**Replacement Proposal for REC2D-01-23**

*Revise footnote ‘a’ of Table R402.1.2 as follows:*

a. Nonfenestration *U*-factors and *F*-factors shall be obtained from measurement, calculation, ~~or~~ an approved source, or Appendix RF of this code where such appendix is adopted or approved.

*REASON: (1) Provides a single location to reference Appendix RF which is where sources for U-factors and F-factors are currently referenced as approved sources. (2) Allows simplification of code text in the following revisions (and also reduced the complexity of the original proposal).*

*Revise as follows:*

**R402.1.3 *R*-value alternative.** Assemblies with *R*-value of insulation materials equal to or greater than that specified in **Table R402.1.3** shall be an alternative to the *U*-factor or *F*-factor in **Table R402.1.2**. *~~R~~*~~-values of insulation materials for the assemblies specified in Appendix RF that have a~~ *~~U~~*~~-factor less than or equal to the~~ *~~U~~*~~-factor required by Table R402.1.2 shall be permitted~~

*REASON: (1) Redundant with R402.1.2 which provides means to determine equivalent R-value solutions using U-factors. (2) Missing F-factors which inadvertently limits use of F-factors in Section R402.1.2 and in Appendix RF for equivalent slab insulation R-value alternatives.*

*Revise as follows:*

**R402.2.10.2 Alternative slab-on-grade insulation configurations.** For *buildings* complying with Sections R405 or R406, slab-on-grade insulation shall be installed in accordance with the *proposed design* or *rated design*. ~~The~~ *~~proposed design~~* ~~or~~ *~~rated design~~* ~~shall use an alternative insulation configuration and associated F-factor complying with Appendix A of ASHRAE 90.1 or, where adopted, Appendix RF of this code. Where used to comply with Section R401.2.1, the F-factor shall be equal to or less than the F-factor required by Table R402.1.2 for a heated or unheated slab, as applicable.~~

**R402.2.11.2 Alternative crawl space wall insulation configurations.** For *buildings* complying with Sections R405 or R406 *crawl space wall* insulation shall be installed in accordance with the *proposed design* or *rated design*. ~~The~~ *~~proposed design~~* ~~or~~ *~~rated design~~* ~~shall use an alternative insulation configuration and associated U-factor or C-factor complying with Appendix A of ASHRAE 90.1 or, where adopted, Appendix RF of this code. Where used to comply with Section R401.2.1, the U-factor or C-factor shall be equal to or less than the U-factor required by Table R402.1.2 for crawl space walls.~~

*REASON: Deleted text is not needed by adding a single reference to Appendix RF in existing footnote ‘a’ of Table R402.1.2 (see above). This footnote already establishes sources for U-factors and F-factors and is the appropriate location for such sources. Also, the last sentence in each of the above sections is wrong and would limit the ability to do TC trade-offs with slabs or crawlspaces in Section R402.1.5 (through the reference to R401.2.1 which includes R402.1.5).*

*Revise Appendix RF as follows:*

(NOTE: underlining in tables omitted for clarity)

**RF105**

**BASEMENT AND CRAWL SPACE WALLS~~. RESERVED.~~**

**RF105.1 Basement and Crawlspace Walls.** U-factors for basement and crawl space walls shall be as specified in accordance with Table RF105.1. Effective U-factors for the proposed and reference foundation wall design must be used to demonstrate compliance with Section R402.1.5. Effective U-factors shall not be used for other compliance methods referenced in Section R401.2.1 of the code.

**TABLE RF105.1**

**U-FACTORS FOR BASEMENT AND CRAWL SPACE WALLSa**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Insulation Configurationsb** | **Wall**  **U-factorc**  **(Btu/hr-ft2-F)** | **Wall Effective U-factord by Percentage of Wall Height Projecting Above Grade (Btu/hr-ft2-F)**  **for Use Only with Section R402.1.5** | | | |
| **50%** | **35%** | **20%** | **5%** |
| BASEMENT WALLS | | | | | |
| Uninsulated & unfinished basement wall | 0.360 | 0.324 | 0.288 | 0.252 | 0.216 |
| Continuous Insulation  R-5ci  R-7.5ci  R-10ci  R-15ci  R-20ci  R-25ci | 0.122  0.093  0.076  0.055  0.043  0.035 | 0.109  0.084  0.068  0.049  0.039  0.032 | 0.097  0.075  0.060  0.044  0.034  0.028 | 0.085  0.065  0.053  0.038  0.030  0.025 | 0.073  0.056  0.045  0.033  0.026  0.021 |
| Cavity Insulation  R-11  R-13  R-15  R-19  R-21 | 0.076  0.067  0.060  0.050  0.045 | 0.068  0.060  0.054  0.045  0.041 | 0.060  0.054  0.048  0.040  0.036 | 0.053  0.047  0.042  0.035  0.032 | 0.045  0.040  0.036  0.030  0.027 |
| Cavity + Continuous Insulation  R-13 + R-5ci  R-13 + R-7.5ci  R-13 + R-10ci  R-19 + R-5ci  R-19 + R-7.5ci  R-19 + R-10ci | 0.050  0.045  0.040  0.040  0.036  0.033 | 0.045  0.040  0.036  0.036  0.033  0.030 | 0.040  0.036  0.032  0.032  0.029  0.027 | 0.035  0.031  0.028  0.028  0.025  0.023 | 0.030  0.027  0.024  0.024  0.022  0.020 |

Table RF105.1 (continued)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Insulation Configurationsb** | **Wall**  **U-factorc**  **(Btu/hr-ft2-F)** | **Wall Effective U-factord by Percentage of Wall Height Projecting Above Grade (Btu/hr-ft2-F)**  **for Use Only with Section R402.1.5** | | | |
| **50%** | **35%** | **20%** | **5%** |
| CRAWL SPACE WALLS | | | | | |
| Uninsulated crawl space wall | 0.477 | 0.429 | 0.382 | 0.334 | n/a |
| Continuous Insulation  R-5ci  R-7.5ci  R-10ci  R-15ci  R-20ci  R-25ci | 0.141  0.104  0.083  0.058  0.045  0.037 | 0.127  0.094  0.074  0.053  0.041  0.033 | 0.113  0.083  0.066  0.047  0.036  0.030 | 0.099  0.073  0.058  0.041  0.032  0.026 | n/a |
| Cavity Insulation  R-11  R-13  R-15  R-19  R-21 | 0.083  0.072  0.065  0.054  0.048 | 0.074  0.065  0.058  0.049  0.043 | 0.066  0.058  0.052  0.043  0.038 | 0.058  0.051  0.045  0.038  0.033 | n/a |
| Cavity + Continuous Insulation  R-13 + R-5ci  R-13 + R-7.5ci  R-13 + R-10ci  R-19 + R-5ci  R-19 + R-7.5ci  R-19 + R-10ci | 0.053  0.047  0.042  0.043  0.039  0.035 | 0.048  0.042  0.038  0.038  0.035  0.032 | 0.043  0.038  0.034  0.034  0.031  0.028 | 0.037  0.033  0.029  0.030  0.027  0.025 | n/a |

n/a = not applicable

Table Notes:

1. The wall U-factor excludes exterior air-film R-value and, for insulated assemblies, includes the following: 0.68 R for interior air film, 0.45 R for ½” gypsum panel finish (insulated basement walls only), and 2.1 R for 12” block basement wall or 1.4 R for 8” block crawlspace wall, both with empty cells. Where cavity insulation is included between 2x4 or 2x6 framing on the interior side of a foundation wall, wood stud material with thermal resistivity of R-1.25/in is assumed to be spaced at not less than 16-inches on center with an assumed framing factor not greater than 0.15.
2. All insulation configurations extend from top of foundation wall to floor of basement or crawlspace. Extrapolation to partial height insulation shall not be permitted; U-factors for such insulation configurations shall be determined by accepted engineering practice for modeling of thermal bridging and ground-coupled assemblies.
3. Applicable to Sections R402.1.2, R405 and R406.
4. Effective U-factors are adjusted to account for ground-coupling effects to provide equivalency to U-factors used for above-grade building thermal envelope assemblies. The Effective U-factors are provided for use with Section R402.1.5 for evaluation of trade-offs with above-grade assemblies and other components of the *building thermal envelope*. The Effective U-factor shall apply to the foundation wall area from interior floor or ground surface to top of wall. Interpolation between R-values and percentage of wall height projecting above grade within a given insulation configuration type is permitted.

**~~RF106~~**

**~~CRAWLSPACE WALLS. RESERVED.~~**

**RF106 ~~RF107~~**

**SLABS-ON-GRADE~~. RESERVED.~~**

**RF106.1 Slabs-on-grade.** F-factors for unheated and heated slabs-on-grade shall be as specified in Table RF106.1. All applicable adjustment factors in the table footnotes shall apply. F-factors for basement floor slabs and crawl space ground surface located below exterior grade shall be adjusted in accordance footnote ‘f’ as applicable.

**TABLE RF106.1**

**F-FACTORS FOR SLABS-ON-GRADEa,b,c,d,e,f**

|  |  |
| --- | --- |
| **Unheated Slabs-on-Grade – Insulation Configurations** | **F-FACTOR (Btu/hr-ft-F)** |
| Uninsulated Slab | 0.73 |
| Horizontal Insulation Under Slab at Slab Perimeter – Slab Edge Not Insulated  ≥R-5 for 2 ft  R-5 for 4 ft  ≥R-10 for 4 ft | 0.70  0.67  0.64 |
| Vertical Insulation on Exterior Faceg – Slab Edge Insulatedh  R-2.5 for 2ft  R-5 for 2 ft  R-7.5 for 2 ft  R-10 for 2 ft  R-15 for 2 ft  R-5 for 3 ft  R-7.5 for 3 ft  R-10 for 3 ft  R-15 for 3 ft  R-5 for 4 ft  R-7.5 for 4 ft  R-10 for 4 ft  R-15 for 4 ft | 0.66  0.58  0.56  0.54  0.52  0.56  0.54  0.51  0.49  0.54  0.51  0.48  0.45 |
| Fully Insulated Slab – Full Slab Area and Slab Edge Continuously Insulated  R-5 entire slab area and R-3.5 edge  R-5 entire slab area and edge  R-7.5 entire slab area and R-3.5 edge  R-7.5 entire slab area and edge  R-10 entire slab area and R-5 edge  R-10 entire slab area and edge  R-15 entire slab area and R-5 edge  R-15 entire slab area and edge  R-10 slab edge and under slab perimeter inward 4 ft; R-5 remaining slab area  R-15 slab edge and under slab perimeter inward 4 ft; R-5 remaining slab area  R-15 slab edge and under slab perimeter inward 4 ft; R-10 remaining slab area | 0.48  0.46  0.45  0.41  0.40  0.36  0.35  0.30  0.42  0.40  0.34 |

Table RF106.1 continued

|  |  |
| --- | --- |
| **Heated Slabs-on-Grade – Insulation Configurations** | **F-FACTOR (Btu/hr-ft-F)** |
| Uninsulated | 1.35 |
| Fully Insulated Slab – Full Slab Area and Slab Edge Continuously Insulated  R-5 entire slab area and R-3.5 edge  R-5 entire slab area and edge  R-7.5 entire slab area and R-3.5 edge  R-7.5 entire slab area and edge  R-10 entire slab area and R-5 edge  R-10 entire slab area and edge  R-15 entire slab area and R-5 edge  R-15 entire slab area and edge  R-20 entire slab area and R-7.5 edge  R-20 entire slab area and edge  R-5 entire slab area and R-10 slab edge extending downward for minimum 3 ft  R-10 slab edge and under slab perimeter inward 4 ft; R-5 remaining slab area  R-15 slab edge and under slab perimeter inward 4 ft; R-5 remaining slab area  R-15 slab edge and under slab perimeter inward 4 ft; R-10 remaining slab area | 0.77  0.74  0.71  0.64  0.62  0.55  0.54  0.44  0.44  0.37  0.66  0.66  0.62  0.51 |

Table Notes:

1. For alternative slab-on-grade insulation configurations, F-factors shall be determined in accordance with accepted engineering practice for modeling three dimensional ground-coupled building assemblies using project-specific building and site conditions to estimate annual energy use attributed to foundation heat transfer and converting the result to an equivalent air-to-air F-factor basis.
2. Interpolation between R-values for a given insulation configuration type is permitted.
3. Tabulated F-factors are based on a typical soil thermal conductivity of 0.75 Btu/hr-ft-F and shall be multiplied by one of the following adjustment factors as applicable to site soil conditions: (1) rock or any soil on sites with poor drainage or high water table – 1.2; (2) sandy soils – 1.1; (3) loam or clay soils on well-drained sites in dry climate zones – 0.85; and (3) for all other soil or site conditions – 1.00. Where soil conditions are unknown, use of 1.00 is permitted.
4. Tabulated F-factors are based on a slab area to perimeter length ratio of 9:1 and shall be multiplied by one of the following adjustment factors as applicable to a slab’s area to perimeter length ratio: 5:1 – 0.7; 6:1 – 0.8; 7:1 – 0.9; 8:1 – 0.95; 9:1 – 1.0; 10:1 – 1.05; 15:1 – 1.2; 20:1 – 1.35; 30:1 – 1.5; and for ≥ 40:1 – 1.7,
5. Tabulated F-factors are based on a slab perimeter edge projection above exterior finish grade of 6 inches. For portions of slab perimeter projecting 12 inches or more above grade, multiply the tabulated F-factors by one of the following adjustment factors as applicable: less than 12 inches – 1.0; 12 inches – 1.05; 18 inches – 1.1; 24 inches – 1.15; and 30 inches – 1.2.
6. For basement floor slabs and crawlspaces slabs or gravel floors, the tabulated F-factors shall be multiplied by one of the following adjustment factors based on the depth of the floor surface below exterior finish grade: less than 1ft – 1.0; 1 ft – 0.95; 3 ft – 0.9; and 6 ft or more – 0.8.
7. Vertical insulation on the exterior shall extend for the indicated depth below finish grade and above grade to the top of slab or stem wall. Where insulation is placed on the interior side of a foundation stem wall, it shall extend from the top of slab to the indicated depth below the exterior finish grade and the applicable tabulated F-factor shall be multiplied by 1.05.
8. The R-value of the vertical insulation located on the interior side of a stem wall shall be permitted to be reduced to R-2.5 at the slab edge, not exceeding 6 inches thick, provided the applicable F-factor is multiplied by 1.15 where R-5 vertical insulation is specified, 1.2 where R-10 vertical insulation is specified, or 1.25 where R-15 vertical insulation is specified.

**REASON:** The main purpose of this [REPLACEMENT] proposal is to coordinate with changes to R402.2.10.2 (slabs-on-grade) and R402.2.11.2 (crawlspace walls) which added a reference to Appendix RF in the legislative draft, but the appendix did not include solutions for these assemblies (only placeholders). This proposal provides the solutions and data in Appendix RF as anticipated as a follow-up to these changes made during the recently completed Draft 2 development. It also adds a consistent reference to Appendix RF for alternative assemblies used in the simulated performance compliance path (Section R405). The tabulated F-factors align with those used for R-value and F-factor requirements in Tables R402.1.2 and R402.1.3 of the code. The values are based on the same research used for the code and also referenced in ASHRAE 90.1 Appendix A (see bibliography).

More importantly, tabulated U-factors (and Effective U-factors) for below-grade walls (enclosing conditioned basements or crawlspaces) are also provided based on the same research. The Effective U-factors for below grade walls in Section RF105.1 are derived in the same manner as F-factors where ground coupling effects are considered and then used to convert the U-factor (or C-factor as used in the commercial code) to an effective value based on air-to-air (instead of air-to-ground) heat exchange such that they have the same basis as U-factors used for above grade assemblies in terms of impacts on annual energy use. This also ensures that equivalent “apples-to-apples” trade-offs are made between above- and below-grade assemblies when using Section R402.1.5 (see revisions to R402.1.5 to coordinate). It also ensures consistent additional UA credits are achieved in accordance with Section R408 for above- and below-grade assemblies since TC calculated per Section R402.1.5 is referenced for that purpose. Without these effective U-factors for basement and crawlspace walls, the trade-off value of adding insulation to a typical basement or crawlspace could be over-estimated by as much as 60%. This degree of non-conservative error or bias should not be tolerable. Effective U-factors are only applicable for compliance in accordance with Section R402.1.5 and are not applicable to other code compliance paths, such as R402.1.2, R405, and R406 which are based on modeling to account for ground coupling effects using a traditional U-factor for foundation walls.

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Cleaveland, J.P. and Akridge, J.M. (198?). Slab-on-Grade Thermal Loss in Hot Climates. Georgia Institute of Technology for ASHRAE.

Bahnfleth, W.P. and Amber, J. (1990). Algorithms for Slab-on-Grade Heat Transfer Calculations. U.S. Army Corps of Engineers, USACERL Technical Report E-90/15, September 1990.

**Cost Impact:** The code change proposal will decrease the cost of construction.

This proposal provides U-factor and F-factor data (for a wide variety of R-value solutions) to assist in compliance with the code and provides flexibility in solutions that are equivalent to code or which support accurate trade-offs per Section R402.1.5 with greater accuracy. It also corrects errors as noted in the reason statement which would have increased cost and restricted options unnecessarily.