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AISI S250-21w/S1-22

American
Iron and Steel
Institute

AISI STANDARD

North American Standard for Thermal Transmittance of Building Envelopes with Cold-Formed Steel Framing

2021 Edition With Supplement 1

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DISCLAIMER

The material contained herein has been developed by the American Iron and Steel Institute (AISI) Committee on Framing Standards. The Committee has made a diligent effort to present accurate, reliable and useful information on cold-formed steel framing design and installation. The Committee acknowledges and is grateful for the contributions of the numerous researchers, engineers, and others who have contributed to the body of knowledge on the subject. Specific references are included in the *Commentary*.

With anticipated improvements in understanding of the behavior of cold-formed steel framing and the continuing development of new technology, this material will become dated. It is anticipated that AISI will publish updates of this material as new information becomes available, but this cannot be guaranteed.

The materials set forth herein are for general purposes only. They are not a substitute for competent professional advice. Application of this information to a specific project should be reviewed by a design professional. Indeed, in many jurisdictions, such review is required by law. Anyone making use of the information set forth herein does so at their own risk and assumes any and all liability arising therefrom.

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PREFACE

The American Iron and Steel Institute Committee on Framing Standards has developed AISI S250, *North American Standard for Thermal Transmittance of Building Envelopes with Cold-Formed Steel Framing*, to provide calculation tools, methodologies, and testing standards for use in determining the thermal performance of floor, above-grade wall, and roof/ceiling assemblies constructed with *cold-formed steel* framing. This Standard is intended for adoption and use in the United States, Canada, and Mexico.

The equations in this Standard are based on U.S. customary units. When using SI units, the user of this Standard must convert the values to U.S. customary units, execute the equations, and then convert the result(s) to SI units.

The American Iron and Steel Institute also created a spreadsheet that performs mathematical calculations for determining the *thermal transmittance* of wall assemblies and conventional and *truss* roof assemblies based on AISI S250-21 with Supplement 1. Click **HERE** to download.

The Committee acknowledges and is grateful for the contributions of the numerous engineers, researchers, producers, and others who have contributed to the body of knowledge on the subjects. The Committee wishes to also express its appreciation for the support of the Canadian Sheet Steel Building Institute.

In the second printing, the changes in Supplement 1 are incorporated.

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AISI acknowledges the contributions of Andre Desjarlais, Oak Ridge National Laboratory; Alex McGowan, WSP Group; and Paul Shipp, USG Corporation to this first edition of the Standard.

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SYMBOLS

Symbol	Definition	Section
C_0, C_1, C_2, etc.	OTZ coefficients	B3.1.1
CFS_{depth}	*Web* depth of *cold-formed steel* framing member that is in contact with cavity insulation (inches)	B3.1.3, Appendix 1
CFS_{flange}	*Flange* width of *cold-formed steel* framing member (inches)	B3.1.2, Appendix 1
$CFS_{webairspace}$	Depth of air space in cavity (inches)	B3.1.4, Appendix 1
CFS_t	*Designation thickness* of *cold-formed steel* framing member (mils)	B3.1.2, Appendix 1
F_c	Correction factor (dimensionless)	B3.2, B3.2.1, B4.1
FF_{cs}	*C-shape framing factor* (dimensionless)	B3.1.2, B3.1.3, B3.1.4
FF_{otz}	*OTZ framing factor* (dimensionless)	B3.1.7, B3.1.8
FS	Spacing of *cold-formed steel* framing members (inches)	B3.1.7, Appendix 1
k	Thermal conductivity (Btu/h·ft^{2}·°F)	B3.1.3, B3.1.4, Appendix 1
OTZ	*Overall thermal zone* (inches)	B3.1.1, B3.1.7
R_1, R_2, R_3	*Thermal resistance (R-values)* (h·ft^{2}·°F/Btu)	B3.1.3, B3.1.4, B3.1.5, B3.1.6
R_{air}	*Thermal resistance (R-value)* of the cavity air space (h·ft^{2}·°F/Btu)	B3.1.1, B3.1.4, B3.1.6
R_{cav}	Total *thermal resistance (R-value)* of the *wall* cavity (h·ft^{2}·°F/Btu)	B3.1.1
R_{cum}	Cumulative *thermal resistance (R-value)* (h·ft^{2}·°F/Btu)	B3.2.1
R_i	*Thermal resistance (R-value)* of indoor air film (h·ft^{2}·°F/Btu)	B3.1.6, Appendix 1
R_o	*Thermal resistance (R-value)* of outdoor air film (h·ft^{2}·°F/Btu)	B3.1.6, Appendix 1
R_{ins}	*Thermal resistance (R-value)* of cavity insulation (h·ft^{2}·°F/Btu)	B3.1.1, B3.1.3, B3.1.6, B3.2.1, B4.1, B4.2.1, B4.2.2, B4.2.3, Appendix 1
R_{result}	Resulting *thermal resistance (R-value)* (h·ft^{2}·°F/Btu)	B3.2.1
$R_{s\text{-}roof}$	Cumulative *thermal resistance (R-value)* of roof/ceiling components along a path of heat transfer (h·ft^{2}·°F/Btu)	B4.1
$R_{s\text{-}wall}$	*Thermal resistance (R-value)* of the *wall* assembly at the *web* of the *cold-formed steel* framing member (h·ft^{2}·°F/Btu)	B3.1.3
R_{she}	*Thermal resistance (R-value)* of exterior *continuous insulation* (h·ft^{2}·°F/Btu)	B3.1.1, B3.1.6, Appendix 1
R_{spc}	*Thermal resistance (R-value)* of all materials in the design assembly in series for the cavity path (h·ft^{2}·°F/Btu)	B3.1.6, B3.1.8
R_{sps}	*Thermal resistance (R-value)* of all materials in the design assembly in series for the *C-shape* path (h·ft^{2}·°F/Btu)	B3.1.6, B3.1.8
R_{tot}	Whole assembly *thermal resistance (R-value)* (h·ft^{2}·°F/Btu)	B3.2.1
$Sheath_{ext}$	*Thermal resistance (R-value)* of all exterior sheathing(s) (h·ft^{2}·°F/Btu)	B3.1.6, Appendix 1
$Sheath_{int}$	*Thermal resistance (R-value)* of all interior sheathing(s) (h·ft^{2}·°F/Btu)	B3.1.6, Appendix 1

$Side_{ext}$	*Thermal resistance (R-value)* of exterior siding (h·ft^2·°F/Btu)	B3.1.6, Appendix 1
U_1, U_2, U_o, U_r, U_t	*Thermal transmittance (U-factors)* (Btu/h·ft^2·°F)	B3.1.3, B3.1.4, B3.1.8, B4.1, B4.2, B4.2.1, B4.2.2, B4.2.3

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NORTH AMERICAN STANDARD FOR THERMAL TRANSMITTANCE OF BUILDING ENVELOPES WITH COLD-FORMED STEEL FRAMING

A. GENERAL

A1 Scope and Applicability

A1.1 Scope

This Standard applies to the overall *thermal transmittance (U-factor)* of building envelopes containing *cold-formed steel* framing.

A1.2 Applicability

A1.2.1 This Standard shall be used to determine *thermal transmittance (U-factors)* for assessing the energy code compliance of building envelopes for the following:

(a) floor assemblies,
(b) *above-grade wall* assemblies, and
(c) roof/ceiling assemblies.

A1.2.2 Where conflicts between this Standard and the *applicable code* occur, the requirements of the *applicable code* shall govern. In areas without an *applicable code*, this Standard defines the minimum acceptable standards for elements falling within the scope of this Standard, as defined in Section A1.1.

A1.2.3 This Standard does not preclude the use of other *approved* materials, assemblies, structures or designs of equivalent performance.

A1.2.4 This Standard includes Sections A through B and Appendix 1.

A2 Definitions

In this Standard, "shall" is used to express a mandatory requirement; i.e., a provision that the user is obliged to satisfy in order to comply with the Standard. Provisions described as "permitted" are optional, and the election to use such provisions is at the discretion of the *registered design professional*.

Where the following terms appear in this Standard in italics, such terms shall have meaning as defined herein. Terms not defined in Section A2 shall have the ordinary accepted meaning in the context for which they are intended.

Applicable Code. The code under which the building is designed.

Approved. Acceptable to the *authority having jurisdiction*. [AISI S240]

Authority Having Jurisdiction. An organization, political subdivision, office, or individual charged with the responsibility of administering and enforcing the provisions of the *applicable code.*

Base Steel Thickness. The thickness of bare steel exclusive of all coatings. [AISI S240]

Ceiling Joist. A horizontal *structural member* that supports ceiling components and which may be subject to attic *loads*. [AISI S240]

Chord Member. A *structural member* that forms the top or bottom component of a *truss*. [AISI S240]

Cold-Formed Sheet Steel. Sheet steel or strip steel that is manufactured by (1) press-braking blanks sheared from sheets or cut length of coils or plates, or by (2) continuous roll forming of cold- or hot-rolled coils of sheet steel; both forming operations are performed at ambient room temperature, that is, without any addition of heat such as would be required for hot forming.

[AISI S240]

Cold-Formed Steel. See *Cold-Formed Sheet Steel*. [AISI S240]

Continuous Insulation (c.i.). Insulation that is uncompressed and 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. [ASHRAE 90.1-2019]

C-Shape. A *cold-formed steel* shape used for *structural members* and *nonstructural members* consisting of a *web*, two (2) *flanges* and two (2) *lips* (*edge stiffeners*). [AISI S240]

C-Shape Truss. A *truss* assembled using *C-shape chord members* and *C-shape web members*.

Designation Thickness. The minimum *base steel thickness* expressed in *mils* and rounded to a whole number. [AISI S240]

Edge Stiffener. See *Lip*. [AISI S240]

Flange. For a *C-shape*, U-shape or *track*, that portion of the framing member that is perpendicular to the *web*. For a furring channel, that portion of the framing member that connects the *webs*. [AISI S240]

Framing Factor (FF). The fraction of the total area that is framing.

Framing Factor, C-Shape (FF_{cs}). The *designation thickness* of the *cold-formed steel* framing member (converted from mils to inches) divided by the width of the *flange*.

Framing Factor, OTZ (FF_{otz}). The *Overall Thermal Zone* (*OTZ*) divided by the on-center spacing of the framing members.

Joist. A *structural member* primarily used in floor and ceiling framing. [AISI S240]

Light-Frame Construction. Construction where the vertical and horizontal structural elements are primarily formed by a system of repetitive *cold-formed steel* or wood framing members. [AISI S240]

Lip. That part of a *structural* or *nonstructural member* that extends from the *flange* as a stiffening element. [AISI S240]

Load. Force or other action that results from the weight of building materials, occupants and their possessions, environmental effects, differential movement, or restrained dimensional changes. [AISI S240]

Mil. A unit of measurement equal to 1/1000 inch.

Nonstructural Member. A member in a steel-framed system that is not a part of the gravity load-resisting system, lateral force-resisting system or building envelope. [AISI S240]

Overall Thermal Zone (OTZ). The resultant effective area based on an analysis procedure that is designed to account for the thermal impact of *cold-formed steel* framing members in the resultant overall *thermal transmittance (U-factor)* of the wall assembly.

Registered Design Professional. Architect or engineer who is licensed to practice their respective design profession as defined by the legal requirements of the jurisdiction in which the building is to be constructed. [AISI S240]

Roof Rafter. A horizontal or sloped *structural member* that supports roof *loads*. [AISI S240]

Structural Member. A member that resists design loads [factored loads], as required by the *applicable code*, except when defined as a *nonstructural member*. [AISI S240]

Stud. A vertical *structural member* or *nonstructural member* in a wall system or assembly. [AISI S240]

Thermal Resistance (R-value). Reciprocal of the time rate of heat flow through a unit area induced by a unit temperature difference between two defined surfaces of material or construction under steady-state conditions (h·ft^2·°F/Btu). [ASHRAE 90.1-2019]

Thermal Transmittance (U-factor). Heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side (Btu/h·ft²·°F). [ASHRAE 90.1-2019]

Track. A *structural member* or *nonstructural member* consisting of only a *web* and two (2) *flanges*. *Track web* depth measurements are taken to the inside of the *flanges*. [AISI S240]

Truss. A coplanar system of *structural members* joined together at their ends typically to construct a series of triangles that form a stable beam-like framework. [AISI S240]

Wall. That portion of the building envelope, including opaque area and fenestration, that is vertical or tilted at an angle of 60 degrees from horizontal or greater.

Wall, Above-Grade. That portion of a *wall* that is entirely above the finish grade of the building and is not in contact with any soils or plant medium.

Web. That portion of a framing member that connects the *flanges*. [AISI S240]

Web Member. A *structural member* in a *truss* that is connected to the top and bottom *chord members*, but is not a *chord member*. [AISI S240]

A3 Units of Symbols and Terms

The equations in this Standard are based on U.S. customary units. When using SI units, the user of this Standard must convert the values to U.S. customary units, execute the equations, and then convert the result(s) to SI units.

A4 Referenced Documents

The following documents or portions thereof are referenced in this Standard and shall be considered part of the requirements of this document.

1. AISI S240-20, *North American Standard for Cold-Formed Steel Structural Framing*, 2020 Edition, American Iron and Steel Institute, Washington, DC.
2. ASHRAE 90.1-2019, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, 2019 Edition, ASHRAE, Atlanta, GA.
3. ASTM C1363-19, *Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus*, 2019 Edition, ASTM International, West Conshohocken, PA.

B. DESIGN

B1 General

Thermal transmittance (U-factors) for building envelopes containing *cold-formed steel* framing shall be determined in accordance with Sections B2 through B4, as applicable.

B2 Floor Framing

[Reserved.]

B3 Wall Framing

Thermal transmittance (U-factors) of *above-grade wall* assemblies shall be determined in accordance with Section B3.1 or Section B3.2, as applicable.

Section B3.1 shall apply to standard *C-shapes* that comply with the requirements of AISI S240 Section A5.6. Section B3.2 shall apply to non-standard shapes.

B3.1 Standard C-Shape Framing

Thermal transmittance (U-factors) of *above-grade wall* assemblies constructed with standard *C-shape studs* and *track*, where the framing spacing is 6, 12, 16 or 24 inches on-center, shall be determined in accordance with Equation B3.1.8-1 using Sections B3.1.1 through B3.1.8 or shall be determined in accordance with Appendix 1. Where a non-standard *designation thickness* for the *cold-formed steel* framing member is applicable, values for the *OTZ* coefficients from Table B3.1.1-1 and thermal conductivity from Table B3.1.3-1 shall be based on linear interpolation for the intermediate value of *designation thickness* or shall be based on the next larger standard *designation thickness*. Extrapolation is not permitted.

B3.1.1 Overall Thermal Zone

The *overall thermal zone* (*OTZ*) shall be determined in accordance with Equation B3.1.1-1. The appropriate coefficients for use in Equation B3.1.1-1 shall be obtained from Table B3.1.1-1 with the given on-center spacing of framing members and *C-shape designation thickness*.

$$OTZ = C_0 + C_1 \cdot R_{cav} + C_2 \cdot R_{she} + C_3 \cdot R_{cav}^2 + C_4 \cdot R_{she}^2 + C_5 \cdot R_{cav} \cdot R_{she} \qquad (Eq.\ B3.1.1\text{-}1)$$

where

C_0 = Coefficient from Table B3.1.1-1
C_1 = Coefficient from Table B3.1.1-1
C_2 = Coefficient from Table B3.1.1-1
C_3 = Coefficient from Table B3.1.1-1
C_4 = Coefficient from Table B3.1.1-1
C_5 = Coefficient from Table B3.1.1-1
R_{cav} = Total *thermal resistance (R-value)* of the *wall* cavity ($h \cdot ft^2 \cdot {}^oF/Btu$)
= R_{ins} when the *wall* cavity is filled with insulation
= R_{air} when the *wall* cavity contains an air space only
= $R_{ins} + R_{air}$ when *wall* cavity contains both insulation and an air space
R_{ins} = *Thermal resistance (R-value)* of cavity insulation ($h \cdot ft^2 \cdot {}^oF/Btu$)
R_{air} = *Thermal resistance (R-value)* of the cavity air space ($h \cdot ft^2 \cdot {}^oF/Btu$)
= 0.91 where *wall* cavity contains an air space
= 0 where *wall* cavity contains no air space
R_{she} = *Thermal resistance (R-value)* of exterior *continuous insulation* ($h \cdot ft^2 \cdot {}^oF/Btu$). R_{she} does not include wood or gypsum panels.

Table B3.1.1-1
OTZ Coefficients

Member Spacing (inches)	Designation Thickness (mils)	C_0	C_1	C_2	C_3	C_4	C_5
6	33	1.8583	0.07478	0.1488	-0.001859	-0.005103	0.002013
6	43	1.9826	0.07360	0.1501	-0.001816	-0.005314	0.002149
6	54	2.0814	0.07131	0.1522	-0.001713	-0.005295	0.002050
6	68	2.2110	0.06816	0.1508	-0.001652	-0.005576	0.002300
12	33	2.1584	0.05118	0.2079	-0.001384	-0.005367	0.002253
12	43	2.2077	0.06381	0.1992	-0.001713	-0.006235	0.003499
12	54	2.2974	0.06439	0.2043	-0.001686	-0.006908	0.003943
12	68	2.4136	0.05185	0.2166	-0.001216	-0.006840	0.003748
16	33	2.2771	0.03843	0.1964	-0.001141	-0.005237	0.003197
16	43	2.3769	0.04037	0.2011	-0.001195	-0.005677	0.003714
16	54	2.4945	0.04089	0.1996	-0.001161	-0.005719	0.003927
16	68	2.5917	0.04614	0.1922	-0.001391	-0.005884	0.004606
24	33	3.1820	-0.02946	0.2432	0.000000	-0.007520	0.003572
24	43	2.7510	0.01280	0.1965	-0.000740	-0.006709	0.005169
24	54	2.5720	0.00426	0.2285	0.000000	-0.006100	0.003509
24	68	2.9360	-0.00324	0.2256	0.000000	-0.006430	0.004190

B3.1.2 C-Shape Framing Factor

The *C-shape framing factor* (*FF_{cs}*) for the *cold-formed steel* framing shall be determined in accordance with Equation B3.1.2-1:

$$FF_{cs} = (CFS_t/1000)/CFS_{flange} \qquad (Eq.\ B3.1.2\text{-}1)$$

where

CFS_t = *Designation thickness* of *cold-formed steel* framing member (mils)

CFS_{flange} = *Flange* width of *cold-formed steel framing* member (inches)

B3.1.3 Properties of C-Shape Path with Cavity Insulation

B3.1.3.1 Thermal Resistance of C-Shape Web

The *thermal resistance (R-value)* of the *web* of the *cold-formed steel* framing member ($R_{s\text{-}wall}$) shall be determined in accordance with Equation B3.1.3-1:

$$R_{s\text{-}wall} = CFS_{depth}/k \qquad (Eq.\ B3.1.3\text{-}1)$$

where

CFS_{depth} = *Web* depth of *cold-formed steel* framing member that is in contact with cavity insulation (inches) as illustrated by Figure B3.1.3-1 without cavity air space and Figure B3.1.3-2 with cavity air space

k = Thermal conductivity of *cold-formed steel* as selected from Table B3.1.3-1 (Btu/h·ft^2·°F)

Table B3.1.3-1
Cold-Formed Steel Thermal Conductivity

Designation Thickness (mil)	Thermal Conductivity (k) (Btu/h·ft^{2}·°F)
33	381
43	495
54	622
68	783

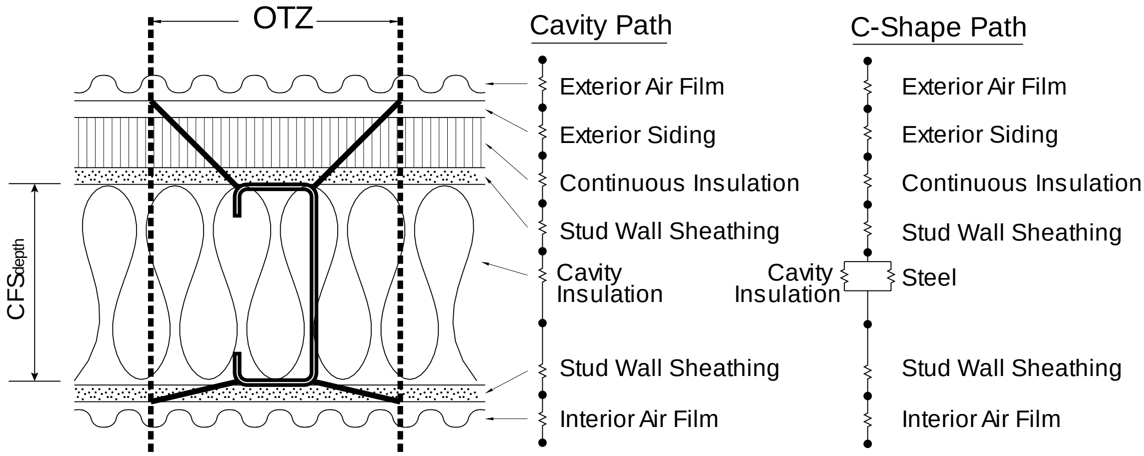

Figure B3.1.3-1 Wall Assembly and Circuit Diagram – Without Cavity Air Space

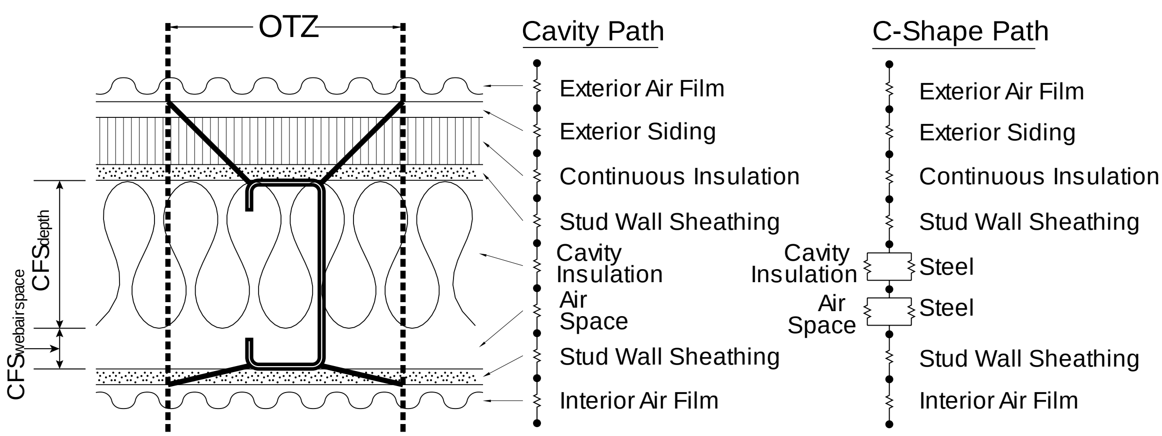

Figure B3.1.3-2 Wall Assembly and Circuit Diagram – With Cavity Air Space

B3.1.3.2 Thermal Transmittance of Cavity with Insulation

The parallel path *thermal transmittance (U-factor)* of the assembly where insulation(s) are in contact with *cold-formed steel* framing member (U_1) shall be determined in accordance with Equation B3.1.3-2. Where there is no insulation in the *wall* cavity, Equation B3.1.3-2 shall not be used and the resultant value of R_1 in Equation B3.1.3-3 shall be "zero" (0).

$U_1 = (1 – FF_{cs})/R_{ins} + FF_{cs}/R_{s\text{-}wall}$ (*Eq.* B3.1.3-2)

where

FF_{cs} = *C-shape framing factor* determined from Equation B3.1.2-1

R_{ins} = *Thermal resistance (R-value)* of cavity insulation (h·ft^{2}·°F/Btu)

$R_{s\text{-}wall}$ = *Thermal resistance (R-value)* of the *wall* assembly at the *web* of the *cold-formed steel* framing member determined from Equation B3.1.3-1 (h·ft^{2}·°F/Btu)

B3.1.3.3 Effective Thermal Resistance (R-value) of Cavity with Insulation

The effective *thermal resistance (R-value)* of the assembly where insulation(s) are in contact with *cold-formed steel* framing member (R_1) shall be determined in accordance with Equation B3.1.3-3:

$R_1 = 1/U_1$ (*Eq.* B3.1.3-3)

where

U_1 = *Thermal transmittance (U-factor)* determined from Equation B3.1.3-2

B3.1.4 Properties of C-Shape Path at Cavity Air Space

B3.1.4.1 Thermal Transmittance of Cavity at Air Space

Where an air space is designed into the *wall* cavity, the parallel path *thermal transmittance (U-factor)* of the assembly at the cavity air space (U_2) shall be determined in accordance with Equation B3.1.4-1. Where there is no air space in the *wall* cavity, Equation B3.1.4-1 shall not be used and the resultant value for R_2 in Equation B3.1.4-2 shall be "zero" (0).

$U_2 = (1 – FF_{cs})/R_{air} + FF_{cs}/(CFS_{webairspace}/k)$ (*Eq.* B3.1.4-1)

where

FF_{cs} = *C-shape framing factor* determined from Equation B3.1.2-1

R_{air} = *Thermal resistance (R-value)* of the cavity air space (h·ft^{2}·°F/Btu)

= 0.91 where *wall* cavity contains an air space

$CFS_{webairspace}$ = Depth of air space in cavity (inches)

k = Thermal conductivity determined from Table B3.1.3-1

B3.1.4.2 Effective Thermal Resistance (R-value) of Cavity at Air Space

The effective *thermal resistance (R-value)* of the assembly at the cavity air space (R_2) shall be determined in accordance with Equation B3.1.4-2:

$R_2 = 1\ /U_2$ (*Eq.* B3.1.4-2)

where

U_2 = *Thermal transmittance (U-factor)* determined from Equation B3.1.4-1

B3.1.5 Combined Thermal Resistance (R-Value)

The combined *thermal resistance (R-value)* of the cavity with insulation and cavity at air space (R_3) shall be determined in accordance with Equation B3.1.5-1:

$R_3 = R_1 + R_2$ (*Eq.* B3.1.5-1)

where

R_1 = *Thermal resistance (R-value)* determined from Equation B3.1.3-3

= 0 with no insulation (i.e., $CFS_{depth} = 0$)

R_2 = *Thermal resistance (R-value)* determined from Equation B3.1.4-2 with air space

= 0 with no air space (i.e., $CFS_{webairspace} = 0$)

B3.1.6 Thermal Resistance (R-value) of Series Paths

B3.1.6.1 C-Shape Path

The effective *thermal resistance (R-value)* of all materials in the design assembly in series for the path containing *cold-formed steel* (R_{sps}), illustrated as the *C-shape* path in Figure B3.1.3-1 or Figure B3.1.3-2, shall be determined using Equation B3.1.6-1:

$$R_{sps} = R_o + Side_{ext} + R_{she} + Sheath_{ext} + R_3 + Sheath_{int} + R_i \qquad (Eq.\ B3.1.6\text{-}1)$$

where

R_o = *Thermal resistance (R-value)* of outside air film (h·ft²·°F/Btu)
= 0.17

$Side_{ext}$ = *Thermal resistance (R-value)* of exterior siding (h·ft²·°F/Btu)

R_{she} = *Thermal resistance* (*R-value*) of exterior continuous insulation (h·ft²·°F/Btu)

$Sheath_{ext}$ = *Thermal resistance (R-value)* of all exterior sheathing(s) (h·ft²·°F/Btu)

R_3 = *Thermal resistance (R-value)* determined from Equation B3.1.5-1 (h·ft²·°F/Btu)

$Sheath_{int}$ = *Thermal resistance (R-value)* of all interior sheathing(s) (h·ft²·°F/Btu)

R_i = *Thermal resistance (R-value)* of inside air film (h·ft²·°F/Btu)
= 0.68

B3.1.6.2 Cavity Path

The *thermal resistance (R-value)* of all materials in the design assembly in series for the path containing only cavity insulation (R_{spc}), illustrated as the cavity path in Figure B3.1.3-1 or Figure B3.1.3-2, shall be determined using Equation B3.1.6-2:

$$R_{spc} = R_o + Side_{ext} + R_{she} + Sheath_{ext} + R_{ins} + R_{air} + Sheath_{int} + R_i \qquad (Eq.\ B3.1.6\text{-}2)$$

where

R_o = *Thermal resistance (R-value)* of outside air film (h·ft²·°F/Btu)
= 0.17

$Side_{ext}$ = *Thermal resistance (R-value)* of exterior siding (h·ft²·°F/Btu)

R_{she} = *Thermal resistance* (*R-value*) of exterior continuous insulation (h·ft²·°F/Btu)

$Sheath_{ext}$ = *Thermal resistance (R-value)* of all exterior sheathing(s) (h·ft²·°F/Btu)

R_{ins} = *Thermal resistance (R-value)* of cavity insulation (h·ft²·°F/Btu)

R_{air} = *Thermal resistance (R-value)* of the cavity air space (h·ft²·°F/Btu)
= 0.91 where *wall* cavity contains an air space
= 0.00 where *wall* cavity contains no air space

$Sheath_{int}$ = *Thermal resistance (R-value)* of all interior sheathing(s) (h·ft²·°F/Btu)

R_i = *Thermal resistance (R-value)* of inside air film (h·ft²·°F/Btu)
= 0.68

User Note:
Commentary provides *thermal resistance (R-value)* properties of commonly used materials.

B3.1.7 OTZ Framing Factor

The *OTZ Framing Factor* (FF_{otz}) shall be determined using Equation B3.1.7-1:

$$FF_{otz} = OTZ/FS \qquad (Eq.\ B3.1.7\text{-}1)$$

where

OTZ = *Overall Thermal Zone* determined from Equation B3.1.1-1 (inches)

FS = Spacing of *cold-formed steel* framing members (inches)

B3.1.8 Overall Thermal Transmittance (U-Factor)

The overall *thermal transmittance (U-factor)* of the *above-grade wall* assembly (U_o) shall be determined using Equation B3.1.8-1:

$$U_o = (1\text{-}FF_{otz})/R_{spc} + FF_{otz}/R_{sps} \qquad (Eq.\ B3.1.8\text{-}1)$$

where

FF_{otz} = *OTZ Framing Factor* determined from Equation B3.1.7-1 (dimensionless)

R_{spc} = *Thermal resistance (R-value)* of all materials in the design assembly in series for the cavity path determined from Equation B3.1.6-2 ($h{\cdot}ft^2{\cdot}{}^oF/Btu$)

R_{sps} = *Thermal resistance (R-value)* of all materials in the design assembly in series for the *C-shape* path determined from Equation B3.1.6-1 ($h{\cdot}ft^2{\cdot}{}^oF/Btu$)

B3.2 Other Than Standard C-Shape Framing

Thermal transmittance (U-factors) of assemblies constructed with shapes other than *C-shape studs* and *track* that penetrate the insulation shall be determined in accordance with Section B3.2.1 with Correction Factor (F_c) values as determined by tests or test data in accordance with ASTM C1363, or other methods permitted by this Standard.

B3.2.1 Calculation Option for Other Than Standard C-Shape Framing

Correction Factor (F_c) values shall be determined by the method shown in Steps 1 through 5, as follows:

1. Determine the surface-to-surface *thermal transmittance (U-factor)* of the assembly from the ASTM C1363 results. Take the reciprocal of this value to obtain a *thermal resistance (R-value)* for the whole assembly (R_{tot}).
2. Determine the cumulative *thermal resistance (R-value)* of components that are outside of the cavity (R_{cum}). Subtract this value from the whole assembly *thermal resistance (R-value)* from Step 1 (R_{tot}) to determine the resulting *thermal resistance (R-value)* (R_{result}) using Equation B3.2.1-1.

   $$R_{result} = R_{tot} - R_{cum} \qquad (Eq.\ B3.2.1\text{-}1)$$
3. Divide the resulting *thermal resistance (R-value)* from Step 2 (R_{result}) by the tested *thermal resistance (R-value)* of the cavity insulation (R_{ins}) to obtain the Correction Factor (F_c) for a single test using Equation B3.2.1-2.

   $$F_c = R_{result} / R_{ins} \qquad (Eq.\ B3.2.1\text{-}2)$$
4. Conduct the above on a minimum of five (5) assemblies, one of which must be an assembly without *continuous insulation* and the others with *continuous insulation* with a range of *thermal resistance (R-values)*. The highest *thermal resistance (R-value)* of *continuous insulation* shall be the upper limit of applicability of this method.
5. Use linear regression to develop a curve fit and equation for the F_c values of assemblies that are not specifically tested.

B4 Roof/Ceiling Framing

Thermal transmittance (U-factors) of roof/ceiling assemblies shall be determined in accordance with Section B4.1 or Section B4.2, as applicable.

Sections B4.1 and B4.2 shall apply to standard *C-shapes* that comply with the requirements of AISI S240 Section A5.6.

B4.1 Standard Joist and Rafter Framing

Thermal transmittance (U-factors) for assemblies using standard *C-shape ceiling joist* and *roof rafter* framing (U_r) shall be determined using Equation B4.1-1 and the Correction Factor (F_c) values from Table B4.1-1, or shall be determined by test in accordance with ASTM C1363.

$$U_r = 1/(R_{s\text{-}roof} + (F_c \cdot R_{ins})) \qquad (Eq.\ B4.1\text{-}1)$$

where

$R_{s\text{-}roof}$ = Cumulative *thermal resistance (R-value)* of roof/ceiling components along the path of heat transfer perpendicular to the face of the roof/ceiling, exclusive of the steel and cavity insulation ($h{\cdot}ft^2{\cdot}{}^oF/Btu$)

R_{ins} = *Thermal resistance (R-value)* of cavity insulation between the *ceiling joists* ($h{\cdot}ft^2{\cdot}{}^oF/Btu$)

F_c = Correction factor from Table B4.1-1

Table B4.1-1
F_c Values for Roof/Ceiling Assemblies with Joist Framing [1, 2]

		Thermal Resistance (R-value) of Insulation Between Joists		
Joist Depth	**Joist Spacing**	**R-30**	**R-38**	**R-49**
3.5 to 4	16 inch	0.94	0.95	0.96
6		0.81	0.85	0.88
8		0.65	0.72	0.78
10		0.27	0.62	0.70
12		0.27	0.51	0.62
3.5 to 4	24 inch	0.96	0.97	0.97
6		0.86	0.88	0.91
8		0.72	0.78	0.83
10		0.35	0.69	0.76
12		0.35	0.61	0.69

1 Applies to *cold-formed steel* framing member up to a maximum *base steel thickness* of 0.064 inches.
2 Linear interpolation for determining correction factors which are intermediate between those illustrated in the table is permitted.

B4.2 Standard Truss Framing

Thermal transmittance (U-factors) of roof/ceiling assemblies constructed with standard *C-shape truss* framing (U_t) shall be determined in accordance with Sections B4.2.1 through B4.2.3, as applicable, subject to the following limitations:

(a) On-center spacing of *trusses* is 24 inches or greater, and
(b) Number of penetrations of the *truss web members* through the cavity insulation is not greater than three for each 4-foot length of the *truss*.

B4.2.1 Trusses Without Rigid Foam Insulation

Thermal transmittance (U-factors) of assemblies without rigid foam insulation between the gypsum board ceiling and *truss* bottom *chord member* (U_t) shall be determined using Equation B4.2-1:

$$U_t = \frac{1}{0.864 \cdot R_{ins} + 0.330} \qquad (Eq.\ B4.2\text{-}1)$$

where

R_{ins} = *Thermal resistance (R-value)* of cavity insulation at the bottom *chord member* ($h \cdot ft^2 \cdot {}^oF/Btu$)

B4.2.2 Trusses with R-3 Rigid Foam Insulation

Thermal transmittance (U-factors) of assemblies with R-3 rigid foam insulation between the gypsum board ceiling and *truss* bottom *chord member* (U_t) shall be determined using Equation B4.2-2:

$$U_t = \frac{1}{0.864 \cdot R_{ins} + 4.994} \qquad (Eq.\ B4.2\text{-}2)$$

where

R_{ins} = *Thermal resistance (R-value)* of cavity insulation at the bottom *chord member* ($h \cdot ft^2 \cdot {}^oF/Btu$)

B4.2.3 Trusses with R-5 Rigid Foam Insulation

Thermal transmittance (U-factors) of assemblies with R-5 rigid foam insulation between the gypsum board ceiling and *truss* bottom *chord member* (U_t) shall be determined using Equation B4.2-3:

$$U_t = \frac{1}{0.864 \cdot R_{ins} + 7.082} \qquad (Eq.\ B4.2\text{-}3)$$

where

R_{ins} = *Thermal resistance (R-value)* of cavity insulation at the bottom *chord member* ($h \cdot ft^2 \cdot {}^oF/Btu$)

APPENDIX 1, PRE-CALCULATED WALL ASSEMBLY TABLES

Thermal transmittance (U-factors) of *above grade wall* assemblies constructed with *C-shape studs* and *track* is permitted to be determined in accordance with Tables 1-1(a), 1-1(b), 1-2(a) and 1-2(b), as applicable, subject to the following limitations:

Cold-Formed Steel Framing:

Framing spacing (FS) = As shown in table
Flange width (CFS_{flange}) = 1.625 inches
Designation thickness (CFS_t) = 43 mils
Conductivity (k) = 495 (Btu/h·ft^{2}·°F)

Construction *Thermal Resistance (R-values)* (h·ft^{2}·°F/Btu):

Air film outside (R_o) = 0.17
Siding ($Side_{ext}$) = 0.07, assumed stucco
Continuous insulation (R_{she}) = As shown in table
Exterior sheathing ($Sheath_{ext}$) = 0.56, assumed gypsum board
Cavity insulation (R_{ins}) = As shown in table
Cavity insulation = Full depth of cavity
Interior sheathing ($Sheath_{int}$) = 0.56, assumed gypsum board
Air film inside (R_i) = 0.68

Interpolation between values within Table 1-1(a), 1-1(b), 1-2(a) or 1-2(b) is permitted for rated *thermal resistance* (*R-values*) of insulation, including insulated sheathing. Interpolation between the tables and extrapolation beyond values in a table shall not be permitted.

If the *authority having jurisdiction* determines that the proposed construction assembly is not adequately represented in Appendix 1, then the calculation procedure in Section B3 shall be applied.

Table 1-1(a) Framing Spacing = 16 inches

Web Depth (Inches)	Cavity Insulation Thermal Resistance (R-value) [a]	Overall [b] Thermal Transmittance (U-factor)	Overall Thermal Transmittance (U-factor) for Wall Assembly Plus Continuous Insulation (Uninterrupted by steel framing)							
			Rated Thermal Resistance (R-value) of Continuous Insulation							
			R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8
3.5	0	0.355	0.262	0.208	0.172	0.147	0.128	0.114	0.102	0.093
3.5	13	0.129	0.107	0.093	0.084	0.076	0.071	0.066	0.062	0.058
3.5	15	0.122	0.101	0.089	0.080	0.073	0.067	0.063	0.059	0.056
6	19	0.108	0.090	0.080	0.072	0.066	0.062	0.058	0.055	0.052
6	21	0.104	0.087	0.077	0.070	0.064	0.060	0.056	0.053	0.050
8	25	0.093	0.079	0.071	0.065	0.060	0.056	0.053	0.050	0.047

a. A full web depth cavity insulation is assumed when a non-zero value is provided (i.e., CFS_{depth} = Web Depth and $CFS_{webairspace}$ = 0). Otherwise, a full depth cavity air space is assumed (i.e., CFS_{depth} = 0, and $CFS_{webairspace}$ = Web Depth).

b. Without continuous insulation.

Table 1-1(b) Framing Spacing = 16 inches

Web Depth (Inches)	Cavity Insulation Thermal Resistance (R-value) [a]	Overall [b] Thermal Transmittance (U-factor)	Overall Thermal Transmittance (U-factor) for Wall Assembly Plus Continuous Insulation (Uninterrupted by steel framing)							
			Rated Thermal Resistance (R-value) of Continuous Insulation							
			R-8	R-9	R-10	R-12	R-14	R-16	R-18	R-20
3.5	0	0.354	0.093	0.085	0.078	0.068	0.060	0.053	0.048	0.044
3.5	13	0.128	0.058	0.055	0.052	0.047	0.043	0.040	0.037	0.034
3.5	15	0.122	0.056	0.053	0.050	0.045	0.042	0.038	0.036	0.033
6	19	0.107	0.052	0.049	0.047	0.043	0.039	0.036	0.034	0.032
6	21	0.104	0.050	0.048	0.046	0.042	0.039	0.036	0.033	0.031
8	25	0.093	0.047	0.045	0.043	0.040	0.037	0.034	0.032	0.030

a. A full web depth cavity insulation is assumed when a non-zero value is provided (i.e., CFS_{depth} = Web Depth and $CFS_{webairspace}$ = 0). Otherwise, a full depth cavity air space is assumed (i.e., CFS_{depth} = 0, and $CFS_{webairspace}$ = Web Depth).

b. Without continuous insulation.

Table 1-2(a) Framing Spacing = 24 inches

Web Depth (Inches)	Cavity Insulation Thermal Resistance (R-value) [a]	Overall [b] Thermal Transmittance (U-factor)	Overall Thermal Transmittance (U-factor) for Wall Assembly Plus Continuous Insulation (Uninterrupted by steel framing)							
			Rated Thermal Resistance (R-value) of Continuous Insulation							
			R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8
3.5	0	0.351	0.260	0.206	0.171	0.146	0.128	0.113	0.102	0.092
3.5	13	0.109	0.093	0.083	0.075	0.069	0.064	0.060	0.057	0.053
3.5	15	0.102	0.087	0.077	0.070	0.065	0.061	0.057	0.054	0.051
6	19	0.088	0.076	0.068	0.062	0.058	0.054	0.051	0.049	0.046
6	21	0.084	0.072	0.065	0.060	0.056	0.052	0.049	0.047	0.045
8	25	0.074	0.065	0.059	0.054	0.051	0.048	0.046	0.044	0.042

a. A full web depth cavity insulation is assumed when a non-zero value is provided (i.e., CFS_{depth} = Web Depth and $CFS_{webairspace}$ = 0). Otherwise, a full depth cavity air space is assumed (i.e., CFS_{depth} = 0, and $CFS_{webairspace}$ = Web Depth).

b. Without continuous insulation.

Table 1-2(b) Framing Spacing = 24 inches

Web Depth (Inches)	Cavity Insulation Thermal Resistance (R-value) [a]	Overall [b] Thermal Transmittance (U-factor)	Overall Thermal Transmittance (U-factor) for Wall Assembly Plus Continuous Insulation (Uninterrupted by steel framing)							
			Rated Thermal Resistance (R-value) of Continuous Insulation							
			R-8	R-9	R-10	R-12	R-14	R-16	R-18	R-20
3.5	0	0.350	0.092	0.085	0.078	0.067	0.059	0.053	0.048	0.044
3.5	13	0.109	0.053	0.051	0.048	0.044	0.040	0.037	0.035	0.032
3.5	15	0.102	0.051	0.048	0.046	0.042	0.039	0.036	0.033	0.031
6	19	0.088	0.046	0.044	0.042	0.039	0.036	0.033	0.031	0.029
6	21	0.083	0.045	0.043	0.041	0.038	0.035	0.033	0.030	0.029
8	25	0.074	0.042	0.040	0.038	0.035	0.033	0.031	0.029	0.027

a. A full web depth cavity insulation is assumed when a non-zero value is provided (i.e., CFS_{depth} = Web Depth and $CFS_{webairspace}$ = 0). Otherwise, a full depth cavity air space is assumed (i.e., CFS_{depth} = 0, and $CFS_{webairspace}$ = Web Depth).
b. Without continuous insulation.

American Iron and Steel Institute

AISI STANDARD

Commentary on the North American Standard for Thermal Transmittance of Building Envelopes with Cold-Formed Steel Framing

2021 Edition

DISCLAIMER

The material contained herein has been developed by the American Iron and Steel Institute (AISI) Committee on Framing Standards. The Committee has made a diligent effort to present accurate, reliable and useful information on cold-formed steel framing design and installation. The Committee acknowledges and is grateful for the contributions of the numerous researchers, engineers, and others who have contributed to the body of knowledge on the subject. Specific references are included in the *Commentary*.

With anticipated improvements in understanding of the behavior of cold-formed steel framing and the continuing development of new technology, this material will become dated. It is anticipated that AISI will publish updates of this material as new information becomes available, but this cannot be guaranteed.

The materials set forth herein are for general purposes only. They are not a substitute for competent professional advice. Application of this information to a specific project should be reviewed by a design professional. Indeed, in many jurisdictions, such review is required by law. Anyone making use of the information set forth herein does so at their own risk and assumes any and all liability arising therefrom.

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PREFACE

This *Commentary* is intended to facilitate the use and provide an understanding of the background of AISI S250, *North American Standard for Thermal Transmittance of Building Envelopes with Cold-Formed Steel Framing*. In the *Commentary*, sections are identified by the same notation as used in the Standard. Words that are italicized are defined in AISI S250.

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COMMENTARY ON THE NORTH AMERICAN STANDARD FOR THERMAL TRANSMITTANCE OF BUILDING ENVELOPES WITH COLD-FORMED STEEL FRAMING

A. GENERAL

A1 Scope and Applicability

AISI S250 applies to the overall *thermal transmittance (U-factors)* of building envelopes containing *cold-formed steel* framing and is to be used to determine energy code compliance of building envelopes for floor assemblies, *above-grade wall* assemblies, and roof/ceiling assemblies.

The Standard covers the most common and readily available *cold-formed steel* shapes and dimensions. The Standard does not intend to stifle innovation. As such, it states: "This Standard does not preclude the use of other approved materials, assemblies, structures, or designs of equivalent performance."

A1.2.2 This Standard is intended to be used as part of the requirements of the applicable code and is not designed to abridge or conflict with the use and application of that applicable code.

A2 Definitions

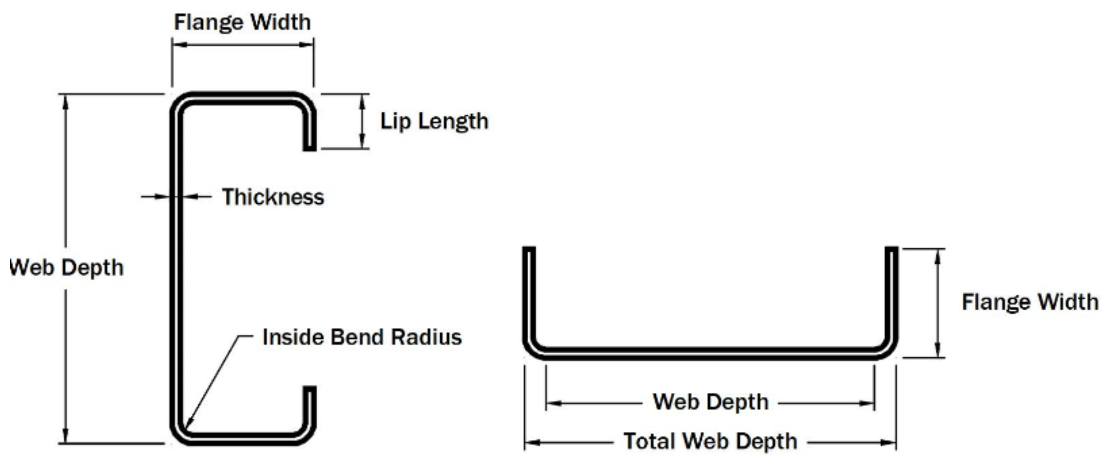
Codes and standards by their nature are technical, and as such specific words and phrases can change the intent of the provisions if not properly defined. As a result, it is necessary to establish a common platform by clearly stating the meaning of specific terms for the purpose of this Standard and other standards that reference it. Wherever practical, the Standard uses the nomenclature of *cold-formed steel light-frame construction* as defined in AISI S240, *North American Standard for Cold-Formed Steel Structural Framing*. Terms that are defined exactly as in AISI S240 are annotated by [AISI S240]. Terms that are defined exactly as in ASHRAE 90.1-2019 are annotated similarly.

The Standard is based on the use of *designation thickness* (mils). Standard thicknesses for *cold-formed steel* framing are listed in Table C-A2-1. The Standard does not recognize gauge numbers, which are an obsolete method of specifying sheet and strip thickness. This Standard is based on testing of industry standard products and, therefore, protective coatings are implicit in its methodologies. All *cold-formed steel* members in this Standard are assumed to have some form of corrosion protection in accordance with AISI S240 Section A4.

Table C-A2-1
Standard Thicknesses for Cold-Formed Steel Framing

Designation Thickness (Mils)	Minimum Base Steel Thickness (in.)	Design Thickness (in.)
33	0.0329	0.0346
43	0.0428	0.0451
54	0.0538	0.0566
68	0.0677	0.0713

The Standard is applicable to standard *C-shape studs* and *joists* and *track* sections, as defined in AISI S240 Section A5.6 and illustrated in Figure C-A2-1. This is important to understand because equations in the Standard use dimensions of the framing members.



C-Shape (Stud or Joist) **Track Section**

Figure C-A2-1 Standard Cold-Formed Steel Framing Members

The provisions of the Standard are based on *C-shape* framing members without web holes (punchouts), which represents a worst-case scenario with respect to *thermal transmittance (U-factor)*. Framing members with web holes provide better thermal efficiency (lower *thermal transmittance (U-factor)*) than framing members without web holes.

A3 Units of Symbols and Terms

The equations in the Standard are based on U.S. customary units. When using SI units, the user of this Standard must convert the values to U.S. customary units, execute the equations, and then convert the result(s) to SI units.

B. DESIGN

B1 General

The Standard is organized to address floor, wall and roof/ceiling assemblies separately in Sections B2, B3 and B4 in order to recognize differences in methods of construction and *thermal resistance (R-value)* for these applications.

B2 Floor Framing

The Standard does not currently address floor framing, such as floor assemblies over unconditioned spaces, which is pending upon future testing and analysis of such applications.

B3 Wall Framing

The Standard provides methods for determining the *thermal transmittance (U-factors)* of wall assemblies containing standard *C-shapes* based on analysis (McBride, 2020; Norris, 2018), available guidance (ASHRAE, 2020) and previous research (ASHRAE, 1996; Barbour, 1994; Desjarlais, 2012; Desjarlais 2011).

Section B3.2 defers to testing for wall assemblies containing non-standard shapes due to the proprietary nature of such products. It is recognized that the methodology provided in Section B3.1 could be conservatively applied for most non-standard shapes and could gain acceptance for use in a building design by the *authority having jurisdiction*.

B3.1 Standard C-Shape Framing

The Standard offers two methods for determining the *thermal transmittance (U-factors)* of wall assemblies containing standard *C-shape studs* and *track*. Sections B3.1.1 through B3.1.8 outline a calculation method. Appendix 1 provides pre-calculated *thermal transmittance (U-factors)* for common wall assemblies. When a wall assembly design is special or unique it is recommended that the calculation method be employed for greater accuracy and potential acceptance by the *authority having jurisdiction*.

The Standard permits linear interpolation for a *cold-formed steel* framing member that is of a non-standard *designation thickness* for the *OTZ* coefficients from Table B3.1.1-1 and thermal conductivity from Table B3.1.3-1. Alternatively, the Standard permits use of the next larger standard *designation thickness,* which would represent a more conservative approach.

B3.1.1 Overall Thermal Zone

The *Overall Thermal Zone* (*OTZ*) analysis procedure is designed to account for the thermal impact of *cold-formed steel C-shape* framing in the overall wall assembly. The procedure is based on the parallel path approach. With this method there are two parallel paths, the *cold-formed steel C-shape* path and the wall cavity path that has no influence of a *cold-formed steel C-shape*. In cases where the cavity also contains an air space, the *OTZ* analysis procedure includes a calculation to account for that effect.

The coefficients C_0, C_1, C_2, C_3, C_4, and C_5 used in Equation B3.1.1-1 and listed in Table B3.1.1-1 were derived based on a series of regression analyses that correlated the *OTZ* with five key construction variables (McBride, 2020).

The *OTZ* analysis procedure relies on thermal property data of other materials for completing the analysis. Tables C-B3.1-1 through C-B3.1-6 provide some, but not all, of the thermal properties of materials. The values in the tables are intended to be representative of materials that are readily available and commonly used in the design of wall assemblies containing *cold-formed steel* framing. Users should consult material providers for actual thermal property data when specifying products and applying the provisions of this Standard. Users must be careful when applying values from other reliable sources to ensure consistent units with the intent of the Standard.

Table C-B3.1-1
Batt Insulation Thermal Resistance (R-Value) Properties

Insulation (Marked Value)	Thickness (Inches)	Thermal Resistance (R-Value) ($h \cdot ft^2 \cdot {}^oF/Btu$)
11	3.5	10.8
13	3.5	13.3
15	3.5	15.4
19	6.25	19.3
21	5.5	20.8
25	8	25.6
30	9.5	30.4
38	12	38.5

Table C-B3.1-2
Foam Insulation Thermal Resistance (R-Value) Properties

Insulation Type	Thermal Resistance (R-Value) per Inch Thickness (Average) [1] ($h \cdot ft^2 \cdot {}^oF/Btu$)
Expanded polystyrene (Panels)	3.84
Extruded polystyrene (Panels)	5.00
Polyisocyanurate (Panels)	6.00
Spray Foam on Site (Open or closed cell)	(varies, see mfg.)

1. Note: *Thermal resistance* (R-values) vary based on density and other properties besides thickness. The values in the above table are based on an average of a variety of products. The user should consult with the chosen manufacturer of the insulation product to verify the *thermal resistance (R-value)* per inch thickness as said values can be different for each manufacturer.

Table C-B3.1-3
Mineral Fiber Thermal Resistance (R-Value) Properties

Insulation Type	Thermal Resistance (R-Value) per Inch Thickness (Average) [1] ($h \cdot ft^2 \cdot {}^oF/Btu$)
Mineral Fiber Insulation	4.0

Source: ASHRAE International © Handbook-Fundamentals, 2020.

1. Note: *Thermal resistance* (R-values) vary based on density and other properties besides thickness. The values in the above table are based on an average of a variety of products. The user should consult with the chosen manufacturer of the insulation product to verify the *thermal resistance (R-value)* per inch thickness as said values can be different for each manufacturer.

Table C-B3.1-4
Spray Cellulose Thermal Resistance (R-Value) Properties

Insulation Type	Thermal Resistance (R-Value) per Inch Thickness (Average) [1] (h·ft^2·°F/Btu)
Cellulose	3.6 – 3.8
Fiberglass Blown	3.7 – 4.3
Mineral Fiber Blown	3.1 – 4.0

Source: ASHRAE International © Handbook-Fundamentals, 2020.

[1] Note: *Thermal resistance* (R-values) vary based on density and other properties besides thickness. The values in the above table are based on an average of a variety of products. The user should consult with the chosen manufacturer of the insulation product to verify the *thermal resistance (R-value)* per inch thickness as said values (e.g., type, installed density) can be different for each manufacturer.

Table C-B3.1-5
Other Materials Thermal Resistance (R-Value) Properties

Material	Thickness (Inches)	Thermal Resistance (R-Value) (Average) [1] (h·ft^2·°F/Btu)
Gypsum board	0.5	0.39
Stucco (3 coat)	0.619	0.07

Source: ASHRAE International © Handbook-Fundamentals, 2020.

[1] Note: *Thermal resistance* (R-values) vary based on density and other properties besides thickness. The values in the above table are based on an average of a variety of products. The user should consult with the chosen manufacturer of the insulation product to verify the *thermal resistance (R-value)* per inch thickness as said values (e.g., type, installed density) can be different for each manufacturer.

Table C-B3.1-6
Air Film Coefficients Thermal Resistance (R-Value) Properties

Surface Location	Thermal Resistance (R-Value) per Inch Thickness (Varies) (h·ft^2·°F/Btu)
Exterior (Wall)	0.17
Interior (Wall)	0.68

Source: ASHRAE International © Handbook-Fundamentals, 2020.

B4 Roof/Ceiling Framing

The Standard provides methods for determining the *thermal transmittance (U-factors)* and *thermal resistance (R-value)* of roof/ceiling assemblies containing standard *C-shape ceiling joist* and *roof rafter* framing in Section B4.1 and standard *C-shape truss* framing in Section B4.2.

While the original ASTM C1363 hot-box apparatus tests used standard *C-shape* members in the test assemblies, a designer can attempt to receive approval from the *authority having jurisdiction* to allow these methods for use on non-standard (proprietary) designs under the "alternative means and methods" provisions of the *applicable code*. The *applicable code* includes these provisions because it recognizes that a material, product or method of construction may not be addressed in the *applicable code* and therefore is not intended to be prohibited.

As an alternative, submission of an ASTM C1363 hot-box apparatus test conducted on a non-standard (proprietary) configuration could also be submitted as part of the permit process. However, if such a test report is submitted, the design and construction of the actual roof/ceiling assembly will need to match or exceed the tested design in order to receive approval from the *authority having jurisdiction*.

B4.1 Standard Joist and Rafter Framing

Section B4.1 covers assemblies using standard *C-shape ceiling joist* and *roof rafter* framing, such as for buildings that have a steep (>2:12) pitched roof. Equation B4.1-1 is based on hot-box apparatus testing of full-scale test samples (Desjarlais, 2001) in accordance with ASTM C1363.

Equation B4.1-1 uses the correction factor method for designing where the insulation that is installed between and above the *ceiling joists* (horizontal member cavity space) is modified because of the thermal bridging effects of the *cold-formed steel*. This Standard method uses batt type insulation values in Table B4.1-1; however, if another type of insulation (e.g., spray or blown insulations) is used in the building design, it is permitted in this section only if the insulation has an equivalent depth and *thermal resistance (R-value)*.

B4.2 Standard Truss Framing

Section B4.2 covers assemblies using standard *C-shape truss* framing. In this case there are three (3) equations shown for three different scenarios. For each scenario, the user must use the *thermal resistance (R-value)* of the "cavity" insulation, which represents the insulation that is installed between the gypsum board ceiling and *truss* bottom *chord member*. The equations are based on a maximum of three (3) penetrations of the *truss web members* through the cavity insulation for each 4-foot (1220 mm) length of the *truss*, as shown in Figure C-B4.1-1.

The provisions of Section B4.2 are limited to an on-center spacing of the *trusses* not less than 24 inches based on available research. Engineering judgment would allow use of the Standard for spacings greater than 24" on center; however, use of the Standard becomes increasingly conservative.

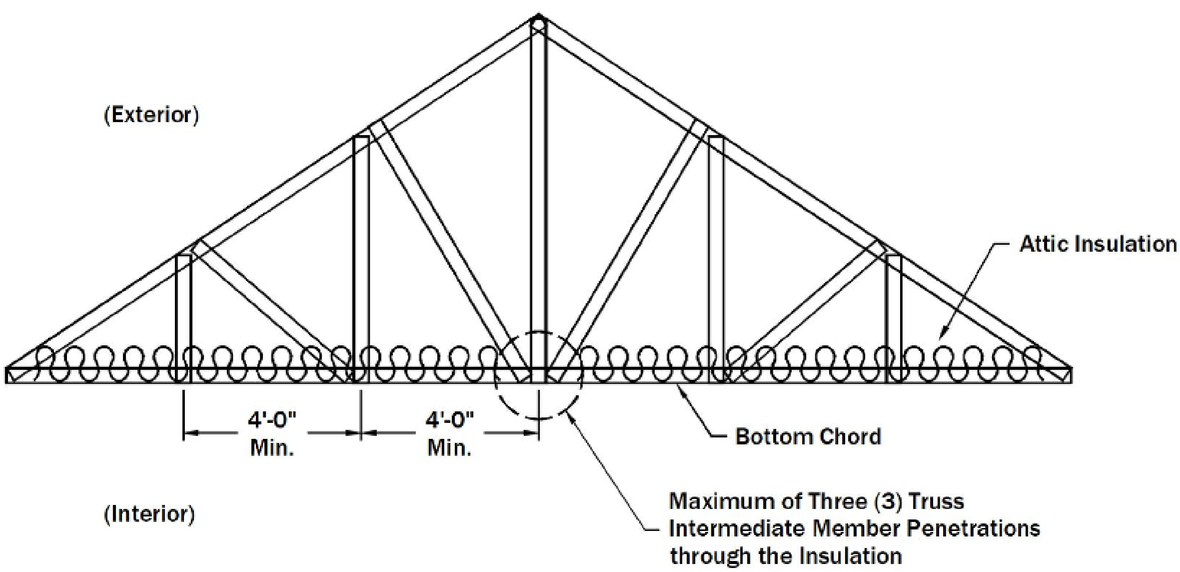


Figure C-B4.1-1 Standard Truss Framing in Roof/Ceiling Assembly

When designing with the rigid foam insulation attached between the gypsum board ceiling and *truss* bottom *chord member*, consideration should be taken to provide adequate blocking or framing at junction boxes penetrating the rigid foam insulation and ceiling sheathing for such things as: light fixtures, ceiling fans, etc. in addition to properly sealing around the junction boxes in order to comply with the air barrier requirements. In addition, most building codes require that the ceiling sheathing consists of a product that complies with the "thermal barrier" requirements when rigid foam insulation is installed, such as the use of gypsum board.

APPENDIX 1, PRE-CALCULATED WALL ASSEMBLY TABLES

Appendix 1 is included in the Standard to offer users the benefit of pre-calculated assembly values. The material property values in Appendix 1 are intended to be representative of materials that are readily available and commonly used in the design of wall assemblies containing *cold-formed steel* framing. If the design assembly uses materials other than those listed in Appendix 1, the *OTZ* analysis procedure, in conjunction with published thermal data for the specified materials, should be used to determine the thermal performance.

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