



**BSR/ASHRAE/IES Addendum ai
to ANSI/ASHRAE/IES Standard 90.1-2019**

Public Review Draft

Proposed Addendum ai to Standard 90.1-2019, Energy Standard for Buildings Except Low-Rise Residential Buildings

**First Public Review (May 2021)
(Draft Shows Proposed Changes to Current Standard)**

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(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

Following the receipt of numerous informal inquiries to the SSPC 90.1 Envelope Subcommittee, this proposal modifies Appendix A to provide greater detail and clarity to the insulation requirements for the following metal building assemblies:

- *Standing Seam Roofs with Thermal Spacer Blocks, Double Layer*
- *Through-fastened Roofs without Thermal Spacer Blocks, Single Layer*
- *Single Compressed Layer Walls*
- *Single Layer In-Cavity Walls*
- *Double Layer Walls*

The U-factors of these assemblies were determined by the calculation procedures of Section A9.4.6 and are listed in Tables A2.3.3 and A3.2.3. This proposal adds requisite insulation requirements to Section A9.4.6 as well as making other revisions to provide consistency and clarity in all affected sections of 90.1.

It is important to note that this proposal does not prevent any insulation from being used in the listed assemblies. It only stipulates the insulation requirements assumed by the underlying U-factor calculations used to populate Tables A2.3.3 and A3.2.3.

Note: This addendum does not change any existing criteria and therefore was not subject to any cost analysis.

[Note to Reviewers: This addendum makes proposed changes to the current standard. These changes are indicated in the text by underlining (for additions) and ~~striketrough~~ (for deletions) except where the reviewer instructions specifically describe some other means of showing the changes. Only these changes to the current standard are open for review and comment at this time. Additional material is provided for context only and is not open for comment except as it relates to the proposed changes.]

Addendum ai to 90.1-2019

Modify the standard as follows (IP and SI Units)

Chapter 12 – Normative References

Reference	Title
<u>ASTM C167-18</u>	<u>Standard Test Methods for Thickness and Density of Blanket or Batt Thermal Insulations</u>

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A2.3.2 Rated R-value of Insulation

A2.3.2.1 Single Layer

The *rated R-value of insulation* is for insulation installed perpendicular to and draped over purlins and then compressed when the metal *roof* panels are attached. Where indicated in Table A2.3.3, a minimum R-3 (R-0.5) thermal spacer block between the purlins and the metal *roof* panels is required unless compliance is shown by the overall assembly *U-factor*. When a *U-factor* from Table A2.3.3 is used, fiberglass insulation must meet the requirements for thermal conductivity (k') and density (ρ') of Equations A9.4-2 and A9.4-3 respectively.

A2.3.2.2 Double Layer

The first *rated R-value* of insulation is for insulation installed perpendicular to and draped over purlins. The second *rated R-value* of insulation is for unfaced insulation installed above the first layer and parallel to the purlins and then compressed when the metal *roof* panels are attached. A minimum R-3 (R-0.5) thermal spacer block between the purlins and the metal *roof* panels is required unless compliance is shown by the overall assembly *U-factor*. When a *U-factor* from Table A2.3.3 is used, fiberglass insulation must meet the requirements for thermal conductivity (k') and density (ρ') of Equations A9.4-2 and A9.4-3 respectively.

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A3.2.3 U-factors for Metal Building Walls

U-factors for *metal building walls* shall be taken from Table A3.2.3 or determined in accordance with Section A9.2, provided the average girt spacing is at least 52 in. (1300 mm.) *U-factors* for *metal building wall* assemblies with average girt spacing less than 52 in. (1300 mm) shall be determined in accordance with Section A9.2. When a *U-factor* from Table A3.2.3 is used, fiberglass insulation must meet the requirements for thermal conductivity (k') and density (ρ') of Equations A9.4-2 and A9.4-3 respectively.

Modify Table A2.3.3 as follows (I-P Units)

Table A2.3.3 Assembly U-factors for Metal Building Roofs

Insulation System	Rated R-value of Insulation	Overall U-factor for Entire Base Roof Assembly	Overall U-factor for Entire Base Roof Plus Continuous Insulation (Uninterrupted by Framing)								
			Rated R-value of Continuous Insulation								
			R-6.5	R-9.8	R-13	R-15.8	R-19	R-22.1	R-25	R-32	R-38
Standing Seam Roofs with Thermal Spacer Blocks^{a,b}											
Single Layer ^d	None	1.280	0.137	0.095	0.073	0.060	0.051	0.044	0.039	0.031	0.026
	R-10	0.115	0.066	0.054	0.046	0.041	0.036	0.032	0.030	0.025	0.021
	R-11	0.107	0.063	0.052	0.045	0.040	0.035	0.032	0.029	0.024	0.021
	R-13	0.101	0.061	0.051	0.044	0.039	0.035	0.031	0.029	0.024	0.021
	R-16	0.096	0.059	0.049	0.043	0.038	0.034	0.031	0.028	0.024	0.021
	R-19	0.082	0.053	0.045	0.040	0.036	0.032	0.029	0.027	0.023	0.020
Double Layer ^d	R-10 + R-10	0.088	0.056	0.047	0.041	0.037	0.033	0.030	0.028	0.023	0.020
	R-10 + R-11	0.086	0.055	0.047	0.041	0.036	0.033	0.030	0.027	0.023	0.020
	R-11 + R-11	0.085	0.055	0.046	0.040	0.036	0.033	0.030	0.027	0.023	0.020
	R-10 + R-13	0.084	0.054	0.046	0.040	0.036	0.032	0.029	0.027	0.023	0.020
	R-11 + R-13	0.082	0.053	0.045	0.040	0.036	0.032	0.029	0.027	0.023	0.020
	R-13 + R-13	0.075	0.050	0.043	0.038	0.034	0.031	0.028	0.026	0.022	0.019
	R-10 + R-19	0.074 <u>0.073</u>	0.050	0.043	0.038	0.034	0.031	0.028	0.026	0.022	0.019
	R-11 + R-19	0.072	0.049	0.042	0.037	0.034	0.030	0.028	0.026	0.022	0.019
	R-13 + R-19	0.068	0.047	0.041	0.036	0.033	0.030	0.027	0.025	0.021	0.019
	R-16 + R-19	0.065	0.046	0.040	0.035	0.032	0.029	0.027	0.025	0.021	0.019
R-19 + R-19	0.060	0.043	0.038	0.034	0.031	0.028	0.026	0.024	0.021	0.018	
Liner System	R-19 + R-11	0.037									
	R-25 + R-8	0.037									
	R-25 + R-11	0.031									
	R-30 + R-11	0.029									
	R-25 + R-11 + R-11	0.026									
Filled Cavity with Thermal Spacer Blocks^c											
	R-10 + R-19	0.041	0.032	0.029	0.027	0.025	0.023	0.022	0.020	0.018	0.016
	R-19 + R-11	0.037									
Standing Seam Roofs without Thermal Spacer Blocks											
Liner System	R-19 + R-11	0.040									
Through-Fastened Roofs without Thermal Spacer Blocks											
Single Layer ^d	R-10	0.184	0.084	0.066	0.054	0.047	0.041	0.036	0.033	0.027	0.023
	R-11	0.182	0.083	0.065	0.054	0.047	0.041	0.036	0.033	0.027	0.023
	R-13	0.174	0.082	0.064	0.053	0.046	0.040	0.036	0.033	0.026	0.023
	R-16	0.157	0.078	0.062	0.052	0.045	0.039	0.035	0.032	0.026	0.023
	R-19	0.151	0.076	0.061	0.051	0.045	0.039	0.035	0.032	0.026	0.022
Liner System	R-19 + R-11	0.044									

(Multiple R-values are listed in order from inside to outside)

- a. A standing seam roof clip that provides a minimum 1.5 in. distance between the top of the roof purlin and the underside of the metal roof panels is required.
- b. A minimum R-3 thermal spacer block is required.
- c. A minimum R-5 thermal spacer block is required.
- d. U-factors are calculated in accordance with Section A9.4.6.

Modify Table A2.3.3 as follows (SI Units)

Insulation System	Rated R-Value of Insulation	Overall U-Factor for Entire Base Roof Assembly	Overall U-Factor for Assembly of Base Roof Plus Continuous Insulation (Uninterrupted by Framing)								
			Rated R-Value of Continuous Insulation								
			R-1.1	R-1.7	R-2.3	R-2.8	R-3.3	R-3.9	R-4.4	R-5.6	R-6.7
Standing Seam Roofs with Thermal Spacer Blocks^{a, b}											
Single Layer ^d	None	7.27	0.780	0.54	0.41	0.34	0.29	0.25	0.22	0.17	0.15
	R-1.8	0.653	0.37	0.31	0.26	0.23	0.21	0.18	0.17	0.14	0.12
	R-1.9	0.608	0.36	0.30	0.25	0.23	0.20	0.18	0.17	0.14	0.12
	R-2.3	0.573	0.35	0.29	0.25	0.22	0.20	0.18	0.16	0.14	0.12
	R-2.8	0.55	0.34	0.28	0.24	0.22	0.19	0.17	0.16	0.13	0.12
	R-3.3	0.47	0.30	0.26	0.23	0.20	0.18	0.17	0.15	0.13	0.11
Double Layer ^d	R-1.8 + R-1.8	0.50	0.32	0.27	0.23	0.21	0.19	0.17	0.16	0.13	0.12
	R-1.8 + R-1.9	0.49	0.31	0.26	0.23	0.21	0.19	0.17	0.16	0.13	0.11
	R-1.9 + R-1.9	0.48	0.31	0.26	0.23	0.21	0.18	0.17	0.15	0.13	0.11
	R-1.8 + R-2.3	0.48	0.31	0.26	0.23	0.20	0.18	0.17	0.15	0.13	0.11
	R-1.9 + R-2.3	0.47	0.30	0.26	0.23	0.20	0.18	0.17	0.15	0.13	0.11
	R-2.3 + R-2.3	0.43	0.28	0.25	0.22	0.19	0.18	0.16	0.15	0.13	0.11
	R-1.8 + R-3.3	0.42 0.41	0.28	0.24	0.22	0.19	0.17	0.16	0.15	0.12	0.11
	R-1.9 + R-3.3	0.41	0.28	0.24	0.21	0.19	0.17	0.16	0.15	0.12	0.11
	R-2.3 + R-3.3	0.39	0.27	0.23	0.20	0.19	0.17	0.15	0.14	0.12	0.11
	R-2.8 + R-3.3	0.37	0.26	0.23	0.20	0.18	0.17	0.15	0.14	0.12	0.11
	R-3.3 + R-3.3	0.34	0.25	0.21	0.19	0.17	0.16	0.15	0.14	0.12	0.10
Liner system	R-3.3 + R-1.9	0.21									
	R-4.4 + R-1.4	0.21									
	R-4.4 + R-1.9	0.18									
	R-5.3 + R-1.9	0.16									
	R-4.4 + R-1.9 + R-1.9	0.15									
Filled Cavity with Thermal Spacer Blocks^c											
	R-1.8 + R-3.3	0.23	0.18	0.17	0.15	0.14	0.13	0.14	0.11	0.10	0.09
	R-3.3 + R-1.9	0.21									
Standing Seam Roofs without Thermal Spacer Blocks											
Liner system	R-3.3 + R-1.9	0.23									
Through-Fastened Roofs without Thermal Spacer Blocks											
Single Layer ^d	R-1.8	1.04	0.48	0.37	0.31	0.27	0.23	0.21	0.19	0.15	0.13
	R-1.9	1.03	0.47	0.37	0.31	0.27	0.23	0.21	0.19	0.15	0.13
	R-2.3	0.988	0.46	0.37	0.30	0.26	0.23	0.20	0.18	0.15	0.13
	R-2.8	0.891	0.44	0.35	0.29	0.26	0.22	0.20	0.18	0.15	0.13
	R-3.3	0.857	0.43	0.35	0.29	0.25	0.22	0.20	0.18	0.15	0.13
Liner system	R-3.3 + R-1.9	0.25									
(Multiple R-values are listed in order from inside to outside)											

- A standing seam roof clip that provides a minimum 3.8 cm distance between the top of the purlins and the underside of the metal roof panels is required.
- A minimum R-0.5 thermal spacer block is required.
- A minimum R-0.9 thermal spacer block is required.
- U-factors are calculated in accordance with Section A9.4.6.

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Modify Table A3.2.3 as follows (I-P version is shown as an example; corresponding changes are proposed for the SI table and footnotes. No changes to the current values are proposed for either the I-P or SI table.)

Table A3.2.3 Assembly U-factors for Metal Building Walls

Insulation System	Rated R-value of Insulation	Overall U-factor for Entire Base Roof Assembly	Overall U-factor for Entire Base Roof Plus Continuous Insulation (Uninterrupted by Framing)								
			Rated R-value of Continuous Insulation								
			R-6.5	R-9.8	R-13	R-15.8	R-19	R-22.1	R-25	R-32	R-38
Continuous insulation only	R-0	1.180	0.136	0.094	0.072	0.060	0.050	0.044	0.039	0.030	0.026
Single Compressed Layer ^d	R-10	0.186	0.084	0.066	0.054	0.047	0.041	0.036	0.033	0.027	0.023
	R-11	0.185	0.084	0.066	0.054	0.047	0.041	0.036	0.033	0.027	0.023
	R-13	0.162	0.079	0.063	0.052	0.046	0.040	0.035	0.032	0.026	0.023
	R-16	0.155	0.077	0.062	0.051	0.045	0.039	0.035	0.032	0.026	0.022
	R-19	0.147	0.075	0.060	0.050	0.044	0.039	0.035	0.031	0.026	0.022
Single layer in cavity ^d	R-25 ^a	0.059	0.044	0.039	0.035	0.032	0.029	0.027	0.025	0.021	0.019
	R-30 ^b	0.052	0.042	0.037	0.033	0.031	0.028	0.026	0.024	0.021	0.019
Double Layer ^d	R-25 + R-10	0.047	0.038	0.034	0.031	0.028	0.026	0.024	0.023	0.020	0.018
	R-25 + R-16	0.042	0.036	0.032	0.029	0.027	0.025	0.023	0.022	0.019	0.018
	R-25 + R-10 ^c	0.039	0.032	0.029	0.027	0.025	0.023	0.022	0.021	0.018	0.017
	R-30 + R-10	0.039	0.036	0.032	0.029	0.027	0.025	0.023	0.022	0.019	0.017

(Multiple R-values are listed in order from inside to outside)

a. A minimum R-0.375 thermal spacer block or thermal break strip is required when installed without continuous insulation.

b. A minimum R-0.75 thermal spacer block or thermal break strip is required when installed without continuous insulation.

c. A minimum R-3 thermal spacer block is required.

d. U-factors are calculated in accordance with Section A9.4.6.

Modify Section A9.4.6 as follows (I-P); renumber existing equations accordingly.

A9.4.6 Metal Building U-Factor Equations

The calculation procedures in this section shall use a fixed purlin and girt spacing of 60 in., and the results shall be permitted to be used in accordance with Sections A2.3.3 and A3.2.3. All fiberglass insulation shall meet the requirements for thermal conductivity (k') and density (ρ') of Equations A9.4-2 and A9.4-3 respectively:

$$k' = \frac{t}{R} \leq 1.03k_0 \quad \text{(A9.4-2)}$$

$$\rho' \geq \frac{\rho_0}{1.03} \quad \text{(A9.4-3)}$$

where

k' = k-factor of the insulation calculated for the purposes of Equation A9.4-2, Btu/h·ft·°F

R = Rated R-value of the insulation, h·ft²·°F/Btu as determined by ASTM C177 or ASTM C518

t = thickness of insulation, ft, as determined by ASTM C167

ρ' = density of insulation, lb/ft³, as determined by ASTM C167

k_0 = reference k-factor of insulation from Table A9.4.6.1

ρ_0 = reference density of insulation from Table A9.4.6.1

For single-layer *metal building roof* and single-layer compressed *metal building wall systems*, the calculation procedure outlined in Section A9.4.6.1 shall be used to calculate the assembly *U-factor*. For double-layer *metal building roof systems*, the calculation procedure outlined in Section A9.4.6.2 shall be used to calculate the assembly *U-factor*. For single-layer in cavity and double-layer *metal building wall systems*, the calculation procedure outlined in Section A9.4.6.3 shall be used to calculate the assembly *U-factor*. Each of the above insulation methods and calculation procedures also shall be used where *continuous insulation* is applied to the assembly. The calculation procedures outlined in this section shall not be used for other *metal building roof* and *wall systems*.

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A9.4.6.3 Single-Layer in Cavity and Double-Layer Walls

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Step 1: The thermal conductivity of the mineral fiber insulation is represented by a thermal curve of the form in Equation A9.4-224:

$$k = A + B \frac{\rho_0 \delta_0}{y} + C \frac{y}{\rho_0 \delta_0} \quad (\text{A9.4-224})$$

where

k = thermal conductivity, Btu·ft/h·ft²·°F

ρ_0 = ~~nominal~~ reference density, lb/ft³

δ_0 = ~~nominal~~ reference thickness, ft

y = thickness of the insulation, ft

A = 0.014917

B = 0.0004377

C = 0.0056897

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Table A9.4.6.1 Fiberglass Reference Properties^a

<i>R-value</i> , h·ft ² ·°F/Btu	Weight, lb/ft ²	Density, lb/ft ³	Thickness, ft	<i>k-factor</i> , Btu·ft/h·ft ² ·°F
10	0.149	0.605	0.2458	<u>0.0246</u>
11	0.168	0.630	0.2667	<u>0.0242</u>
13	0.199	0.628	0.3167	<u>0.0244</u>
16	0.243	0.634	0.3833	<u>0.0240</u>
19	0.297	0.653	0.4542	<u>0.0239</u>
25	0.427	0.742	0.5750	<u>0.0230</u>
30	0.520	0.766	0.6792	<u>0.0226</u>

a. Linear interpolation between *R-values* is permitted to determine the applicable reference properties. Extrapolation beyond *R-values* is not allowed.

Modify Section A9.4.6 as follows (SI); renumber existing equations accordingly.

A9.4.6 Metal Building U-Factor Equations

The calculation procedures in this section shall use a fixed purlin and girt spacing of 60 in. (1.52 m), and the results shall be permitted to be used in accordance with Sections A2.3.3 and A3.2.3. All fiberglass insulation shall meet the requirements for thermal conductivity (k') and density (ρ') of Equations A9.4-2 and A9.4-3 respectively:

$$k' = \frac{t}{R} \leq 1.03k_0 \quad \text{(A9.4-2)}$$

$$\rho' \geq \frac{\rho_0}{1.03} \quad \text{(A9.4-3)}$$

where

k' = k-factor of the insulation calculated for the purposes of Equation A9.4-2, W/m·°C

R = Rated *R-value* of the insulation, m²·°C/W as determined by ASTM C177 or ASTM C518

t = thickness of insulation, m, as determined by ASTM C167

ρ' = density of insulation, kg/m³, as determined by ASTM C167

k_0 = reference k-factor of insulation from Table A9.4.6.1

ρ_0 = reference density of insulation from Table A9.4.6.1

For single-layer *metal building roof* and single-layer compressed *metal building wall systems*, the calculation procedure outlined in Section A9.4.6.1 shall be used to calculate the assembly *U-factor*. For double-layer *metal building roof systems*, the calculation procedure outlined in Section A9.4.6.2 shall be used to calculate the assembly *U-factor*. For single-layer in cavity and double-layer *metal building wall systems*, the calculation procedure outlined in Section A9.4.6.3 shall be used to calculate the assembly *U-factor*. Each of the above insulation methods and calculation procedures also shall be used where *continuous insulation* is applied to the assembly. The calculation procedures outlined in this section shall not be used for other *metal building roof* and *wall systems*.

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A9.4.6.3 Single-Layer in Cavity and Double-Layer Walls

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Step 1: The thermal conductivity of the mineral fiber insulation is represented by a thermal curve of the form in Equation A9.4-224:

$$k = A + B \frac{\rho_0 \delta_0}{y} + C \frac{y}{\rho_0 \delta_0} \quad \text{(A9.4-224)}$$

where

k = thermal conductivity, W/m·°C

ρ_0 = ~~nominal~~ reference density, kg/m³

δ_0 = ~~nominal~~ reference thickness, m

y = thickness of the insulation, m

A = 0.0258168

B = 0.000047295

$$C = 0.157740033$$

...

Table A9.4.6.1 Fiberglass Reference Properties^a

R-Value, m ² ·°C/W	Weight, kg/m ²	Density, kg/m ³	Thickness, m	k-factor, W/m·°C
1.76	0.727	9.680	0.075	<u>0.0426</u>
1.94	0.820	10.080	0.081	<u>0.0418</u>
2.29	0.971	10.048	0.097	<u>0.0424</u>
2.82	1.186	10.144	0.117	<u>0.0415</u>
3.34	1.449	10.448	0.138	<u>0.0413</u>
4.40	2.084	11.872	0.175	<u>0.0398</u>
5.28	2.538	12.256	0.207	<u>0.0392</u>

a. Linear interpolation between R-values is permitted to determine the applicable reference properties. Extrapolation beyond R-values is not allowed.