# Air Infiltration Prevention – What the Test Results Showed

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*Dedicated to improving home building since 1964.*

# NAHB Research Center History

- **Founded in 1964**
- **Wholly-owned subsidiary of NAHB**
- **Independent, for-profit research firm**
- **Originally a small product testing lab**
- **Grown to full-service housing technology/product research firm**

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# NAHB Research Center Mission

**To improve the quality and affordability of housing…**

# Methodology

**Promote innovation in home building products/systems, technology, and construction processes**

# Capabilities

- **Market Research**
- **ISO 17025 accredited Test Lab**
- **Field Evaluations & Demonstrations**
- **Information Dissemination**
  - **www.Toolbase.org**
- **Green Building Certification**

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# Laboratory Credentials

***Recognized test laboratory, quality assurance agency, and certified product listing agency***

- **IAS** *(International Accreditation Service)*
- **NIST – NVLAP** *(National Voluntary Laboratory Accreditation Program)*
- **U.S. Department of Housing & Urban Development Product Standards & Certification**
- **IAPMO** *(International Association of Plumbing and Mechanical Officials)*
- **City of Los Angeles, CA - Testing Agency License**

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# Lab & Market Research Facility

***Completed Spring 2007***

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# Shear Wall Structural Testing


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# Universal Test Machine


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# Calibrated Hot Box

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# The Changing Market

- **Energy Costs are rising rapidly**
- **80% of builders report energy efficiency impact their decisions**
- **Green building is gaining momentum**

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# Air Infiltration Opportunities

- **Windows/Doors**
- **Sill plates**
- **Band joists**
- **Penetrations**
- **Floors/Ceilings**
- **Walls**

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# Preventing Air Infiltration Options - Walls

- **Air Sealing Options**
  - **Caulk plates & seams**
  - **“picture fame” sealing**
- **House wrap**
- **Sealed sheathing systems**
- **Foaming**
- **Alternate technology (e.g. SIP, ICF)**

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# Test Wall

- 8’ x 8’
- Vinyl Siding
- House wrap (optional w/ & w/o taped seams)
- OSB sheathing (7/16”)
- 2 x 4 framing
  - 16” OC
  - Single bottom plate
  - Double top plate
- Various insulation materials
- ½ drywall
  - Screwed on
  - 1 coat of tape joint compound

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# Test Wall

- **74 % of new homes use OSB or plywood sheathing**
- **73% use house wrap**
- **22% use vinyl siding**

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# TEST WALL

- **OSB installation**
  - **Horizontal**
  - **1/8” gap between sheets**
- **Penetrations**
  - **One interior electrical box/outlet w/ cover plate**
  - **One horizontal wiring run**

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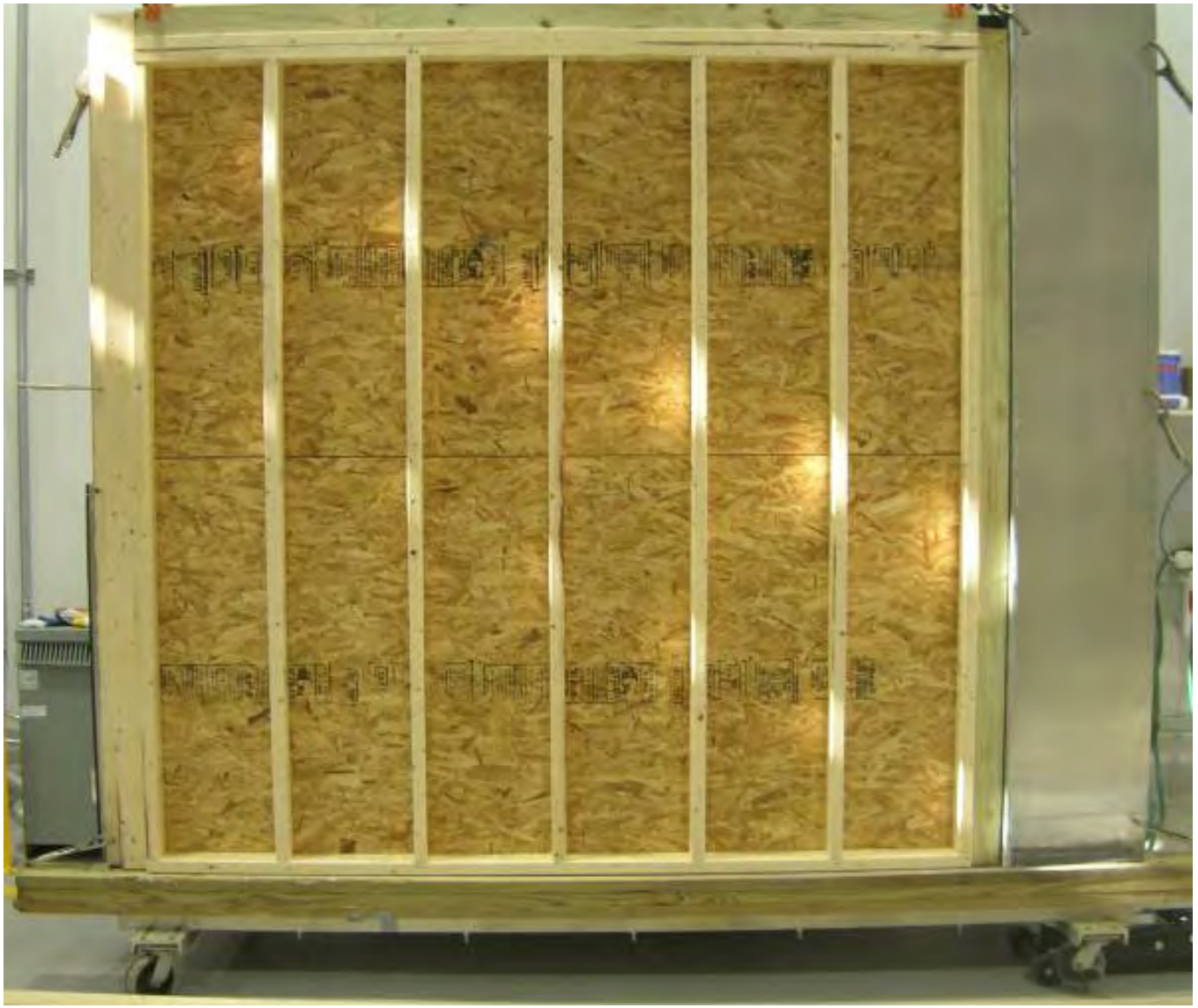
# Test Wall



# Test Wall
# House Wrap Details


1” cap nails

6” seam overlap

# TEST WALL INSULATION

- **Insulation systems**
  - **Inset stapled kraft faced R-13 fiberglass batt**
  - **Face stapled kraft faced R-13 fiberglass batt**
  - **Net & blow loose fill fiberglass**
  - **Wet spray cellulose**
  - **½ pcf spray foam**
- **Contractor used for installation of net & blow, cellulose, and foam**

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# TEST Wall Installation

- **Top, bottom, & sides sealed to chamber with gasket & caulk**
- **Drywall sealing**
  - **Top & Sides caulked to framing**
    - **Typically wall would extend and would be taped to ceiling**
  - **Bottom not sealed**
    - **Typically no additional sealing drywall to frame at base.**

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# Test Plan

- **Test base wall w/o insulation**
- **Keep the “frame” constant**
- **Install insulation and/or house wrap & retest**
- **Modify system configuration & re-test**

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# Test Method

- **ASTM E283**
  - **Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen**

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# Test Method

- Install test wall
- Cover/seal wall with plastic film
- Pressurize the chamber
- Measure flow to determine test chamber/system leakage
- Remove plastic film
- Pressurize chamber & measure leakage thru wall & chamber
- Subtract system leakage to get wall leakage

- Air flow from exterior to interior

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# Test Method

- **Air flow measurement**
  - **Calibrated orifice plate**
  - **Inclined manometer**
  - **Two orifice plates available**
    - **Flow rate determined which plate to measure with**
    - **Each plate had a different uncertainty**

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# Test Plan - Wall 1

| Test | House Wrap | Insulation |
|---|---|---|
| 1-1 | none | None |
| 1-2 | none | R-13 FG batt – inset stapled |
| 1-2A | house wrap | R-13 FG batt – inset stapled |
| 1-2B | house wrap – taped joints | R-13 FG batt – inset stapled |
| 1-2C | house wrap – taped joints | R-13 FG batt – face stapled |
| 1-3 | house wrap – taped joints | R-15 blown in fiber glass |
| 1-1A | house wrap – taped joints | None |
| 1-4 | none | R-13 damp spray cellulose |
| 1-4A | house wrap | R-13 damp spray cellulose |
| 1-4B | house wrap – taped joints | R-13 damp spray cellulose |
| 1-2D* | house wrap – taped joints | R-13 FG batt – inset stapled |
| 1-5 | none | 0.5 pcf spray foam |
| 1-5A | house wrap | 0.5 pcf spray foam |
| 1-5B | house wrap – taped joints | 0.5 pcf spray foam |

* Vinyl siding added

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# Test Results - Wall 1 Fiberglass Insulation

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-1 | no insulation no house wrap | 6.2 | 12.3 |
| 1-2 | inset FG batt no house wrap | 3.6 | 7.2 |
| % reduction with R-13 inset Fiberglass | | 42% | 41% |

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# Test Results - Wall 1 Fiberglass Insulation

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-2 | inset FG batt no house wrap | 3.6 | 7.2 |
| 1-2A | inset FG batt house wrap | 0.86 | 1.8 |
| 1-2B | inset FG batt taped house wrap | 0.37 | 0.35 |

| | | |
|---|---|---|
| % reduction by adding house wrap | 76% | 75% |
| % reduction with taping house wrap seams | | |
| From no house wrap | 90% | 95% |
| From with house wrap | 57% | 80% |

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# Test Results - Wall 1 Fiberglass Insulation Inset vs Face Stapling

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-2B | inset FG batt taped house wrap | 0.37 | 0.35 |
| 1-2C | face FG stapled taped house wrap | 0.26 | 0.4 |

% reduction with face stapling 30%

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# Test Results - Wall 1
# Fiberglass Insulation
# Inset staple vs net & blow

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-2B | inset FG batt taped house wrap | 0.37 | 0.35 |
| 1-3 | blown in FG taped house wrap | 0.04 | 0.1 |
| % reduction with net & blow system | | 89% | 71% |

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# Test Results - Wall 1 Cellulose Insulation

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-1 | no insulation no house wrap | 6.2 | 12.3 |
| 1-4 | cellulose no house wrap | 1.29 | 2.7 |

| | | |
|---|---|---|
| % reduction with wet spray cellulose | 79% | 78% |

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# Test Results - Wall 1 Cellulose Insulation

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-4 | cellulose no house wrap | 1.29 | 2.7 |
| 1-4A | cellulose house wrap not taped | 0.41 | 0.8 |
| 1-4B | cellulose taped house wrap | 0.08 | 0.01 |

| | | |
|---|---|---|
| % reduction by adding house wrap | 68% | 70% |
| % reduction with taped house wrap seams | | |
| From no house wrap | 94% | 99% |
| From with house wrap | 80% | 99% |

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# Test Results - Wall 1
# Spray Foam Insulation

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-1 | no insulation no house wrap | 6.2 | 12.3 |
| 1-5 | spray foam no house wrap | 0.00 | 0.1 |
| 1-5A | spray foam house wrap not taped | 0.00 | 0.0 |
| 1-5B | spray foam taped house wrap | 0.00 | 0.0 |

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# Testing Repeatability

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-2 | inset FG batt no house wrap | 3.6 | 7.9 |
| 1-2 (repeat) | inset FG batt no house wrap | 3.6 | 6.4 |
| | % difference | 0 | 19% |
| 1-2A | inset FG batt house wrap not taped | 1.11 | 2.9 |
| 1-2A (repeat) | inset FG batt house wrap not taped | 0.60 | 0.7 |
| | % difference | 46% | 75% |
| 1-2B | inset FG batt taped house wrap | 0.40 | 0.4 |
| 1-2B (repeat) | inset FG batt taped house wrap | 0.33 | 0.3 |
| | % difference | 18% | 25% |

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# House Wrap Effect

| | Fiberglass (inset) | | Cellulose | |
|---|---|---|---|---|
| | 0.1” | 0.3” | 0.1” | 0.3” |
| Reduction due to house wrap addition | 76% | 75% | 68% | 70% |
| Additional reduction with taped seams | 57% | 80% | 80% | 99% |

# House Wrap Effect

| | No house Wrap | | House Wrap | | House Wrap Taped Seams | |
|---|---|---|---|---|---|---|
| | CFM @ 0.1” | CFM @ 0.3” | CFM @ 0.1” | CFM @ 0.3” | CFM @ 0.1” | CFM @ 0.3” |
| Inset Fiberglass | 3.6 | 7.2 | 0.86 | 1.8 | 0.37 | 0.35 |
| Face Stapled Fiberglas | -- | -- | -- | -- | 0.47 | 0.5 |
| Net & Blow Fiberglass | -- | -- | -- | -- | 0.04 | 0.1 |
| Cellulose | 1.29 | 2.7 | .41 | 0.8 | 0.08 | 0 |
| Foam | 0 | 0.1 | 0 | 0 | 0 | 0 |

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# Siding Effect

| | House Wrap Taped Seams | | House Wrap Taped Seams Vinyl Siding | |
|---|---|---|---|---|
| | 0.1” | 0.3” | 0.1” | 0.3” |
| Inset Fiberglass | 0.37 | 0.35 | 0.47 | 0.57 |

# Test Wall 2

- **Identical construction to wall 1**
- **EXCEPT**
  - **Wall installed on top of simulated band joist/joists/subfloor**
- **No sealing between bottom plate and subfloor**

- **Test chamber limited the depth of joist to 2x4**

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# Simulated floor system

# Test Results
# Wall 1 vs Wall 2

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-2 | inset FG batt no house wrap | 3.6 | 7.2 |
| 1-6 | inset FG batt no house wrap w/ Band Joist | 7.2 | 14.1 |

The band joist simulation doubled the air leakage

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# Test Results
# Wall 1 vs Wall 2

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-2A | inset FG batt house wrap | 0.86 | 1.8 |
| 1-6A | inset FG batt house wrap With Band Joist | 2.06 | 3.7 |

The band joist simulation doubled the air leakage

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# Test Results
# Wall 1 vs Wall 2

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-2B | inset FG batt taped house wrap | 0.37 | 0.35 |
| 1-6B | inset FG batt taped house wrap w/ Band Joist | 1.23 | 2.1 |

The band joist simulation more than tripled the air leakage

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# Test Results – Wall 2 over Band Joist

| Test | Description (with band joist) | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-6 | inset FG batt no house wrap | 7.2 | 14.1 |
| 1-6A | inset FG batt house wrap not taped | 2.06 | 3.7 |
| 1-6B | inset FG batt taped house wrap | 1.23 | 2.1 |

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# Test Results – Wall 2 over Band Joist

| % Reduction | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|
| By adding house wrap | 71% | 74% |
| After taping house wrap (reduction from no wrap) | 83% | 85% |

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# Test Wall 3

- **Identical construction as Wall 1**
- **EXCEPT**
  - **Air sealed with caulk**
    - **Gap between OSB sheathing**
    - **“picture frame” inside of wall cavity**

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# Caulking Detail

# Test Results
# Wall 1 vs Wall 3

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-2 | inset FG batt no house wrap | 3.6 | 7.2 |
| 2-1 | inset FG batt no house wrap caulked | 0.83 | 1.2 |
| Air Infiltration Reduction due to Caulking | | 77% | 83% |

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# Test Results
# Wall 1 vs Wall 3

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-2B | inset FG batt taped house wrap | 0.37 | 0.35 |
| 2-1A | inset FG batt taped house wrap caulked | 0.16 | 0.01 |

| | | |
|---|---|---|
| Air Infiltration Reduction due to Caulking | 57% | 97% |

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# Test Results
# Wall 1 vs Wall 3

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-2C | face FG stapled taped house wrap | 0.26 | 0.4 |
| 2-2A | face stapled FG batt taped house wrap caulked | 0.16 | 0.1 |

| | | |
|---|---|---|
| Air Infiltration Reduction due to Caulking | 38% | 75% |

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# Test Results
# Wall 1 vs Wall 3

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 1-3 | blown in FG taped house wrap | 0.04 | 0.1 |
| 2-2C | blown in FG taped house wrap caulked | 0.00 | 0.2 |

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# Test Results
# Wall 4

| Test | Description | CFM @ 0.1 W.C. | CFM @ 0.3 W.C. |
|---|---|---|---|
| 2-3A | spray foam<br>house wrap not taped<br>w/ band Joist | 0.87 | 1.3 |
| 2-3B | spray foam<br>taped house wrap<br>w/ band Joist | 0.56 | 0.8 |

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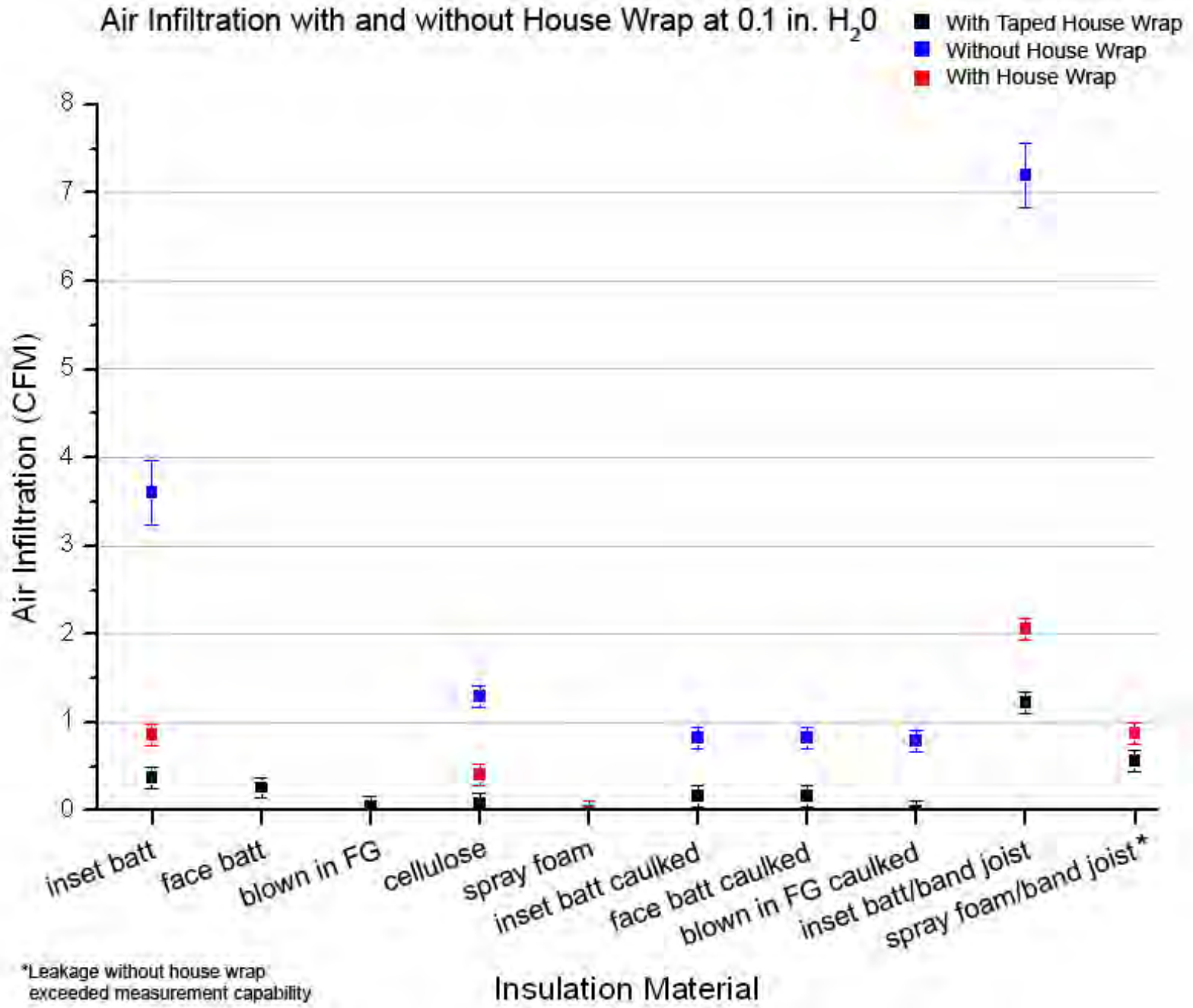
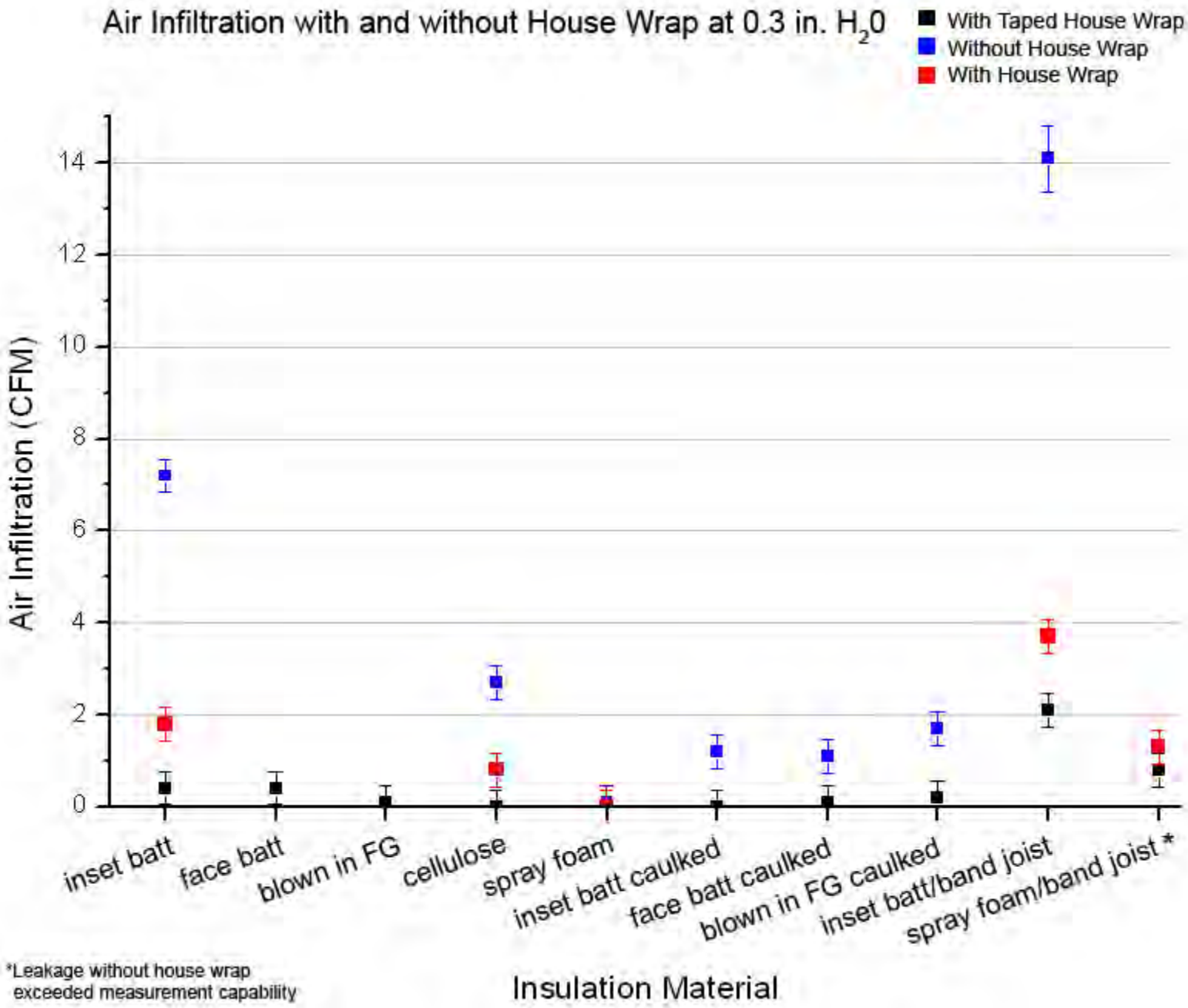

Air Infiltration with and without House Wrap at 0.1 in. $H_20$
With Taped House Wrap
Without House Wrap
With House Wrap
Air Infiltration (CFM)
0
1
2
3
4
5
6
7
8
inset batt
face batt
blown in FG
cellulose
spray foam
inset batt caulked
face batt caulked
blown in FG caulked
inset batt/band joist
spray foam/band joist*
*Leakage without house wrap exceeded measurement capability
Insulation Material


Air Infiltration with and without House Wrap at 0.3 in. $H_20$
With Taped House Wrap
Without House Wrap
With House Wrap
Air Infiltration (CFM)
0
2
4
6
8
10
12
14
inset batt
face batt
blown in FG
cellulose
spray foam
inset batt caulked
face batt caulked
blown in FG caulked
inset batt/band joist
spray foam/band joist *
*Leakage without house wrap exceeded measurement capability
Insulation Material

# Test Wall 5

- **Similar to wall 1**
- **Except**
  - **Wall dimension 8.5’ high x 10’ long**
  - **Horizontal OSB**
    - **Two horizontal 1/8” gaps**

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# TEST WALL 5

# Test Wall 6

- **Same as Wall 5**
- **Except**
  - **Vertical OSB**
    - **4’ x 9’ panels**
    - **Gapped 1/8” @ seams but all seams on framing**

# Test Results

| Test Wall | CFM At 0.1” H2O | | CFM At 0.3” H2O | |
|---|---|---|---|---|
| | 4 x 8 panels Wall 5 | 4 x 9 Panels Wall 6 | 4 x 8 panels Wall 5 | 4 x 9 Panels Wall 6 |
| Base Wall | 3.72 | 2.30 | 8.50 | 4.85 |
| With House Wrap | 2.49 | 1.76 | 3.86 | 3.03 |
| With House Wrap Taped | 0.48 | 0.21 | 1.24 | 0.46 |

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# Test Wall 7

- **Similar to Test Wall 1**
- **Except**
  - **8’ high x 10’ long**
  - **Vertical OSB (no horizontal gaps)**
  - **House wrap – no tape**
  - **Vinyl Siding**
  - **Net & blow fiberglass insulation**

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# Test Results – Wall 7
# Density Effect
# Fiberglass

| Density pcf | CFM @ 0.2” | CFM @ 0.3” |
|---|---|---|
| 1.85 (typical) | 1.65 | 2.25 |
| 2.46 (dense pack) | 1.27 | 1.51 |

| | | |
|---|---|---|
| Reduction due to dense packing | 23% | 33% |

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# Test Results – Wall 7
# Density Effect
# Cellulose

| Density pcf | CFM @ 0.2” | CFM @ 0.3” |
|---|---|---|
| 3.00 (typical) | 1.60 | 2.04 |
| 3.74 (dense pack) | 1.30 | 1.64 |

Reduction due to dense packing 19% 20%

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# Test Results – Wall 7 Spray Foam

| CFM @ 0.2” | CFM @ 0.3” |
|---|---|
| 1.39 | 2.53 |

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# Conclusions

- **For clear walls with fiberglass or cellulose insulation**
  - **House wrap provides a significant reduction in air infiltration (~75%)**
  - **Taping house wrap seams provides another significant reduction (~50-90%)**

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# Conclusions

- **For clear walls with band joist and with fiberglass or cellulose insulation**
  - **House wrap provides a significant reduction in air infiltration (~70-75%)**
  - **Taping house wrap seams provides another significant reduction (~40-45%)**

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# Conclusions

- **For tall clear walls eliminating horizontal gaps reduces air infiltration 25-60%**
- **Dense packing blown in systems reduces air infiltration by 20-30%**

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# Conclusions

- **Details are important**
- **Remember**
  - **Clear walls are not the only source of air infiltration**

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- **Thanks to**
  - **NAIMA**
  - **Norbord**
  - **Owens Corning**

**For allowing the use of their data**


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