SAND2015-10983PE

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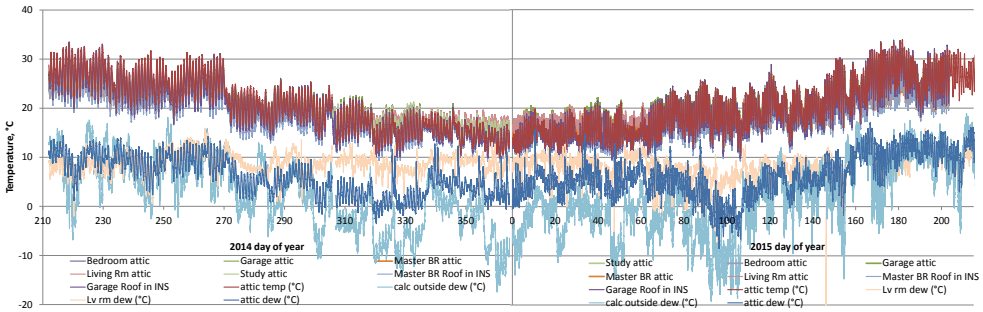

Unventilated Attic Humidity Measurements:

4636 Piedras St., Farmington, New Mexico

Eric Lindgren, Sandia National Laboratories

Doug Lenberg, Real Green Building Systems LLC and study home owner

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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Funding

- This study was funded by the New Mexico Small Business Assistance (NMSBA) Program at Sandia National Laboratories.
  - Created in response to the “Laboratory Partnership with Small Business Tax Credit Act”
  - Allows Sandia researchers to assist New Mexico’s small businesses in solving critical challenges

Dew Point Temperature (T_{DP})

- The **Dew Point** is the temperature at which water vapor starts to condense out of the air (the temperature at which air becomes completely saturated). Above this temperature the moisture will stay in the air.
  - The Dew Point (T_{DP}) is a measure of the absolute humidity
    - The lower the dew point the lower the absolute humidity and the drier the air
    - Calculated from measurement of relative humidity (RH) and air temperature (T_{air})
      - $\mathbf{T_{DP}}$ =243.04*(LN(RH/100)+((17.625*T_{air})/(243.04+T_{air})))/(17.625- LN(RH/100)-((17.625*T_{air})/(243.04+T_{air})))

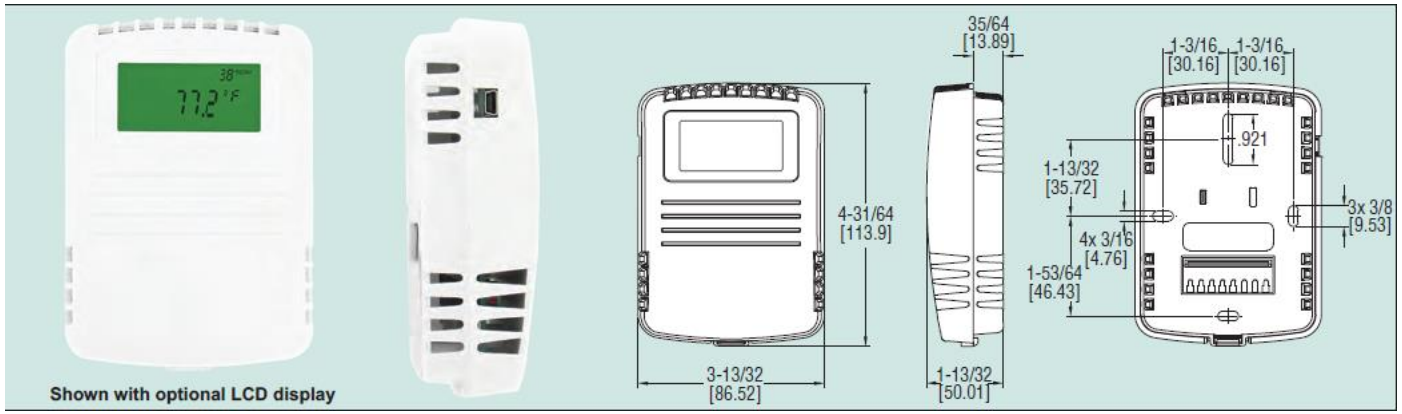
Typical Attic

- Ventilated and unheated
  - Ventilation provides means to remove moisture
  - Keeps T_{DP} at outdoor conditions
    - T_{DP} fluctuates with changes in weather
  - Moisture migration from living space to attic is removed by ventilation
    - Prevention of condensation in building materials that may support mold growth

Humidity Changes in an Unventilated Attic

- In an ideal closed system
  - The absolute humidity (or T_{DP}) is constant
- Attics are far from ideal systems
  - Moisture migration into attic from living space
  - Moisture content of wooden structure changes
  - Condensation on cold surfaces
- What to look for
  - Trends of T_{DP} increasing with time.
  - Attic surface temperatures that approach T_{DP}.

Humidity Instrumentation



- RHP-2W22 Wall mount humidity/temperature transmitter, 2% sensor, 0-10 VDC output.

Humidity Instrumentation Details

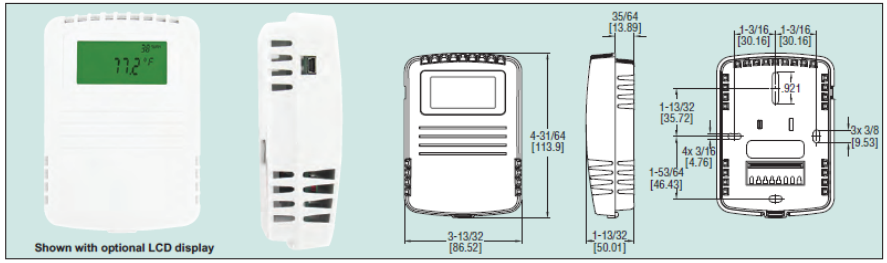
Sandia National Laboratories

Series RHP-W

Wall Mount Humidity/Temperature/ Dew Point Transmitter

Optional LCD Display, Replaceable Sensors

CE



The Series RHP-W Wall Mount Humidity/Temperature/Dew Point Transmitter is the most versatile room transmitter on the market. The stylish housing is well vented to provide air flow across the sensor to improve measurement accuracy. An optional LCD display can be integral to the transmitter or a remote display can be ordered for building balancing or LEED® validation. The LCD display indicates the ambient temperature along with the humidity or dew point. The transmitter has internal dip switches to select the temperature engineering units and whether the transmitter outputs humidity or dew point. The humidity and temperature sensors are field replaceable to reduce service cost and inventory. The humidity and the dew point are measured using a capacitive polymer sensor that completely recovers from 100% saturation. The humidity and dew point can have either a current or voltage output, while the optional temperature output can be a current, voltage, RTD or thermistor. For models with current or voltage for the temperature output, the temperature range is field selectable.

Example	RHP	3	W	2	A	Options	RHP-3W2A-LCD	Price
Series	RHP						Humidity/Temperature/ Dew Point Transmitter	
Accuracy		2					2% Accuracy	**+$30.00**
		3					3% Accuracy	**+10.00**
		5					5% Accuracy	-
Housing			W				Wall Mount	**69.00**
Humidity/ Dew Point Output				4			4-20mA/0-5 VDC/0-10 VDC	-
Temperature Output					0		None	-
					4		4-20mA/0-5 VDC/0-10 VDC	**+5.00**
					A		10KΩ @ 25°C Thermistor Type III	**+5.00**
					B		10KΩ @ 25°C Thermistor Type II	**+5.00**
					C		3KΩ @ 25°C Thermistor	**+6.00**
					D		100Ω RTD DIN 385	**+6.00**
					E		1KΩ RTD DIN 385	**+6.00**
					F		20KΩ @ 25°C Thermistor	**+5.00**
Options						LCD	LCD Display	**+50.00**
						NIST	NIST traceable calibration certificate	**121.00**Ⓝ

Ⓝ Items are net priced and are not subject to any discount.

ACCESSORIES

A-449, Remote LCD Display allows remote indication of select Dwyer Wall Mount Transmitters for validation or certification purposes . . . . . **$50.00**Ⓑ

SCD-PS, 100-240 VAC/VDC to 24 VDC Power Supply . . . . . **30.00**Ⓑ

Ⓑ Items are subject to Schedule B discounts.

SPECIFICATIONS

Relative Humidity Range: 0 to 100% RH.
Temperature Range: -40 to 140°F (-40 to 60°C) for thermistor and RTD sensors. -20 to 140°F (-28.9 to 60°C) for solid state temperature sensors.
Dew Point Temperature Range: -20 to 140°F (-28.9 to 60°C); 0 to 100°F (-17.8 to 37.8°C); 40 to 90°F (4.4 to 32.3°C); -4 to 140°F (-20 to 60°C) field-selectable ranges.
Accuracy:
RH: Model RHP-2XXX ±2% 10-90% RH @ 25°C; Model RHP-3XXX ±3% 20-80% RH @ 25°C; Model RHP-5XXX ±5% 20-80% RH @ 25°C;
Thermistor temperature sensor: ±0.36°F @ 77°F (±0.2°C @ 25°C);
RTD temperature sensor: DIN Class B; ±0.54°F @ 32°F (±0.3°C @ 0°C);
Solid state temperature sensor: ±0.9°F @ 72°F (±0.3°C @ 25°C).
Hysteresis: ±1%.
Repeatability: ±0.1% typical.
Temperature Limits:
Operating: -40 to 140°F (-40 to 60°C);
Storage: -40 to 176°F (-40 to 80°C).
Compensated Temperature Range: -4 to 140°F (-20 to 60°C).
4-20 mA Loop Powered Outputs:
Power requirements: 10 to 35 VDC;
Output signal: 4 to 20 mA, 2 channels for humidity/solid state temperature sensor models (loop powered on RH). Switch selectable RH/dew point. Switch selectable normal or reverse output.
0-5/10V Outputs:
Power requirements: 15 to 35 VDC or 15 to 29 VAC;
Output load: 5 mA max., 2 channels for humidity/solid state temperature sensor models. Switch selectable 0-10V/2-10V or 0-5V/1-5V output. Switch selectable RH/dew point. Switch selectable normal or reverse output.
Solid State Temperature Sensor Output Ranges: Switch selectable, -20 to 140°F (-28.9 to 60°C); 0 to 100°F (-17.8 to 37.8°C); 40 to 90°F (4.4 to 32.3°C); -4 to 140°F (-20 to 60°C).
Response Time: 15 seconds.
Electrical Connections: Screw terminal block.
Drift: <1% RH/year.
RH Sensor: Capacitance polymer.
Enclosure Material: Warm gray polycarbonate.
Display: Optional LCD, backlit on 0-5/10V models. Switch selectable %RH or dew point, °F/°C.
Display Resolution: RH: 1%; Temperature: 0.1°F (0.1°C); Dew Point: 1°F (1°C).
Weight: 0.3 lb (0.14 kg).
Agency Approvals: CE.

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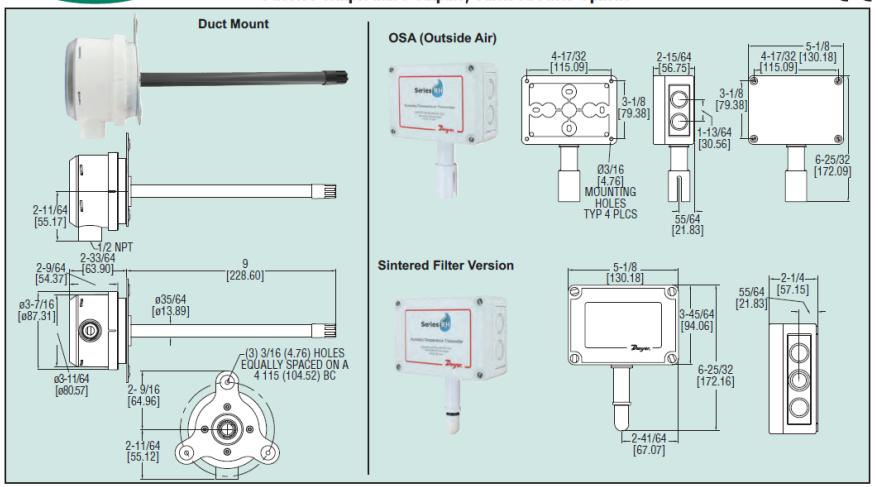
Series RHP

Humidity/Temperature Transmitter

Passive Temperature Outputs, Sintered Filter Options

CE



The Series RHP Temperature and Humidity Transmitter combine the voltage or current humidity transmitter output with a passive temperature thermistor or RTD output. The polymer capacitance humidity sensor is not affected by condensation, fog, high humidity, or contaminants. The humidity sensors are available with 2%, 3% or 5% accuracies. Duct mounted transmitters are available with an optional two-line alpha numeric LCD display. The Series RHP is available with interchangeable filter options as well as replaceable sensors.

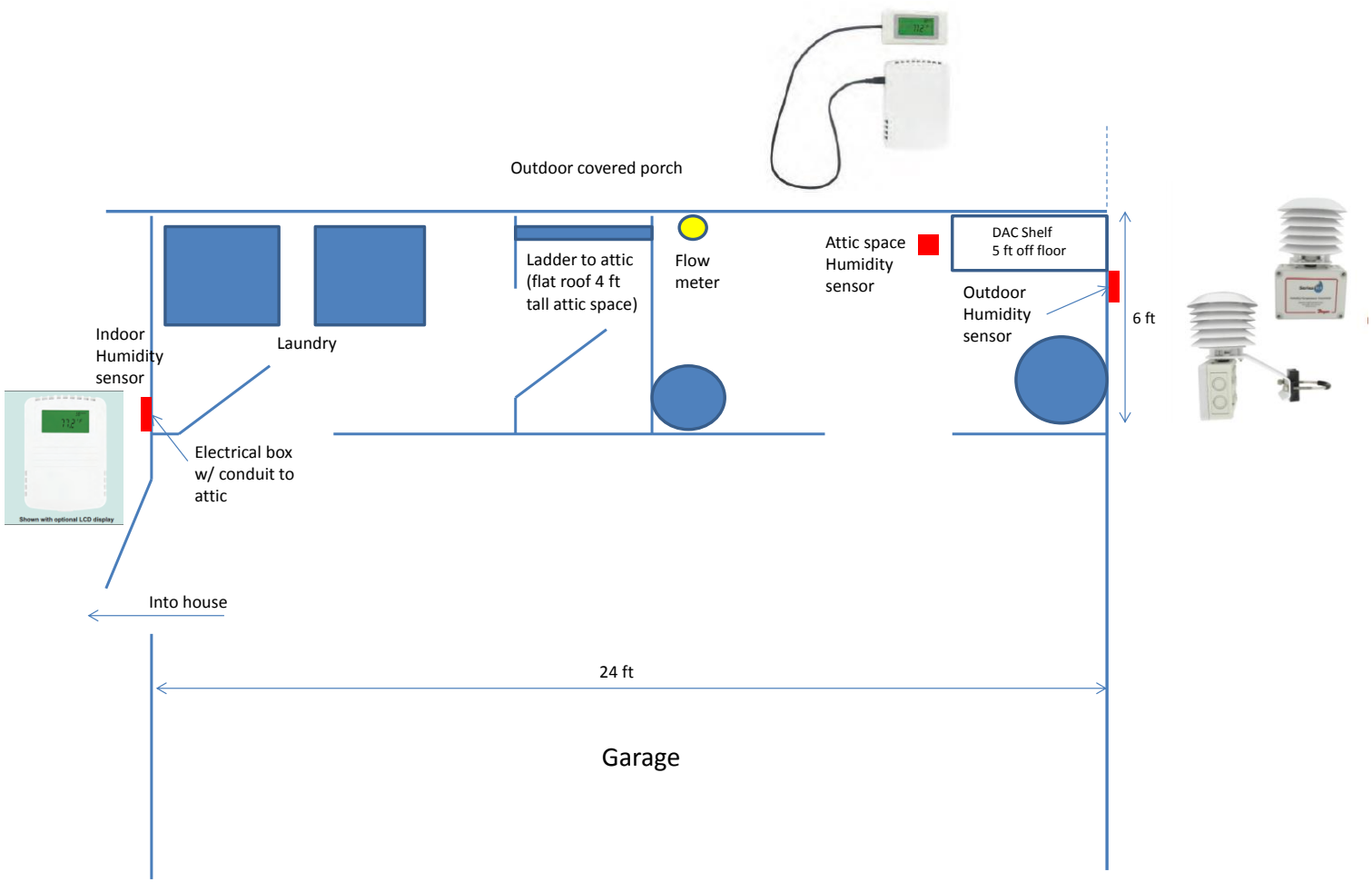
Example	RHP	2	D	1	A	LCD	RHP-2D1A-LCD	Price
Series	RHP						RH/Passive Temperature Sensor Transmitter	-
Accuracy		2					2% Accuracy	**+$30.00**
		3					3% Accuracy	**+15.00**
		5					5% Accuracy	-
Housing Type			D				Duct Mount w/Membrane Filter	**90.00**
			F				Duct Mount w/Sintered Filter	**95.00**
			O				OSA (Outside Air)	**95.00**
			S				OSA w/Sintered Filter*	**100.00**
			R				Radiation Shield	**150.00**
RH Output				1			4 to 20mA	-
				2			0 to 10V	-
				3			0-5V	-
Temperature Sensor					0		None	**-10.00**
					1		4 to 20mA	**+5.00**
					2		0 to 10 VDC	**+5.00**
					3		0-5V	**+5.00**
					A		10K @ 25°C Thermistor Type III	**+5.00**
					B		10K @ 25°C Thermistor Type II	**+5.00**
					C		3K @ 25°C Thermistor	**+6.00**
					D		100Ω RTD DIN 385	**+6.00**
					E		1KΩ RTD DIN 385	**+6.00**
					F		20KΩ @ 25°C Thermistor	**+5.00**
Option						LCD	LCD Display	**+50.00**
						NIST	NIST traceable calibration certificate	**121.00**Ⓝ

*Model RHRS Radiation Shield is required for sintered filter OSA models.
Ⓝ Items are net priced and are not subject to any discount.

SPECIFICATIONS

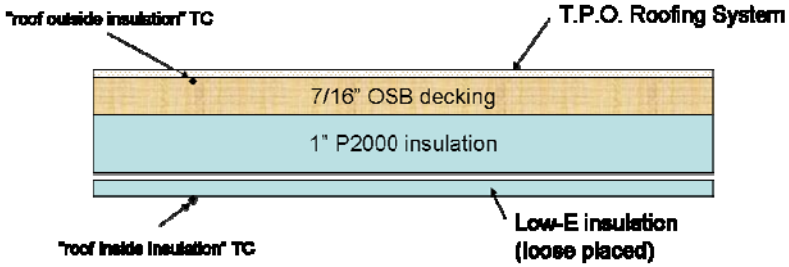
Relative Humidity Range: 0 to 100% RH.
Temperature Range: -40 to 140°F (-40 to 60°C).
Accuracy, RH: Model RHP-2XXX ±2% 10-90% RH @ 25°C; Model RHP-3XXX ±3% 20-80% RH @ 25°C; Model RHP-5XXX ±5% 20-80% RH @ 25°C;
Accuracy, Thermistor Temp Sensor: ±0.2°C @ 25°C (±0.36°F @ 77°F).
Accuracy, RTD Temp Sensor: DIN Class B; ±0.3°C @ 0°C (±0.54°F @ 32°F).
Hysteresis: ±1%.
Repeatability: ±0.1% typical.
Temperature Limits: -40 to 140°F (-40 to 60°C).
Storage Temperature: -40 to 176°F (-40 to 80°C).
Compensated Temperature Range: -4 to 140°F (-20 to 60°C).
4 to 20 mA Loop Powered Models: Power requirements: 10 to 35 VDC; Output signal: 4 to 20 mA.
0-5/10V Output Models: Power requirements: 15 to 35 VDC or 15 to 29 VAC; Output signal: 0 to 10V @ 5 mA max.
Response Time: 15 seconds.
Electrical Connections: Removable screw terminal block.
Conduit Connection: Duct mount: 1/2" NPS; OSA: 1/2" (22.3 mm).
Drift: <1% RH/year.
RH Sensor: Capacitance polymer.
Temperature Sensor: Curves A, B, C: Thermistor; Curves D, E: Platinum RTD DIN 385.
Enclosure: Duct mount: PBT; OSA: Polycarbonate.
Enclosure Rating: NEMA 4X (IP66) for OSA mount only.
Display: Duct mount only, optional 2-line alpha numeric, 8 characters/line.
Display Resolution: RH: 0.1%; 0.1°F (0.1°C).
Weight: Duct mount: .616 lb (.3 kg); OSA: 1 lb (.45 kg).
Agency Approvals: CE.

Humidity Monitoring Locations

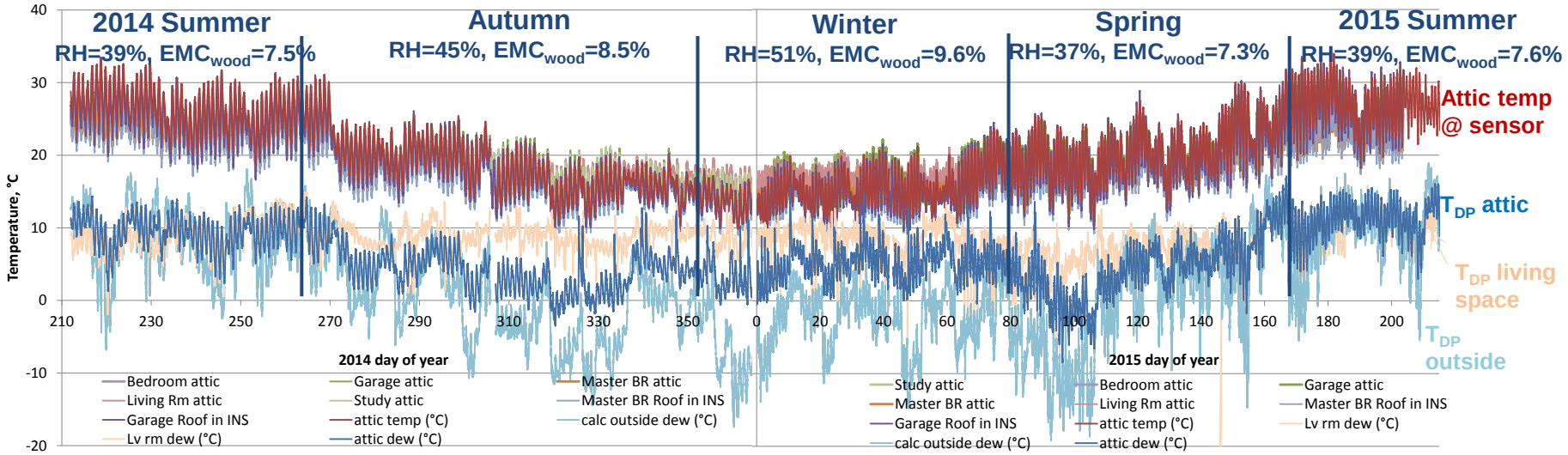


One Year of Measurements

- Attic temperatures
  - Air and insulation surface (in INS)
    - ~25 °C summer, ~15 °C winter
    - 10 °C diurnal temperature cycles result in ~3% attic air exchange daily.
  - Dew Point Temperatures
    - ~10 °C summer, ~5 °C winter & no yearly increase trend evident
    - T_{DP} Living Area> Attic>Outside: in autumn, winter and spring
      - Attic should have limited communication with drier outside air; no communication with less dry living space.

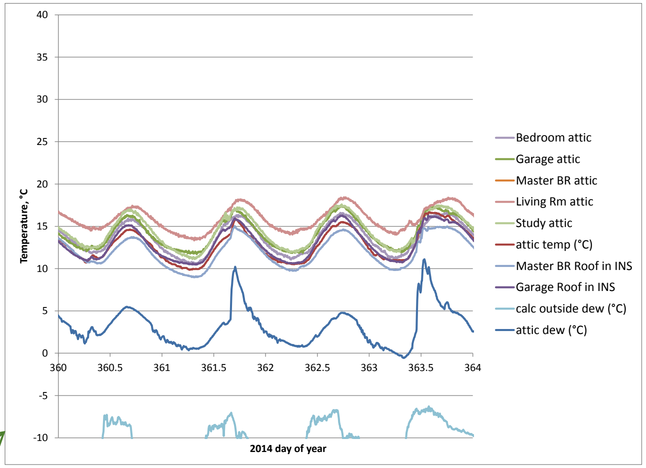


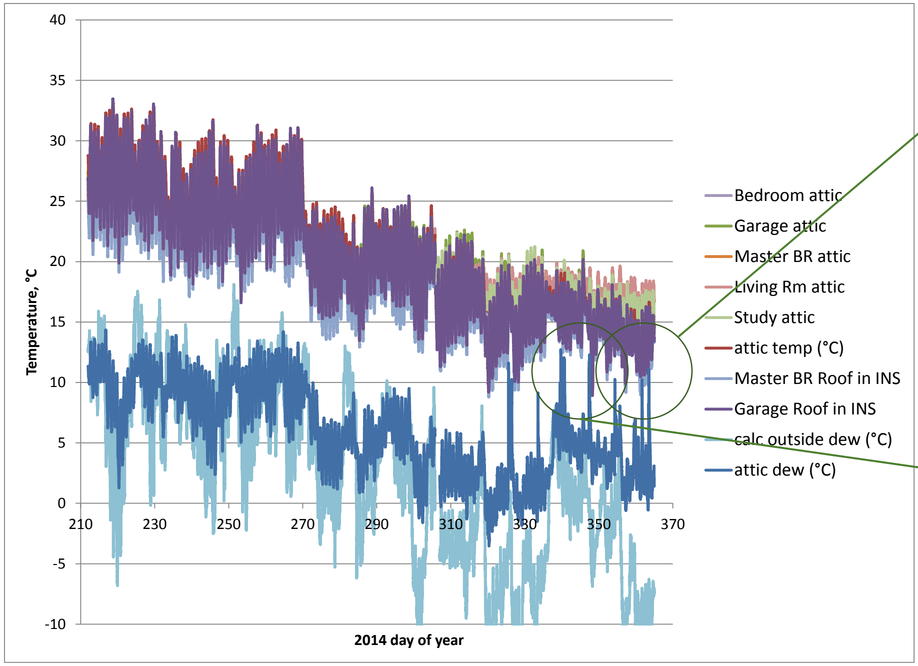
- Trends
  - Attic temperature and T_{DP} higher in summer, lower otherwise
    - 5°C drop in T_{DP} may be due to wood moisture increase (Equilibrium Moisture Content up 2% in winter)
  - Summer 2015 T_{DP} returned to Summer 2014 level
  - Generally $T_{attic} > T_{DP}$ except for periodic spikes during colder months

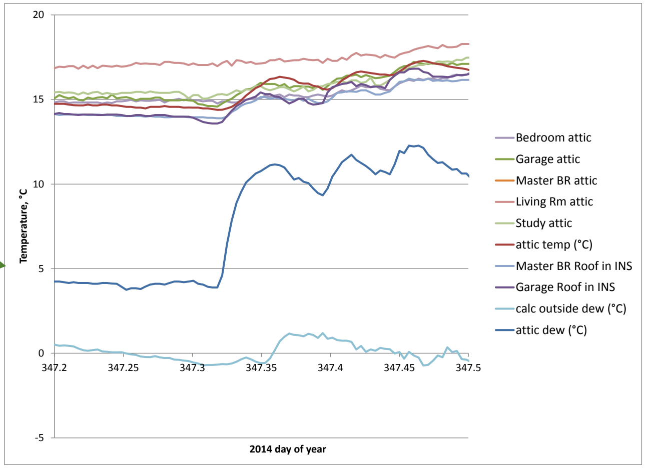


August to December 2014

- Periodic spikes
  - ~weekly during cold months
  - 2 to 3 hours
  - Middle of day
  - Laundry dryer vented inside?

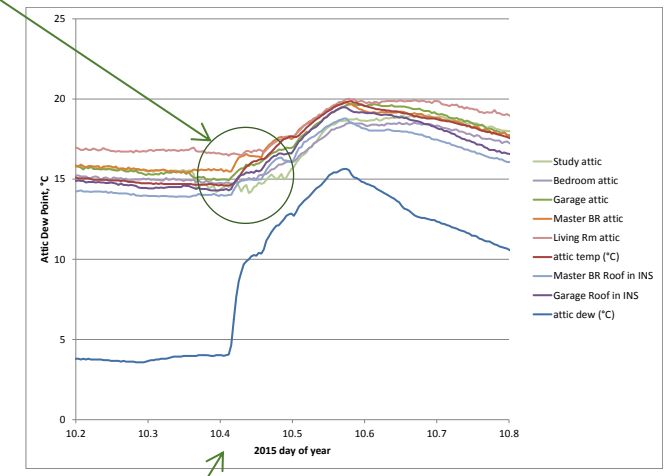


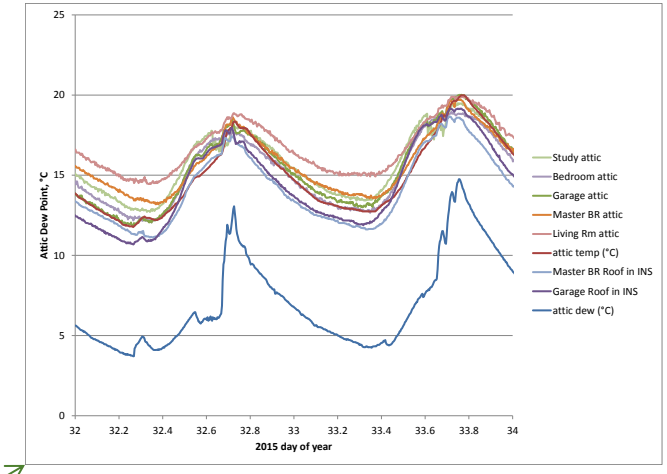


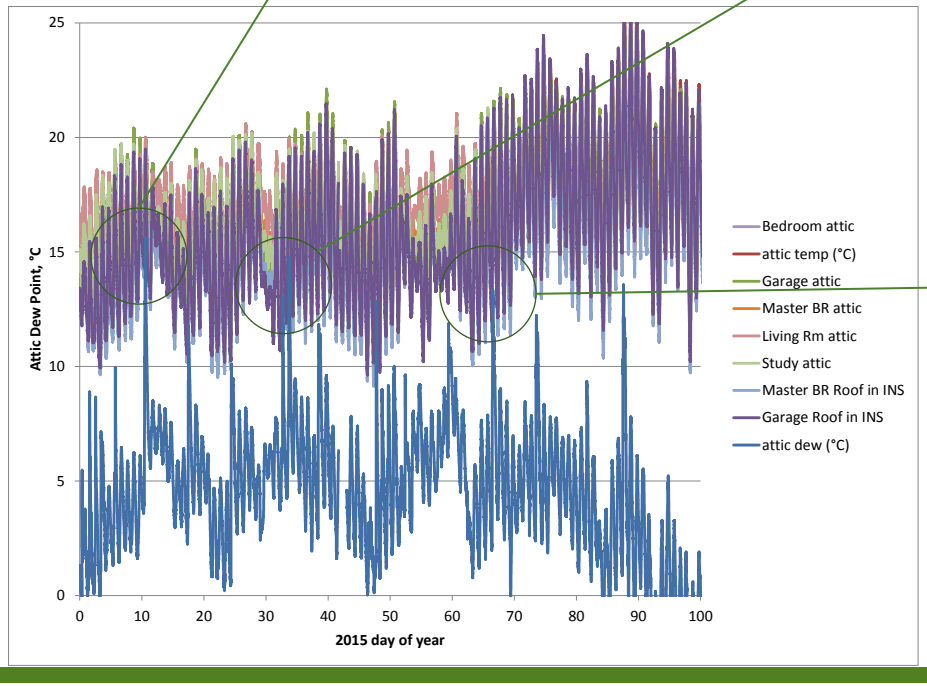


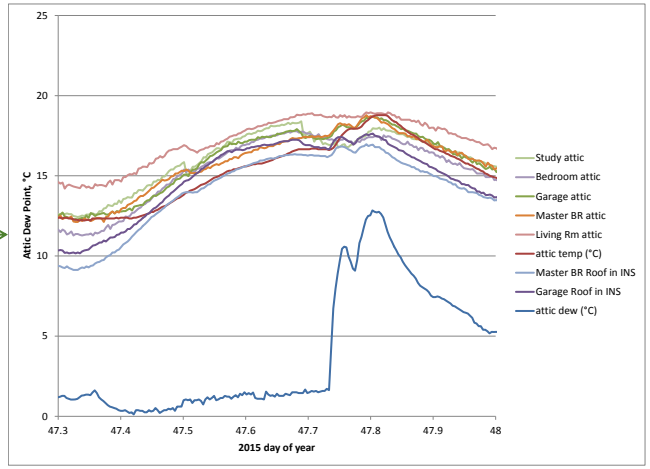
January to March 2015

Note flatness
Best indication of condensation









No signs of lasting condensation

Summary and Recommendations

- After one year of monitoring
  - No indication of moisture accumulation in attic
    - Summer 2015 T_{DP} similar to Summer 2014
    - Daily and yearly cycles complicate trend analysis
      - Keep monitoring
  - No sign of prolonged condensation
    - Indoor laundry dryer venting may have caused periodic moisture spikes in attic
  - In arid climates
    - Small attic vent that allows attic to cycle dryer air from outdoors is recommended.
      - Venting should be such that it does not promote any cross flow in attic