FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

Summer Infiltration/Ventilation Test Results from the FRTF Laboratory

Building America
Technical Review Meeting

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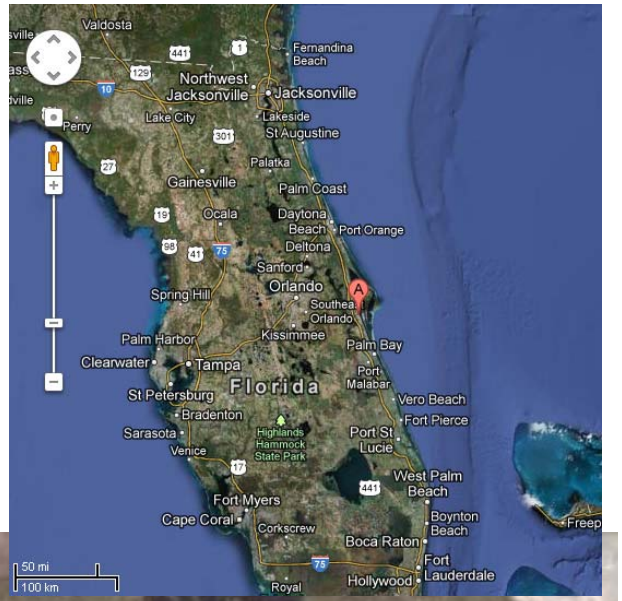
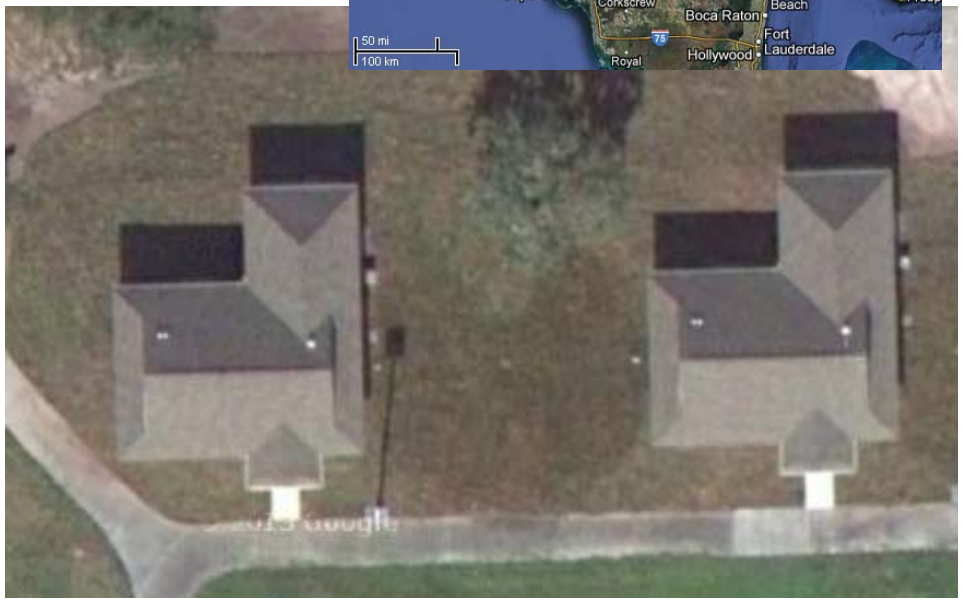
Study Objectives

Empirical data on impacts of natural air infiltration /ventilation on energy, relative humidity in a hot-humid climate

- Produce high-quality empirical data suitable for energy simulation verification.



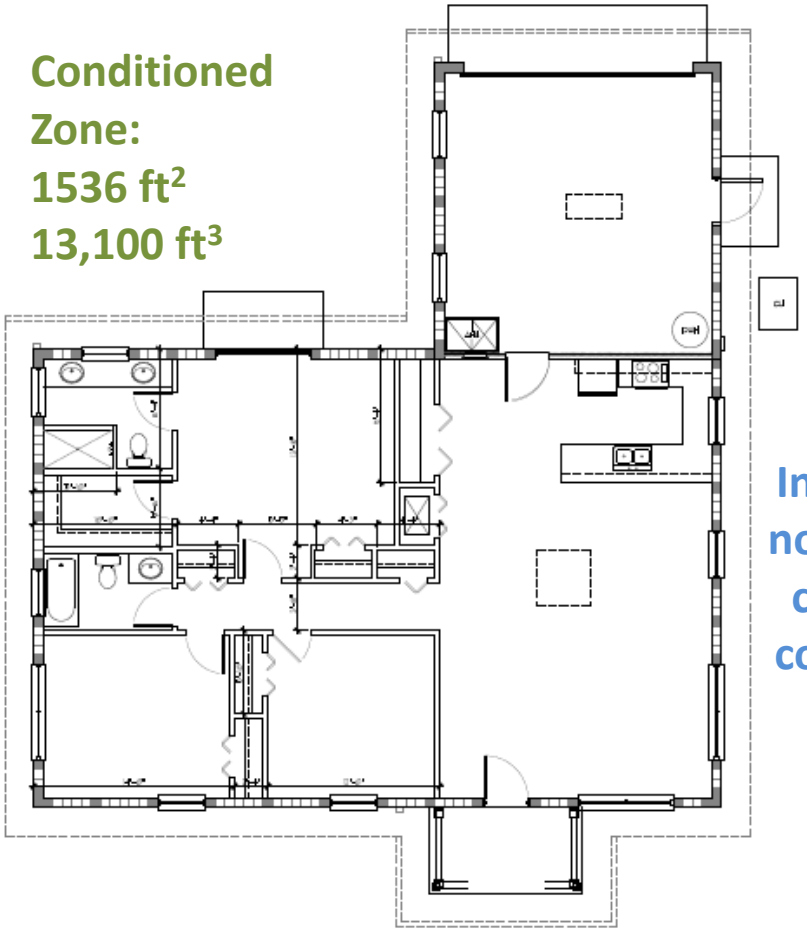


- Two identical side-by-side 1536 ft^2, concrete block, slab-on-grade residences
- Single pane fenestration, evenly distributed
- No concrete block wall insulation
- R-19 ceiling insulation (current code minimum)
- SEER-13 w/strip heat HVAC systems

Caveats

- Lab homes have little moisture capacitance
  - No interior walls
  - No carpeting and no furnishings
- Lab homes operation is atypical
  - No exterior door openings
  - No kitchen or bathroom ventilation fan operation
- Internal moisture generation the largest source of humidity control problem?

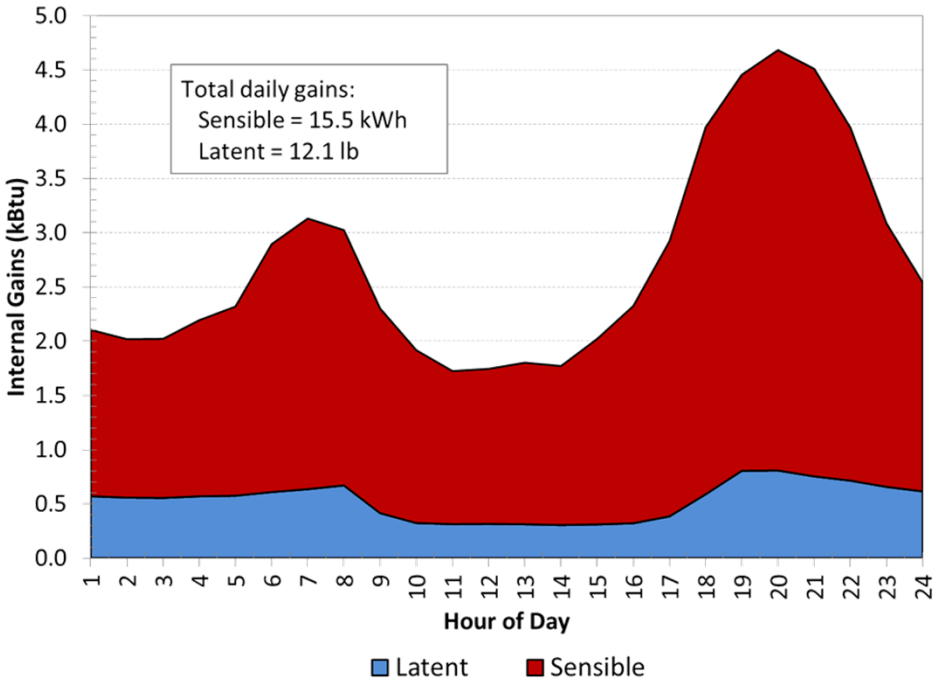
Conditioned Zone:
1536 ft^2
13,100 ft^3



Interior walls not present in current test configuration

Occupancy Gains

- Automated (computer controlled) heat and moisture gains scheduled by time of day
- Based on RESNET lighting, appliance and miscellaneous energy usage amendment
- Imposed using BA benchmark hourly schedules with slight modifications
- Includes lighting and appliance gains and occupant gains
  - Sensible gains ≈ 15.5 kWh/day
  - Latent gains ≈ 12.1 lb H_2O/day



Infiltration Sites

Ceiling-side port

Attic-side port

Metal stand-off shims
For vertical plane leaks

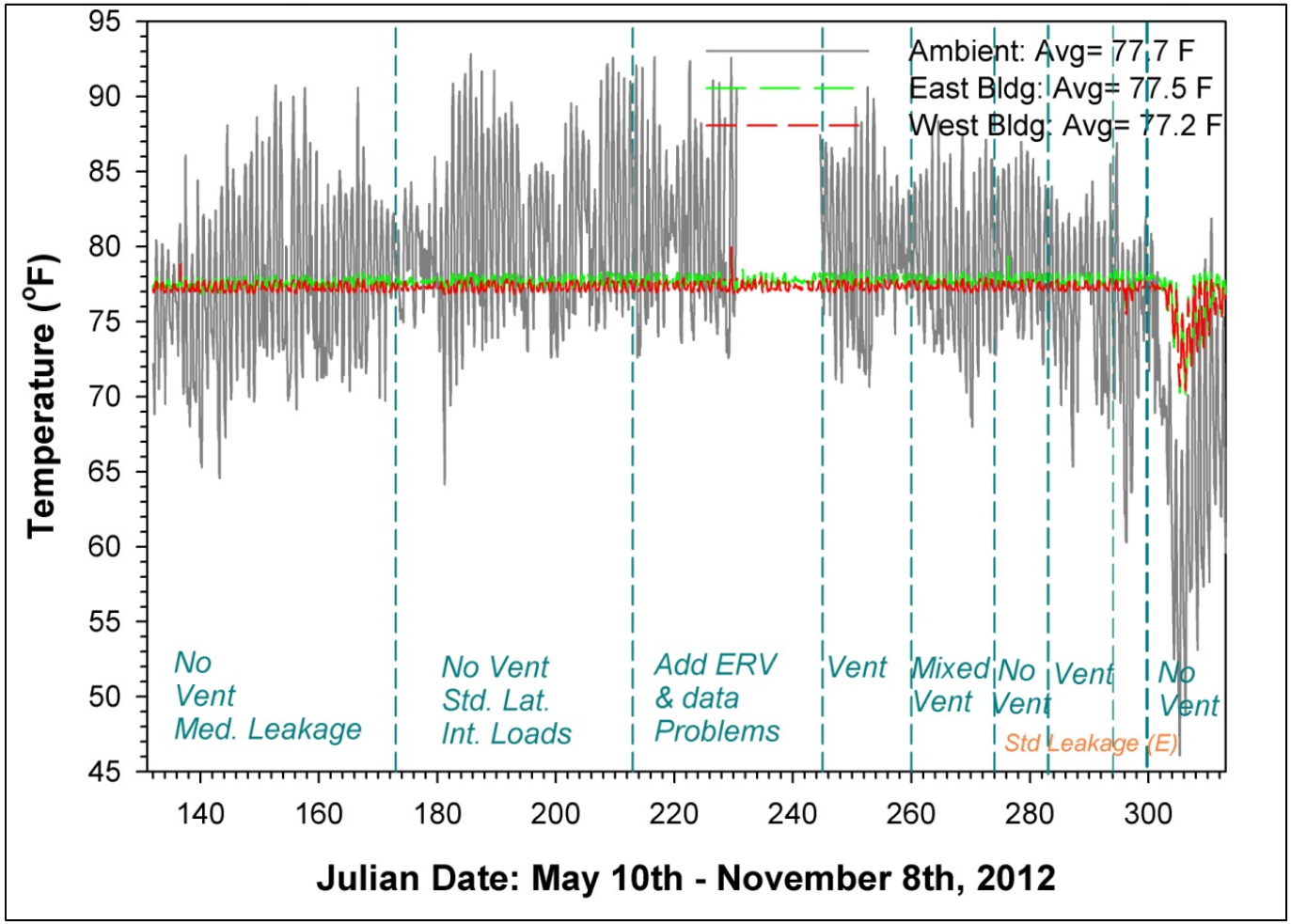
Enclosure Air Leakage Set-Up

- Both home enclosures air-tightened to achieve 2.5 ach50; West building left tight
- Air distribution systems in both homes tightened to achieve 20 cfm25 (Qn=0.013). Very tight.
- Leaky home configured with 4 controllable ceiling leakage sites providing ~70% of leakage area ~9 ach50
- Remaining 30% of leakage area in leaky home achieved w/ metal shims on windows.
- Experiments staged every two weeks
- Began with lower internal moisture rate (6 lbs/day)

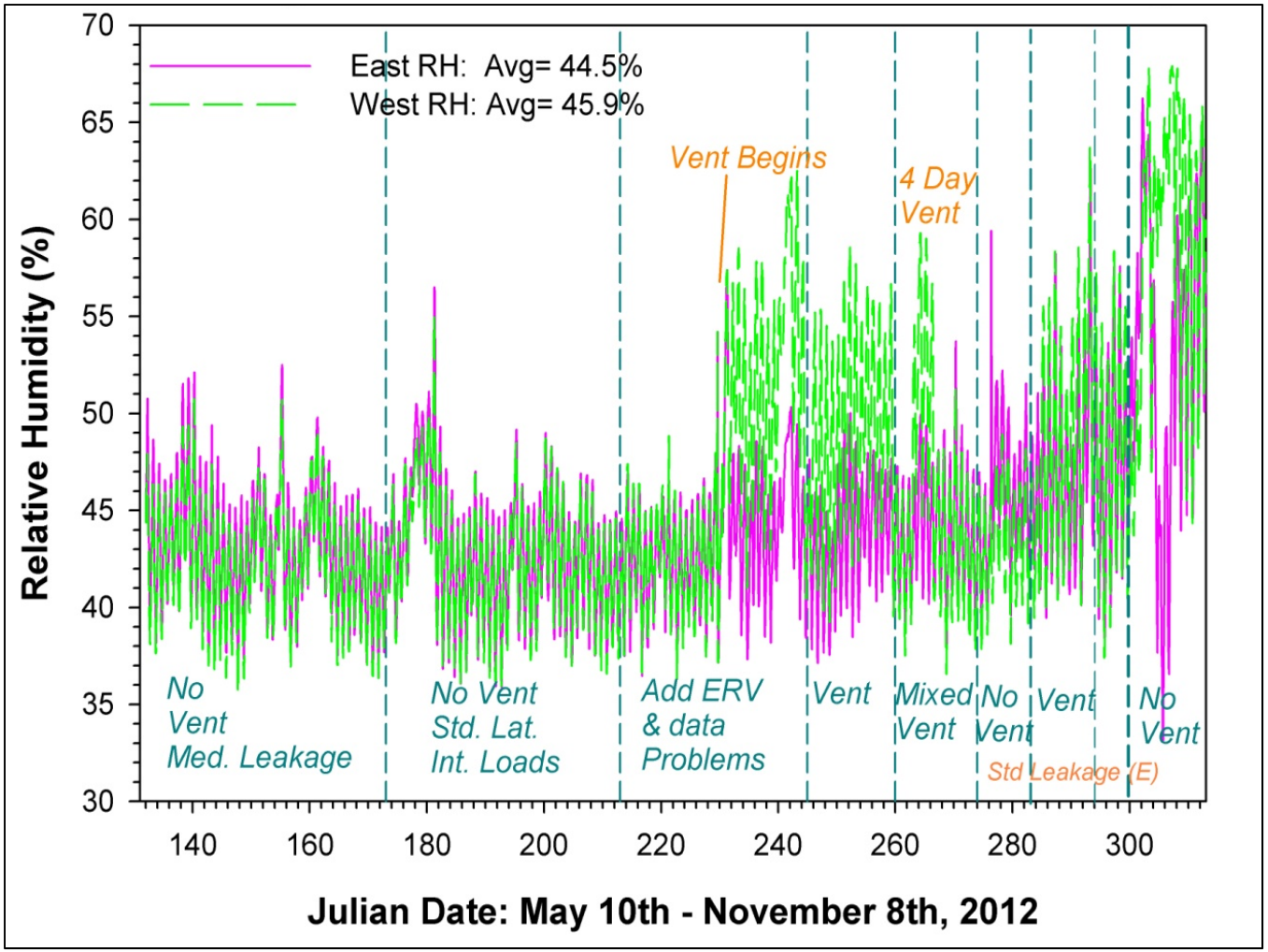
Enclosure Leakage Test Results

Leakage Parameter:	Leaky Home	Tight Home
cfm50	1926	520
ach50	9.17	2.48
C	182.3	36.0
n	0.603	0.683
R-sq	0.99805	0.99983
ELA (in^2)	118.9	26.3
SLA	0.000538	0.000119

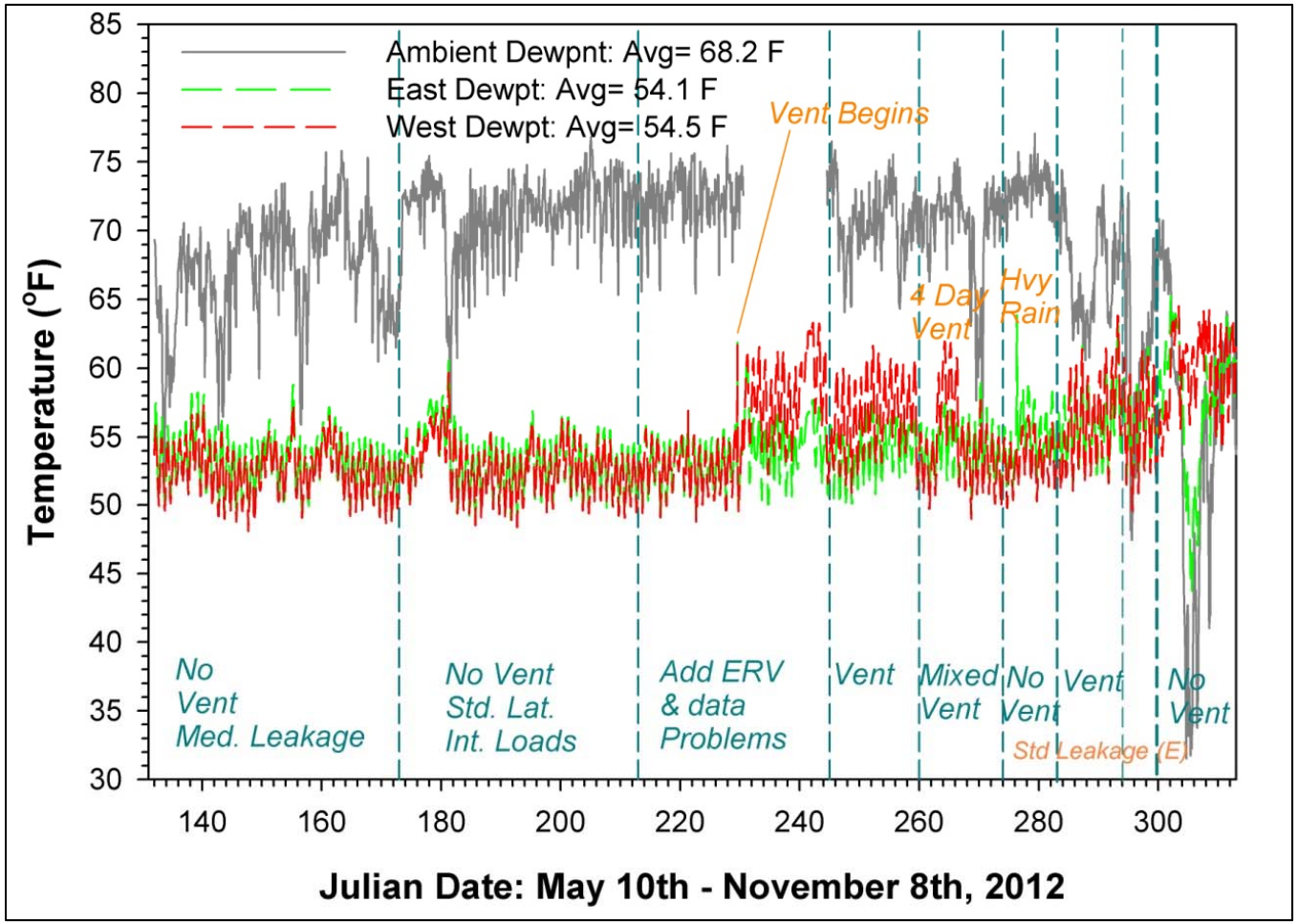
Outdoor ambient air temperature and interior temperature by the interior thermostat in the two test buildings over the entire summer



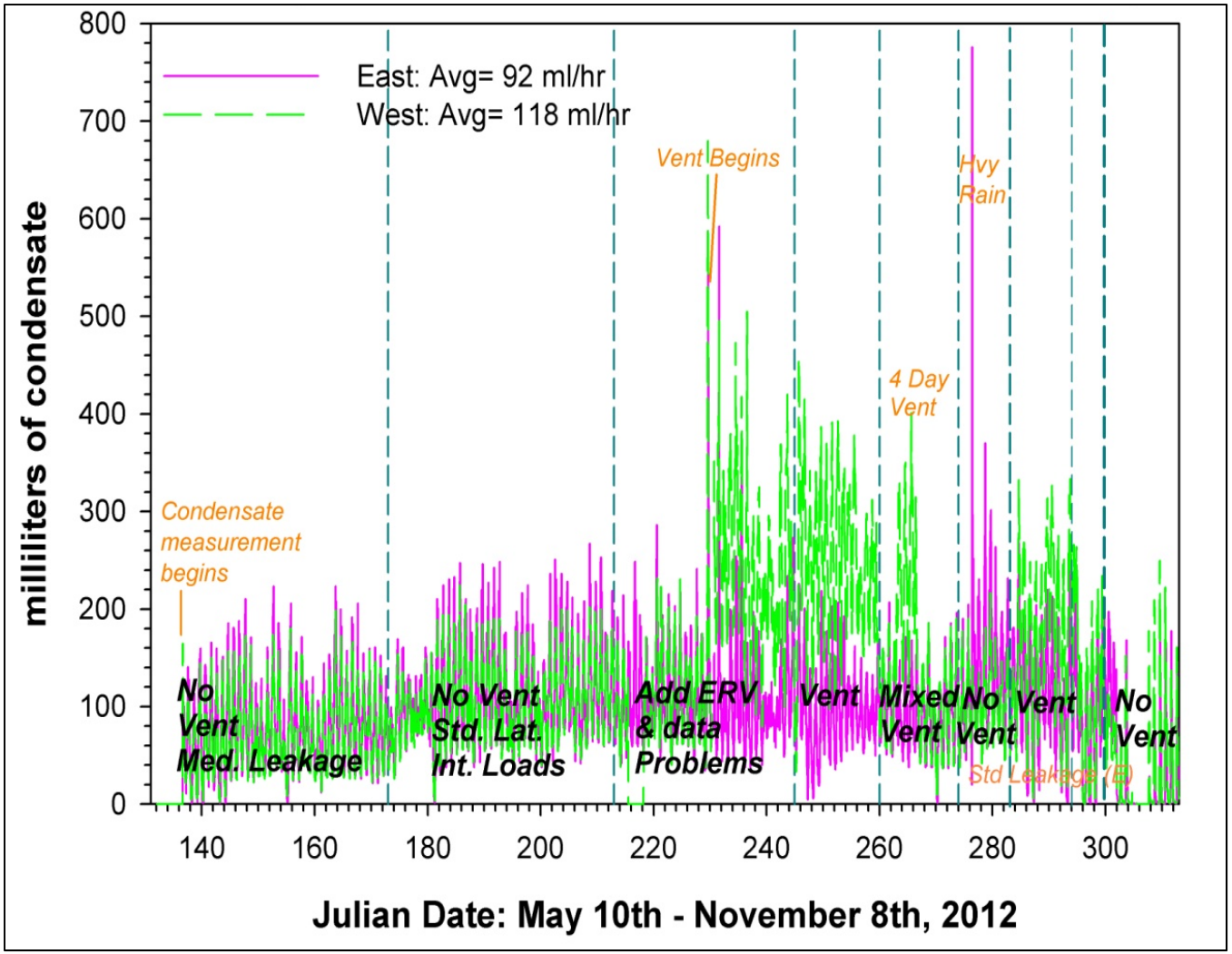
Measured indoor relative humidity by the thermostat in the two test buildings over the entire summer



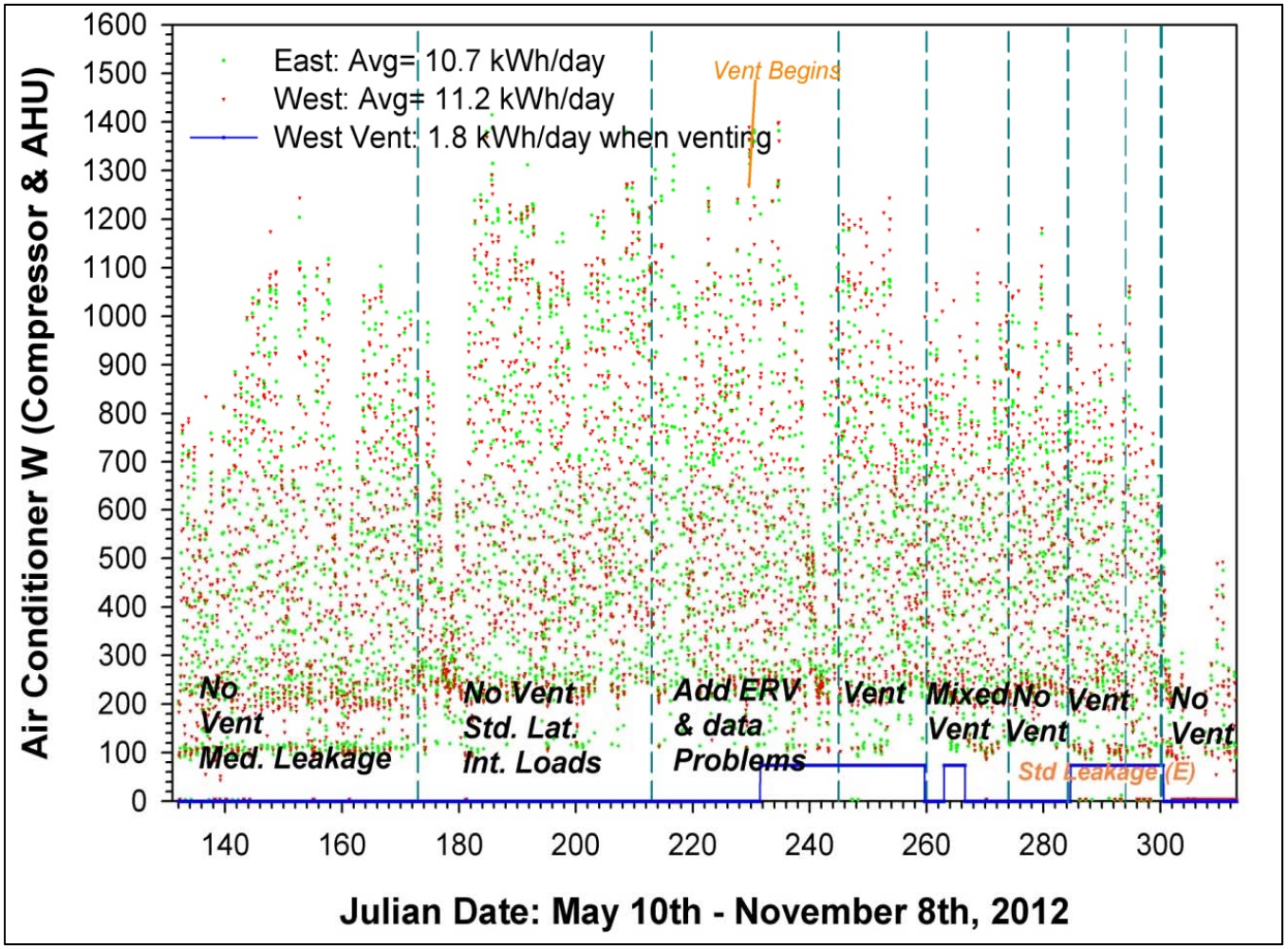
Measured indoor and outdoor dewpoint temperatures in the two test buildings over the entire summer



Measured air conditioner condensate in the two test buildings over the entire summer



Measured air conditioner and ventilation system power in the two test buildings over the entire summer



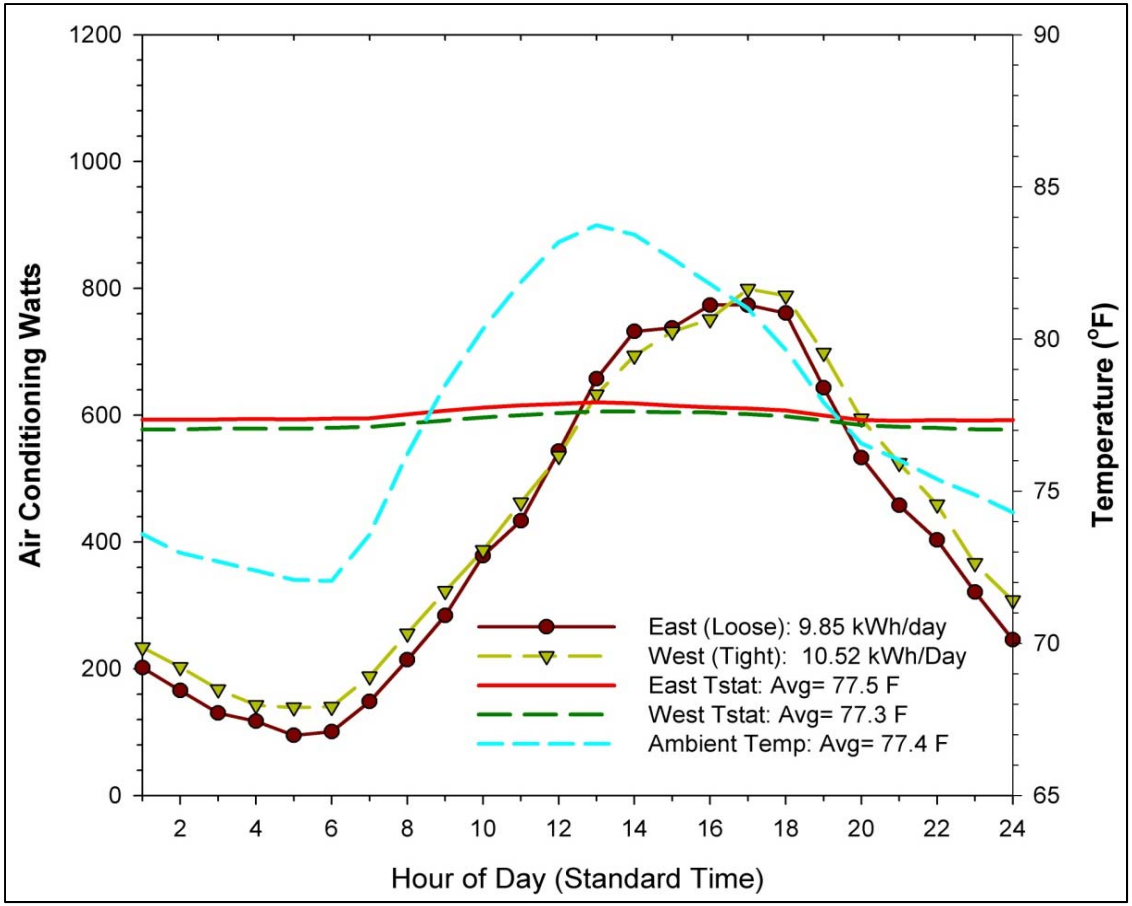
Overall observations

- Humidity: 38-51% prior to mechanical ventilation
- No indication of large impact of building tightness on interior relative humidity
- No indication of large impact of doubled internal moisture rate
  - cooling system condensate rate is much higher
- With mechanical ventilation, RH is noticeably increased to 55-60% RH range
- Much higher internal moisture levels as cooling system run-time falls in late autumn

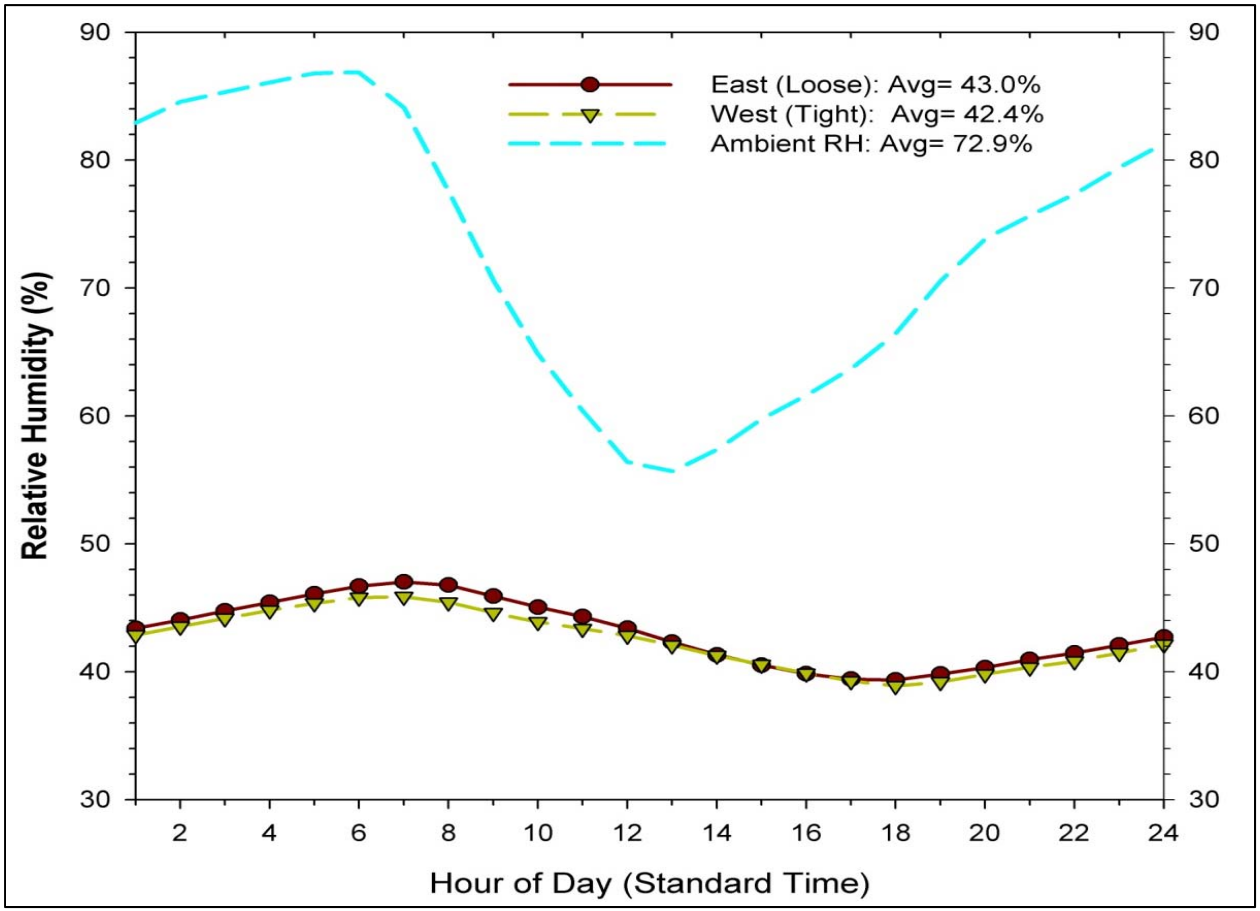
May 10th – June 21st, 2012 (Natural Air Infiltration, Low Moisture Generation)

	East	West	Δ	%
Thermostat Temp	77.5°	77.3°	-0.2	-0.4
Relative H	43.0%	42.4%	-0.6	-1.4
DewPoint (°F)	53.3°	52.6°	-0.7	-1.3
Condensate (L)	1.70L	1.56L	0.14	-8.2
AC Power (kWh/day)	9.85 kW	10.50	+0.67	+6.8
	Avg.	**Min**	**Max**	
Amb T(°F)	77.4°	64.6°	90.7°	
Amb RH (%)	72.9%	36.6%	95.0%	
Amb DewPoint (°F)	67.3°	52.0°	75.8°	

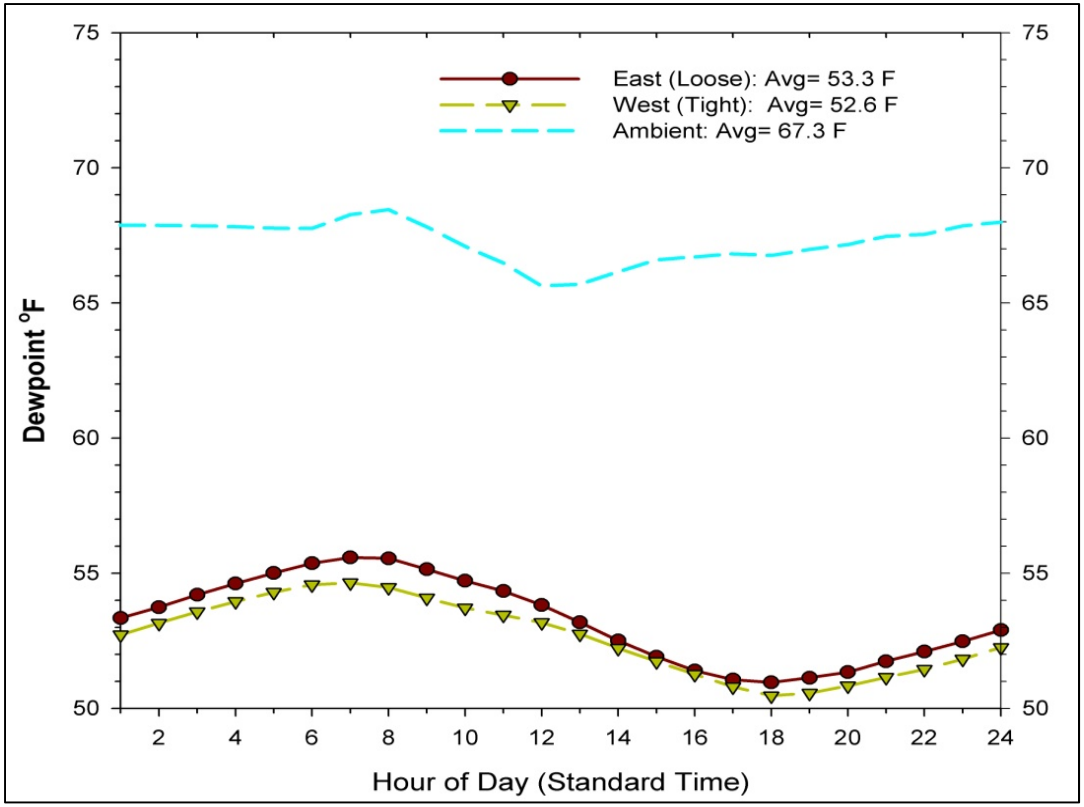
AC energy use May 10th – June 21st, 2012: Infiltration tests, no mechanical ventilation, low internal moisture loading



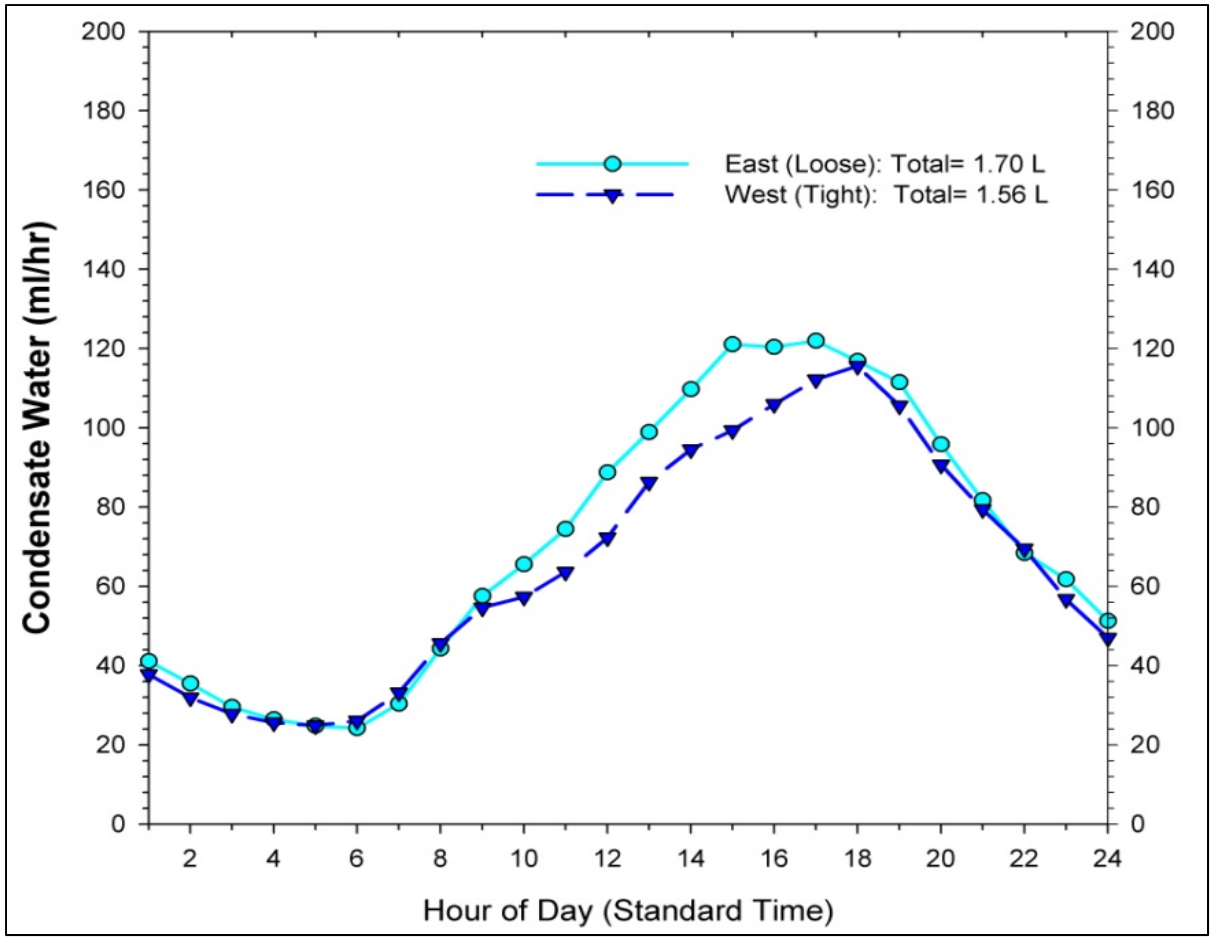
Comparative relative humidity May 10th – June 21st, 2012: Infiltration tests no mechanical ventilation, low internal moisture loading



Comparative dewpoint temperatures May 10th – June 21st, 2012: Infiltration tests no mechanical ventilation



Comparative condensate removal May 10th – June 21st, 2012: Infiltration tests no mechanical ventilation, low internal moisture loading



Change in Moisture Generation Rate

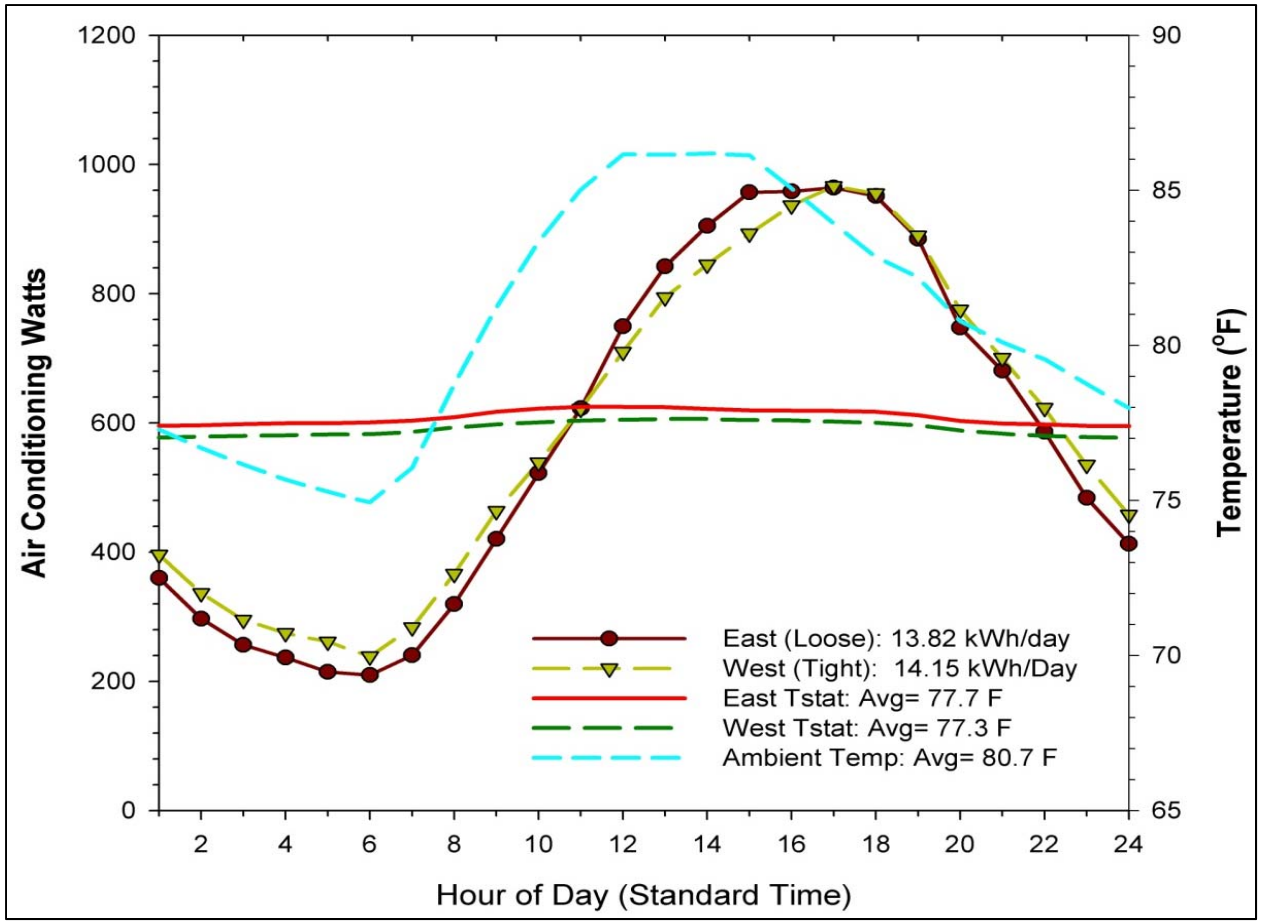
- Problems had been experienced in the tighter building with moisture damage in winter of 2011; internal moisture rate had been cut to from 12 lb/day to 6 lbs/day.
- Likely half the standard moisture release rate
- Immediately following the May – June test period, moisture level was increased back to std
  - Internal moisture generation was increased from 6.05 lb/day to 12.10 lb/day
- Higher rate for the balance of the summer

June 23rd – July 31st, 2012 (Natural Air Infiltration, Standard Moisture Generation)

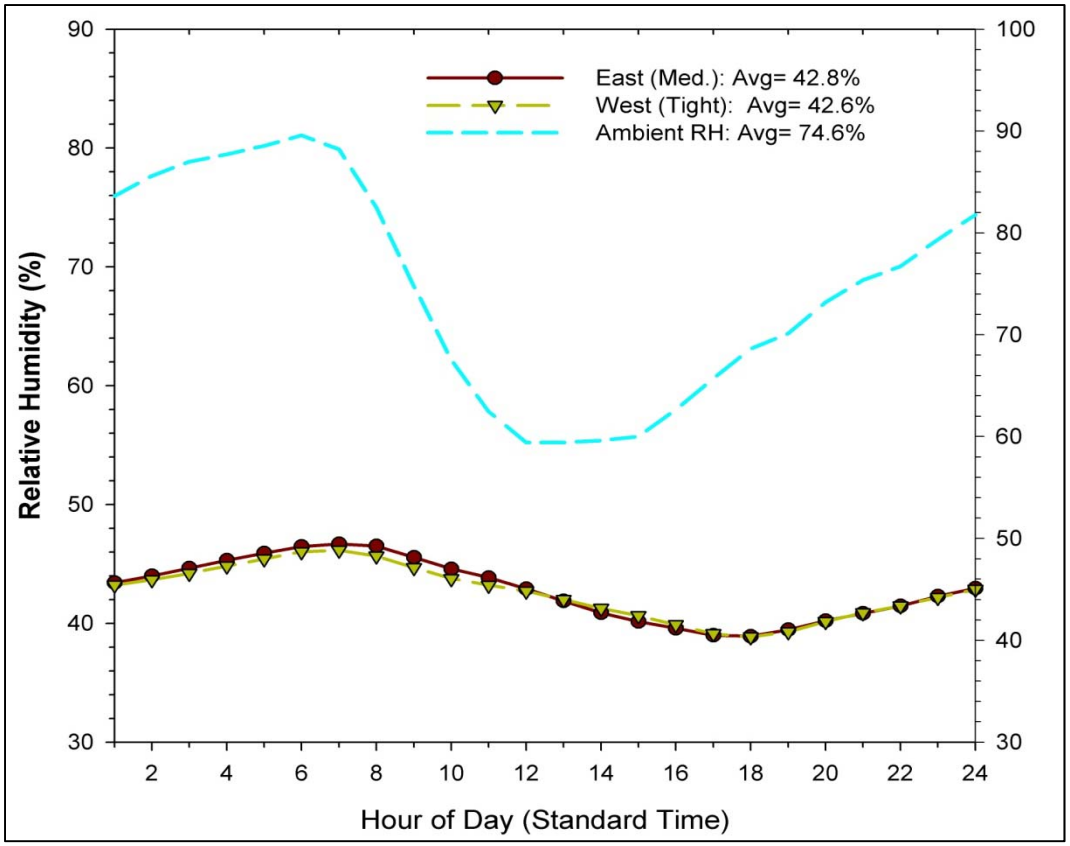
	East	West	Δ	%
Thermostat Temp	77.7°	77.3°	-0.4	-0.5
Relative H	42.8%	42.6%	-0.2	-0.4
Dewpoint (°F)	53.2°	52.7°	-0.5	-0.9
Condensate (L)	2.65L	2.59L	-0.06	-2.2
AC Power (kWh/day)	13.82 kWh	14.15	+0.33	+2.4
	Avg.	**Min**	**Max**	
Amb T (°F)	80.7°	64.1°	92.8°	
Amb RH (%)	74.6%	36.7%	94.2%	
Amb Dewpoint (°F)	71.2°	56.1°	76.8°	

While interior RH did not increase significantly; condensate and AC power did go up with increased moisture loading….

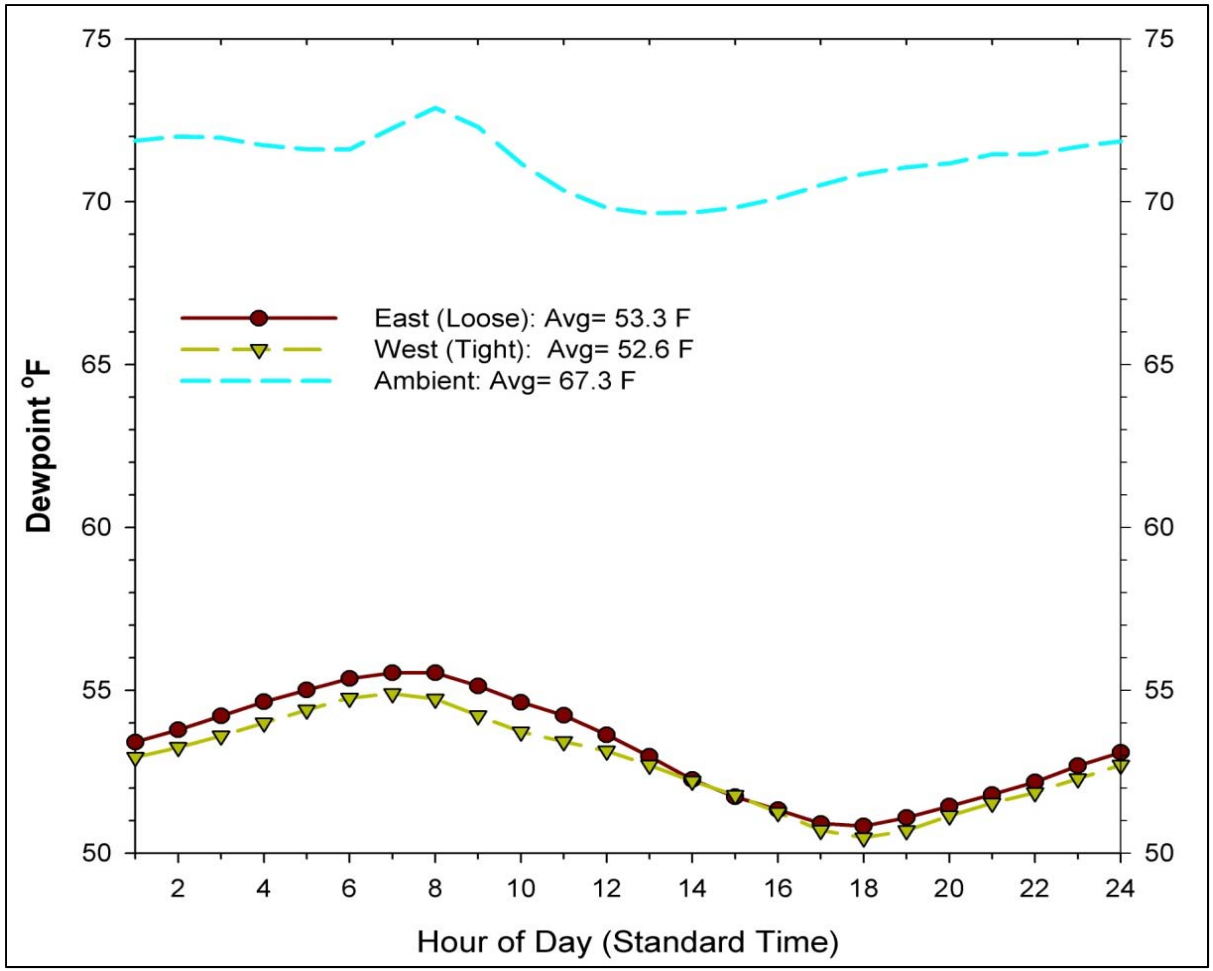
AC energy use June 23rd – July 31st, 2012: Infiltration test no mechanical ventilation, standard internal moisture loading



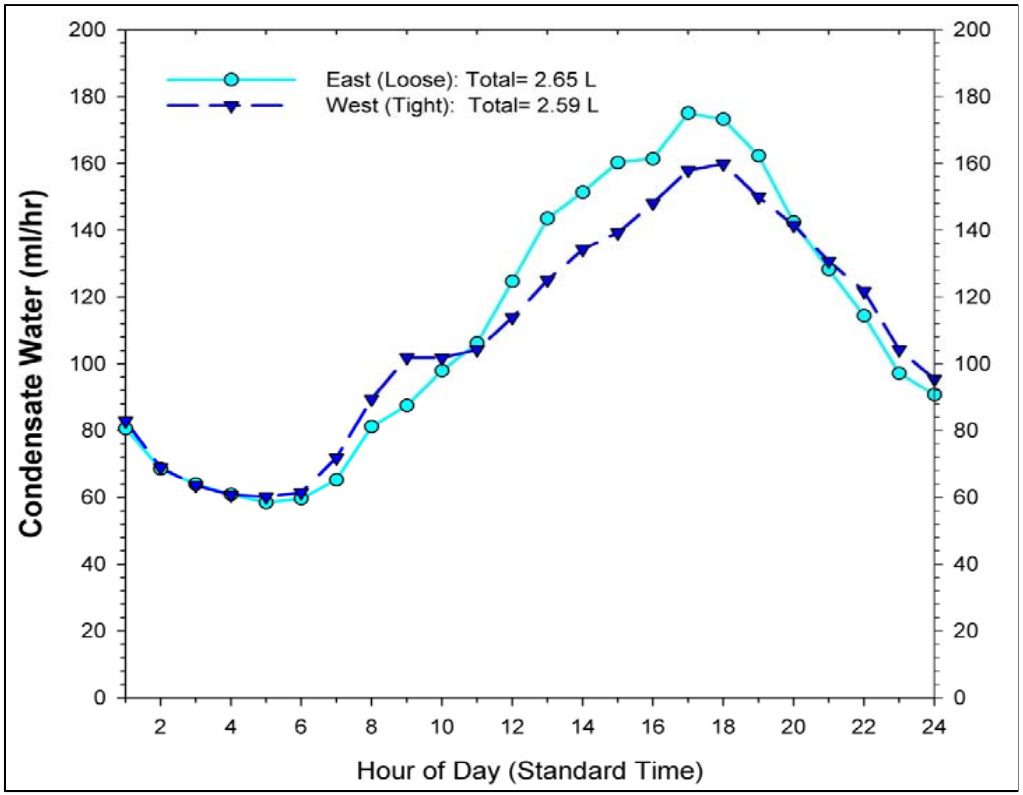
Comparative condensate removal June 23rd – July 31st, 2012: Infiltration tests no mechanical ventilation, standard internal moisture loading



Comparative dewpoint temperatures June 23rd – July 31st, 2012: Infiltration tests no mechanical ventilation, standard internal moisture loading



Comparative condensate June 23rd – July 31st, 2012: Infiltration tests no mechanical ventilation, standard internal moisture loading



Supply ventilation installed Aug 2012

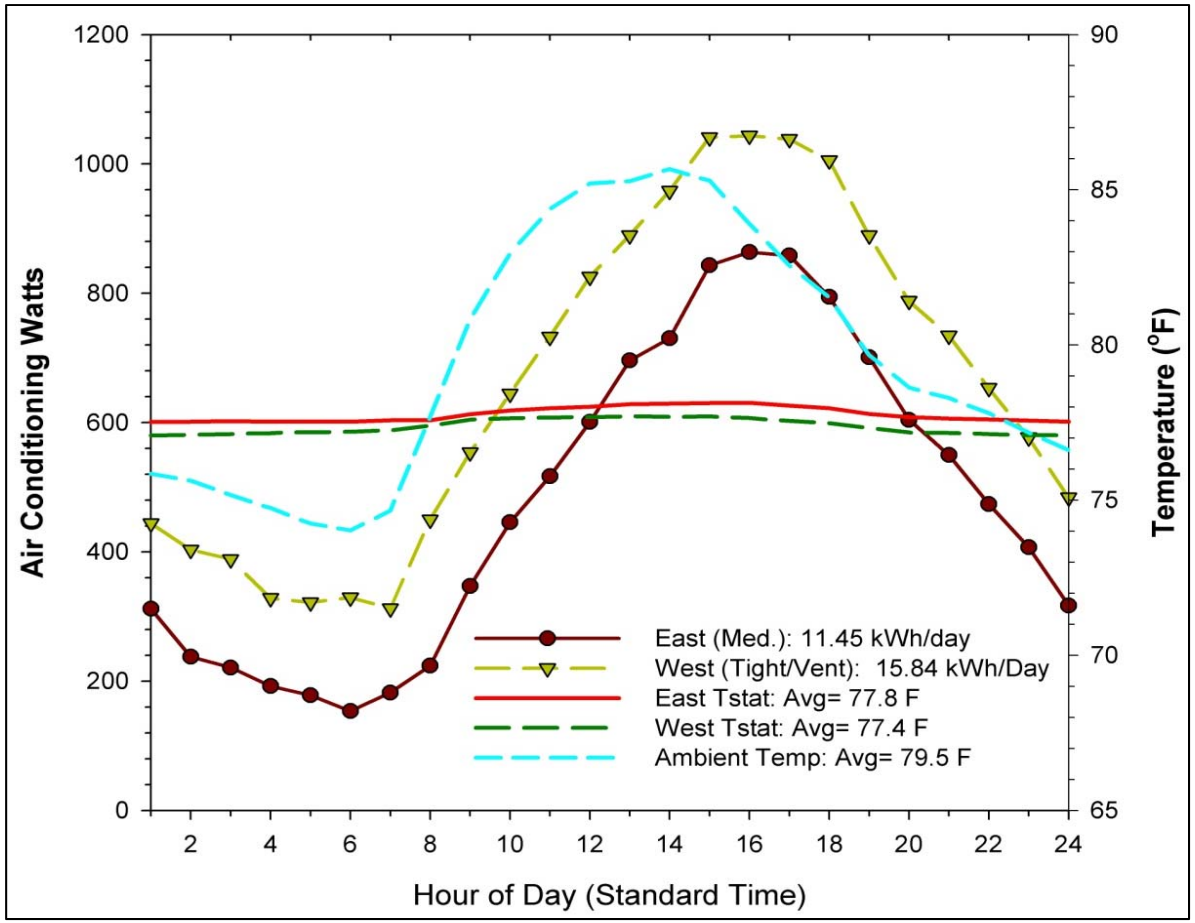
- *Honeywell ER-200*
  - Enthalpy recovery deleted, no heat recovery
  - Supply air to the space of tighter west building
  - 63 cfm continuous added to space
  - 74 Watts continuous
  - 1.77 kWh/day
  - Would meet ASHRAE Standard 62.2-2013
  - ~75 cfm of ventilation air including infiltration

Sept. 1st – Sept. 13th, 2012 (West Unit Vented)

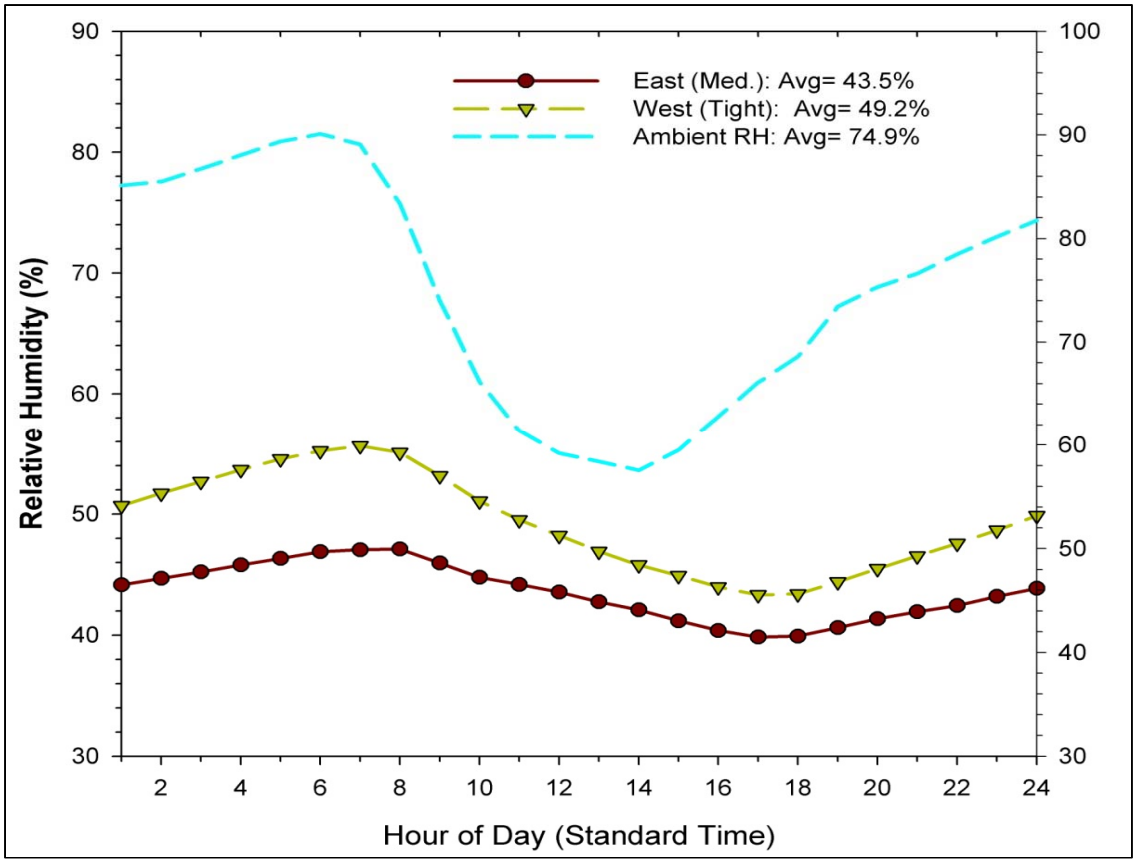
	East	West	Δ	%
Thermostat Temp	77.8°	77.4°	-0.4	-1.8
Relative H	43.5%	49.2%	5.7%	+13.1
Dewpoint (°F)	53.8°	56.8°	+3.0	+5.6
Condensate (L)	2.23L	6.00L	+3.77	+296.1
AC Power (kWh/day)	11.45 kWh	15.84 kWh	+4.39	+38.3
	Avg.	**Min**	**Max**	
Amb T(°F)	79.5°	70.6°	90.6°	
Amb RH (%)	74.9%	47.3%	94.5%	
Amb Dewpoint(°F)	70.3°	64.0°	75.6°	

With mechanical ventilation: RH significantly increased as well as total AC power condensate rate nearly tripled

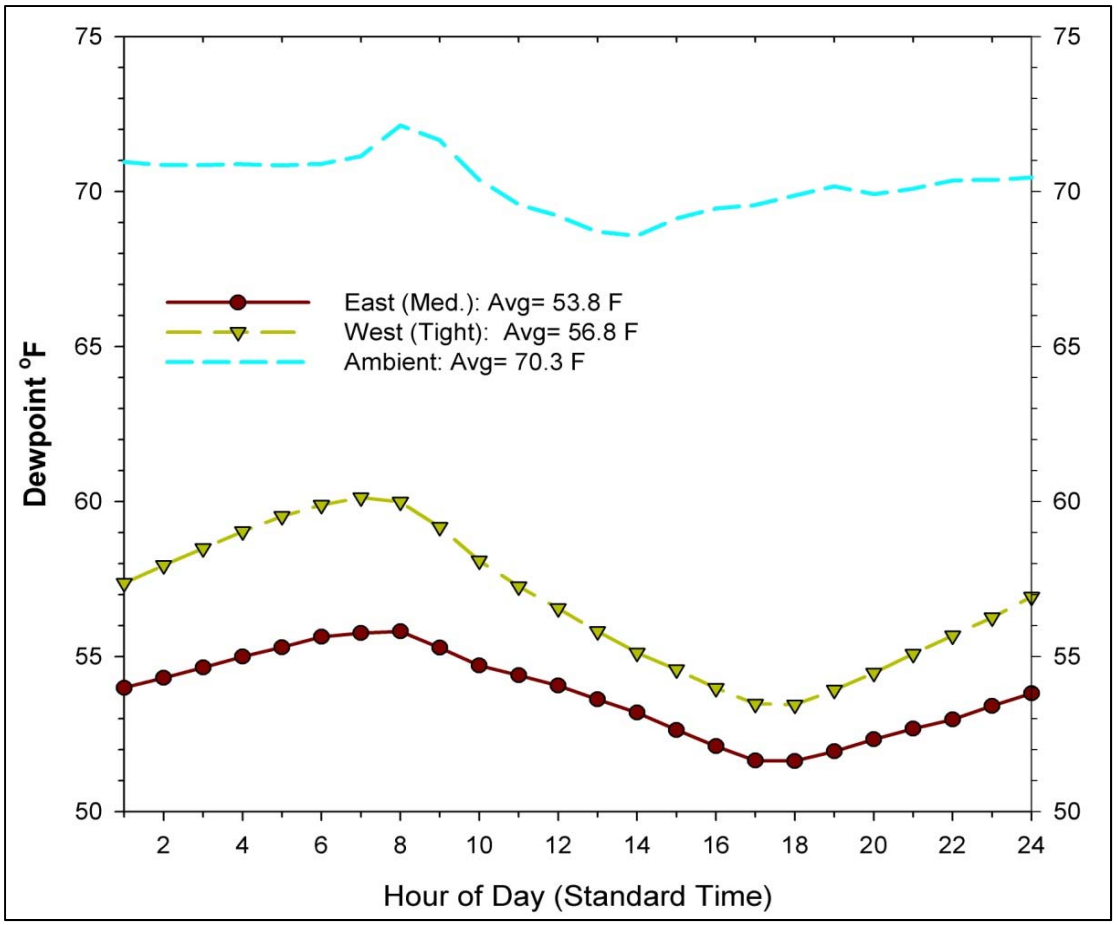
AC energy use September 1st – 13th, 2012: Infiltration tests mechanical ventilation (west), standard internal moisture loading



Comparative relative humidity September 1st – 13th, 2012: Infiltration tests mechanical ventilation (west), standard internal moisture loading

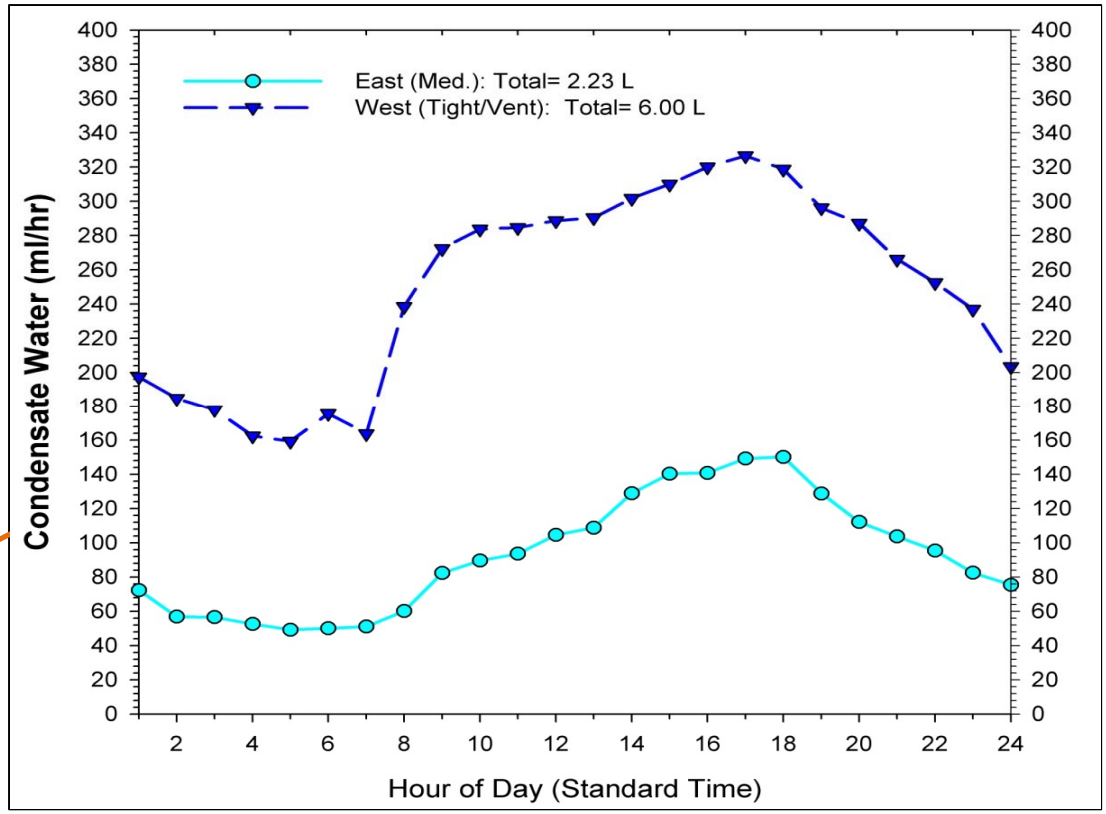


Comparative dewpoint temperatures September 1st – 13th, 2012: Infiltration tests mechanical ventilation, standard internal moisture loading



Comparative condensate removal September 1st – 13th, 2012: Infiltration tests mechanical ventilation (west), standard internal moisture loading

Note condensate is 3x in mechanically Ventilated building

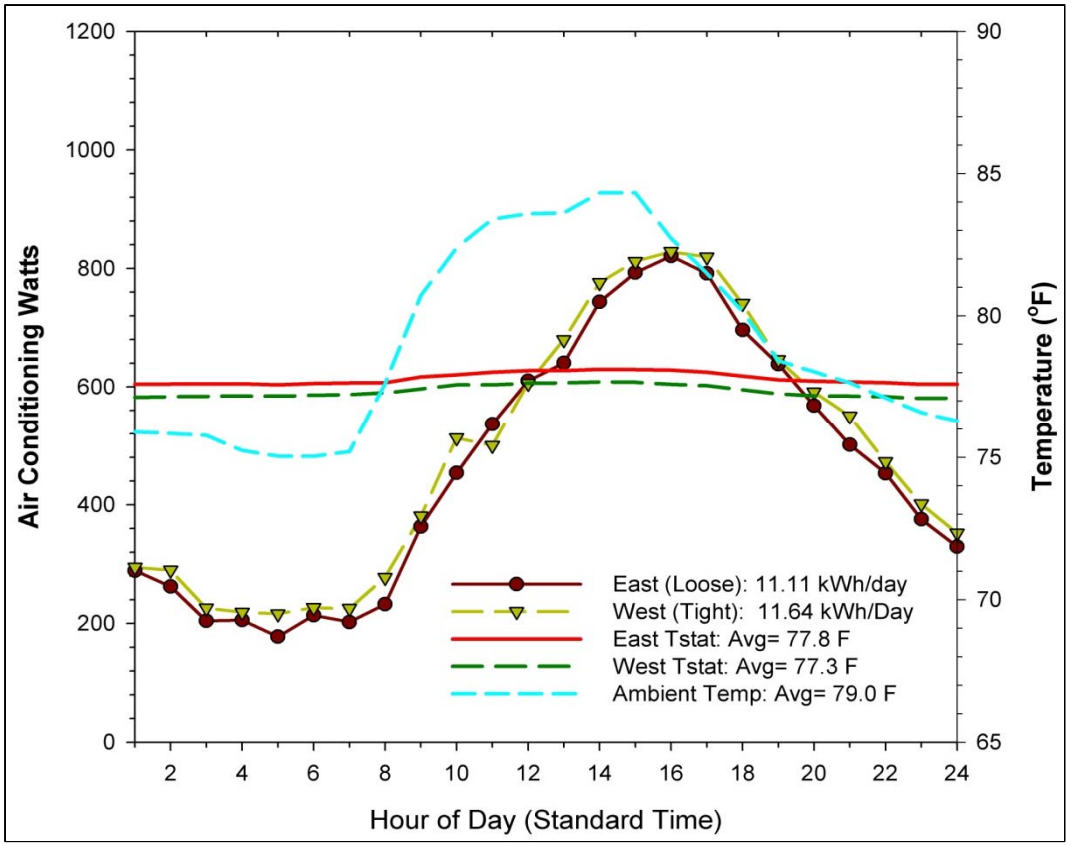


October 2nd – October 8th, 2012 (Unvented, East Building goes Hi Leakage)

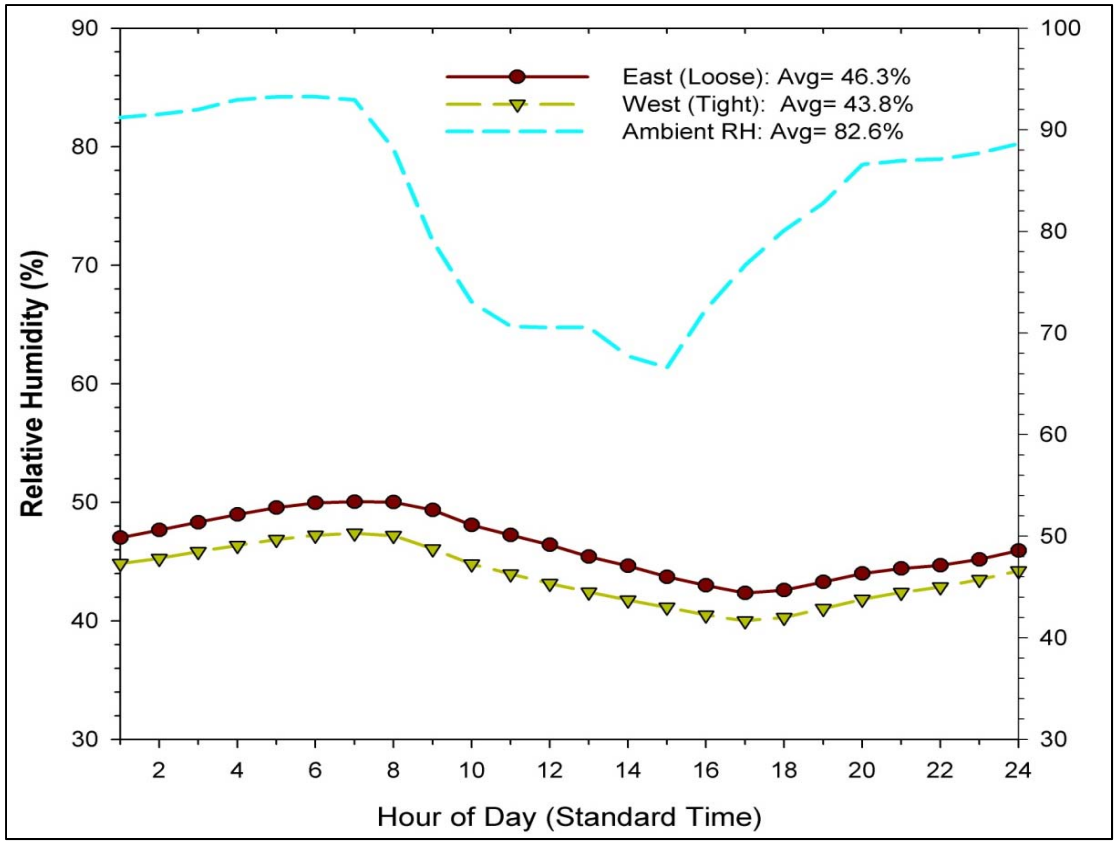
	East	West	Δ	%
Thermostat Temp	77.8°	77.3°	0.5	-0.6
Relative H	46.3%	43.8%	-2.5	-5.3
Dewpoint (°F)	55.5°	53.6°	-1.9	-3.4
Condensate (L)	3.42L	2.52L	-0.90L	-26.3
AC Power (kWh/day)	11.11	11.64	+0.53	+4.7
	Avg.	**Min**	**Max**	
Amb T (°F)	79.0°	72.1°	87.0°	
Amb RH (%)	82.6%	60.1%	95.1%	
Amb Dewpoint (°F)	73.0°	68.3°	77.1°	

With building leakage increased, loose East unit experiences moderate increase in Interior RH & dewpoint, although 25% higher condensate levels. Little effect on AC power.

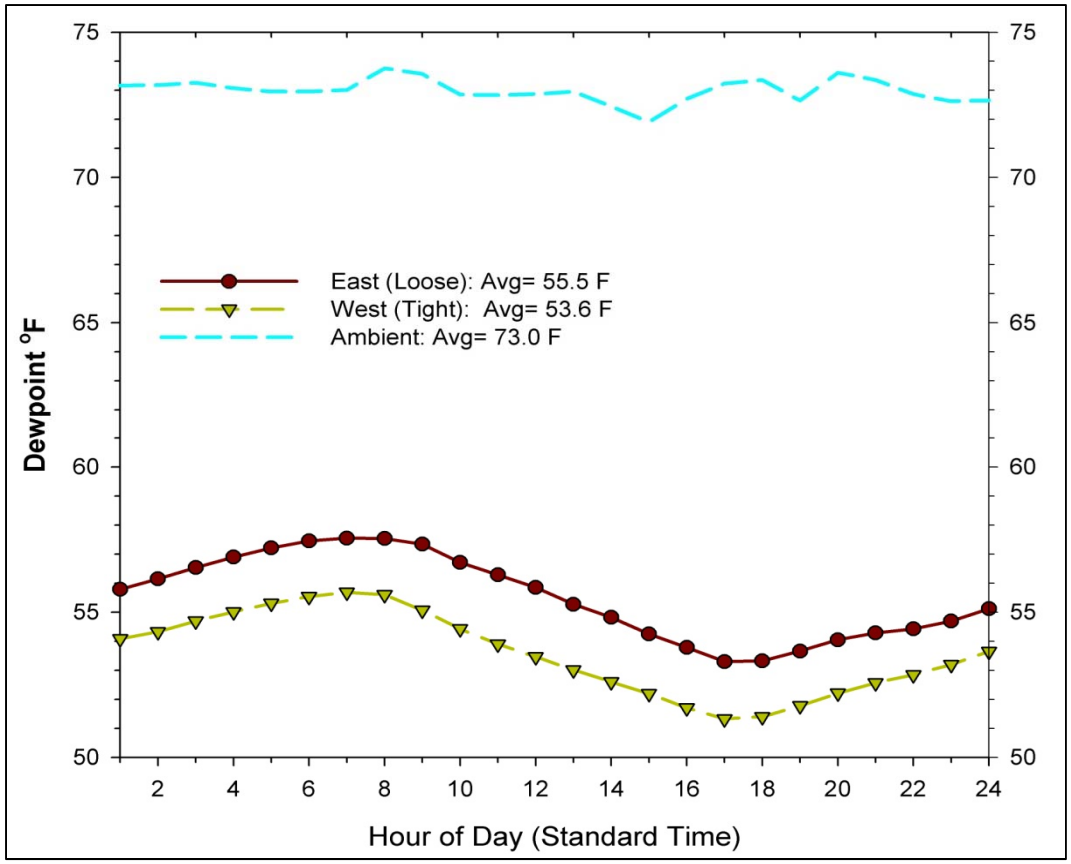
AC energy use October 2nd – October 8th, 2012: Infiltration tests; higher east leakage no mechanical ventilation, standard internal moisture loading



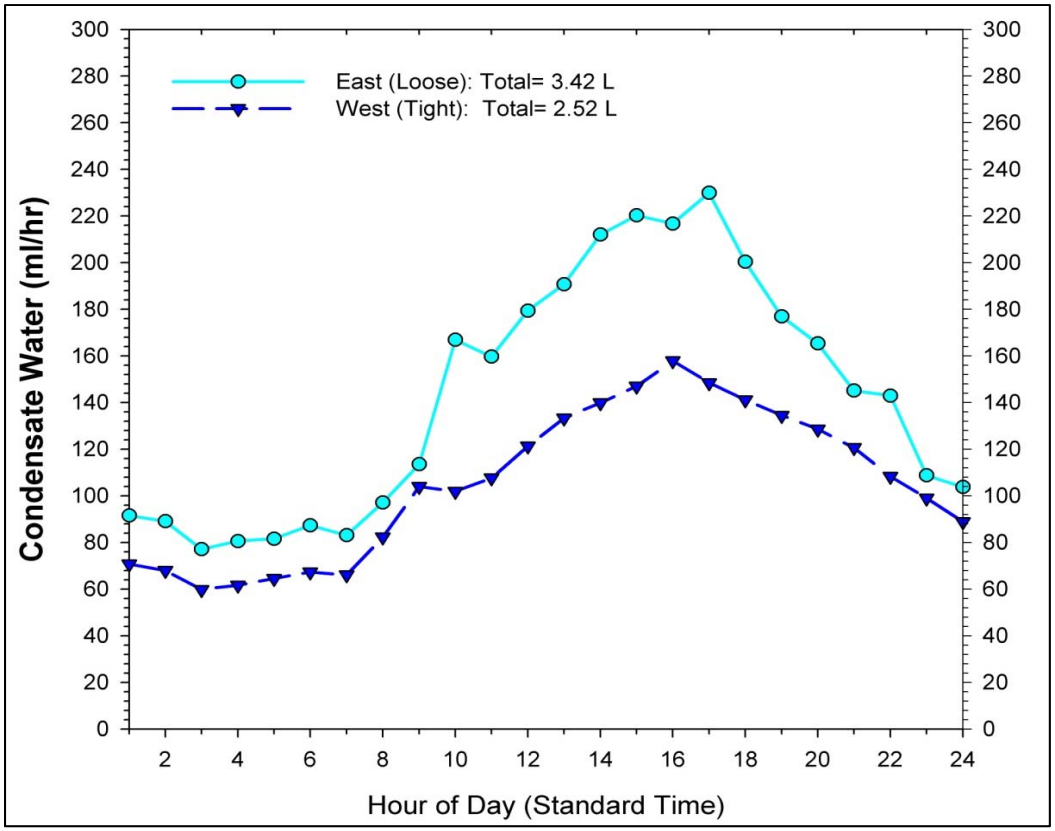
Comparative relative humidity October 2nd – October 8th, 2012: Infiltration tests no mechanical ventilation, standard internal moisture loading



Comparative dewpoint temperatures October 2nd – October 8th, 2012: Infiltration tests no mechanical ventilation, standard internal moisture loading



Comparative condensate removal October 2nd – October 8th, 2012: Infiltration tests no mechanical ventilation, standard internal moisture loading

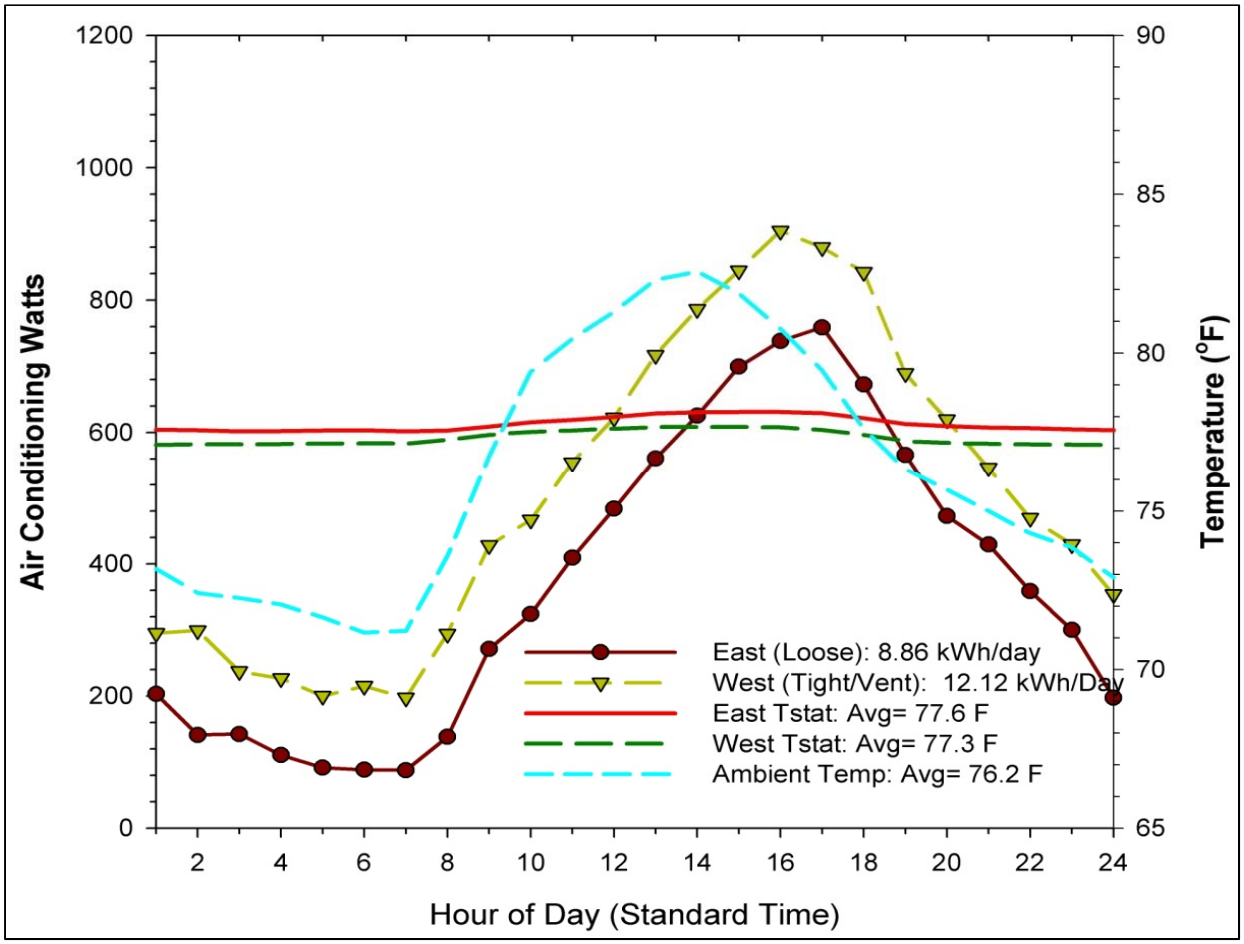


October 10th – October 20th, 2012 (Vented)

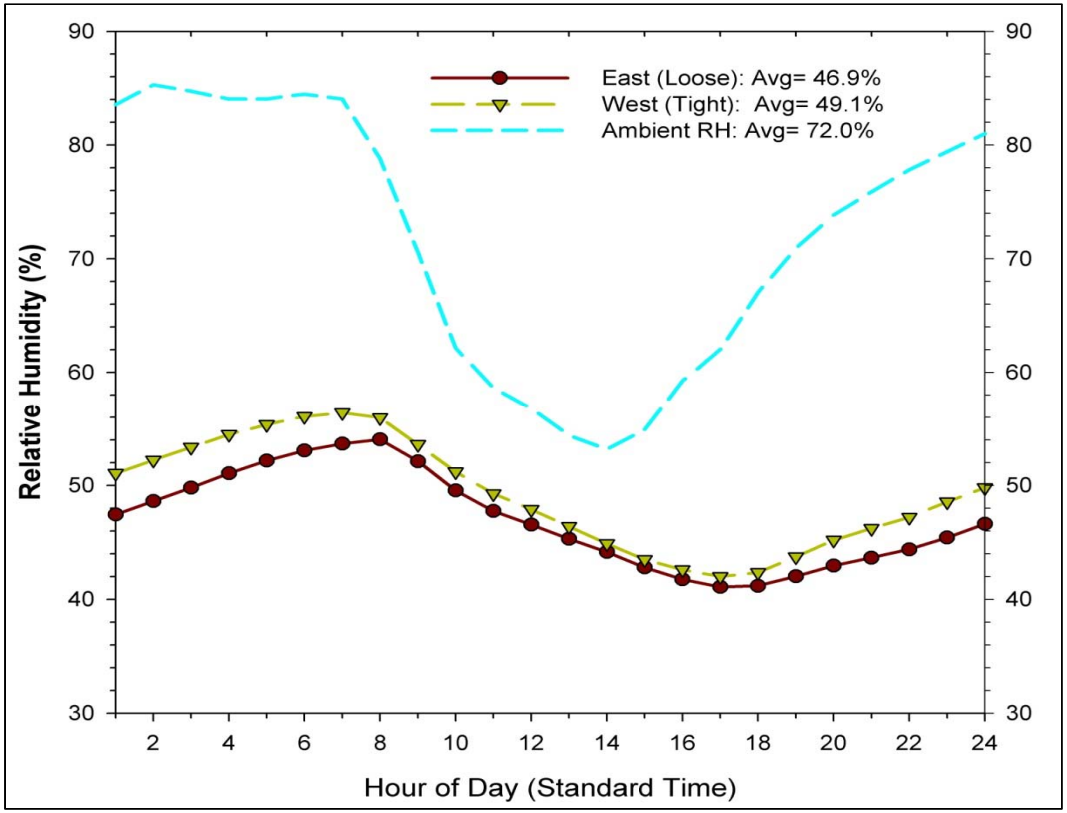
	East	West	Δ	%
Thermostat Temp.	77.6°	77.3°	-0.3	
Relative H	46.9%	49.1%	+2.2	
Dewpoint (°F)	55.7°	56.6°	+1.1	
Condensate (%)	2.57L	4.20L	+1.63	
AC Power (kWh/day)	8.86	12.12	+1.48	
	Avg.	**Min**	**Max**	
Amb T (°F)	76.2°	62.2°	86.9°	
Amb RH (%)	72.0%	31.9%	95.2%	
Amb Dewpoint (°F)	65.7°	47.4°	73.3°	

Vented operation in October shows slight increase in interior RH & dewpoint in vented West unit, although condensate and AC power noticeably increased.

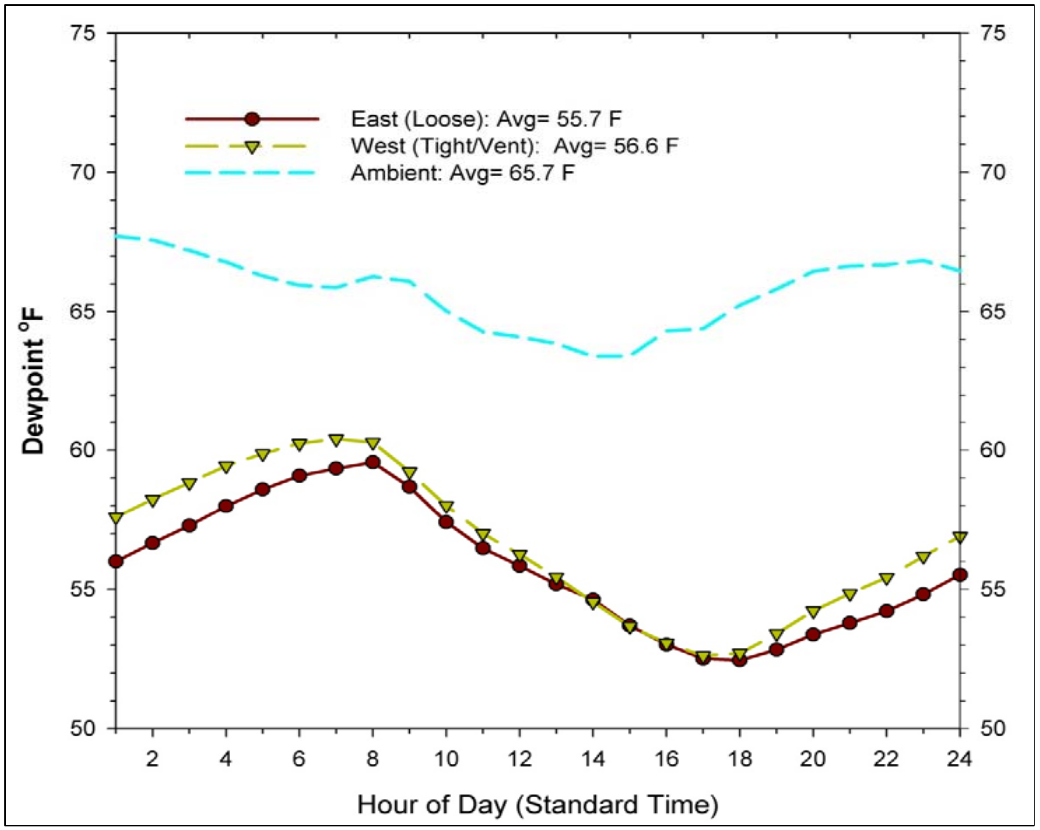
AC energy use October 10th – October 20th, 2012: Infiltration tests east leakage mechanical ventilation: standard internal moisture loading



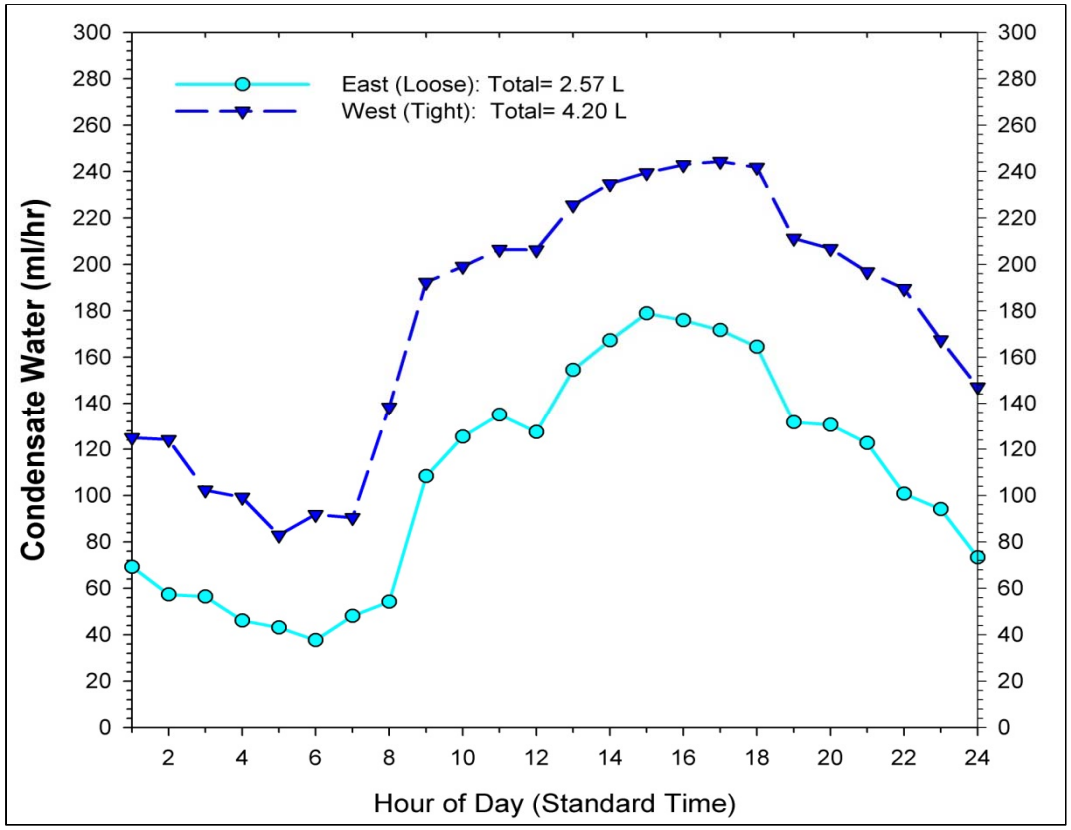
Comparative relative humidity October 10th – October 20th, 2012: Infiltration tests mechanical ventilation, standard internal moisture loading



Comparative dewpoint temperatures October 10th – October 20th, 2012: Infiltration tests mechanical ventilation, standard internal moisture loading



Comparative condensate removal October 10th – October 20th, 2012: Infiltration tests mechanical ventilation, standard internal moisture loading

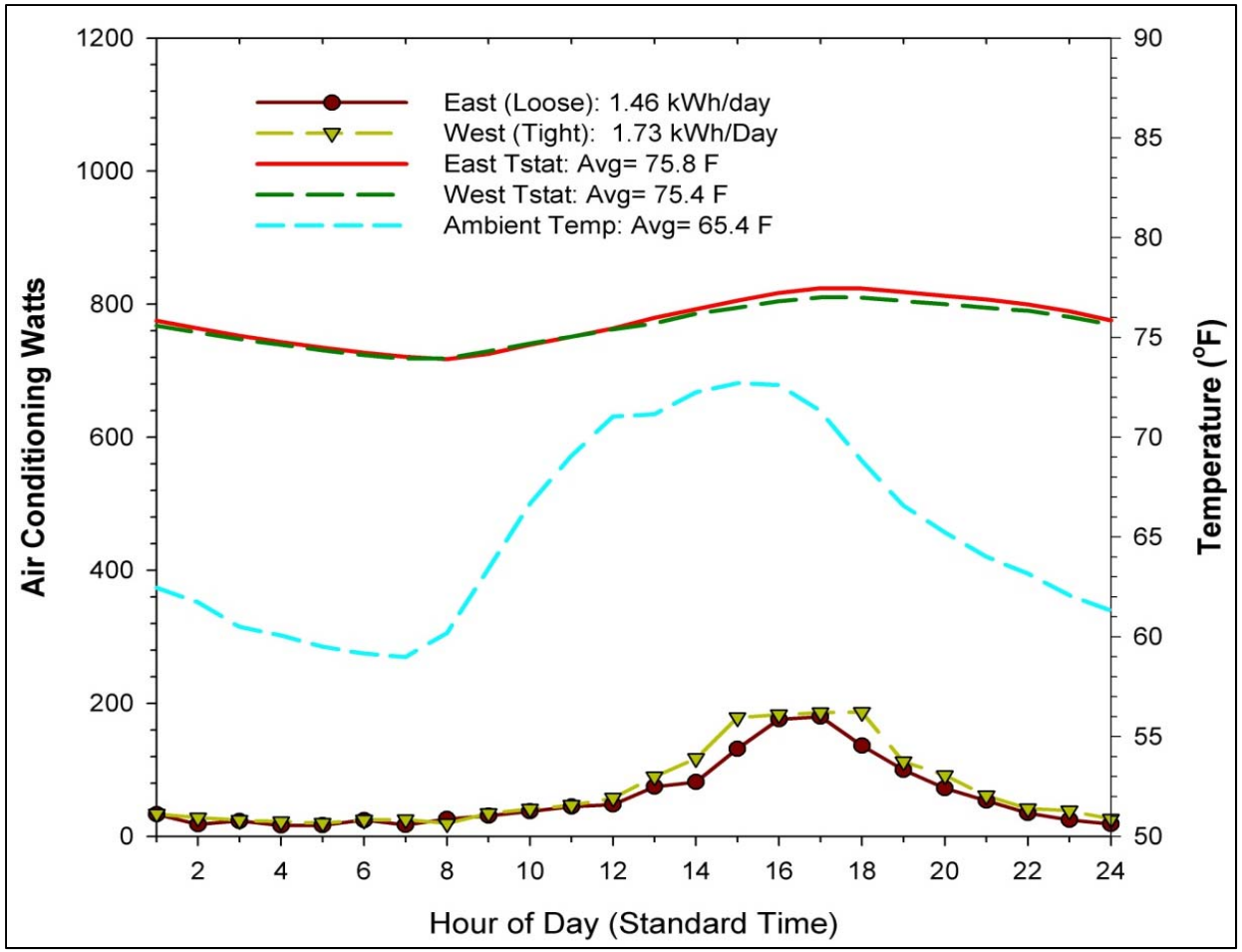


October 25th – November 8th, 2012 (Unvented)

	East	West	Δ	%
Thermostat Temp.	75.8°	75.4°	-0.4	-0.5
Relative H	53.1%	59.0%	+6.9	+11.1
Dewpoint (°F)	57.3°	60.0°	+2.7	+4.7
Condensate (%)	0.66L	0.73	+0.7L	+10.1
AC Power (kWh/day)	1.46	1.73	0.27	+18.5
	Avg.	**Min**	**Max**	
Amb T(°F)	65.4°	46.1°	81.9°	
Amb RH (%)	69.4%	26.7%	95.0%	
Amb Dewpoint (°F)	54.0°	31.5°	70.9°	

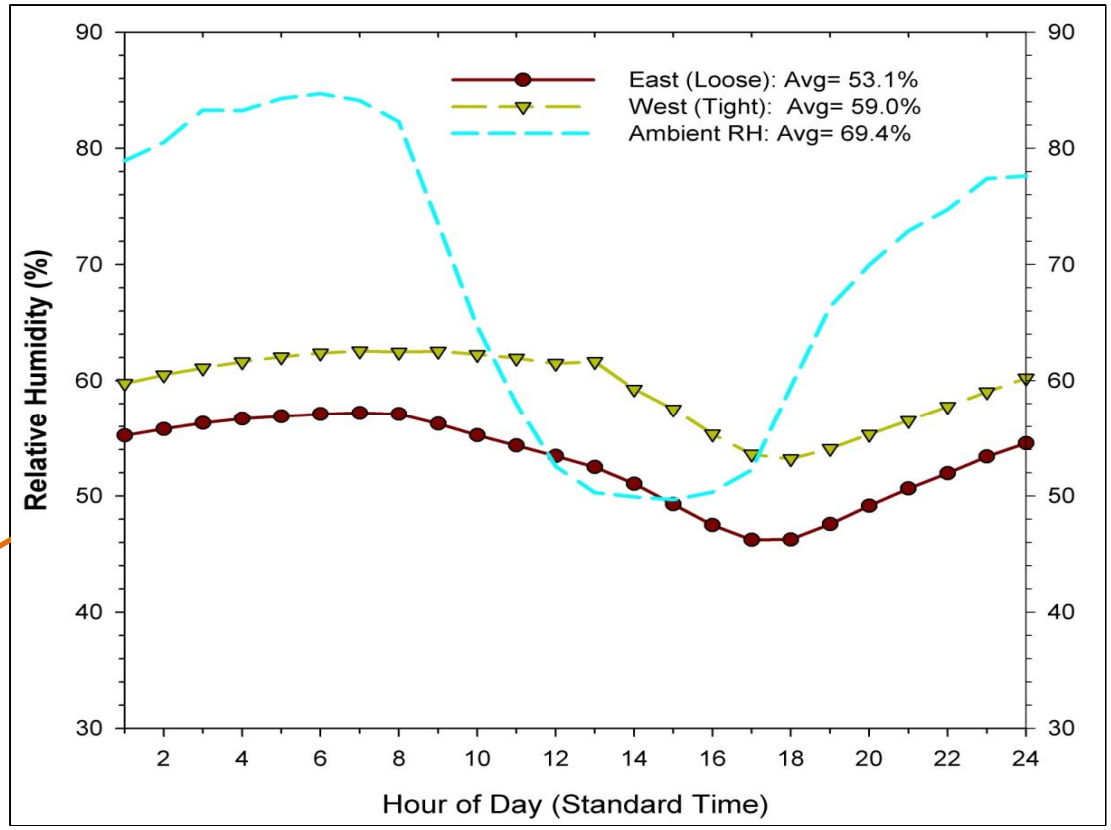
Final unvented test during period when mechanical cooling falling shows tighter west unit experiencing considerably elevated relative humidity and dewpoints, reflecting much lower rate of moisture removal by AC equipment.

AC energy use October 25th – November 8th, 2012: Infiltration tests, higher east leakage no mechanical ventilation, standard internal moisture loading

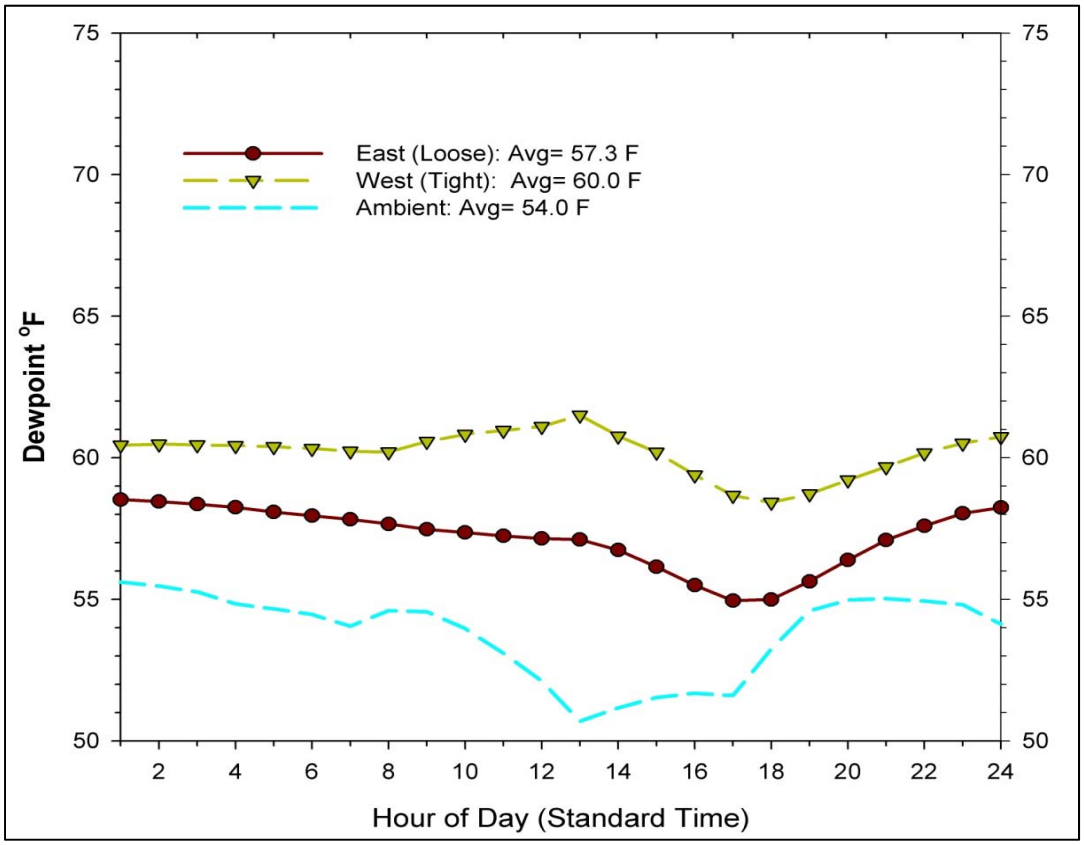


Comparative relative humidity October 25th – November 8th, 2012: Infiltration tests no mechanical ventilation, standard internal moisture loading

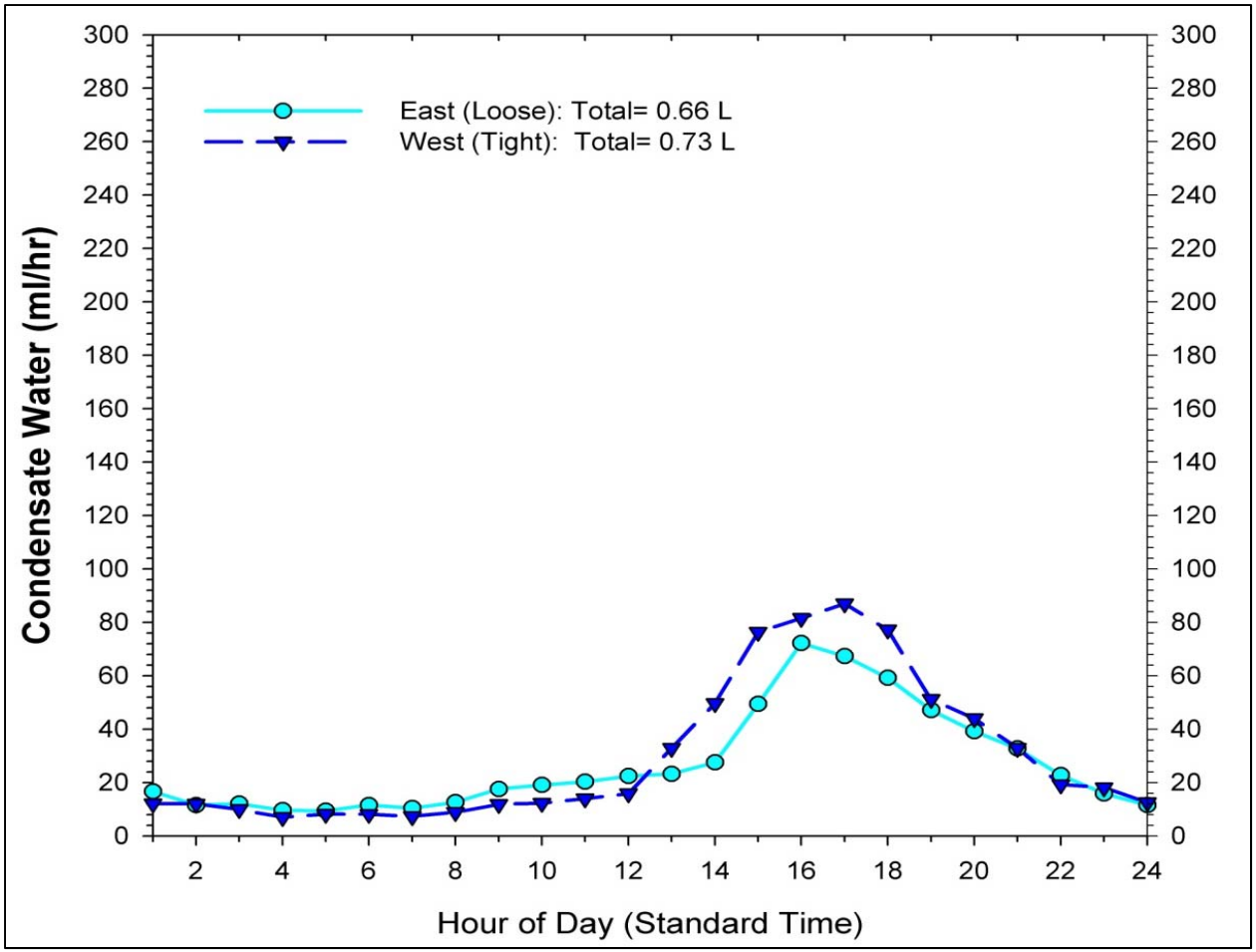
Swing month problem emerging with tight building



Comparative dewpoint temperatures October 25th – November 8th, 2012: Infiltration tests no mechanical ventilation, standard internal moisture loading



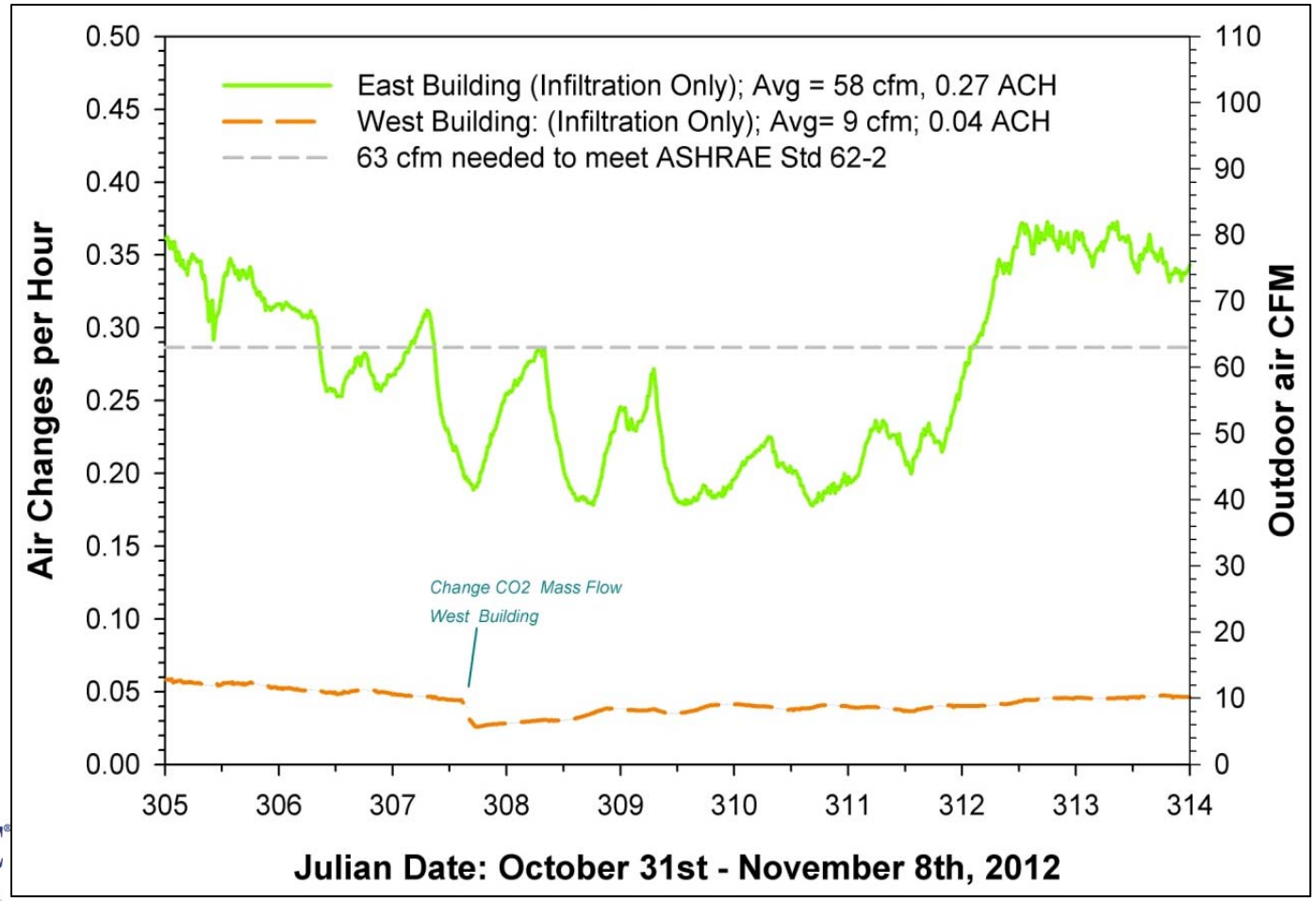
Comparative condensate removal October 25th – November 8th, 2012: Infiltration tests no mechanical ventilation, standard internal moisture loading



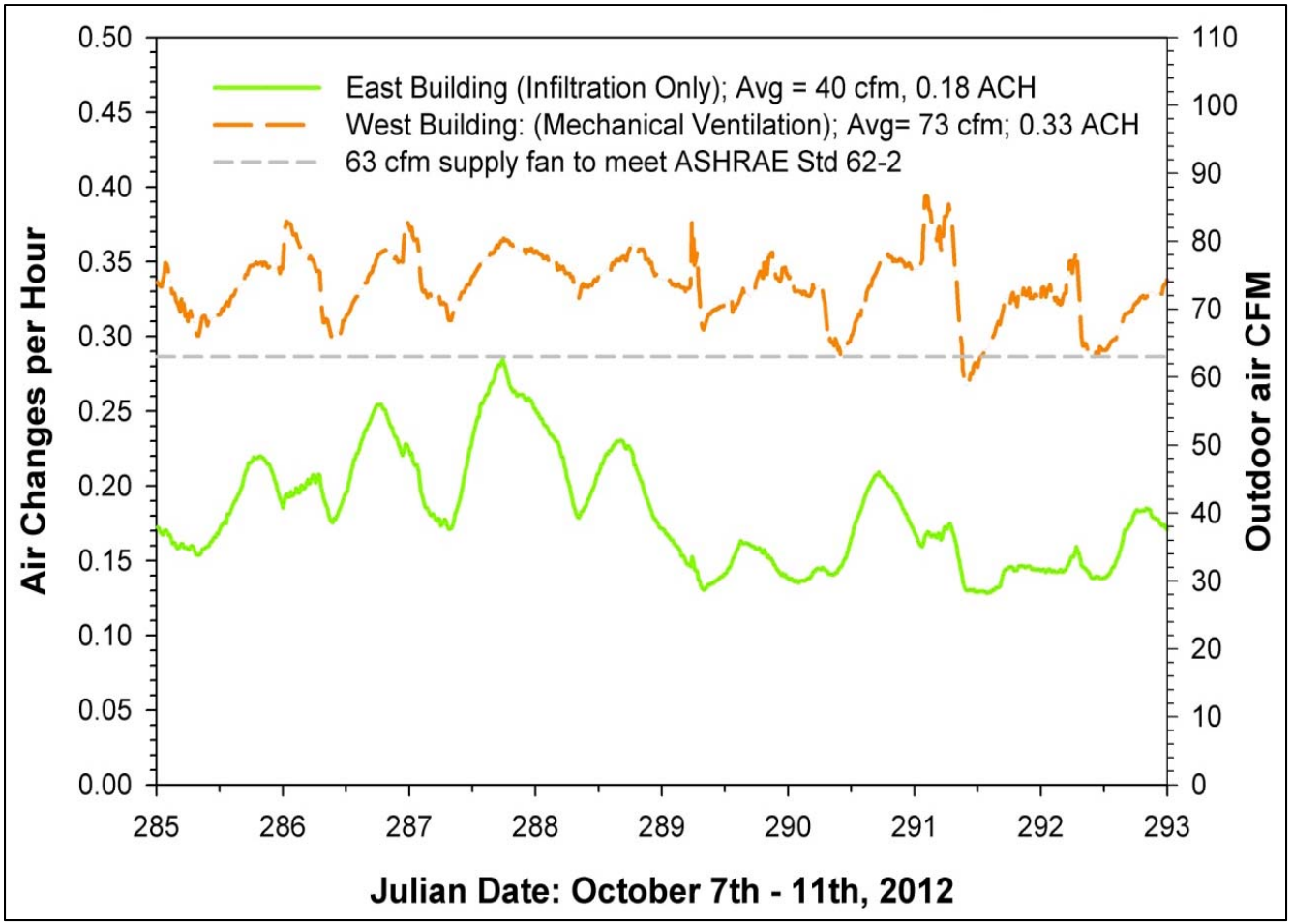
What were the infiltration/ventilation rates during these tests?

- *CO_2 trace dosing system installed*
- *Differential measurement to outdoor CO_2*
- *Used differences to estimate real-time air change rate*
- *Approximately 4 hour time lag*
- *How close to* meeting ASHRAE Standard 62?

Measured infiltration rate by CO_2 tracer, infiltration only in both buildings



Measured infiltration rate by CO_2 tracer, mechanical ventilation in west building



Key Findings

- Moisture control not a big issue with consistent air conditioning
  - Air conditioning equipment compensates for loads
  - No large difference in RH from building tightness
  - No large difference in RH from changed internal moisture loads
  - Modest increase in AC power.
- Mechanical supply ventilation does significantly impact interior humidity and dewpoint
  - Large increases to condensate and AC power
  - Overwhelms ability of mechanical cooling to remove
  - Larger increase in AC and fan power (1.8 kWh/day for fan)
- Mild autumn weather results in poor humidity control
- **LARGE Factor: low cooling loads & tight construction/no ventilation= moisture problems**
- Will assess enthalpy recovery ventilation in summer 2013
- Enthalpy *controlled* ventilation systems should be evaluated

FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

Questions?