
# Concealed Insulation Defects

## SHOULD YOU WORRY ABOUT THINGS YOU CANNOT SEE?

# Disclaimer

*SPFA does NOT warrant, represent, or guarantee the safety practices or workmanship of these materials used by any contractor and specifically disclaims any and all liability and responsibility for any injuries, losses, or damages of any kind or nature arising out of a contractor's performance, materials used, or the contractor's use of or reliance upon this document and its contents.*

# Copyright

## Richard S. Duncan, Ph.D., P.E.
## Technical Director, Spray Polyurethane Foam Alliance

Rick is currently Technical Director for the Spray Polyurethane Foam Alliance. Prior to joining SPFA, he was the Senior Marketing Manager for Honeywell's Spray Foam Insulation business from 2006 to 2008. From 1997 to 2006, he was the Global Program Director for CertainTeed/Saint-Gobain Insulation's New Materials and Applications Portfolio. From 1989 to 1997 he was a Visiting Assistant Professor of Mechanical Engineering at Bucknell University. He holds a Ph.D. in Engineering Science and Mechanics from The Pennsylvania State University, MSME from Bucknell and a BSME from the University of Maryland. Rick is a Registered Professional Engineer in Pennsylvania and is a certified BPI Building Analyst.

# Introduction

This presentation will discuss how to identify both visible and concealed insulation defects, along with their causes and remedies. If will also discuss the importance of these defects as they relate to thermal performance of the building envelope.

# Overview

Visible and Concealed Insulation Defects
- Identification
- Cause
- Remedy

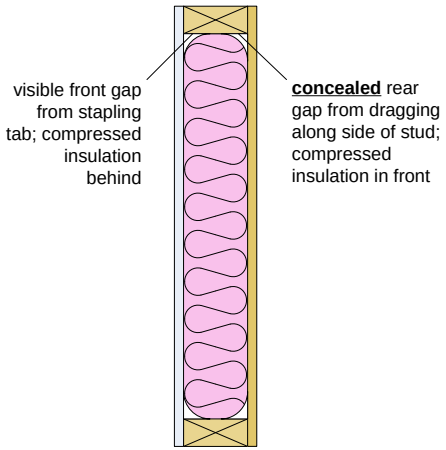
Inspection Techniques for Concealed Defects

Impact of Concealed Defects
- Thermal Performance
- Air-Barrier Performance (SPF)

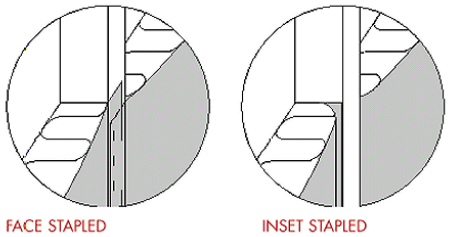
Summary

Questions

# Insulation Defects: Inset Stapling




Inset Stapling




**Identification:**

- Visible front air gap on sides of batt running along entire length of stud or joist
- Concealed rear air gap along rear sides of batt along entire length

**Cause:**

- Front gap from stapling tab to side of stud or joist
- Rear gap from dragging during installation

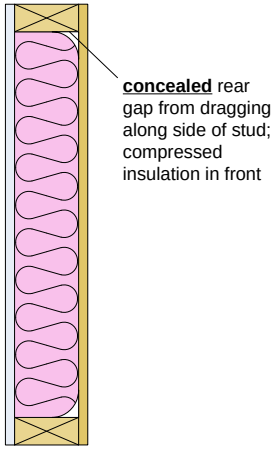
**Concern:**

- Convection cell development on both sides of batt
- Compressed insulation on sides of batt

**Remedy:**

- Don’t inset staple, or use tab-less friction-fit batts

# Insulation Defects: Friction-Fit Batts




Friction-Fit Batts

**Identification:**

- Concealed rear air gap along rear sides of batt along entire length

**Cause:**

- Rear gap from dragging during installation

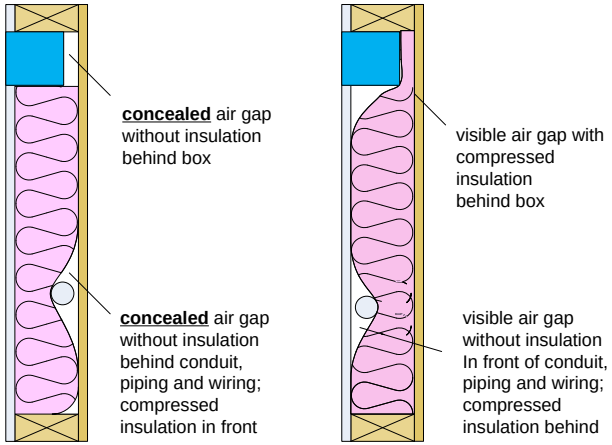
**Concern:**

- Missing insulation in cavity corners
- Compressed insulation along sides of batt
- Not as serious issue as inset stapling in terms of convection cell development

**Remedy:**

- Use loose-fill insulation

# Insulation Defects: Cavity Wiring and Piping




Piping and Wiring

**Identification:**

- Concealed air gap behind outlet boxes, wiring and piping
- Visible air gap when insulation is compressed behind wiring and piping

**Cause:**

- Improper trimming of batt
- Hasty installation procedures

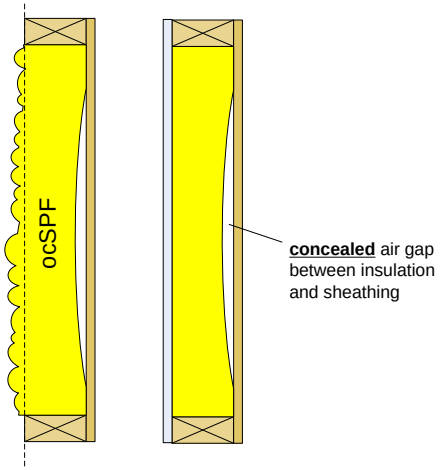
**Concern:**

- Missing insulation
- Compressed insulation

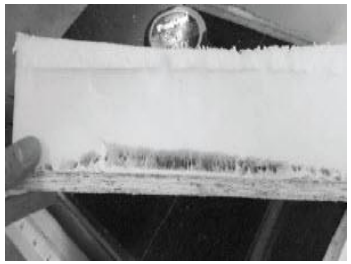
**Remedy:**

- Installer training to cut and fill batts into these areas

# Insulation Defects: Poor SPF Adhesion




Poor Adhesion to Substrate



**Identification:**

- Concealed air gap between insulation and sheathing
- Typically ¼" to ½" thick gap
- Most common with ocSPF

**Cause:**

- Moisture on substrates
- Application technique and equipment setup

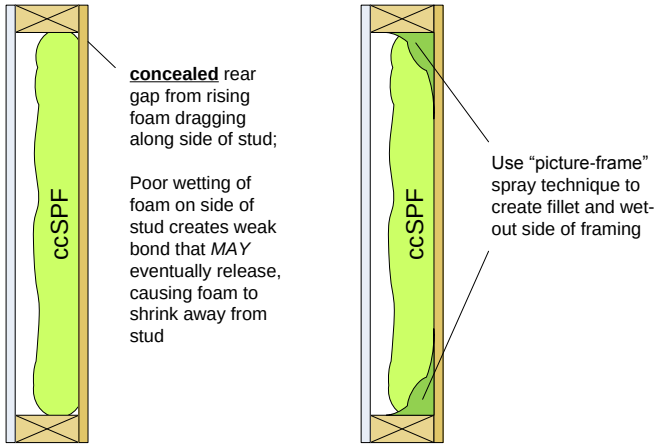
**Concern:**

- Missing insulation R-value

**Remedy:**

- Installer training
- Can be immediately repaired by injection procedure

# Insulation Defects: Stud/Sheathing Voids




**Identification:**

- Concealed air gap between studs and sheathing
- Can occur with ccSPF or ocSPF

**Cause:**

- Improper spray pattern (ocSPF)
- Improper application technique

**Concern:**

- Poor or zero adhesion to stud wall
- May result in delamination and shrinkage (ccSPF)

**Remedy:**

- Proper spray pattern (ocSPF)
- Use of "picture-framing" technique

# Insulation Defects: Cavity Wiring and Piping


**concealed** air gap without insulation behind box

Junction/Outlet Box

**Identification:**

- Concealed air gap between junction box and sheathing
- Can occur with ccSPF or ocSPF
- Inspect/probe wire openings of outlet box

**Cause:**

- Improper application
- Hasty installation procedures

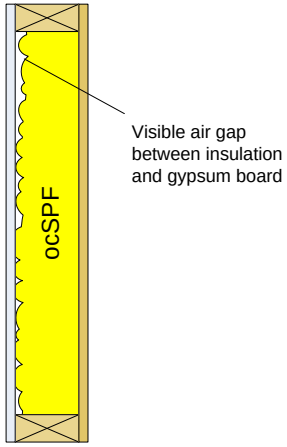
**Concern:**

- Missing insulation R-value
- Air leakage if box is mounted on a stud with a sheathing seam

**Remedy:**

- Installer training
- Can inject can foam into outlet box openings

# Insulation Defects: Underfilled Cavities




Slightly Underfilled Cavity

**Identification:**

- Visible air gap between insulation and gypsum board
- Can occur with ocSPF to minimize trip waste

**Cause:**

- Incomplete cavity fill
- Used to reduce ocSPF scrap

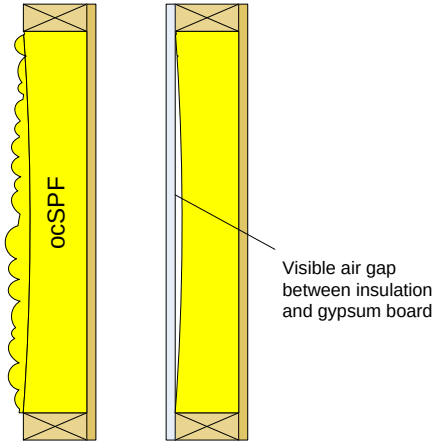
**Concern:**

- Missing insulation R-value (?)

**Remedy:**

- It depends on extent and depth of underfill

# Insulation Defects: Concave Trimming




Concave Face Trimming

**Identification:**

- Visible air gap between insulation and gypsum board
- Can occur with ocSPF during trimming

**Cause:**

- Flexible trimming saw with too much pressure

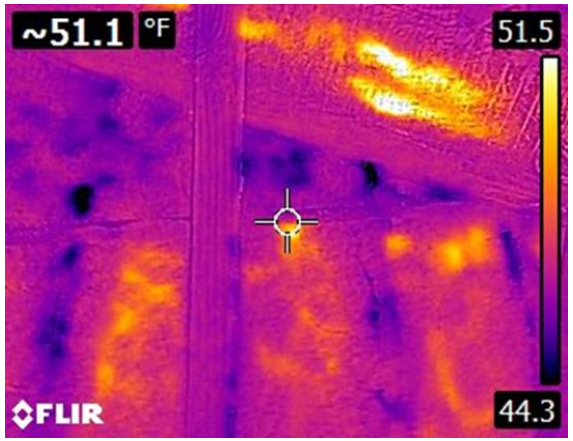
**Concern:**

- Missing insulation R-value (?)

**Remedy:**

- Modify trimming technique
- Use different trimming equipment

# Inspection and Detection Techniques: Non-Destructive




Courtesy Mason Knowles Consulting

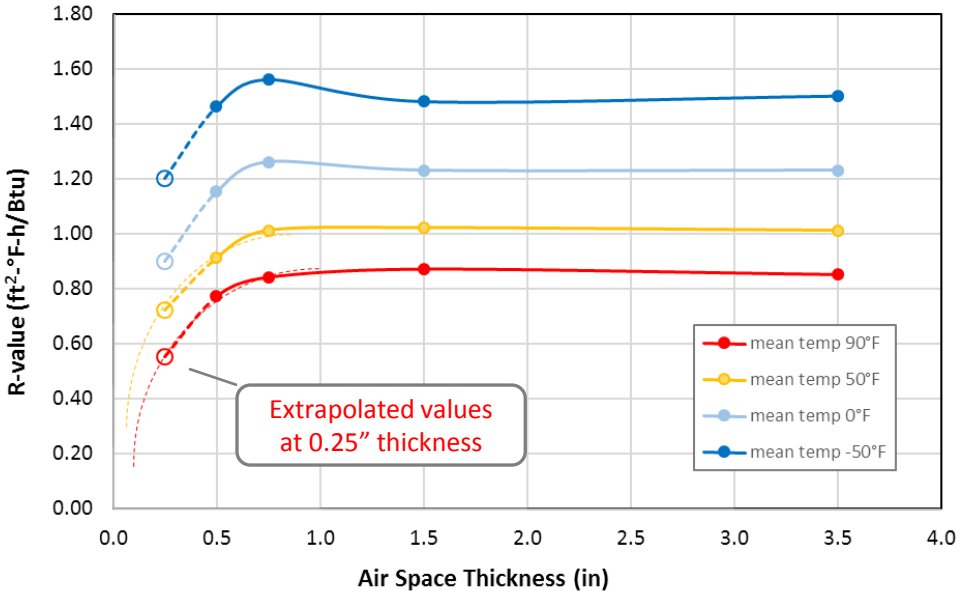
**IR Imaging**

Emphasizes surface defects (cold spots not warmed by interior surface convection)

May not show hidden interior defects

***Most hidden SPF delamination defects can be detected by pushing or knocking on insulation.***

# Impact of Concealed Defects: Thermal Performance of Air-Gaps

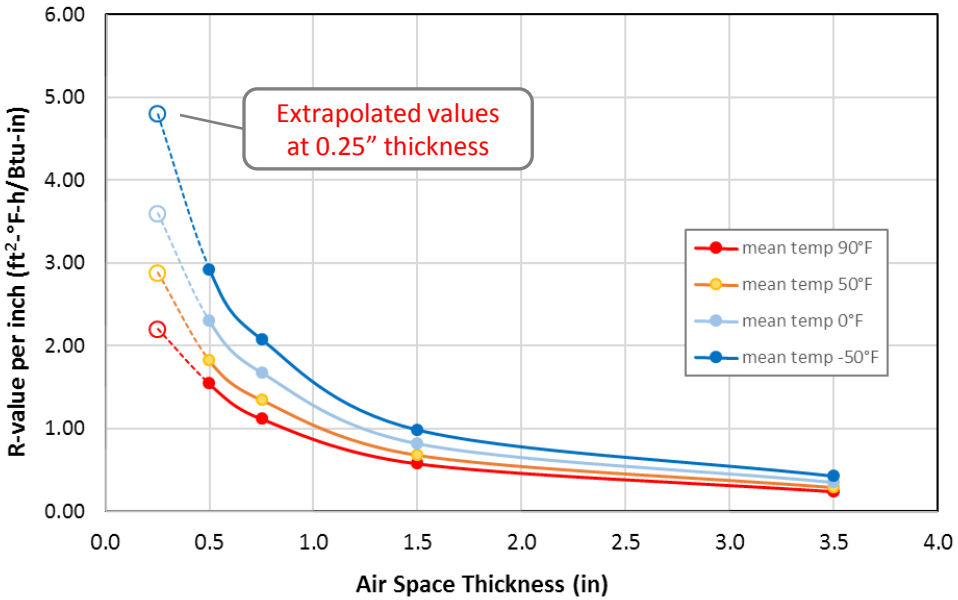



$\varepsilon_{eff} = 0.82$
$\Delta T = 10°F$

**2005 ASHRAE Handbook of Fundamentals, Ch 25 Table 3** (Robinson et al. 1954)

- R-value versus thickness of air gap (0.5" to 3.5") for heat flow in different directions
- Function of mean air gap temperature and temperature difference, emissivity of gap surfaces
- Assumes air gap is sealed against air leakage

# Impact of Concealed Defects: Thermal Performance of Air-Gaps

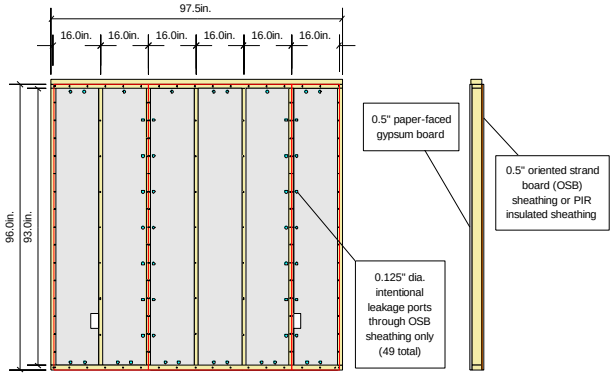



$\varepsilon_{eff} = 0.82$
$\Delta T = 10°F$

**Convert to R-value per inch thickness versus gap thickness**

- R-value/inch increase with decreasing gap thickness, approaching that of insulation as gap size decreases below ½"
- Do small air gaps in the insulation actually reduce R-value?

# Impact of Concealed Defects: Thermal Performance of Air-Gaps

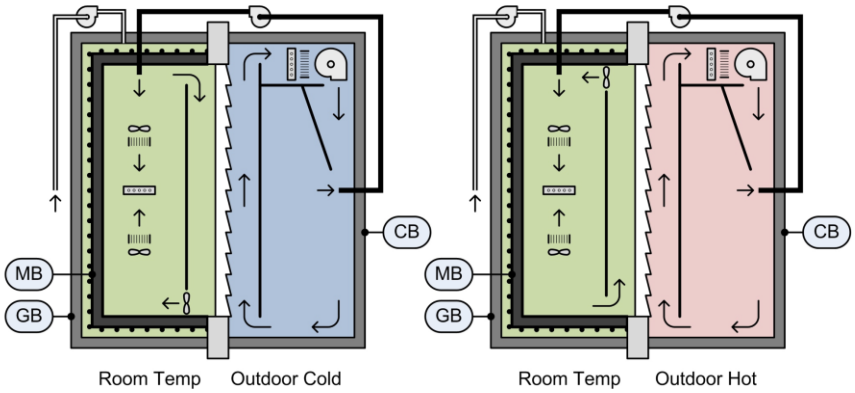


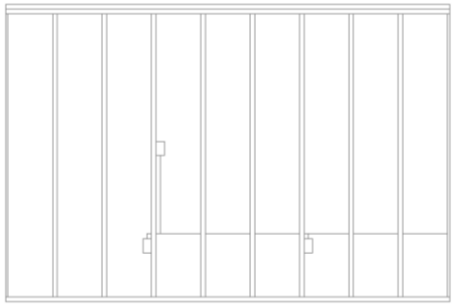

**SPFA-funded C1363 Testing at ATI (2007)**

- ocSPF was applied to nearly fill the cavity and then trimmed (see photo below)
- Under-filled area about 40-50% of cavity surface
- Average under-fill was about 0.35”
- Full-cavity R-value: R3.6/inch x 3.5” = R12.6
- C1363 measured R-value: R12.35
- Calculated R-value for R air-gap=0:
  - R3.6/inch x (3.5-0.35) = R11.34 over half cavity area
  - R11.34*50%+R12.6*50% = R11.95
- Calculated R-value for R air-gap=R2.5/inch:
  - R3.6/inch x (3.5-0.35)+ R2.5/inch x (0.35) = R12.21 over half cavity area
  - R12.21*50%+R12.6*50% = R12.41

Small air gap has measureable R-value and should not be assumed zero.

# Impact of Concealed Defects: Thermal Performance



**Building Science Corp Thermal Metric Project (June 2015)**

- Eight typical wood-frame walls constructed
- Thermal performance measured with advanced guarded hotbox apparatus
- Like C1363, but includes effect of air leakage and interaction between air leakage and R-value
- Thermal performance of real-world wall assemblies under extreme temperature conditions
- Shows impact of inset stapling, delamination of ocSPF.

# Impact of Concealed Defects: Thermal Performance

| Wall ID | Insulation | Cavity R-value | WINTER (-1°F) ENERGY FLOW (Btu/hr) | | | | | SUMMER (+108°F) ENERGY FLOW (Btu/hr) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sealed | As-Built | InFil+ExFil | InFil | Hole | Sealed | As-Built | InFil+ExFil | InFil | Hole |
| 2 | R13 FG Inset Stapled | 13.0 | 466 | 524 | 619 | 835 | 889 | 270 | 303 | 340 | 437 | 465 |
| 3 | R13 FG Face Stapled | 13.0 | 442 | 494 | 586 | 777 | 821 | 285 | 297 | 357 | 454 | 457 |
| 4 | Damp Spray Cellulose | | 463 | 508 | 566 | 713 | 745 | 260 | 298 | 320 | 386 | 378 |
| 5 | Open-Cell SPF | 12.6 | 475 | 529 | 548 | 594 | 568 | 286 | 317 | 340 | 371 | 344 |
| 5-II | Open-Cell SPF | 12.6 | 439 | 490 | 491 | 502 | 414 | 278 | 302 | 302 | 327 | 257 |
| 6 | Closed-Cell SPF | 12.0 | 452 | 485 | 551 | 638 | 612 | 255 | 281 | 310 | 338 | 296 |
| 7 | R13+1"XPS-ci | 13.0 (+5) | 357 | 403 | 505 | 690 | 718 | 241 | 259 | 332 | 433 | 407 |
| 8 | R21 FG Batt Unfaced | 21.0 | 344 | 401 | 490 | 718 | 776 | 200 | 247 | 242 | 338 | 378 |

| | |
|---|---|
| **Sealed** | **Continuous PE sheets installed inside drywall and outside sheathing (CONTROL). Both sides sealed**. No pressure difference applied. |
| **As-Built** | See wall panel description; all PE sheets removed |
| **InFil+ExFil** | Same as 'As-Built' with 10 Pa induced positive pressure on windward wall and 10 Pa induced negative pressure on leeward wall |
| **InFil** | Same as 'As-Built' with 10 Pa induced negative pressure on all walls from exhaust fan |
| **Hole** | Prediction of energy losses from $\dot{m} \cdot c_p \cdot \Delta T$ calculation based on measured air leakage |

| 8' x 12' wall panels tested | | | | |
|---|---|---|---|---|
| Frame | Interior | Exterior | WRB | Ext. Cladding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 1" XPS | none | vinyl siding |
| 2x6-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| | | | | |
| All GWB and OSB shimmed to provide controlled air gap | | | | |

# Impact of Concealed Defects: Thermal Performance

| Wall ID | Insulation | Cavity R-value | WINTER (-1°F) ENERGY FLOW (Btu/hr) | | | | | SUMMER (+108°F) ENERGY FLOW (Btu/hr) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sealed | As-Built | InFil+ExFil | InFil | Hole | Sealed | As-Built | InFil+ExFil | InFil | Hole |
| 2 | R13 FG Inset Stapled | 13.0 | 466 | 524 | 619 | 835 | 889 | 270 | 303 | 340 | 437 | 465 |
| 3 | R13 FG Face Stapled | 13.0 | 442 | 494 | 586 | 777 | 821 | 285 | 297 | 357 | 454 | 457 |
| 4 | Damp Spray Cellulose | | 463 | 508 | 566 | 713 | 745 | 260 | 298 | 320 | 386 | 378 |
| 5 | Open-Cell SPF | 12.6 | 475 | 529 | 548 | 594 | 568 | 286 | 317 | 340 | 371 | 344 |
| 5-II | Open-Cell SPF | 12.6 | 439 | 490 | 491 | 502 | 414 | 278 | 302 | 302 | 327 | 257 |
| 6 | Closed-Cell SPF | 12.0 | 452 | 485 | 551 | 638 | 612 | 255 | 281 | 310 | 338 | 296 |
| 7 | R13+1"XPS-ci | 13.0 (+5) | 357 | 403 | 505 | 690 | 718 | 241 | 259 | 332 | 433 | 407 |
| 8 | R21 FG Batt Unfaced | 21.0 | 344 | 401 | 490 | 718 | 776 | 200 | 247 | 242 | 338 | 378 |

| | |
|---|---|
| **Sealed** | **Continuous PE sheets installed inside drywall and outside sheathing (CONTROL). Both sides sealed**. No pressure difference applied. |
| **As-Built** | See wall panel description; all PE sheets removed |
| **InFil+ExFil** | Same as 'As-Built' with 10 Pa induced positive pressure on windward wall and 10 Pa induced negative pressure on leeward wall |
| **InFil** | Same as 'As-Built' with 10 Pa induced negative pressure on all walls from exhaust fan |
| **Hole** | Prediction of energy losses from $\dot{m} \cdot c_p \cdot \Delta T$ calculation based on measured air leakage |

*Small (5%) differences between inset and face stapled batts*

| 8' x 12' wall panels tested | | | | |
|---|---|---|---|---|
| Frame | Interior | Exterior | WRB | Ext. Cladding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| 2x4-16 | 1/2" GWB | 1" XPS | none | vinyl siding |
| 2x6-16 | 1/2" GWB | 7/16" OSB | SBPO wrap | vinyl siding |
| | | | | |
| All GWB and OSB shimmed to provide controlled air gap | | | | |

# Impact of Concealed Defects: Thermal Performance

| Wall ID | Insulation | Cavity R-value | WINTER (-1°F) ENERGY FLOW (Btu/hr) | | | | | SUMMER (+108°F) ENERGY FLOW (Btu/hr) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sealed | As-Built | InFil+ExFil | InFil | Hole | Sealed | As-Built | InFil+ExFil | InFil | Hole |
| 2 | R13 FG Inset Stapled | 13.0 | 466 | 524 | 619 | 835 | 889 | 270 | 303 | 340 | 437 | 465 |
| 3 | R13 FG Face Stapled | 13.0 | 442 | 494 | 586 | 777 | 821 | 285 | 297 | 357 | 454 | 457 |
| 4 | Damp Spray Cellulose | | 463 | 508 | 566 | 713 | 745 | 260 | 298 | 320 | 386 | 378 |
| 5 | Open-Cell SPF | 12.6 | 475 | 529 | 548 | 594 | 568 | 286 | 317 | 340 | 371 | 344 |
| 5-II | Open-Cell SPF | 12.6 | 439 | 490 | 491 | 502 | 414 | 278 | 302 | 302 | 327 | 257 |
| 6 | Closed-Cell SPF | 12.0 | 452 | 485 | 551 | 638 | 612 | 255 | 281 | 310 | 338 | 296 |
| 7 | R13+1"XPS-ci | 13.0 (+5) | 357 | 403 | 505 | 690 | 718 | 241 | 259 | 332 | 433 | 407 |
| 8 | R21 FG Batt Unfaced | 21.0 | 344 | 401 | 490 | 718 | 776 | 200 | 247 | 242 | 338 | 378 |

| | |
|---|---|
| **Sealed** | **Continuous PE sheets installed inside drywall and outside sheathing (CONTROL). Both sides sealed**. No pressure difference applied. |
| **As-Built** | See wall panel description; all PE sheets removed |
| **InFil+ExFil** | Same as 'As-Built' with 10 Pa induced positive pressure on windward wall and 10 Pa induced negative pressure on leeward wall |
| **InFil** | Same as 'As-Built' with 10 Pa induced negative pressure on all walls from exhaust fan |
| **Hole** | Prediction of energy losses from $\dot{m} \cdot c_p \cdot \Delta T$ calculation based on measured air leakage |

*Larger (8%) differences between ocSPF with large gap (Wall 5) and small gap (Wall 5-II)*

*Small ocSPF gap performance comparable to other insulations installed without defects…Small gaps not important!*


# Summary

- Cavity insulations can have insulation defects when installation best-practice is not followed
- Defects may be visible or concealed
- Most defects, when detected, can be repaired
- There are non-destructive means to find concealed defects in cavity insulation
- Cracks and gaps in cavity insulation may not affect cavity R-value, depending on defect size.

# Impact of Concealed Defects: Thermal Performance

| Wall ID | Energy Loss | Clear Wall R-value | WINTER (-1°F) ASSEMBLY R-VALUE | | | | | SUMMER (+108°F) ASSEMBLY R-VALUE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sealed | As-Built | ExFil | InFil | Avg ExIn | Sealed | As-Built | ExFil | InFil | Avg ExIn |
| 2 | R13 FG Inset Stapled | 13.0 | 0.97 | 0.89 | 1.15 | 0.55 | 0.85 | 0.84 | 0.77 | 0.97 | 0.53 | 0.75 |
| 3 | R13 FG Face Stapled | 13.0 | 1.01 | 0.94 | 1.17 | 0.59 | 0.88 | 0.79 | 0.80 | 0.91 | 0.51 | 0.71 |
| 4 | Damp Spray Cellulose | 13.0 | 0.96 | 0.91 | 1.11 | 0.64 | 0.88 | 0.86 | 0.78 | 0.93 | 0.60 | 0.77 |
| 5 | Open-Cell SPF | 12.8 | 0.93 | 0.86 | 0.90 | 0.76 | 0.83 | 0.79 | 0.74 | 0.75 | 0.63 | 0.69 |
| 5-II | Open-Cell SPF | 12.8 | 1.02 | 0.95 | 0.97 | 0.92 | 0.95 | 0.83 | 0.77 | 0.86 | 0.73 | 0.80 |
| 6 | Closed-Cell SPF | 12.9 | 1.01 | 0.98 | 1.02 | 0.74 | 0.88 | 0.90 | 0.85 | 0.84 | 0.69 | 0.77 |
| 7 | R13+1"XPS-ci | 17.6 | 0.95 | 0.87 | 1.10 | 0.51 | 0.80 | 0.72 | 0.69 | 0.77 | 0.41 | 0.59 |
| 8 | R21 FG Batt Unfaced | 18.9 | 0.95 | 0.83 | 1.27 | 0.46 | 0.87 | 0.82 | 0.68 | 1.17 | 0.49 | 0.83 |

| | |
|---|---|
| **Sealed** | **Continuous PE sheets installed inside drywall and outside sheathing (CONTROL). Both sides sealed**. No pressure difference applied. |
| **As-Built** | All PE sheets removed. No pressure difference applied. |
| **ExFil** | Same as 'As-Built' with 10 Pa induced positive pressure on wall |
| **InFil** | Same as 'As-Built' with 10 Pa induced negative pressure on wall |
| **Hole** | Prediction of energy losses from $\dot{m} \cdot c_p \cdot \Delta T$ calculation based on measured air leakage |