



AAON®

F1 Series
Indoor Air Handlers
Engineering Catalog

AAON®

CB/CC Series
Condensing Units
Engineering Catalog

D = *Modulating Hot Gas Reheat*

- Selection provides a reheat coil mounted downstream of the evaporator with digital control actuation of modulating valves to offer precision temperature and humidity management.
- Modulating valves control the flow of refrigerant to the reheat coil to maintain precise supply air temperature and humidity. A wall mount humidistat is available as an accessory.
- Field installed receiver tanks are standard with this option.
- Requires field installation of a hot gas line to route compressor discharge refrigerant from the outdoor unit.

www.aaon.com

Performance Data

Table P1 - Matching CB and F1, Air Conditioner Performance Data

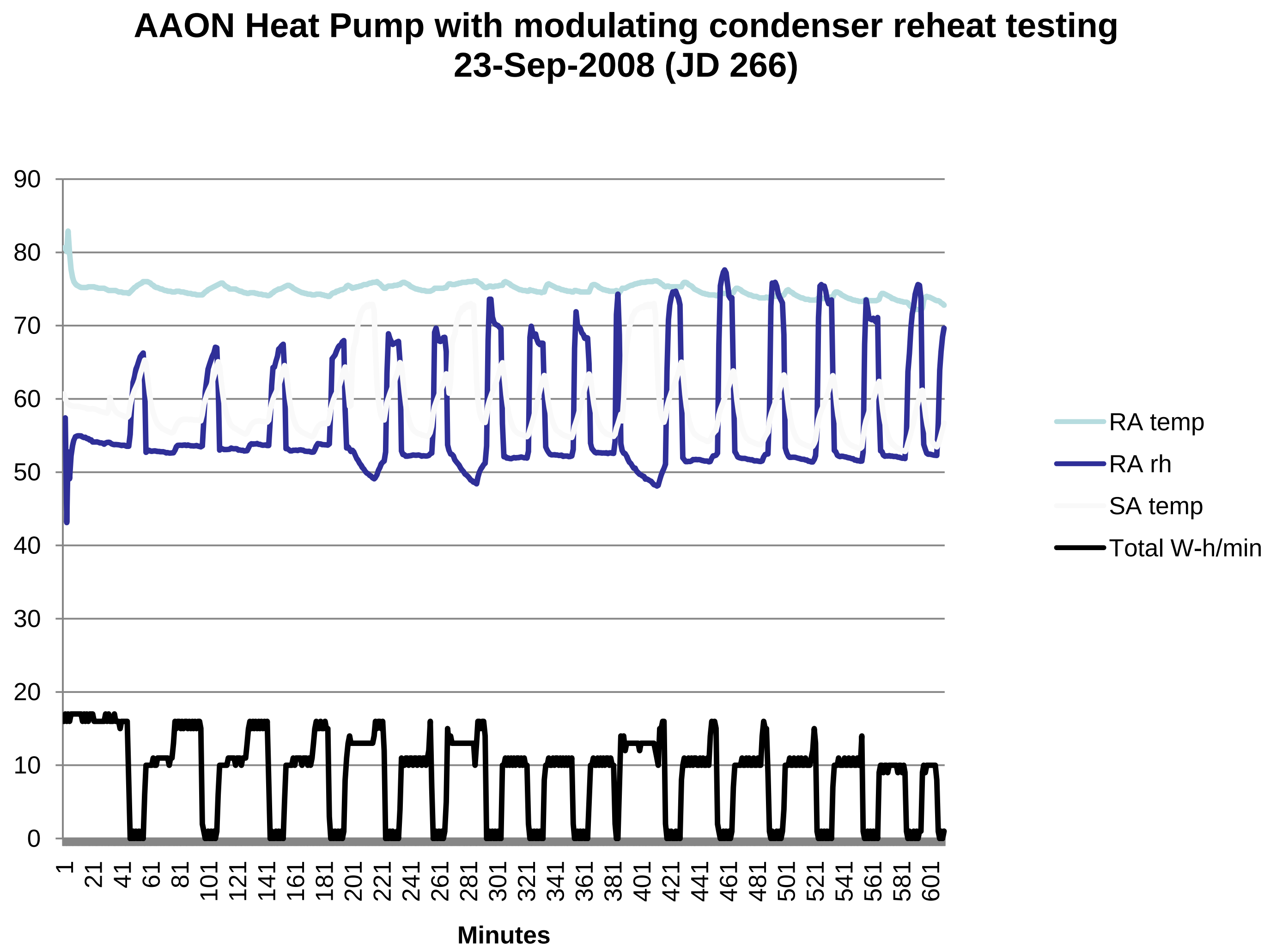
Condensing Unit	Air Handler	Nominal Capacity	SEER
CB-024	F1-024	24 MBH / 2 Tons	17.2
CB-036	F1-036	36 MBH / 3 Tons	15.5
CB-048	F1-048	48 MBH / 4 Tons	15.6
CB-060	F1-060	60 MBH / 5 Tons	14.6

Table P2 - Matching CB and F1, Heat Pump Performance Data

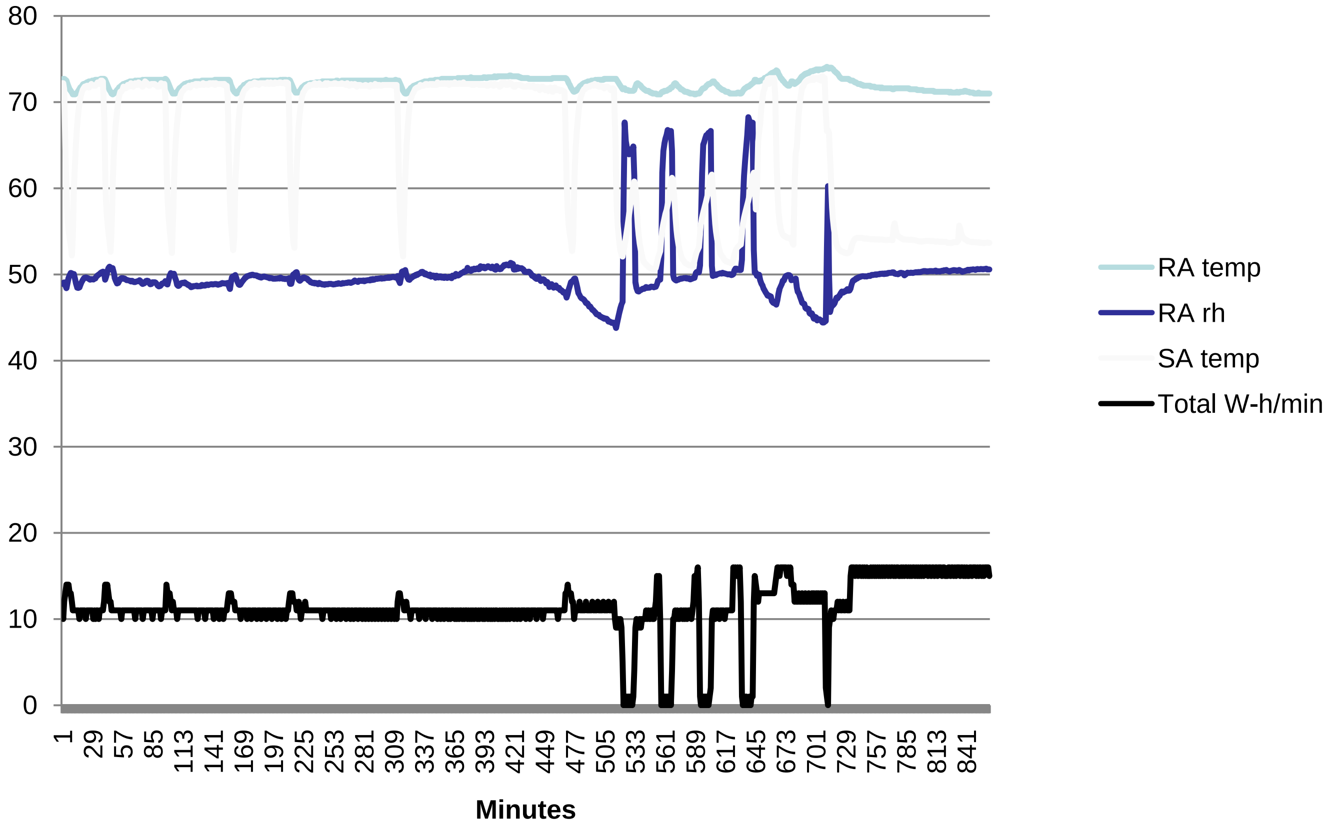
Condensing Unit	Air Handler	Nominal Capacity	SEER	HSPF
CB-024	F1-024	24 MBH / 2 Tons	16.30	8.45
CB-036	F1-036	36 MBH / 3 Tons	14.80	8.50
CB-048	F1-048	48 MBH / 4 Tons	14.65	8.65
CB-060	F1-060	60 MBH / 5 Tons	14.40	8.30



WARNING
THIS UNIT MUST
BE INSTALLED
LEVEL
AIRFLOW


AAON Heat Pump with modulating condenser reheat testing
23-Sep-2008 (JD 266)
90
80
70
60
50
40
30
20
10
0
1
21
41
61
81
101
121
141
161
181
201
221
241
261
281
301
321
341
361
381
401
421
441
461
481
501
521
541
561
581
601
Minutes
RA temp
RA rh
SA temp
Total W-h/min

AAON Heat Pump with modulating condenser reheat testing
27-Sep-2008 (JD 270)



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 field test method that that provides a consistent basis of comparison of performance between different types of equipment
- Demonstrate that the method works based on field tests in high performance homes (gate 3-prototype evaluations)
- Adapt the field test method to provide equipment rating (gate 2-equipment rating/lab testing)
- Hold expert meetings with stakeholders to build consensus for performance goals and test methods
- Integrate equipment performance maps into annual energy simulations (gate 1- analysis of performance impacts)
- Publish test methods, rating procedures, and test and analysis results

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		

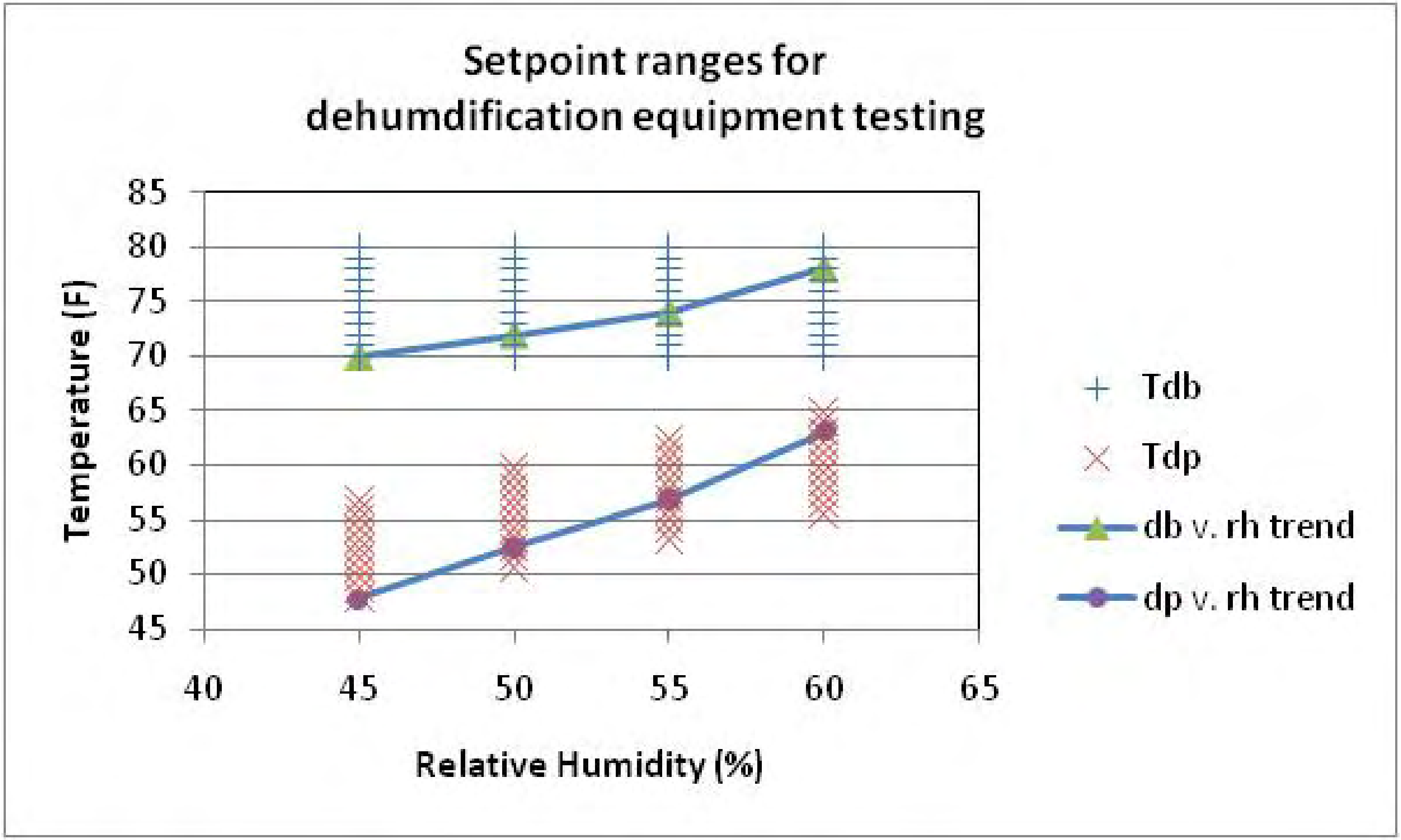
Notes: (1) The specified test condition only applies if the unit rejects condensate to the outdoor coil.

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 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