

An ACI and TMS Standard

Thermal Properties of Concrete and Masonry for Use in Determining Energy Code Compliance Except for Low- Rise Residential Buildings— Code Requirements and Commentary

Reported by Joint ACI-TMS Committee 122



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Thermal Properties of Concrete and Masonry for Use in Determining Energy Code Compliance Except for Low-Rise Residential Buildings—Code Requirements and Commentary

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An ACI and TMS Standard

Reported by Joint ACI-TMS Committee 122

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This Code prescribes minimum design and construction requirements for energy efficiency of building envelopes of new buildings and additions to buildings. It applies to buildings having concrete walls, roofs, or floors; masonry walls; and masonry veneer, including veneer attached to frame walls as part of the building envelope. It also provides minimum thermal properties for these assemblies for code compliance.

This Code is applicable to commercial and mid- to high-rise residential buildings that use either electricity from any generation source or fossil fuel. It can be used with applicable energy codes and standards such as ASHRAE 90.1 and the International Energy Conservation Code (IECC).

Keywords: energy efficiency; specific heat; thermal conductivity; thermal diffusivity; thermal resistance; thermal transmittance.

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PREFACE

This Code provides procedures that can be used to meet the requirements of energy efficiency codes and standards that have been adopted by the authority having jurisdiction. This Code has three alternative paths: 1) a prescriptive path; 2) a building envelope trade-off methodology; and 3) a whole building energy simulation trade-off methodology.

CODE

CHAPTER 1—GENERAL

1.1—Scope

1.1.1 This Code provides design and construction requirements to establish a minimum level of energy efficiency in new buildings and additions to buildings constructed with building envelopes of concrete or masonry construction. This Code is only applicable to commercial and mid- to high-rise residential buildings. For low-rise residential buildings, refer to **ACI/TMS CODE-122.2**, “Thermal Properties of Concrete and Masonry for Use in Determining Energy Code Compliance for Low-Rise Residential Buildings—Code Requirements and Commentary.” This Code also lists thermal properties for these assemblies for use in code compliance. This Code shall be used with all applicable energy-efficiency codes and standards.

1.2—General

1.2.1 The provisions of this Code apply to:

- (a) Portions of buildings having above-grade and below-grade walls consisting of concrete; masonry; or masonry veneer, including veneers attached to frame walls
- (b) Portions of buildings having concrete floors above unconditioned space and slab-on-ground floors

1.2.2 The provisions of this Code do not apply to:

- (a) Single-family houses and residential structures with three stories or less above grade
- (b) Buildings that do not use electricity or fossil fuel

1.3—Purpose

The purpose of this Code is to establish the minimum energy efficiency requirements for buildings with concrete and masonry envelope components. This purpose is accomplished by providing the following for compliance with energy codes and standards:

- (a) Criteria for prescriptive and performance methods applicable to concrete and masonry
- (b) Thermal properties of concrete and masonry
- (c) A method of determining thermal properties of concrete and masonry by test or calculation

1.4—Applicability

1.4.1 This Code shall not be used to circumvent any safety, health, or environmental requirements contained in other applicable codes or ordinances.

1.4.2 This Code does not address moisture control or provide criteria to prevent moisture migration.

COMMENTARY

R1—GENERAL

R1.1—Scope

R1.1.1 This Code applies to buildings having concrete walls, roofs, or floors; masonry walls; or masonry veneer, including veneer attached to frame walls.

This Code applied to commercial and mid- to high-rise residential buildings that use either electricity from any generation source or fossil fuel. It can be used with applicable energy codes and standards such as **ASHRAE 90.1** or the **International Energy Conservation Code (IECC)**.

Criteria covered includes above-grade walls, below-grade walls, and floors above unconditioned space and slab-on-ground floors.

R1.2—General

The code compliance of concrete and masonry walls and floors, with or without insulation, is complex because heat loss and heat gain through the building envelope depend on thermal inertia (thermal mass) as well as thermal resistance.

This Code does not consider the potential for moisture or condensation on or within the assemblies that comply nor does it provide criteria to prevent moisture migration or condensation. Condensate has the potential to accumulate between some dissimilar materials in some climate conditions. In addition, some insulation materials are moisture-sensitive. When these insulation materials become wet due to condensation or moisture infiltration, their rated R-value may decrease, the insulation may degrade, or both. A separate analysis is recommended to ensure that the assemblies used in design do not have the potential for condensation or moisture-related issues. The **ASHRAE Handbook—Fundamentals** provides guidance on methods of analysis.

CODE

COMMENTARY

1.4.3 Construction means and methods are not addressed by this Code.

1.5—Interpretation

1.5.1 The official version of this Code is the English language version using inch-pound units published jointly by the American Concrete Institute and The Masonry Society

1.5.2 In case of conflict between the official version of the standard and other versions of the standard, the official version governs.

CODE

COMMENTARY

CHAPTER 2—NOTATION AND DEFINITIONS

R2—NOTATION AND DEFINITIONS

2.1—Code notation

The terms in this list are used in the code and as needed in the commentary.

a_{np}	=	fractional area of material heat flow path n' in thermal layer p in the CMU, ft^2
a_{wallX}	=	area of the wall assembly attributed to U_{wallX} , ft^2
C	=	C -factor (thermal conductance), $\text{Btu}/\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}$
F	=	F -factor; the perimeter heat loss for slab-on-ground floors, $\text{Btu}/\text{h}\cdot\text{ft}\cdot^\circ\text{F}$
R	=	R -value (thermal resistance), $\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}/\text{Btu}$
R_{min}	=	minimum insulation R -value, $\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}/\text{Btu}$
$R_1, R_2, \dots R_n$	=	R -value of each individual material layer, $\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}/\text{Btu}$
R_i	=	R -value of the indoor air film, $\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}/\text{Btu}$
R_{np}	=	thermal resistance of material heat flow path n in thermal layer p in the CMU, $\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}/\text{Btu}$
R_o	=	R -value of the exterior or outdoor air film, $\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}/\text{Btu}$
R_T	=	CMU thermal resistance, including surface air films, $\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}/\text{Btu}$
R_{total}	=	total R -value of the assembly, $\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}/\text{Btu}$
U	=	U -factor (thermal transmittance), $\text{Btu}/\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}$
U_{max}	=	maximum assembly U -factor, $\text{Btu}/\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}$
U_{mv}	=	U -factor of the clay masonry veneer and air space layers from Table 8.1d
U_{pp}	=	area-weighted average U -factor calculated using the parallel-path method, $\text{Btu}/\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}$
U_{wallX}	=	U -factor of the portion of the wall assembly attributed to a_{wallX} , $\text{Btu}/\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}$

2.2—Code definitions

The following terms are defined for general use in this Code.

assembly—the finished construction consisting of one or more components that are fitted together to form a portion of the building envelope.

building envelope—the wall, roof, slab, or other component(s) that in combination separate conditioned space (heated, cooled, or both) from outdoor air or unconditioned space.

concrete—the plastic or hardened material comprised of aggregate, cement, and water, with or without other materials.

R2.2—Commentary definitions



CODE

continuous insulation (CI)—insulation that is continuous across, and is not penetrated by, structural members or other thermal bridges except for service openings and fasteners, including veneer ties.

fenestration—glass or glazing assemblies, including frames and door assemblies where the doors are more than 50% glass.

heat capacity—amount of heat required to raise the temperature of a given mass of material by a unit temperature difference (1°F); heat capacity per unit area of wall or floor surface ($\text{Btu}/\text{ft}^2\cdot^{\circ}\text{F}$) is calculated as the sum of the products of the mass per unit of surface area of each individual material in the wall or floor surface multiplied by its individual specific heat.

integral insulation—insulation that is neither exterior nor interior to concrete or masonry.

low-rise residential buildings—detached one- and two-family dwellings, townhouses, apartments, condominiums, and dormitories with three stories or less above grade.

masonry—wall construction consisting of manufactured units made of modular CMU, fired clay or shale, or natural stone.

mass (wall, roof, or floor)—an assembly consisting at least partially of concrete, masonry, or masonry veneer where the heat capacity of the assembly is either:

- (a) Greater than or equal to $7 \text{ Btu}/\text{ft}^2\cdot^{\circ}\text{F}$ when the density of the material is greater than $120 \text{ lb}/\text{ft}^3$, or
- (b) Greater than or equal to $5 \text{ Btu}/\text{ft}^2\cdot^{\circ}\text{F}$ when the density of the material is not greater than $120 \text{ lb}/\text{ft}^3$.

COMMENTARY

continuous insulation—insulation installed between, and in the same plane as, wood or steel framing is not continuous insulation.

integral insulation—Integral insulation includes insulated concrete masonry unit (CMU), hollow clay or shale units, and concrete walls having concrete or masonry material on both sides of the insulation. A masonry veneer with a masonry or concrete backing veneer where insulation is between the masonry veneer and the backing is a wall with exterior insulation because the masonry veneer is considered cladding.

low-rise residential buildings—This Code applies to commercial and mid- to high-rise residential buildings. Refer to [ACI/TMS CODE-122.2](#) for the design of the thermal envelope of low-rise residential construction.

mass (wall or floor)—While thermal inertia (thermal mass effects) is generally a function of thermal diffusivity (thermal conductivity divided by the product of specific heat and density), in energy codes, it is usually defined as a function of heat capacity, which is a function of specific heat and density. For this reason, different thresholds are provided for lower and higher densities of concrete and masonry; this is an approximation for their different thermal diffusivities ([VanGeem et al. 2013](#)). These values are consistent with the values in [ASHRAE 90.1](#) and the [IECC](#). CMU complying with the requirements of [ASTM C90](#) have three density classifications as follows:

- (a) Lightweight CMU: Density less than $105 \text{ lb}/\text{ft}^3$
- (b) Mediumweight CMU: Density equal to or greater than $105 \text{ lb}/\text{ft}^3$ and less than $125 \text{ lb}/\text{ft}^3$
- (c) Normalweight CMU: Density equal to or greater than $125 \text{ lb}/\text{ft}^3$

CODE

COMMENTARY

CHAPTER 3—REFERENCED STANDARDS

Standards cited in this Code are listed by name and designation, including year.

3.1—American Concrete Institute (ACI)

ACI 301-20—Specifications for Structural Concrete

3.2—American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

ASHRAE 90.1-2019—Energy Standard for Buildings except Low-Rise Residential Buildings

ASHRAE 169-2013—Climatic Data for Building Design Standards

2017 *ASHRAE Handbook—Fundamentals*

3.3—ASTM International

ASTM C55-22—Standard Specification for Concrete Building Brick

ASTM C62-23—Standard Specification for Building Brick (Solid Masonry Units Made from Clay or Shale)

ASTM C90-22—Standard Specification for Loadbearing Concrete Masonry Units

ASTM C126-22—Standard Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick, and Solid Masonry Units

ASTM C129-22—Standard Specification for Nonload-bearing Concrete Masonry Units

ASTM C177-19—Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

ASTM C216-23—Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)

ASTM C652-22—Standard Specification for Hollow Brick (Hollow Masonry Units Made from Clay or Shale)

ASTM C744-21—Standard Specification for Prefaced Concrete Masonry and Calcium Silicate Masonry Units

ASTM C1363-19—Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus

ASTM C1371-15(2022)—Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers

ASTM C1405-23—Standard Specification for Glazed Brick (Single Fired, Brick Units)

ASTM C1549-16(2022)—Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer

ASTM C1634-23—Standard Specification for Concrete Facing Brick

ASTM E1918-21—Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field

ASTM E1980-11(2019)—Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces



CODE

COMMENTARY

3.4—International Code Council (ICC)

IECC 2021—International Energy Conservation Code

CODE

COMMENTARY

CHAPTER 4—GENERAL REQUIREMENTS

R4—GENERAL REQUIREMENTS

4.1—Material requirements

Concrete and masonry materials shall comply with one of the following specifications: [ASTM C55](#), [ASTM C62](#), [ASTM C90](#), [ASTM C126](#), [ASTM C129](#), [ASTM C216](#), [ASTM C652](#), [ASTM C744](#), [ASTM C1405](#), [ASTM C1634](#), or [ACI 301](#).

4.2—Climate zones

Climate zones used to meet the requirements of this Code shall be from one of the following:

- (a) [2021 IECC](#) Table C301.1
- (b) [ASHRAE 169-2013](#) Table B-1
- (c) [ASHRAE 169-2013](#) Table A-5
- (d) [ASHRAE 169-2013](#) Table A-6

4.3—Building envelope compliance

4.3.1 These provisions apply to the following assemblies in new buildings, additions to buildings, and alterations to the following assemblies:

- (a) Portions of buildings having above-grade and below-grade walls consisting of concrete, masonry, or masonry veneer including veneers attached to frame walls
- (b) Portions of buildings having concrete floors above unconditioned space and slab-on-ground floors.

4.3.2 The building envelope shall comply with one of the following compliance methods:

- (a) The prescriptive method in [Chapter 5](#)
- (b) Building envelope tradeoff method in [Chapter 6](#)
- (c) A whole-building simulation model in [Chapter 7](#)

R4.2—Climate zones

Climate zone maps for use with the IECC and ASHRAE 90.1 have been provided in Appendix A for convenience. The climate zones in the IECC, [ASHRAE 90.1](#), and ASHRAE 169 contain the same requirements and information.

ASHRAE 169 contains climate data for some locations outside of the United States and a procedure for determining climate zone information for locations that are not provided.

R4.3—Building envelope compliance

Chapters 5 through 7 provide three paths for compliance. These are consistent with the compliance methods of the IECC and national consensus standards for energy efficiency. The prescriptive compliance path of Chapter 5 is often the easiest to apply in practice but is also the least flexible and tends to yield less economical results. The tradeoff option of Chapter 6 offers more flexibility and represents a good compromise between ease and application flexibility when demonstrating energy efficiency compliance. The whole building simulation method detailed in Chapter 7 is the most flexible of the three compliance paths but tends to be used only when project complexity or design objectives warrant the additional expense associated with this design approach.

The intent of this Code is to address the envelope thermal resistance portion of governing energy codes. Other potential requirements adopted into governing energy efficiency codes are not addressed in this Code. For instance, the air leakage requirements of the IECC or the applicable state or jurisdictional energy code are not covered by this Code but should be applied where required.

CODE

CHAPTER 5—PRESCRIPTIVE METHOD

5.1—Concrete and masonry

Each opaque concrete or masonry building envelope that is an assembly listed in Table 5.1 shall comply with one of the following for the applicable climate zone:

- (a) Equal to or more than the minimum R -value of the added insulation in framing cavities and continuous insulation.
- (b) Equal to or less than the maximum U -factor, C -factor, or F -factor for the entire assembly. Area-weighted averages of U -factors, C -factors, or F -factors are allowed for compliance for each type of assembly listed in Tables 8.1a through 8.1e.
- (c) Each building envelope assembly of a semi-heated space as defined by **ASHRAE 90.1** shall comply with the semi-heated building envelope requirements in ASHRAE 90.1.

COMMENTARY

R5—PRESCRIPTIVE METHOD

R5.1—Concrete and masonry

Most energy codes and standards account for thermal inertia of mass walls by requiring less-stringent criteria for R -values and U -factors for mass wall assemblies compared to frame wall assemblies. Refer to **Appendix C** for a more detailed overview of thermal mass attributes and design considerations. These requirements, developed using computer simulations, are dependent on the climate and building type (low-rise residential versus buildings other than low-rise residential). Most code provisions developed to date in the United States reflect the cost of adding insulation to the wall assembly.

Above-grade walls should meet the definition of a mass wall to use the path described in 5.1. Floors above unconditioned space should meet the definition of a mass floor to use the path described in 5.1.

ASHRAE 90.1 has separate requirements for building envelopes of nonresidential spaces and those of mid- to high-rise residential spaces. Since this distinction was made in the 1999 version of ASHRAE 90.1, the differences in insulation requirements for these two types of spaces have decreased. Thus, for ease of use of this standard, only one category that covers both residential and nonresidential spaces is included in this Code. This is a benefit to the users of this Code because many buildings are now mixed-use buildings.

Below-grade walls are portions of walls that are below grade level and in contact with earth. Portions of foundation walls and crawl space walls that are below grade level are considered below-grade walls. Due to other design objectives (structural, water penetration, connection detailing), below-grade concrete and masonry walls intrinsically have sufficient thickness to be considered mass walls and are therefore deemed-to-comply with the mass wall criteria.

(a) *Minimum R -value requirements*—When using the minimum R -value method for compliance, only the R -value of the insulation is considered. Concrete, masonry, and masonry veneer are not insulation in this context. Insulation has an R -value provided by the manufacturer on the product, package, or bulk container.

An R -value is a steady-state property and does not include thermal mass or dynamic effects. U -factors, C -factors, and F -factors are also steady-state properties.

Continuous insulation (CI) can be on the indoor side, the outdoor side, or integral to the concrete or masonry. Insulation on the outdoor side of the concrete or masonry will generally reduce heat losses or gains, and increase energy savings, compared to insulation on the indoor side of the concrete or masonry. However, the location of insulation placement should be balanced against the need for a durable outdoor surface. While increased energy savings may be realized by placing insulation on the outdoor side of the concrete or masonry, the prescriptive path contained in ASHRAE 90.1 and the IECC code provisions requires that the insulation is placed on the interior side of the mass.

CODE

COMMENTARY

Table 5.1—Building envelope requirements

Opaque assembly	Climate Zone 0		Climate Zone 1		Climate Zone 2		Climate Zone 3		Climate Zone 4		Climate Zone 5		Climate Zone 6		Climate Zone 7		Climate Zone 8	
	U_{max}	R_{min}	U_{max}	R_{min}	U_{max}	R_{min}	U_{max}	R_{min}	U_{max}	R_{min}	U_{max}	R_{min}	U_{max}	R_{min}	U_{max}	R_{min}	U_{max}	R_{min}
Mass walls, above-grade	NR or $U-0.580$	NR	NR or $U-0.580$	NR	$U-0.151$	$R-5.7$ CI*	$U-0.123$	$R-7.6$ CI	$U-0.104$	$R-9.5$ CI	$U-0.090$	$R-11.4$ CI	$U-0.080$	$R-13.3$ CI	$U-0.071$	$R-15.2$ CI	$U-0.048$	$R-19$ CI
Masonry veneer, above-grade walls, minimum specified thickness of 2-5/8 in.																		
Metal-framed walls	$U-0.133$	$R-8.6$	$U-0.133$	$R-8.6$	$U-0.089$	$R-13 + R-1.7$ CI†	$U-0.089$	$R-13 + R-2.1$ CI†	$U-0.069$	$R-13 + R-4.6$ CI†	$U-0.066$	$R-13 + R-5.3$ CI†	$U-0.067$	$R-13 + R-5.1$ CI†	$U-0.067$	$R-13 + R-5.1$ CI†	$U-0.038$	$R-13 + R-16.5$ CI†
Wood-framed walls	$U-0.106$	$R-7.3$	$U-0.106$	$R-7.3$	$U-0.109$	$R-7.0$	$U-0.100$	$R-8.0$	$U-0.066$	$R-13 + R-1.1$ CI†	$U-0.066$	$R-13 + R-1.1$ CI†	$U-0.053$	$R-13 + R-4.9$ CI†	$U-0.067$	$R-13 + R-4.9$ CI†	$U-0.033$	$R-13 + R-16.5$ CI†
Mass floors above unconditioned space	NR or $U-0.322$	NR	NR or $U-0.322$	NR	$U-0.107$	$R-6.3$ CI	$U-0.074$	$R-10$ CI	$U-0.074$	$R-10$ CI	$U-0.074$	$R-10$ CI	$U-0.064$	$R-12.5$ CI	$U-0.055$	$R-15$ CI	$U-0.055$	$R-15$ CI
Slab-on-ground floors																		
Unheated	NR or $F-0.730$	NR	NR or $F-0.730$	NR	NR or $F-0.730$	NR	NR or $F-0.730$	NR	$F-0.540$	$R-10$ for 24 in.	$F-0.540$	$R-10$ for 24 in.	$F-0.540$	$R-10$ for 24 in.	$F-0.400$	$R-15$ for 24 in.	$F-0.400$	$R-15$ for 24 in.
Heated	NR or $F-1.020$	NR	NR or $F-1.020$	NR	$F-0.900$	$R-10$ for 24 in.	$F-0.860$	$R-15$ for 24 in.	$F-0.823$	$R-20$ for 24 in.	$F-0.688$	$R-20$ for 48 in.	$F-0.688$	$R-20$ for 48 in.	$F-0.671$	$R-25$ for 48 in.	$F-0.671$	$R-25$ for 48 in.
Below-grade walls	NR or $C-1.140$	NR	NR or $C-1.140$	NR	NR or $C-1.140$	NR	NR or $C-1.140$	NR	$C-0.119$	$R-7.5$ CI	$C-0.119$	$R-7.5$ CI	$C-0.119$	$R-7.5$ CI	$C-0.092$	$R-10$ CI	$C-0.092$	$R-10$ CI

*Partially grouted or ungrouted ASTM C90 CMU walls are allowed to meet this requirement when ungrouted cores openings (cores and cells) are filled with insulation material with a thermal conductivity of 0.44 Btu·in./h·ft²·°F or greater.

†Where the surface adjacent to the air space and opposite the veneer has an emissivity no greater than 0.05 when measured in accordance with ASTM C1371, the CI requirement is permitted to be reduced by $R-1.6$ CI. Where such a surface is installed and the CI requirement is $R-1.6$ CI or less, no CI shall be required.

Notes: U_{max} is maximum assembly U -factor; R_{min} is minimum insulation R -value; NR is no insulation requirement; and CI is continuous insulation. Units for U -factors and C -factors are Btu/h·ft²·°F. Units for R -values are h·ft²·°F/Btu. Units for F -factors are Btu/h·ft·°F.

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decoupling the mass from the conditioned space. Where benefits of insulation placement are significant, they may be seen when using an envelope tradeoff analysis according to [Chapter 6](#) or the performance path in [Chapter 7](#).

(b) *Maximum U-factor, C-factor, or F-factor requirements*—Currently, the mass wall and below-grade insulation requirements in this Code are for continuous insulation as in [ASHRAE 90.1](#) and the IECC. When using insulation that is between framing or furring, *U*-factor (above-grade) or *C*-factor (below-grade) compliance is required.

When using the minimum *U*-factor or *C*-factor method for compliance, these factors include all of the components of the assembly, including the insulation and the concrete, masonry, or masonry veneer. In addition, *U*-factors include thermal resistances of the inside and outside air films. *C*-factors include thermal transmittances but not earth or air films. *F*-factors for slab-on-ground floors are based on an *R*-value of insulation and depth of insulation, and are provided in ASHRAE 90.1-2019, Appendix A.

Area weighted averages of *U*-factors, *C*-factors, and *F*-factors for each type of building envelope assembly are allowed for compliance. For example, if one mass wall meets the requirement in Tables 8.1a through 8.1e, but another one does not, the area weighted *U*-factor of the two walls can be used for compliance. The following equation can be used

$$UA_{des} = \frac{(a_{wall1})(U_{wall1}) + (a_{wall2})(U_{wall2}) + (a_{wall3})(U_{wall3}) \dots}{a_{wall1} + a_{wall2} + a_{wall3} \dots}$$

where UA_{des} is the design area-weighted average *U*-factor for the building or wall assemblies under consideration ($\text{Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$); a_{wallX} is area of the wall assembly attributed to U_{wallX} (ft^2); and U_{wallX} is the *U*-factor of the portion of the wall assembly attributed to a_{wallX} ($\text{Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$).

If the area-weighted *U*-factor meets the requirement in Tables 8.1a through 8.1e, then all the walls included in the area-weighted *U*-factor comply.

Refer to [8.1](#) for *R*-values, *U*-factors, and *C*-factors for concrete and masonry systems, as well as acceptable test methods and calculation methods.

(c) *Building envelope assemblies of semi-heated spaces*—ASHRAE 90.1 has separate insulation requirements for building envelope components that are part of semi-heated spaces. The definition of a semi-heated space was originally meant to be for a warehouse heated to approximately 50°F. However, the threshold for semi-heated spaces is in terms of heat provided per unit of floor area. As more buildings are constructed that use very little energy, it is challenging to differentiate between a low-energy-use building and a minimally heated warehouse. Therefore, not many warehouses or similar buildings will meet the definition of a semi-heated space. Building envelope insulation requirements for semi-heated spaces are generally less than those in Tables 8.1a through 8.1e. The IECC does not have equivalent requirements for semi-heated spaces.

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5.2—Other assemblies

Building envelope assemblies not listed in Tables 8.1a through 8.1e, including above-grade walls that are not mass walls or masonry veneer walls and floors above unconditioned space that are not mass floors, shall comply with the energy code adopted by the authority having jurisdiction.

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ASHRAE 90.1 and the IECC define low-energy-use buildings or equipment buildings that do not need to comply with building envelope insulation requirements. The IECC also exempts greenhouses. There are special cases such as small utility buildings that, for example, might only have a light and a fan.

R5.2—Other assemblies

Wood- or steel-frame walls with masonry veneer that do not meet the requirements for masonry veneer in Tables 8.1a through 8.1e should meet the requirements of the IECC or other energy code adopted by the authority having jurisdiction for wood- or steel-frame walls, respectively. Concrete floors above unconditioned space that do not meet the requirements for a mass floor must meet the other floor requirements of ASHRAE 90.1, IECC, or other applicable codes.

CODE

CHAPTER 6—BUILDING ENVELOPE TRADE-OFF METHOD

6.1—Building envelope trade-off method

Building envelope tradeoff method shall comply with the applicable energy efficiency code or standard. This Code does not allow, and does not prescribe, limits on the amount of energy loss that is allocated to the building envelope in building envelope trade-off methods.

When using the building envelope trade-off method, the following building envelope assemblies shall be used to determine baseline energy savings for the proposed building.

- (a) The applicable requirements for concrete and masonry assemblies from 5.1 of this Code shall be used.
- (b) The applicable requirements for the base energy code in the jurisdiction shall be used for building envelope assemblies that are not concrete and masonry.

When using computer software as part of the building envelope trade-off method, where the baseline energy savings on the computer software report states, “Envelope PASSES: Design 0.0% better than code” or similar statement indicating passing, the building envelope trade-off method provides accurate results for the project. Where the baseline energy savings on the computer software report states, “Envelope FAILS: Design xx% worse than code,” or similar statement, the “xx%” is the baseline for the project and more energy savings than this baseline need to be demonstrated for the project.

For building envelope compliance, either the assembly *U*-factors or *C*-factors in available in the building envelope trade-off method computer software or those determined using 8.1 of this Code shall be used for the proposed building.

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R6—BUILDING ENVELOPE TRADE-OFF METHOD

R6.1—Building envelope trade-off method

COMcheck, supported by the Department of Energy, is a commonly used program used to meet the building envelope requirements of ASHRAE 90.1 or the IECC, even though it is not mentioned in either. It is often used when one or more prescriptive envelope measures cannot be met. Those envelope-related energy losses associated with noncompliant systems can often be made up by insulating another component beyond the prescriptive requirements or by using more efficient fenestration.

This Code does not provide limits on the amount of energy loss that is allocated to the building envelope in building envelope tradeoff methods, such as those that may occur in future versions of ASHRAE 90.1 or the IECC.

COMcheck allows the selection of the applicable edition of the IECC, ASHRAE 90.1, and other U.S.-based energy codes. Many states and local jurisdictions modify the base energy efficiency requirements of the model energy code. Many of these modifications are captured by COMcheck when selecting a location-specific energy code within the software. COMcheck is widely used for compliance for concrete and masonry because of the thousands of possible configurations of concrete, masonry, and insulation.

This section provides the methodology for adjusting COMcheck for this Code. The baseline energy use for the building envelope for this Code for the applicable building project needs to be determined. This is determined by inputting all building assemblies and their areas for the building project into COMcheck. For concrete and masonry assemblies, the applicable insulation requirements from 5.1 of this Code are input. For building envelope assemblies not covered by 5.1 of this Code, such as roof insulation, the applicable insulation requirements from the applicable base energy code are input. The baseline energy is determined by the COMcheck building envelope results. If the building envelope passes, then COMcheck can be used without modification. If the building envelope fails, then the percentage that the envelope fails by is used as the baseline energy for this Code. For example, if the COMcheck indicates that the building envelope fails by 10%, then when the actual insulation for the building assemblies for the building project are input, the building should pass COMcheck or should fail by not more than 10%.

Refer to 8.1 for *R*-values, *U*-factors, and *C*-factors for concrete and masonry systems as well as acceptable test methods and calculation methods. COMcheck also has pull-down menus that provide *U*-factors, *C*-factors, and *F*-factors for many concrete and masonry systems.

CODE

CHAPTER 7—WHOLE-BUILDING SIMULATION
METHOD

7.1—Whole- building simulation model

The whole-building simulation compliance method shall be conducted in compliance with the applicable energy efficiency code or standard. The amount of energy loss that is allocated to the building envelope components in building envelope tradeoff methods shall not be limited.

COMMENTARY

R7—WHOLE-BUILDING SIMULATION
METHOD

R7.1—Whole-building simulation method

Whole-building simulation methods require modeling of the entire building, including the building envelope, all the HVAC systems, and all of the lighting systems. Specific rules should be followed. Whole-building simulation methods are complicated and expensive but provide a great deal of flexibility in the design of the building envelope. For instance, less insulation can be used when those energy losses are made up by more efficient mechanical systems. Whole building compliance methods are, for example, detailed in Chapter 11 or Appendix G in [ASHRAE 90.1-2019](#) or Section 407 in the [2021 IECC](#). The whole-building simulation compliance method should be conducted in compliance with the applicable energy efficiency code or standard.

This Code does not allow, and does not prescribe, limits on the amount of energy loss allocated to the building envelope in the whole-building simulation methods, such as those that may occur in future versions of ASHRAE 90.1 or the IECC. The language here gives architects and designers flexibility when meeting requirements.

When using whole-building simulation programs such as [DOE2](#)-based programs or [EnergyPlus](#), it is important to enter accurate thermal conductivity, specific heat, and density of the building envelope materials for the thermal mass effects to be properly considered. If only the *R*-value of the building envelope components are entered, then the analysis will be a steady-state analysis.

Refer to [8.1](#) for *R*-values, *U*-factors, and *C*-factors for concrete and masonry systems as well as acceptable test methods and calculation methods. *F*-factors for slab-on-ground floors are based on the *R*-value of insulation and depth of insulation and are provided in ASHRAE 90.1-2019 Appendix A. Refer to [8.2](#) for thermal conductivity and [8.3](#) for specific heat values that are needed for simulations.

This path has not been modified to consider any differences in prescriptive insulation requirements in this Code and the base energy code. Performance paths, including ASHRAE 90.1-2019 Appendix G, are often not a one-to-one mapping of energy savings of the prescriptive path to energy savings of the performance path. Also, small changes in insulation will not likely have a large effect on the energy performance of an entire building. In warm and mild climates, small changes in the amount of insulation are likely negligible.

CODE

CHAPTER 8—THERMAL PROPERTIES FOR DETERMINING COMPLIANCE

The properties for determining energy code compliance shall be determined according to this section.

8.1—*U*-factors, *C*-factors, and *R*-values of assemblies

The thermal transmittance (*U*-factor) or thermal conductance (*C*-factor) of the concrete or masonry assembly used for compliance shall be determined or established using one of the following:

- The applicable values listed in Tables 8.1a through 8.1e or Tables 8.1.1a through 8.1.1v
- ASTM C177, ASTM C1363, or another laboratory test provided the test is calibrated for a thermal transmittance that is similar to that of the concrete or masonry assembly
- A published value from a guide, standard, handbook, specification, government publication, or peer-reviewed publication
- A calculation method as described in 8.1.5

COMMENTARY

R8—THERMAL PROPERTIES FOR DETERMINING COMPLIANCE

R8.1—*U*-factors, *C*-factors, and *R*-values of assemblies

Chapter 8 provides procedures for determining the *U*-factor or *C*-factor of the entire assembly that is used for compliance with Chapter 5. An assembly can be a simple solid concrete or brick wall, or may contain other materials including insulation, framing, sheathing, wall ties and load-bearing or veneer, masonry units.

Chapter 5 is based on the added *R*-value of the insulation, or the *U*-factor or *C*-factor of the entire assembly determined from Chapter 8. In Chapter 5, when using the *R*-value path, only the *R*-value of the insulation is considered.

An *R*-value is a steady-state property and does not include thermal mass or dynamic effects. *U*-factors, *C*-factors, and *F*-factors are also steady-state properties.

U-factors, *C*-factors, and *F*-factors include all of the components of the assembly including the insulation and the concrete, masonry, or masonry veneer. In addition, *U*-factors include thermal resistances of the inside and outside air films. *C*-factors include only thermal transmittances of the components of the assembly but do not include the effects of earth or air films.

The total *R*-value of the assembly is the inverse of the *U*-factor of the assembly. The total *R*-value of the assembly without air films is the inverse of the *C*-factor of the assembly. However, the *R*-value of the assembly is not used for compliance.

Table 8.1a—Assembly *U*-factors, *C*-factors, *R_u*, *R_c*, and heat capacity (HC) for concrete

Density, lb/ft ³	Properties	Concrete thickness, in.									
		3	4	5	6	7	8	9	10	11	12
20	<i>U</i> -factor	0.22	0.17	0.14	0.12	0.10	0.09	0.08	0.07	0.07	0.06
	<i>C</i> -factor	0.27	0.20	0.16	0.13	0.11	0.10	0.09	0.08	0.07	0.07
	<i>R_u</i>	4.60	5.85	7.10	8.35	9.60	10.85	12.10	13.35	14.60	15.85
	<i>R_c</i>	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50	13.75	15.00
	HC	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0
30	<i>U</i> -factor	0.28	0.22	0.19	0.16	0.14	0.12	0.11	0.10	0.09	0.09
	<i>C</i> -factor	0.37	0.28	0.22	0.18	0.16	0.14	0.12	0.11	0.10	0.09
	<i>R_u</i>	3.58	4.49	5.40	6.30	7.21	8.12	9.03	9.94	10.85	11.76
	<i>R_c</i>	2.73	3.64	4.55	5.45	6.36	7.27	8.18	9.09	10.00	10.91
	HC	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
40	<i>U</i> -factor	0.33	0.27	0.23	0.19	0.17	0.15	0.14	0.13	0.11	0.11
	<i>C</i> -factor	0.47	0.35	0.28	0.23	0.20	0.18	0.16	0.14	0.13	0.12
	<i>R_u</i>	2.99	3.71	4.42	5.14	5.85	6.56	7.28	7.99	8.71	9.42
	<i>R_c</i>	2.14	2.86	3.57	4.29	5.00	5.71	6.43	7.14	7.86	8.57
	HC	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0

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Table 8.1a, cont.—Assembly U -factors, C -factors, R_u , R_c , and heat capacity (HC) for concrete

Density, lb/ft ³	Properties	Concrete thickness, in.									
		3	4	5	6	7	8	9	10	11	12
50	U -factor	0.38	0.31	0.26	0.23	0.20	0.18	0.16	0.15	0.14	0.13
	C -factor	0.57	0.43	0.34	0.28	0.24	0.21	0.19	0.17	0.15	0.14
	R_u	2.61	3.20	3.79	4.38	4.97	5.56	6.14	6.73	7.32	7.91
	R_c	1.76	2.35	2.94	3.53	4.12	4.71	5.29	5.88	6.47	7.06
	HC	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3	9.2	10.0
85	U -factor	0.65	0.56	0.50	0.44	0.40	0.37	0.34	0.31	0.29	0.27
	C -factor	1.43	1.08	0.86	0.71	0.61	0.54	0.48	0.43	0.39	0.36
	R_u	1.55	1.78	2.01	2.25	2.48	2.71	2.94	3.18	3.41	3.64
	R_c	0.70	0.93	1.16	1.40	1.63	1.86	2.09	2.33	2.56	2.79
	HC	4.3	5.7	7.1	8.5	9.9	11.3	12.8	14.2	15.6	17.0
95	U -factor	0.72	0.64	0.57	0.52	0.48	0.44	0.41	0.38	0.36	0.33
	C -factor	1.85	1.41	1.12	0.93	0.80	0.70	0.62	0.56	0.51	0.47
	R_u	1.39	1.56	1.74	1.92	2.10	2.28	2.46	2.64	2.81	2.99
	R_c	0.54	0.71	0.89	1.07	1.25	1.43	1.61	1.79	1.96	2.14
	HC	4.8	6.3	7.9	9.5	11.1	12.7	14.3	15.8	17.4	19.0
105	U -factor	0.79	0.71	0.65	0.59	0.54	0.51	0.47	0.44	0.42	0.39
	C -factor	2.38	1.79	1.43	1.18	1.01	0.88	0.79	0.71	0.65	0.59
	R_u	1.27	1.41	1.56	1.70	1.84	1.98	2.12	2.26	2.40	2.54
	R_c	0.42	0.56	0.70	0.85	0.99	1.13	1.27	1.41	1.55	1.69
	HC	5.3	7.0	8.8	10.5	12.3	14.0	15.8	17.5	19.3	21.0
115	U -factor	0.84	0.77	0.70	0.65	0.61	0.57	0.53	0.50	0.48	0.45
	C -factor	2.94	2.22	1.75	1.47	1.25	1.10	0.98	0.88	0.80	0.74
	R_u	1.19	1.30	1.42	1.53	1.65	1.76	1.87	1.99	2.10	2.21
	R_c	0.34	0.45	0.57	0.68	0.80	0.91	1.02	1.14	1.25	1.36
	HC	5.8	7.7	9.6	11.5	13.4	15.3	17.3	19.2	21.1	23.0
125	U -factor	0.88	0.82	0.76	0.71	0.67	0.63	0.60	0.56	0.53	0.51
	C -factor	3.57	2.70	2.17	1.79	1.54	1.35	1.20	1.03	0.98	0.90
	R_u	1.13	1.22	1.31	1.41	1.50	1.59	1.68	1.78	1.87	1.96
	R_c	0.28	0.37	0.46	0.56	0.65	0.74	0.83	0.93	1.02	1.11
	HC	6.3	8.3	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0
135	U -factor	0.93	0.87	0.82	0.77	0.73	0.69	0.66	0.63	0.60	0.57
	C -factor	4.55	3.33	2.70	2.22	1.92	1.67	1.49	1.33	1.22	1.11
	R_u	1.07	1.15	1.22	1.30	1.37	1.45	1.52	1.60	1.67	1.75
	R_c	0.22	0.30	0.37	0.45	0.52	0.60	0.67	0.75	0.82	0.90
	HC	6.8	9.0	11.3	13.5	15.8	18.0	20.3	22.5	24.8	27.0
144	U -factor	0.96	0.91	0.86	0.81	0.78	0.74	0.71	0.68	0.65	0.63
	C -factor	5.26	4.00	3.23	2.63	2.27	2.00	1.79	1.59	1.45	1.33
	R_u	1.04	1.10	1.16	1.23	1.29	1.35	1.41	1.48	1.54	1.60
	R_c	0.19	0.25	0.31	0.38	0.44	0.50	0.56	0.63	0.69	0.75
	HC	7.2	9.6	12.0	14.4	16.8	19.2	21.6	24.0	26.4	28.8

Notes: The U -factors and R_u include standard air film resistances. The C -factors and R_c are for the same assembly without air film resistance.

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Table 8.1b—Assembly *U*-factors for above-grade normalweight concrete walls

Framing type and depth	Rated <i>R</i> -value of insulation alone	Assembly <i>U</i> -factors 8 in. normal-weight 145 lb/ft ³ solid concrete walls
<i>Continuous metal framing at 24 in. on-center horizontally</i>		
1.0 in.	<i>R</i> -0	<i>U</i> -0.414
	<i>R</i> -3.8	<i>U</i> -0.325
	<i>R</i> -5	<i>U</i> -0.314
	<i>R</i> -6.5	<i>U</i> -0.305
1.5 in.	<i>R</i> -11	<i>U</i> -0.267
2.0 in.	<i>R</i> -7.6	<i>U</i> -0.230
	<i>R</i> -10	<i>U</i> -0.219
	<i>R</i> -13	<i>U</i> -0.210
3.0 in.	<i>R</i> -11.4	<i>U</i> -0.178
	<i>R</i> -15	<i>U</i> -0.168
	<i>R</i> -19.0	<i>U</i> -0.161
3.5 in.	<i>R</i> -11.0	<i>U</i> -0.168
	<i>R</i> -13.0	<i>U</i> -0.161
	<i>R</i> -15.0	<i>U</i> -0.155
4.5 in.	<i>R</i> -17.1	<i>U</i> -0.133
	<i>R</i> -22.5	<i>U</i> -0.124
	<i>R</i> -25.2	<i>U</i> -0.122
5.0 in.	<i>R</i> -19.0	<i>U</i> -0.122
	<i>R</i> -25.0	<i>U</i> -0.115
	<i>R</i> -28.0	<i>U</i> -0.112
	<i>R</i> -32.0	<i>U</i> -0.109
5.5 in.	<i>R</i> -19.0	<i>U</i> -0.118
	<i>R</i> -20.9	<i>U</i> -0.114
	<i>R</i> -21.0	<i>U</i> -0.113
	<i>R</i> -27.5	<i>U</i> -0.106
	<i>R</i> -30.8	<i>U</i> -0.104
6.0 in.	<i>R</i> -22.8	<i>U</i> -0.106
	<i>R</i> -30.0	<i>U</i> -0.099
	<i>R</i> -33.6	<i>U</i> -0.096
6.5 in.	<i>R</i> -24.7	<i>U</i> -0.099
7.0 in.	<i>R</i> -26.6	<i>U</i> -0.093
7.5 in.	<i>R</i> -28.5	<i>U</i> -0.088
8.0 in.	<i>R</i> -30.4	<i>U</i> -0.083
<i>Continuous insulation uninterrupted by framing</i>		
No framing	<i>R</i> -1.0	<i>U</i> -0.425
No framing	<i>R</i> -2.0	<i>U</i> -0.298
No framing	<i>R</i> -3.0	<i>U</i> -0.230
No framing	<i>R</i> -4.0	<i>U</i> -0.187
No framing	<i>R</i> -5.0	<i>U</i> -0.157
No framing	<i>R</i> -6.0	<i>U</i> -0.136
No framing	<i>R</i> -7.0	<i>U</i> -0.120

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Table 8.1b, cont.—Assembly *U*-factors for above-grade normalweight concrete walls

Framing type and depth	Rated <i>R</i> -value of insulation alone	Assembly <i>U</i> -factors 8 in. normal-weight 145 lb/ft ³ solid concrete walls
<i>Continuous insulation uninterrupted by framing</i>		
No framing	<i>R</i> -8.0	<i>U</i> -0.107
No framing	<i>R</i> -9.0	<i>U</i> -0.097
No framing	<i>R</i> -10.0	<i>U</i> -0.088
No framing	<i>R</i> -11.0	<i>U</i> -0.081
No framing	<i>R</i> -12.0	<i>U</i> -0.075
No framing	<i>R</i> -13.0	<i>U</i> -0.070
No framing	<i>R</i> -14.0	<i>U</i> -0.065
No framing	<i>R</i> -15.0	<i>U</i> -0.061
No framing	<i>R</i> -16.0	<i>U</i> -0.058
No framing	<i>R</i> -17.0	<i>U</i> -0.054
No framing	<i>R</i> -18.0	<i>U</i> -0.052
No framing	<i>R</i> -19.0	<i>U</i> -0.049
No framing	<i>R</i> -20.0	<i>U</i> -0.047
No framing	<i>R</i> -21.0	<i>U</i> -0.045
No framing	<i>R</i> -22.0	<i>U</i> -0.043
No framing	<i>R</i> -23.0	<i>U</i> -0.041
No framing	<i>R</i> -24.0	<i>U</i> -0.039
No framing	<i>R</i> -25.0	<i>U</i> -0.038
No framing	<i>R</i> -30.0	<i>U</i> -0.032
No framing	<i>R</i> -35.0	<i>U</i> -0.028
No framing	<i>R</i> -40.0	<i>U</i> -0.024
No framing	<i>R</i> -45.0	<i>U</i> -0.022
No framing	<i>R</i> -50.0	<i>U</i> -0.019
No framing	<i>R</i> -55.0	<i>U</i> -0.018
No framing	<i>R</i> -60.0	<i>U</i> -0.016
<i>Brick cavity wall with continuous insulation</i>		
No framing	<i>R</i> -0	<i>U</i> -0.337
No framing	<i>R</i> -3.8	<i>U</i> -0.148
No framing	<i>R</i> -5.0	<i>U</i> -0.125
No framing	<i>R</i> -6.5	<i>U</i> -0.106
No framing	<i>R</i> -7.6	<i>U</i> -0.095
No framing	<i>R</i> -10	<i>U</i> -0.077
No framing	<i>R</i> -10.5	<i>U</i> -0.079
No framing	<i>R</i> -11.4	<i>U</i> -0.070
No framing	<i>R</i> -15	<i>U</i> -0.056
No framing	<i>R</i> -16.5	<i>U</i> -0.054
No framing	<i>R</i> -19.0	<i>U</i> -0.046
No framing	<i>R</i> -22.5	<i>U</i> -0.041
No framing	<i>R</i> -28.5	<i>U</i> -0.033

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Table 8.1b, cont.—Assembly *U*-factors for above-grade normalweight concrete walls

Framing type and depth	Rated <i>R</i> -value of insulation alone	Assembly <i>U</i> -factors 8 in. normalweight 145 lb/ft ³ solid concrete walls
<i>Continuous insulation uninterrupted by framing with stucco and continuous metal framing at 24 in. on-center horizontally</i>		
1.0 in.	<i>R</i> -0+ <i>R</i> -19.0 CI	<i>U</i> -0.047
	<i>R</i> -3.8+ <i>R</i> -19.0 CI	<i>U</i> -0.045
	<i>R</i> -5+ <i>R</i> -19.0 CI	<i>U</i> -0.045
	<i>R</i> -6.5+ <i>R</i> -19.0 CI	<i>U</i> -0.045
1.5 in.	<i>R</i> -11+ <i>R</i> -19.0 CI	<i>U</i> -0.044
2.0 in.	<i>R</i> -7.6+ <i>R</i> -19.0 CI	<i>U</i> -0.043
	<i>R</i> -10+ <i>R</i> -19.0 CI	<i>U</i> -0.042
	<i>R</i> -13+ <i>R</i> -19.0 CI	<i>U</i> -0.042
3.0 in.	<i>R</i> -11.4+ <i>R</i> -19.0 CI	<i>U</i> -0.041
	<i>R</i> -15+ <i>R</i> -19.0 CI	<i>U</i> -0.040
	<i>R</i> -19.5+ <i>R</i> -19.0 CI	<i>U</i> -0.040
3.5 in.	<i>R</i> -11.0+ <i>R</i> -19.0 CI	<i>U</i> -0.040
	<i>R</i> -13.0+ <i>R</i> -19.0 CI	<i>U</i> -0.040
5.0 in.	<i>R</i> -19.0+ <i>R</i> -19.0 CI	<i>U</i> -0.037
	<i>R</i> -25+ <i>R</i> -19.0 CI	<i>U</i> -0.036
	<i>R</i> -32.5+ <i>R</i> -19.0 CI	<i>U</i> -0.035
5.5 in.	<i>R</i> -19.0+ <i>R</i> -19.0 CI	<i>U</i> -0.036
	<i>R</i> -21.0+ <i>R</i> -19.0 CI	<i>U</i> -0.035

Table 8.1c—Assembly *U*-factors for above-grade walls with nominal 4 in. clay masonry veneer

Backing material	Stud gauge thickness	Stud width x depth, in.	Stud spacing, in.	Sheathing	Stud cavity insulation	Continuous insulation*	Air space, in.	Assembly <i>U</i> -factor
Cold-formed metal frame	18	1-1/2 x 6	16	5/8 in. thick fiberglass-faced gypsum	<i>R</i> -21	None	2	0.094
Cold-formed metal frame	18	1-1/2 x 6	16	5/8 in. thick fiberglass-faced gypsum	<i>R</i> -21	<i>R</i> -10	3	0.048
Cold-formed metal frame	18	1-1/2 x 6	16	5/8 in. thick fiberglass-faced gypsum	None	<i>R</i> -10	3	0.085
Wood frame	NA	Nom. 2 x 4	16	7/16 in. thick oriented strand board	<i>R</i> -13	None	1	0.068

*In air space.

Notes: NA is not applicable; Nom. = nominal.

Table 8.1d—*U*-factor for clay masonry veneer and air space layers of wall assembly (Btu/h·ft²·°F)*

Minimum width clay masonry veneer, in.	Air space	Air space with reflective surface opposite veneer†
2-5/8	0.703	0.332
3-1/2	0.641	0.318

*Does not include air film.

†Reflective surface shall have an emissivity no greater than 0.05 when measured in accordance with ASTM C1371.

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Table 8.1e—Assembly C-factors for below-grade walls

Framing type and depth	Rated <i>R</i> -value of insulation alone	Specified <i>C</i> -factors (wall only, without soil and air films)
No framing	<i>R</i> -0	<i>C</i> -1.140
<i>Exterior insulation, continuous and uninterrupted by framing</i>		
No framing	<i>R</i> -5.0	<i>C</i> -0.170
No framing	<i>R</i> -7.5	<i>C</i> -0.119
No framing	<i>R</i> -10.0	<i>C</i> -0.092
No framing	<i>R</i> -12.5	<i>C</i> -0.075
No framing	<i>R</i> -15.0	<i>C</i> -0.063
No framing	<i>R</i> -17.5	<i>C</i> -0.054
No framing	<i>R</i> -20.0	<i>C</i> -0.048
No framing	<i>R</i> -25.0	<i>C</i> -0.039
No framing	<i>R</i> -30.0	<i>C</i> -0.032
No framing	<i>R</i> -35.0	<i>C</i> -0.028
No framing	<i>R</i> -40.0	<i>C</i> -0.025
No framing	<i>R</i> -45.0	<i>C</i> -0.022
No framing	<i>R</i> -50.0	<i>C</i> -0.020
<i>Continuous metal framing at 24 in. on-center horizontally</i>		
3.5 in.	<i>R</i> -11.0	<i>C</i> -0.182
3.5 in.	<i>R</i> -13.0	<i>C</i> -0.174
3.5 in.	<i>R</i> -15.0	<i>C</i> -0.168
5.5 in.	<i>R</i> -19.0	<i>C</i> -0.125
5.5 in.	<i>R</i> -21.0	<i>C</i> -0.120

8.1.1 Above-grade wall assemblies—Tables 8.1.1a through 8.1.1v provide the *U*-factors for concrete and masonry assemblies or masonry veneer. Where indicated they include insulation, interior finishes, and exterior finishes. *C*-factors and heat capacity (HC) are also provided for some assemblies.

To determine the *R*-values of assemblies with additional continuous insulation, air spaces of uniform thickness, or additional finishes, the *R*-values of the additional continuous insulation, air spaces, and finishes are added to the *R*-values of the assemblies in the table. The *U*-factor for compliance is the inverse of this total *R*-value. Unless otherwise indicated, the values in the tables include air film resistances.

R8.1.1 Above-grade wall assemblies—Calculated *U*-factors (based on the series-parallel method) for various single wythe concrete masonry wall assemblies are listed in Tables 8.1.1a through 8.1.1v. The walls in Tables 8.1.1a through 8.1.1g are single wythe with no interior or exterior insulation and no finishes. The walls in Tables 8.1.1h through 8.1.1n are single wythe with core insulation and no finishes. The walls in Tables 8.1.1o through 8.1.1v are single wythe walls with core insulation, inserts, and no finishes.

To determine calculated *U*-factors from Tables 8.1.1a through 8.1.1v, grout percentage and normalized web area is required. Examples of various CMU configurations with different normalized web areas are illustrated in Fig. R8.1.1. These can be calculated using Tables R8.1.1a and R8.1.1b. *R*-values of any core or exterior insulation or finish system are simply added to the *R*-value of the concrete masonry wall from Tables 8.1.1a through 8.1.1v to obtain the total *R*-value of the total assembly.

The thermal resistance (*R*-value) and thermal transmittance (*U*-factor) of an individual concrete masonry unit is largely governed by the density of the unit. In the case of hollow masonry units, the total area and length of

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web(s) connecting the face shells of the unit, which in turn act as a thermal bridge as illustrated in the series-parallel heat flow model in Figure R8.1.5. The location of the web(s) within the cross section of the unit has negligible impact on a unit's thermal properties. The resulting thermal properties of a masonry assembly are in turn influenced by the thermal properties of the masonry units used in its construction, the presence and location of insulation (interior, exterior, or integral), and presence of grout within the cells of the units.

The overall U -factor of a partially grouted masonry wall is calculated from the area-weighted average of the U -factor of the grouted area and the U -factor of the ungrouted area as follows

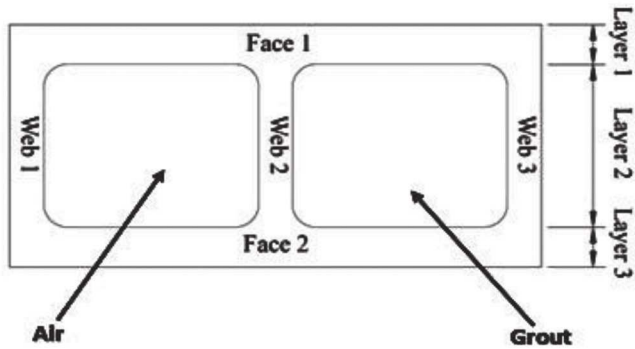
$$UA_{Avg} = \frac{(a_{gr})(U_{gr}) + (a_{ungr})(U_{ungr})}{a_{un} + a_{ungr}}$$

where a_{gr} is area of the wall assembly that is grouted (ft²); a_{ungr} is area of the wall assembly that is ungrouted (ft²); U_{gr} is U -factor of the grouted portion of the wall assembly (Btu/h·ft²·°F); U_{ungr} is U -factor of the ungrouted portion of the wall assembly (Btu/h·ft²·°F); and UA_{Avg} is area-weighted average U -factor of the wall assembly (Btu/h·ft²·°F).

Proportionate areas for typical grouted and ungrouted concrete masonry unit assemblies are provided in Table R8.1.1a.

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Table 8.1.1a—4 x 8 x 16 in. concrete masonry assembly without insulation *U*-factors (Btu/h-ft²-°F) and heat capacity values (Btu/ft²-°F)

Normalized web area, in. ² /ft ²	Density CMU, lb/ft ²	Grout percentage																					
		0%		10%		20%		30%		40%		50%		60%		70%		80%		90%		100%	
		<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC
6.5	85	0.455	2.6	0.477	3.1	0.500	3.5	0.523	4.0	0.545	4.4	0.568	5.1	0.590	5.5	0.613	5.9	0.635	6.4	0.658	6.8	0.681	7.3
	95	0.471	2.9	0.495	3.3	0.519	4.0	0.543	4.4	0.567	4.8	0.591	5.3	0.615	5.7	0.639	6.2	0.663	6.6	0.687	7.0	0.711	7.5
	105	0.487	3.3	0.512	3.7	0.537	4.2	0.562	4.6	0.588	5.1	0.613	5.5	0.638	5.9	0.663	6.4	0.689	6.8	0.714	7.3	0.739	7.7
	115	0.503	3.5	0.529	4.0	0.555	4.4	0.582	4.8	0.608	5.3	0.634	5.7	0.661	6.2	0.687	6.6	0.713	7.0	0.739	7.7	0.766	8.1
	125	0.519	3.7	0.546	4.2	0.573	4.6	0.600	5.1	0.627	5.5	0.655	5.9	0.682	6.6	0.709	7.0	0.736	7.5	0.763	7.9	0.790	8.4
	135	0.535	4.0	0.563	4.4	0.591	5.1	0.619	5.5	0.646	5.9	0.674	6.4	0.702	6.8	0.730	7.3	0.757	7.7	0.785	8.1	0.813	8.6
7.5	85	0.455	2.6	0.478	3.1	0.500	3.5	0.523	4.0	0.545	4.6	0.568	5.1	0.590	5.5	0.613	5.9	0.635	6.4	0.658	6.8	0.680	7.3
	95	0.472	3.1	0.496	3.5	0.520	4.0	0.543	4.4	0.567	4.8	0.591	5.3	0.615	5.7	0.639	6.2	0.662	6.6	0.686	7.0	0.710	7.5
	105	0.489	3.3	0.514	3.7	0.539	4.2	0.564	4.6	0.589	5.1	0.614	5.5	0.639	5.9	0.664	6.4	0.689	6.8	0.714	7.3	0.739	7.7
	115	0.505	3.5	0.531	4.0	0.557	4.4	0.583	4.8	0.609	5.3	0.635	5.7	0.661	6.2	0.687	6.8	0.713	7.3	0.739	7.7	0.765	8.1
	125	0.522	3.7	0.549	4.2	0.576	4.6	0.603	5.1	0.629	5.7	0.656	6.2	0.683	6.6	0.710	7.0	0.737	7.5	0.763	7.9	0.790	8.4
	135	0.540	4.2	0.567	4.6	0.594	5.1	0.622	5.5	0.649	5.9	0.676	6.4	0.704	6.8	0.731	7.3	0.758	7.7	0.785	8.1	0.813	8.6
8.5	85	0.456	2.6	0.478	3.1	0.501	3.7	0.523	4.2	0.546	4.6	0.568	5.1	0.590	5.5	0.613	5.9	0.635	6.4	0.657	6.8	0.680	7.3
	95	0.473	3.1	0.497	3.5	0.520	4.0	0.544	4.4	0.568	4.8	0.591	5.3	0.615	5.7	0.639	6.2	0.662	6.6	0.686	7.0	0.710	7.5
	105	0.490	3.3	0.515	3.7	0.540	4.2	0.565	4.6	0.589	5.1	0.614	5.5	0.639	5.9	0.664	6.4	0.689	6.8	0.713	7.5	0.738	7.9
	115	0.508	3.5	0.533	4.0	0.559	4.4	0.585	4.8	0.611	5.3	0.636	5.9	0.662	6.4	0.688	6.8	0.714	7.3	0.739	7.7	0.765	8.1
	125	0.526	3.7	0.552	4.4	0.578	4.8	0.605	5.3	0.631	5.7	0.658	6.2	0.684	6.6	0.711	7.0	0.737	7.5	0.763	7.9	0.790	8.4
	135	0.544	4.2	0.571	4.6	0.598	5.1	0.625	5.5	0.652	5.9	0.678	6.4	0.705	6.8	0.732	7.3	0.759	7.7	0.786	8.1	0.813	8.6

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Table 8.1.1a, cont.—4 x 8 x 16 in. concrete masonry assembly without insulation *U*-factors (Btu/h-ft²-°F) and heat capacity values (Btu/ft²-°F)

Normalized web area, in. ² /ft ²	Density CMU, lb/ft ³	Grout percentage																					
		0%		10%		20%		30%		40%		50%		60%		70%		80%		90%		100%	
		<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC
10	85	0.457	2.9	0.479	3.3	0.501	3.7	0.524	4.2	0.546	4.6	0.568	5.1	0.590	5.5	0.612	5.9	0.635	6.4	0.657	6.8	0.679	7.3
	95	0.475	3.1	0.498	3.5	0.522	4.0	0.545	4.4	0.568	4.8	0.592	5.3	0.615	5.7	0.639	6.2	0.662	6.6	0.685	7.0	0.709	7.7
	105	0.493	3.3	0.517	3.7	0.542	4.2	0.566	4.6	0.591	5.1	0.615	5.5	0.640	6.2	0.664	6.6	0.689	7.0	0.713	7.5	0.738	7.9
	115	0.511	3.5	0.537	4.0	0.562	4.6	0.587	5.1	0.613	5.5	0.638	5.9	0.663	6.4	0.689	6.8	0.714	7.3	0.739	7.7	0.764	8.1
	125	0.531	4.0	0.556	4.4	0.582	4.8	0.608	5.3	0.634	5.7	0.660	6.2	0.686	6.6	0.712	7.0	0.738	7.5	0.764	7.9	0.789	8.4
	135	0.551	4.2	0.577	4.6	0.603	5.1	0.629	5.5	0.655	5.9	0.682	6.4	0.708	6.8	0.734	7.3	0.760	7.9	0.786	8.4	0.813	8.8
12	85	0.458	2.9	0.480	3.3	0.502	3.7	0.524	4.2	0.546	4.6	0.568	5.1	0.590	5.5	0.612	5.9	0.634	6.4	0.656	6.8	0.678	7.3
	95	0.477	3.1	0.500	3.5	0.523	4.0	0.546	4.4	0.569	4.8	0.593	5.3	0.616	5.7	0.639	6.4	0.662	6.8	0.685	7.3	0.708	7.7
	105	0.496	3.3	0.520	3.7	0.544	4.2	0.568	4.8	0.592	5.3	0.616	5.7	0.641	6.2	0.665	6.6	0.689	7.0	0.713	7.5	0.737	7.9
	115	0.516	3.7	0.541	4.2	0.566	4.6	0.590	5.1	0.615	5.5	0.640	5.9	0.665	6.4	0.689	6.8	0.714	7.3	0.739	7.7	0.764	8.1
	125	0.537	4.0	0.562	4.4	0.587	4.8	0.613	5.3	0.638	5.7	0.663	6.2	0.688	6.6	0.713	7.0	0.739	7.7	0.764	8.1	0.789	8.6
	135	0.559	4.2	0.584	4.6	0.610	5.1	0.635	5.5	0.660	6.2	0.686	6.6	0.711	7.0	0.736	7.5	0.762	7.9	0.787	8.4	0.812	8.8
14	85	0.460	2.9	0.481	3.3	0.503	3.7	0.525	4.2	0.547	4.6	0.568	5.1	0.590	5.5	0.612	5.9	0.633	6.6	0.655	7.0	0.677	7.5
	95	0.479	3.1	0.502	3.5	0.525	4.0	0.548	4.4	0.570	5.1	0.593	5.5	0.616	5.9	0.639	6.4	0.661	6.8	0.684	7.3	0.707	7.7
	105	0.500	3.5	0.523	4.0	0.547	4.4	0.570	4.8	0.594	5.3	0.618	5.7	0.641	6.2	0.665	6.6	0.689	7.0	0.712	7.5	0.736	7.9
	115	0.521	3.7	0.545	4.2	0.569	4.6	0.594	5.1	0.618	5.5	0.642	5.9	0.666	6.4	0.690	6.8	0.715	7.5	0.739	7.9	0.763	8.4
	125	0.543	4.0	0.568	4.4	0.592	4.8	0.617	5.3	0.641	5.9	0.666	6.4	0.690	6.8	0.715	7.3	0.739	7.7	0.764	8.1	0.788	8.6
	135	0.567	4.4	0.592	4.8	0.616	5.3	0.641	5.7	0.665	6.2	0.690	6.6	0.714	7.0	0.739	7.5	0.763	7.9	0.788	8.4	0.812	8.8
16	85	0.461	2.9	0.482	3.3	0.504	3.7	0.525	4.2	0.547	4.6	0.568	5.3	0.590	5.7	0.611	6.2	0.633	6.6	0.654	7.0	0.676	7.5
	95	0.481	3.3	0.504	3.7	0.526	4.2	0.549	4.6	0.571	5.1	0.594	5.5	0.616	5.9	0.639	6.4	0.661	6.8	0.683	7.3	0.706	7.7
	105	0.503	3.5	0.526	4.0	0.549	4.4	0.572	4.8	0.596	5.3	0.619	5.7	0.642	6.2	0.665	6.6	0.688	7.0	0.712	7.7	0.735	8.1
	115	0.525	3.7	0.549	4.2	0.573	4.6	0.597	5.1	0.620	5.7	0.644	6.2	0.668	6.6	0.691	7.0	0.715	7.5	0.739	7.9	0.762	8.4
	125	0.549	4.2	0.573	4.6	0.597	5.1	0.621	5.5	0.645	5.9	0.669	6.4	0.693	6.8	0.716	7.3	0.740	7.7	0.764	8.1	0.788	8.6
	135	0.575	4.4	0.599	4.8	0.622	5.3	0.646	5.7	0.670	6.2	0.693	6.6	0.717	7.0	0.741	7.5	0.764	8.1	0.788	8.6	0.812	9.0

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Table 8.1.1a, cont.—4 x 8 x 16 in. concrete masonry assembly without insulation *U*-factors (Btu/h-ft²-°F) and heat capacity values (Btu/ft²-°F)

Normalized web area, in. ² /ft ²	Density CMU, lb/ft ³	Grout percentage																					
		0%		10%		20%		30%		40%		50%		60%		70%		80%		90%		100%	
		<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC
18	85	0.462	2.9	0.484	3.3	0.505	3.7	0.526	4.4	0.547	4.8	0.569	5.3	0.590	5.7	0.611	6.2	0.632	6.6	0.653	7.0	0.675	7.5
	95	0.484	3.3	0.506	3.7	0.528	4.2	0.550	4.6	0.572	5.1	0.594	5.5	0.616	5.9	0.639	6.4	0.661	6.8	0.683	7.3	0.705	7.7
	105	0.506	3.5	0.529	4.0	0.552	4.4	0.574	4.8	0.597	5.3	0.620	5.7	0.643	6.4	0.666	6.8	0.688	7.3	0.711	7.7	0.734	8.1
	115	0.530	4.0	0.553	4.4	0.576	4.8	0.599	5.3	0.623	5.7	0.646	6.2	0.669	6.6	0.692	7.0	0.715	7.5	0.738	7.9	0.761	8.4
	125	0.555	4.2	0.579	4.6	0.602	5.1	0.625	5.5	0.648	5.9	0.671	6.4	0.695	6.8	0.718	7.3	0.741	7.7	0.764	8.4	0.787	8.8
	135	0.582	4.4	0.605	4.8	0.628	5.3	0.651	5.7	0.674	6.4	0.697	6.8	0.720	7.3	0.743	7.7	0.766	8.1	0.789	8.6	0.812	9.0
20	85	0.464	3.1	0.485	3.5	0.506	4.0	0.527	4.4	0.548	4.8	0.569	5.3	0.590	5.7	0.611	6.2	0.632	6.6	0.653	7.0	0.674	7.5
	95	0.486	3.3	0.508	3.7	0.529	4.2	0.551	4.6	0.573	5.1	0.595	5.5	0.617	5.9	0.638	6.4	0.660	7.0	0.682	7.5	0.704	7.9
	105	0.509	3.5	0.532	4.0	0.554	4.6	0.576	5.1	0.599	5.5	0.621	5.9	0.644	6.4	0.666	6.8	0.688	7.3	0.711	7.7	0.733	8.1
	115	0.534	4.0	0.557	4.4	0.580	4.8	0.602	5.3	0.625	5.7	0.648	6.2	0.670	6.6	0.693	7.0	0.715	7.5	0.738	7.9	0.761	8.6
	125	0.561	4.2	0.584	4.6	0.606	5.1	0.629	5.5	0.651	5.9	0.674	6.6	0.697	7.0	0.719	7.5	0.742	7.9	0.764	8.4	0.787	8.8
	135	0.590	4.6	0.612	5.1	0.634	5.5	0.656	5.9	0.678	6.4	0.700	6.8	0.723	7.3	0.745	7.7	0.767	8.1	0.789	8.6	0.811	9.0
22	85	0.465	3.1	0.486	3.5	0.506	4.0	0.527	4.4	0.548	4.8	0.569	5.3	0.589	5.7	0.610	6.2	0.631	6.6	0.652	7.0	0.673	7.5
	95	0.488	3.3	0.509	3.7	0.531	4.2	0.552	4.6	0.574	5.1	0.595	5.7	0.617	6.2	0.638	6.6	0.660	7.0	0.681	7.5	0.703	7.9
	105	0.512	3.7	0.534	4.2	0.556	4.6	0.578	5.1	0.600	5.5	0.622	5.9	0.644	6.4	0.666	6.8	0.688	7.3	0.710	7.7	0.732	8.1
	115	0.539	4.0	0.561	4.4	0.583	4.8	0.605	5.3	0.627	5.7	0.649	6.2	0.671	6.8	0.694	7.3	0.716	7.7	0.738	8.1	0.760	8.6
	125	0.567	4.4	0.589	4.8	0.611	5.3	0.633	5.7	0.654	6.2	0.676	6.6	0.698	7.0	0.720	7.5	0.742	7.9	0.764	8.4	0.786	8.8
	135	0.596	4.6	0.618	5.1	0.639	5.5	0.661	5.9	0.682	6.4	0.704	6.8	0.725	7.3	0.747	7.7	0.768	8.4	0.790	8.8	0.811	9.2

- Both face shell thickness: 3/4 in.
- Mortar joint thickness: 3/8 in.
- Ungrouted cells are filled with air.
- Specific heat of concrete masonry unit: 0.22 Btu/lb-°F.
- To calculate thermal resistance (*R*-value): $R = 1/U$ (h-ft²-°F/Btu).
- To determine grout percentage, refer to Table R8.1.1a.
- To determine normalized web area for typical concrete masonry unit, refer to Table R8.1.1b.
- Linear interpolation can be done to calculate *U*-factor and heat capacity values for intermediate grout percentage.
- Mortar density: 125 lb/ft³.
- Grout density: 140 lb/ft³.

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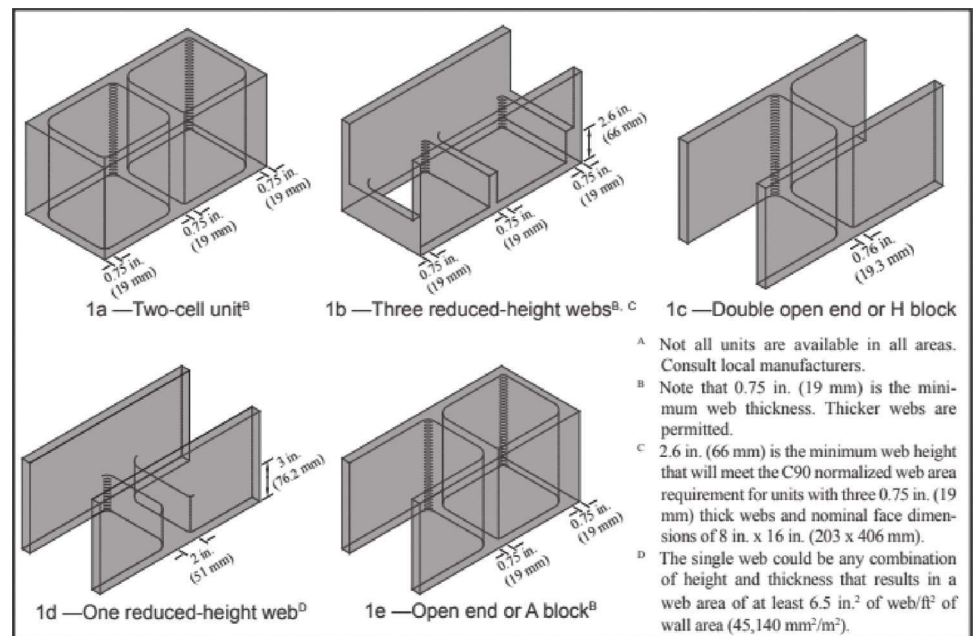


Fig R8.1.1—Examples of CMU web configurations permitted under ASTM C90.

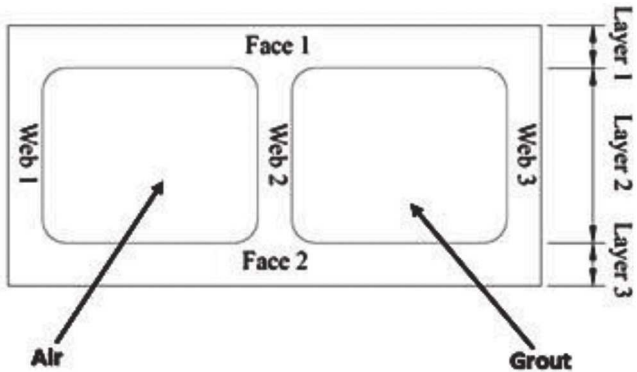
Table R8.1.1a—Concrete masonry assembly grout percentage*, %

Spacing of horizontally grouted courses, in.	Spacing of vertically grouted cells, in.															
	None	120	112	104	96	88	80	72	64	56	48	40	32	24	16	8
None	0	6.7	7.1	7.7	8.3	9.1	10.0	11.1	12.5	14.3	16.7	20.0	25.0	33.3	50.0	100
120	6.7	12.9	13.3	13.9	14.4	15.2	16.0	17.0	18.3	20.0	22.2	25.3	30.0	37.8	53.3	100
112	7.1	13.3	13.8	14.3	14.9	15.6	16.4	17.5	18.8	20.4	22.6	25.7	30.4	38.1	53.6	100
104	7.7	13.9	14.3	14.8	15.4	16.1	16.9	18.0	19.2	20.9	23.1	26.2	30.8	38.5	53.9	100
96	8.3	14.4	14.9	15.4	16.0	16.7	17.5	18.5	19.8	21.4	23.6	26.7	31.3	38.9	54.2	100
88	9.1	15.2	15.6	16.1	16.7	17.4	18.2	19.2	20.5	22.1	24.2	27.3	31.8	39.4	54.6	100
80	10.0	16.0	16.4	16.9	17.5	18.2	19.0	20.0	21.3	22.9	25.0	28.0	32.5	40.0	55.0	100
72	11.1	17.0	17.5	18.0	18.5	19.2	20.0	21.0	22.2	23.8	25.9	28.9	33.3	40.7	55.6	100
64	12.5	18.3	18.8	19.2	19.8	20.5	21.3	22.2	23.4	25.0	27.1	30.0	34.4	41.7	56.3	100
56	14.3	20.0	20.4	20.9	21.4	22.1	22.9	23.8	25.0	26.5	28.6	31.4	35.7	42.9	57.1	100
48	16.7	22.2	22.6	23.1	23.6	24.2	25.0	25.9	27.1	28.6	30.6	33.3	37.5	44.4	58.3	100
40	20.0	25.3	25.7	26.2	26.7	27.3	28.0	28.9	30.0	31.4	33.3	36.0	40.0	46.7	60.0	100
32	25.0	30.0	30.4	30.8	31.3	31.8	32.5	33.3	34.4	35.7	37.5	40.0	43.8	50.0	62.5	100
24	33.3	37.8	38.1	38.5	38.9	39.4	40.0	40.7	41.7	42.9	44.4	46.7	50.0	55.6	66.7	100
16	50.0	53.3	53.6	53.9	54.2	54.6	55.0	55.6	56.3	57.1	58.3	60.0	62.5	66.7	75.0	100
8	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

*Percentage of grout values are based on a unit configuration consisting of two cells and three full-height webs. Similar values can be calculated for other unit configurations.

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Table 8.1.1b—6 x 8 x 16 in. concrete masonry assembly without insulation *U*-factors (Btu/h-ft²-°F) and heat capacity values (Btu/ft²-°F)

Normalized web area, in. ² /ft ²	Density CMU, lb/ft ³	Grout percentage																			
		0%		10%		20%		30%		40%		50%		60%		70%		80%		90%	
		<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC
6.5	85	0.424	3.5	0.438	4.4	0.453	5.1	0.467	5.9	0.482	6.6	0.497	7.5	0.511	8.1	0.526	9.0	0.540	9.9	0.555	10.6
	95	0.441	4.0	0.456	4.8	0.472	5.5	0.488	6.4	0.503	7.0	0.519	7.9	0.535	8.6	0.550	9.5	0.566	10.1	0.582	11.0
	105	0.457	4.4	0.474	5.1	0.491	5.9	0.507	6.6	0.524	7.5	0.541	8.1	0.557	9.0	0.574	9.7	0.591	10.6	0.608	11.2
	115	0.473	4.6	0.491	5.5	0.508	6.2	0.526	7.0	0.544	7.7	0.562	8.6	0.579	9.5	0.597	10.1	0.615	11.0	0.632	11.7
	125	0.489	5.1	0.507	5.9	0.526	6.6	0.544	7.5	0.563	8.1	0.581	9.0	0.600	9.7	0.618	10.6	0.637	11.2	0.655	12.1
	135	0.504	5.5	0.523	6.2	0.542	7.0	0.562	7.7	0.581	8.6	0.600	9.2	0.619	10.1	0.638	10.8	0.658	11.7	0.677	12.5
7.5	85	0.424	3.5	0.438	4.4	0.453	5.3	0.467	5.9	0.482	6.8	0.496	7.5	0.511	8.4	0.525	9.0	0.540	9.9	0.554	10.6
	95	0.441	4.0	0.456	4.8	0.472	5.5	0.488	6.4	0.503	7.0	0.519	7.9	0.534	8.6	0.550	9.5	0.565	10.1	0.581	11.0
	105	0.458	4.4	0.474	5.1	0.491	5.9	0.507	6.6	0.524	7.5	0.541	8.4	0.557	9.0	0.574	9.9	0.591	10.6	0.607	11.4
	115	0.474	4.8	0.492	5.5	0.509	6.4	0.527	7.0	0.544	7.9	0.562	8.6	0.579	9.5	0.597	10.1	0.614	11.0	0.632	11.7
	125	0.490	5.1	0.508	5.9	0.527	6.6	0.545	7.5	0.563	8.1	0.582	9.0	0.600	9.9	0.619	10.6	0.637	11.4	0.655	12.1
	135	0.506	5.5	0.525	6.4	0.544	7.0	0.563	7.9	0.582	8.6	0.601	9.5	0.620	10.1	0.639	11.0	0.658	11.7	0.677	12.5
8.5	85	0.424	3.7	0.438	4.4	0.452	5.3	0.467	5.9	0.481	6.8	0.496	7.5	0.510	8.4	0.525	9.0	0.539	9.9	0.553	10.6
	95	0.441	4.0	0.456	4.8	0.472	5.5	0.488	6.4	0.503	7.3	0.519	7.9	0.534	8.8	0.550	9.5	0.565	10.3	0.581	11.0
	105	0.458	4.4	0.475	5.3	0.491	5.9	0.508	6.8	0.524	7.5	0.541	8.4	0.557	9.0	0.574	9.9	0.590	10.6	0.607	11.4
	115	0.475	4.8	0.492	5.5	0.510	6.4	0.527	7.0	0.545	7.9	0.562	8.8	0.579	9.5	0.597	10.3	0.614	11.0	0.632	11.9
	125	0.491	5.3	0.510	5.9	0.528	6.8	0.546	7.5	0.564	8.4	0.582	9.0	0.601	9.9	0.619	10.6	0.637	11.4	0.655	12.1
	135	0.508	5.5	0.527	6.4	0.546	7.0	0.564	7.9	0.583	8.6	0.602	9.5	0.621	10.3	0.640	11.0	0.658	11.9	0.677	12.5

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Table 8.1.1b, cont.—6 x 8 x 16 in. concrete masonry assembly without insulation *U*-factors (Btu/h-ft²-°F) and heat capacity values (Btu/ft²-°F)

Normalized web area, in. ² /ft ²	Density CMU, lb/ft ³	Grout percentage																			
		0%		10%		20%		30%		40%		50%		60%		70%		80%		90%	
		<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC
10	85	0.423	3.7	0.438	4.4	0.452	5.3	0.466	6.2	0.481	6.8	0.495	7.7	0.510	8.4	0.524	9.2	0.538	9.9	0.553	10.8
	95	0.441	4.2	0.457	4.8	0.472	5.7	0.487	6.4	0.503	7.3	0.518	7.9	0.534	8.8	0.549	9.5	0.564	10.3	0.580	11.0
	105	0.459	4.4	0.475	5.3	0.491	6.2	0.508	6.8	0.524	7.7	0.541	8.4	0.557	9.2	0.573	9.9	0.590	10.8	0.606	11.4
	115	0.476	4.8	0.493	5.7	0.511	6.4	0.528	7.3	0.545	7.9	0.562	8.8	0.579	9.5	0.597	10.3	0.614	11.0	0.631	11.9
	125	0.493	5.3	0.511	5.9	0.529	6.8	0.547	7.7	0.565	8.4	0.583	9.2	0.601	9.9	0.619	10.8	0.637	11.4	0.655	12.3
	135	0.511	5.7	0.529	6.4	0.548	7.3	0.566	7.9	0.585	8.8	0.603	9.5	0.622	10.3	0.640	11.0	0.659	11.9	0.677	12.8
12	85	0.423	3.7	0.437	4.6	0.452	5.3	0.466	6.2	0.480	6.8	0.494	7.7	0.509	8.4	0.523	9.2	0.537	10.1	0.552	10.8
	95	0.441	4.2	0.457	5.1	0.472	5.7	0.487	6.6	0.502	7.3	0.518	8.1	0.533	8.8	0.548	9.7	0.563	10.3	0.579	11.2
	105	0.460	4.6	0.476	5.3	0.492	6.2	0.508	6.8	0.524	7.7	0.540	8.6	0.557	9.2	0.573	10.1	0.589	10.8	0.605	11.7
	115	0.478	5.1	0.495	5.7	0.512	6.6	0.529	7.3	0.546	8.1	0.563	8.8	0.580	9.7	0.597	10.3	0.614	11.2	0.631	11.9
	125	0.496	5.3	0.514	6.2	0.531	7.0	0.549	7.7	0.567	8.6	0.584	9.2	0.602	10.1	0.619	10.8	0.637	11.7	0.655	12.3
	135	0.515	5.7	0.533	6.6	0.551	7.3	0.569	8.1	0.587	8.8	0.605	9.7	0.623	10.3	0.641	11.2	0.659	12.1	0.677	12.8
14	85	0.423	4.0	0.437	4.6	0.451	5.5	0.465	6.2	0.480	7.0	0.494	7.7	0.508	8.6	0.522	9.2	0.536	10.1	0.550	10.8
	95	0.442	4.2	0.457	5.1	0.472	5.9	0.487	6.6	0.502	7.5	0.517	8.1	0.532	9.0	0.547	9.7	0.563	10.6	0.578	11.2
	105	0.460	4.6	0.476	5.5	0.492	6.2	0.508	7.0	0.524	7.7	0.540	8.6	0.556	9.5	0.572	10.1	0.588	11.0	0.604	11.7
	115	0.479	5.1	0.496	5.9	0.513	6.6	0.530	7.5	0.546	8.1	0.563	9.0	0.580	9.7	0.596	10.6	0.613	11.2	0.630	12.1
	125	0.499	5.5	0.516	6.4	0.533	7.0	0.551	7.9	0.568	8.6	0.585	9.5	0.603	10.1	0.620	11.0	0.637	11.7	0.654	12.5
	135	0.519	5.9	0.537	6.6	0.554	7.5	0.572	8.1	0.589	9.0	0.607	9.9	0.625	10.6	0.642	11.4	0.660	12.1	0.678	13.0
16	85	0.423	4.0	0.437	4.8	0.451	5.5	0.465	6.4	0.479	7.0	0.493	7.9	0.507	8.6	0.521	9.5	0.535	10.1	0.549	11.0
	95	0.442	4.4	0.457	5.1	0.472	5.9	0.487	6.6	0.502	7.5	0.517	8.4	0.532	9.0	0.547	9.9	0.562	10.6	0.577	11.4
	105	0.461	4.8	0.477	5.5	0.493	6.4	0.509	7.0	0.524	7.9	0.540	8.6	0.556	9.5	0.572	10.3	0.588	11.0	0.603	11.9
	115	0.481	5.3	0.498	5.9	0.514	6.8	0.530	7.5	0.547	8.4	0.563	9.0	0.580	9.9	0.596	10.6	0.613	11.4	0.629	12.1
	125	0.502	5.7	0.519	6.4	0.535	7.3	0.552	7.9	0.569	8.8	0.586	9.5	0.603	10.3	0.620	11.0	0.637	11.9	0.654	12.5
	135	0.523	5.9	0.540	6.8	0.557	7.5	0.574	8.4	0.592	9.2	0.609	9.9	0.626	10.8	0.643	11.4	0.661	12.3	0.678	13.0



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Table 8.1.1b, cont.—6 x 8 x 16 in. concrete masonry assembly without insulation *U*-factors (Btu/h-ft²-°F) and heat capacity values (Btu/ft²-°F)

Normalized web area, in. ² /ft ²	Density CMU, lb/ft ²	Grout percentage																			
		0%		10%		20%		30%		40%		50%		60%		70%		80%		90%	
		<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC
18	85	0.422	4.0	0.436	4.8	0.450	5.5	0.464	6.4	0.478	7.0	0.492	7.9	0.506	8.8	0.520	9.5	0.534	10.3	0.548	11.0
	95	0.442	4.4	0.457	5.3	0.472	5.9	0.486	6.8	0.501	7.5	0.516	8.4	0.531	9.0	0.546	9.9	0.561	10.8	0.576	11.4
	105	0.462	4.8	0.478	5.7	0.493	6.4	0.509	7.3	0.524	7.9	0.540	8.8	0.556	9.5	0.571	10.3	0.587	11.0	0.602	11.9
	115	0.483	5.3	0.499	6.2	0.515	6.8	0.531	7.7	0.548	8.4	0.564	9.2	0.580	9.9	0.596	10.8	0.612	11.4	0.629	12.3
	125	0.504	5.7	0.521	6.6	0.537	7.3	0.554	8.1	0.571	8.8	0.587	9.7	0.604	10.3	0.620	11.2	0.637	11.9	0.654	12.8
	135	0.527	6.2	0.543	7.0	0.560	7.7	0.577	8.6	0.594	9.2	0.611	10.1	0.627	10.8	0.644	11.7	0.661	12.3	0.678	13.2
20	85	0.422	4.2	0.436	4.8	0.450	5.7	0.464	6.4	0.477	7.3	0.491	7.9	0.505	8.8	0.519	9.5	0.533	10.3	0.547	11.2
	95	0.442	4.6	0.457	5.3	0.471	6.2	0.486	6.8	0.501	7.7	0.516	8.4	0.530	9.2	0.545	9.9	0.560	10.8	0.574	11.4
	105	0.463	5.1	0.478	5.7	0.494	6.6	0.509	7.3	0.524	8.1	0.540	8.8	0.555	9.7	0.571	10.3	0.586	11.2	0.602	11.9
	115	0.484	5.5	0.500	6.2	0.516	7.0	0.532	7.7	0.548	8.6	0.564	9.2	0.580	10.1	0.596	10.8	0.612	11.7	0.628	12.3
	125	0.507	5.9	0.523	6.6	0.539	7.5	0.556	8.1	0.572	9.0	0.588	9.7	0.604	10.6	0.621	11.2	0.637	12.1	0.653	12.8
	135	0.530	6.4	0.547	7.0	0.563	7.9	0.580	8.6	0.596	9.5	0.612	10.1	0.629	11.0	0.645	11.7	0.662	12.5	0.678	13.2
22	85	0.422	4.2	0.435	5.1	0.449	5.7	0.463	6.6	0.477	7.3	0.491	8.1	0.504	8.8	0.518	9.7	0.532	10.3	0.546	11.2
	95	0.442	4.6	0.457	5.5	0.471	6.2	0.486	7.0	0.501	7.7	0.515	8.6	0.530	9.2	0.544	10.1	0.559	10.8	0.573	11.7
	105	0.464	5.1	0.479	5.9	0.494	6.6	0.509	7.5	0.525	8.1	0.540	9.0	0.555	9.7	0.570	10.6	0.585	11.2	0.601	12.1
	115	0.486	5.5	0.502	6.4	0.517	7.0	0.533	7.9	0.549	8.6	0.564	9.5	0.580	10.1	0.596	11.0	0.611	11.7	0.627	12.5
	125	0.509	5.9	0.525	6.8	0.541	7.5	0.557	8.4	0.573	9.0	0.589	9.9	0.605	10.6	0.621	11.4	0.637	12.1	0.653	13.0
	135	0.534	6.4	0.550	7.3	0.566	7.9	0.582	8.8	0.598	9.5	0.614	10.3	0.630	11.0	0.646	11.9	0.662	12.5	0.678	13.4

1. Both face shell thickness: 1 in.

2. Mortar joint thickness: 3/8 in.

3. UngROUTED cells are filled with air.

4. Specific heat of concrete masonry unit: 0.22 Btu/lb·°F.

5. To calculate thermal resistance (*R*-value): $R = 1/U$ (h-ft²-°F/Btu).

6. To determine grout percentage, refer to Table R8.1.1a.

7. To determine normalized web area for typical concrete masonry unit, refer to Table R8.1.1b.

8. Linear interpolation can be done to calculate *U*-factor and heat capacity values for intermediate grout percentage.9. Mortar density: 125 lb/ft³.10. Grout density: 140 lb/ft³.

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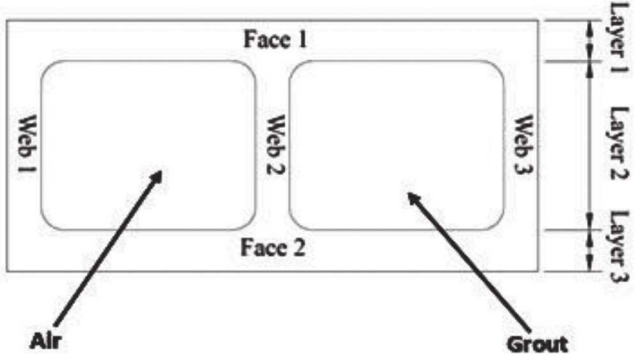
Table R8.1.1b—Normalized web area: Typical CMU

Unit configuration	Web area per unit, in. ²	Normalized web area, in. ² /ft ²
3 full-height webs: Fig. R8.1.1(1a)	17.16	19.3
3 reduced-height webs: Fig. R8.1.1(1b)	5.85	6.6
1 web double open-end, full-height web: Fig. R8.1.1(1c)	5.80	6.5
1 web double open-end, reduced-height web: Fig. R8.1.1(1d)	6.00	6.8
2 full-height webs: Fig. R8.1.1(1e)	11.44	12.9

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Table 8.1.1c—8 x 8 x 16 in. concrete masonry assembly without insulation *U*-factors (Btu/h-ft²-°F) and heat capacity values (Btu/ft²-°F)

																							
Normalized web area, in. ² /ft ²	Density CMU, lb/ft ³	Grout percentage																					
		0%		10%		20%		30%		40%		50%		60%		70%		80%		90%		100%	
		<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC	<i>U</i>	HC
6.5	85	0.399	4.4	0.408	5.5	0.417	6.6	0.426	7.7	0.435	8.8	0.444	9.9	0.453	11.0	0.462	12.1	0.471	13.2	0.480	14.3	0.489	15.4
	95	0.417	5.1	0.427	6.2	0.437	7.3	0.447	8.4	0.456	9.5	0.466	10.6	0.476	11.7	0.486	12.8	0.496	13.9	0.505	15.0	0.515	16.1
	105	0.435	5.5	0.445	6.6	0.456	7.7	0.467	8.8	0.477	9.9	0.488	11.0	0.498	12.1	0.509	13.2	0.519	14.3	0.530	15.4	0.540	16.5
	115	0.452	5.9	0.463	7.0	0.474	8.1	0.486	9.2	0.497	10.3	0.508	11.4	0.519	12.5	0.531	13.6	0.542	14.7	0.553	15.8	0.565	16.9
	125	0.468	6.4	0.480	7.5	0.492	8.6	0.504	9.7	0.516	10.8	0.528	11.9	0.540	13.0	0.552	14.1	0.564	15.2	0.575	16.3	0.587	17.4
	135	0.483	6.8	0.496	7.9	0.509	9.0	0.521	10.1	0.534	11.2	0.546	12.3	0.559	13.4	0.571	14.5	0.584	15.6	0.596	16.7	0.609	17.8
7.5	85	0.399	4.6	0.408	5.7	0.417	6.8	0.426	7.9	0.435	9.0	0.444	10.1	0.453	11.2	0.462	12.3	0.470	13.4	0.479	14.5	0.488	15.6
	95	0.417	5.1	0.427	6.2	0.437	7.3	0.446	8.4	0.456	9.5	0.466	10.6	0.476	11.7	0.485	12.8	0.495	13.9	0.505	15.0	0.514	16.1
	105	0.435	5.5	0.445	6.6	0.456	7.7	0.466	8.8	0.477	9.9	0.487	11.0	0.498	12.1	0.508	13.2	0.519	14.3	0.529	15.4	0.540	16.5
	115	0.452	5.9	0.463	7.0	0.474	8.1	0.486	9.2	0.497	10.3	0.508	11.4	0.519	12.5	0.530	13.6	0.542	14.7	0.553	15.8	0.564	16.9
	125	0.468	6.4	0.480	7.5	0.492	8.6	0.504	9.7	0.516	10.8	0.528	11.9	0.540	13.0	0.552	14.1	0.563	15.2	0.575	16.3	0.587	17.4
	135	0.484	6.8	0.497	7.9	0.509	9.0	0.522	10.1	0.534	11.2	0.547	12.3	0.559	13.4	0.571	14.5	0.584	15.6	0.596	16.7	0.609	17.8
8.5	85	0.399	4.6	0.407	5.7	0.416	6.8	0.425	7.9	0.434	9.0	0.443	10.1	0.452	11.2	0.461	12.3	0.470	13.4	0.479	14.5	0.488	15.6
	95	0.417	5.1	0.427	6.2	0.436	7.3	0.446	8.4	0.456	9.5	0.465	10.6	0.475	11.7	0.485	12.8	0.494	13.9	0.504	15.0	0.514	16.1
	105	0.435	5.5	0.445	6.6	0.456	7.7	0.466	8.8	0.477	9.9	0.487	11.0	0.497	12.1	0.508	13.2	0.518	14.3	0.529	15.4	0.539	16.5
	115	0.452	6.2	0.463	7.0	0.474	8.1	0.486	9.2	0.497	10.3	0.508	11.4	0.519	12.5	0.530	13.6	0.541	14.7	0.553	15.8	0.564	16.9
	125	0.469	6.6	0.481	7.7	0.493	8.8	0.504	9.9	0.516	11.0	0.528	12.1	0.540	13.2	0.551	14.3	0.563	15.4	0.575	16.5	0.587	17.6
	135	0.485	7.0	0.498	8.1	0.510	9.2	0.522	10.3	0.535	11.4	0.547	12.5	0.559	13.6	0.572	14.7	0.584	15.8	0.596	16.9	0.608	18.0

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Table 8.1.1c, cont.—8 x 8 x 16 in. concrete masonry assembly without insulation *U*-factors (Btu/h-ft²-°F) and heat capacity values (Btu/ft²-°F)

Normalized web area, in. ² /ft ²	Density CMU, lb/ft ²	Grout percentage																							
		0%		10%		20%		30%		40%		50%		60%		70%		80%		90%		100%			
		U	HC	U	HC	U	HC	U	HC	U	HC	U	HC	U	HC	U	HC	U	HC	U	HC	U	HC		
10	85	0.398	4.6	0.407	5.7	0.416	6.8	0.425	7.9	0.433	9.0	0.442	10.1	0.451	11.2	0.460	12.3	0.469	13.4	0.478	14.5	0.487	15.6		
	95	0.416	5.3	0.426	6.4	0.436	7.5	0.445	8.6	0.455	9.7	0.465	10.8	0.474	11.9	0.484	13.0	0.494	14.1	0.503	15.2	0.513	16.3		
	105	0.435	5.7	0.445	6.8	0.455	7.9	0.466	9.0	0.476	10.1	0.487	11.2	0.497	12.3	0.507	13.4	0.518	14.5	0.528	15.6	0.538	16.7		
	115	0.452	6.2	0.463	7.3	0.475	8.4	0.486	9.5	0.497	10.6	0.508	11.7	0.519	12.8	0.530	13.9	0.541	15.0	0.552	16.1	0.563	17.2		
	125	0.470	6.6	0.481	7.7	0.493	8.8	0.505	9.9	0.516	11.0	0.528	12.1	0.540	13.2	0.551	14.3	0.563	15.4	0.575	16.5	0.586	17.6		
	135	0.487	7.0	0.499	8.1	0.511	9.2	0.523	10.3	0.536	11.4	0.548	12.5	0.560	13.6	0.572	14.7	0.584	15.8	0.596	16.9	0.608	18.0		
12	85	0.397	4.8	0.406	5.9	0.415	7.0	0.424	8.1	0.432	9.2	0.441	10.3	0.450	11.4	0.459	12.5	0.468	13.6	0.477	14.7	0.486	15.8		
	95	0.416	5.3	0.425	6.4	0.435	7.5	0.445	8.6	0.454	9.7	0.464	10.8	0.473	11.9	0.483	13.0	0.493	14.1	0.502	15.2	0.512	16.3		
	105	0.434	5.7	0.445	6.8	0.455	7.9	0.465	9.0	0.476	10.1	0.486	11.2	0.496	12.3	0.506	13.4	0.517	14.5	0.527	15.6	0.537	16.7		
	115	0.453	6.4	0.464	7.5	0.475	8.6	0.486	9.7	0.496	10.8	0.507	11.9	0.518	13.0	0.529	14.1	0.540	15.2	0.551	16.3	0.562	17.4		
	125	0.471	6.8	0.482	7.9	0.494	9.0	0.505	10.1	0.517	11.2	0.528	12.3	0.540	13.4	0.551	14.5	0.563	15.6	0.574	16.7	0.586	17.8		
	135	0.489	7.3	0.501	8.4	0.513	9.5	0.525	10.6	0.537	11.7	0.548	12.8	0.560	13.9	0.572	15.0	0.584	16.1	0.596	17.2	0.608	18.3		
14	85	0.396	4.8	0.405	5.9	0.414	7.0	0.423	8.1	0.431	9.2	0.440	10.3	0.449	11.4	0.458	12.5	0.467	13.6	0.475	14.7	0.484	15.8		
	95	0.415	5.5	0.425	6.6	0.434	7.7	0.444	8.8	0.453	9.9	0.463	11.0	0.472	12.1	0.482	13.2	0.491	14.3	0.501	15.4	0.510	16.5		
	105	0.434	5.9	0.444	7.0	0.455	8.1	0.465	9.2	0.475	10.3	0.485	11.4	0.495	12.5	0.506	13.6	0.516	14.7	0.526	15.8	0.536	16.9		
	115	0.453	6.4	0.464	7.5	0.475	8.6	0.485	9.7	0.496	10.8	0.507	11.9	0.518	13.0	0.529	14.1	0.539	15.2	0.550	16.3	0.561	17.4		
	125	0.472	7.0	0.483	8.1	0.495	9.2	0.506	10.3	0.517	11.4	0.528	12.5	0.540	13.6	0.551	14.7	0.562	15.8	0.574	16.9	0.585	18.0		
	135	0.491	7.5	0.503	8.6	0.514	9.7	0.526	10.8	0.538	11.9	0.549	13.0	0.561	14.1	0.573	15.2	0.584	16.3	0.596	17.4	0.608	18.5		
16	85	0.395	5.1	0.404	6.2	0.413	7.3	0.422	8.4	0.430	9.5	0.439	10.6	0.448	11.7	0.457	12.8	0.465	13.9	0.474	15.0	0.483	16.1		
	95	0.415	5.5	0.424	6.6	0.434	7.7	0.443	8.8	0.452	9.9	0.462	11.0	0.471	12.1	0.481	13.2	0.490	14.3	0.500	15.4	0.509	16.5		
	105	0.434	6.2	0.444	7.3	0.454	8.4	0.464	9.5	0.474	10.6	0.485	11.7	0.495	12.8	0.505	13.9	0.515	15.0	0.525	16.1	0.535	17.2		
	115	0.453	6.6	0.464	7.7	0.475	8.8	0.485	9.9	0.496	11.0	0.507	12.1	0.517	13.2	0.528	14.3	0.539	15.4	0.549	16.5	0.560	17.6		
	125	0.473	7.0	0.484	8.1	0.495	9.2	0.506	10.3	0.518	11.4	0.529	12.5	0.540	13.6	0.551	14.7	0.562	15.8	0.573	16.9	0.584	18.0		
	135	0.493	7.7	0.504	8.8	0.516	9.9	0.527	11.0	0.539	12.1	0.550	13.2	0.562	14.3	0.573	15.4	0.584	16.5	0.596	17.6	0.607	18.7		
8	85	0.394	5.1	0.403	6.2	0.412	7.3	0.421	8.4	0.429	9.5	0.438	10.6	0.447	11.7	0.455	12.8	0.464	13.9	0.473	15.0	0.482	16.1		
	95	0.414	5.7	0.423	6.8	0.433	7.9	0.442	9.0	0.452	10.1	0.461	11.2	0.470	12.3	0.480	13.4	0.489	14.5	0.499	15.6	0.508	16.7		
	105	0.434	6.2	0.444	7.3	0.454	8.4	0.464	9.5	0.474	10.6	0.484	11.7	0.494	12.8	0.504	13.9	0.514	15.0	0.524	16.1	0.534	17.2		
	115	0.454	6.8	0.464	7.9	0.475	9.0	0.485	10.1	0.496	11.2	0.506	12.3	0.517	13.4	0.527	14.5	0.538	15.6	0.549	16.7	0.559	17.8		
	125	0.474	7.3	0.485	8.4	0.496	9.5	0.507	10.6	0.518	11.7	0.529	12.8	0.540	13.9	0.551	15.0	0.562	16.1	0.573	17.2	0.583	18.3		
	135	0.495	7.9	0.506	9.0	0.517	10.1	0.529	11.2	0.540	12.3	0.551	13.4	0.562	14.5	0.573	15.6	0.585	16.7	0.596	17.8	0.607	18.9		

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