If Walls Could Talk…

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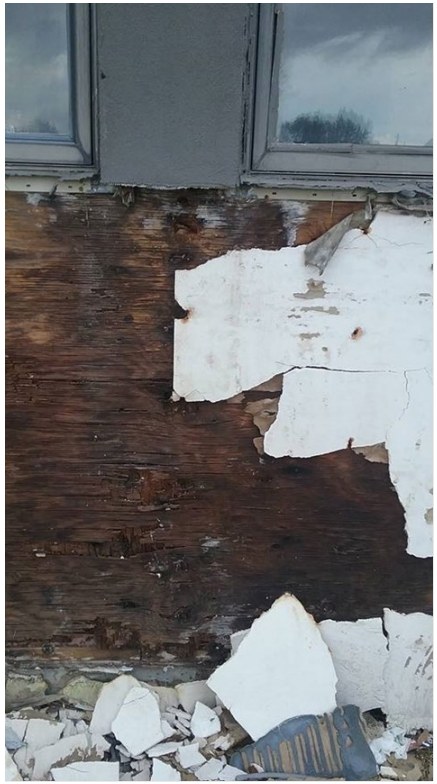
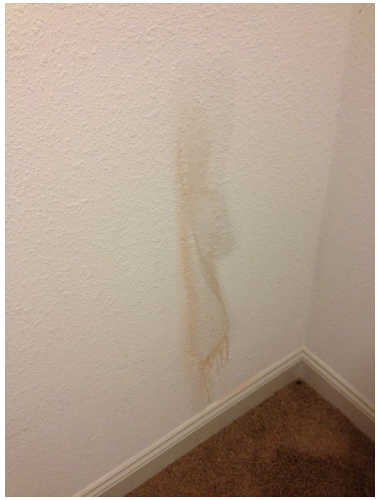
Foam Plastic Applications for Better Building





If Walls Could Talk, What Might We Learn?

- There is building science baked into the code that provides correct guidance for the construction of opaque walls. Unfortunately . . .
  - Sometimes important “ingredients” or inter-related provisions are ignored or misapplied.
  - The code includes exceptions and trade-offs (i.e., allowing substitute ingredients) that can lead to unintended consequences
- We will identify problematic provisions and provide examples of the unintended consequences
- We will identify 2021 IECC solutions to some of the problematic exceptions in the current code
- We will provide recommendations for avoiding the other unintended consequences

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The “Recipe” and “Main Ingredients” of a Wall

- Structure, Safety and Durability ~1/3 Cup
  - These are the foundational ingredients
  - Thermal and moisture control ingredients must be correctly added to maximize value and protect the structure and occupants
  - Recipe varies by climate/hazard condition
- Thermal Performance ~1/3 Cup
  - Continuous Insulation
  - Cavity Insulation & Framing Factor (thermal bridging)
  - Amount of each insulation component
- Moisture Control ~1/3 Cup
  - Water-resistive barrier (WRB)
  - Air barrier (AB) – also important for thermal performance
  - Vapor retarders (VR)
  - Proportion of Cavity and Ci insulation matters

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Potential for Incorrect R-value Compliance

TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.32	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13+5[h]	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20+5[h] or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.30	0.55	NR	49	20+5[h] or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

NR = Not Required.

For SI: 1 foot = 304.8 mm.

a. *R*-values are minimums. *U*-factors and SHGC are maximums. Where insulation is installed in a cavity that is less than the label or design thickness of the insulation, the installed *R*-value of the insulation shall be not less than the *R*-value specified in the table.

b. The fenestration *U*-factor column excludes skylights. The SHGC column applies to all glazed fenestration.
Exception: In Climate Zones 1 through 3, skylights shall be permitted to be excluded from glazed fenestration SHGC requirements provided that the SHGC for such skylights does not exceed 0.30.

c. "10/13" means R-10 continuous insulation on the interior or exterior of the home or R-13 cavity insulation on the interior of the basement wall.
"15/19" means R-15 continuous insulation on the interior or exterior of the home or R-19 cavity insulation at the interior of the basement wall. Alternatively, compliance with "15/19" shall be R-13 cavity insulation on the interior of the basement wall plus R-5 continuous insulation on the interior or exterior of the home.

d. R-5 insulation … dicated in the table. The slab …

e. There are no S…

f. Basement wal…

g. Alternatively, …

h. The first valu… ion plus R-5 continuous ins…

i. Mass walls sh… he mass wall.

R402.1.3 *R*-value computation. Insulation material used in layers, such as framing *cavity insulation* or continuous insulation, shall be summed to compute the corresponding component *R*-value. The manufacturer's settled *R*-value shall be used for blown-in insulation. Computed *R*-values shall not include an *R*-value for other building materials or air films. Where insulated siding is used for the purpose of complying with the continuous insulation requirements of Table R402.1.2, the manufacturer's labeled *R*-value for the insulated siding shall be reduced by R-0.6.

- The Issues:
  - The performance characteristics of continuous insulation and cavity insulation are not well understood
  - The definitions of cavity insulation and continuous insulation are not well understood
  - The "+" is misinterpreted
  - Users want an easy button for a cavity only solution
- Example: R20+5 ≠ R25

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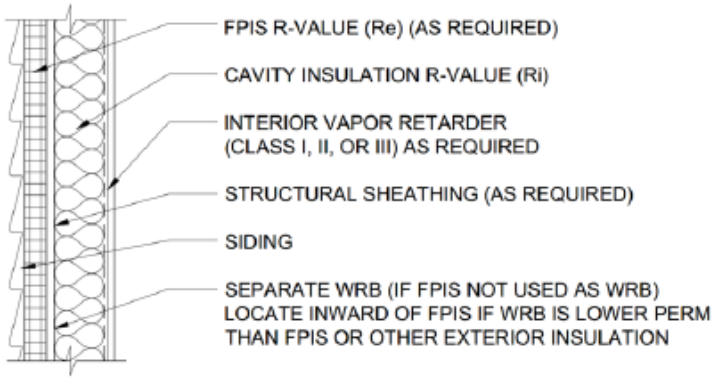
DEFINITIONS: Cavity and Continuous Insulation (2021 IECC)

- **CONTINUOUS INSULATION (ci):** Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior, or is integral to any opaque surface, of the building envelope.

- **CAVITY INSULATION:** Insulating material located between framing members.

Cavity + Continuous + Interior VR



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R-value computation clarified in 2021 IECC

- 2021 IECC revised as follows (CE60-19 Part II):

R402.1.3 (IRC N1102.1.3) *R*-value computation. ~~Insulation material used in layers, such as framing *cavity insulation* or continuous insulation,~~ Cavity insulation alone shall be used to determine compliance with the cavity insulation *R*-value requirements in Table R402.1.2. ~~Where~~ cavity insulation is installed in multiple layers, the *R*-values of the cavity insulation layers shall be summed to ~~compute the corresponding component *R*-value.~~ determine compliance with the cavity insulation *R*-value requirements. The manufacturer's settled *R*-value shall be used for blown-in insulation. Continuous insulation alone shall be used to determine compliance with the continuous insulation (ci) *R*-value requirements in Table R402.1.2. Where continuous insulation is installed in multiple layers, the *R*-values of the continuous insulation layers shall be summed to determine compliance with the continuous insulation *R*-value requirements. Cavity insulation *R*-values shall not be used to determine compliance with the continuous insulation *R*-value requirements in Table R402.1.2. Computed *R*-values shall not include an *R*-value for other building materials or air films. Where insulated siding is used for the purpose of complying with the continuous insulation requirements of Table R402.1.2, the manufacturer's labeled R-value for the insulated siding shall be reduced by R-0.6.

R-value “+” and “/” symbols clarified in 2021 IECC (RE28-19)

- The “+” was always a symbol meaning “AND”, not addition. Thus, “&” is now used for insulation strategies requiring cavity and continuous insulation.
- The “/” was always as symbol meaning “OR”, not division.
- The “ci” designation added to clarify cavity vs. continuous insulation components

CLIMATEZONE	WOODFRAME WALLR-VALUE	BASEMENT[c] WALLR-VALUE
1	13	0
2	13	0
3	20 or ~~13+5~~[h] 13&5ci[h]	~~5/13~~[f] 5ci or 13[f]
4 exceptMarine	20 or ~~13+5~~[h] 13&5ci	~~10/13~~ 10ci or 13
5 andMarine 4	20 or ~~13+5~~[h] 13&5ci	~~15/19~~ 15ci or 19
6	~~20+5~~[h] ~~or 13+10~~[h] 20&5ci or 13&10ci	~~15/19~~ 15ci or 19
7 and 8	~~20+5~~[h] ~~or 13+10~~[h] 20&5ci or 13&10ci	~~15/19~~ 15ci or 19

Why is this important?...(example)

Wall Construction & Insulation Strategy:	2x6@16”oc Wood Frame Wall	
	“R25” (cavity only)	“R20+5” (cavity & ci)
Total Nominal R-value of Insulation:	R25	R25
U-factor	0.0573	0.0464
Effective R-value	**17.5**	**21.6**

- R20+5 ≠ R25

- They do not perform the same because simple R-value summation does not include the framing factor impact to cavity insulation. Must do proper energy code math (parallel path analysis).
- Refer to wall calculator for thermal and moisture check: https://www.continuousinsulation.org/wood-wall-calculator

Weakening Footnote

- The Issue:
  - Footnote g, allows R19 in lieu of R30 or R38
  - There is no requirement to make up the energy losses through improved performance in other areas of the envelope
  - Results in 39% reduction of the R30 requirement and 50% reduction of the R38 requirement

TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b,e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
						3/4	13	0	0	0
						4/6	13	0	0	0
						8/13	19	5/13[f]	0	5/13
						8/13	19	10 /13	10, 2 ft	10/13
						13/17	30[g]	15/19	10, 2 ft	15/19
						15/20	30[g]	15/19	10, 4 ft	15/19
						19/21	38[g]	15/19	10, 4 ft	15/19

in a cavity that is less than the label or design thickness of the
the table.
fenestration.
azed fenestration SHGC requirements provided that the SHGC

ty insulation on the interior of the basement wall.
ty insulation at the interior of the basement wall. Alternatively,
plus R-5 continuous insulation on the interior or exterior of the

d. R-5 insulation shall be provided under the full slab area of a heated slab in addition to the required slab edge insulation *R*-value for slabs. as indicated in the table. The slab edge insulation for heated slabs shall not be required to extend below the slab.
e. There are no SHGC requirements in the Marine Zone.
f. Basement wall insulation is not required in warm-humid locations as defined by Figure R301.1 and Table R301.1.
g. Alternatively, insulation sufficient to fill the framing cavity and providing not less than an *R*-value of R-19.
h. The first value is cavity insulation, the second value is continuous insulation. Therefore, as an example, "13+5" means R-13 cavity insulation plus R-5 continuous insulation.
i. Mass walls shall be in accordance with Section R402.2.5. The second *R*-value applies where more than half of the insulation is on the interior of the mass wall.

There's a better way…

- 2021 IECC deletes footnote 'g' allowing minimum R19 floor insulation (RE52-19)
- The provision is obsolete as new construction materials and methods rarely, if ever, use 2x6 or 2x8 floor construction (IRC joist tables limit span to 10' to 12' for 2x6 and 2x8 No. 1 grade lumber at 16"oc).
- Where needed for existing construction, IECC Chapter 5, Section R503.1.1 allows for simply filling a floor, wall, or ceiling cavity with insulation when the cavity is exposed during an alteration.
- For new construction, the U-factor and Total UA alternative (e.g., REScheck) provide a means for compliance without reducing the floor or overall building envelope performance.

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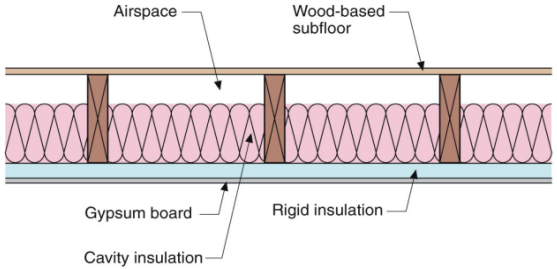
Examples of a better way…



- Consider a rare case where a 2x6 floor is used for an average 2-story home in Climate Zone 5, or
- A small 2-story addition to an existing home to match existing floor depth and crawlspace depth or basement clearance.
- NOTE: In the two solutions, the addition of R-10ci to the underside of floor or R-5ci to the exterior of the wall is sized in proportion to cavity insulation to provide improved water vapor performance in addition to thermal performance. Use of ci with sealed/taped joints also helps control inward vapor movement from crawlspace. Use of ci on wall and floor also improves comfort.

- **U-factor Solution for Floor** (U=0.033):
  - Use R21 cavity insulation in 2x6 floor with R-10ci (i.e., R21+R10)
- **Total UA Solution for Envelope***:
  - Use R19 in 2x6 floor (in lieu of R30)
  - Use R19+5ci wall (in lieu of R20)
  - All other R-values and window U-factors unchanged and total UA of envelope remains the same.
  - Same UA method can trade-up walls for less ceiling insulation to avoid energy-heel trusses where architecturally infeasible

* Uses DOE baseline 2-story 2500 sqft home

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Potentially Problematic Trade-offs in most Compliance Options

TABLE R402.1.4
EQUIVALENT *U*-FACTORS[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR	SKYLIGHT *U*-FACTOR	CEILING *U*-FACTOR	FRAME WALL *U*-FACTOR	MASS WALL *U*-FACTOR[b]	FLOOR *U*-FACTOR	BASEMENT WALL *U*-FACTOR	CRAWL SPACE WALL *U*-FACTOR
1	0.50	0.75	0.035	0.084	0.197	0.064	0.360	0.477
2	0.40	0.65	0.030	0.084	0.165	0.064	0.360	0.477
3	0.32	0.55	0.030	0.060	0.098	0.047	0.091[c]	0.136
4 except Marine	0.32	0.55	0.026	0.060	0.098	0.047	0.059	0.065
5 and Marine 4	0.30	0.55	0.026	0.060	0.082	0.033	0.050	0.055
6	0.30	0.55	0.026	0.045	0.060	0.033	0.050	0.055
7 and 8	0.30	0.55	0.026	0.045	0.057	0.028	0.050	0.055

R402.1.4 *U*-factor alternative. An assembly with a *U*-factor equal to or less than that specified in Table R402.1.4 shall be an alternative to the *R*-value in Table R402.1.2.

The “Prescriptive Option” of the IECC allows the you to choose either R-values, U-factors, or a Total UA to comply with the insulation requirements.

R402.1.5 Total UA alternative. Where the total *building thermal envelope* UA, the sum of *U*-factor times assembly area, is less than or equal to the total UA resulting from multiplying the *U*-factors in Table R402.1.4 by the same assembly area as in the proposed *building*, the *building* shall be considered to be in compliance with Table R402.1.2. The UA calculation shall be performed using a method consistent with the ASHRAE *Handbook of Fundamentals* and shall include the thermal bridging effects of framing materials. In addition to UA compliance, the SHGC requirements shall be met.

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Potentially Problematic Trade-offs in most Compliance Options

TABLE R402.1.4
EQUIVALENT *U*-FACTORS[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR	SKYLIGHT *U*-FACTOR	CEILING *U*-FACTOR	FRAME WALL *U*-FACTOR	MASS WALL *U*-FACTOR[b]	FLOOR *U*-FACTOR	BASEMENT WALL *U*-FACTOR	CRAWL SPACE WALL *U*-FACTOR
1	0.50	0.75	0.035	0.084	0.197	0.064	0.360	0.477
2	0.40	0.65	0.030	0.084	0.165	0.064	0.360	0.477
3	0.32	0.55	0.030	0.060	0.098	0.047	0.091[c]	0.136
4 except Marine	0.32	0.55	0.026	0.060	0.098	0.047	0.059	0.065
5 and Marine 4	0.30	0.55	0.026	0.060	0.082	0.033	0.050	0.055
6	0.30	0.55	0.026	0.045	0.060	0.033	0.050	0.055
7 and 8	0.30	0.55	0.026	0.045	0.057	0.028	0.050	0.055

R402.1.4 *U*-factor alternative. An assembly with a *U*-factor equal to or less than that specified in Table R402.1.4 shall be an alternative to the *R*-value in Table R402.1.2.

Component R-values and assembly U-factors have some self limiting trade-off characteristics.

However, when utilizing the Total UA Alternative there is no limit on how much any given insulated assembly can be traded-off for another.

R402.1.5 Total UA alternative. Where the total *building thermal envelope* UA, the sum of *U*-factor times assembly area, is less than or equal to the total UA resulting from multiplying the *U*-factors in Table R402.1.4 by the same assembly area as in the proposed *building*, the *building* shall be considered to be in compliance with Table R402.1.2. The UA calculation shall be performed using a method consistent with the ASHRAE *Handbook of Fundamentals* and shall include the thermal bridging effects of framing materials. In addition to UA compliance, the SHGC requirements shall be met.

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Potentially Problematic Trade-offs in most Compliance Options

TABLE R405.5.2(1)
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Above-grade walls	Type: mass, where the proposed wall is a mass wall; otherwise, wood frame.	As proposed
	Gross area: same as proposed.	As proposed
	U-factor: as specified in Table R402.1.4.	As proposed
	Solar absorptance = 0.75.	As proposed
	Emittance = 0.90.	As proposed
Basement and crawl space walls	Type: same as proposed.	As proposed
	Gross area: same as proposed.	As proposed
	U-factor: as specified in Table R402.1.4, with the insulation layer on the interior side of the walls.	As proposed
Above-grade floors	Type: wood frame.	As proposed
	Gross area: same as proposed.	As proposed
	U-factor: as specified in Table R402.1.4.	As proposed
	Type: wood frame	As proposed

SECTION R406
ENERGY RATING INDEX
COMPLIANCE ALTERNATIVE

R406.1 Scope. This section establishes criteria for compliance using an Energy Rating Index (ERI) analysis.

R406.2 Mandatory requirements. Compliance with this section requires that the provisions identified in Sections R401 through R404 indicated as "Mandatory" and Section R403.5.3 be met. The *building thermal envelope* shall be greater than or equal to levels of efficiency and *Solar Heat Gain Coefficients* in Table 402.1.1 or 402.1.3 of the 2009 *International Energy Conservation Code*.

a. Where on-site renewable energy is included for compliance using the ERI analysis of Section R406.4, the building shall meet the mandatory requirements of Section R406.2, and the building thermal envelope shall be greater than or equal to the levels of efficiency and SHGC in Table R402.1.2 or Table R402.1.4 of the 2015 *International Energy Conservation Code*.

- The Performance and ERI Compliance options are based on the assembly U-factor requirements.
- Performance option – no trade-off limit
- ERI without renewable energy - 2009 IECC backstop
- ERI with renewable energy - 2015 IECC backstop

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WARNING #1:
Avoid “Trade-off” Tunnel Vision

- All compliance paths and envelope “trade-offs” can have unintended consequences if the following factors are not considered in full view:
  - It matters what “ingredients” are used (e.g., R-value, permeance, etc. of insulation and building material layers)
  - It matters in what order these ingredients are arranged in a wall
  - The ingredients and recipe for combining them change with climate
  - Don’t use renewable energy to “trade-off” envelope energy efficiency (conservation) thereby negating the primary value of renewable resources to reduce the use of non-renewable fuels, GHG emissions, and pollutants
- The problem with the energy code compliance paths is that they only look at thermal performance and, taken alone, this can set a trap for unintended consequences.

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WARNING #2:
With flexibility comes responsibility

- Vast Number of Options: 4 VR x 3 AB x 3 ci x 2 cavity x 3 WRB x 3 structural sheathing x 2 cladding = **1,296 options** to configure a wall!
  - This calculation of the number of wall assembly options is just for basic material types/categories/arrangements, not including specific material variations within category or changes in R-values of ci or cavity insulation.
  - At least half of these combinations are wrong for any given climate
  - Some are marginal depending on climate and indoor moisture loads
  - Conversely, some combinations are good for all climates
- Some examples of unintended consequences follow…

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Unintended Consequences: Examples (All Energy Code Compliance Paths)

- Climate Zone 7 Example
- Energy code says OK to use R20+5ci wall
- Current building code simply says to use a Class I or II vapor retarder – no other "ingredients" or "recipe" conditions are mentioned.
- REALITY CHECK: This wall is OK in Climate Zone 6, but NOT Climate Zone 7 from a vapor control standpoint!
- Why? The *insulation ratio (?)* is not quite enough for Climate Zone 7 (but is adequate for Climate Zone 6 or lower)
- Huh?

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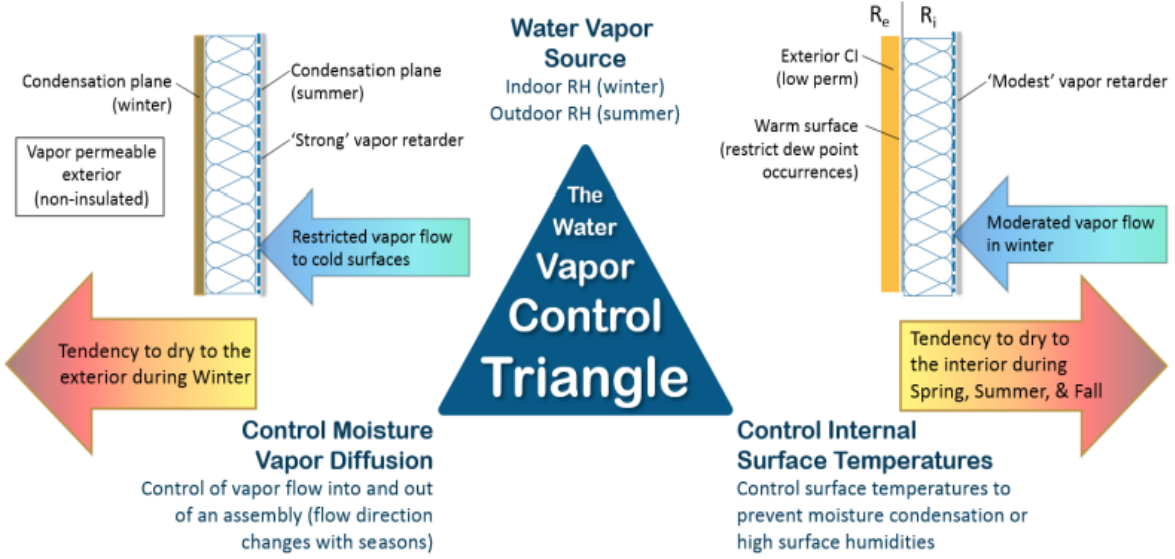
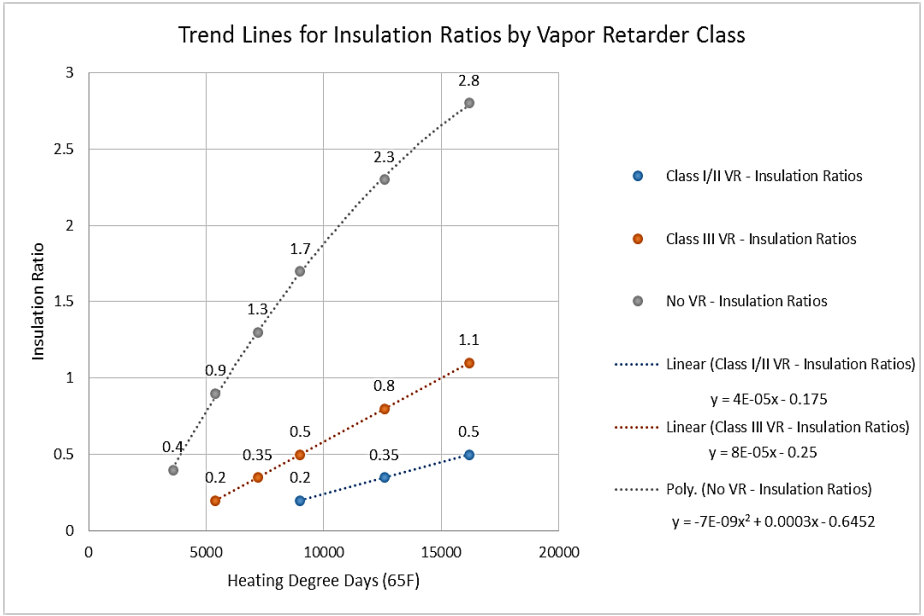
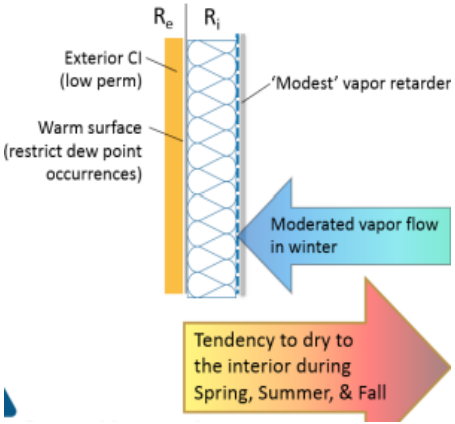
WAIT A MINUTE! What is Insulation Ratio? – the "secret" to the recipe

These two wall parameters are important for two different wall strategies:



Insulation Ratio (basis of 2021 IRC)





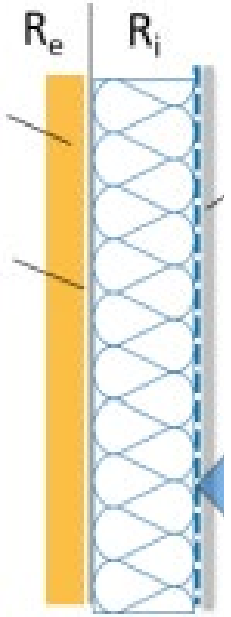
Source: http://www.appliedbuildingtech.com/rr/1410-03

Insulation Ratio (basis of 2021 IRC)

MINIMUM INSULATION RATIO OR CONTINUOUS INSULATION R-VALUE FOR LIGHT-FRAME WALLS WHERE EXTERIOR CONTINUOUS INSULATION (ci) IS USED [a,b,c,d]

Climate Zone (Fig. 2)	Maximum Heating Degree Days (65F basis)	Interior Vapor Retarder (VR) Class			
		Class I	Class II	Class III	No VR[e]
1	N/A	NP	NP[f]	R-2ci minimum	R-2ci minimum
2	N/A	NP	NP[f]	R-2ci minimum	R-2ci minimum
3	3,600	NP	R-2ci minimum	R-2ci minimum	0.4
4	5,400	NP	R-2ci minimum	0.2	0.9
5	7,200	0.2	0.2	0.35	1.3
6	9,000	0.2	0.2	0.5	1.7
7	12,600	0.35	0.35	0.8	2.3
8[g]	16,200	0.5	0.5	1.1	2.8

For SI: 1 heating degree day (65°F basis) = 0.56 heating degree days (18°C basis)
NP = indicated vapor retarder class is not permitted in the indicated Climate Zone.
Table Notes & Commentary:



Source: http://www.appliedbuildingtech.com/rr/1701-01

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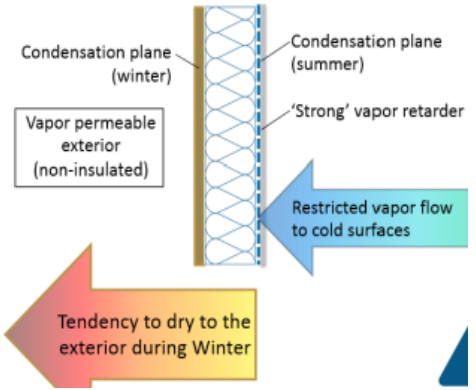
Permeance Ratio (not included in 2021 IRC)

MINIMUM NET WATER VAPOR PERMEANCE (WVP)
FOR MATERIAL LAYERS LOCATED ON THE EXTERIOR SIDE OF WALL STUDS [a,b,c]

Climate Zone (Fig. 2)	Interior Vapor Retarder Class		
	Class I	Class II	Class III
1	NP	NP[d]	No minimum
2	NP	NP[d]	No minimum
3	NP	No minimum	No minimum
4	0.5 perm (Marine 4) and otherwise NP	0.5 perm	3 perm
5	0.5 perm	3 perm	5 perm
6	1 perm	5 perm	15 perm
7	1 perm	15 perm	NP
8[e]	1.5 perm	NP	NP

For SI: 1 perm = 57.2 ng/s-m^2-Pa
NP = indicated vapor retarder class is not permitted in the indicated Climate Zone
Table Notes & Commentary:



NOTE: For use with cavity insulation only walls, or walls that have continuous insulation but inadequate insulation ratio.

Source: http://www.appliedbuildingtech.com/rr/1701-01

Updated 2021 IRC and IBC Vapor Retarder Provisions

- Based on IRC proposal RB223-19 (nearly identical for IBC)
- First, vapor retarder classes are broadly defined…

TABLE R702.7(1)
VAPOR RETARDER MATERIALS AND CLASSES

CLASS	ACCEPTABLE MATERIALS
I	Sheet polyethylene, nonperforated aluminum foil, or other approved materials with a perm rating of less than or equal to 0.1.
II	Kraft-faced fiberglass batts, vapor retarder paint, or other approved materials applied in accordance with the manufacturer's installation instructions for a perm rating greater than 0.1 and less than or equal to 1.0.
III	Latex pain, enamel paint, or other approved materials applied in accordance with the manufacturer's installation instructions for a perm rating of grater than 1.0 and less than or equal to 10.0.

Updated 2021 IRC and IBC Vapor Retarder Provisions

- Second, their application by climate zone is tabulated with footnotes addressing cases where ci is used or may be necessary to help control moisture

TABLE R702.7(2)
VAPOR RETARDER OPTIONS

CLIMATE ZONE	VAPOR RETARDER CLASS		
	CLASS I[a]	CLASS II[a]	CLASS III
1, 2	Not Permitted	Not Permitted	Permitted
3, 4 (except Marine 4)	Not Permitted	Permitted[c]	Permitted
Marine 4, 5, 6, 7, 8	Permitted[b]	Permitted[c]	See Table R702.7(3)

a. Class I and II vapor retarders with vapor permeance greater than 1 perm when measured by ASTM E96 water method (Procedure B) shall be allowed on the interior side of any frame wall in all climate zones.
b. Use of a Class I interior vapor retarder in frame walls with a Class I vapor retarder on the exterior side shall require an approved design.
c. Where a Class II vapor retarder is used in combination with foam plastic insulating sheathing installed as continuous insulation on the exterior side of frame walls, the continuous insulation shall comply with Table R702.7(4) and the Class II vapor retarder shall have a vapor permeance of greater than 1 perm when measured by ASTM E96 water method (Procedure B).

- Footnote 'b' prevents double vapor barrier unless designed – generally meaning use of a Class I smart vapor retarder (see footnote 'a')
- Footnote 'c' and Table R702.7(3) provide requirements when foam sheathing ('ci') is used.

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Updated 2021 IRC and IBC Vapor Retarder Provisions

- Next, where the wall has a Class II VR and foam sheathing ci…

TABLE R702.7(4)
CONTINUOUS INSULATION WITH CLASS II VAPOR RETARDER

CLIMATE ZONE	CLASS II VAPOR RETARDERS PERMITTED FOR:[a]
3	Continuous insulation with R-value ≥ 2.
4, 5, and 6	Continuous insulation with R-value ≥ 3 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 5 over 2 x 6 wall.
7	Continuous insulation with R-value ≥ 5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 7.5 over 2 x 6 wall.
8	Continuous insulation with R-value ≥ 7.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 10 over 2 x 6 wall.

a. The requirements of this table apply only to insulation used to control moisture in order to permit the use of Class II vapor retarders. The insulation materials used to satisfy this option also contribute to but do not supersede the thermal envelope requirements of Chapter 11.

- This is the “insulation ratio” in prescriptive form (same format as used in the existing Class III VR table shown in next slide)
- As noted in footnote ‘c’ the Class II VR must have a permeance of > 1 perm under “wet cup” ASTM E96 test (e.g., is a smart vapor retarder). Generically, this means a Kraft paper facer on fiberglass batts (or similar).

Updated 2021 IRC and IBC Vapor Retarder Provisions

- Finally, where a Class III VR is used…
- Note that in the colder climates, exterior 'ci' must be used (is the only option) to protect the wall from moisture accumulation when a fairly "vapor open" Class III VR is used.
- Also, note that as the climate gets colder a higher exterior sheathing permeance is required if not using 'ci' to protect the wall from moisture accumulation (same should apply with use of a Class II VR, but not currently in the code).

TABLE R702.7(3)
CLASS III VAPOR RETARDERS

CLIMATE ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR:[a,b]
Marine 4 [or all of 4 for 2021 IBC]	Vented cladding over wood structural panels.
	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 2.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 3.75 over 2 x 6 wall.
5	Vented cladding over wood structural panels.
	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 7.5 over 2 x 6 wall.
6	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 7.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 11.25 over 2 x 6 wall.
7	Continuous insulation with R-value ≥ 10 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 15 over 2 x 6 wall.
8	Continuous insulation with R-value ≥ 12.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 20 over 2 x 6 wall.

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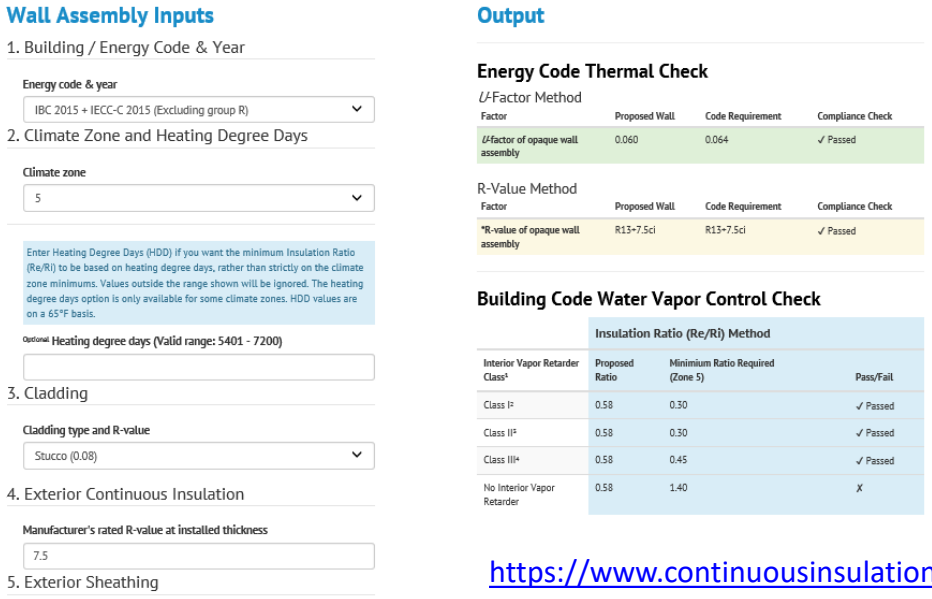
Wall Calculator – Easy Button to IECC and IRC Coordinated Compliance

Implements R-value and U-factor checks per IECC and also a moisture control check per IRC (including insulation and permeance ratio checks)



Wall Assembly Inputs

1. Building / Energy Code & Year

Energy code & year

IBC 2015 + IECC-C 2015 (Excluding group R)

2. Climate Zone and Heating Degree Days

Climate zone

5

Enter Heating Degree Days (HDD) if you want the minimum Insulation Ratio (Re/Ri) to be based on heating degree days, rather than strictly on the climate zone minimums. Values outside the range shown will be ignored. The heating degree days option is only available for some climate zones. HDD values are on a 65°F basis.

Optional Heating degree days (Valid range: 5401 - 7200)

3. Cladding

Cladding type and R-value

Stucco (0.08)

4. Exterior Continuous Insulation

Manufacturer's rated R-value at installed thickness

7.5

5. Exterior Sheathing

Output

Energy Code Thermal Check

U-Factor Method

Factor	Proposed Wall	Code Requirement	Compliance Check
U-factor of opaque wall assembly	0.060	0.064	✓ Passed

R-Value Method

Factor	Proposed Wall	Code Requirement	Compliance Check
*R-value of opaque wall assembly	R13+7.5ci	R13+7.5ci	✓ Passed

Building Code Water Vapor Control Check

Insulation Ratio (Re/Ri) Method

Interior Vapor Retarder Class[1]	Proposed Ratio	Minimum Ratio Required (Zone 5)	Pass/Fail
Class I[2]	0.58	0.30	✓ Passed
Class II[3]	0.58	0.30	✓ Passed
Class III[4]	0.58	0.45	✓ Passed
No Interior Vapor Retarder	0.58	1.40	✗

https://www.continuousinsulation.org

Unintended Consequences: Examples (All Energy Code Compliance Paths)

- Now, let's return to the Climate Zone 7 example with some knowledge as to how to make a good wall recipe using good ingredients…
- BETTER SOLUTIONS: A few examples derived from applying IECC and IRC requirements (or more simply using the "wall calculator"):
  - 2x6 wall, R20+7.5ci with Class II(Kraft/"smart") VR gives IR = 7.5/20 = 0.38 > 0.35 min. OK (wall dries to the inside & prevents diffusion wetting) – Meets IRC and more stringent than R20+5ci for IECC compliance
  - 2x4 wall, R13+10ci with a Class III (e.g., Latex paint) VR gives IR = 0.77 > 0.7 min. OK (wall dries even faster to inside & similarly prevents diffusion wetting in winter) – Meets IECC R-value and IRC.
  - Any wall, R0+20ci with Class III or no interior VR gives IR=20/1 = 20! (extreme inward drying potential & maximum prevention of diffusion wetting); meets IECC wall U-factor for CZ 7 and better than IRC moisture control.

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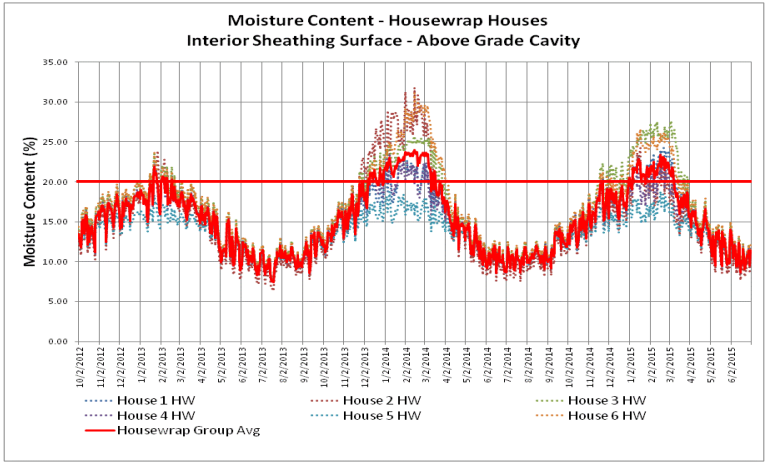
Unintended Consequences: Examples (All Energy Code Compliance Paths)

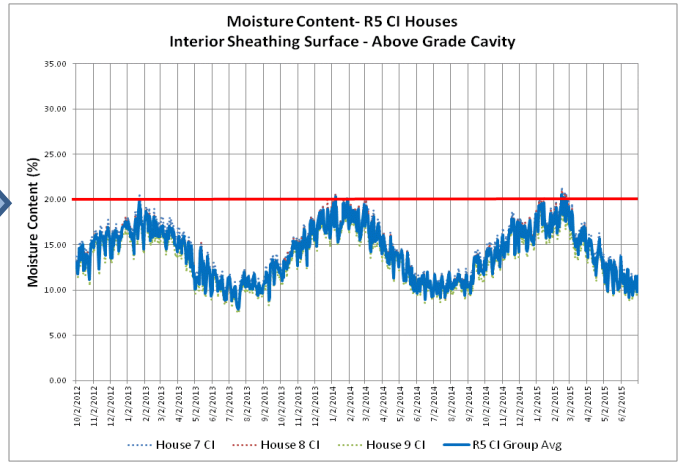
- Climate Zone 5 Example
- IECC currently allows use of R20 cavity only insulation in CZ5
- IRC simply says to use a Class I or II vapor retarder – no other “ingredients” or “recipe” conditions are mentioned.
- Don’t recommend using a Class II (Kraft paper) vapor retarder to avoid high (>20% to 30% saturated) moisture cycling in OSB:



OSB MC - Actual data from 6 occupied homes with R20 walls

Unintended Consequences: Examples (All Energy Code Compliance Paths)

- BETTER SOLUTIONS: Derived from applying IECC and IRC requirements (or more simply using the "wall calculator"):
  - For an R20 2x6 wall (air permeable cavity insulation only) in CZ 5, a Class I VR is needed to provide an acceptable *permeance ratio* for this wall and the Class I VR should also be "smart" to avoid condensation on the VR in the summer AC/cooling season.
  - Or, by adding R5ci to the exterior (R20+5ci), a Class II (Kraft) VR can be used resulting in a much dryer (<20% MC) and more stable environment for the OSB:



Actual data from 6 occupied homes with R20+5 walls

Unintended Consequences: State & Local Modifications (examples)

- R13+1ci (replacing R13+5ci) in CZ 4
  - This is not thermally equivalent to an R20 or R13+5 wall as currently required by the IECC.
  - This wall may also experience moisture problems if minimum R-3ci is not used with a Class II (Kraft) VR to achieve an adequate insulation ratio and drying to interior.
- R21 replacing R20+5ci or R13+10ci in CZs 6 & 7
  - Using R21 cavity insulation is far from being thermally equivalent to R20+5ci or R13+10ci
  - If used, a Class I “smart” VR should be used with carefully sealed interior AB to prevent exterior sheathing from cycling through high moisture every year and avoid condensation on VR in summer (AC cooling).

SOLUTION: Follow the latest codes 2021 IECC and IRC – weakening thermal performance can inadvertently result in lessened durability.

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2021 IECC Updates to R-value Path (Section R402)

- 2021 IECC Wall R-value requirements improved over earlier editions.
- These provide more options to help make good choices informed also by improvements to 2021 IRC R702.7 vapor control provisions.
- Covers all options (cavity only, cavity + continuous, continuous only) with thermally equivalent solutions
- When coordinated with 2021 IRC:
  - Adding R20+5 to CZ 4 and 5 will improve moisture performance with use of Class II (Kraft) VR
  - Having an R30 cavity equivalent in CZ 5-8 will raise importance of using Class I "smart" VR (although not required by 2021 IRC); or using at least part-fill with low-perm ccSPF complying with earlier insulation ratios and a Class II (Kraft) VR for improved inward drying.

CLIMATE ZONE	WOOD FRAME WALL R-VALUE
1	13 or 0+10ci^{h}
2	13 or 0+10ci^{h}
3	20 or 13+5ci^{h} or 0+15ci^{h}
4 except Marine	30 or 20+5ci^{h} or 13+10ci^{h} or 0+20ci^{h}
5 and Marine 4	30 or 20+5ci^{h} or 13+10ci^{h} or 0+20ci^{h}
6	30 or 20+5ci^{h} or 13+10ci^{h} or 0+20ci^{h}
7 and 8	30 or 20+5ci^{h} or 13+10ci^{h} or 0+20ci^{h}

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2021 Updates to ERI Path (Section R406)

- Current ERI path has a 2009 IECC envelope backstop without solar
  - This backstop only prevents excessive trading-off of envelope thermal performance; it does not prevent trade-offs that could create moisture control problems.
- The 2021 IECC …
  - Changes the ERI backstop to 1.15UA multiplier (RE150-19), this still allows some CZs to be traded-off in ways that could create moisture problems as per the current backstop.
  - Changes the backstop with renewable energy to 2018 IECC envelope R-values (RE182-19) combined with a 5% of total building energy use limit on crediting renewable energy production to the ERI score (RE184-19).
  - Also, ERI scores (targets) are reduced by about 5 points (RE192-19) for better energy conservation performance and this will help mitigate unintended consequences of envelope trade-offs.

2021 Updates to Performance Path (Section R405)

- The current performance path has no backstop…
  - Envelope insulation could theoretically be traded down to pre-energy code levels (e.g., prior to 1970s)
  - 2021 IECC continues to prevent this by prohibiting HVAC equipment efficiency (through use of an outdated Federal baseline efficiency standard) from being used to enable severe trade-offs of envelope performance.
- The 2021 IECC will include a 2009 IECC R-value backstop (RE151-19) but this will not necessary prevent envelope trade-offs that might cause moisture problems – must follow 2021 IRC vapor retarder requirements.

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Potentially Problematic Steel Frame Compliance

- Failure to update this table has left users wanting for appropriate equivalent prescriptive solutions
- Values highlighted in blue are not found in Table R402.1.2 so they are not relevant
- Some values in Table R402.1.2 are not found in this Steel framed equivalence table.
  - R13+5
  - R13+10

TABLE R402.2.6
STEEL-FRAME CEILING, WALL AND FLOOR INSULATION *R*-VALUES

Steel-Framed Wall, 16 inches on center	
R-13	R-13 + 4.2 or R-21 + 2.8 or R-0 + 9.3 or R-15 + 3.8 or R-21 + 3.1
R-13 + 3	R-0 + 11.2 or R-13 + 6.1 or R-15 + 5.7 or R-19 + 5.0 or R-21 + 4.7
R-20	R-0 + 14.0 or R-13 + 8.9 or R-15 + 8.5 or R-19 + 7.8 or R-19 + 6.2 or R-21 + 7.5
R-20 + 5	R-13 + 12.7 or R-15 + 12.3 or R-19 + 11.6 or R-21 + 11.3 or R-25 + 10.9
R-21	R-0 + 14.6 or R-15 + 9.5 or R-19 + 9.1 or R-19 + 8.4 or R-21 + 8.1 or R-25 + 7.7
Steel Framed Wall, 24 inches on center	
R-13	R-0 + 9.3 or R-13 + 3.0 or R-15 + 2.4
R-13 + 3	R-0 + 11.2 or R-13 + 4.9 or R-15 + 4.3 or R-19 + 3.5 or R-21 + 3.1
R-20	R-0 + 14.0 or R-15 + 7.7 or R-19 + 7.1 or R-19 + 6.3 or R-21 + 5.9
R-20 + 5	R-13 + 11.5 or R-15 + 10.9 or R-19 + 10.1 or R-21 + 9.7 or R-25 + 9.1
R-21	R-0 + 14.6 or R-13 + 8.3 or R-15 + 7.7 or R-19 + 6.9 or R-21 + 6.5 or R-25 + 5.9

2021 IECC Responds…

- The following steel frame wall equivalent R-values have been added to the 2021 IECC Table R402.2.6 (RE51-19):

Wood Frame Wall R-value Required (Table R402.1.2)	Steel Frame Wall R-value Equivalent (cavity + ci)	
	16"oc Studs	24"oc studs
R13+5ci	R-0+15 or R-13+9 or R-15+8.5 or R-19+8 or R-21+7	R-0+15 or R-13+7.5 or R-15+7 or R-19+6 or R-21+6
R13+10ci	R0+20 or R-13+15 or R-15+14 or R-19+13 or R-21+13	R-0+20 or R-13+13 or R-15+12 or R-19+11 or R-21+11

NOTE: While R13+10ci and R20+5ci are thermally equivalent walls for wood framing, they each require different solutions for steel framing due to difference in 4" and 6" steel stud impact on cavity insulation effective R-value (40-50% of cavity insulation rated R-value). This is why equivalent steel frame walls always require continuous insulation, even when compared to a wood stud wall with cavity insulation only.

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Potentially Problematic Insulation trade-off on Walls with Partial Sheathing

- This language was intended to address intermittent structural sheathing challenges
- Unfortunately it has created more problems by not addressing it correctly
- There is not requirement to make up for energy losses due to this loophole

R402.2.7 Walls with partial structural sheathing. Where Section R402.1.2 requires continuous insulation on *exterior walls* and structural sheathing covers 40 percent or less of the gross area of all *exterior walls*, the required continuous insulation *R*-value shall be permitted to be reduced by an amount necessary, but not more than R-3 to result in a consistent total sheathing thickness on areas of the walls covered by structural sheathing. This reduction shall not apply to the *U*-factor alternative in Section R402.1.4 and the Total UA alternative in Section R402.1.5.

But, again, there's a better way…

- This provision is obsolete. With newer bracing provisions in IRC, most homes are fully or continuously structurally sheathed.
- CI can be applied uniformly as "over-sheathing" and is now common practice.
- Using thinner Ci over corner brace panels can result in --- you got it -- inadequate insulation ratio and unintended moisture consequences (in the braced portion of the wall where its perhaps most important)!

Sources:

(1) http://www.greenbuildingadvisor.com/blogs/dept/musings/osb-airtight

(2) http://buildingscience.com/documents/digests/bsd-139-deep-energy-retrofit...

(3) Baby It's Cold Outside – Nazareth College, Rochester, NY (Wikimedia commons)

CONCLUSIONS

- What are walls telling us?
  - With the right ingredients and recipe, advancements in the energy code can actually serve to improve energy performance and durability.
  - Conversely, misinformed use of weakening trade-offs or even some of the existing prescriptive R-value solutions can result in unintended consequences (even though technically “code compliant”).
  - The IECC and latest water vapor control provisions of the 2021 IRC and IBC need to be used in tandem to ensure a good recipe “mix”.
  - All other factors equal, increasing the insulation ratio (adding more ci) will improve moisture and thermal performance; reducing ci will have the opposite effect (don’t go below the 2021 IRC code minimums for a given climate)

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CONCLUSIONS

- Trading off ci can lead to moisture control problems when not meeting the required insulation ratio because of the absence of “permeance ratio” limits in the code (except when using a Class III VR).
- Southern/Warm climates – using ci to block inward vapor drives (also applies to reservoir claddings – see new 2021 IRC stucco provisions); insulation ratio is not a concern in warm climates.
- IECC residential above grade walls will include a “perfect wall” option for all climates using ci only (i.e., optimal from a moisture control standpoint for all climate zones)

Thank you!

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