Efficiency Vermont is a Registered Provider with ***The American Institute of Architects Continuing Education Systems (AIA/CES)***. Credit(s) earned on completion of this program will be reported to ***AIA/CES*** for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This program is registered with ***AIA/CES*** for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

BETTER BUILDINGS BY DESIGN | 2012

Efficiency Vermont

Learning Objectives

- *Identify and communicate the basis for R-Values listed on product specifications and their limitations.*
- *Apply preventative approaches in designing and installing systems with potentially significant R-Value Losses*
- *Use research results presented to make better product, systems and application choices*
- *Support recommendations with real-life examples of various design choices considered*

bsc

Building America U.S. Department of Energy

R-value "Myth Busting"

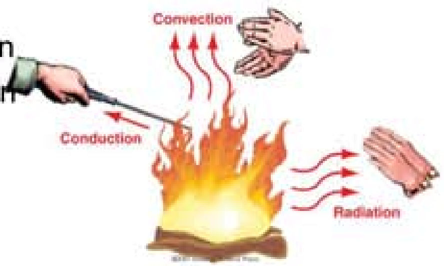
Dr John Straube, P.Eng.
Building Science Corp
Associate Professor
University of Waterloo
www.BuildingScience.com

R Values

12-02-09

How to Control Heat Flow?

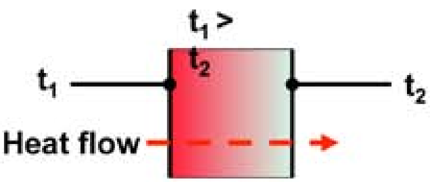
Modes of heat transfer:
- Radiation
- Convection
- Conduction



Building Science 2008 Insulation and Thermal Bridges No. 5/65

Conduction

- Heat Flow by direct contact
- Vibrating molecules
- Most important for solids



Building Science 2008 Insulation and Thermal Bridges No. 6/65

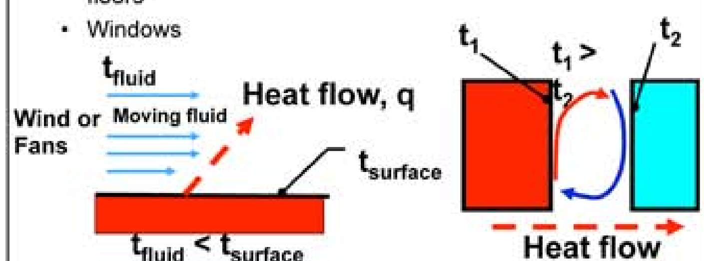
Thermal Performance

- Thermal Conductivity: material
  - Symbol is “k” or “λ”
- Thermal Conductance : layer
  - C = k / thickness
- Resistance “R-value”: layer
  - R = thickness / conductivity
- R, k, C assume “effective” conductivity
  - includes other modes

Building Science 2008 Insulation and Thermal Bridges No. 7/65

Convection

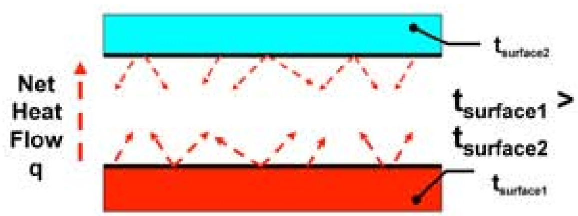
- Heat Flow by bulk movement of molecules
- Most important for liquids and gases
- Critical for surface heat transfer (e.g convectors, “radiant floors”
- Windows



Building Science 2008 Insulation and Thermal Bridges No. 8/65

Radiation

- Heat flow by electromagnetic waves
- Heat radiates from *all* materials, e.g. campfire
- Passes through gases and vacuum (NOT Solid)
- Varies as T^4



Radiation

- Important for surfaces, air spaces, voids
  - e.g. Thermos bottle
- Key for low-e Windows
- Foil faced insulation, radiant barriers only work when facing an air space
- Radiation within *pores* important for high void insulation (e.g., glass batt)
- Emissivity is the measure

Building Science 2008

Material testing

- ASTM C518

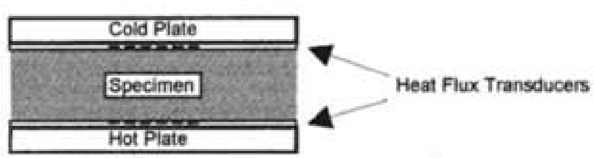
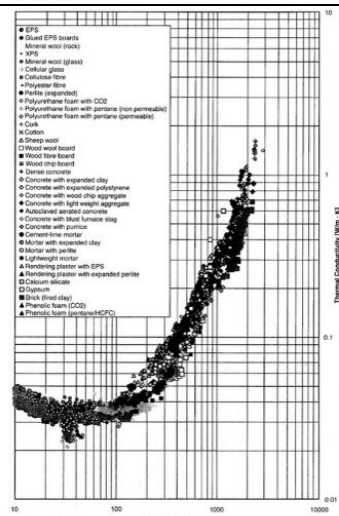


FIG. 3 Apparatus with Two Heat Flux Transducers and One Specimen

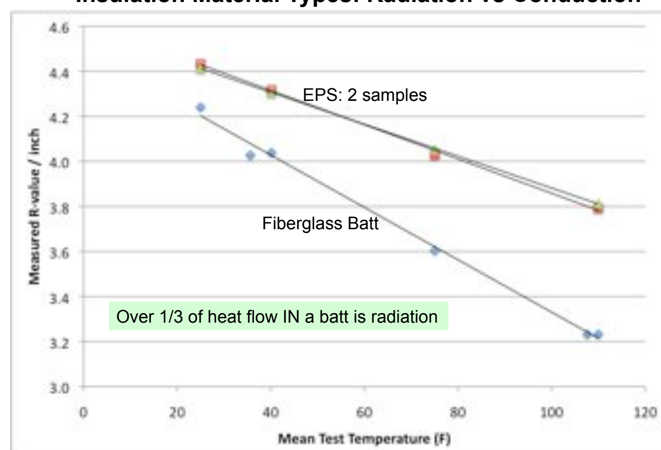
What Impacts R-value of materials

- Density
- Material
- Temperature (FTC rule)
- Airflow

- Gas fill for some foams

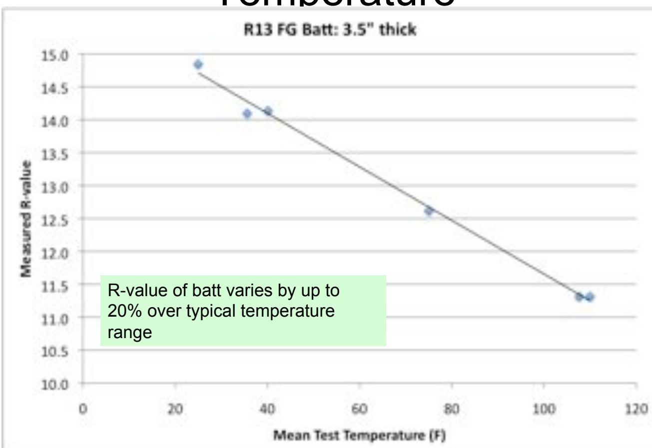


Insulation Material Types: Radiation vs Conduction



© buildingscience.com

Temperature



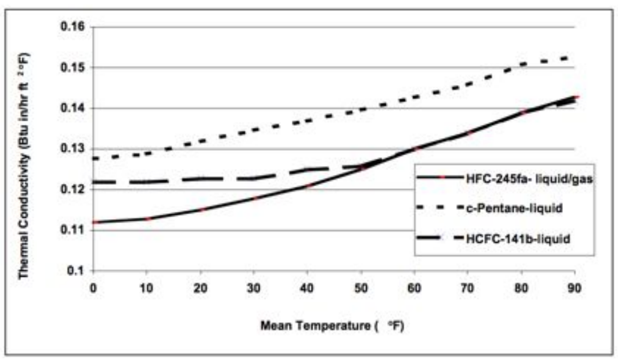
Polystyrene Types, Density

STANDARD SPECIFICATIONS (ASTM C 578-95)
FOR PREFORMED, CELLULAR POLYSTYRENE THERMAL INSULATION

PROPERTY	UNITS	ASTM TEST			VALUE		
Type Classification			Type XI	Type I	Type VIII	Type II	Type IX
Density Minimum	min lbs./ft.3 (kg/M3)	C303,D1622	0.70 (12)	0.90 (15)	1.15 (18)	1.35 (22)	1.80 (29)
Density Range		0.70-0.89 (12-14)	0.90-1.14 (15-17)	1.15-1.34 (18-21)	1.35-1.79 (22-28)	1.80-2.20 (29-32)	
Thermal Resistance (R-value)* @ 25Deg F (-3.90C) 40 Deg F (4.40C) 75 Deg F (23.90C) 100 Deg F (43.30C)	min R. for 1" thickness C177, C518		3.45 (0.61) 3.30 (0.58) 3.10 (0.55) 2.90 (0.51)	4.20 (0.74) 4.00 (0.70) 3.60 (0.63) 3.25 (0.57)	4.40 (0.77) 4.20 (0.74) 3.80 (0.67) 3.45 (0.61)	4.60 (0.81) 4.40 (0.77) 4.00 (0.70) 3.65 (0.64)	4.80 (0.84) 4.60 (0.81) 4.20 (0.74) 3.85 (0.69)
Compressive Resistance at Yield or 10% Deformation	min psi (kPa)	D1621, -L C165	5.0 (3 5)	10.0 (69)	13.0 (90)	15.0 (104)	25.0 (173)
Flexural Strength	min psi (kPa)	C203	10.0 (70)	25.0 (173)	30.0 (208)	40.0 (276)	50.0 (345)
Moisture Resistance Water Vapor Permeability of 1" (25.4mm) Thickness max. perm.	max perm./in. (ng/Pa-S-M2)	E-96	5.0 (287)	5.0 (287)	3.5 (201)	3.5 (201)	2.0 (115)
Water Absorption (by total immersion)	% by vol. max.	C272	4.0	4.0	3.0	3.0	2.0
Dimensional Stability (change in dimensions)	max. %	D2126	2.0	2.0	2.0	2.0	2.0
Oxygen index	min. vol. %	D2863	24.0	24.0	24.0	24.0	24.0

* "R" means resistance to heat flow. The higher the R-value, the greater the insulating power.

Different gases



Some polyiso is not so great at low temperatures!

Future products

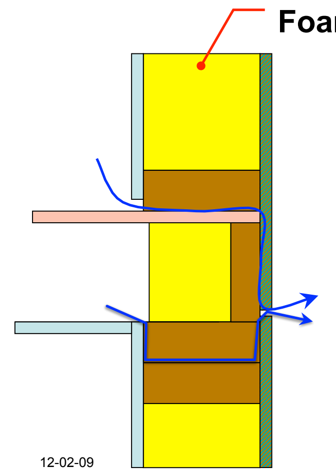
- Vaccum panels: Depends on vacuum
  - R20-30/inch
  - VacuPor (Porextherm)
- Nanogel/aerogel
  - R12-20/inch
  - AspenAerogel

Building Science .com

© buildingscience.com

What affects R-value of walls?

- In order of potential performance impact
  1. air leakage
  2. thermal bridging
  3. temperature
  4. convection loops

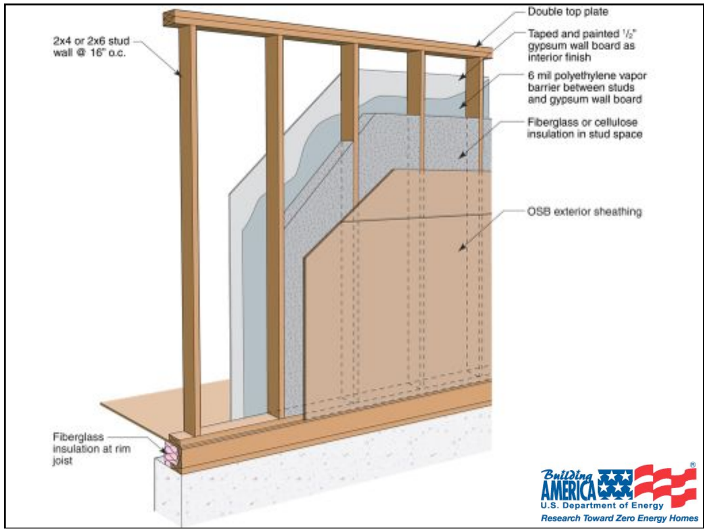


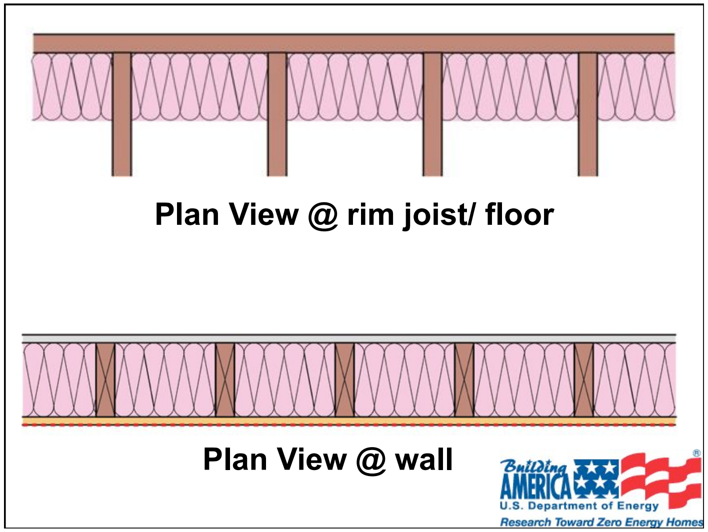
Air Sealing Walls

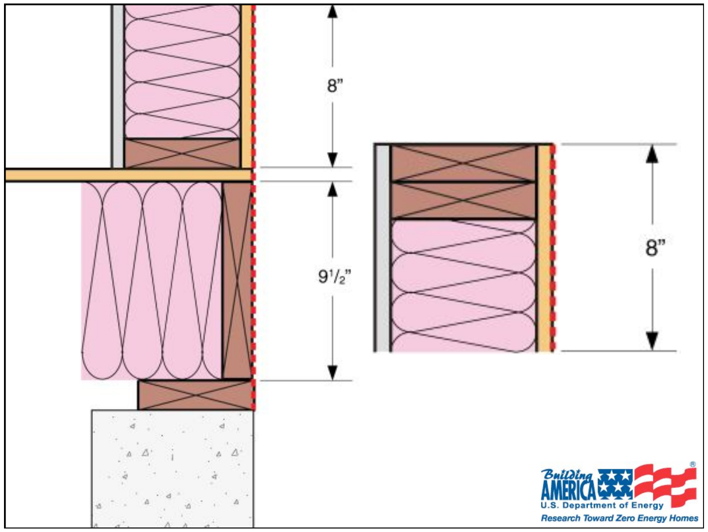
Most air leakage at
- **rim joist**
- **windows**
- **penetrations**
- **bath rooms**

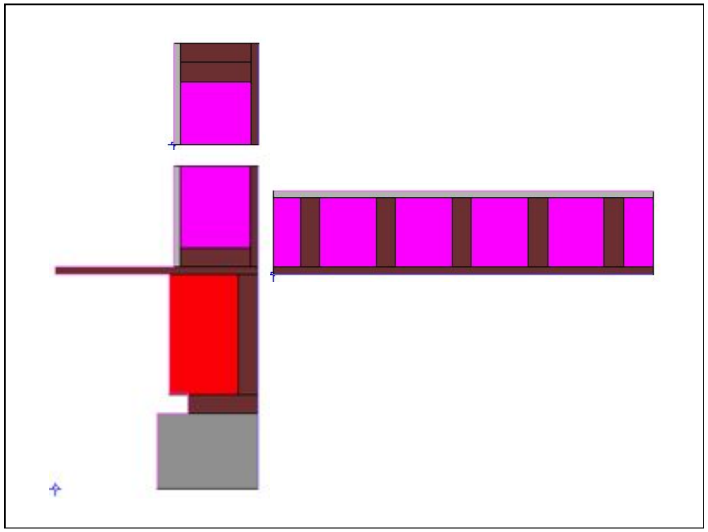
12-02-09 22

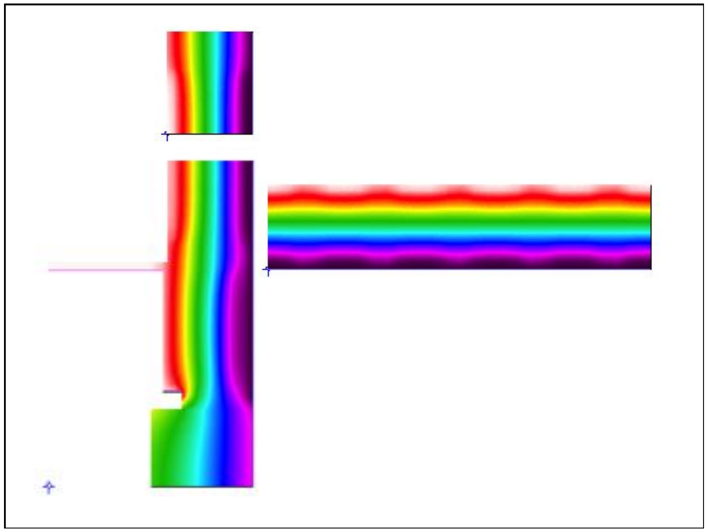
© buildingscience.com

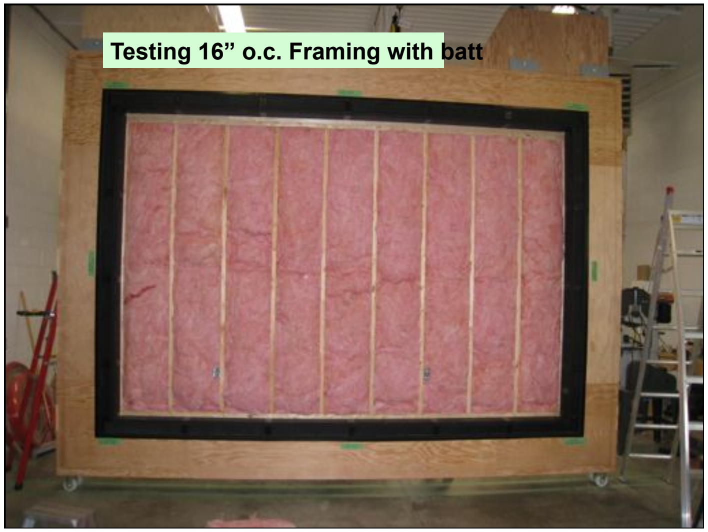

2x4 or 2x6 stud wall @ 16" o.c.
Double top plate
Taped and painted ½" gypsum wall board as interior finish
6 mil polyethylene vapor barrier between studs and gypsum wall board
Fiberglass or cellulose insulation in stud space
OSB exterior sheathing
Fiberglass insulation at rim joist
Building America
U.S. Department of Energy
Research Toward Zero Energy Homes

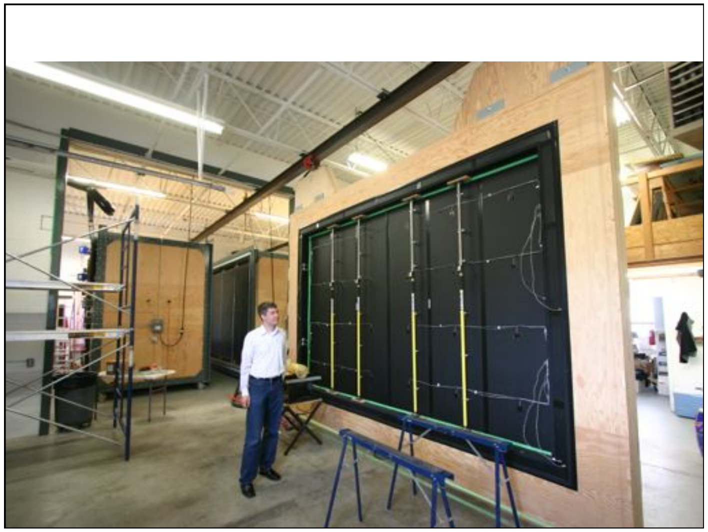

Plan View @ rim joist/ floor
Plan View @ wall
Building America
U.S. Department of Energy
Research Toward Zero Energy Homes


8"
9 1/2"
8"
Building America
U.S. Department of Energy
Research Toward Zero Energy Homes



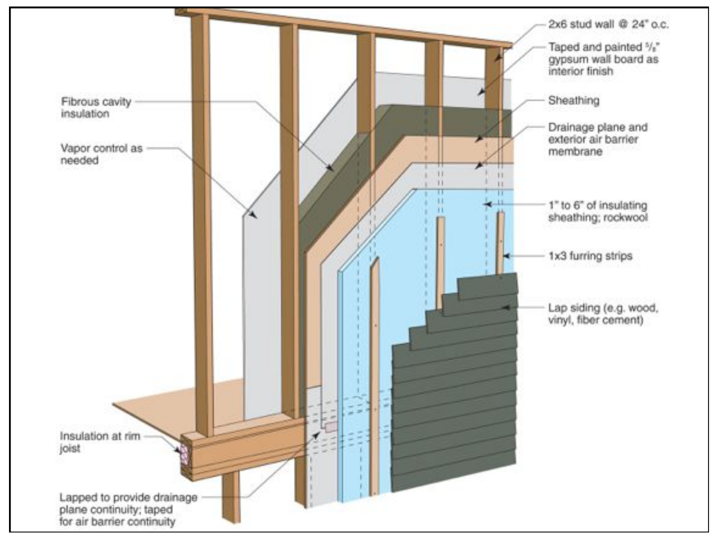


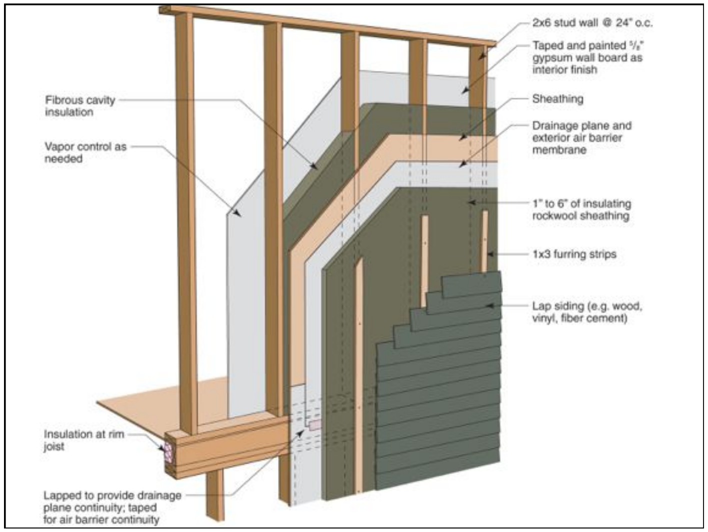

Testing 16" o.c. Framing with batt

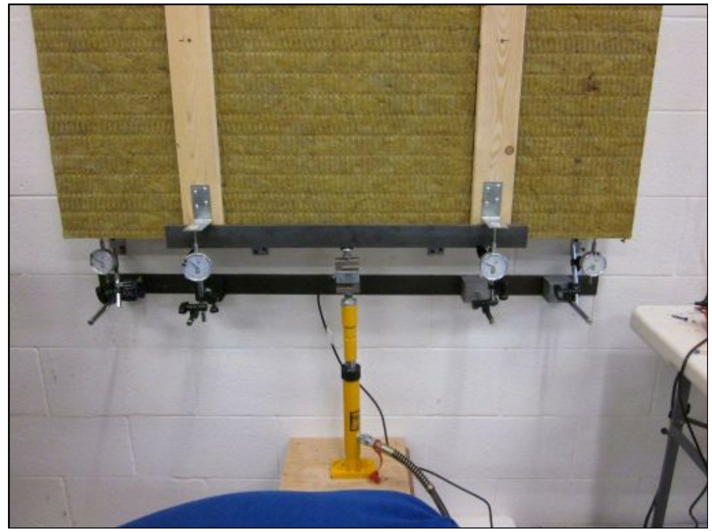


Experimental Verification

- C518 tested each material used in wall sample at temperature being tested
- Therm predicts better than 5% of measured overall True R-value
- Will be testing more high-R walls in the future







Summary of results

Case	Description		Whole Wall R-value	Rim Joist	Clear Wall R-value	Top Plate
1bii	2x4, 16"oc, R13FG + OSB (25%ff)	R13	**10.0**	9.8	10.1	9.8
1b	2x4 AF, 24"oc, R13FG + OSB		**11.1**	9.8	11.5	9.8
1aii	2x6, 16"oc, R19FG + OSB (25%ff)		**13.7**	12.3	14.1	12.5
6a	SIPs (3.5" EPS)		**14.1**	12.3	14.5	10.6
1a	2x6 AF, 24"oc, R19FG + OSB	R19	**15.2**	12.3	16.1	12.5
7a	ICF - 8" foam ICF (4" EPS)		**16.4**		16.4	
8b	2x6 AF, 24" o.c., 5.5" R21 0.5 pcf SPF, OSB	R21	**16.5**	13.1	17.2	16.6
7c	ICF - 14" cement woodfiber ICF with Rockwool		**17.4**		17.4	
9	2x6 AF, 24"oc, 2" SPF and 3.5" cellulose		**17.5**	13.2	18.4	17.7
8a	2x6 AF, 24" o.c., 5" 2 pcf R29 SPF, OSB	R29	**19.1**	13.6	20.3	19.5
2a	2x6 AF, 24"oc R19FG + 1" R5 XPS		**20.2**	18.5	20.6	20.3
7b	ICF - 15" foam ICF (5" EPS)		**20.6**		20.6	
3	2x6 AF, 24"oc, 2x3 R19+R8 FG		**21.5**	13.4	23.5	18.4
4	Double stud wall 9.5" R34 cellulose	R35	**30.1**	14.4	33.5	28.8
12	2x6 AF, 24"oc, EIFS - 4" EPS		**30.1**	23.8	31.4	31.1
10	Double stud with 2" 2.0 pcf foam, 7.5" cell.		**32.4**	15.9	36.2	28.5
2b	2x6 AF, 24"oc R19FG + 4" R20 XPS		**34.5**	29.0	35.6	35.4
6b	SIPs (11.25" EPS)		**36.2**	14	41.6	28.2
5	Truss wall 12" R43 cellulose		**36.5**	18.6	40.5	34.4
11	Offset frame wall with ext. spray foam		**37.1**	18.8	40.6	41.9

*AF - Advanced Framing

BuildingScience.com

- Search “High-R Walls”

Building America Special Research Project: High-R Walls Case Study Analysis

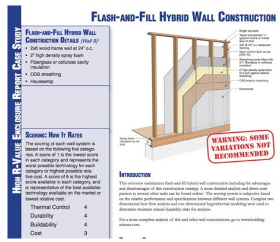
Research Report - 0903

March 11, 2009 (rev. 8/7/09)

John Straube and Jonathan Smegal

Abstract:

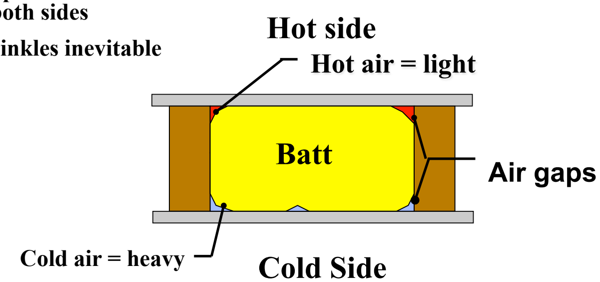
Many concerns, including the rising cost of energy, climate change concerns, and demands for increased comfort, have lead to the desire for increased insulation levels in many new and existing buildings. More building codes are being modified to require higher levels of thermal control than ever before. This report considers a number of promising wall systems that can meet the requirement for better thermal control. Unlike previous studies, this one considers performance in a more realistic matter, including some true three-dimensional heat flow and the relative risk of moisture damage.



Building America
U.S. Department of Energy
Research Toward Zero Energy Homes

Internal Stack Effect & Insulation

- Gaps in batt insulation on both sides
- Wrinkles inevitable



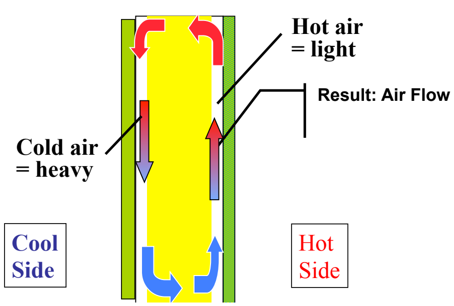
Common installation problem

42

Internal Stack Effect

- Gaps in batt insulation on both sides
- closed circuit
- energy cost
- cold surfaces

Cold or Hot Weather



43

Brown and Bomberg 1993

- Defects in guarded hot box

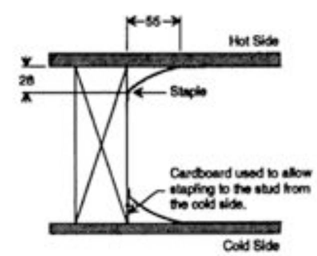


FIGURE 3. Detail of 6% installation defect.

44

Results

- Glass Fiber and Rockwool

Table 3. Thermal resistance measured for frame walls insulated with three different MFI products installed with three different levels of defects.

	Product 1			Product 2			Product 3		
T_{cold}	0%	3%	6%	0%	3%	6%	0%	3%	6%
−5°C	3.15	3.08	2.87	3.29	3.22	3.10	2.95	2.80	2.53
−20°C	—	3.07	2.62	3.37	3.23	2.97	—	2.76	2.24
−35°C	3.38	2.96	2.35	3.43	3.12	2.75	3.14	2.68	2.00

30% 20% 36%

45

What affects R-value of walls?

1. air leakage
   – +/- infinity, often 30%
2. thermal bridging
   – 5-30% reduction w/wood
3. Temperature
   - 10% reduction at high, 10% boost at low
   - Except some polysio
4. convection loops
   – 10-30% reduction if present

R-value

- Choose materials, but
- Design
- Construction
- Are the most critical

- All insulation is good. More is better.
- www.BuildingScience.com

Course Evaluations

In order to maintain high-quality learning experiences, please access the evaluation for this course by logging into CES Discovery and clicking on the Course Evaluation link on the left side of the page.