


Kohta Ueno

The BS* + Beer Show


Building Monitoring: Show Me the Data

March 11, 2021



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Enclosure Monitoring: Background





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Background

- Not an originator—only a practitioner
- U Waterloo BEG/John Straube and RDH
- Not much of a how-to presentation: research level instrumentation... but inspiration/ideas?
- Thank you, Building America/DOE!





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Monitoring Projects (Back to 2003)

- Kraft vs. polyethylene vs. MemBrain (w. Cellulose/FG)
- Basement wall insulation
- Polyethylene vs. latex paint and brick veneer inward drive
- Drainage gaps and wetting/drying
- Masonry walls with interior insulation
- Masonry wall embedded joist ends after insulation
- Double stud walls w. cellulose & ocSPF
- Unvented roofs with fibrous insulation, diffusion vents
 - Chicago, Houston, Orlando, Boston



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Got the T-Shirt...

- The 2001-2005 concert tour cities

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Watching Star Wars vs. SFX Making Of?

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Enclosure Experimental Design

- What do you want to learn?
- Comparing side-by-side variations
- Orientation/exposure (North vs. south)
- What are the key interfaces to measure?
 - Wintertime condensation = sheathing-to-insulation, first condensing plane
 - Summertime condensation or inward vapor drive = cavity insulation-to-interior gypsum
- How long do you have access to the site?
 - Multiple years best—performance over time
- Vary conditions over time—e.g., interior RH

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Enclosure Monitoring: Instrumentation

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Typical Monitoring Instruments/Sensors


- Temperature
- Relative humidity
- Wood moisture content
- “Wafer” sensor
- Redundant placement-instrumentation failures
- Differential pressures—hard problem



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Moisture Content Measurement




Delmhorst BD10
Pin-based MC meter
Wood products (typical)
Electrical resistance

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Wood Moisture Contents

- Below 20% MC=safe
- 25-30% MC mold range
 - But seasonally survivable!
- 28%+ MC decay fungi
- Really wet wood is obvious (feels wet)
- Liquid water condensation
- Don't forget about temperature when wet (mold doesn't grow in the freezer)

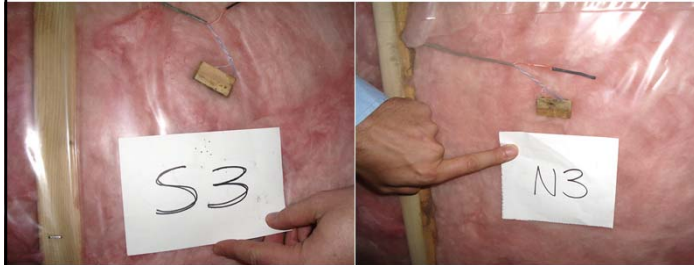


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Wood Wafer Sensors

- MC pins embedded in small wood pieces
- Long term RH at interfaces, mold growth
- Can indicate liquid water condensation (mold ↑↑)




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Enclosure Monitoring: Implementation and Examples

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Instrumentation Design: Double Stud Walls

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Test Wall Instrumentation

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Test Wall Instrumentation

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Instrumentation Design: Unvented Roof

The diagram shows a cross-section of a roof assembly with various sensor locations. A photograph of a roof interior shows the placement of a moisture content block (MCB) on the sheathing. Labels include: MC/T Sheathing High, Sheathing Mid, RH/T Ridge, Wafer at Ridge, Wafer (South only), and RH/T Mid Interior. A sensor key identifies: Temperature (red triangle), Relative humidity/temperature (green circle), Moisture content/temperature (blue square), and Moisture content block (black square).

Notes:

- "MC/T Sheathing High" is at top edge of sheathing at diffusion vent, or equivalent location in non-DV roofs
- Wafer and RH/T at ridge are directly under ridge

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Exterior Conditions: Field Monitoring





- Basics: Temperature/RH
- Advanced: Add rain, wind direction/speed
- Budget: Hourly airport weather data

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Logger Setups: Simple, Complicated


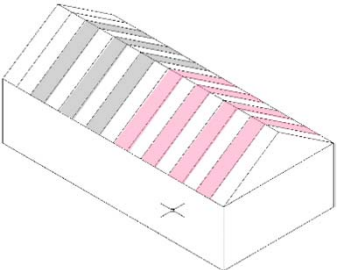





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Experimental 'Guard Bays'

- Keep test assemblies from cross-communicating
- Air leakage, vapor flow?

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Experimental 'Guard Bays'




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Adding Air Leakage Injection System

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Adding “Wetting Events”

- How well does this assembly recover from occasional water leaks? Drying out
- Most useful in side-by-side comparisons

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Enclosure Monitoring: Interpreting Data

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Moisture Failure Criteria


- No mold growth with wood below 20% (FPL)
 - Optimum growth 25%–30% MC range
- Decay fungi @ MC > 28%
- Doll (2002)—liquid water (e.g., condensation), mold growth takes off
- Calculations to show “is this assembly moisture-safe or not?”

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Moisture Failure Criteria

- Old ASHRAE 160 criteria too conservative
 - Multiple field tests-160 shows failure, visual OK
 - Walls with known track records of success fail ASHRAE 160 criteria



ANSI/ASHRAE Standard 160-2009

ASHRAE STANDARD

Criteria for Moisture-Control Design Analysis in Buildings

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Viitanen's mold index

Index	Description of growth rate	Microscopic observation	Observation with the naked eye
0	No growth	None	None
1	Initial stages of local growth	Small amounts of mold on surface	None
2	---	Several local colonies	None
3	New spores produced	<50% coverage	<10% coverage
4	Moderate growth	>50% coverage	10%-50% coverage
5	Plenty of growth	---	>50% coverage
6	Heavy and tight growth	---	about 100% coverage

Based on work by Hannu Viitanen and colleagues since the 1980s

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Moisture Failure Takeaways

- Mold index model is a big improvement
 - Does not fail assemblies that work
 - Test cases using measurements show that model agrees with observations (mold & no-mold cases)
 - Material sensitivity, mold decline accounted for
- But is mold index passing risky assemblies?

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Opening the Walls

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Best Case: Monitor then Disassemble

S2 (12" cellulose) S1 (12" ocSPF)
 S3 (6" ocSPF)
 N2 (12" cellulose)

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UWaterloo (CZ 6A) Walls

- Interior run at 68 F/50% RH year round
- Very challenging interior condition N1/S1=XPS, paint
- Walls 2x4 + XPS, 2x6 paint/poly N2/S2=paint
- N3/S3=polyethylene

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North Side Sill Plate MCs

- 20-30% MC usual "concerning" range
- XPS wall sill plate soaking wet

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UWaterloo (CZ 6A) Year 1 Disassembly

- Slight spotting on XPS surface
- Wetting event correlated with XPS T>32 F
- Frost accumulation followed by thaw & rundown


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Questions?


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Indoor Air Quality Monitoring


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Consumer-Level IAQ Monitors

- Temperature, humidity, VOCs, CO₂, PM2.5



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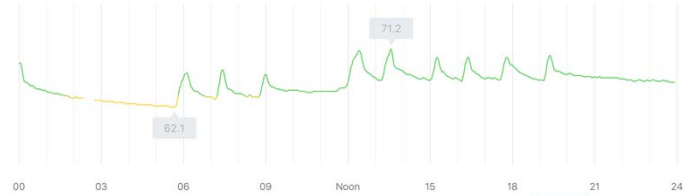
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Temperature

- Tracking HVAC cycling/operation


Daily Average
65.8 °F

Away Score Temp Humidity CO₂ Chemicals PM2.5



00 03 06 09 Noon 15 18 21 24


DAY WEEK Thu 18 Fri 19 Sat 20 Sun 21 Mon 22 Tue 23 Today

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CO₂ Carbon Dioxide-Ventilation Metric

- Somerville Triple Decker, third floor unit

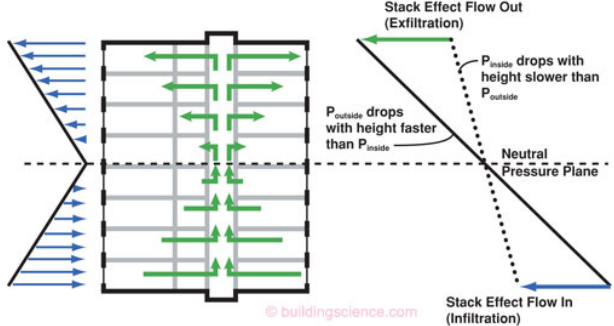


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Stack Effect in Multifamily Buildings

- Make-up air comes from units below




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CO₂ Carbon Dioxide-Ventilation Metric

- Effect of adding an ERV to ~1000 sf unit, BR CO₂
- High CO₂ levels and cognition

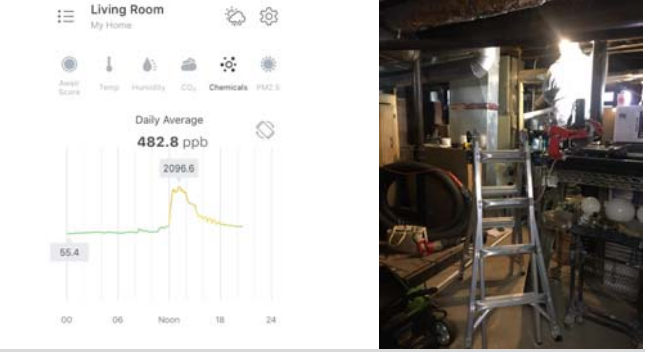


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VOCs/Volatile Organic Compounds

- Harmful...



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VOCs/Volatile Organic Compounds

- ... Vs. not too harmful?

Living Room
My Home

Temp Humidity CO₂ Chemicals PM2.5

Daily Average
410.3 ppb

1816.8
245.0

00 06 Noon 18 24

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PM2.5 Particulates

- Health effects of breathing PM2.5 (LBNL)
- Cooking causes big spikes—even w. range hood
- PM2.5 spike while out of town.... Thanksgiving
- But also, humidifiers!

Temp Humidity CO₂ Chemicals PM2.5

Daily Average
15.7 µg/m³

133.5
1.9

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