

An ACI and TMS Standard

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

Reported by Joint ACI-TMS Committee 122



American Concrete Institute
Always advancing





This document is the intellectual property of ACI and the cosponsor, and both have copyright. All rights reserved. This material may not be reproduced or copied, in whole or in part, in any printed, mechanical, electronic, film, or other distribution and storage media, without written consent. ACI is the lead sponsor of this joint committee, and its operating procedures were followed. ACI's information is below; the cosponsor's information is on the inside back cover of this document.

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

Copyright by the American Concrete Institute, Farmington Hills, MI. All rights reserved. This material may not be reproduced or copied, in whole or part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of ACI.

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. Despite these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI via the errata website at <http://concrete.org/Publications/DocumentErrata.aspx>. Proper use of this document includes periodically checking for errata for the most up-to-date revisions.

ACI committee documents are intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided “as is” without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations regarding health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

ACI documents are written via a consensus-based process. The characteristics of ACI technical committee operations include:

- (a) Open committee membership
- (b) Balance/lack of dominance
- (c) Coordination and harmonization of information
- (d) Transparency of committee activities to public
- (e) Consideration of views and objections
- (f) Resolution through consensus process

The technical committee documents of the American Concrete Institute represent the consensus of the committee and ACI. Technical committee members are individuals who volunteer their services to ACI and specific technical committees.

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: +1.248.848.3700
Fax: +1.248.848.3701

www.concrete.org

AVA Documents
Document Sharing Hub

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

An ACI and TMS Standard

Reported by Joint ACI-TMS Committee 122

Kevin Cavanaugh, Chair

Rajiv Pathak, Secretary

Charles B. Clark Jr.
Darryl E. Dixon

Emily B. Lorenz
Hongyan Ma

William Mark McGinley
Martha G. VanGeem

Hongyu Zhou

Consulting Members

Maribeth S. Bradfield

John P. Ries

Phillip J. Samblanet

Christine A. Subasic

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 low-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 the International Energy Conservation Code (IECC).

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

CONTENTS

PREFACE, p. 2

CHAPTER 1—GENERAL, p. 3

- 1.1—Scope, p. 3
- 1.2—General, p. 3
- 1.3—Purpose, p. 3
- 1.4—Applicability, p. 3
- 1.5—Interpretation, p. 4

CHAPTER 2—NOTATION AND DEFINITIONS, p. 5

- 2.1—Code notation, p. 5
- 2.2—Code definitions, p. 5

CHAPTER 3—REFERENCED STANDARDS, p. 7

- 3.1—American Concrete Institute (ACI), p. 7
- 3.2—American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), p. 7
- 3.3—ASTM International, p. 7
- 3.4—International Code Council (ICC), p. 8

CHAPTER 4—GENERAL REQUIREMENTS, p. 9

- 4.1—Material requirements, p. 9
- 4.2—Climate zones, p. 9
- 4.3—Building envelope compliance, p. 9

CHAPTER 5—PRESCRIPTIVE METHOD, p. 10

- 5.1—Concrete and masonry, p. 10
- 5.2—Other assemblies, p. 12

CHAPTER 6—BUILDING ENVELOPE TRADE-OFF METHOD, p. 13

- 6.1—Building envelope trade-off method, p. 13

ACI-TMS CODE-122.2-24 was approved by the ACI Standards Board for publication January 2024, and published April 2024. Approved as a standard of the American Concrete Institute (January 2024) and The Masonry Society (January 2024) in accordance with each organization's standardization procedure.

Copyright © 2024, American Concrete Institute.

All rights reserved including rights of reproduction and use in any form or by any means, including the making of copies by any photo process, or by electronic or mechanical device, printed, written, or oral, or recording, for any purpose, reproduction or for use in any knowledge or retrieval system or device, unless permission in writing is obtained from the copyright proprietor.

CHAPTER 7—WHOLE BUILDING SIMULATION METHOD, p. 15

7.1—Whole building simulation method, p. 15

CHAPTER 8—THERMAL PROPERTIES FOR DETERMINING COMPLIANCE, p. 16

8.1—*U*-factors, *C*-factors, and *R*-values of assemblies, p. 16

8.2—Thermal conductivity, p. 95

8.3—Thermal inertia including heat capacity and specific heat, p. 96

8.4—Solar reflectance and solar reflectance index, p. 98

COMMENTARY REFERENCES, p. 99

Authored documents, p. 99

Software, p. 100

APPENDIX A—CLIMATE ZONE MAPS, p. 101**APPENDIX B—THERMAL CONDUCTIVITY, p. 102**

B.1—Thermal conductivity of concrete, concrete masonry, and clay masonry, p. 102

B.2—Influence of moisture, p. 103

B.3—Thermal conductivity of aggregates and cement paste, p. 103

B.4—Thermal conductivity of concrete used in CMU, p. 104

B.5—Practical thermal conductivity, p. 104

APPENDIX C—THERMAL INERTIA (THERMAL MASS), p. 106

C.1—Thermal mass in walls, p. 106

C.2—Thermal mass in buildings, p. 107

APPENDIX D—THERMAL PERFORMANCE OF WALLS WITH MASONRY VENEER, p. 108**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. This code was developed by a consensus process.



CODE

COMMENTARY

CHAPTER 1—GENERAL

R1—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 with building envelopes of concrete or masonry construction. This Code is only applicable to low-rise residential buildings. For commercial and mid- to high-rise residential construction, refer to **ACI/TMS CODE-122.3**, “Thermal Properties of Concrete and Masonry for Use in Determining Energy Code Compliance Except 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) Transient housing, such as hotels and motels
- (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.

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 applies to low-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 the **International Energy Conservation Code (IECC)**.

Criteria covered includes above-grade walls, below-grade walls (basement and crawl space walls), and floors above unconditioned space (unconditioned crawl spaces and unconditioned basements) 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), Btu/h·ft ² ·°F
F	= F -factor; the perimeter heat loss for slab-on-ground floors, Btu/h·ft·°F
R	= R -value (thermal resistance), h·ft ² ·°F/Btu
$R_1, R_2,$ $\dots R_n$	= R -value of each individual material layer, h·ft ² ·°F/Btu
R_i	= R -value of the indoor air film, h·ft ² ·°F/Btu
R_{min}	= minimum insulation R -value, h·ft ² ·°F/Btu
R_{np}	= thermal resistance of material heat flow path n in thermal layer p in the CMU, h·ft ² ·°F/Btu
R_o	= R -value of the exterior or outdoor air film, h·ft ² ·°F/Btu
R_T	= CMU thermal resistance, including surface air films, (h·ft ² ·°F)/Btu
R_{total}	= total R -value of the assembly, h·ft ² ·°F/Btu
U	= U -factor (thermal transmittance), Btu/h·ft ² ·°F
UA	= total building envelope area weighted thermal transmittance, Btu/h·°F
UA_{code}	= code-required total building envelope area weighted thermal transmittance, Btu/h·°F
UA_{des}	= provided design total building envelope area weighted thermal transmittance, Btu/h·°F
U_{max}	= maximum assembly U -factor, Btu/h·ft ² ·°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, Btu/h·ft ² ·°F
U_{wallX}	= U -factor of the portion of the wall assembly attributed to a_{wallX} , Btu/h·ft ² ·°F

2.2—Code definitions

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

assembly—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 composed of aggregate, cement, and water, with or without other materials.

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.

R2.2—Commentary definitions

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

CODE

COMMENTARY

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 $6 \text{ Btu}/\text{ft}^2\cdot^{\circ}\text{F}$ 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 $120 \text{ lb}/\text{ft}^3$.

integral insulation—Integral insulation includes insulated 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 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—Use of this document is intended for residential buildings three stories or less above grade that are not covered by the IECC commercial. In the ICC family of model building codes, low-rise residential includes Type *R-2*, *R-3*, and *R-4* buildings as well as detached one- and two-family dwellings and townhouses.

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). The IECC residential uses a heat capacity of $6 \text{ Btu}/\text{ft}^2\cdot^{\circ}\text{F}$ as the definition for a mass wall. 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 Concrete Construction

ACI/TMS CODE-122.3-24—Thermal Properties of Concrete and Masonry for use in Determining Energy Code Compliance Except for Low-Rise Residential Buildings—Code Requirements and Commentary

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

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 C90-23—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 C129-23—Standard Specification for Nonload-bearing Concrete Masonry Units

ASTM C177-19^{e1}—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

CODE

COMMENTARY

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

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 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 have been provided in Appendix A for convenience. The climate zones in the IECC 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 assembly listed in Table 5.1 shall comply with one of the following for the applicable climate zone:

- (a) R -values for both insulation in the framing cavities and continuous insulation shall be equal to or greater than the listed minimums.
- (b) U -factors or F -factors for the entire assembly shall be equal to or less than the listed maximum. Area-weighted averages of U -factors or F -factors are allowed for compliance for each type of assembly listed in Table 8.1a through 8.1e.

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 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.

The insulation requirements for floors above unconditioned spaces (basements and crawl spaces) in the IECC are for framed floors. Because concrete floors do not have metal or wood framing below them, values from ASHRAE 90.1 have been used for Climate Zones 3 through 8. These are conservative because the values in ASHRAE 90.1 are for floors over outdoor air; basement air temperatures seldom reach the extremes of outdoor air. Climate Zones 0 through 2 are mild climates and do not require insulation for floors over unconditioned basements due to the tempering effect of the air in basements. The U -factors for wall insulation below grade have been modified from the IECC to be equivalent to the R -value requirements.

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.

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, and 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 and F -factors are also steady-state properties.

Requirements for mass walls differ when insulation is on the outdoor side of the mass layer in the wall or when the insulation is on the inside of the mass wall. Specifically, more insulation is required when more than half of the insulation is on the interior side of the mass.

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

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																		
50% or less of the insulation on the interior of the wall mass	$U-0.197$	$R-3$	$U-0.197$	$R-3$	$U-0.165$	$R-4$	$U-0.098$	$R-8$	$U-0.098$	$R-8$	$U-0.082$	$R-13$	$U-0.060$	$R-15$	$U-0.057$	$R-19$	$U-0.057$	$R-19$
More than 50% of the insulation on the interior of the wall mass	$U-0.170$	$R-4$	$U-0.170$	$R-4$	$U-0.140$	$R-6$	$U-0.087$	$R-13$	$U-0.087$	$R-13$	$U-0.065$	$R-17$	$U-0.057$	$R-20$	$U-0.057$	$R-21$	$U-0.057$	$R-21$
Masonry veneer, above-grade, minimum specified thickness of 2-5/8 in.																		
Metal-framed walls																		
Surface emissivity equals 0.05 or less*	$U-0.095$	$R-13 + R-1.1$ CI	$U-0.095$	$R-13 + R-1.1$ CI	$U-0.089$	$R-13 + R-1.7$ CI	$U-0.076$	$R-13 + R-3.4$ CI	$U-0.064$	$R-13 + R-5.7$ CI	$U-0.062$	$R-13 + R-6.2$ CI	$U-0.046$	$R-13 + R-11.9$ CI	$U-0.046$	$R-13 + R-11.9$ CI	$U-0.038$	$R-13 + R-16.5$ CI
Surface emissivity greater than 0.05*	$U-0.095$	$R-13$	$U-0.095$	$R-13$	$U-0.089$	$R-13 + R-0.1$ CI	$U-0.076$	$R-13 + R-1.8$ CI	$U-0.064$	$R-13 + R-4.1$ CI	$U-0.062$	$R-13 + R-4.6$ CI	$U-0.076$	$R-13 + R-10.3$ CI	$U-0.064$	$R-13 + R-10.3$ CI	$U-0.062$	$R-13 + R-14.9$ CI
Wood-framed walls																		
Surface emissivity equals 0.05 or less*	$U-0.101$	$R-7.8$	$U-0.101$	$R-7.8$	$U-0.103$	$R-7.6$	$U-0.068$	$R-13 + R-0.7$ CI	$U-0.062$	$R-13 + R-2.1$ CI	$U-0.062$	$R-13 + R-2.1$ CI	$U-0.047$	$R-13 + R-7.3$ CI	$U-0.047$	$R-13 + R-7.3$ CI	$U-0.033$	$R-13 + R-16.6$ CI
Surface emissivity greater than 0.05*	$U-0.101$	$R-7.8$	$U-0.101$	$R-7.8$	$U-0.103$	$R-7.6$	$U-0.068$	$R-13 + R-0.7$ CI	$U-0.062$	$R-13 + R-2.1$ CI	$U-0.062$	$R-13 + R-2.1$ CI	$U-0.068$	$R-13 + R-5.7$ CI	$U-0.062$	$R-13 + R-5.7$ CI	$U-0.062$	$R-13 + R-15$ CI
Mass floors above unconditioned space	NR or $U-0.322$	NR	NR or $U-0.322$	NR	NR or $U-0.322$	NR	$U-0.074$	$R-10$ 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 slabs																		
Perimeter insulation	NR or $F-0.73^{\dagger}$	$NR^{\dagger}$	NR or $F-0.73^{\dagger}$	$NR^{\dagger}$	NR or $F-0.73^{\dagger}$	$NR^{\dagger}$	NR or $F-0.73^{\dagger}$	$NR^{\dagger}$	$F-0.54^{\dagger}$	$R-10$ for 2 ft ²	$F-0.54^{\dagger}$	$R-10$ for 2 ft ²	$F-0.48$	$R-10$ for 4 ft ²	$F-0.48$	$R-10$ for 4 ft ²	$F-0.48$	$R-10$ for 4 ft ²
Perimeter insulation	NR or $F-0.73^{\dagger}$	$NR^{\dagger}$	NR or $F-0.73^{\dagger}$	$NR^{\dagger}$	NR or $F-0.73^{\dagger}$	$NR^{\dagger}$	NR or $F-0.73^{\dagger}$	$NR^{\dagger}$	$F-0.54^{\dagger}$	$R-10$ for 2 ft ²	$F-0.54^{\dagger}$	$R-10$ for 2 ft ²	$F-0.48$	$R-10$ for 4 ft ²	$F-0.48$	$R-10$ for 4 ft ²	$F-0.48$	$R-10$ for 4 ft ²
Under slab insulation	NA	$R-5$	NA	$R-5$	NA	$R-5$	NA	$R-5$	NA	$R-5$	NA	$R-5$	NA	$R-5$	NA	$R-5$	NA	$R-5$
Below-grade walls																		
50% or less of the insulation on the interior of the wall mass	NR or $U-0.580$	NR	NR or $U-0.580$	NR	NR or $U-0.580$	NR	NR or $U-0.580$	NR	$U-0.088$	$R-10$	$U-0.061$	$R-15$	$U-0.061$	$R-15$	$U-0.061$	$R-15$	$U-0.061$	$R-15$
More than 50% of the insulation on the interior of the wall mass	NR or $U-0.580$	NR	NR or $U-0.580$	NR	NR or $U-0.580$	NR	NR or $U-0.580$	NR	$U-0.088$	$R-13$	$U-0.061$	$R-19$	$U-0.061$	$R-19$	$U-0.061$	$R-19$	$U-0.061$	$R-19$

* Emissivity of the surface adjacent to the airspace and opposite the veneer shall be measured in accordance with ASTM C1371.

[†] The edge insulation for heated slabs shall not be required to extend below the slab.

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 are Btu/h·ft²·°F. Units for R -values are h·ft²·°F/Btu. Units for F -factors are Btu/h·ft·°F.

CODE

COMMENTARY

placement should be balanced against the need for a durable outdoor surface as well as other design considerations such as fire resistance. The categories for insulation requirements in this code mirror those of the IECC for both continuous insulation and insulation between framing.

(b) *Maximum U-factor or F-factor requirements*—When using the maximum *U*-factor method for compliance, these factors include all 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. *F*-factors for slab-on-ground floors are based on *R*-value of insulation and depth of insulation, and are provided in **ASHRAE 90.1-2019** Appendix A. While the requirements of ASHRAE 90.1 apply to commercial, not residential, buildings, the thermal properties of materials and systems are generally applicable to both applications.

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, *C*-factors, and *U*-factors for concrete and masonry systems as well as acceptable test methods and calculation methods.

(c) *Sunrooms*—The IECC has separate requirements for sunrooms that are thermally isolated from the rest of the residence.

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.

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 and masonry walls that do not meet the requirements for a mass wall should meet the other wall requirements of the IECC or other energy code adopted by the authority having jurisdiction. Concrete floors above unconditioned space that do not meet the requirements for a mass floor should meet the other floor requirements of the IECC or other applicable code.

CODE

CHAPTER 6—BUILDING ENVELOPE TRADE-OFF METHOD

6.1—Building envelope trade-off method

The building envelope performance shall be determined using one of the following methods:

6.1.1 Total UA — UA_{code} shall be less than UA_{des} , where UA is total building thermal envelope UA .

For assemblies not described in Tables 8.1a through 8.1e, the required U -factor from the applicable energy efficiency code or standard shall be used.

COMMENTARY

R6—BUILDING ENVELOPE TRADE-OFF METHOD

6.1—Building envelope trade-off method

R6.1.1 Total UA —The UA tradeoff methodology requires the calculation of the UA for the code or standard requirements as well as the calculation of the UA for the proposed building as designed. For assemblies where the requirements are not provided in this Code, such as fenestration and ceiling insulation, the applicable energy efficiency code or standard needs to be used to determine the required U -factor.

F -factors and the solar heat gain coefficient (SHGC) are not expressed as a U -factor and are not included in the equation. Therefore, floor slab insulation and SHGC of windows cannot be traded. The requirements for floor slab insulation in Tables 8.1a through 8.1e should be used. The requirements for the SHGC of fenestration in the applicable energy efficiency code or standard should be used. Doors can be ignored.

Example: Determine the maximum required U -factor for the mass walls ($UA_{MassWallReq}$) of a single-family house located in Climate Zone 3. The house has a footprint of 1600 ft², a perimeter length of 160 ft, 8 ft tall walls, and does not have a basement. Assume a 20% window-to-wall ratio and that the wall insulation is located on the exterior side of the mass.

Assembly	Code-required maximum U -factor	Provided maximum U -factor
Ceiling	0.026	0.026
Fenestration	0.300	0.250
Mass walls	0.098	$UA_{MassWallReq}$

$$\text{Total wall area } a_{WallTot} = (160 \text{ ft})(8 \text{ ft}) = 1280 \text{ ft}^2$$

$$\text{Mass wall area } a_{WallMass} = (1280 \text{ ft}^2)(0.8) = 1024 \text{ ft}^2$$

$$\text{Fenestration area } a_{WallFen} = (1280 \text{ ft}^2)(0.2) = 256 \text{ ft}^2$$

The maximum code-required baseline U -factor for the envelope, $UA_{CodeEnv}$, is determined as follows

$$UA_{CodeEnv} = \frac{(1600 \text{ ft}^2)(0.026) + (1024 \text{ ft}^2)(0.098) + (256 \text{ ft}^2)(0.300)}{1600 \text{ ft}^2 + 1280 \text{ ft}^2} = 0.076$$

Rearranging the aforementioned expression and solving for the maximum required U -factor for the mass wall assembly, $UA_{MassWallReq}$, using the provided assembly U -factors listed previously

$$UA_{MassWallReq} = \frac{(2880 \text{ ft}^2)(0.076) - (1600 \text{ ft}^2)(0.026) - (256 \text{ ft}^2)(0.250)}{1024 \text{ ft}^2} = 0.111$$

Therefore, mass walls providing a maximum U -factor of 0.111 (minimum R -value of 9.0) would meet these code requirements for energy efficiency.

CODE

6.1.2 Building envelope trade-off method—The building envelope trade-off 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 available in the building envelope trade-off method computer software or those determined using Section 8.1 of this Code shall be used for the proposed building. The building complies with this standard when the building envelope trade-off method computer software energy savings for the proposed building is better than the energy savings for the baseline building described in this section.

COMMENTARY

R6.1.2 Building envelope trade-off method—A building envelope performance method 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.

REScheck is a commonly used program used to meet the building envelope requirements of the IECC, even though it is not mentioned in the IECC.

REScheck allows the selection of the applicable edition of the IECC and other energy codes for many local jurisdictions. REScheck 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 REScheck for this standard. The baseline energy use for the building envelope for this standard 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 REScheck. 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 REScheck building envelope results. If the building envelope passes, then REScheck 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 standard. For example, if the REScheck 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 REScheck or should fail by not more than 10%.

Refer to 8.1 for *R*-values, *C*-factors, and *U*-factors for concrete and masonry systems as well as acceptable test methods and calculation methods. REScheck also has pull down menus that provide *U*-factors, *C*-factors, and *F*-factors for many concrete and masonry systems. While either the values in 8.1 or those in REScheck may be used for compliance, users are encouraged to determine thermal properties in accordance with this code and input those into REScheck, rather than using the pull-down menu values. More accurate thermal properties for specific assemblies can be determined using this Code.

CODE

CHAPTER 7—WHOLE BUILDING SIMULATION
METHOD

7.1—Whole building simulation method

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 and HVAC systems. Specific rules should be followed. Whole building simulation methods 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 described, for example, in Section 405 in the 2021 IECC. However, Section 405 of the 2021 IECC does not allow trading off insulation for a more efficient mechanical system, so using Section 405 does not provide much utility beyond the building envelope performance methods described in Section 6.1 of this Code.

This Code does not provide limits on the amount of energy loss allocated to the building envelope in whole building simulation methods, such as minimum insulation requirements in the IECC. The language herein 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 standard and the base energy code. 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:

- (a) The applicable values listed in Tables 8.1a through 8.1e or Tables 8.1.1a through 8.1.1v
- (b) **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
- (c) A published value from a guide, standard, handbook, specification, government publication, or peer-reviewed publication
- (d) 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 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.

CODE

COMMENTARY

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	U -factor	0.22	0.17	0.14	0.12	0.10	0.09	0.08	0.07	0.07	0.06
	C -factor	0.27	0.20	0.16	0.13	0.11	0.10	0.09	0.08	0.07	0.07
	R_u	4.60	5.85	7.10	8.35	9.60	10.85	12.10	13.35	14.60	15.85
	R_c	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	U -factor	0.28	0.22	0.19	0.16	0.14	0.12	0.11	0.10	0.09	0.09
	C -factor	0.37	0.28	0.22	0.18	0.16	0.14	0.12	0.11	0.10	0.09
	R_u	3.58	4.49	5.40	6.30	7.21	8.12	9.03	9.94	10.85	11.76
	R_c	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	U -factor	0.33	0.27	0.23	0.19	0.17	0.15	0.14	0.13	0.11	0.11
	C -factor	0.47	0.35	0.28	0.23	0.20	0.18	0.16	0.14	0.13	0.12
	R_u	2.99	3.71	4.42	5.14	5.85	6.56	7.28	7.99	8.71	9.42
	R_c	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
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

CODE

COMMENTARY

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
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.

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

Framing type and depth	Rated R -value of insulation alone	Assembly U -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.	R -0	U -0.414
	R -3.8	U -0.325
	R -5	U -0.314
	R -6.5	U -0.305
1.5 in.	R -11	U -0.267
2.0 in.	R -7.6	U -0.230
	R -10	U -0.219
	R -13	U -0.210
3.0 in.	R -11.4	U -0.178
	R -15	U -0.168
	R -19.0	U -0.161
3.5 in.	R -11.0	U -0.168
	R -13.0	U -0.161
	R -15.0	U -0.155
4.5 in.	R -17.1	U -0.133
	R -22.5	U -0.124
	R -25.2	U -0.122
5.0 in.	R -19.0	U -0.122
	R -25.0	U -0.115
	R -28.0	U -0.112
	R -32.0	U -0.109

CODE

COMMENTARY

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
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
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

CODE

COMMENTARY

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
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
<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

CODE

COMMENTARY

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
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

*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.

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

CODE

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.

COMMENTARY

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 interior insulation and no finishes. The walls in Tables 8.1.1o through 8.1.1v are single wythe walls with interior 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 interior 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 masonry unit are largely governed by the density of the material, and in the case of hollow masonry units, the total area and length of 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 Fig. 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.

CODE

COMMENTARY

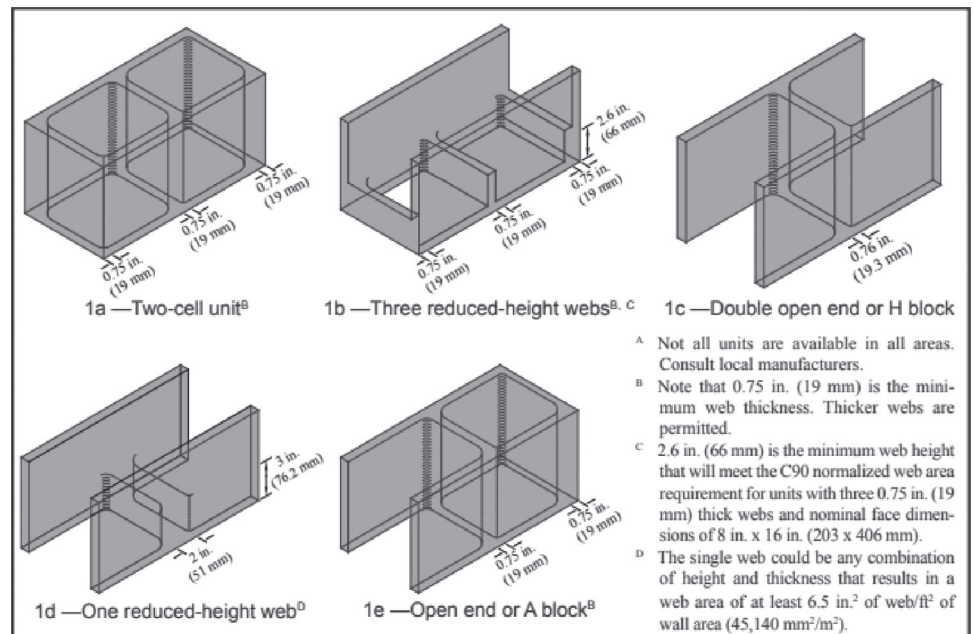


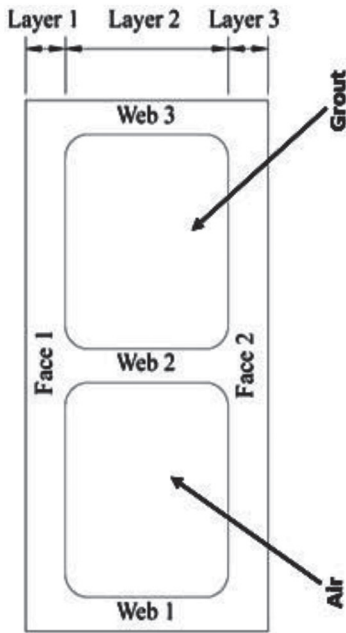
Fig R8.1.1—Examples of CMU web configurations permitted under ASTM C90.

CODE

COMMENTARY

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 ³	Grout percentage																	
		0%		10%		20%		30%		40%		50%		60%		70%		80%	
		<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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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



CODE

COMMENTARY

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%	
		<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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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

CODE

COMMENTARY

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 ²	Grout percentage																	
		0%		10%		20%		30%		40%		50%		60%		70%		80%	
		<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
	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
	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
20	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
	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
	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
22	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
	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
	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
24	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
	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
	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
26	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
	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
	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
28	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
	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
	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

1. Both face shell thickness: 3/4 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.



CODE

COMMENTARY

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

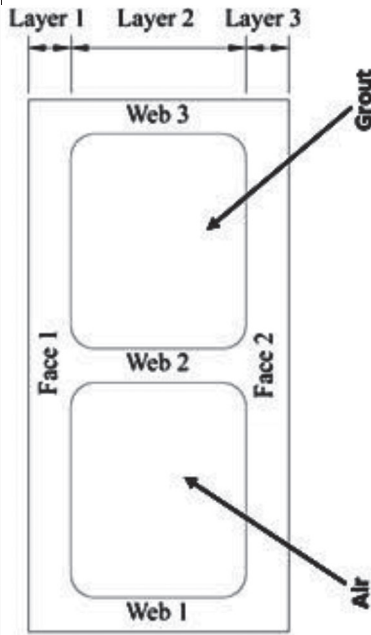
*Percentage of grout values are based on a unit configuration consisting of two cells and three full-height webs. Similar values can be calculated for other unit configurations.

CODE

COMMENTARY

Table 8.1.1b—6 x 8 x 16 in. concrete masonry assembly without insulation U -factors ($\text{Btu}/\text{h}\cdot\text{ft}^2\cdot^\circ\text{F}$) and heat capacity values ($\text{Btu}/\text{ft}^2\cdot^\circ\text{F}$)

Normalized web area, $\text{in.}^2/\text{ft}^2$	Density CMU, lb/ft^3	Grout percentage																	
		0%		10%		20%		30%		40%		50%		60%		70%		80%	
		U	HC	U	HC	U	HC	U	HC	U	HC	U	HC	U	HC	U	HC	U	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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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



CODE

COMMENTARY

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%	
		<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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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



CODE

COMMENTARY

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%	
		<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
	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
	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
	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
	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
20	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
	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
	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
	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
	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
22	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
	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
	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
	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
	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
	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
	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
	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

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.

CODE

COMMENTARY

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



CODE

COMMENTARY

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%	
		<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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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
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
	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
	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
	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
	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
	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

