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Air Barriers for Residential and Commercial Buildings

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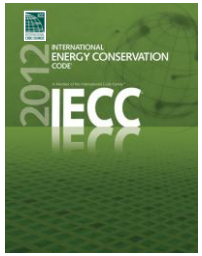
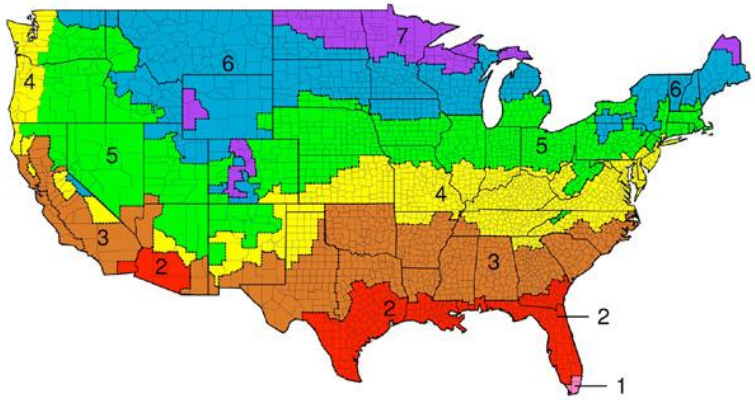
Problem Statement & Project Focus

- Air leakage is a significant contributor to HVAC loads
  - ~50% in residential buildings (Sherman and Matson 1997)
  - ~33% of heating loads in office buildings (Emmerich et al. 2005)
- Airtightness of buildings listed in BTO prioritization tool
- IECC 2012 airtightness requirements





Residential Construction

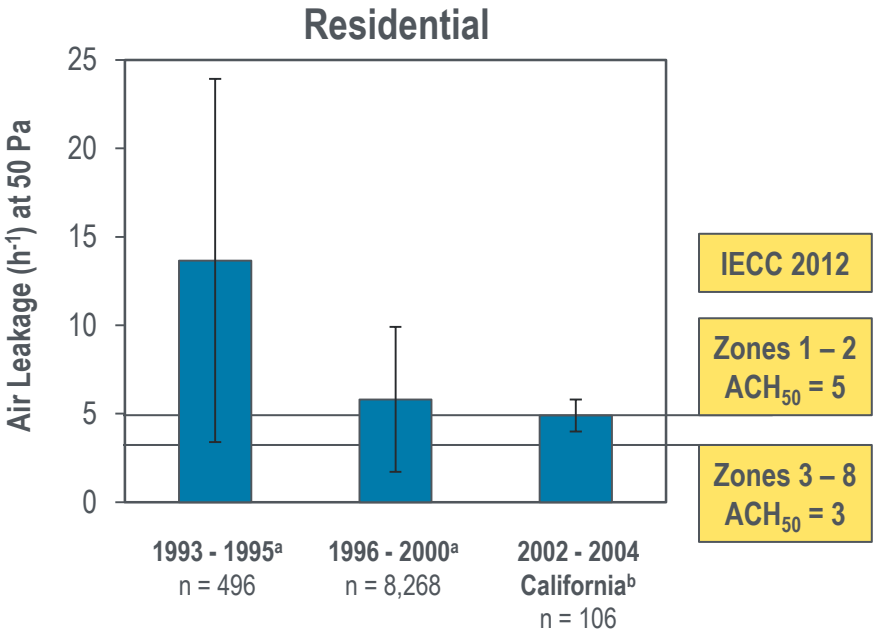
- Zones 1 and 2: $ACH_{50} \leq 5$
- Zones 3 through 8: $ACH_{50} \leq 3$

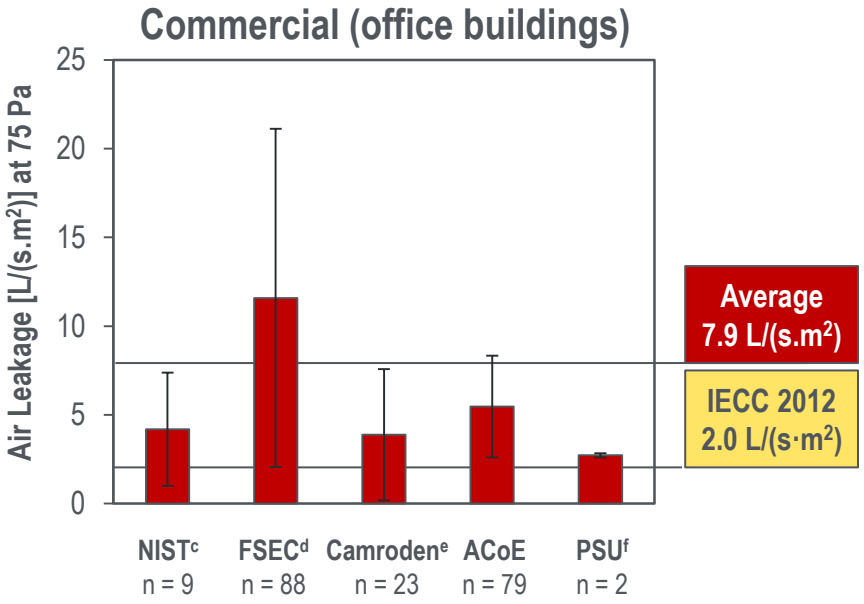
Commercial Construction

- Zones 1 through 3: no air barrier required
- Zones 4 through 8:
  - Air barrier material ≤ 0.02 L/(s·m^2) at 75 Pa or
  - Air barrier assembly ≤ 0.2 L/(s·m^2) at 75 Pa or
  - Building enclosure ≤ 2 L/(s·m^2) at 75 Pa

Problem Statement

Field measurements vs. IECC 2012





a. Sherman and Matson 2002
b. Offermann 2009
c. Persily and Grot 1986; Persily et al. 1991; Musser and Persily 2002
d. Cummings et al. 1996; Cummings et al. 2000
e. Brennan et al. 1992
f. Bahnfleth et al. 1999

ACoE: US Army Corps of Engineers
FSEC: Florida Solar Energy Center
NIST: National Institute of Standards and Technology
PSU: Penn State University

Impact of Project & Overall Approach

- Cost-effective means to meet and exceed IECC 2012 requirements

- Evaluate the eight typical air barrier types

Membranes

Interior

Mechanically-fastened

Self-adhered

Fluid-applied non-foaming

Sheathings

Non-insulating

Insulating

Sealants

Spray-applied foam

- Tests

Field test

Sub-assembly tests

Material characterization

Phase 2: Field Tests

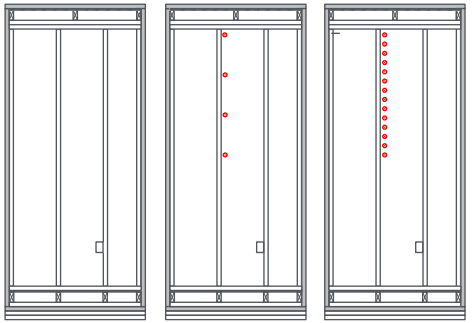
- Effect of air leakage on energy and durability
  - Material: Level 1 → 0.02 L/(s·m^2) @ 75 Pa → **Baseline**
  - Assembly: Level 2 → 0.2 L/(s·m^2) @ 75 Pa
  - Enclosure: Level 3 → 2 L/(s·m^2) @ 75 Pa

Syracuse natural exposure test facility

- Eight air barrier types

- Three wall samples per air barrier type
  - Representative of residential or commercial construction
  - Simulated imperfections

- Data collection started in November 2011



Field Tests: Wall Assembly

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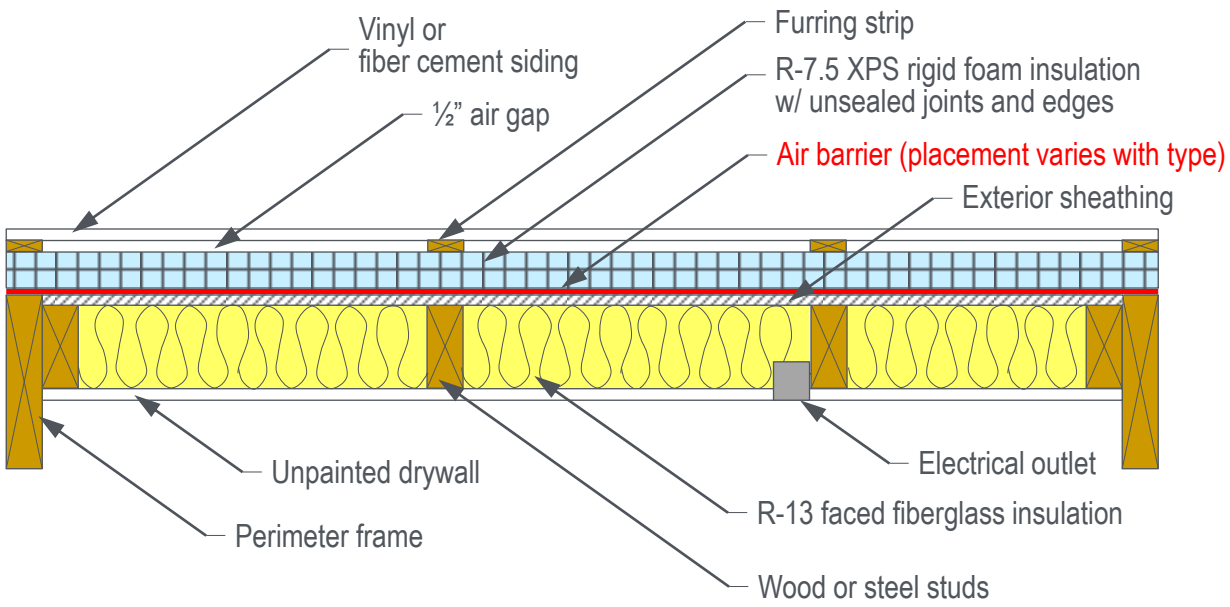
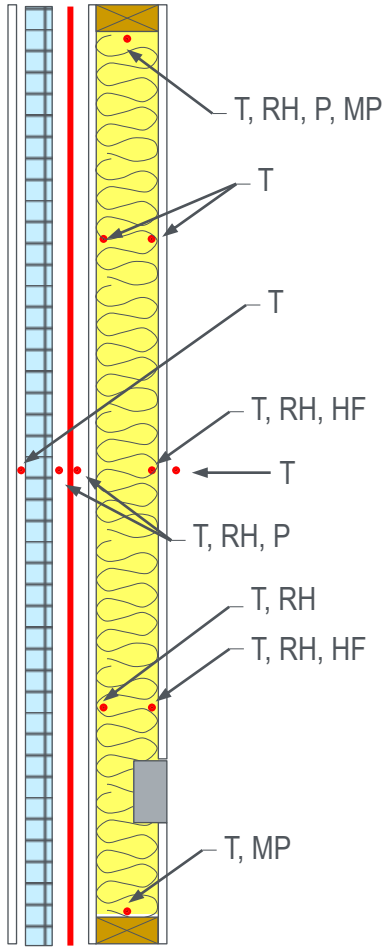
General Material Layout
Horizontal Cross Section of Wall



General Sensor Layout
Vertical Cross Section of Wall



HF: heat flux
MP: moisture pin
P: pressure
RH: relative humidity
T: temperature

Field Tests: Heat Flux Data

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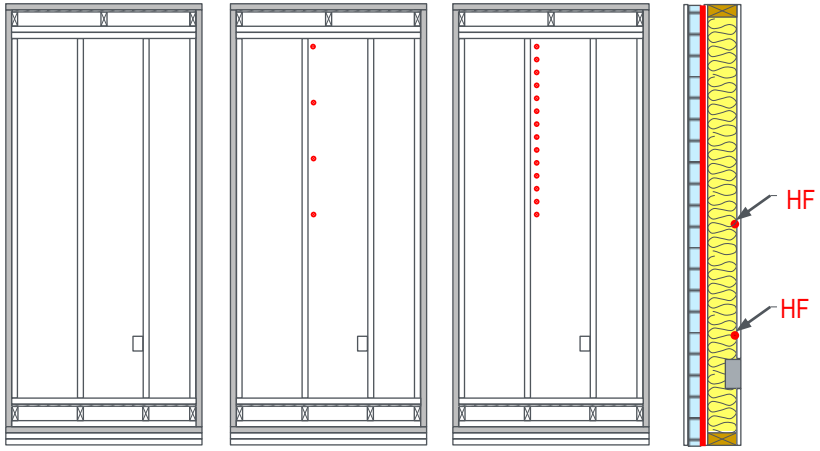
Air barrier type: non-insulating sheathing (south facing walls)

Imperfection: unsealed OSB joint at stud

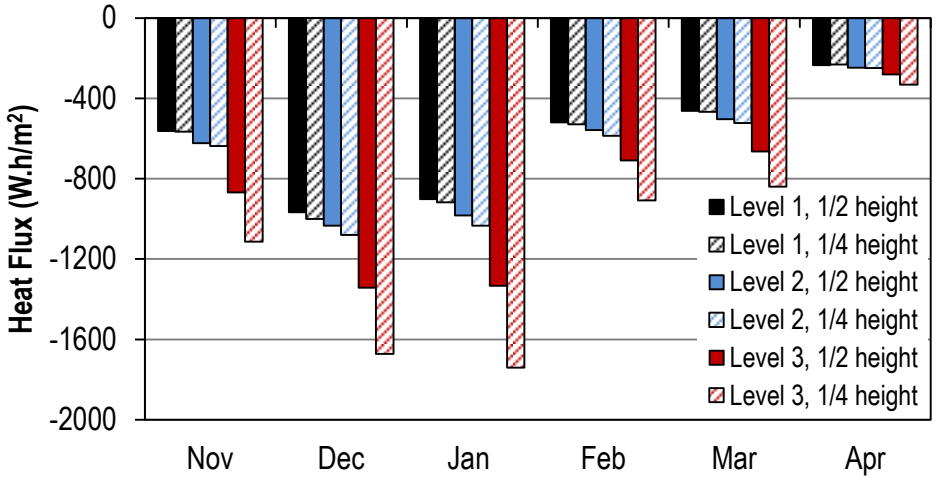


Level 1 – Baseline
< 0.02 L/(s·m²)

Level 2
0.26 L/(s·m²)

Level 3
0.7 L/(s·m²)

@ ΔP = 75 Pa



% Increase in Heat Flux

Compared air leakage levels	Sensor location	Nov	Dec	Jan	Feb	Mar	Apr
Level 3 vs. Level 1	½ height	54	39	48	37	44	19
Level 2 vs. Level 1		11	7	9	7	9	5
Level 3 vs. Level 1	¼ height	97	67	90	71	80	43
Level 2 vs. Level 1		13	8	13	11	12	8

Field Tests: Moisture in Wall Cavities

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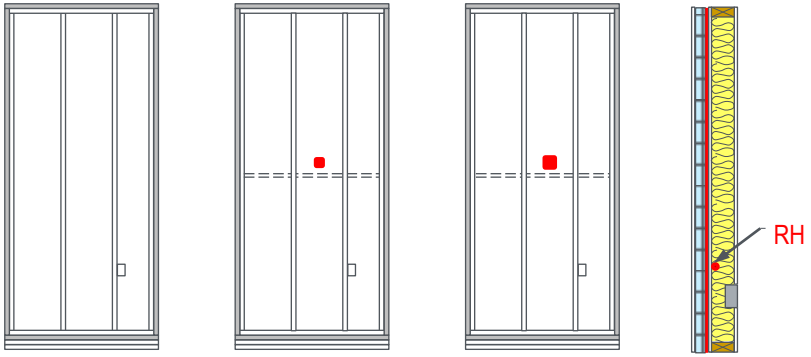
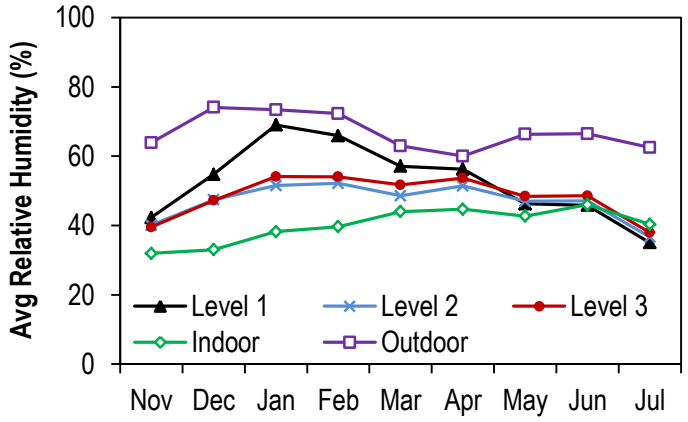
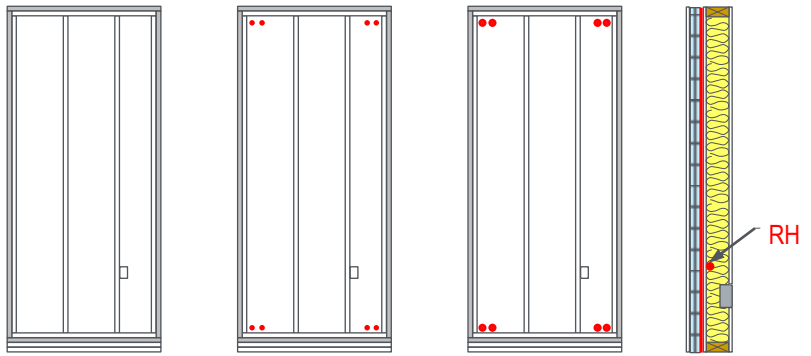
Air barrier type: mechanically-fastened membrane
South facing walls
Imperfection: penetration through air barrier



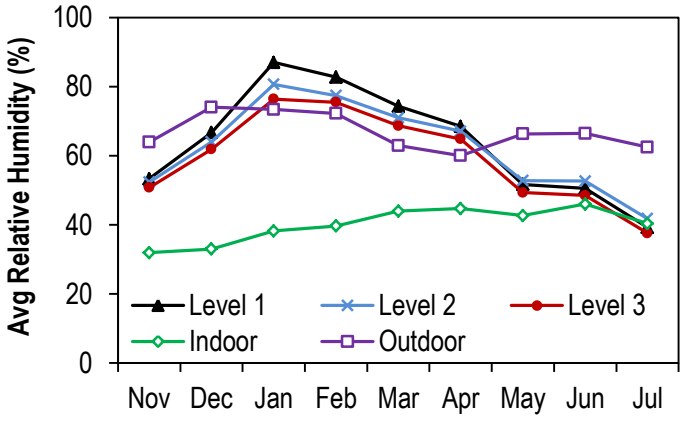
Level 1 – Baseline 0.07 L/(s·m²)
Level 2 0.28 L/(s·m²)
Level 3 0.73 L/(s·m²) @ ΔP = 75 Pa



Air barrier type: insulating sheathing
East facing walls
Imperfection: gaps between top/bottom track & stud



Level 1 – Baseline 0.03 L/(s·m²)
Level 2 0.36 L/(s·m²)
Level 3 0.5 L/(s·m²) @ ΔP = 75 Pa



Field Tests: Moisture in Wall Cavities

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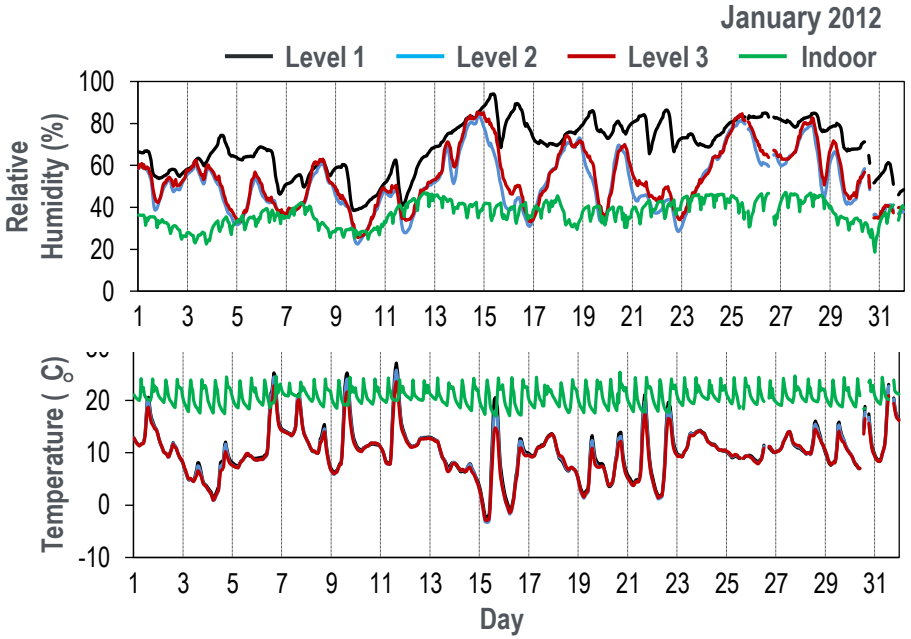
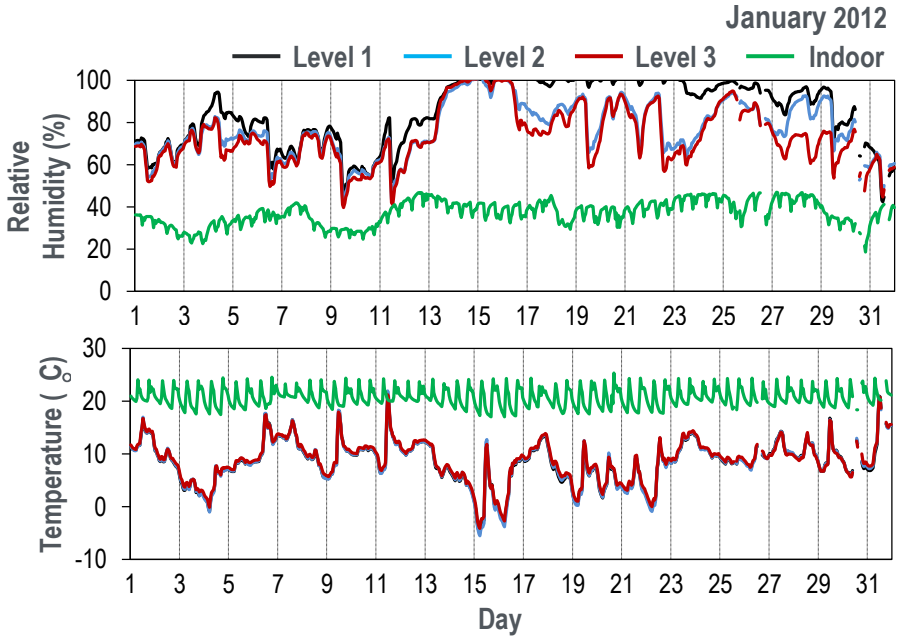
Air barrier type: mechanically-fastened membrane
South facing walls



Air barrier type: insulating sheathing
East facing walls



- **Airtightness can affect the drying potential of walls**
- **Condensation occurred despite the R-7.5 XPS exterior insulation**

Phase 3: Sub-Assembly Tests

- Characterize major air leakage paths
  - Joints: wall / foundation, wall / roof, exterior sheathing
  - Penetrations: electrical outlets, pipes
  - ASTM E2357
- Assess common sealing methods for each air barrier type
- Test matrix

Air barrier type	Wall framing		
	Wood (8'×8')	Steel (8'×8')	6" CMU (6'×4')
Fluid-applied non-foaming liquid			
Insulating sheathing			
Non-insulating sheathing		NA	NA
Interior air barrier		NA	NA
Mechanically-fastened membrane			
Self-adhered membrane			
Spray-applied foam			
Sealants w/ backup structure		NA	NA
Interior drywall		NA	NA
Baseline (i.e., no air barrier)			
Number of tests	**10**	**6**	**6**

Complete

In progress

Not started

Sub-Assembly Tests:
Characterization of Major Air Leakage Paths

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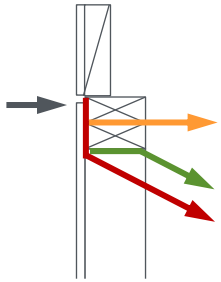
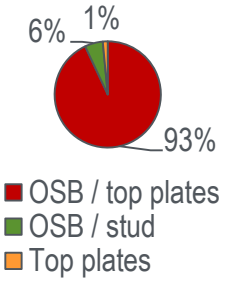
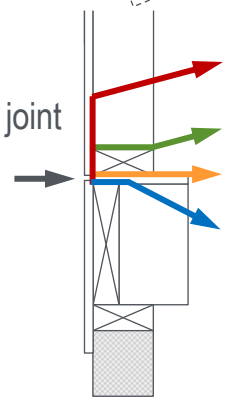
Air Leakage Effects

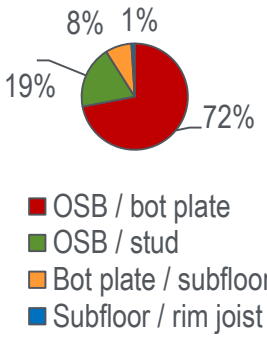
Sheathing / roof joint
1.7 (L/s)/m @ 50 Pa
1.1 cfm/(ft) @ 50 Pa

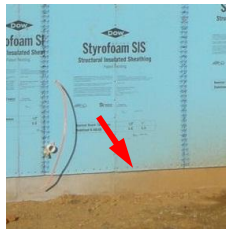




Sheathing / foundation joint
1.7 (L/s)/m @ 50 Pa
1.1 cfm/(ft) @ 50 Pa







2-Story house (Floor area = 2,000 ft²)

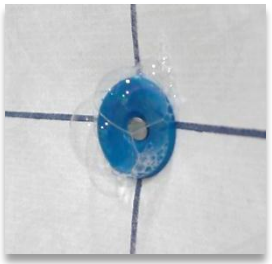
IECC 2012 requirement = 3 ACH_{50}

1. Both joints unsealed ≅ 1 ACH_{50}
   Contribution to IECC requirement ≅ 33%
2. Both joints unsealed + bottom plate sealed to flooring + top plates continuously sealed ≅ 0.96 ACH_{50}
   Contribution to IECC requirement ≅ 32%

Sub-Assembly Tests: Comparison of Air Barrier Types

- Airtight drywall approach (ADA)
  - Economical
  - Time consuming

- Mechanically-fastened membrane
  - Economical
  - Air leaked at nailed fasteners
  - Will repeat test with screwed fasteners



- Non-insulating sheathing
  - Easier to meet wall assembly airtightness requirements
  - More expensive than ADA

- Fluid-applied membrane
  - Easier to meet wall assembly airtightness requirements
  - More expensive than other tested systems

Project Plan & Schedule

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Summary		Legend	
			Work completed
			Active Task
			Milestones & Deliverables (Original Plan)
			Milestones & Deliverables (Actual)

	FY2012				FY2013				FY2014			
Task / Event	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Octt-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Project Name: Air Barriers for Residential and Commercial Buildings												
Complete CRADA with ABAA												
Interim report for Phase 2												
Current work and future research												
Q1: Heat-air-moisture chamber quality assurance test and delivery to ORNL												
Q2: Complete first year of Phase 2												
Q3: Commissioning of heat-air-moisture chamber												
Q4: Continue Phase 3												
Continue Phase 2 tests												
Airtightness assessment of Flexible Research Platform (FRP) facilities												

Project Budget

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Project budget

- FY13 project budget is $275K ($150K from ET and $125K from RBI)

Variances

- No variances from planned budget

Cost to date

- As of 20 March, $115K or 42% of budget expended

Additional funding

- No other funding sources beyond in-kind contributions

Budget History					
FY2010		FY2011		FY2012	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$550K	$300K	$400K	$300K	$400K	$600K

Project Integration, Collaboration & Market Impact

Partners and Technology Transfer

Communications

- Hun and Desjarlais (2011) Update to ABAA research participants, Syracuse, NY
- Hun and Desjarlais (2012) Air Barrier Conference, Chicago, IL
- Hun and Desjarlais (2013) Durability + Design Journal
- Hun and Desjarlais (2013) Air Barrier Conference, Chicago, IL
- Hun and Desjarlais (2013) Update to ABAA research participants, Indianapolis, IN
- Hun et al. (2013) Buildings XII Conference, Clearwater, FL

Next Steps and Future Plans: Continue CRADA with ABAA

- Continue monitoring some of the Phase 2 panels
- Finish sub-assembly tests
- Airtightness retrofits of Flexible Research Platforms
  - Simulate light commercial buildings from the 1980s
  - 1-story FRP: Metal Building Manufacturers Association (MBMA)
  - 2-story FRP: Energy Efficient Buildings Hub (EEB Hub)

MBMA METAL BUILDING MANUFACTURERS ASSOCIATION ©

eebHUB Energy Efficient Buildings Hub
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