IECC®

2015 CODE AND COMMENTARY

The complete IECC with commentary after each section

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2015 International Energy Conservation Code® and Commentary

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With the cooperation of:
Jack Bailey
Jim Edelson
Steve Ferguson
Mark Heizer
Amanda Hickman
Duane Jonlin
Eric Makala

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PREFACE

The principal purpose of the Commentary is to provide a basic volume of knowledge and facts relating to building construction as it pertains to the regulations set forth in the 2015 *International Energy Conservation Code®*. The person who is serious about effectively designing, constructing and regulating buildings and structures will find the Commentary to be a reliable data source and reference to almost all components of the built environment.

As a follow-up to the *International Energy Conservation Code*, we offer a companion document, the *International Energy Conservation Code Commentary*. The basic appeal of the Commentary is thus: it provides in a small package and at reasonable cost thorough coverage of many issues likely to be dealt with when using the *International Energy Conservation Code*—and then supplements that coverage with historical and technical background. Reference lists, information sources and bibliographies are also included.

Throughout all of this, strenuous effort has been made to keep the vast quantity of material accessible and its method of presentation useful. With a comprehensive yet concise summary of each section, the Commentary provides a convenient reference for regulations applicable to the construction of buildings and structures. In the chapters that follow, discussions focus on the full meaning and implications of the code text. Guidelines suggest the most effective method of application and the consequences of not adhering to the code text. Illustrations are provided to aid understanding; they do not necessarily illustrate the only methods of achieving code compliance.

The format of the Commentary includes the full text of each section, table and figure in the code, followed immediately by the commentary applicable to that text. At the time of printing, the Commentary reflects the most up-to-date text of the 2015 *International Energy Conservation Code*. Each section's narrative includes a statement of its objective and intent and usually includes a discussion about why the requirement commands the conditions set forth. Code text and commentary text are easily distinguished from each other. All code text is shown as it appears in the *International Energy Conservation Code*, and all commentary is indented below the code text and begins with the symbol ❖.

Readers should note that the Commentary is to be used in conjunction with the *International Energy Conservation Code* and not as a substitute for the code. **The Commentary is advisory only;** the code official alone possesses the authority and responsibility for interpreting the code.

Comments and recommendations are encouraged, for through your input, we can improve future editions. Please direct your comments to the Codes and Standards Development Department at the Central Regional Office.

IECC—RESIDENTIAL PROVISIONS

TABLE OF CONTENTS

Chapter 1 [RE]: Scope and Administration

General Comments

The 2015 edition of the *International Energy Conservation Code*®—Residential Provisions will regulate the design and construction of low-rise residential buildings for efficient energy consumption over their useful life. It includes measures for the thermal envelope, heating, ventilating and air-conditioning (HVAC) systems, and electrical systems of residential buildings up to three stories in height.

Purpose

Though not stated specifically, the code is applicable to all buildings and structures and their components and systems that use energy primarily for human comfort and needs. The code does not regulate the energy for items such as computers or coffee pots. This portion of the code addresses the design of energy-efficient building envelopes and the selection and installation of energy-efficient mechanical, service water heating, electrical distribution and illumination systems and equipment in residential buildings.

PART 1—SCOPE AND APPLICATION

SECTION R101 SCOPE AND GENERAL REQUIREMENTS

R101.1 Title. This code shall be known as the *International Energy Conservation Code* of **[NAME OF JURISDICTION]**, and shall be cited as such. It is referred to herein as "this code."

❖ This section directs the adopting jurisdiction to insert the name of the jurisdiction into the code. Because the IECC is a "model" code, it is not an enforceable document until it is adopted by a jurisdiction or agency that has enforcement powers.

R101.2 Scope. This code applies to *residential buildings* and the building sites and associated systems and equipment.

❖ The code applies to portions of the building thermal envelope that enclose conditioned space, as shown in Commentary Figure R101.2(1). Conditioned space is the area provided with heating or cooling either directly, through a positive heating/cooling supply system (such as registers located in the space), or indirectly through an opening that allows heated or cooled air to communicate directly with the space. For example, a walk-in closet connected to a master bedroom suite may not contain a positive heating supply through a register, but it would be conditioned indirectly by the free passage of heated or cooled air into the space from the bedroom.

A good example of the exception would be an unconditioned garage or attic space. In the case of a garage, if the unconditioned garage area is separated from the conditioned portions of the residence by an assembly that meets the "building envelope" criteria (meaning that the wall between them is insulated), the exterior walls of the garage would not need to be insulated to separate the garage from the exterior climate.

The building thermal envelope consists of the wall, roof/ceiling and floor assemblies that surround the conditioned space. Raised floors over a crawl space or garage, or directly exposed to the outside air are considered to be part of the floor assembly. Walls surrounding a conditioned basement (in addition to surrounding conditioned spaces above grade) are part of the building envelope. The code defines above-grade walls surrounding conditioned spaces as exterior walls. This definition includes walls between the conditioned space and unconditioned garage; roof and basement knee, dormer and gable-end walls; walls enclosing a mansard roof; and basement walls with an average below-grade area that is less than 50 percent of the total basement gross wall area. This definition would not include walls separating an unconditioned garage from the outdoors. The roof/ceiling assembly is the surface where insulation will be installed, typically on top of the gypsum board [see Commentary Figure R101.2(2)].

R101.3 Intent. This code shall regulate the design and construction of buildings for the effective use and conservation of energy over the useful life of each building. This code is intended to provide flexibility to permit the use of innovative approaches and techniques to achieve this objective. This code is not intended to abridge safety, health or environmental requirements contained in other applicable codes or ordinances.

❖ This chapter is broad in its application, yet specific to regulating the use of energy in buildings where that energy is used primarily for human comfort or heating and cooling to protect the contents. In general, the requirements of the code address the design of all building systems that affect the visual and thermal comfort of the occupants, including:

- Lighting systems and controls.
- Wall, roof and floor insulation.
- Windows and skylights.
- Cooling equipment (air conditioners, chillers and cooling towers).
- Heating equipment (boilers, furnaces and heat pumps).
- Pumps, piping and liquid circulation systems.
- Supply and return fans.
- Service hot water systems (kitchens and lavatories).

The chapter is intended to define requirements for the portions of a building and building systems that affect energy use in new construction and to promote the effective use of energy. Where a code application for a specific situation is in question, the authority having jurisdiction for the building should favor the action that will promote the effective use of energy. The code official may also consider the cost of the required action compared to the energy that will be saved over the life of that action.

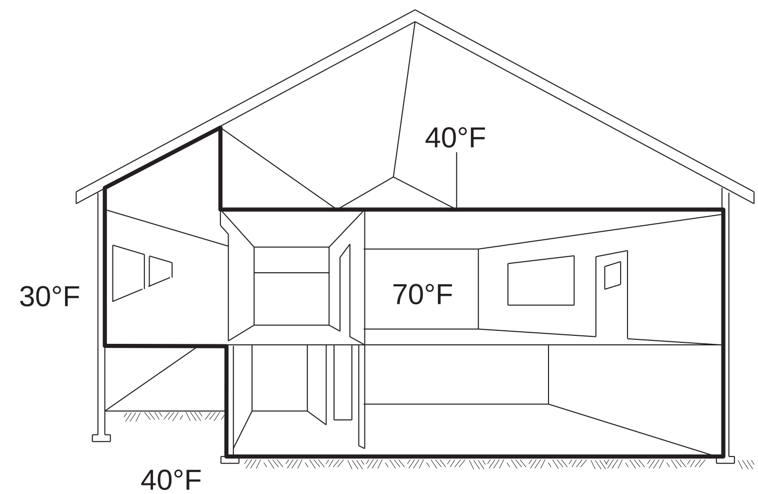

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Figure R101.2(1)
CONDITIONED ENVELOPE

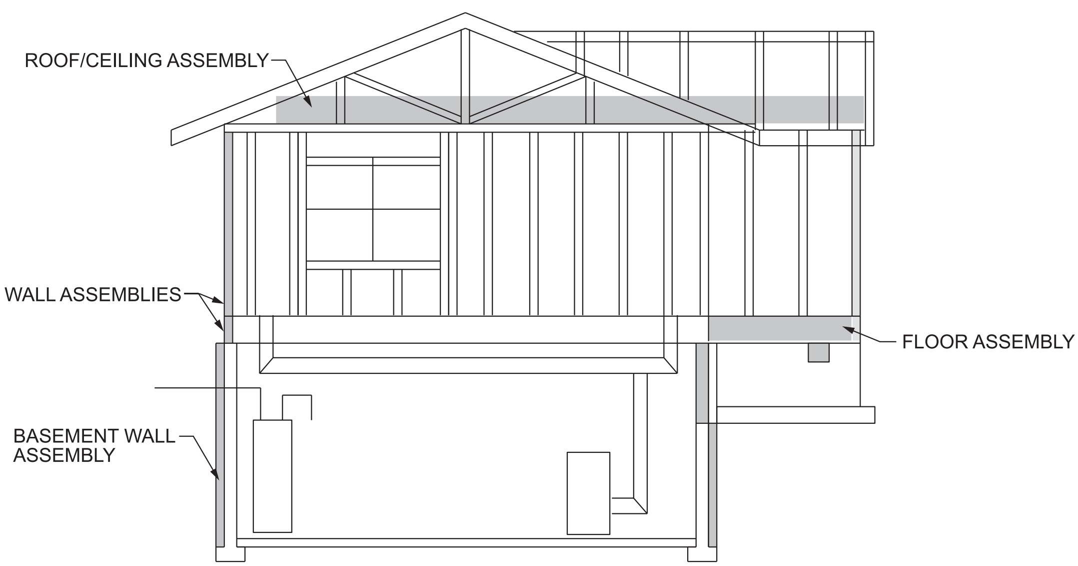

Figure R101.2(2)
BUILDING ENVELOPE

This section of the code supports flexibility in application of the code requirements. Although many of the requirements are given in a prescriptive format for ease of use, the code is not intended to stifle innovation—especially innovative techniques that conserve energy. Innovative approaches that lead to energy efficiency should be encouraged, even if the approach is not specifically listed in the code or does not meet the strict letter of the code. This principle should be applied to methods for determining compliance with the code and the building construction techniques used to meet the code.

Any design should first be evaluated to see whether it meets the code requirements directly. If an innovative approach is preferred, the applicant is responsible for demonstrating that the innovative concept promotes energy efficiency. Where the literal code requirements have not been satisfied but the applicant claims to meet the intent, the code official will likely have to exercise professional judgment to determine whether the proposed design meets the intent of the code in the interest of energy efficiency (see commentary, Section R103).

R101.4 Applicability. Where, in any specific case, different sections of this code specify different materials, methods of construction or other requirements, the most restrictive shall govern. Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall govern.

❖ In general, the most restrictive requirement is to apply where there may be different requirements in the code for a specific issue. However, in cases where the code establishes a specific requirement for a certain condition, that requirement is applicable even if it is less restrictive than a general requirement elsewhere in the code.

R101.4.1 Mixed occupancy. Where a building includes both *residential* and *commercial* occupancies, each occupancy shall be separately considered and meet the applicable provisions of the IECC—Commercial Provisions or IECC—Residential Provisions.

❖ A mixed-occupancy building is one that contains both residential and commercial uses (see definitions in Chapter 2 [RE]). Where residential and commercial uses coexist in a building, each occupancy must be evaluated separately. In situations where the majority of the space is one occupancy and only a small portion of the floor is different, such evaluation is sometimes aided by the accessory area requirements found in the IBC. For example, the residential portions of that story must meet the residential requirements of the code unless 90 percent or more of the floor level is commercial, in which case the story in question (inclusive of the 10-percent residential) may, with the code official's approval, be considered commercial.

For example, consider the three-story apartment building in Commentary Figure R101.4.1, with a portion of the first story leased out to a convenience store (a commercial use). The top two stories are clearly residential because they are devoted solely to residential use and the building is not over three stories high. Though not found in the code, the first story could generally be considered all residential if 10 percent or less of the total floor area is occupied by the store. In this case, the entire first floor is subject to the residential portions of the code. When more than 10 percent of the first story is occupied by the store, the first story is considered a mixed occupancy; the portion of the first story occupied by the store is considered commercial and is subject to the applicable commercial requirements in Chapter 4[CE]. The remainder of the first story is considered residential and must meet the residential requirements found in Chapter 4 [RE].

Consider another conceivable situation in which the first story of a four-story building may be one or more retail establishments (or other commercial use). Consider that the remaining stories of this four-story building consist entirely of dwelling units and are classified as residential. This and similar situations can cause confusion over how to apply the code. Is this a commercial building because it is over three stories high, or is it a residential building because it has three stories of dwelling units?

For our current example, the definition of "Residential" makes it clear that the entire building would be considered commercial and be subject to the requirements of Chapter 4[CE]. The approach is based on the fact that the patterns of energy use generally change in buildings four stories or greater in height, and that the code, as well as its predecessor MEC versions, limit residential buildings to a maximum height of three stories above grade. Any structure over three stories is considered a commercial building for purposes of applying the code, regardless of the occupancy classification of the structure. The only exception to this distinction would be single-family or duplex detached residences four stories or greater in height, which is considered rare. See also the definitions and commentary for "Commercial building" and "Residential building" to help clarify the application of the code to mixed-occupancy buildings.

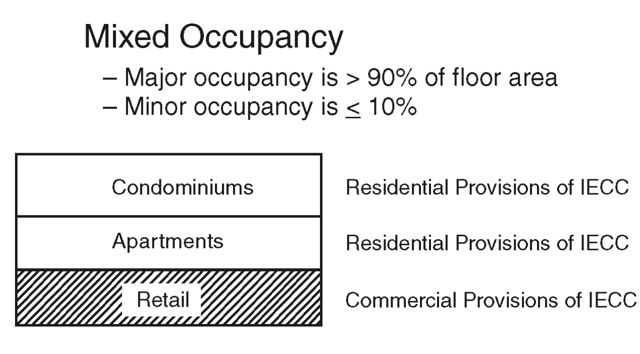

Figure R101.4.1
MIXED OCCUPANCY

R101.5 Compliance. *Residential buildings* shall meet the provisions of IECC—Residential Provisions. *Commercial buildings* shall meet the provisions of IECC—Commercial Provisions.

❖ The code contains three alternative design procedures for detached one- and two-family dwellings and residential buildings three stories or less in height. This section provides the scoping to the various sections and methods of compliance in the code.

R101.5.1 Compliance materials. The *code official* shall be permitted to approve specific computer software, worksheets, compliance manuals and other similar materials that meet the intent of this code.

❖ The code is intended to permit the use of innovative approaches and techniques, provided that they result in the effective use of energy. This section simply recognizes that there are many federal, state and local programs as well as computer software that deal with energy efficiency. Therefore, the code simply states that the code official has the authority to accept those methods of compliance, provided that they meet the intent of the code. Some of the easiest examples to illustrate this provision are the REScheck™ and COMcheck™ software put out by the U.S. Department of Energy (DOE). Another example is the ENERGY STAR program.

SECTION R102 ALTERNATIVE MATERIALS, DESIGN AND METHODS OF CONSTRUCTION AND EQUIPMENT

R102.1 General. The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. The code official shall be permitted to approve an alternative material, design or method of construction where the *code official* finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code.

❖ This section reinforces Section R101.3, which states that the code is meant to be flexible, as long as the intent of the proposed alternative is to promote the effective use of energy. The code is not intended to inhibit innovative ideas or technological advances. A comprehensive regulatory document such as an energy code cannot envision and then address all future innovations in the industry. As a result, a performance code must be applicable to and provide a basis for the approval of an increasing number of newly developed, innovative materials, systems and methods for which no code text or referenced standards yet exist. The fact that a material, product or method of construction is not addressed in the code is not an indication that the material, product or method is prohibited.

The code official is expected to apply sound technical judgment in accepting materials, systems or methods that, while not anticipated by the drafters of the current code text, can be demonstrated to offer equivalent or better performance. The code regulates new and innovative construction practices while addressing the relative safety of building occupants. The code official is responsible for determining whether a requested alternative provides a level of protection of the public health, safety and welfare equal to that required by the code.

R102.1.1 Above code programs. The *code official* or other authority having jurisdiction shall be permitted to deem a national, state or local energy-efficiency program to exceed the energy efficiency required by this code. Buildings *approved* in writing by such an energy-efficiency program shall be considered in compliance with this code. The requirements identified as "mandatory" in Chapter 4 shall be met.

❖ The purpose of this section is to specifically state that the code official has the authority to review and accept compliance with another energy program that may exceed that required by the code, as long as the minimum "mandatory" requirements of the code are met. This provision is really a continuation of the provision stated in Section R101.2 and the fact that the code is intended to accept alternatives as long as the end result is an energy-efficient building that is comparable to or better than that required by the code.

This is also a good section to help reinforce the fact that the code, as a model code, is a "minimum" code. Therefore, it establishes the minimum requirement that must be met and that anything exceeding the level is permitted.

While "above code programs" are acceptable because they do exceed the "minimum" requirements of the code, it would not be proper to require compliance with such "above code programs." Besides the code being the minimum level of acceptable energy efficiency, it is also the maximum efficiency that the code official can require. A building built to the absolute minimum requirement is also the maximum that the code official can demand. It is perfectly acceptable for a designer or builder to exceed the code requirements, but it is not proper for the code official to demand such higher performance.

This section also contains language to ensure that the "mandatory" requirements of the code, such as sealing the building envelope (Section R402.4) and sealing ducts (Section R403.3.2), are complied with for all buildings. Since the code has deemed that the mandatory requirements should apply to all buildings, it is reasonable that "above code programs" not be allowed to bypass these requirements.

PART 2—ADMINISTRATION AND ENFORCEMENT

SECTION R103
CONSTRUCTION DOCUMENTS

R103.1 General. Construction documents, technical reports and other supporting data shall be submitted in one or more sets with each application for a permit. The construction documents and technical reports shall be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed. Where special conditions exist, the *code official* is authorized to require necessary construction documents to be prepared by a registered design professional.

Exception: The *code official* is authorized to waive the requirements for construction documents or other supporting data if the *code official* determines they are not necessary to confirm compliance with this code.

❖ In most jurisdictions, the permit application must be accompanied by not less than two sets of construction documents. The code official can waive the requirements for filing construction documents when the scope of the work is minor and compliance can be verified through other means. When the quality of the materials is essential for conformity to the code, specific information must be given to establish that quality.

The code must not be cited, or the term "legal" or its equivalent used as a substitute for specific information. For example, it would be improper for the plans to simply state "windows per IECC requirements."

A detailed description of the work covered by the application must be submitted. When the work is "minor," either in scope or needed description, the code official may use judgment in determining the need for a detailed description. An example of "minor" work that may not involve a detailed description is the replacement of an existing 60-amp electrical service in a single-family residence with a 100-amp service.

The exception permits the code official to determine construction documents are not necessary when compliance can be obtained and verified without the documents.

R103.2 Information on construction documents. Construction documents shall be drawn to scale upon suitable material. Electronic media documents are permitted to be submitted where *approved* by the *code official*. Construction documents shall be of sufficient clarity to indicate the location, nature and extent of the work proposed, and show in sufficient detail pertinent data and features of the *building*, systems and equipment as herein governed. Details shall include, but are not limited to, the following as applicable:

1. Insulation materials and their *R*-values.
2. Fenestration *U*-factors and solar heat gain coefficients (SHGC).
3. Area-weighted *U*-factor and solar heat gain coefficients (SHGC) calculations.
4. Mechanical system design criteria.
5. Mechanical and service water-heating system and equipment types, sizes and efficiencies.
6. Equipment and system controls.
7. Duct sealing, duct and pipe insulation and location.
8. Air sealing details.

❖ For a comprehensive plan review, all code requirements should be incorporated in the design and construction documents. All of the project information, including specifications, scope, calculations, and detailed drawings, should be submitted to the code official so that code compliance can be verified. All parties should clearly understand what the project entails. A good plan review is essential to ensure code compliance and a successful project. A statement on the construction documents, such as "All insulation levels shall comply with the 2015 edition of the *International Energy Conservation Code®* (IECC®)," is not an acceptable substitute for showing the required information. Note also that the code official is authorized to require additional project and code-related information as necessary.

For example, insulation *R*-values and glazing and door *U*-factors must be clearly marked on the building plans, specifications or forms used to show compliance. Where two or more insulation levels exist for the same component (two insulation levels are used in ceilings), the permit applicant must record each level separately on the plans or specifications and clarify where in the building each level of insulation will be installed.

The following discussion is presented for the benefit of both the applicant and the plans examiner. This is not an all-inclusive list but rather is intended to reflect the minimum scope of information needed to determine energy code compliance:

Permit Applicant's Responsibilities. At permit application, the goal of the applicant is to provide all necessary information to show compliance with the code. If the plans examiner is able to verify compliance in a single review, the permit can be issued and construction may be started without delay.

Depending on whether the prescriptive or performance methods of compliance are used, the amount and detail of the required information may vary. For example, if using the prescriptive method of compliance, the *U*-factor and SHGC may be the only information needed to verify fenestration compliance. If the "total UA alternative" (Section R402.1.4) or the performance option (Section R405) is used, then additional information, such as the fenestration sizes and orientation, may be needed to demonstrate compliance. The envelope information that needs to be on the plans can be presented in a number of ways:

- *On the drawings.* Include elevations that indicate window, door and skylight areas and sections that show insulation position and thickness.

- *On sections and in schedules.* For instance, list *R*-values of insulation on sections and include *U*-factors, shading coefficient, visible light transmittance and air infiltration on fenestration and opaque door schedules.
- *Through notes and callouts.* Note that all exterior joints are to be caulked, gasketed, weatherstripped or otherwise sealed.
- *Through supplementary worksheets or calculations.* Provide area-weighted calculations where required, such as for projection factors and heat capacity. The permit applicant may include these calculations on the drawings, incorporate them as additional columns in the schedule or submit completed code compliance worksheets provided by the jurisdiction.

Incorrect information may be caused by a lack of understanding of the code. More likely, it indicates that the code has changed since the last project. The applicant can use a correction list to update office specifications to avoid receiving this same correction again in the future.

Plans Examiner's Responsibilities. The plans examiner must review each permit application for code compliance before a permit is issued. By letting the designer and contractor know what is expected of them early in the process, the building department can increase the likelihood that the approved drawings will comply with the code. This helps the inspector avoid the headache of correcting a contractor who is following drawings that do not meet code requirements.

The biggest challenge for the plans examiner is often determining where the necessary information is and whether the drawings are complete. The plans examiner should make sure the applicant includes a summary or checklist as part of the submittal package. When building envelope information is provided on the construction documents, it makes the job of the plans examiner easier, generally making for a more thorough review and reducing turnaround time.

A complete building envelope plan review covers all the requirements specific to the architectural building shell, but the electrical drawings may also need to be included and reviewed if the applicant seeks credit for automatic daylighting control for skylights or fenestration. A plan review should:

- Check that duct insulation thickness and conductivity (*k*-value) are on the drawings and comply with the code.
- Check that the duct insulation *R*-value is on the drawings and complies with the code.
- Check that there is a note indicating that ducts are to be constructed and sealed in accordance with the *International Mechanical Code*® (IMC®).
- Check that there is a note indicating that operating and equipment maintenance manuals will be supplied to the owner, that air and hydronic systems will be balanced and that the control system will be tested and calibrated.

R103.2.1 Building thermal envelope depiction. The *building's thermal envelope* shall be represented on the construction documents.

❖ The most important energy and performance aspects of the home are the building's thermal envelope and the alignment of the air barrier and thermal barrier systems. It is crucial that the design professional demonstrate an understanding of location of the thermal envelope and that the effort is made to draw its location so that construction personnel can successfully construct the building in accordance with the code and the specifications that have been drawn. Air sealing details help make this possible, but understanding where the details will be implemented helps ensure better implementation and enforcement.

R103.3 Examination of documents. The *code official* shall examine or cause to be examined the accompanying construction documents and shall ascertain whether the construction indicated and described is in accordance with the requirements of this code and other pertinent laws or ordinances. The *code official* is authorized to utilize a registered design professional, or other *approved* entity not affiliated with the building design or construction, in conducting the review of the plans and specifications for compliance with the code.

❖ This section describes the required action of the code official in response to a permit application. The code official can delegate review of the construction documents to subordinates. In addition, the code official can retain the services of an outside entity, such as a registered design professional, to examine the plans.

R103.3.1 Approval of construction documents. When the *code official* issues a permit where construction documents are required, the construction documents shall be endorsed in writing and stamped "Reviewed for Code Compliance." Such *approved* construction documents shall not be changed, modified or altered without authorization from the *code official*. Work shall be done in accordance with the *approved* construction documents.

One set of construction documents so reviewed shall be retained by the *code official*. The other set shall be returned to the applicant, kept at the site of work and shall be open to inspection by the *code official* or a duly authorized representative.

❖ The code official must stamp or otherwise endorse as "Reviewed for Code Compliance" the construction documents on which the permit is based. One set of approved construction documents must be kept on the construction site to serve as the basis for all subsequent inspections. To avoid confusion, the construction documents on the site must be the documents that were approved and stamped. This is because inspections are to be performed with regard to the approved documents, not the code itself. Additionally, the contractor cannot determine compliance with the approved construction documents unless they are readily available. If the approved construction documents are not available, the inspection should be postponed and work on the project halted.

R103.3.2 Previous approvals. This code shall not require changes in the construction documents, construction or designated occupancy of a structure for which a lawful permit has been heretofore issued or otherwise lawfully authorized, and the construction of which has been pursued in good faith within 180 days after the effective date of this code and has not been abandoned.

❖ If a permit is issued and construction proceeds at a normal pace and a new edition of the code is adopted by the legislative body, requiring that the building be constructed to conform to the new code is unreasonable. This section provides for the continuity of permits issued under previous codes, as long as such permits are being "actively prosecuted" subsequent to the effective date of the ordinance adopting this edition of the code.

R103.3.3 Phased approval. The *code official* shall have the authority to issue a permit for the construction of part of an energy conservation system before the construction documents for the entire system have been submitted or *approved*, provided adequate information and detailed statements have been filed complying with all pertinent requirements of this code. The holders of such permit shall proceed at their own risk without assurance that the permit for the entire energy conservation system will be granted.

❖ The code official has the authority to issue a partial permit to allow for the practice of "fast-tracking" a job. Any construction under a partial permit is "at the holder's own risk" and "without assurance that a permit for the entire structure will be granted." The code official is under no obligation to accept work or issue a complete permit in violation of the code, ordinances or statutes simply because a partial permit had been issued. Fast-tracking puts unusual administrative and technical burdens on the code official. The purpose is to proceed with construction while the design continues for other aspects of the work. Coordinating and correlating the code aspects into the project in phases requires attention to detail and project tracking so that all code issues are addressed. The coordination of these submittals is the responsibility of the registered design professional in responsible charge.

R103.4 Amended construction documents. Work shall be installed in accordance with the approved construction documents, and any changes made during construction that are not in compliance with the *approved* construction documents shall be resubmitted for approval as an amended set of construction documents.

❖ The code requires that all work be done in accordance with the approved plans and other construction documents. Where the construction will not conform to the approved construction documents, the documents must be revised and resubmitted to the code official for review and approval. Code officials should maintain a policy that all amendments be submitted for review. Otherwise, a significant change that is not approved could result in an activity that is not in compliance with the code and, therefore, cause needless delay and extra expense. The code official must retain one set of the amended and approved plans. The other set is to be kept at the construction site, ready for use by the jurisdiction's inspection staff.

R103.5 Retention of construction documents. One set of *approved* construction documents shall be retained by the *code official* for a period of not less than 180 days from date of completion of the permitted work, or as required by state or local laws.

❖ Construction documents must be retained in case a question or dispute arises after completion of the project. Unless modified because of state or local statutes, the retention period for the approved construction documents is a minimum of 180 days following the completion of the work, typically the date the certificate of occupancy is issued. Any further retention of plans by the jurisdiction as an archival record of construction activity in the community is not required by the code.

SECTION R104
INSPECTIONS

R104.1 General. Construction or work for which a permit is required shall be subject to inspection by the *code official* or his or her designated agent, and such construction or work shall remain accessible and exposed for inspection purposes until *approved*. It shall be the duty of the permit applicant to cause the work to remain accessible and exposed for inspection purposes. Neither the *code official* nor the jurisdiction shall be liable for expense entailed in the removal or replacement of any material, product, system or building component required to allow inspection to validate compliance with this code.

❖ Where a permit is required by state or local law, the building is subject to an inspection. The code official must determine whether appropriate energy-efficient features and equipment are installed in accordance with the approved construction documents and applicable code requirements.

Generally, a department's administrative rules will list required periodic inspections. Because the majority of energy-efficient construction occurs in steps or phases, periodic inspections are often necessary before portions of these systems are covered by further construction. The exact number of required inspections cannot always be specified. A reinspection may be necessary if violations are noted and corrections are required (see commentary, Section R104.4). If time permits, frequent inspections of some job sites, especially where the work is complex, can be beneficial to detect potential problems before they become too difficult to correct.

An inspector's ongoing challenge is responding to change orders during construction. In any construction project there will be field changes. The call is easy if a more efficient piece of equipment is being substituted for a less efficient one. For the opaque elements, more insulation is generally better. For fenestration, a lower *U*-factor and SHGC is generally better. Unfortunately, changing the glass almost always changes more than one characteristic, and it is not always clear whether energy efficiency is being improved. If there is any doubt concerning the impact, the inspector should confer with the plans examiner for the project.

A more difficult change order is one that reduces efficiency. For example, if the proposed substitute fenestration has a higher *U*-factor and SHGC, or if the window area is to be increased, the inspector must check with the plans examiner. The amount of information and the ease of confirming compliance will depend on whether the prescriptive or performance approach was used initially. In these cases, compliance is based on a combination of the fenestration area, *U*-factor, SHGC, projection factor, and (if a performance-based analysis has been used) opaque wall characteristics. Although there may be enough latitude to decrease the efficiency somewhat, it is not possible to make such a determination without reviewing all the elements and how compliance was initially demonstrated. Whenever there are significant changes such as described above, the inspector is expected to request that the applicant submit revised plans, so the plans examiner can verify compliance and ensure there is a correct record on file in the building department.

An even tougher case is when the contractor has already installed noncomplying equipment without checking with the inspector. For instance, ordinary double glazing may have been installed instead of double glazing with a low-emissivity coating. The inspector should be quite strict for several reasons. First, because most contracts are awarded on a cost-competitive basis, the low-bid company might win the job and then make its profit by installing noncomplying equipment. This would be unfair to the high-bid contractors.

Second, a lenient inspector's job will be more difficult in the future. If a noncomplying contractor skates by this time, that contractor will most likely have additional requests for future projects. In addition, other contractors will also begin to ask for special treatment. Self-policing, which works well if everyone is being treated fairly, will begin to decline.

Finally, there is the situation in which the approved plans do not contain all of the code requirements. If information or notes are missing from the plans, the inspector can, for instance, simply direct the contractor to make the necessary changes in the field (for example, caulk and seal joints).

The inspector's job is more difficult, however, if drawings contain information that is wrong. Perhaps the inspector in a cold climate notices the metal stud wall is not covered with insulating sheathing, as is required in that climate, and informs the contractor. The contractor responds saying that he or she is following the approved plans, and indeed he or she is. The inspector, as the representative of the code official, is clearly authorized to require the contractor to build the project to code. (If necessary, the inspector can show the contractor the building department note, which says, "Approved subject to errors and omissions." See also IBC Section 104.4.) In this case, it would be appropriate for the inspector to inform the plans examiner of the problem and ask the plans examiner to help solve the problem. The plans examiner may be able to suggest improvements in other areas that would compensate for this shortfall. It is important that the plans examiner and inspector appreciate the challenges of each other's work and the benefits of a team effort.

R104.2 Required inspections. The *code official* or his or her designated agent, upon notification, shall make the inspections set forth in Sections R104.2.1 through R104.2.5.

❖ The contractor, builder, owner or other authorized party is responsible for arranging and coordinating required inspections to prevent work from being concealed prior to inspection. For example:

- Insulation must be inspected prior to concealment. Where the insulation is concealed prior to inspection and approval, the code official has the authority to require removal of the concealing components.
- Basement wall insulation may be installed on the exterior of a below-grade basement wall. Where the insulation application is not confirmed prior to backfilling, reinspection is necessary.
- Glazing assembly *U*-factor labels are to be left on until after the building has been inspected for compliance. The applicant is responsible for giving the inspector adequate information on site to verify code-related features, such as window *U*-factor and equipment efficiencies.

After the field inspector has performed the required inspections and observed any required equipment and system tests (or has received written reports of the results of such tests), the code official must determine whether the installation or work is in compliance with all applicable sections of the code. The code official must issue a written notice of approval if the subject work or installation is in apparent compliance with the code. The notice of approval is given to the permit holder and a copy of the notice is retained on file by the code official.

R104.2.1 Footing and foundation inspection. Inspections associated with footings and foundations shall verify compliance with the code as to *R*-value, location, thickness, depth of burial and protection of insulation as required by the code and *approved* plans and specifications.

❖ Specific inspection details are called out in this section to ensure code requirements are met. In the case of footings and foundations, proper installation of the insulation is key to the performance of the building thermal envelope.

R104.2.2 Framing and rough-in inspection. Inspections at framing and rough-in shall be made before application of interior finish and shall verify compliance with the code as to types of insulation and corresponding *R*-values and their correct location and proper installation; fenestration properties (*U*-factor and SHGC) and proper installation; and air leakage controls as required by the code and approved plans and specifications.

❖ Specific inspection details are called out in this section to ensure code requirements are met. It is important to conduct inspections at the time of framing rough-in to be able to verify that the required insulation *R*-value is installed and that the installation details are followed. The code also provides detailed requirements for air barrier installation (see Section R402.4.1.1).

R104.2.3 Plumbing rough-in inspection. Inspections at plumbing rough-in shall verify compliance as required by the code and *approved* plans and specifications as to types of insulation and corresponding *R*-values and protection, and required control.

❖ Specific inspection details are called out in this section to ensure code requirements are met. In this case the integrity of the hot water supply insulation is important for meeting the energy efficiency requirements of the code.

R104.2.4 Mechanical rough-in inspection. Inspections at mechanical rough-in shall verify compliance as required by the code and *approved* plans and specifications as to installed HVAC equipment type and size, required controls, system insulation and corresponding *R*-value, system air leakage control, programmable thermostats, dampers, whole-house ventilation, and minimum fan efficiency.

> **Exception:** Systems serving multiple dwelling units shall be inspected in accordance with Section C104.2.4.

❖ Specific inspection details are called out in this section to ensure code requirements are met. In this case the HVAC system equipment type and installation, the duct insulation, and the system controls all have requirements in the code that must be met to ensure that the building is meeting the minimum energy efficiency requirements. The exception simply points to the Commercial Provisions for a situation in which the Commercial Provisions are more appropriate than these provisions.

R104.2.5 Final inspection. The *building* shall have a final inspection and shall not be occupied until *approved*. The final inspection shall include verification of the installation of all required *building* systems, equipment and controls and their proper operation and the required number of high-efficacy lamps and fixtures.

❖ To establish compliance with all previously issued correction orders and to determine whether subsequent violations exist, a final inspection is required. The final inspection is conducted after all work is completed. Typically, the final inspection includes all items installed after the rough-in inspection and not concealed in the building construction. Subsequent reinspection is necessary if the final inspection generates a notice of violation (see commentary, Section R104.4). All violations observed during the final inspection must be noted and the permit holder must be advised of them.

R104.3 Reinspection. A *building* shall be reinspected when determined necessary by the *code official*.

❖ The provisions for reinspection could affect the entire structure or a portion thereof. For example, if no approval was given to apply interior finish that conceals ducts in an exterior wall, the code official must require removal of the interior finish to verify the ducts are insulated to code.

Reinspections generally occur when some type of violation or correction notice was issued during one of the previous inspections or where the work was not ready for the inspection. For example, if the inspector went to the project to conduct an insulation inspection and not all of the insulation was installed at that point, the inspector would need to go back to the project and "reinspect" the insulation to verify that it had been completed. After the reinspection, the inspector would issue the approval (see Section R104.2) to permit the wall or ceiling cavities to be enclosed and therefore conceal the insulation.

R104.4 Approved inspection agencies. The *code official* is authorized to accept reports of third-party inspection agencies not affiliated with the building design or construction, provided such agencies are *approved* as to qualifications and reliability relevant to the building components and systems they are inspecting.

❖ As an alternative to the code official conducting the inspection, he or she is permitted to accept inspections of and reports by approved inspection agencies. Appropriate criteria on which to base approval of inspection agencies can be found in IBC Section 1703.

R104.5 Inspection requests. It shall be the duty of the holder of the permit or their duly authorized agent to notify the *code official* when work is ready for inspection. It shall be the duty of the permit holder to provide access to and means for inspections of such work that are required by this code.

❖ It is the responsibility of the permit holder or other authorized person, such as the contractor performing the work, to arrange for the required inspections when completed work is ready and to allow for sufficient time for the code official to schedule a visit to the site to prevent work from being concealed prior to being inspected. Access to the work to be inspected must be provided, including any special means such as a ladder.

R104.6 Reinspection and testing. Where any work or installation does not pass an initial test or inspection, the necessary corrections shall be made to achieve compliance with this code. The work or installation shall then be resubmitted to the *code official* for inspection and testing.

❖ This section provides for necessary actions in the event that a tested or inspected item is not originally in compliance with the code.

R104.7 Approval. After the prescribed tests and inspections indicate that the work complies in all respects with this code, a notice of approval shall be issued by the *code official*.

❖ This section mandates that a notice of approval be issued by the code official to indicate completion of an energy conservation installation. While certificates of occupancy for construction are traditionally under the purview of one of the construction codes, the notice of approval will fill a need with regard to application and enforcement of nonbuilding codes.

R104.7.1 Revocation. The *code official* is authorized to, in writing, suspend or revoke a notice of approval issued under the provisions of this code wherever the certificate is issued in error, or on the basis of incorrect information supplied, or where it is determined that the *building* or structure, premise, or portion thereof is in violation of any ordinance or regulation or any of the provisions of this code.

❖ This section provides an important administrative tool by giving the code official the authority to revoke a certificate of completion for the reasons indicated in the text. The code official may also suspend the certificate until any code violations are corrected.

SECTION R105
VALIDITY

R105.1 General. If a portion of this code is held to be illegal or void, such a decision shall not affect the validity of the remainder of this code.

❖ This section is applicable when a court of law rules that a portion of the code (or the jurisdiction's energy code) is invalid. Only invalid sections of the code (as established by the court of jurisdiction) can be set aside. This is essential to safeguard the application of the code text to situations in which a provision of the code is declared illegal or unconstitutional. This section preserves the original legislative action that put the legal requirements (energy code) in place.

All sections of the code not judged invalid must remain in effect. Although a dispute over a particular issue (such as an appliance efficiency requirement) may have precipitated the litigation causing the requirement to be found invalid, the remainder of the code must still be considered applicable. This is sometimes called the "severability clause" and simply means that the invalid section can be removed from the code without affecting the entire document.

SECTION R106
REFERENCED STANDARDS

R106.1 Referenced codes and standards. The codes and standards referenced in this code shall be those listed in Chapter 5, and such codes and standards shall be considered as part of the requirements of this code to the prescribed extent of each such reference and as further regulated in Sections R106.1.1 and R106.1.2.

❖ The code references many standards promulgated and published by other organizations. A complete list of these standards appears in Chapter 6 [RE]. The wording of this section was carefully chosen to establish the edition of the standard that is enforceable under the code.

Although a standard is referenced, its full scope and content are not necessarily applicable. The standard is applicable only to the extent indicated in the text in which the standard is specifically referenced. A referenced standard or the portion cited in the text is an enforceable extension of the code as if the content of the standard was included in the body of the code. The use and applicability of referenced standards are limited to those portions of the standards that are specifically identified.

R106.1.1 Conflicts. Where conflicts occur between provisions of this code and referenced codes and standards, the provisions of this code shall apply.

❖ The use of referenced codes and standards to cover certain aspects of various occupancies and operations rather than write parallel or competing requirements into the code is a longstanding code development principle. Often, however, questions and potential conflicts in the use of referenced codes and standards can arise, leading to inconsistent enforcement of the code. This section of the code is intended to establish that the provisions of the code would prevail in such a conflict, regardless of the level of stringency.

R106.1.2 Provisions in referenced codes and standards. Where the extent of the reference to a referenced code or standard includes subject matter that is within the scope of this code, the provisions of this code, as applicable, shall take precedence over the provisions in the referenced code or standard.

❖ Section R106.1.2 expands on the provisions of Section R106.1.1 by making it clear that even if a referenced standard contains requirements that parallel the code [or the other referenced section(s)], the provisions of the code will always take precedence.

R106.2 Application of references. References to chapter or section numbers, or to provisions not specifically identified by number, shall be construed to refer to such chapter, section or provision of this code.

❖ This section provides some information on the use of the code and the conventions used in making references to other portions of the code. By implication then, a reference that is intended to provide information from another code would be required to state what code the reference is from.

R106.3 Other laws. The provisions of this code shall not be deemed to nullify any provisions of local, state or federal law.

❖ This provision is intended to assist the code official in dealing with situations where other laws enacted by the jurisdiction or the state or federal government may be applicable to a condition that is also governed by a requirement in the code. In such circumstances, the requirements of the code would be in addition to that other law that is still in effect, although the code official may not be responsible for its enforcement.

SECTION R107 FEES

R107.1 Fees. A permit shall not be issued until the fees prescribed in Section R107.2 have been paid, nor shall an amendment to a permit be released until the additional fee, if any, has been paid.

❖ This section requires that all fees be paid prior to permit issuance or release of an amendment to a permit. Since department operations are usually intended to be supported by fees paid by the user of department activities, it is important that these fees are received before incurring any expense.

R107.2 Schedule of permit fees. A fee for each permit shall be paid as required, in accordance with the schedule as established by the applicable governing authority.

❖ This section authorizes the establishment of a schedule of fees by the jurisdiction. The fees are usually established by law, such as in an ordinance adopting the code, a separate ordinance or legally promulgated regulation as required by state or local law, and are often based on a valuation of the work to be performed.

R107.3 Work commencing before permit issuance. Any person who commences any work before obtaining the necessary permits shall be subject to an additional fee established by the *code official* that shall be in addition to the required permit fees.

❖ The department will incur certain costs (i.e., inspection time and administrative) when investigating and citing a person who has commenced work without having obtained a permit. This section authorizes the code official to recover those costs by establishing a fee, in addition to that collected when the required permit is issued, to be imposed on the responsible party.

R107.4 Related fees. The payment of the fee for the construction, *alteration*, removal or demolition of work done in connection to or concurrently with the work or activity authorized by a permit shall not relieve the applicant or holder of the permit from the payment of other fees that are prescribed by law.

❖ This section provides the code official with a useful administrative tool establishing that all applicable fees of the jurisdiction for regulated work collateral to the work being done under the code's permit, such as sewer connections, water taps, driveways, signs, etc., must be paid.

R107.5 Refunds. The *code official* is authorized to establish a refund policy.

❖ This section authorizes the code official to establish a policy to regulate the refund of fees, which may be full or partial, typically resulting from the revocation, abandonment or discontinuance of a building project for which a permit has been issued and fees have been collected.

SECTION R108 STOP WORK ORDER

R108.1 Authority. Where the *code official* finds any work regulated by this code being performed in a manner either contrary to the provisions of this code or dangerous or unsafe, the *code official* is authorized to issue a stop work order.

❖ This section provides for the suspension of work for which a permit was issued, pending the removal or correction of a severe violation or unsafe condition identified by the code official. Stop work orders are issued when enforcement can be accomplished no other way or when a dangerous condition exists.

R108.2 Issuance. The stop work order shall be in writing and shall be given to the owner of the property involved, to the owner's authorized agent, or to the person doing the work. Upon issuance of a stop work order, the cited work shall immediately cease. The stop work order shall state the reason for the order and the conditions under which the cited work will be permitted to resume.

❖ This section makes it clear that, upon receipt of a violation notice from the code official, all construction activities identified in the notice must immediately cease, except as expressly permitted to correct the violation.

R108.3 Emergencies. Where an emergency exists, the *code official* shall not be required to give a written notice prior to stopping the work.

❖ This section gives the code official the authority to stop the work in dispute immediately when, in his or her opinion, there is an unsafe emergency condition that has been created by the work. The need for the written notice is suspended for this situation so that the work can be stopped immediately.

R108.4 Failure to comply. Any person who shall continue any work after having been served with a stop work order, except such work as that person is directed to perform to remove a violation or unsafe condition, shall be subject to a fine as set by the applicable governing authority.

❖ This section establishes consequences for disregarding a stop work order and continuing the work that is at issue, other than abatement work. The dollar amounts for the minimum and maximum fines are to be specified in the adopting ordinance.

SECTION R109 BOARD OF APPEALS

R109.1 General. In order to hear and decide appeals of orders, decisions or determinations made by the *code official* relative to the application and interpretation of this code, there shall be and is hereby created a board of appeals. The *code official* shall be an ex officio member of said board but shall not have a vote on any matter before the board. The board of appeals shall be appointed by the governing body and shall hold office at its pleasure. The board shall adopt rules of procedure for conducting its business, and shall render all decisions and findings in writing to the appellant with a duplicate copy to the *code official*.

❖ This section provides an aggrieved party that has a material interest in the decision of the code official a process to appeal such a decision before a board of appeals. This provides a forum, other than the court of jurisdiction, in which to review the code official's actions. The intent of the appeal process is not to waive or set aside a code requirement; rather it is intended to provide a means of reviewing a code official's decision on an interpretation or application of the code.

R109.2 Limitations on authority. An application for appeal shall be based on a claim that the true intent of this code or the rules legally adopted thereunder have been incorrectly interpreted, the provisions of this code do not fully apply or an equally good or better form of construction is proposed. The board shall not have authority to waive requirements of this code.

❖ This section establishes the grounds for an appeal that claims that the code official has misinterpreted or misapplied a code provision. The board is not allowed to set aside any of the technical requirements of the code; however, it is allowed to consider alternative methods of compliance with the technical requirements.

R109.3 Qualifications. The board of appeals shall consist of members who are qualified by experience and training and are not employees of the jurisdiction.

❖ This section requires that the members of the appeals board are to have experience in building construction and system matters because the decisions of the appeals board are to be based purely on the technical merits involved in an appeal.

Bibliography

The following resource materials were used in the preparation of the commentary for this chapter of the code.

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Chapter 2 [RE]: Definitions

General Comments

All terms defined in the code are listed alphabetically in Chapter 2 [RE]. The words or terms defined in this chapter are considered to be of prime importance in either specifying the subject matter of code provisions or in giving meaning to certain terms used throughout the code for administrative or enforcement purposes. The code user should be familiar with what terms are found in this chapter because the definitions are essential to the correct interpretation of the code and because the user might not be aware of the fact that a particular term found in the text is defined.

Purpose

Codes, by their nature, are technical documents. Every word, term and punctuation mark can alter a sentence's meaning and, if misused, muddy its intent. Further, the code, with its broad scope of applicability, includes terms inherent in a variety of construction disciplines. These terms can often have multiple meanings, depending on the context or discipline in which they are being used. For these reasons, maintaining a consensus on the specific meaning of terms contained in the code is essential. Chapter 2 [RE] performs this function by stating clearly what specific terms mean for the purpose of the code.

SECTION R201 GENERAL

R201.1 Scope. Unless stated otherwise, the following words and terms in this code shall have the meanings indicated in this chapter.

❖ For the purposes of the code, certain abbreviations, terms, phrases, words and their derivatives have the meanings given in Chapter 2 [RE]. The code, with its broad scope of applicability, includes terms used in a variety of construction and energy-related disciplines. These terms can often have multiple meanings, depending on their context or discipline. Therefore, Chapter 2 [RE] establishes specific meanings for these terms.

R201.2 Interchangeability. Words used in the present tense include the future; words in the masculine gender include the feminine and neuter; the singular number includes the plural and the plural includes the singular.

❖ Although the definitions contained in Chapter 2 [RE] are to be taken literally, gender, number and tense are considered to be interchangeable.

R201.3 Terms defined in other codes. Terms that are not defined in this code but are defined in the *International Building Code*, *International Fire Code*, *International Fuel Gas Code*, *International Mechanical Code*, *International Plumbing Code* or the *International Residential Code* shall have the meanings ascribed to them in those codes.

❖ When a word or term that is not defined in this chapter appears in the code, other references may be used to find its definition, such as other *International Codes®* (I-Codes®). Definitions that are applicable in other I-Codes are applicable everywhere the term is used in the code. As stated in both the "Purpose" section above and in the commentary to Section R201.1, a bit of caution is needed when looking at definitions from other codes. Because the context and discipline can vary, it is important to determine that the term does fit within the code context. As an example, the term "accessible" would have a different meaning in the *International Mechanical Code®* (IMC®) and the *International Plumbing Code®* (IPC®) versus that of the *International Building Code®* (IBC®).

R201.4 Terms not defined. Terms not defined by this chapter shall have ordinarily accepted meanings such as the context implies.

❖ Another option for defining words or terms not defined here or in other codes is their "ordinarily accepted meanings." The intent of this statement is that a dictionary definition may suffice if the definition is in context. Often, construction terms used throughout the code may not be defined in Chapter 2 [RE] or in a dictionary. In such a case, the definitions contained in the referenced standards (see Chapter 5 [RE]) and in published textbooks on the subject in question are good resources.

SECTION R202 GENERAL DEFINITIONS

ABOVE-GRADE WALL. A wall more than 50 percent above grade and enclosing *conditioned space*. This includes between-floor spandrels, peripheral edges of floors, roof and basement knee walls, dormer walls, gable end walls, walls enclosing a mansard roof and skylight shafts.

❖ This definition details which walls must be treated as above-grade walls. This will help to make the distinction between these walls and basement walls (see definition and commentary, "Basement wall"). These two wall types face a different amount of energy transfer and therefore have different insulation requirements. In order to determine the proper insulation requirements for the various walls, both definitions should be reviewed. The definition includes any wall that is a part of the building thermal envelope ("enclosing conditioned space") and meets the area requirements. For example, the wall between a dwelling and an unconditioned garage would be included in this definition (see commentary, "Building thermal envelope").

ACCESSIBLE. Admitting close approach as a result of not being guarded by locked doors, elevation or other effective means (see "Readily *accessible*").

❖ Providing access to mechanical equipment and appliances is necessary to facilitate inspection, observation, maintenance, adjustment, repair or replacement. Access to equipment means the equipment can be physically reached without having to remove a permanent portion of the structure. It is acceptable, for example, to install equipment in an interstitial space that would require removal of lay-in suspended ceiling panels to gain access. Equipment would not be considered accessible if it were necessary to remove or open any portion of a structure other than panels, doors, covers or similar obstructions intended to be removed or opened (see the definition of "Readily accessible"). Access can be described as the capability of being reached or approached for the purpose of inspection, observation, maintenance, adjustment, repair or replacement. Achieving access may first require the removal or opening of a panel, door or similar obstruction, and may require the overcoming of an obstacle such as elevation.

ADDITION. An extension or increase in the *conditioned space* floor area or height of a building or structure.

❖ The code uses this term to reflect new construction that is being added to an existing building. This definition is important when determining the applicability of the code provisions (see Section R502).

AIR BARRIER. Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or a combination of materials.

❖ Building tightness against air infiltration is an important aspect of energy conservation. The term "air barrier" is defined to support the provisions of Section R402.4 regarding air leakage and building tightness. Note that an air barrier is not a single membrane but rather the system of sealants, seals, insulation and wall sheathing that prevents air infiltration.

ALTERATION. Any construction, retrofit or renovation to an existing structure other than repair or addition that requires a permit. Also, a change in a building, electrical, gas, mechanical or plumbing system that involves an extension, addition or change to the arrangement, type or purpose of the original installation that requires a permit.

❖ This definition actually includes two separate definitions: one that applies to building construction and the other to mechanical systems. An alteration is any modification or change made to an existing installation. For example, changing refrigerant types or heat transfer fluids in a system would be considered an alteration. This definition specifically excludes additions or repairs and also ties the term to situations where a permit is required. See Chapter 1 of the IBC and IMC for the information regarding when a permit is required.

APPROVED. Approval by the *code official* as a result of investigation and tests conducted by him or her, or by reason of accepted principles or tests by nationally recognized organizations.

❖ As related to the process of accepting envelope, mechanical, service water heating, lighting and electrical power installations, including materials, equipment and construction systems, this definition identifies where ultimate authority rests. Whenever this term is used, it intends that only the enforcing authority can accept a specific installation or component as complying with the code.

The definition does not force the code official to accept any third-party test. It merely permits the acceptance of the test so that the code official does not have to personally test the item. One example that demonstrates this process is an ICC Evaluation Report. An evaluation report prepared and published by the International Code Council (ICC)® is permitted to be used by a code official to aid in his or her review and approval of the material or method described in the report. Although the evaluation and report are prepared by the ICC, the code official is not obligated to accept or approve the product based on the evaluation report. The term "approved" is always tied to the code official's approval of the product or project. That the ICC published an evaluation report does not supersede the fact that the approval of the code official is still needed for the material or method described in the report.

APPROVED AGENCY. An established and recognized agency regularly engaged in conducting tests or furnishing inspection services, when such agency has been approved by the *code official.*

❖ This definition is added to the code to parallel the remaining I-Codes. It is quite often misunderstood that an authoritative agency cannot provide any services in the building construction or testing without the approval of the code official.

AUTOMATIC. Self-acting, operating by its own mechanism when actuated by some impersonal influence, as, for example, a change in current strength, pressure, temperature or mechanical configuration (see "Manual").

❖ Operation or control devices or systems operating automatically, as opposed to manually, are designed to operate safely with only periodic human intervention or supervision. A thermostat would be an example of something that is automatic. While a person would set the thermostat to the desired temperature, the thermostat would cycle the heating or cooling system on or off on its own once the temperature hits the established setpoints.

BASEMENT WALL. A wall 50 percent or more below grade and enclosing *conditioned space*.

❖ Because basement walls are in contact with the ground and ground temperatures differ from air temperatures, the amount of energy transferred through a basement wall is different than the energy transfered through a wall predominantly above grade. Therefore, the code provides different thermal requirements for basement walls and above-grade walls. An individual wall enclosing conditioned space is classified as a basement wall where the gross wall area is 50 percent or more below grade and is bounded by soil; otherwise, the wall is classified as an above-grade wall. This definition includes a below-grade interior wall separating a basement from a crawl space that meets the percentage requirement. This basement wall classification applies to the whole wall area, even if a portion of the individual wall is not below grade. Therefore, the above-grade portion of the wall is considered as part of the basement wall where the total wall is 50 percent or more below grade. Both sections of the wall (above grade and below grade) are then insulated as a "basement wall." Likewise, where an exterior wall is less than 50 percent below grade, the whole wall area is classified as an above-grade wall, including the portion underground [see Commentary Figure R202(1)]. For example, the wall of a walk-out basement that is entirely above grade is not considered a basement wall. The wall area of the walk-out wall must be considered as an above-grade wall and compared to the code requirements for above-grade walls. Thus, where the average below-grade depth of the sidewalls is 50 percent or greater, they are basement walls. If not, they are above-grade walls. The intent of this definition is to apply the provision to each wall enclosing the space. It is not intended to be applied to the aggregate of all of the walls of the basement. Therefore, this classification is done for each individual wall segment and not on an aggregate basis. The basement wall requirements apply only to the opaque basement wall area, excluding windows and doors. For purposes of meeting the code requirements, windows and doors in a basement wall are regulated as any other fenestration opening.

BUILDING. Any structure used or intended for supporting or sheltering any use or occupancy, including any mechanical systems, service water heating systems and electric power and lighting systems located on the building site and supporting the building.

❖ This definition indicates that where this term is used in the code, it means a structure intended to provide shelter or support for some activity or occupancy. Though not addressed in the code, it is important to note that the IBC does permit that a fire wall forms a demarcation in between two separate, structurally independent buildings. Therefore, the code provisions could be applied to each building separately or to the structure as a whole. This would be a designer's decision.

BUILDING SITE. A continguous area of land that is under the ownership or control of one entity.

❖ "Building site" is a key term used throughout the code. It is the area of land that is under the ownership of one entity.

BUILDING THERMAL ENVELOPE. The basement walls, exterior walls, floor, roof and any other building elements that enclose conditioned space or provide a boundary between conditioned space and *exempt* or unconditioned *space*.

❖ "Building thermal envelope" is a key term and resounding theme used throughout the code. It

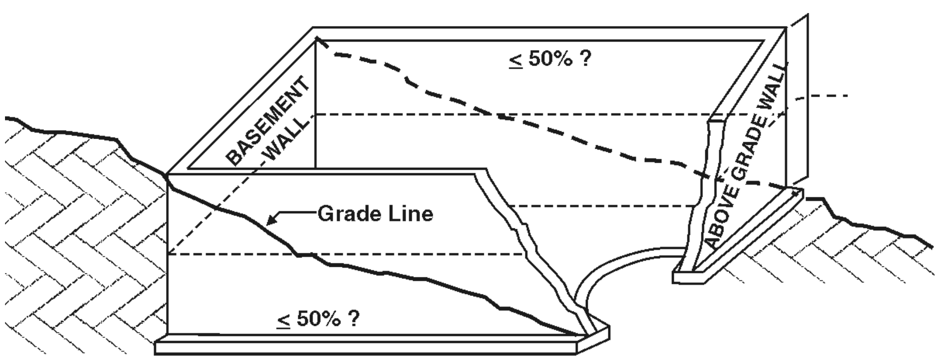


Figure R202(1)
BASEMENT WALLS

defines what portions of the building form a structurally bound conditioned space and are thereby covered by the insulation and infiltration (air leakage) requirements of the code. The building thermal envelope includes all building components separating conditioned spaces (see commentary, "Conditioned space") from unconditioned spaces or outside ambient conditions and through which heat is transferred. For example, the walls and doors separating an unheated garage (unconditioned space) from a living area (conditioned space) are part of the building thermal envelope. The walls and doors separating an unheated garage from the outdoors are not part of the building thermal envelope. Walls, floors and other building components separating two conditioned spaces are not part of the building thermal envelope. For example, interior partition walls, the common or party walls separating dwelling units in multiple-family buildings and the wall between a new conditioned addition and the existing conditioned space are not considered part of the building thermal envelope. Unconditioned spaces (areas having no heating or cooling sources) are placed outside the building envelope. A space is conditioned if it is heated or cooled directly or where a space is indirectly supplied with heating or cooling through uninsulated walls, floors or uninsulated ducts or heating, ventilating and air-conditioning (HVAC) piping. Boundaries that define the building envelope include the following:

- Building assemblies separating a conditioned space from outdoor ambient weather conditions.
- Building assemblies separating a conditioned space from the ground under or around that space, such as the ground around the perimeter of a slab or the soil at the exterior of a conditioned basement wall. Note that the code does not specify requirements for insulating basement floors or underneath slab floors (except at the perimeter edges).
- Building assemblies separating a conditioned space from an unconditioned garage, unconditioned sunroom or similar unheated/cooled area.

The code specifies requirements for ceiling, wall, floor, basement wall, slab-edge and crawl space wall components of the building envelope. In some cases, it may be unclear how to classify a particular part of a building. For example, skylight shafts have properties of a wall assembly but are located in the ceiling assembly. Because many of these items are not addressed specifically in the code, the code official should make the determination as to the appropriate classification and construction. When no distinction exists between roof and wall, such as in an A-frame structure, the code official should determine the appropriate classification. Historically, some codes have designated a wall as having a slope of 60 degrees or greater from the horizontal plane. In such situations, if the wall slope is less than 60 degrees, then classification as a "roof" is appropriate. Because the code is silent on this issue, other options such as stating that the roof could be considered to begin at a point 8 feet (2439 mm) above the floor surface of the uppermost story could be used. The phrase "exempt space" in the definition of "Building thermal envelope" refers to spaces identified as exempt from this scope of the code (see commentary, Section R101.4).

***C*-FACTOR (THERMAL CONDUCTANCE).** The coefficient of heat transmission (surface to surface) through a building component or assembly, equal to the time rate of heat flow per unit area and the unit temperature difference between the warm side and cold side surfaces (Btu/h · ft^2 · °F) [W/(m^2 · K)].

❖ This definition addresses a term needed in the provisions of the code for the *U*-factor alternative given in Section R402.1.4.

CIRCULATING HOT WATER SYSTEM. A specifically designed water distribution system where one or more pumps are operated in the service hot water piping to circulate heated water from the water-heating equipment to fixtures and back to the water-heating equipment.

❖ In order to ensure hot water is available immediately at a faucet, circulating hot water systems can be installed to circulate hot water when the hot water supply system is not in use.

CLIMATE ZONE. A geographical region based on climatic criteria as specified in this code.

❖ See the commentary to Section R301.1.

CODE OFFICIAL. The officer or other designated authority charged with the administration and enforcement of this code, or a duly authorized representative.

❖ The statutory power to enforce the code is usually vested in a building department of a state, county or municipality with a designated enforcement officer who is termed the "code official."

COMMERCIAL BUILDING. For this code, all buildings that are not included in the definition of "Residential building."

❖ Commercial buildings include, among others, occupancies for assembly, educational, business, institutional, mercantile, factory/industrial, hazardous storage and utility occupancies (see definition and commentary, "Residential building").

One item that may easily be overlooked is that a Group R-1 occupancy building (a hotel or motel) would be classified as a "commercial building" because it is not included in the definition of "Residential building." Although classified as a residential occupancy by the IBC, hotels and motels tend to be more closely associated with commercial buildings as far as energy usage and operation.

CONDITIONED FLOOR AREA. The horizontal projection of the floors associated with the *conditioned space*.

❖ The conditioned floor area is the total area of all floors in the conditioned space of the building.

CONDITIONED SPACE. An area, room or space that is enclosed within the building thermal envelope and that is directly or indirectly heated or cooled. Spaces are indirectly heated or cooled where they communicate through openings with conditioned spaces, where they are separated from conditioned spaces by uninsulated walls, floors or ceilings, or where they contain uninsulated ducts, piping or other sources of heating or cooling.

❖ A conditioned space is typically any space that does not communicate directly to the outside; that is, a space not directly ventilated to the outdoors and meets one of the following criteria:

1. The space has a heating or cooling supply register.
2. The space has heating or cooling equipment designed to heat or cool the space, or both, such as a radiant heater built into the ceiling, a baseboard heater or a wall-mounted gas heater.
3. The space contains uninsulated ducts or uninsulated hydronic heating surfaces.
4. The space is inside the building thermal envelope. For example:
   - A basement with insulated walls but without insulation on the basement ceiling.
   - A closet on a home's exterior wall that is insulated on the exterior surface of the closet wall.
   - A space adjacent to and not physically separated from a conditioned space (such as a room adjacent to another room with a heating duct but without a door that can be closed between the rooms).
   - A room completely surrounded by conditioned spaces.

The builder/designer has some flexibility in defining the bounds of the conditioned space as long as the building envelope requirements are met. Spaces that are not conditioned directly but have uninsulated surfaces separating them from conditioned spaces are included within the insulated envelope of the building. For example, an unventilated crawl space below an uninsulated floor is considered part of the conditioned space, even where no heat is directly supplied to the crawl space area. Where the crawl space is included as a conditioned space, the builder must insulate the exterior crawl space walls instead of the floor above. The task of defining the building envelope is left to the permit applicant.

Examples of unconditioned spaces include garages and basements that are neither heated nor cooled if all duct surfaces running through these spaces are insulated; attached sunrooms that are neither heated nor cooled and have insulated/weatherstripped doors to separate the sun space from the conditioned space; attics; and ventilated crawl spaces. Note that the boundary between the conditioned and unconditioned space is subject to the infiltration control requirements of the code (see commentary, Section R402.4).

Historically, the code tied this definition to "conditioning for human comfort" or by specifying that the conditioning fall within a specific range. Starting with the 2006 edition, the code considers any type of conditioning as creating a "conditioned space." Therefore, providing heating within a storage building to keep the stock from freezing would still be considered as creating a conditioned space.

CONTINUOUS AIR BARRIER. A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

❖ This term is used throughout the code. This definition is necessary to clarify the options for meeting continuous air barrier requirements.

CONTINUOUS INSULATION (ci). Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior, or is integral to any opaque surface, of the building envelope.

❖ The need for more insulation on exterior walls has created the need to specify continuous insulation on the exterior side of the wall for certain climate zones in Chapter 4. Thus the need for this definition.

CRAWL SPACE WALL. The opaque portion of a wall that encloses a crawl space and is partially or totally below grade.

❖ Because exterior crawl space walls may be in contact with the ground, they exhibit different heat transfer properties than those of exterior above-grade walls or even basement walls. Thus, the code includes different thermal requirements for exterior crawl space walls.

This definition and distinction is also to help coordinate with Section R402.2.11. While a basement is defined as a "conditioned space," crawl spaces may be designed to be either conditioned or unconditioned spaces.

CURTAIN WALL. Fenestration products used to create an external nonload-bearing wall that is designed to separate the exterior and interior environments.

❖ This definition is included to help classify and properly apply the code requirements to these products. The industry uses the term to help establish the requirements and separate the products into different groupings. Without defining the curtain wall as a fenestration product, it would be difficult to determine how to properly apply the building envelope requirements.

DEMAND RECIRCULATION WATER SYSTEM. A water distribution system where pump(s) prime the service hot water piping with heated water upon demand for hot water.

❖ This is essential in the code to define a water distribution system in order to establish requirements for insulation to retain the heated water upon demand for hot water and conserve energy usage.

DUCT. A tube or conduit utilized for conveying air. The air passages of self-contained systems are not to be construed as air ducts.

❖ Ducts can be factory manufactured or field constructed of sheet metal, gypsum board, fibrous glass board or other approved materials. Ducts are used in air distribution systems, exhaust systems, smoke control systems and combustion air-supply systems. Air passageways that are integral parts of an air handler, packaged air-conditioning unit or similar piece of self-contained, factory-built equipment are not considered ducts in the context of the code.

DUCT SYSTEM. A continuous passageway for the transmission of air that, in addition to ducts, includes duct fittings, dampers, plenums, fans and accessory air-handling equipment and appliances.

❖ Duct systems are part of an air distribution system and include supply, return, transfer and relief/exhaust air systems.

DWELLING UNIT. A single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking and sanitation.

❖ A dwelling unit contains elements necessary for independent living (living spaces such as family rooms, dining rooms, living rooms, dens, etc.; sleeping quarters; food preparation and eating spaces; and personal hygiene, cleanliness and sanitation facilities). A dwelling unit is typically owner occupied, rented or leased. The code requirements are applied consistently to all dwellings whether owner occupied, rented or leased. A dwelling unit can exist singularly as a one-family dwelling or in combination with other dwelling units. When two dwelling units are grouped together in the same structure, the structure is considered a two-family dwelling. Three or more dwelling units in the same structure are considered a multiple-family dwelling. Note that under this definition, rooms in hotels and motels are not considered dwelling units but rather guestrooms or a sleeping unit, because they usually lack complete living, sanitation and eating facilities and are generally characterized as having transient occupancy patterns.

ENERGY ANALYSIS. A method for estimating the annual energy use of the *proposed design* and *standard reference design* based on estimates of energy use.

❖ Designs founded on simulated performance alternative (performance) (see Section R405) use energy analysis when the design professional requires more flexibility for a sophisticated or innovative design. Using the total-building-performance design methodology, the proposed design is evaluated based on the cost of various types of energy used rather than the units of energy used (Btu, kWh). That cost must be established using an hour-by-hour, full-year (8,760 hours) simulation tool capable of simulating the performance of both the proposed and standard designs (see commentary, "Energy simulation tool"). The simulation must be capable of converting calculated energy demand and consumption into utility costs using the actual utility rate schedules rather than the average cost of electricity or gas.

ENERGY COST. The total estimated annual cost for purchased energy for the building functions regulated by this code, including applicable demand charges.

❖ The total annual cost for purchased energy includes demand, power and fuel adjustment charges and the impact of special rate programs for large volume customers. A thorough evaluation of existing tariffs and fee schedules may uncover substantial savings opportunities. In some states, for example, manufacturing customers are exempt from sales taxes for energy. In other states, utilities may have multiple tariff options.

ENERGY SIMULATION TOOL. An *approved* software program or calculation-based methodology that projects the annual energy use of a building.

❖ An energy simulation tool is typically a software package incorporating, among other features, an hour-by-hour, full-year (8,760 hours), multiple-zone program to simulate the performance of both proposed and standard design buildings. It is possible to use other types of simulation tools to approximate the dynamics of hourly energy programs and that can be shown to produce equivalent results for the type of building and HVAC systems under consideration. However, the simulation must be capable of converting calculated energy demand and consumption into utility costs using the actual utility rate schedules (rather than average cost of electricity or gas). Some examples of when an hour-by-hour, full-year type of program is required are:

- When the features intended to reduce energy consumption require time-of-day interactions between weather, loads and operating criteria. Examples include: night ventilation or building thermal storage; chilled water or ice storage; heat recovery; daylighting; and water economizer cooling.
- When utility rates are time-of-day sensitive, and the proposed design uses time-of-day load shifting between different types of mechanical plant components.

Another distinguishing feature among simulation tools is their sophistication in modeling HVAC systems and plant equipment. Basically, three levels of complexity are used: constant efficiency models; models with simple part-load efficiency adjustment; and models with complex part-load efficiency adjustment. Simulation tools in the first category simply calculate hourly equipment input power requirements at part load by applying the full-load efficiency at any given hour. These programs should be avoided for all but constant load applications. Simulated tools with simple part-load efficiency adjustments use a profile of percent-rated input power versus percent-rated load. At each hour, these programs calculate input power to each piece of equipment. These tools are far more accurate than the constant-efficiency models, but still lack accurate compensation for environmental variables.

Building energy simulation tools, available for analyzing daylighting, passive solar design and solar systems, are described in more detail at www.eere.energy.gov/buildings/tools_directory/. This is a portion of the U.S. Department of Energy's Energy Efficiency and Renewable Energy website.

The information includes program uses, computer hardware required, price and contact information. The most sophisticated simulation tools incorporate a number of profiles for each and every piece of equipment. For variable flow fans, this might be as simple as a single profile of percent-rated input power versus percent-rated airflow. For more complex equipment, such as a cooling tower, the program considers such variables as the wet-bulb temperature, the approach (difference between the condenser water supply temperature and the wet-bulb temperature) and the range (difference between the condenser water entering and leaving temperatures). Each of these variables is used to adjust both the hourly capacity of the tower and the hourly operation (one fan, two fans, no fans). For all but the simplest systems, programs of this category must be used to obtain accurate results. Questions regarding a particular tool's ability to model the building on an hour-by-hour, full-year basis should be addressed to the proprietor or distributor.

ERI REFERENCE DESIGN. A version of the rated design that meets the minimum requirements of the 2006 *International Energy Conservation Code.*

❖ The Energy Rating Index compliance alternative utilizes the ERI Reference Design (see Section R406).

EXTERIOR WALL. Walls including both above-grade walls and basement walls.

❖ Wall insulation requirements defined in the code include almost all opaque exterior construction bounding conditioned space. Depending on the compliance method, the wall type, glazing percentage and whether the wall is on the exterior or just separating conditioned from unconditioned space can affect the wall insulation requirement. Note also that doors (both glazed and opaque) are considered fenestration (see commentary, "Fenestration").

In earlier editions, the code included the limitation that an exterior wall is vertical or sloped at an angle of 60 degrees (1.1 rad) or greater from the horizontal. This limitation may still be helpful to consider if dealing with unusual situations such as an A-frame building. Where a determination is needed to decide whether the roof or wall provisions are appropriate, this limitation could be helpful.

FENESTRATION. Products classified as either *vertical fenestration* or *skylights*.

❖ The term "fenestration" refers both to opaque and glazed doors and the light-transmitting areas of a wall or roof, but primarily windows and skylights. The code sets performance requirements for fenestration by establishing requirements that differ from the wall and roof requirements based on the type of fenestration and in the case of the prescriptive commercial requirements by limiting the fenestration area. In some of the compliance options the fenestration type and area allowed depend on the shading coefficient, the size of overhangs, the thermal performance (*U*-factor) and whether daylighting controls are installed.

FENESTRATION PRODUCT, SITE-BUILT. A fenestration designed to be made up of field-glazed or field-assembled units using specific factory cut or otherwise factory-formed framing and glazing units. Examples of site-built fenestration include storefront systems, curtain walls and atrium roof systems.

❖ Fenestration products can be site-built, not to be confused with field-fabricated fenestration products. This definition is installed to make that distinction.

***F*-FACTOR.** The perimeter heat loss factor for slab-on-grade floors (Btu/h · ft · °F) [W/(m · K)].

❖ As defined, *F*-factor is needed in the provisions of the code for the *U*-factor alternative given in Section R402.1.4.

HEATED SLAB. Slab-on-grade construction in which the heating elements, hydronic tubing, or hot air distribution system is in contact with, or placed within or under, the slab.

❖ The space above a heated slab is always conditioned (heated). The definition clarifies that certain slabs are the heating source and, as covered in the code, may require more insulation than unheated slabs. The installation of a radiant heat source in a space does not, in and of itself, qualify a slab as heated.

HIGH-EFFICACY LAMPS. Compact fluorescent lamps, T-8 or smaller diameter linear fluorescent lamps, or lamps with a minimum efficacy of:

1. 60 lumens per watt for lamps over 40 watts;
2. 50 lumens per watt for lamps over 15 watts to 40 watts; and
3. 40 lumens per watt for lamps 15 watts or less.

❖ The code requires that a percentage of permanent lighting fixtures have high-efficacy lamps. Therefore, this definition is necessary to specify the required performance to qualify as a high-efficacy lamp.

HISTORIC BUILDING. Any building or structure that is one or more of the following:

1. Listed, or certified as eligible for listing by the State Historic Preservation Officer or the Keeper of the National Register of Historic Places, in the National Register of Historic Places.
2. Designated as historic under an applicable state or local law.
3. Certified as a contributing resource within a National Register-listed, state-designated or locally designated historic district.

❖ Historic buildings are given some relief from the requirements of the code (see Section R501.6).

INFILTRATION. The uncontrolled inward air leakage into a building caused by the pressure effects of wind or the effect of differences in the indoor and outdoor air density or both.

❖ Air leakage is random movement of air into and out of a building through cracks and holes in the building envelope. In technical terms, air leakage is called "infiltration" (air moving into a building) or "exfiltration" (air moving out of a building). In nontechnical terms, air leaks are often referred to as "drafts." Infiltration may be reduced by either reducing the sources of air leakage (joints, penetrations and holes in the building envelope) or by reducing the pressures driving the airflow.

INSULATED SIDING. A type of continuous insulation with manufacturer-installed insulating material as an integral part of the cladding product having a minimum *R*-value of R-2.

INSULATING SHEATHING. An insulating board with a core material having a minimum *R*-value of R-2.

❖ Some exterior hardboard and vinyl siding products are not recommended for use in direct contact with aluminum-foil-faced sheathing products (check with the product manufacturer). Other sheathing products are uniquely designed for use in direct contact with wood, brick, vinyl, aluminum and hardboard-based sidings. To be considered insulating sheathing the product must have an *R*-value no less than R-2.

LABELED. Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, inspection agency or other organization concerned with product evaluation that maintains periodic inspection of the production of the above-labeled items and where labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

❖ When a product is labeled, the label indicates that the equipment or material has been tested for conformance to an applicable standard and that the component is subject to third-party inspection, which verifies that the minimum level of quality required by the applicable standard is maintained. Labeling is a readily available source of information that is useful for field inspection of installed products. The label identifies the product or material and provides other information that can be further investigated if there is a question concerning the suitability of the product or material for the specific installation. The labeling agency performing the third-party inspection must be approved by the code official and the basis for this approval may include, but is not necessarily limited to, the capacity and capability of the agency to perform the specific testing and inspection. The applicable referenced standard often states the minimum identifying information that must be on a label. The data contained on a label typically includes, but is not necessarily limited to, the name of the manufacturer, the product name or serial number, installation specifications, applicable tests and standards, the testing approved and the labeling agency.

LISTED. Equipment, materials, products or services included in a list published by an organization acceptable to the *code official* and concerned with evaluation of products or services that maintains periodic inspection of production of *listed* equipment or materials or periodic evaluation of services and where the listing states either that the equipment, material, product or service meets identified standards or has been tested and found suitable for a specified purpose.

❖ Not all testing laboratories, inspection agencies and other organizations concerned with product evaluation use the same means for identifying listed equipment, appliances or materials. Some do not recognize equipment, appliances or materials as listed unless they are also labeled. The authority having jurisdiction must use the same system used by the listing organization to identify a listed product. In general, all equipment and appliances regulated by the I-Codes are to be listed and labeled unless otherwise approved in accordance with Section R102.1, which allows use of alternative materials, methods and equipment. As stated in the definition, the listing states either that the equipment or material meets nationally recognized standards or it has been found suitable for use in a specified manner. The listing becomes part of the documentation that the code official can use to approve or disapprove the equipment or appliance.

LOW-VOLTAGE LIGHTING. Lighting equipment powered through a transformer such as a cable conductor, a rail conductor and track lighting.

❖ Track lighting is a form of low-voltage lighting featuring a continuous-powered track that accepts fixtures (called heads) anywhere along its length. The heads and the wide variety of lamps (bulbs) they accept suit virtually every lighting situation, and most heads are also adjustable. One-, two-, three- and four-circuit tracks let the lighting design professional mix standard and low-voltage heads or have multiple switching options. Track systems are easily modified or added to as lighting needs change. Although tracks can be recessed flush with a ceiling surface or suspended from posts, they are typically fastened to the surface either directly or with mounting clips. Controls ranging from a simple on/off switch to elaborate programmable dimming devices are widely available, making the system extremely flexible.

MANUAL. Capable of being operated by personal intervention (see "Automatic").

❖ Devices, systems or equipment having manual controls or overrides are designed to operate safely with only human intervention instead of having an automatic operation or control system (see commentary, "Automatic").

A typical light switch would be an example of a manual device. The lights that the switch controls stay either off or on until a person flips the switch to the appropriate position.

PROPOSED DESIGN. A description of the proposed *building* used to estimate annual energy use for determining compliance based on total building performance.

❖ The proposed design is simply a description of the proposed building, used to estimate annual energy costs for determining compliance based on total building performance. The proposed design is effectively the subject building intended to be built. The performance of the proposed design (the building exactly as it is anticipated to be constructed) is then compared to the standard reference design (a similar building that is assumed to be built to a prescriptive set of minimum code requirements). Although the method permits trade-offs in energy use between different systems, the proposed design must still comply with the general requirements. General "mandatory" requirements are separately specified in Chapter 4 [RE]. For instance, the air-leakage requirements are general requirements that apply, even if the project uses any one of the two performance methods referenced above. The general requirements still apply for several reasons, including:

- Many basic requirements cannot be accurately modeled (such as subdivision of feeders).
- Many requirements are inherently cost effective (such as variable speed drives or large motors and minimizing air leakage).
- Some basic requirements are calculation methodologies that establish a fair basis for comparing component performance (such as *U*-factor calculations).
- Some basic requirements are not intended for trade-offs (such as exterior lighting).

RATED DESIGN. A description of the proposed *building* used to determine the energy rating index.

❖ See Section 406 for application.

READILY ACCESSIBLE. Capable of being reached quickly for operation, renewal or inspection without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders or access equipment (see "*Accessible*").

❖ Readily accessible can be described as able to be quickly reached or approached for operation, inspection, observation or emergency action. Ready access does not require the removal or movement of any door panel or similar obstruction, or overcoming physical obstructions or obstacles, including differential elevation.

REPAIR. The reconstruction or renewal of any part of an existing building for the purpose of its maintenance or to correct damage.

❖ The repair of an item, appliance, energy-using subsystem or other piece of equipment typically does not require a permit. This definition makes it clear that a repair is limited to work on the item, and does not include its replacement or other new work.

This definition is important when applying the provisions of Section R504 and determining how the code will apply to existing buildings and installations.

REROOFING. The process of recovering or replacing an existing *roof covering*. See "Roof recover" and "Roof replacement."

RESIDENTIAL BUILDING. For this code, includes detached one- and two-family dwellings and multiple single-family dwellings (townhouses) as well as Group R-2, R-3 and R-4 buildings three stories or less in height above grade plane.

❖ The definition of a residential building is important not only for what it does include, but also for what it does not. One of the primary limitations of this definition is the fact that this term will only include Group R-2 and R-4 occupancies when they are three stories or less in height. Therefore, if a Group R-2 or R-4 occupancy is over three stories in height, it would be defined as a "Commercial building" (see definition, "Commercial building") and be required to comply with the requirements of Chapter 4[CE] instead of the residential provisions of Chapter 4 [RE]. Buildings that are classified as an R-3 are not affected by the three-story limitation. Because of this, a one- or two-family dwelling would always be considered as a residential building regardless of the number of stories.

It should be noted that a Group R-1 building is not included in this definition. Therefore, any hotel, motel or similar use that is classified as an R-1 must comply with commercial building requirements. This applies even if the hotel or motel is three stories or less in height.

Though not specifically addressed within this definition, any building built under the provisions of the *International Residential Code*® (IRC®) would also be considered a "residential building."

The Group R-2 classification of residential buildings includes apartments and condominiums where three or more units are physically attached. In addition, it includes certain boarding houses, convents, dormitories, fraternities or other such facilities. The code defines a dwelling unit as a single housekeeping unit of one or more rooms providing complete independent living facilities, including permanent provisions for living, sleeping, cooking and sanitation (see commentary, “Dwelling unit”). Many of the code provisions address dwelling units specifically. All of the elements listed in the definition must be present for a dwelling unit to exist. Guestrooms (sleeping units) in hotels, motels, nursing homes and larger group care facilities do not meet this criteria. Therefore, these buildings are considered as commercial uses, even if they are three stories or less in height (see the IBC for additional information on dwelling units). Although this definition closely follows the Group R-2 occupancy classification of the IBC, it is important to note there are differences. The main distinction is the three-story limitation, which is found only in the code. It is also important to note that townhouses are not considered as being a part of this definition.

The R-4 classification is included in order to coordinate the provisions of the code with the IBC. These small residential care/assisted-living facilities are considered residential buildings based on Sections 310.1 and 310.2 of the IBC. This distinction is important because larger facilities are classified by the IBC as institutional occupancies and, therefore, would be considered commercial buildings by the code (see “Commercial building”).

As mentioned earlier, it is important to note the application of the three-story limitation, which is found only in the code. This issue of defining a residential building over three stories in height as a commercial building coordinates the code with ANSI/ASHRAE/IESNA 90.1.

ROOF ASSEMBLY. A system designed to provide weather protection and resistance to design loads. The system consists of a roof covering and roof deck or a single component serving as both the roof covering and the roof deck. A roof assembly includes the roof covering, underlayment, roof deck, insulation, vapor retarder and interior finish.

❖ This section basically defines the cover or protection over a building but it will be important to the energy requirements in several sections. The roof assembly generally serves as the building thermal envelope for the top of the building. By defining the various elements that are included in the definition, the phrase can be applied to situations where the insulation is installed above the roof deck, beneath the roof deck or above a ceiling that occurs below.

The “Roof assembly” definition will be important not only when applying the prescriptive insulation requirements of the building thermal envelope but also when applying the performance requirements where the type of roof covering and ventilation can affect the energy efficiency.

Numerous horizontal and sloped surfaces may be associated with the roof or roof/ceiling assembly, including flat and cathedral ceilings, dormer roofs, bay-window roofs, overhead portions of an interior stairway to an attic, or other unconditioned space, attic hatches and skylights. When determining the area of the assembly under the performance options, ceiling assembly areas should be measured on the slope of the finished interior surface.

In earlier editions, the code included the limitation that a roof is generally horizontal or sloped at an angle of less than 60 degrees (1.1 rad) from the horizontal. This limitation may still be helpful to consider if dealing with unusual situations such as an A-frame building. Where a determination is needed to decide whether the roof or wall provisions are appropriate, this limitation could be helpful (see commentary, “Exterior wall” and “Skylight,” as well as the definition in IBC Section 202).

ROOF RECOVER. The process of installing an additional *roof covering* over a prepared existing *roof covering* without removing the existing *roof covering*.

❖ Roof recover is considered an alteration to the building. In the application of Section R503, roof recover is exempt from the code requirements.

ROOF REPAIR. Reconstruction or renewal of any part of an existing roof for the purposes of its maintenance.

❖ See Section R504 for application.

ROOF REPLACEMENT. The process of removing the existing *roof covering*, repairing any damaged substrate and installing a new *roof covering*.

❖ This is a form of alteration to a building and may or may not require additional energy conservation measures, such as insulation in the roof cavity, depending upon the extent of work (see Section R503).

***R*-VALUE (THERMAL RESISTANCE).** The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area ($h \cdot ft^2 \cdot °F/Btu$) [$(m^2 \cdot K)/W$].

❖ Thermal resistance measures how well a material or series of materials retards heat flow. Insulation thermal resistance is rated using *R*-values. As the *R*-value of an element or assembly increases, the heat loss or gain through that element or assembly decreases. Thus, a higher *R*-value is considered better than a lower *R*-value.

SERVICE WATER HEATING. Supply of hot water for purposes other than comfort heating.

❖ Although the definition makes it clear that the code requirement applies to equipment used to produce and distribute hot water for purposes other than comfort heating, the definition also applies to energy-efficient process water heating systems and equipment. Equipment providing or distributing hot water for uses such as restrooms, showers, laundries, kitchens, pools and spas, defrosting of sidewalks and driveways, carwashes, beauty salons and other commercial enterprises are included. Space-conditioning boilers and distribution systems are not considered service water heating components.

SKYLIGHT. Glass or other transparent or translucent glazing material installed at a slope of less than 60 degrees (1.05 rad) from horizontal.

❖ A skylight is a glazed opening in a roof to admit daylight. Skylights are often the only method of bringing natural light into an interior, enclosed area. Unfortunately, these fixtures often do their job too well. Installing too many skylights or ones too large for the room can lead to overheating during warm-weather months. Also, choosing the most energy-efficient models can compromise light transmission—the reason people buy skylights in the first place.

Skylights are available in a variety of sizes and shapes, though rectangular units are the most common. Although most skylights are fixed or inoperable, others can be opened and shut like a window or have hidden ventilating systems. Large operable skylights designed for the sloping ceilings of attic rooms are even marketed as “roof windows.” These approaches help cool the room in warm weather by venting hot air. The IBC requires either tempered or laminated glass in skylights. Both types are designed to stand up to snow loads and provide protection against falling objects. Tempered glass breaks into small pieces, rather than large shards, if damaged. Laminated glass, which is fused with a thin layer of plastic, stays in place for added safety if broken. Laminated glass is also better at keeping out sound and is slightly more energy efficient, though also slightly more expensive. Skylights are not energy efficient. They collect little heat during the winter, which is when it is needed most, when the sun is low in the sky. Worse yet, because they’re located where the pressure difference between the inside and outside of the house is greatest, skylights are an easy escape route for heated air. Also, in the summer they can heat up the home quickly—when it is not needed.

Like windows, skylights offer a variety of energy-efficient glazing options, including low-e and tinted glass. Green tints are better than bronze tints for reducing solar heat gain while letting in plenty of visible light. And because skylights usually are not visible from the street, tinted glazings are less likely to affect aesthetics.

It is important to note that the term “skylight” can also include glazed roofs and sloped walls. This distinction can affect the proper application of the code requirements. To help determine the appropriate *U*-factor, this definition includes the slope limitation, which is shown. If the slope of the roof or sloped wall is 15 degrees (0.26 rad) or more from the vertical, then the skylight *U*-factor is appropriate. If the slope is less than 15 degrees (0.26 rad), then the glazing would be considered a fenestration in a wall. As an example using the requirements of Table R402.1.2 for Climate Zone 1, a skylight would require a *U*-factor of 0.75, while the fenestration in a wall would require a *U*-factor of 1.20. Both the skylight and the more vertical wall fenestration would require a solar heat gain coefficient (SHGC) of 0.30 (see Table R402.1.2, Note b).

SOLAR HEAT GAIN COEFFICIENT (SHGC). The ratio of the solar heat gain entering the space through the fenestration assembly to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation that is then reradiated, conducted or convected into the space.

❖ The SHGC is the fraction of incident solar radiation admitted through a window or skylight. This includes the solar radiation that is directly transmitted, and that which is absorbed and subsequently released inward. Therefore, the SHGC measures how well a window blocks the heat from sunlight. The SHGC is the fraction of the heat from the sun that enters through a window. SHGC is expressed as a number between 0 and 1. The lower a window’s SHGC, the less solar heat it transmits.

In the warmer climate zones, where cooling is the dominant requirement, the code will generally impose a limitation on the amount of solar heat gain permitted. In colder climate zones, the code will generally not place any SHGC requirement on the fenestration. Thus, it will depend on the climate zone as to whether a higher or lower SHGC is best. While windows with lower SHGC values reduce summer cooling and overheating, they also reduce free winter solar heat gain.

STANDARD REFERENCE DESIGN. A version of the *proposed design* that meets the minimum requirements of this code and is used to determine the maximum annual energy use requirement for compliance based on total building performance.

❖ The standard reference design is simply the same building design as that intended to be built (see commentary, “Proposed design”), except the energy conservation features required by the code (insulation, windows, infiltration, mechanical, lighting and service water-heating systems) are modified to meet the minimum prescriptive requirements, as applicable. Note that the standard reference design is not truly a separate building, and it is never actually built. It is the baseline against which the proposed design is measured.

The performance of the proposed design (the building exactly as it is anticipated to be constructed) is then compared to the standard reference design (a similar building that is assumed to be built to a prescriptive set of minimum code requirements). Under the performance paths, if the energy efficiency of the proposed design is equal to or better than that of the standard reference design, then the proposed design is acceptable and in compliance with the code requirements.

SUNROOM. A one-story structure attached to a dwelling with a glazing area in excess of 40 percent of the gross area of the structure’s exterior walls and roof.

❖ Sunrooms are unique rooms that create a space differing in character from that provided by conventional portions of a dwelling. Sunrooms and other highly glazed structures are sometimes called conservatories or solariums. These sunrooms are often added onto an existing building but there is nothing in the code that would prohibit them from being constructed as a part of a new dwelling.

This definition distinguishes sunrooms from other conventional spaces because they are limited to one story in height and the total glazing area needs to be at least 40 percent of the exterior wall and roof area of the sunroom. This definition and its use in Sections R402.2.2 and R402.3.5 are important since most dwellings do not have such large amounts of glazing.

Many of these sunrooms are constructed to be unconditioned spaces and will not have any type of heating or cooling. Other sunrooms may be conditioned indirectly by openings from the adjacent conditioned space of the dwelling, provided with a separate space conditioning system or designed as a separate zone from the dwelling's space conditioning system. Due to the large amount of glazing and, therefore, the probability that the sunroom will either be hot in the summer or cold in the winter and may be unused during such times, the code provisions address the thermal isolation of these spaces (see definition, "Thermal isolation"). When addressing the thermal isolation of sunrooms, the provisions of Sections R402.2.13 and R402.3.5 need to be reviewed and code users need to realize how those sections cordinate with Section R501.1.1. Section R402.3.5 requires that "new" walls separating a sunroom from a conditioned space must comply with the building thermal envelope requirements. Therefore, if a sunroom is built as an addition to an existing dwelling, the existing wall between the sunroom and any conditioned space is not regulated.

THERMAL ISOLATION. Physical and space conditioning separation from *conditioned space(s)*. The *conditioned space*(s) shall be controlled as separate zones for heating and cooling or conditioned by separate equipment.

❖ This term is conceptually similar to the separation provided by the building envelope, but instead of being between conditioned space and the exterior or conditioned space and unconditioned space, this separation occurs between two conditioned spaces. In this situation it is the separation between the dwelling and the sunroom. Therefore, where the sunroom is an addition, the existing exterior wall of the dwelling will generally provide the thermal isolation between the dwelling and the sunroom at the point where the sunroom addition is attached. If a new door or window opening is added to permit passage between or to provide a connection with the dwelling and the sunroom, that new door or window is required to comply with the fenestration *U*-factor specified in Table R402.1.2. By requiring the maximum *U*-factor, it ensures a reasonable level of energy conservation between the dwelling and the sunroom, so they would not need to be brought into compliance with the *U*-factor specified in the table.

This exemption for the existing doors and windows is based not only on the language in this definition, but also on the scoping requirements found in Section R402.3.5. Since these existing doors and windows would serve as a part of the building envelope for the dwelling prior to the addition of the sunroom, they may be accepted as a part of the thermal isolation between the dwelling and any new sunroom addition (see commentary, "Sunroom" and Section R402.3.5).

This definition is also important due to the restriction that it places on the heating and cooling system for the various spaces. In order to be thermally isolated, the two spaces are either served by separate systems or as separate zones on a common system.

THERMOSTAT. An automatic control device used to maintain temperature at a fixed or adjustable set point.

❖ Thermostats combine control and sensing functions in a single device. Thermostats may signal other control devices to trigger an action when certain temperatures are reached or surpassed. Because thermostats are so prevalent, the various types and their operating characteristics are described here.

The occupied-unoccupied or dual-temperature room thermostat reduces temperature at night. It may be indexed (changed from occupied to unoccupied operation or vice versa) individually from a remote point or in a group by a manual or time switch. Some types have an individual clock and switch built in.

The pneumatic day-night thermostat uses a two-pressure air supply system, where changing the pressure at a central point from one value to the other actuates switching devices in the thermostat and indexes it.

The heating-cooling or summer-winter thermostat can have its action reversed and its set point changed in response to outdoor and comfort conditions. It is used to actuate controlled devices, such as valves or dampers that regulate a heating source at one time and a cooling source at another. The pneumatic heating-cooling thermostat uses a two-pressure air supply similar to that described for occupied-unoccupied thermostats.

Multistage thermostats are arranged to operate two or more successive steps in sequence.

A submaster thermostat has its set point raised or lowered over a predetermined range, in accordance with variations in output from a master controller. The master controller can be a thermostat, manual switch, pressure controller or similar device. For example, a master thermostat measuring outdoor air temperature can be used to readjust the set point of a submaster thermostat that controls the water temperature in a heating system.

A wet-bulb thermostat is often used (in combination with a dry-bulb thermostat) for humidity control. Using a wick or another means of keeping the bulb wet with pure (distilled) water and rapid air motion to ensure a true wet-bulb measurement is essential. Wet-bulb thermostats are seldom used.

A dew-point thermostat is designed to control dew-point temperatures.

A dead-band thermostat has a wide differential over which the thermostat remains neutral, requiring neither heating nor cooling. This differential may be adjustable up to 10°F (-12°C) (see Section C403.2.4.1.2).

***U*-FACTOR (THERMAL TRANSMITTANCE).** The coefficient of heat transmission (air to air) through a building component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films ($Btu/h \cdot ft^2 \cdot °F$) [$W/(m^2 \cdot K)$].

❖ Thermal transmittance (*U*-factor) is a measure of how well a material or series of materials conducts heat. *U*-factors for window and door assemblies are the reciprocal of the assembly *R*-value:

$$U\text{-factor} = \frac{1}{R\text{-value}}$$

For other building assemblies, such as a wall or roof/ceiling, the *R*-value used in the above equation is the *R*-value of the entire assembly, not just the insulation. This distinction is important and reflects the provisions of Sections R402.1.4 and R402.1.5. It also explains why there are differences between the comparable values of Tables R402.1.2 and R402.1.4.

The *U*-factors will be used in a number of locations of the code. When using the performance options or the “total UA alternative” (see Section R402.1.5), the individual thermal transmittance (*U*-factor) of each element is multiplied by the area of each envelope component (walls, floors, and ceilings) and the area of each fenestration element (doors, windows and skylights). Therefore, the UA is simply the *U*-factor times the area. For example, a 400-square-foot (37 m^2) wall with a *U*-factor of 0.082 would result in a UA of 32.8 (400 × 0.082 = 32.8). The total UA would simply be the sum of all of the individual UAs for each building element (walls, floors, ceilings, doors, windows and skylights).

VENTILATION. The natural or mechanical process of supplying conditioned or unconditioned air to, or removing such air from, any space.

❖ Ventilation is provided by the wind, naturally occurring pressure and temperature differences or mechanical systems typically consisting of fans and blowers.

VENTILATION AIR. That portion of supply air that comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space.

❖ Ventilation air can be used for comfort cooling, control of air contaminants, equipment cooling and replenishing oxygen levels (see commentary, “Ventilation”).

VERTICAL FENESTRATION. Windows (fixed or moveable), opaque doors, glazed doors, glazed block and combination opaque/glazed doors composed of glass or other transparent or translucent glazing materials and installed at a slope of a least 60 degrees (1.05 rad) from horizontal.

❖ Vertical fenestration is that which is typically installed on exterior walls. The required thermal efficiency of fenestration varies by climate zone (see Section R402.3).

VISIBLE TRANSMITTANCE [VT]. The ratio of visible light entering the space through the fenestration product assembly to the incident visible light, Visible Transmittance, includes the effects of glazing material and frame and is expressed as a number between 0 and 1.

❖ Use of daylight for energy conservation is now a fundamental part of the code. However, requirements for lower SHGC values for glazing can work against this because glazing with lower SHGC values generally will allow less visible light through the glazing. Therefore, the code now must include a limit on VT.

WHOLE HOUSE MECHANICAL VENTILATION SYSTEM. An exhaust system, supply system, or combination thereof that is designed to mechanically exchange indoor air with outdoor air when operating continuously or through a programmed intermittent schedule to satisfy the whole house ventilation rates.

❖ It is beneficial to have “Whole house mechanical ventilation system” defined in the code, as findings from a recent study commissioned by the DOE and the California Energy Commission identified that energy consumption of whole house mechanical ventilation systems is significant. Further, the study revealed that large disparities exist in the energy consumption and associated operating costs of whole house mechanical ventilation systems in cold, mild and hot, dry climates. Within the study, exhaust only systems balanced heat recovery systems, supply only systems, and central fan integrated systems were all modeled to assess resultant energy use and associated costs.

ZONE. A space or group of spaces within a building with heating or cooling requirements that are sufficiently similar so that desired conditions can be maintained throughout using a single controlling device.

❖ The simplest all-air system is a supply unit serving a single-temperature control zone. Ideally, this system responds completely to the space needs, and well-designed control systems maintain temperature and humidity closely and efficiently. Single-zone systems can be shut down when not required without affecting the operation of adjacent areas. Thus, in a thorough discussion of the term “zone,” the concept of “zoning” for temperature control requires consideration.

Exterior zoning. Exterior zones are affected by varying weather conditions—wind, temperature and sun—and, depending on the geographic area and season, require both heating and cooling. This variation gives the designer considerable flexibility in choosing a system and results in the greatest advantages. The need for separate perimeter zone heating is determined by:

- Severity of the heating load (i.e., geographic location).
- Nature and orientation of the building envelope.
- Effects of downdraft at windows and the radiant effect of the cold glass surface (type of glass, area, height and *U*-factor).
- Type of occupancy (sedentary versus transient).
- Operating costs (in buildings such as offices and schools that are occupied for considerable periods). Fan operating costs can be reduced by heating with perimeter radiation during unoccupied periods rather than operating the main supply fans or local unit fans.

Interior zoning. Conditions in interior spaces are relatively constant because they are isolated from external influences. Usually, interior spaces require cooling throughout the year. Interior spaces with a roof exposure, however, may require similar treatment to perimeter spaces requiring heat. To summarize, zone control is required when the conditions at the thermostat are not representative of all the rooms or the entire exposure. This situation will almost certainly occur if any of the following conditions exist:

- The building has more than one level.
- One or more spaces are used for entertaining large groups.
- One or more spaces have large glass areas.
- The building has an indoor swimming pool or hot tub.
- The building has a solarium or atrium. In addition, zoning may be required when several rooms or spaces are isolated from each other and from the thermostat.
- The building spreads out in many directions (wings).
- Some spaces are distinctly isolated from the rest of the building.
- The envelope only has one or two exposures.
- The building has a room or rooms in a basement.
- The building has a room or rooms in an attic space.
- The building has one or more rooms with slab or exposed floor.
- Zone control can be achieved by insulation.
- There are discrete heating/cooling duct systems for each zone requiring control.
- There are automatic zone damper systems in a single heating/cooling duct system.

Chapter 3 [RE]: General Requirements

General Comments

Chapter 3 [RE] specifies the climate zones establishing exterior design conditions and provides general requirements for interior design conditions, and materials, systems and equipment. In general, the climate zone provisions are determined simply by referring to the map (see Figure R301.1) or by looking at the tables [see Tables R301.1, R301.3(1) and R301.3(2)]. In addition, Section R302 details the interior design conditions that are used for heating and cooling load calculations. Section R303 provides requirements for fenestration, identification of insulation and other basic general requirements for insulation materials.

Purpose

Climate has a major impact on the energy use of most commercial and residential buildings. The code establishes many requirements, such as wall and roof insulation *R*-values, window and door thermal transmittance requirements (*U*-factors), as well as provisions that affect the mechanical systems based on the climate where the building is located. This chapter contains the information used to properly assign the building location into the correct climate zone, which will then be used as the basis for establishing or eliminating requirements.

Materials and systems used to provide insulation and fenestration values, including *U*-factor and solar heat gain coefficient (SHGC) ratings, must be based on data used by appropriate tests. This establishes a level playing field for manufacturers of products.

Discussion and Development of the Climate Zone Map

The 2006 code made a dramatic shift in the classification of climate zones. While this change in the climate zone map was a part of the major revision to help simplify the code and make both compliance and enforcement easier, the climate zone revisions were a lengthy, very detailed and complicated process. Much of the new climate zone development was based on a paper titled "Climate Classification for Building Energy Codes and Standards." This paper was written by Robert S. Briggs, Robert G. Lucas and Z. Todd Taylor of the U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL). Some aspects of this paper may help users better understand the climate zones and also help people feel comfortable with these new classifications.

Climate zones were developed based on the following criteria:

1. Offer consistent climate materials for all compliance methods and code sections (including both commercial and residential).
2. Enable the code to be self-contained with respect to climate data.
3. Be technically sound.
4. Map to political boundaries.
5. Provide a long-term climate classification solution.
6. Be generic and neutral (i.e., not overly tailored to current code requirements).
7. Be useful in beyond-code and future-code contexts.
8. Offer a more concise set of climate zones and presentation formats.
9. Be acceptable to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and usable in ASHRAE standards and guidelines.
10. Provide a basis for use outside of the United States.

The reasons that the authors cited for some of the less obvious items include:

Item 4 – Mapping climate zones to easily recognizable political boundaries instead of to abstract climatic parameters facilitates code implementation. Users and jurisdictions are able to easily tell what requirements apply, which is not the case in some locations when climate parameters are used.

Item 7 – "Useful in future-code and beyond-code contexts" reflects the view that minimum acceptable practice codes and standards can provide an effective platform on which to build other efficiency programs. Beyond-code programs are likely to encourage features and technologies not included in current codes, many of which are likely to be more climate-sensitive than current requirements.

Item 9 – "Usable in ASHRAE standards and guidelines" is important because effective coordination of both content and formats used in the code and ASHRAE standards offers the potential to facilitate rapid migration of ASHRAE standards into model codes. Previous efforts to translate ASHRAE criteria into the simpler and more prescriptive forms most desired by the code enforcement community has, in some cases, added years to the adoption process and widespread implementation of updated criteria.

The belief in developing the climate zones was that any new system needed to show substantial improvement over the previously existing systems. In addition, any new classification must be at least roughly compatible with the previous climate-dependent requirements in order to allow for the conversion and inclusion of existing, generally accepted requirements. The intent was to develop a set of climate classifications that could support simple, approximate ways of prescribing energy-efficiency measures for buildings. It was not intended to develop a set of categories that could be used for all purposes.

The new climate zones were developed in an open process involving several standards committees of ASHRAE, the U.S. Department of Energy (DOE) staff and other interested parties.

Given the interest of the International Code Council (ICC®) and ASHRAE in producing documents that are capable of being used internationally, an effort was made to develop a system and climate zones that could work outside of the United States. The new climate definitions were developed using the International System of Units, abbreviated SI, from the French Le Systéme International d'Unités. By using the SI units and climate indices, which are widely available internationally, the climate zones and the development of building energy-efficiency provisions can be applied anywhere in the world. The boundaries between the various climate zones in Table R301.3(2) occur in multiples of 900°F days, which converts to 500°C days. Distinguishing the climate zones with these numbers results in a clean and understandable division between the climate zones in either system of temperature measurement.

The developers of the climate zone map selected bands of 1000 HDD18°C (1800 HDD65°F) because they resulted in boundaries that align with boundaries established in ANSI/ASHRAE/IESNA 90.1, plus they facilitate the use of both SI and inch-pound (I-P) units and were able to affect a significant reduction in the number of climate zones.

An objective for any effective classification is to maximize the differences between the selected criteria for each climate zone, while minimizing the variations that occur within the group. A large variation between the groups enables generalizations embodied in the code requirements to be better tailored to each climate zone. A small variation in each climate zone will ensure that the generalizations better fit the climate zone. It was the developers' feeling that the new classification better represents the climatic diversity, while defining more coherent climate zones than what the code previously used. It should be noted that mountainous regions defy clean geographic separation of clusters.

SECTION R301
CLIMATE ZONES

R301.1 General. *Climate zones* from Figure R301.1 or Table R301.1 shall be used in determining the applicable requirements from Chapter 4. Locations not in Table R301.1 (outside the United States) shall be assigned a *climate zone* based on Section R301.3.

❖ Climate involves temperature, moisture, wind and sun and also includes both daily and seasonal patterns of variation of the parameters. To account for these variations, the code establishes climate zones that serve as the basis for code provisions.

This section serves as the starting point for determining virtually all of the code requirements, especially under the prescriptive compliance paths. Because of their easy-to-understand graphic nature, maps have proven useful over the years as an effective way to help code users determine climate-dependent requirements. Therefore, for the United States, the climate zones are shown in the map in Figure R301.1. Because of the limited size of the map, the code also includes a listing of the climate zones by states and counties in Table R301.1. Table R301.1 will allow users to positively identify climate-zone assignments in those few locations for which the map interpretation may be difficult. Whether the map or the county list is used, the climate classification for each area will be the same.

When dealing with prescriptive compliance paths, the code user would simply look at the map or listing and select the proper climate zone based on the location of the building. When using a performance approach, additional climatic data may be needed.

Virtually every building energy code that has been developed for use in the United States has included a performance-based compliance path, which allows users to perform an energy analysis and demonstrate compliance based on equivalence with the prescriptive requirements. To perform these analyses, users must select appropriate weather data for their given project's location. The selection of appropriate weather data is straightforward for any project located in or around one of the various weather stations in the United States. For other locations, selecting the most appropriate weather site can be problematic. The codes themselves provide little help with this selection process. During the development of the new climate zones, the developers mapped every county in the United States to the most appropriate SAMSON station (National Climatic Data Center "Solar and Meteorological Surface Observation Network" station) for each county as a whole. This mapping is not included in the code but may be used in some compliance software. Designating an appropriate SAMSON station should not be considered to be the only climate data permitted for a given county. It could, however, be used in the absence of better information. Where local data better reflects regional or microclimatic conditions of an area, they would be appropriate to use. For example, elevation has a large impact on climate and can vary dramatically within individual counties, especially in the western United States. Where elevation differences are significant, code officials may require use of sites that differ from the sites designated as being the most appropriate for the county. For additional information on this topic, review the paper "Climate Classification for Building Energy Codes and Standards," which is referenced in the commentary text that precedes Section R301.

The new climate classifications do not attempt to resolve the issue of what the appropriate treatment for elevation differences is. This aspect is left in the hands of the local code official.

R301.2 Warm humid counties. Warm humid counties are identified in Table R301.1 by an asterisk.

❖ Table R301.1 lists the counties in the southeastern United States that fall below the white-dashed line appearing on the map in Figure R301.1. The warm-humid climate designation includes parts of eight states and also covers all of Florida, Hawaii and the U.S. territories. Table R301.3(1) provides the details that were used to determine the classification of the warm-humid designation for the counties.

There currently are very few requirements in the code specifically tied to the warm-humid climate criteria. Although not tied directly to the warm-humid designation, many other code sections, such as those addressing moisture control and energy recovery ventilation systems, do take these climatic features into account.

R301.3 International climate zones. The *climate zone* for any location outside the United States shall be determined by applying Table R301.3(1) and then Table R301.3(2).

❖ Although the code and the climate zone classifications it includes are predominately used in the United States, they can be used in any location. Because the mapping and decisions that were made during the development of the climate zones focused primarily on the United States, this section details how to properly classify the climate zones based on thermal criteria [Table R301.3(2)], the major climate types [Table R301.3(1)] and the warm-humid criteria for locations outside of the United States (see Commentary Figure R301.3).

In developing the climate zone designations, two climate zones were defined in the classification, but not thoroughly evaluated or actively applied because no sites in the United States or its territories required their use. The two climate zones are 1B [dry and greater than 5,000 CDD10°C (9,000 CDD50°F)], characterized as "very hot-dry," and 5C [marine and 3,000 < HDD18°C ≤ 400 (5,400, HDD65°F ≤ 7,200)], characterized as "cool marine." The marine (C) designation was not used for climate zones colder than Climate Zone 5 or hotter than Cimate Zone 3, as marine climates are inherently neither very cold nor very hot. In addition, the humid (A) and dry (B) divisions were dropped for climate zones colder than Climate Zone 6 because they did not appear to be warranted based on differences in appropriate building design requirements. Reevaluation of these decisions might be warranted before applying the new climate classifications to locations outside of the United States.

R301.4 Tropical climate zone. The tropical *climate zone* shall be defined as:

1. Hawaii, Puerto Rico, Guam, American Samoa, U.S. Virgin Islands, Commonwealth of Northern Mariana Islands; and
2. Islands in the area between the Tropic of Cancer and the Tropic of Capricorn.

❖ Tropical areas are quite different from the U.S. mainland in climate, construction techniques, traditional construction and energy prices. Prior to the installation of these new provisions, the IECC treated tropical climates as if they were simply a southern extension of the U.S. mainland. Traditional residences, especially less-expensive residences, have evolved inexpensive ways to work with the tropical climates to provide comfortable interior spaces without the need for substantial space conditioning. Tropical electrical prices, usually over 20 cents per kwh, provide a substantial incentive for energy conservation. Solar water heating works particularly well in tropical climates.

This section provides a simple option for a newly defined climate zone, the "tropical zone." The area between the Tropic of Cancer and the Tropic of Capricorn is the area between 23.5 degrees northern and southern latitude of the equator.

Traditional construction, especially with solar water heating, is usually more energy efficient than the construction style typically assumed in the IECC, as is shown by an analysis done for Puerto Rico. Using energy-efficient versions of traditional construction saves more energy and is much more cost-effective than pushing those in tropical climates to adopt mainland construction practices. Traditional tropical construction focuses on greatly reducing or eliminating the need for space conditioning by making a living space that is comfortable without space conditioning.

These requirements are based on informal conversations with those who live in tropical regions.

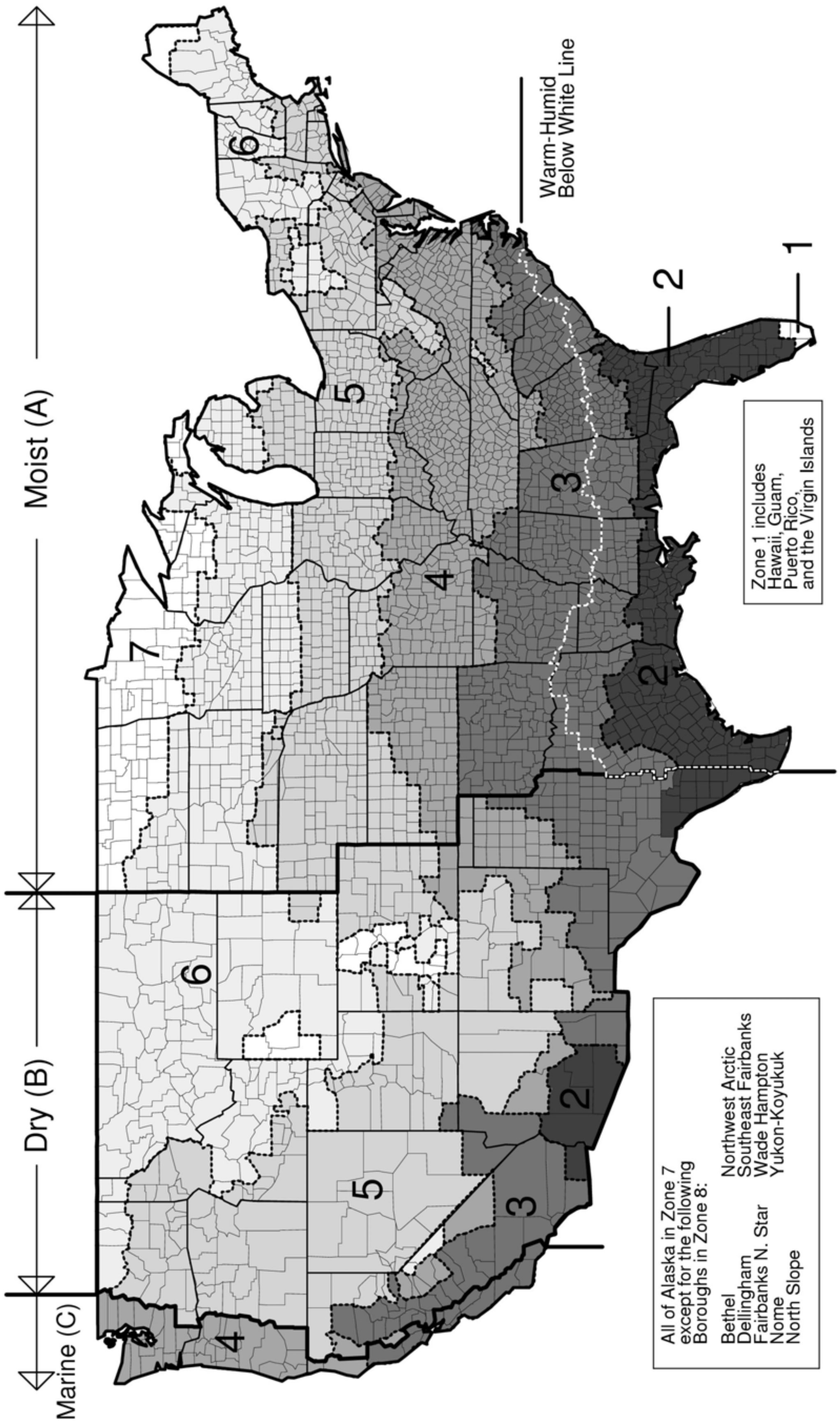


FIGURE R301.1
CLIMATE ZONES

ZONE NUMBER	CLIMATE ZONE NAME AND TYPE[2]	THERMAL CRITERIA [1, 3, 6]	REPRESENTATIVE U.S. CITY[4]
1A	Very Hot-Humid	9000 < CDD50°F	Miami, FL
1B[5]	Very Hot-Dry	9000 < CDD50°F	—
2A	Hot-Humid	6300 < CDD50°F ≤ 9000	Houston, TX
2B	Hot-Dry	6300 < CDD50°F ≤ 9000	Phoenix, AZ
3A	Warm-Humid	4500 < CDD50°F ≤ 6300	Memphis, TN
3B	Warm-Dry	4500 < CDD50°F ≤ 6300	El Paso, TX
3C	Warm-Marine	HDD65°F ≤ 3600	San Francisco, CA
4A	Mixed-Humid	CDD50°F ≤ 4500 AND HDD65°F ≤ 5400	Baltimore, MD
4B	Mixed-Dry	CDD50°F ≤ 4500 AND HDD65°F ≤ 5400	Albuquerque, NM
4C	Mixed-Marine	3600 < HDD65°F ≤ 5400	Salem, OR
5A	Cool-Humid	5400 < HDD65°F ≤ 7200	Chicago, IL
5B	Cool-Dry	5400 < HDD65°F ≤ 7200	Boise, ID
5C[5]	Cool-Marine	5400 < HDD65°F ≤ 7200	—
6A	Cool-Humid	7200 < HDD65°F ≤ 9000	Burlington, VT
6B	Cool-Dry	7200 < HDD65°F ≤ 9000	Helena, MT
7	Very Cold	9000 < HDD65°F ≤ 12600	Duluth, MN
8	Sub Arctic	12600 < HDD65°F	Fairbanks, AK

Notes:

1. Column 1 contains alphanumeric designations for each climate zone. These designations are intended for use when the climate zones are referenced in the code. The numeric part of the designation relates to the thermal properties of the climate zone. The letter part indicates the major climatic group to which the climate zone belongs; A indicates humid, B indicates dry, and C indicates marine. The climatic group designation was dropped for Climate Zones 7 and 8 because the developers of the new climate zone classifications did not anticipate any building design criteria sensitive to the humid/dry/marine distinction in very cold climates. Climate Zones 1B and 5C have been defined but are not used for the United States. Zone 6C [Marine and HDD18ºC > 4000 (HDD65ºF > 7200)] might appear to be necessary for consistency. However, very few locations in the world are both as mild as is required by the marine zone definition and as cold as necessary to accumulate that many heating degree days. In addition, such sites do not appear climatically very different from sites in Zone 6A, which is where they are assigned in the absence of a Zone 6C.
2. Column 2 contains a descriptive name for each climate zone and the major climate type. The names can be used in place of the alphanumeric designations wherever a more descriptive designation is appropriate.
3. Column 3 contains definitions for the climate zone divisions based on degree day cooling and/or heating criteria. The humid/dry/marine divisions must be determined first before these criteria are applied. The definitions in Tables R301.3(1) and R301.3(2) contain logic capable of assigning a climate zone designation to any location with the necessary climate data anywhere in the world. However, the work to develop this classification focused on the 50 United States. Application of the classification to locations outside of the United States is untested.
4. Column 4 contains the name of a SAMSON station (National Climatic Data Center “Solar and Meteorological Surface Observation Network” station) found to best represent the climate zone as a whole. See the discussions at the beginning of this chapter regarding the development of the new climate zones for an explanation of how the representative cities were selected.
5. Climate Zones 1B and 5C do not occur in the United States, and no representative cities were selected for these climate zones due to data limitations. Climates meeting the listed criteria do exist in such locations as Saudi Arabia; British Columbia, Canada; and Northern Europe.
6. SI to I-P Conversions:
   2500 CDD10ºC = 4500 CDD50ºF
   3000 HDD18ºC = 5400 HDD65ºF
   3500 CDD10ºC = 6300 CDD50ºF
   4000 HDD18ºC = 7200 HDD65ºF
   5000 CDD10ºC = 9000 CDD50ºF
   5000 HDD18ºC = 9000 HDD65ºF
   2000 HDD18ºC = 3600 HDD65ºF
   7000 HDD18ºC = 12600 HDD65ºF

Figure R301.3
CLIMATE ZONE DEFINITIONS

TABLE R301.3(1)
INTERNATIONAL CLIMATE ZONE DEFINITIONS

MAJOR CLIMATE TYPE DEFINITIONS
Marine (C) Definition—Locations meeting all four criteria: 1. Mean temperature of coldest month between -3°C (27°F) and 18°C (65°F). 2. Warmest month mean < 22°C (72°F). 3. At least four months with mean temperatures over 10°C (50°F). 4. Dry season in summer. The month with the heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation in the rest of the year. The cold season is October through March in the Northern Hemisphere and April through September in the Southern Hemisphere.
Dry (B) Definition—Locations meeting the following criteria: Not marine and $P_{in} < 0.44 \times (TF - 19.5)$ [$P_{cm} < 2.0 \times (TC + 7)$ in SI units] where: P_{in} = Annual precipitation in inches (cm) T = Annual mean temperature in °F (°C)
Moist (A) Definition—Locations that are not marine and not dry.
Warm-humid Definition—Moist (A) locations where either of the following wet-bulb temperature conditions shall occur during the warmest six consecutive months of the year: 1. 67°F (19.4°C) or higher for 3,000 or more hours; or 2. 73°F (22.8°C) or higher for 1,500 or more hours.

For SI: °C = [(°F)-32]/1.8, 1 inch = 2.54 cm.

TABLE R301.3(2)
INTERNATIONAL CLIMATE ZONE DEFINITIONS

ZONE NUMBER	THERMAL CRITERIA	
	IP Units	SI Units
1	9000 < CDD50°F	5000 < CDD10°C
2	6300 < CDD50°F ≤ 9000	3500 < CDD10°C ≤ 5000
3A and 3B	4500 < CDD50°F ≤ 6300 AND HDD65°F ≤ 5400	2500 < CDD10°C ≤ 3500 AND HDD18°C ≤ 3000
4A and 4B	CDD50°F ≤ 4500 AND HDD65°F ≤ 5400	CDD10°C ≤ 2500 AND HDD18°C ≤ 3000
3C	HDD65°F ≤ 3600	HDD18°C ≤ 2000
4C	3600 < HDD65°F ≤ 5400	2000 < HDD18°C ≤ 3000
5	5400 < HDD65°F ≤ 7200	3000 < HDD18°C ≤ 4000
6	7200 < HDD65°F ≤ 9000	4000 < HDD18°C ≤ 5000
7	9000 < HDD65°F ≤ 12600	5000 < HDD18°C ≤ 7000
8	12600 < HDD65°F	7000 < HDD18°C

For SI: °C = [(°F)-32]/1.8.

TABLE R301.1
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

Key: A – Moist, B – Dry, C – Marine. Absence of moisture designation indicates moisture regime is irrelevant. Asterisk (*) indicates a warm-humid location.

US STATES

ALABAMA

3A Autauga*
2A Baldwin*
3A Barbour*
3A Bibb
3A Blount
3A Bullock*
3A Butler*
3A Calhoun
3A Chambers
3A Cherokee
3A Chilton
3A Choctaw*
3A Clarke*
3A Clay
3A Cleburne
3A Coffee*
3A Colbert
3A Conecuh*
3A Coosa
3A Covington*
3A Crenshaw*
3A Cullman
3A Dale*
3A Dallas*
3A DeKalb
3A Elmore*
3A Escambia*
3A Etowah
3A Fayette
3A Franklin
3A Geneva*
3A Greene
3A Hale
3A Henry*
3A Houston*
3A Jackson
3A Jefferson
3A Lamar
3A Lauderdale
3A Lawrence
3A Lee
3A Limestone
3A Lowndes*
3A Macon*
3A Madison
3A Marengo*
3A Marion
3A Marshall
2A Mobile*
3A Monroe*
3A Montgomery*
3A Morgan
3A Perry*
3A Pickens
3A Pike*
3A Randolph
3A Russell*
3A Shelby
3A St. Clair
3A Sumter
3A Talladega
3A Tallapoosa
3A Tuscaloosa
3A Walker
3A Washington*
3A Wilcox*
3A Winston

ALASKA

7 Aleutians East
7 Aleutians West
7 Anchorage
8 Bethel
7 Bristol Bay
7 Denali
8 Dillingham
8 Fairbanks North Star
7 Haines
7 Juneau
7 Kenai Peninsula
7 Ketchikan Gateway
7 Kodiak Island
7 Lake and Peninsula
7 Matanuska-Susitna
8 Nome
8 North Slope
8 Northwest Arctic
7 Prince of Wales-Outer Ketchikan
7 Sitka
7 Skagway-Hoonah-Angoon
8 Southeast Fairbanks
7 Valdez-Cordova
8 Wade Hampton
7 Wrangell-Petersburg
7 Yakutat
8 Yukon-Koyukuk

ARIZONA

5B Apache
3B Cochise
5B Coconino
4B Gila
3B Graham
3B Greenlee
2B La Paz
2B Maricopa
3B Mohave
5B Navajo
2B Pima
2B Pinal
3B Santa Cruz
4B Yavapai
2B Yuma

ARKANSAS

3A Arkansas
3A Ashley
4A Baxter
4A Benton
4A Boone
3A Bradley
3A Calhoun
4A Carroll
3A Chicot
3A Clark
3A Clay
3A Cleburne
3A Cleveland
3A Columbia*
3A Conway
3A Craighead
3A Crawford
3A Crittenden
3A Cross
3A Dallas
3A Desha
3A Drew
3A Faulkner
3A Franklin
4A Fulton
3A Garland
3A Grant
3A Greene
3A Hempstead*
3A Hot Spring
3A Howard
3A Independence
4A Izard
3A Jackson
3A Jefferson
3A Johnson
3A Lafayette*
3A Lawrence
3A Lee
3A Lincoln
3A Little River*
3A Logan
3A Lonoke
4A Madison
4A Marion
3A Miller*
3A Mississippi
3A Monroe
3A Montgomery
3A Nevada
4A Newton
3A Ouachita
3A Perry
3A Phillips
3A Pike
3A Poinsett
3A Polk
3A Pope
3A Prairie
3A Pulaski
3A Randolph
3A Saline
3A Scott
4A Searcy
3A Sebastian
3A Sevier*
3A Sharp
3A St. Francis
4A Stone
3A Union*
3A Van Buren
4A Washington
3A White
3A Woodruff
3A Yell

CALIFORNIA

3C Alameda
6B Alpine
4B Amador
3B Butte
4B Calaveras
3B Colusa
3B Contra Costa
4C Del Norte
4B El Dorado
3B Fresno
3B Glenn

(continued)

TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

4C Humboldt
2B Imperial
4B Inyo
3B Kern
3B Kings
4B Lake
5B Lassen
3B Los Angeles
3B Madera
3C Marin
4B Mariposa
3C Mendocino
3B Merced
5B Modoc
6B Mono
3C Monterey
3C Napa
5B Nevada
3B Orange
3B Placer
5B Plumas
3B Riverside
3B Sacramento
3C San Benito
3B San Bernardino
3B San Diego
3C San Francisco
3B San Joaquin
3C San Luis Obispo
3C San Mateo
3C Santa Barbara
3C Santa Clara
3C Santa Cruz
3B Shasta
5B Sierra
5B Siskiyou
3B Solano
3C Sonoma
3B Stanislaus
3B Sutter
3B Tehama
4B Trinity
3B Tulare
4B Tuolumne
3C Ventura
3B Yolo
3B Yuba

COLORADO

5B Adams
6B Alamosa
5B Arapahoe
6B Archuleta
4B Baca
5B Bent
5B Boulder
5B Broomfield
6B Chaffee
5B Cheyenne
7 Clear Creek
6B Conejos
6B Costilla
5B Crowley
6B Custer
5B Delta
5B Denver
6B Dolores
5B Douglas
6B Eagle
5B Elbert
5B El Paso
5B Fremont
5B Garfield
5B Gilpin
7 Grand
7 Gunnison
7 Hinsdale
5B Huerfano
7 Jackson
5B Jefferson
5B Kiowa
5B Kit Carson
7 Lake
5B La Plata
5B Larimer
4B Las Animas
5B Lincoln
5B Logan
5B Mesa
7 Mineral
6B Moffat
5B Montezuma
5B Montrose
5B Morgan
4B Otero
6B Ouray
7 Park
5B Phillips
7 Pitkin
5B Prowers
5B Pueblo
6B Rio Blanco
7 Rio Grande
7 Routt
6B Saguache
7 San Juan
6B San Miguel
5B Sedgwick
7 Summit
5B Teller
5B Washington
5B Weld
5B Yuma

CONNECTICUT

5A (all)

DELAWARE

4A (all)

DISTRICT OF COLUMBIA

4A (all)

FLORIDA

2A Alachua*
2A Baker*
2A Bay*
2A Bradford*
2A Brevard*
1A Broward*
2A Calhoun*
2A Charlotte*
2A Citrus*
2A Clay*
2A Collier*
2A Columbia*
2A DeSoto*
2A Dixie*
2A Duval*
2A Escambia*
2A Flagler*
2A Franklin*
2A Gadsden*
2A Gilchrist*
2A Glades*
2A Gulf*
2A Hamilton*
2A Hardee*
2A Hendry*
2A Hernando*
2A Highlands*
2A Hillsborough*
2A Holmes*
2A Indian River*
2A Jackson*
2A Jefferson*
2A Lafayette*
2A Lake*
2A Lee*
2A Leon*
2A Levy*
2A Liberty*
2A Madison*
2A Manatee*
2A Marion*
2A Martin*
1A Miami-Dade*
1A Monroe*
2A Nassau*
2A Okaloosa*
2A Okeechobee*
2A Orange*
2A Osceola*
2A Palm Beach*
2A Pasco*
2A Pinellas*
2A Polk*
2A Putnam*
2A Santa Rosa*
2A Sarasota*
2A Seminole*
2A St. Johns*
2A St. Lucie*
2A Sumter*
2A Suwannee*
2A Taylor*
2A Union*
2A Volusia*
2A Wakulla*
2A Walton*
2A Washington*

GEORGIA

2A Appling*
2A Atkinson*
2A Bacon*
2A Baker*
3A Baldwin
4A Banks
3A Barrow
3A Bartow
3A Ben Hill*
2A Berrien*
3A Bibb
3A Bleckley*
2A Brantley*
2A Brooks*
2A Bryan*
3A Bulloch*
3A Burke
3A Butts
3A Calhoun*
2A Camden*
3A Candler*
3A Carroll
4A Catoosa
2A Charlton*
2A Chatham*
3A Chattahoochee*
4A Chattooga
3A Cherokee
3A Clarke
3A Clay*
3A Clayton
2A Clinch*
3A Cobb
3A Coffee*
2A Colquitt*
3A Columbia
2A Cook*
3A Coweta

(continued)

TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

3A Crawford
3A Crisp*
4A Dade
4A Dawson
2A Decatur*
3A DeKalb
3A Dodge*
3A Dooly*
3A Dougherty*
3A Douglas
3A Early*
2A Echols*
2A Effingham*
3A Elbert
3A Emanuel*
2A Evans*
4A Fannin
3A Fayette
4A Floyd
3A Forsyth
4A Franklin
3A Fulton
4A Gilmer
3A Glascock
2A Glynn*
4A Gordon
2A Grady*
3A Greene
3A Gwinnett
4A Habersham
4A Hall
3A Hancock
3A Haralson
3A Harris
3A Hart
3A Heard
3A Henry
3A Houston*
3A Irwin*
3A Jackson
3A Jasper
2A Jeff Davis*
3A Jefferson
3A Jenkins*
3A Johnson*
3A Jones
3A Lamar
2A Lanier*
3A Laurens*
3A Lee*
2A Liberty*
3A Lincoln
2A Long*
2A Lowndes*
4A Lumpkin
3A Macon*
3A Madison
3A Marion*
3A McDuffie
2A McIntosh*
3A Meriwether
2A Miller*
2A Mitchell*
3A Monroe
3A Montgomery*
3A Morgan
4A Murray
3A Muscogee
3A Newton
3A Oconee
3A Oglethorpe
3A Paulding
3A Peach*
4A Pickens
2A Pierce*
3A Pike
3A Polk
3A Pulaski*
3A Putnam
3A Quitman*
4A Rabun
3A Randolph*
3A Richmond
3A Rockdale
3A Schley*
3A Screven*
2A Seminole*
3A Spalding
4A Stephens
3A Stewart*
3A Sumter*
3A Talbot
3A Taliaferro
2A Tattnall*
3A Taylor*
3A Telfair*
3A Terrell*
2A Thomas*
3A Tift*
2A Toombs*
4A Towns
3A Treutlen*
3A Troup
3A Turner*
3A Twiggs*
4A Union
3A Upson
4A Walker
3A Walton
2A Ware*
3A Warren
3A Washington
2A Wayne*
3A Webster*
3A Wheeler*
4A White
4A Whitfield
3A Wilcox*
3A Wilkes
3A Wilkinson
3A Worth*

HAWAII

1A (all)*

IDAHO

5B Ada
6B Adams
6B Bannock
6B Bear Lake
5B Benewah
6B Bingham
6B Blaine
6B Boise
6B Bonner
6B Bonneville
6B Boundary
6B Butte
6B Camas
5B Canyon
6B Caribou
5B Cassia
6B Clark
5B Clearwater
6B Custer
5B Elmore
6B Franklin
6B Fremont
5B Gem
5B Gooding
5B Idaho
6B Jefferson
5B Jerome
5B Kootenai
5B Latah
6B Lemhi
5B Lewis
5B Lincoln
6B Madison
5B Minidoka
5B Nez Perce
6B Oneida
5B Owyhee
5B Payette
5B Power
5B Shoshone
6B Teton
5B Twin Falls
6B Valley
5B Washington

ILLINOIS

5A Adams
4A Alexander
4A Bond
5A Boone
5A Brown
5A Bureau
5A Calhoun
5A Carroll
5A Cass
5A Champaign
4A Christian
5A Clark
4A Clay
4A Clinton
5A Coles
5A Cook
4A Crawford
5A Cumberland
5A DeKalb
5A De Witt
5A Douglas
5A DuPage
5A Edgar
4A Edwards
4A Effingham
4A Fayette
5A Ford
4A Franklin
5A Fulton
4A Gallatin
5A Greene
5A Grundy
4A Hamilton
5A Hancock
4A Hardin
5A Henderson
5A Henry
5A Iroquois
4A Jackson
4A Jasper
4A Jefferson
5A Jersey
5A Jo Daviess
4A Johnson
5A Kane
5A Kankakee
5A Kendall
5A Knox
5A Lake
5A La Salle
4A Lawrence
5A Lee
5A Livingston
5A Logan
5A Macon
4A Macoupin
4A Madison
4A Marion
5A Marshall
5A Mason
4A Massac
5A McDonough
5A McHenry

(continued)

TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

5A McLean
5A Menard
5A Mercer
4A Monroe
4A Montgomery
5A Morgan
5A Moultrie
5A Ogle
5A Peoria
4A Perry
5A Piatt
5A Pike
4A Pope
4A Pulaski
5A Putnam
4A Randolph
4A Richland
5A Rock Island
4A Saline
5A Sangamon
5A Schuyler
5A Scott
4A Shelby
5A Stark
4A St. Clair
5A Stephenson
5A Tazewell
4A Union
5A Vermilion
4A Wabash
5A Warren
4A Washington
4A Wayne
4A White
5A Whiteside
5A Will
4A Williamson
5A Winnebago
5A Woodford

INDIANA

5A Adams
5A Allen
5A Bartholomew
5A Benton
5A Blackford
5A Boone
4A Brown
5A Carroll
5A Cass
4A Clark
5A Clay
5A Clinton
4A Crawford
4A Daviess
4A Dearborn
5A Decatur
5A De Kalb
5A Delaware
4A Dubois
5A Elkhart
5A Fayette
4A Floyd
5A Fountain
5A Franklin
5A Fulton
4A Gibson
5A Grant
4A Greene
5A Hamilton
5A Hancock
4A Harrison
5A Hendricks
5A Henry
5A Howard
5A Huntington
4A Jackson
5A Jasper
5A Jay
4A Jefferson
4A Jennings
5A Johnson
4A Knox
5A Kosciusko
5A LaGrange
5A Lake
5A LaPorte
4A Lawrence
5A Madison
5A Marion
5A Marshall
4A Martin
5A Miami
4A Monroe
5A Montgomery
5A Morgan
5A Newton
5A Noble
4A Ohio
4A Orange
5A Owen
5A Parke
4A Perry
4A Pike
5A Porter
4A Posey
5A Pulaski
5A Putnam
5A Randolph
4A Ripley
5A Rush
4A Scott
5A Shelby
4A Spencer
5A Starke
5A Steuben
5A St. Joseph
4A Sullivan
4A Switzerland
5A Tippecanoe
5A Tipton
5A Union
4A Vanderburgh
5A Vermillion
5A Vigo
5A Wabash
5A Warren
4A Warrick
4A Washington
5A Wayne
5A Wells
5A White
5A Whitley

IOWA

5A Adair
5A Adams
6A Allamakee
5A Appanoose
5A Audubon
5A Benton
6A Black Hawk
5A Boone
6A Bremer
6A Buchanan
6A Buena Vista
6A Butler
6A Calhoun
5A Carroll
5A Cass
5A Cedar
6A Cerro Gordo
6A Cherokee
6A Chickasaw
5A Clarke
6A Clay
6A Clayton
5A Clinton
5A Crawford
5A Dallas
5A Davis
5A Decatur
6A Delaware
5A Des Moines
6A Dickinson
5A Dubuque
6A Emmet
6A Fayette
6A Floyd
6A Franklin
5A Fremont
5A Greene
6A Grundy
5A Guthrie
6A Hamilton
6A Hancock
6A Hardin
5A Harrison
5A Henry
6A Howard
6A Humboldt
6A Ida
5A Iowa
5A Jackson
5A Jasper
5A Jefferson
5A Johnson
5A Jones
5A Keokuk
6A Kossuth
5A Lee
5A Linn
5A Louisa
5A Lucas
6A Lyon
5A Madison
5A Mahaska
5A Marion
5A Marshall
5A Mills
6A Mitchell
5A Monona
5A Monroe
5A Montgomery
5A Muscatine
6A O'Brien
6A Osceola
5A Page
6A Palo Alto
6A Plymouth
6A Pocahontas
5A Polk
5A Pottawattamie
5A Poweshiek
5A Ringgold
6A Sac
5A Scott
5A Shelby
6A Sioux
5A Story
5A Tama
5A Taylor
5A Union
5A Van Buren
5A Wapello
5A Warren
5A Washington
5A Wayne
6A Webster
6A Winnebago

(continued)

**TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID
DESIGNATIONS BY STATE, COUNTY AND TERRITORY**

6A Winneshiek
5A Woodbury
6A Worth
6A Wright

KANSAS

4A Allen
4A Anderson
4A Atchison
4A Barber
4A Barton
4A Bourbon
4A Brown
4A Butler
4A Chase
4A Chautauqua
4A Cherokee
5A Cheyenne
4A Clark
4A Clay
5A Cloud
4A Coffey
4A Comanche
4A Cowley
4A Crawford
5A Decatur
4A Dickinson
4A Doniphan
4A Douglas
4A Edwards
4A Elk
5A Ellis
4A Ellsworth
4A Finney
4A Ford
4A Franklin
4A Geary
5A Gove
5A Graham
4A Grant
4A Gray
5A Greeley
4A Greenwood
5A Hamilton
4A Harper
4A Harvey
4A Haskell
4A Hodgeman
4A Jackson
4A Jefferson
5A Jewell
4A Johnson
4A Kearny
4A Kingman
4A Kiowa
4A Labette
5A Lane
4A Leavenworth
4A Lincoln
4A Linn
5A Logan
4A Lyon
4A Marion
4A Marshall
4A McPherson
4A Meade
4A Miami
5A Mitchell
4A Montgomery
4A Morris
4A Morton
4A Nemaha
4A Neosho
5A Ness
5A Norton
4A Osage
5A Osborne
4A Ottawa
4A Pawnee
5A Phillips
4A Pottawatomie
4A Pratt
5A Rawlins
4A Reno
5A Republic
4A Rice
4A Riley
5A Rooks
4A Rush
4A Russell
4A Saline
5A Scott
4A Sedgwick
4A Seward
4A Shawnee
5A Sheridan
5A Sherman
5A Smith
4A Stafford
4A Stanton
4A Stevens
4A Sumner
5A Thomas
5A Trego
4A Wabaunsee
5A Wallace
4A Washington
5A Wichita
4A Wilson
4A Woodson
4A Wyandotte

KENTUCKY

4A (all)

LOUISIANA

2A Acadia*
2A Allen*
2A Ascension*
2A Assumption*
2A Avoyelles*
2A Beauregard*
3A Bienville*
3A Bossier*
3A Caddo*
2A Calcasieu*
3A Caldwell*
2A Cameron*
3A Catahoula*
3A Claiborne*
3A Concordia*
3A De Soto*
2A East Baton Rouge*
3A East Carroll
2A East Feliciana*
2A Evangeline*
3A Franklin*
3A Grant*
2A Iberia*
2A Iberville*
3A Jackson*
2A Jefferson*
2A Jefferson Davis*
2A Lafayette*
2A Lafourche*
3A La Salle*
3A Lincoln*
2A Livingston*
3A Madison*
3A Morehouse
3A Natchitoches*
2A Orleans*
3A Ouachita*
2A Plaquemines*
2A Pointe Coupee*
2A Rapides*
3A Red River*
3A Richland*
3A Sabine*
2A St. Bernard*
2A St. Charles*
2A St. Helena*
2A St. James*
2A St. John the Baptist*
2A St. Landry*
2A St. Martin*
2A St. Mary*
2A St. Tammany*
2A Tangipahoa*
3A Tensas*
2A Terrebonne*
3A Union*
2A Vermilion*
3A Vernon*
2A Washington*
3A Webster*
2A West Baton Rouge*
3A West Carroll
2A West Feliciana*
3A Winn*

MAINE

6A Androscoggin
7 Aroostook
6A Cumberland
6A Franklin
6A Hancock
6A Kennebec
6A Knox
6A Lincoln
6A Oxford
6A Penobscot
6A Piscataquis
6A Sagadahoc
6A Somerset
6A Waldo
6A Washington
6A York

MARYLAND

4A Allegany
4A Anne Arundel
4A Baltimore
4A Baltimore (city)
4A Calvert
4A Caroline
4A Carroll
4A Cecil
4A Charles
4A Dorchester
4A Frederick
5A Garrett
4A Harford
4A Howard
4A Kent
4A Montgomery
4A Prince George's
4A Queen Anne's
4A Somerset
4A St. Mary's
4A Talbot
4A Washington
4A Wicomico
4A Worcester

MASSACHSETTS

5A (all)

MICHIGAN

6A Alcona
6A Alger

(continued)

TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

5A Allegan
6A Alpena
6A Antrim
6A Arenac
7 Baraga
5A Barry
5A Bay
6A Benzie
5A Berrien
5A Branch
5A Calhoun
5A Cass
6A Charlevoix
6A Cheboygan
7 Chippewa
6A Clare
5A Clinton
6A Crawford
6A Delta
6A Dickinson
5A Eaton
6A Emmet
5A Genesee
6A Gladwin
7 Gogebic
6A Grand Traverse
5A Gratiot
5A Hillsdale
7 Houghton
6A Huron
5A Ingham
5A Ionia
6A Iosco
7 Iron
6A Isabella
5A Jackson
5A Kalamazoo
6A Kalkaska
5A Kent
7 Keweenaw
6A Lake
5A Lapeer
6A Leelanau
5A Lenawee
5A Livingston
7 Luce
7 Mackinac
5A Macomb
6A Manistee
6A Marquette
6A Mason
6A Mecosta
6A Menominee
5A Midland
6A Missaukee
5A Monroe
5A Montcalm
6A Montmorency
5A Muskegon
6A Newaygo
5A Oakland
6A Oceana
6A Ogemaw
7 Ontonagon
6A Osceola
6A Oscoda
6A Otsego
5A Ottawa
6A Presque Isle
6A Roscommon
5A Saginaw
6A Sanilac
7 Schoolcraft
5A Shiawassee
5A St. Clair
5A St. Joseph
5A Tuscola
5A Van Buren
5A Washtenaw
5A Wayne
6A Wexford

MINNESOTA

7 Aitkin
6A Anoka
7 Becker
7 Beltrami
6A Benton
6A Big Stone
6A Blue Earth
6A Brown
7 Carlton
6A Carver
7 Cass
6A Chippewa
6A Chisago
7 Clay
7 Clearwater
7 Cook
6A Cottonwood
7 Crow Wing
6A Dakota
6A Dodge
6A Douglas
6A Faribault
6A Fillmore
6A Freeborn
6A Goodhue
7 Grant
6A Hennepin
6A Houston
7 Hubbard
6A Isanti
7 Itasca
6A Jackson
7 Kanabec
6A Kandiyohi
7 Kittson
7 Koochiching
6A Lac qui Parle
7 Lake
7 Lake of the Woods
6A Le Sueur
6A Lincoln
6A Lyon
7 Mahnomen
7 Marshall
6A Martin
6A McLeod
6A Meeker
7 Mille Lacs
6A Morrison
6A Mower
6A Murray
6A Nicollet
6A Nobles
7 Norman
6A Olmsted
7 Otter Tail
7 Pennington
7 Pine
6A Pipestone
7 Polk
6A Pope
6A Ramsey
7 Red Lake
6A Redwood
6A Renville
6A Rice
6A Rock
7 Roseau
6A Scott
6A Sherburne
6A Sibley
6A Stearns
6A Steele
6A Stevens
7 St. Louis
6A Swift
6A Todd
6A Traverse
6A Wabasha
7 Wadena
6A Waseca
6A Washington
6A Watonwan
7 Wilkin
6A Winona
6A Wright
6A Yellow Medicine

MISSISSIPPI

3A Adams*
3A Alcorn
3A Amite*
3A Attala
3A Benton
3A Bolivar
3A Calhoun
3A Carroll
3A Chickasaw
3A Choctaw
3A Claiborne*
3A Clarke
3A Clay
3A Coahoma
3A Copiah*
3A Covington*
3A DeSoto
3A Forrest*
3A Franklin*
3A George*
3A Greene*
3A Grenada
2A Hancock*
2A Harrison*
3A Hinds*
3A Holmes
3A Humphreys
3A Issaquena
3A Itawamba
2A Jackson*
3A Jasper
3A Jefferson*
3A Jefferson Davis*
3A Jones*
3A Kemper
3A Lafayette
3A Lamar*
3A Lauderdale
3A Lawrence*
3A Leake
3A Lee
3A Leflore
3A Lincoln*
3A Lowndes
3A Madison
3A Marion*
3A Marshall
3A Monroe
3A Montgomery
3A Neshoba
3A Newton
3A Noxubee
3A Oktibbeha
3A Panola
2A Pearl River*
3A Perry*
3A Pike*

(continued)

TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

3A Pontotoc
3A Prentiss
3A Quitman
3A Rankin*
3A Scott
3A Sharkey
3A Simpson*
3A Smith*
2A Stone*
3A Sunflower
3A Tallahatchie
3A Tate
3A Tippah
3A Tishomingo
3A Tunica
3A Union
3A Walthall*
3A Warren*
3A Washington
3A Wayne*
3A Webster
3A Wilkinson*
3A Winston
3A Yalobusha
3A Yazoo

MISSOURI

5A Adair
5A Andrew
5A Atchison
4A Audrain
4A Barry
4A Barton
4A Bates
4A Benton
4A Bollinger
4A Boone
5A Buchanan
4A Butler
5A Caldwell
4A Callaway
4A Camden
4A Cape Girardeau
4A Carroll
4A Carter
4A Cass
4A Cedar
5A Chariton
4A Christian
5A Clark
4A Clay
5A Clinton
4A Cole
4A Cooper
4A Crawford
4A Dade
4A Dallas
5A Daviess
5A DeKalb
4A Dent
4A Douglas
4A Dunklin
4A Franklin
4A Gasconade
5A Gentry
4A Greene
5A Grundy
5A Harrison
4A Henry
4A Hickory
5A Holt
4A Howard
4A Howell
4A Iron
4A Jackson
4A Jasper
4A Jefferson
4A Johnson
5A Knox
4A Laclede
4A Lafayette
4A Lawrence
5A Lewis
4A Lincoln
5A Linn
5A Livingston
5A Macon
4A Madison
4A Maries
5A Marion
4A McDonald
5A Mercer
4A Miller
4A Mississippi
4A Moniteau
4A Monroe
4A Montgomery
4A Morgan
4A New Madrid
4A Newton
5A Nodaway
4A Oregon
4A Osage
4A Ozark
4A Pemiscot
4A Perry
4A Pettis
4A Phelps
5A Pike
4A Platte
4A Polk
4A Pulaski
5A Putnam
5A Ralls
4A Randolph
4A Ray
4A Reynolds
4A Ripley
4A Saline
5A Schuyler
5A Scotland
4A Scott
4A Shannon
5A Shelby
4A St. Charles
4A St. Clair
4A St. Francois
4A St. Louis
4A St. Louis (city)
4A Ste. Genevieve
4A Stoddard
4A Stone
5A Sullivan
4A Taney
4A Texas
4A Vernon
4A Warren
4A Washington
4A Wayne
4A Webster
5A Worth
4A Wright

MONTANA

6B (all)

NEBRASKA

5A (all)

NEVADA

5B Carson City (city)
5B Churchill
3B Clark
5B Douglas
5B Elko
5B Esmeralda
5B Eureka
5B Humboldt
5B Lander
5B Lincoln
5B Lyon
5B Mineral
5B Nye
5B Pershing
5B Storey
5B Washoe
5B White Pine

NEW HAMPSHIRE

6A Belknap
6A Carroll
5A Cheshire
6A Coos
6A Grafton
5A Hillsborough
6A Merrimack
5A Rockingham
5A Strafford
6A Sullivan

NEW JERSEY

4A Atlantic
5A Bergen
4A Burlington
4A Camden
4A Cape May
4A Cumberland
4A Essex
4A Gloucester
4A Hudson
5A Hunterdon
5A Mercer
4A Middlesex
4A Monmouth
5A Morris
4A Ocean
5A Passaic
4A Salem
5A Somerset
5A Sussex
4A Union
5A Warren

NEW MEXICO

4B Bernalillo
5B Catron
3B Chaves
4B Cibola
5B Colfax
4B Curry
4B DeBaca
3B Dona Ana
3B Eddy
4B Grant
4B Guadalupe
5B Harding
3B Hidalgo
3B Lea
4B Lincoln
5B Los Alamos
3B Luna
5B McKinley
5B Mora
3B Otero
4B Quay
5B Rio Arriba
4B Roosevelt
5B Sandoval
5B San Juan
5B San Miguel
5B Santa Fe
4B Sierra
4B Socorro

(continued)

TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

5B Taos
5B Torrance
4B Union
4B Valencia

NEW YORK

5A Albany
6A Allegany
4A Bronx
6A Broome
6A Cattaraugus
5A Cayuga
5A Chautauqua
5A Chemung
6A Chenango
6A Clinton
5A Columbia
5A Cortland
6A Delaware
5A Dutchess
5A Erie
6A Essex
6A Franklin
6A Fulton
5A Genesee
5A Greene
6A Hamilton
6A Herkimer
6A Jefferson
4A Kings
6A Lewis
5A Livingston
6A Madison
5A Monroe
6A Montgomery
4A Nassau
4A New York
5A Niagara
6A Oneida
5A Onondaga
5A Ontario
5A Orange
5A Orleans
5A Oswego
6A Otsego
5A Putnam
4A Queens
5A Rensselaer
4A Richmond
5A Rockland
5A Saratoga
5A Schenectady
6A Schoharie
6A Schuyler
5A Seneca
6A Steuben
6A St. Lawrence
4A Suffolk
6A Sullivan
5A Tioga
6A Tompkins
6A Ulster
6A Warren
5A Washington
5A Wayne
4A Westchester
6A Wyoming
5A Yates

NORTH CAROLINA

4A Alamance
4A Alexander
5A Alleghany
3A Anson
5A Ashe
5A Avery
3A Beaufort
4A Bertie
3A Bladen
3A Brunswick*
4A Buncombe
4A Burke
3A Cabarrus
4A Caldwell
3A Camden
3A Carteret*
4A Caswell
4A Catawba
4A Chatham
4A Cherokee
3A Chowan
4A Clay
4A Cleveland
3A Columbus*
3A Craven
3A Cumberland
3A Currituck
3A Dare
3A Davidson
4A Davie
3A Duplin
4A Durham
3A Edgecombe
4A Forsyth
4A Franklin
3A Gaston
4A Gates
4A Graham
4A Granville
3A Greene
4A Guilford
4A Halifax
4A Harnett
4A Haywood
4A Henderson
4A Hertford
3A Hoke
3A Hyde
4A Iredell
4A Jackson
3A Johnston
3A Jones
4A Lee
3A Lenoir
4A Lincoln
4A Macon
4A Madison
3A Martin
4A McDowell
3A Mecklenburg
5A Mitchell
3A Montgomery
3A Moore
4A Nash
3A New Hanover*
4A Northampton
3A Onslow*
4A Orange
3A Pamlico
3A Pasquotank
3A Pender*
3A Perquimans
4A Person
3A Pitt
4A Polk
3A Randolph
3A Richmond
3A Robeson
4A Rockingham
3A Rowan
4A Rutherford
3A Sampson
3A Scotland
3A Stanly
4A Stokes
4A Surry
4A Swain
4A Transylvania
3A Tyrrell
3A Union
4A Vance
4A Wake
4A Warren
3A Washington
5A Watauga
3A Wayne
4A Wilkes
3A Wilson
4A Yadkin
5A Yancey

NORTH DAKOTA

6A Adams
7 Barnes
7 Benson
6A Billings
7 Bottineau
6A Bowman
7 Burke
6A Burleigh
7 Cass
7 Cavalier
6A Dickey
7 Divide
6A Dunn
7 Eddy
6A Emmons
7 Foster
6A Golden Valley
7 Grand Forks
6A Grant
7 Griggs
6A Hettinger
7 Kidder
6A LaMoure
6A Logan
7 McHenry
6A McIntosh
6A McKenzie
7 McLean
6A Mercer
6A Morton
7 Mountrail
7 Nelson
6A Oliver
7 Pembina
7 Pierce
7 Ramsey
6A Ransom
7 Renville
6A Richland
7 Rolette
6A Sargent
7 Sheridan
6A Sioux
6A Slope
6A Stark
7 Steele
7 Stutsman
7 Towner
7 Traill
7 Walsh
7 Ward
7 Wells
7 Williams

OHIO

4A Adams
5A Allen

(continued)

TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

5A Ashland
5A Ashtabula
5A Athens
5A Auglaize
5A Belmont
4A Brown
5A Butler
5A Carroll
5A Champaign
5A Clark
4A Clermont
5A Clinton
5A Columbiana
5A Coshocton
5A Crawford
5A Cuyahoga
5A Darke
5A Defiance
5A Delaware
5A Erie
5A Fairfield
5A Fayette
5A Franklin
5A Fulton
4A Gallia
5A Geauga
5A Greene
5A Guernsey
4A Hamilton
5A Hancock
5A Hardin
5A Harrison
5A Henry
5A Highland
5A Hocking
5A Holmes
5A Huron
5A Jackson
5A Jefferson
5A Knox
5A Lake
4A Lawrence
5A Licking
5A Logan
5A Lorain
5A Lucas
5A Madison
5A Mahoning
5A Marion
5A Medina
5A Meigs
5A Mercer
5A Miami
5A Monroe
5A Montgomery
5A Morgan
5A Morrow
5A Muskingum
5A Noble
5A Ottawa
5A Paulding
5A Perry
5A Pickaway
4A Pike
5A Portage
5A Preble
5A Putnam
5A Richland
5A Ross
5A Sandusky
4A Scioto
5A Seneca
5A Shelby
5A Stark
5A Summit
5A Trumbull
5A Tuscarawas
5A Union
5A Van Wert
5A Vinton
5A Warren
4A Washington
5A Wayne
5A Williams
5A Wood
5A Wyandot

OKLAHOMA

3A Adair
3A Alfalfa
3A Atoka
4B Beaver
3A Beckham
3A Blaine
3A Bryan
3A Caddo
3A Canadian
3A Carter
3A Cherokee
3A Choctaw
4B Cimarron
3A Cleveland
3A Coal
3A Comanche
3A Cotton
3A Craig
3A Creek
3A Custer
3A Delaware
3A Dewey
3A Ellis
3A Garfield
3A Garvin
3A Grady
3A Grant
3A Greer
3A Harmon
3A Harper
3A Haskell
3A Hughes
3A Jackson
3A Jefferson
3A Johnston
3A Kay
3A Kingfisher
3A Kiowa
3A Latimer
3A Le Flore
3A Lincoln
3A Logan
3A Love
3A Major
3A Marshall
3A Mayes
3A McClain
3A McCurtain
3A McIntosh
3A Murray
3A Muskogee
3A Noble
3A Nowata
3A Okfuskee
3A Oklahoma
3A Okmulgee
3A Osage
3A Ottawa
3A Pawnee
3A Payne
3A Pittsburg
3A Pontotoc
3A Pottawatomie
3A Pushmataha
3A Roger Mills
3A Rogers
3A Seminole
3A Sequoyah
3A Stephens
4B Texas
3A Tillman
3A Tulsa
3A Wagoner
3A Washington
3A Washita
3A Woods
3A Woodward

OREGON

5B Baker
4C Benton
4C Clackamas
4C Clatsop
4C Columbia
4C Coos
5B Crook
4C Curry
5B Deschutes
4C Douglas
5B Gilliam
5B Grant
5B Harney
5B Hood River
4C Jackson
5B Jefferson
4C Josephine
5B Klamath
5B Lake
4C Lane
4C Lincoln
4C Linn
5B Malheur
4C Marion
5B Morrow
4C Multnomah
4C Polk
5B Sherman
4C Tillamook
5B Umatilla
5B Union
5B Wallowa
5B Wasco
4C Washington
5B Wheeler
4C Yamhill

PENNSYLVANIA

5A Adams
5A Allegheny
5A Armstrong
5A Beaver
5A Bedford
5A Berks
5A Blair
5A Bradford
4A Bucks
5A Butler
5A Cambria
6A Cameron
5A Carbon
5A Centre
4A Chester
5A Clarion
6A Clearfield
5A Clinton
5A Columbia
5A Crawford
5A Cumberland
5A Dauphin
4A Delaware
6A Elk
5A Erie
5A Fayette
5A Forest
5A Franklin
5A Fulton
5A Greene

(continued)

TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

5A Huntingdon
5A Indiana
5A Jefferson
5A Juniata
5A Lackawanna
5A Lancaster
5A Lawrence
5A Lebanon
5A Lehigh
5A Luzerne
5A Lycoming
6A McKean
5A Mercer
5A Mifflin
5A Monroe
4A Montgomery
5A Montour
5A Northampton
5A Northumberland
5A Perry
4A Philadelphia
5A Pike
6A Potter
5A Schuylkill
5A Snyder
5A Somerset
5A Sullivan
6A Susquehanna
6A Tioga
5A Union
5A Venango
5A Warren
5A Washington
6A Wayne
5A Westmoreland
5A Wyoming
4A York

RHODE ISLAND

5A (all)

SOUTH CAROLINA

3A Abbeville
3A Aiken
3A Allendale*
3A Anderson
3A Bamberg*
3A Barnwell*
3A Beaufort*
3A Berkeley*
3A Calhoun
3A Charleston*
3A Cherokee
3A Chester
3A Chesterfield
3A Clarendon
3A Colleton*
3A Darlington
3A Dillon
3A Dorchester*
3A Edgefield
3A Fairfield
3A Florence
3A Georgetown*
3A Greenville
3A Greenwood
3A Hampton*
3A Horry*
3A Jasper*
3A Kershaw
3A Lancaster
3A Laurens
3A Lee
3A Lexington
3A Marion
3A Marlboro
3A McCormick
3A Newberry
3A Oconee
3A Orangeburg
3A Pickens
3A Richland
3A Saluda
3A Spartanburg
3A Sumter
3A Union
3A Williamsburg
3A York

SOUTH DAKOTA

6A Aurora
6A Beadle
5A Bennett
5A Bon Homme
6A Brookings
6A Brown
6A Brule
6A Buffalo
6A Butte
6A Campbell
5A Charles Mix
6A Clark
5A Clay
6A Codington
6A Corson
6A Custer
6A Davison
6A Day
6A Deuel
6A Dewey
5A Douglas
6A Edmunds
6A Fall River
6A Faulk
6A Grant
5A Gregory
6A Haakon
6A Hamlin
6A Hand
6A Hanson
6A Harding
6A Hughes
5A Hutchinson
6A Hyde
5A Jackson
6A Jerauld
6A Jones
6A Kingsbury
6A Lake
6A Lawrence
6A Lincoln
6A Lyman
6A Marshall
6A McCook
6A McPherson
6A Meade
5A Mellette
6A Miner
6A Minnehaha
6A Moody
6A Pennington
6A Perkins
6A Potter
6A Roberts
6A Sanborn
6A Shannon
6A Spink
6A Stanley
6A Sully
5A Todd
5A Tripp
6A Turner
5A Union
6A Walworth
5A Yankton
6A Ziebach

TENNESSEE

4A Anderson
4A Bedford
4A Benton
4A Bledsoe
4A Blount
4A Bradley
4A Campbell
4A Cannon
4A Carroll
4A Carter
4A Cheatham
3A Chester
4A Claiborne
4A Clay
4A Cocke
4A Coffee
3A Crockett
4A Cumberland
4A Davidson
4A Decatur
4A DeKalb
4A Dickson
3A Dyer
3A Fayette
4A Fentress
4A Franklin
4A Gibson
4A Giles
4A Grainger
4A Greene
4A Grundy
4A Hamblen
4A Hamilton
4A Hancock
3A Hardeman
3A Hardin
4A Hawkins
3A Haywood
3A Henderson
4A Henry
4A Hickman
4A Houston
4A Humphreys
4A Jackson
4A Jefferson
4A Johnson
4A Knox
3A Lake
3A Lauderdale
4A Lawrence
4A Lewis
4A Lincoln
4A Loudon
4A Macon
3A Madison
4A Marion
4A Marshall
4A Maury
4A McMinn
3A McNairy
4A Meigs
4A Monroe
4A Montgomery
4A Moore
4A Morgan
4A Obion
4A Overton
4A Perry
4A Pickett
4A Polk
4A Putnam
4A Rhea

(continued)

TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

4A Roane
4A Robertson
4A Rutherford
4A Scott
4A Sequatchie
4A Sevier
3A Shelby
4A Smith
4A Stewart
4A Sullivan
4A Sumner
3A Tipton
4A Trousdale
4A Unicoi
4A Union
4A Van Buren
4A Warren
4A Washington
4A Wayne
4A Weakley
4A White
4A Williamson
4A Wilson

TEXAS

2A Anderson*
3B Andrews
2A Angelina*
2A Aransas*
3A Archer
4B Armstrong
2A Atascosa*
2A Austin*
4B Bailey
2B Bandera
2A Bastrop*
3B Baylor
2A Bee*
2A Bell*
2A Bexar*
3A Blanco*
3B Borden
2A Bosque*
3A Bowie*
2A Brazoria*
2A Brazos*
3B Brewster
4B Briscoe
2A Brooks*
3A Brown*
2A Burleson*
3A Burnet*
2A Caldwell*
2A Calhoun*
3B Callahan
2A Cameron*
3A Camp*
4B Carson
3A Cass*
4B Castro
2A Chambers*
2A Cherokee*
3B Childress
3A Clay
4B Cochran
3B Coke
3B Coleman
3A Collin*
3B Collingsworth
2A Colorado*
2A Comal*
3A Comanche*
3B Concho
3A Cooke
2A Coryell*
3B Cottle
3B Crane
3B Crockett
3B Crosby
3B Culberson
4B Dallam
3A Dallas*
3B Dawson
4B Deaf Smith
3A Delta
3A Denton*
2A DeWitt*
3B Dickens
2B Dimmit
4B Donley
2A Duval*
3A Eastland
3B Ector
2B Edwards
3A Ellis*
3B El Paso
3A Erath*
2A Falls*
3A Fannin
2A Fayette*
3B Fisher
4B Floyd
3B Foard
2A Fort Bend*
3A Franklin*
2A Freestone*
2B Frio
3B Gaines
2A Galveston*
3B Garza
3A Gillespie*
3B Glasscock
2A Goliad*
2A Gonzales*
4B Gray
3A Grayson
3A Gregg*
2A Grimes*
2A Guadalupe*
4B Hale
3B Hall
3A Hamilton*
4B Hansford
3B Hardeman
2A Hardin*
2A Harris*
3A Harrison*
4B Hartley
3B Haskell
2A Hays*
3B Hemphill
3A Henderson*
2A Hidalgo*
2A Hill*
4B Hockley
3A Hood*
3A Hopkins*
2A Houston*
3B Howard
3B Hudspeth
3A Hunt*
4B Hutchinson
3B Irion
3A Jack
2A Jackson*
2A Jasper*
3B Jeff Davis
2A Jefferson*
2A Jim Hogg*
2A Jim Wells*
3A Johnson*
3B Jones
2A Karnes*
3A Kaufman*
3A Kendall*
2A Kenedy*
3B Kent
3B Kerr
3B Kimble
3B King
2B Kinney
2A Kleberg*
3B Knox
3A Lamar*
4B Lamb
3A Lampasas*
2B La Salle
2A Lavaca*
2A Lee*
2A Leon*
2A Liberty*
2A Limestone*
4B Lipscomb
2A Live Oak*
3A Llano*
3B Loving
3B Lubbock
3B Lynn
2A Madison*
3A Marion*
3B Martin
3B Mason
2A Matagorda*
2B Maverick
3B McCulloch
2A McLennan*
2A McMullen*
2B Medina
3B Menard
3B Midland
2A Milam*
3A Mills*
3B Mitchell
3A Montague
2A Montgomery*
4B Moore
3A Morris*
3B Motley
3A Nacogdoches*
3A Navarro*
2A Newton*
3B Nolan
2A Nueces*
4B Ochiltree
4B Oldham
2A Orange*
3A Palo Pinto*
3A Panola*
3A Parker*
4B Parmer
3B Pecos
2A Polk*
4B Potter
3B Presidio
3A Rains*
4B Randall
3B Reagan
2B Real
3A Red River*
3B Reeves
2A Refugio*
4B Roberts
2A Robertson*
3A Rockwall*
3B Runnels
3A Rusk*
3A Sabine*
3A San Augustine*
2A San Jacinto*
2A San Patricio*

(continued)

TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

3A San Saba*
3B Schleicher
3B Scurry
3B Shackelford
3A Shelby*
4B Sherman
3A Smith*
3A Somervell*
2A Starr*
3A Stephens
3B Sterling
3B Stonewall
3B Sutton
4B Swisher
3A Tarrant*
3B Taylor
3B Terrell
3B Terry
3B Throckmorton
3A Titus*
3B Tom Green
2A Travis*
2A Trinity*
2A Tyler*
3A Upshur*
3B Upton
2B Uvalde
2B Val Verde
3A Van Zandt*
2A Victoria*
2A Walker*
2A Waller*
3B Ward
2A Washington*
2B Webb
2A Wharton*
3B Wheeler
3A Wichita
3B Wilbarger
2A Willacy*
2A Williamson*
2A Wilson*
3B Winkler
3A Wise
3A Wood*
4B Yoakum
3A Young
2B Zapata
2B Zavala

UTAH

5B Beaver
6B Box Elder
6B Cache
6B Carbon
6B Daggett
5B Davis
6B Duchesne
5B Emery
5B Garfield
5B Grand
5B Iron
5B Juab
5B Kane
5B Millard
6B Morgan
5B Piute
6B Rich
5B Salt Lake
5B San Juan
5B Sanpete
5B Sevier
6B Summit
5B Tooele
6B Uintah
5B Utah
6B Wasatch
3B Washington
5B Wayne
5B Weber

VERMONT

6A (all)

VIRGINIA

4A (all)

WASHINGTON

5B Adams
5B Asotin
5B Benton
5B Chelan
4C Clallam
4C Clark
5B Columbia
4C Cowlitz
5B Douglas
6B Ferry
5B Franklin
5B Garfield
5B Grant
4C Grays Harbor
4C Island
4C Jefferson
4C King
4C Kitsap
5B Kittitas
5B Klickitat
4C Lewis
5B Lincoln
4C Mason
6B Okanogan
4C Pacific
6B Pend Oreille
4C Pierce
4C San Juan
4C Skagit
5B Skamania
4C Snohomish
5B Spokane
6B Stevens
4C Thurston
4C Wahkiakum
5B Walla Walla
4C Whatcom
5B Whitman
5B Yakima

WEST VIRGINIA

5A Barbour
4A Berkeley
4A Boone
4A Braxton
5A Brooke
4A Cabell
4A Calhoun
4A Clay
5A Doddridge
5A Fayette
4A Gilmer
5A Grant
5A Greenbrier
5A Hampshire
5A Hancock
5A Hardy
5A Harrison
4A Jackson
4A Jefferson
4A Kanawha
5A Lewis
4A Lincoln
4A Logan
5A Marion
5A Marshall
4A Mason
4A McDowell
4A Mercer
5A Mineral
4A Mingo
5A Monongalia
4A Monroe
4A Morgan
5A Nicholas
5A Ohio
5A Pendleton
4A Pleasants
5A Pocahontas
5A Preston
4A Putnam
5A Raleigh
5A Randolph
4A Ritchie
4A Roane
5A Summers
5A Taylor
5A Tucker
4A Tyler
5A Upshur
4A Wayne
5A Webster
5A Wetzel
4A Wirt
4A Wood
4A Wyoming

WISCONSIN

6A Adams
7 Ashland
6A Barron
7 Bayfield
6A Brown
6A Buffalo
7 Burnett
6A Calumet
6A Chippewa
6A Clark
6A Columbia
6A Crawford
6A Dane
6A Dodge
6A Door
7 Douglas
6A Dunn
6A Eau Claire
7 Florence
6A Fond du Lac
7 Forest
6A Grant
6A Green
6A Green Lake
6A Iowa
7 Iron
6A Jackson
6A Jefferson
6A Juneau
6A Kenosha
6A Kewaunee
6A La Crosse
6A Lafayette
7 Langlade
7 Lincoln
6A Manitowoc
6A Marathon
6A Marinette
6A Marquette
6A Menominee
6A Milwaukee
6A Monroe
6A Oconto
7 Oneida
6A Outagamie

(continued)

TABLE R301.1—continued
CLIMATE ZONES, MOISTURE REGIMES, AND WARM-HUMID DESIGNATIONS BY STATE, COUNTY AND TERRITORY

6A Ozaukee
6A Pepin
6A Pierce
6A Polk
6A Portage
7 Price
6A Racine
6A Richland
6A Rock
6A Rusk
6A Sauk
7 Sawyer
6A Shawano
6A Sheboygan
6A St. Croix
7 Taylor
6A Trempealeau
6A Vernon
7 Vilas
6A Walworth
7 Washburn
6A Washington
6A Waukesha
6A Waupaca
6A Waushara
6A Winnebago
6A Wood

WYOMING

6B Albany
6B Big Horn
6B Campbell
6B Carbon
6B Converse
6B Crook
6B Fremont
5B Goshen
6B Hot Springs
6B Johnson
6B Laramie
7 Lincoln
6B Natrona
6B Niobrara
6B Park
5B Platte
6B Sheridan
7 Sublette
6B Sweetwater
7 Teton
6B Uinta
6B Washakie
6B Weston

US TERRITORIES

AMERICAN SAMOA

1A (all)*

GUAM

1A (all)*

NORTHERN MARIANA ISLANDS

1A (all)*

PUERTO RICO

1A (all)*

VIRGIN ISLANDS

1A (all)*

SECTION R302
DESIGN CONDITIONS

R302.1 Interior design conditions. The interior design temperatures used for heating and cooling load calculations shall be a maximum of 72°F (22°C) for heating and minimum of 75°F (24°C) for cooling.

❖ While the previous sections of IECC Chapter 3 address outdoor design conditions, this section provides the interior conditions that will be used for properly sizing the mechanical equipment. The proper sizing of mechanical equipment (see Section R403.7) can vary depending on the selected design conditions. While the code does address oversizing equipment, it is not enforceable without establishing the exact design parameters. This section is included in the code only for system sizing. It does not affect the interior design temperatures required by other codes such as Section 1204 of the IBC or Section 602.2 of the *International Property Maintenance Code®* (IPMC®).

The 75°F (24°C) design temperature for cooling was used in the code so that it coordinated with both the ASHRAE *Handbook of Fundamentals* and the Air Conditioning Contractors of America (ACCA) Manuals S and J, established standards that deal with equipment sizing.

SECTION R303
MATERIALS, SYSTEMS AND EQUIPMENT

R303.1 Identification. Materials, systems and equipment shall be identified in a manner that will allow a determination of compliance with the applicable provisions of this code.

❖ This section is intended to make certain that sufficient information exists to determine compliance with the code during the plan review and field inspection phases. The permittee can submit the required equipment and materials information on the building plans, specification sheets or schedules, or in any other way that allows the code official to clearly identify which specifications apply to which portions of the building (i.e., which parts of the building are insulated to the levels listed). Materials information includes envelope insulation levels, glazing assembly *U*-factors and duct and piping insulation levels. Equipment information includes heating and cooling equipment and appliance efficiencies where high-efficiency equipment is claimed to meet code requirements.

This section contains specific material, equipment and system identification requirements for the approval and installation of the items required by the code. Although the means for permanent marking (tag, stencil, label, stamp, sticker, bar code, etc.) is often determined and applied by the manufacturer, if there is any uncertainty about the product, the mark is subject to the approval of the code official.

R303.1.1 Building thermal envelope insulation. An *R*-value identification mark shall be applied by the manufacturer to each piece of *building thermal envelope* insulation 12 inches (305 mm) or greater in width. Alternately, the insulation installers shall provide a certification listing the type, manufacturer and *R*-value of insulation installed in each element of the *building thermal envelope*. For blown or sprayed insulation (fiberglass and cellulose), the initial installed thickness, settled thickness, settled *R*-value, installed density, coverage area and number of bags installed shall be *listed* on the certification. For sprayed polyurethane foam (SPF) insulation, the installed thickness of the areas covered and *R*-value of installed thickness shall be *listed* on the certification. For insulated siding, the *R*-value shall be labeled on the product's package and shall be *listed* on the certification. The insulation installer shall sign, date and post the certification in a conspicuous location on the job site.

❖ The thermal performance of insulation is rated in terms of *R*-value. For products lacking an *R*-value identification, the installer (or builder) must provide the insulation performance data. For example, some insulation materials, such as foamed-in-place urethane, can be installed in wall, floor and cathedral ceiling cavities. These products are not labeled, as is batt insulation, nor is it appropriate for them to be evaluated as required in the code for blown or sprayed insulation; however, the installer must certify the type, thickness and *R*-value of these materials.

The *R*-value of loose-fill insulation (blown or sprayed) is dependent on both the installed thickness and density (number of bags used). Therefore, loose-fill insulation cannot be directly labeled by the manufacturer. Many blown insulation products carry a manufacturer's *R*-value guarantee when installed to a designated thickness, "inches = *R*-value." Blown insulation products lacking this manufacturer's guarantee can be subjected to special inspection and testing; what is referred to as "cookie cutting." Cookie cutting involves extracting a column of insulation with a cylinder to determine its density. The insulation depth and density must yield the specified *R*-value according to the manufacturer's bag label specification.

The code and Federal Trade Commission Rule 460 require that installers of insulation in homes, apartments and manufactured housing units report this information to the authority having jurisdiction in the form of a certification posted in a conspicuous location (see Commentary Figure R303.1.1).

R303.1.1.1 Blown or sprayed roof/ceiling insulation. The thickness of blown-in or sprayed roof/ceiling insulation (fiberglass or cellulose) shall be written in inches (mm) on markers that are installed at least one for every 300 square feet (28 m^2) throughout the attic space. The markers shall be affixed to the trusses or joists and marked with the minimum initial installed thickness with numbers not less than 1 inch (25 mm) in height. Each marker shall face the attic access opening. Spray polyurethane foam thickness and installed *R*-value shall be *listed* on certification provided by the insulation installer.

❖ To help verify the installed *R*-value of blown-in or spray-applied insulation, the installer must certify the following information in a signed statement posted in a conspicuous place (see Section R303.1.1):

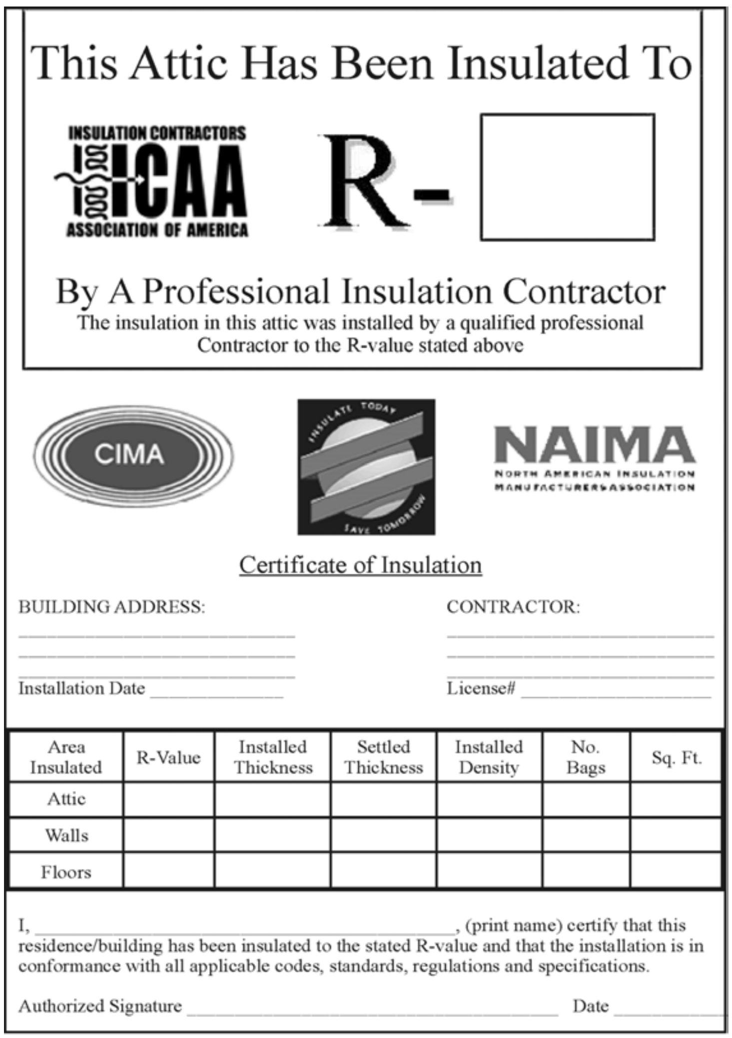
- The type of insulation used and manufacturer.
- The insulation's coverage per bag (the number of bags required to result in a given *R*-value for a given area), as well as the settled *R*-value.
- The initial and settled thickness.
- The number of bags installed.

Under circumstances where the insulation *R*-value is guaranteed, only the initial thickness is required on the certification.

This section helps demonstrate compliance and enforcement of the provisions found in Section R303.1.1. To assist with application and enforcement, loose-fill ceiling insulation also requires thickness markers that are attached to the framing and face the attic access. In a large space, markers placed evenly about every 17 feet (5182 mm) (with some markers at the edge of the space) will meet this requirement. For sprayed polyurethane, such markers are not effective. When using this product, the code requires that the measured thickness and *R*-value be recorded on the certificate.

R303.1.2 Insulation mark installation. Insulating materials shall be installed such that the manufacturer's *R*-value mark is readily observable upon inspection.

❖ For batt insulation, manufacturers' *R*-value designations and stripe codes are often printed directly on the insulation. Where possible, the insulation must be installed so these designations are readable. Backed floor batts can be installed with the designation



This Attic Has Been Insulated To

R-

By A Professional Insulation Contractor

The insulation in this attic was installed by a qualified professional Contractor to the R-value stated above

Certificate of Insulation

BUILDING ADDRESS: ______________________

Installation Date ____________

CONTRACTOR: ______________________

License# ________________

Area Insulated	R-Value	Installed Thickness	Settled Thickness	Installed Density	No. Bags	Sq. Ft.
Attic						
Walls						
Floors						

I, ______________________________, (print name) certify that this residence/building has been insulated to the stated R-value and that the installation is in conformance with all applicable codes, standards, regulations and specifications.

Authorized Signature ______________________________ Date __________

Figure R303.1.1
SAMPLE CERTIFICATE OF INSULATION

(Logos courtesy of Cellulose Insulation Manufacturers Association, http://cellulose.org, Insulation Contractors Association of America, www.insulate.org, and North American Insulation Manufacturers Association, www.NAIMA.org) against the underfloor, which means it would not be visible. In those cases, the *R*-value must be certified by the installer or be validated by some other means (see commentary, Section R303.1.1).

R303.1.3 Fenestration product rating. *U*-factors of fenestration products (windows, doors and skylights) shall be determined in accordance with NFRC 100.

> **Exception:** Where required, garage door *U*-factors shall be determined in accordance with either NFRC 100 or ANSI/DASMA 105.

U-factors shall be determined by an accredited, independent laboratory, and *labeled* and certified by the manufacturer.

Products lacking such a *labeled U*-factor shall be assigned a default *U*-factor from Table R303.1.3(1) or R303.1.3(2). The solar heat gain coefficient (SHGC) and *visible transmittance* (VT) of glazed fenestration products (windows, glazed doors and skylights) shall be determined in accordance with NFRC 200 by an accredited, independent laboratory, and *labeled* and certified by the manufacturer. Products lacking such a *labeled* SHGC or VT shall be assigned a default SHGC or VT from Table R303.1.3(3).

❖ Until recently, the buyers of fenestration products received energy performance information in a variety of ways. Some manufacturers described performance by showing *R*-values of the glass. While the glass might have been a good performer, the rating did not include the effects of the frame. Other manufacturers touted the insulating value of different window components, but these, too, did not reflect the total window system performance. When manufacturers rated the entire product, some used test laboratory measurements and others used computer calculations. Even among those using test laboratory reports, the test laboratories often tested the products under different procedures, making an "apples-to-apples" comparison difficult. The different rating methods confused builders and consumers. They also created headaches for manufacturers trying to differentiate the performance of their products from the performance of their competitors' products.

The National Fenestration Rating Council (NFRC) has developed a fenestration energy rating system based on whole-product performance. This accurately accounts for the energy-related effects of all the product's component parts and prevents information about a single component from being compared in a misleading way to other whole-product properties. With energy ratings based on whole-product performance, the NFRC helps builders, designers and consumers directly compare products with different construction details and attributes.

Products that have been rated by NFRC-approved testing laboratories and certified by NFRC-accredited independent certification and inspection agencies carry a temporary and permanent label featuring the "NFRC-certified" mark. With this mark, the manufacturer stipulates that the energy performance of the product was determined according to NFRC rules and procedures.

By certifying and labeling their products, manufacturers are demonstrating their commitment to providing accurate energy and energy-related performance information. The code purposely sets the default values fairly high. This helps to encourage the use of products that have been tested and also ensures that products that have little energy-saving values are not used inappropriately in the various climate zones. By setting the default value so high, it will also prevent someone from removing the label from a tested window and then using the default values. Therefore, the default values are most representative of the lower end of the energy-efficient products.

A product that is not NFRC certified and does not exactly match the specifications in Tables R303.1.3(1) and R303.1.3(2) must use the tabular specification for the product it most closely resembles. In the absence of tested *U*-factors, the default *U*-factor for doors containing glazing can be a combination of the glazing and door *U*-factor as described in the definition for "*U*-factor" (see commentary, Section R202, "*U*-factor"). NFRC procedures determine *U*-factor and SHGC ratings based on the whole fenestration assembly [untested fenestration products have default *U*-factors and SHGCs assigned as described in the commentary to Tables R303.1.3(1) through R303.1.3(3)]. During construction inspection, the label on each glazing assembly should be checked for conformance to the *U*-factor specified on the approved plans. These labels must be left on the glazing until after the building has been inspected for compliance. A sample NFRC label is shown in Commentary Figure R303.1.3(1).

Products certified according to NFRC procedures are listed in the *Certified Products Directory*. The directory is published annually and contains energy performance information for over 1.4 million fenestration product options listed by over 450 manufacturers. When using the directory or shopping for NFRC-certified products, it is important to note:

1. A product is considered to be NFRC certified only if it carries the NFRC label. Simply being listed in this directory is not enough.
2. The NFRC-certified mark does not signify that the product meets any energy-efficiency standards or criteria.
3. The NFRC neither sets minimum performance standards nor mandates specific performance levels. Rather, NFRC ratings can be used to determine whether a product meets a state or local code or other performance requirement and to compare the energy performance of different products during plan review. For questions about the NFRC and its rating and labeling system, more information is available on the organization's website at www.nfrc.org. The NFRC adopted a new energy performance

label in 2005. It lists the manufacturer, describes the product, provides a source for additional information and includes ratings for one or more energy performance characteristics.

The IECC offers an alternative to NFRC-certified glazed fenestration product *U*-factor ratings. In the absence of *U*-factors based on NFRC test procedures, the default *U*-factors in Table R303.1.3(1) must be used. When a composite of materials from two different product types is used, the code official should be consulted regarding how the product will be rated. Generally, the product must be assigned the higher *U*-factor, although an average based on the *U*-factors and areas may be acceptable in some cases.

The product cannot receive credit for a feature that cannot be seen. Because performance features such as argon fill and low-emissivity coatings for glass are not visually verifiable, they do not receive credit in the default tables. Tested *U*-factors for these windows are often lower, so using tested *U*-factors is to the applicant's advantage. Commentary Figure R303.1.3(2) illustrates visually verifiable window characteristics, among other various window performance, function and cost considerations.

A single-glazed window with an installed storm window may be considered a double-glazed assembly and use the corresponding *U*-factor from the default table. For example, the *U*-factor 0.80 in Table R303.1.3(1) applies to a single-glazed, metal window without a thermal break (but with an installed storm window). If the storm window was not installed, the *U*-factor would be 1.20.

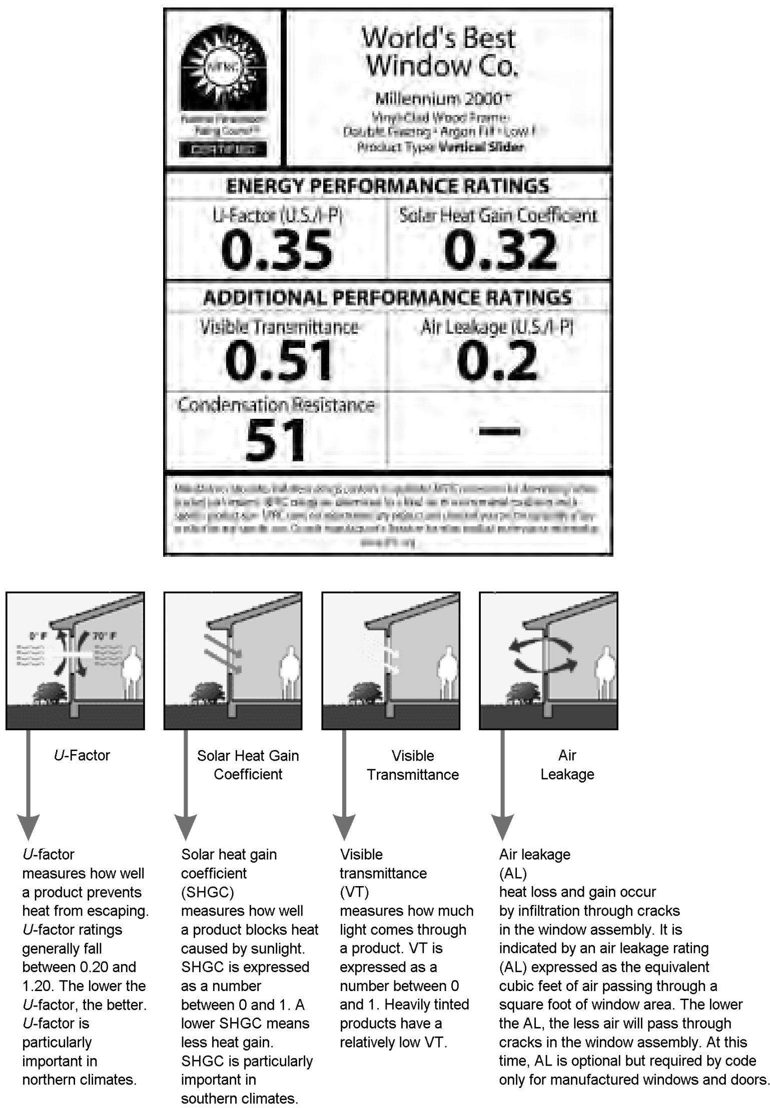


Figure R303.1.3(1)
SAMPLE NATIONAL FENESTRATION RATING COUNCIL (NFRC) LABEL

TABLE R303.1.3(1)
DEFAULT GLAZED FENESTRATION *U*-FACTORS

FRAME TYPE	SINGLE PANE	DOUBLE PANE	SKYLIGHT	
			Single	Double
Metal	1.20	0.80	2.00	1.30
Metal with Thermal Break	1.10	0.65	1.90	1.10
Nonmetal or Metal Clad	0.95	0.55	1.75	1.05
Glazed Block	0.60			

TABLE R303.1.3(2)
DEFAULT DOOR *U*-FACTORS

DOOR TYPE	*U*-FACTOR
Uninsulated Metal	1.20
Insulated Metal	0.60
Wood	0.50
Insulated, nonmetal edge, max 45% glazing, any glazing double pane	0.35

❖ Door *U*-factors in Table R303.1.3(2) should be used wherever NFRC-certified ratings are not available. There are a few other aspects to note about doors. Opaque door *U*-factors must include the effects of the door edge and the frame. Calculating *U*-factors based on a cross section through the insulated portion is not acceptable. To take credit for a thermal break, the door must have a thermal break in both the door slab and in the frame. The values in the table are founded on principles established in the ASHRAE *Handbook of Fundamentals*.

TABLE R303.1.3(3)
DEFAULT GLAZED FENESTRATION SHGC AND VT

	SINGLE GLAZED		DOUBLE GLAZED		GLAZED BLOCK
	Clear	Tinted	Clear	Tinted	
SHGC	0.8	0.7	0.7	0.6	0.6
VT	0.6	0.3	0.6	0.3	0.6

❖ This table offers an alternative to NFRC-certified SHGC and visible transmittance (VT) values based on visually verifiable characteristics of the fenestration product. The SHGC is the fraction of incident solar radiation absorbed and directly transmitted by the window area, then subsequently reradiated, conducted or convected inward. SHGC is a ratio, expressed as a number between 0 and 1. The lower a window's SHGC, the less solar heat it transmits. The VT is the ratio of visible light entering the space through the fenestration product assembly to the incident visible light. VT includes the effects of glazing material and frame and is expressed as a number between 0 and 1.

An SHGC of 0.40 or less is recommended in cooling-dominated climates (Climate Zones 1–3). In heating-dominated climates, a high SHGC increases passive solar gain for the heating but reduces cooling season performance. A low SHGC improves cooling season performance but reduces passive solar gains for heating.

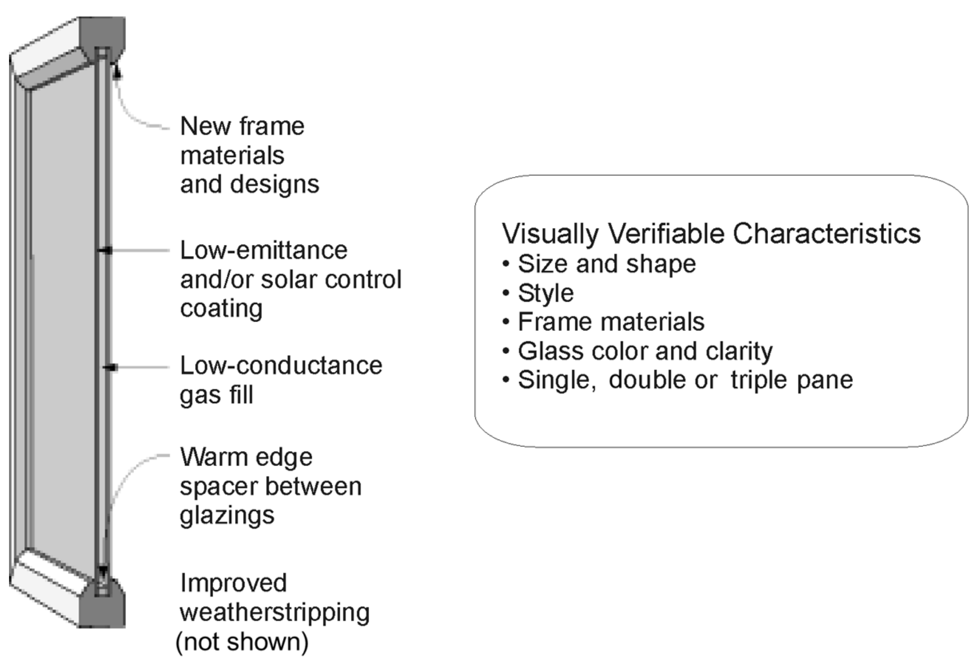


Figure R303.1.3(2)
VISUALLY VERIFIABLE WINDOW CHARACTERISTICS

R303.1.4 Insulation product rating. The thermal resistance (*R*-value) of insulation shall be determined in accordance with the U.S. Federal Trade Commission *R*-value rule (CFR Title 16, Part 460) in units of h · ft^2 · °F/Btu at a mean temperature of 75°F (24°C).

❖ This section brings two important requirements to the code.

First, the Federal Trade Commission *R*-value rule details test standards for insulation. The test standards are specific to the type of insulation and intended use. This clarifies any questions on the rating conditions to be used for insulation materials.

Second, the text above specifies the rating temperature to be used when evaluating the *R*-value of the product, providing consistency not currently in the code. Insulation products sometimes list several *R*-values based on different test temperatures. This eliminates any question as to which *R*-value to use. The temperature selected is a standard rating condition.

R303.1.4.1 Insulated siding. The thermal resistance (*R*-value) of insulated siding shall be determined in accordance with ASTM C 1363. Installation for testing shall be in accordance with the manufacturer's instructions.

❖ Insulated siding is a unique product that requires a special test method for determination of *R*-value. This test method is ASTM C 1363, *Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus*.

R303.2 Installation. Materials, systems and equipment shall be installed in accordance with the manufacturer's instructions and the *International Building Code* or *International Residential Code*, as applicable.

❖ Manufacturers' installation instructions are thoroughly evaluated by the listing agency, verifying that a safe installation is prescribed. When an appliance is tested to obtain a listing and label, the approval agency installs the appliance in accordance with the manufacturer's instructions. The appliance is tested under these conditions; thus, the installation instructions become an integral part of the labeling process. The listing agency can require that the manufacturer alter, delete or add information to the instructions as necessary to achieve compliance with applicable standards and code requirements.

Manufacturers' installation instructions are enforceable extensions of the code and must be in the hands of the code official when an inspection takes place. Inspectors must carefully and completely read and comprehend the manufacturer's instructions in order to properly perform an installation inspection. In some cases, the code will specifically address an installation requirement that is also addressed in the manufacturer's installation instructions. The code requirement may be the same or may exceed the requirement in the manufacturer's installation instructions. The manufacturer's installation instructions could contain requirements that exceed those in the code. In such cases, the more restrictive requirements would apply (see commentary, Section 106).

Even if an installation appears to be in compliance with the manufacturer's instructions, the installation cannot be completed or approved until all associated components, connections and systems that serve the appliance or equipment are also in compliance with the requirements of the applicable *International Codes*® (I-Codes®) of reference. For example, a gas-fired boiler installation must not be approved if the boiler is connected to a deteriorated, undersized or otherwise unsafe chimney or vent. Likewise, the same installation must not be approved if the existing gas piping has insufficient capacity to supply the boiler load or if the electrical supply circuit is inadequate or unsafe.

Manufacturers' installation instructions are often updated and changed for various reasons, such as changes in the appliance, equipment or material design; revisions to the product standards; or as a result of field experiences related to existing installations. The code official should stay abreast of any changes by reviewing the manufacturer's instructions for every installation.

R303.2.1 Protection of exposed foundation insulation. Insulation applied to the exterior of basement walls, crawlspace walls and the perimeter of slab-on-grade floors shall have a rigid, opaque and weather-resistant protective covering to prevent the degradation of the insulation's thermal performance. The protective covering shall cover the exposed exterior insulation and extend not less than 6 inches (153 mm) below grade.

❖ The ultimate performance of insulation material is directly proportional to the workmanship involved in the material's initial installation, as well as the material's integrity over the life of the structure. Accordingly, foundation wall and slab-edge insulation materials installed in the vicinity of the exterior grade line require protection from damage that could occur from contact by lawn-mowing and maintenance equipment, garden hoses, garden tools, perimeter landscape materials, etc. In addition, the long-term thermal performance of foam-plastic insulation materials is adversely affected by direct exposure to the sun. To protect the insulation from sunlight and physical damage, it must have a protective covering that is inflexible, puncture resistant, opaque and weather resistant.

R303.3 Maintenance information. Maintenance instructions shall be furnished for equipment and systems that require preventive maintenance. Required regular maintenance actions shall be clearly stated and incorporated on a readily accessible label. The label shall include the title or publication number for the operation and maintenance manual for that particular model and type of product.

❖ This section establishes an owner's responsibility for maintaining the building in accordance with the requirements of the code and other referenced standards. This section requires, among others, that mechanical and service water heating equipment and appliance maintenance information be made available to the owner/operator. This section does not require that labels be added to existing equipment; having the manufacturer's maintenance literature is usually sufficient to meet this requirement. During final occupancy inspection, the mechanical equipment and water heater should be inspected to verify that the information is taped to each unit or referenced on a label mounted in a conspicuous location on the units.

The code official has the authority to rule on the performance of maintenance work when equipment functions would be affected by such work. He or she also has the authority to require a building and its energy-using systems to be maintained in compliance with the public health and safety provisions required by other I-Codes.

Bibliography

The following resource materials were used in the preparation of the commentary for this chapter of the code.

Morales, C.G.; and A. J. Malavé, A.J. *Energy Modeling of Low Income Residencies*. http://library.witpress.com/pages/PapeInfo.asp?PaperID=22547.
(The paper above is not free. The proponents will send a Puerto Rico Energy Center presentation done for DOE that summarizes that work to anyone who requests this by email.)

Chapter 4 [RE]: Residential Energy Efficiency

General Comments

Chapter 4 [RE] contains the energy-efficiency-related requirements for the design and construction of residential buildings regulated under the code. The applicable portions of the building must comply with the provisions within this chapter for energy efficiency.

Section R401 contains the scope and application of the chapter and also regulates a certificate that must be left with the building. In addition, Section R401 provides an alternative for residential buildings in the Tropical Zone. Section R402 contains the insulation *R*-value requirements for the building envelope, which includes the roof/ceiling assembly, wall assembly and floor assembly, as well as fenestration requirements. Section R403 contains the requirements for heating and cooling systems and includes requirements for equipment sizing, duct installation, piping insulation and the requirements for controls. Section R404 contains electrical power and lighting systems information. Section R405 provides a performance option that will not only provide an additional means of demonstrating compliance with the code but also allows trade-offs between the various systems.

Purpose

This chapter details requirements for the portions of the building and building systems that impact energy use in new residential construction and promotes the effective use of energy. The provisions in the chapter promote energy efficiency in the building envelope, the heating and cooling system, the service water-heating system, and the electrical power and lighting system of the building. Compliance with this chapter will provide a minimum level of energy efficiency for new construction. Greater levels of efficiency can be installed to decrease the energy use of new construction.

SECTION R401 GENERAL

R401.1 Scope. This chapter applies to residential buildings.

❖ This chapter covers "residential" buildings as they are defined in Chapter 2 [RE]. A review of the definition is important because it does not include all buildings that are classified as "residential" by the *International Building Code*® (IBC®). Hotels, motels and other transient occupancies that are classified as a Group R-1 occupancy by the IBC are not included in the definition of "Residential" and would, therefore, need to comply with the "Commercial" provisions that are found in Chapter 4[CE].

Chapter 4 [RE] applies to portions of the building thermal envelope that enclose conditioned space as shown in Commentary Figure R401.1(1). Conditioned space is the area provided with heating and/or cooling either directly through a positive heating/cooling supply system, such as registers located in the space, or indirectly through an opening that allows heated or cooled air to communicate directly with the space. For example, a walk-in closet connected to a master bedroom suite may not contain a positive heating supply through a register, but it would be conditioned indirectly by the free passage of heated or cooled air into the spaces from the bedroom.

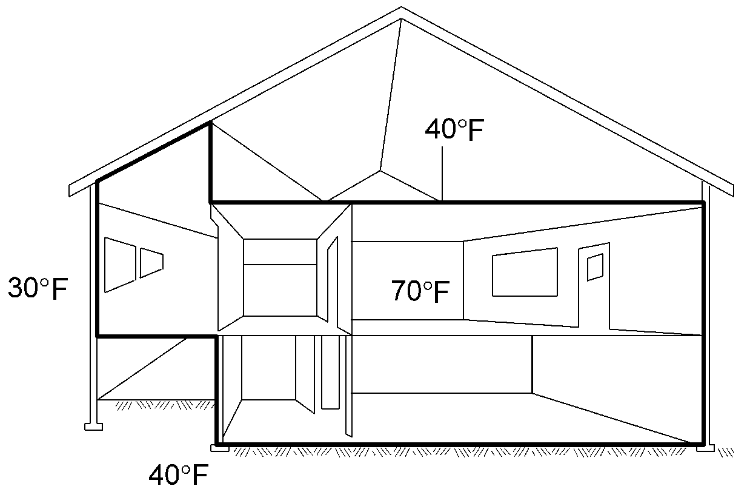
The code through Section R402.1 exempts areas that do not contain conditioned space and are separated from the conditioned spaces of the building by the building envelope from the building thermal envelope requirements. A good example of this would be an unconditioned garage or attic space. In the case of a garage, if the unconditioned garage area is separated from the conditioned portions of the residence by an assembly that meets the building thermal envelope criteria (meaning that the wall between them is insulated), the exterior walls of the garage would not need to be insulated to separate the garage from the exterior climate.

The building thermal envelope consists of the wall, roof/ceiling and floor assemblies that surround the conditioned space. Raised floors over a crawl space or garage or directly exposed to the outside air are considered to be part of the floor assembly. Walls surrounding a conditioned basement (in addition to surrounding conditioned spaces above grade) are part of the building envelope. The code defines "Above-grade walls" surrounding conditioned spaces as exterior walls. This definition includes walls between the conditioned space and unconditioned garage, roof and basement knee walls, dormer walls, gable end walls, walls enclosing a mansard roof and basement walls with an average below-grade wall area that is less than 50 percent of the total basement gross wall area. This definition would not include walls separating an unconditioned garage from the outdoors. The code's definition of "Exterior walls" would also include basement walls. The roof/ceiling assembly is the surface where insulation will be installed, typically on top of the gypsum board [see Commentary Figure R401.1(2)].

R401.2 Compliance. Projects shall comply with one of the following:

1. Sections R401 through R404.
2. Section R405 and the provisions of Sections R401 through R404 labeled "Mandatory."
3. An energy rating index (ERI) approach in Section R406.

❖ This section allows residential buildings to comply with either the prescriptive requirements of Sections R402 through R404, the performance options that are provided in Section R405, or the energy rating index option in Section R406. Under all options, the building must comply with the mandatory requirements that are found in Sections R402.4, R402.5, R403.1, R403.1.2, R403.3.2, R403.3.3, R403.3.5, R403.4, R403.6, R403.7, R403.8, R403.9, R404 and R406.3. A code user may evaluate both options and use the one that fits the project best, as these two differing methods can result in different requirements. Most requirements are given prescriptively. Alternative trade-offs are specified for many requirements, such as for the building thermal envelope requirements. For requirements specified by *U*-factors, an overall



For SI: °C = [(°F) - 32]/1.8.

Figure R401.1(1)
CONDITIONED ENVELOPE

Figure R401.1(2)
BUILDING ENVELOPE

UA (*U*-factor times the area) can be used to show equivalence. A performance-based annual energy calculation also can be met by showing overall energy equivalence.

The majority of the requirements of this chapter are based on the climate zone where the project is being built. The appropriate climate zone can be found in Section R301.1 of the code. Climate Zones 1 through 7 apply to various parts of the continental United States and are defined by county lines. Climate Zones 7 and 8 apply to various parts of Alaska, and Hawaii is classified as Climate Zone 1. The climate zones have been divided into marine, dry and moist to deal with levels of humidity. For more details and background on the development of the new climate zones, see the commentary to Section R301.1.

R401.2.1 Tropical zone. *Residential buildings* in the tropical zone at elevations below 2,400 feet (731.5 m) above sea level shall be deemed to comply with this chapter where the following conditions are met:

1. Not more than one-half of the *occupied* space is air conditioned.
2. The *occupied* space is not heated.
3. Solar, wind or other renewable energy source supplies not less than 80 percent of the energy for service water heating.
4. Glazing in *conditioned* space has a *solar heat gain coefficient* of less than or equal to 0.40, or has an overhang with a projection factor equal to or greater than 0.30.
5. Permanently installed lighting is in accordance with Section R404.
6. The exterior roof surface complies with one of the options in Table C402.3 or the roof/ceiling has insulation with an *R-value* of R-15 or greater. If present, attics above the insulation are vented and attics below the insulation are unvented.
7. Roof surfaces have a minimum slope of $^1/_4$ inch per foot of run. The finished roof does not have water accumulation areas.
8. Operable fenestration provides ventilation area equal to not less than 14 percent of the floor area in each room. Alternatively, equivalent ventilation is provided by a ventilation fan.
9. Bedrooms with exterior walls facing two different directions have operable fenestration on exterior walls facing two directions.
10. Interior doors to bedrooms are capable of being secured in the open position.
11. A ceiling fan or ceiling fan rough-in is provided for bedrooms and the largest space that is not used as a bedroom.

❖ This section provides an alternative for residences in the tropical climates, a simple option for a newly defined climate zone, the “tropical zone.” The area between the Tropic of Cancer and the Tropic of Capricorn is the area between 23.5 degrees northern and southern latitude of the equator. A zone that recognizes the unusually constant and unique climate of this region would help make the *International Codes*® (I-Codes®) more of an “international code.”

Tropical areas are quite different from the US mainland in climate, construction techniques, traditional construction and energy prices. This chapter, and the IECC heretofore, has treated tropical climates as if they were simply a southern extension of the US mainland. Traditional residences, especially the less expensive residences, have evolved inexpensive ways to work with the tropical climates to provide comfortable interior spaces without the need for substantial space conditioning. Tropical electrical prices, usually over 20 cents per hWh, provide a substantial incentive for energy conservation. Solar water heating works particularly well in tropical climates.

Traditional construction, especially with solar water heating, is usually more energy efficient than the construction style assumed in the IECC, as is shown by an analysis done for Puerto Rico. Using energy efficient versions of traditional construction saves more energy and is much more cost-effective than pushing those in tropical climates to adopt mainland construction practices. Traditional tropical construction focuses on greatly reducing or eliminating the need for space conditioning by making a living space that is comfortable without space conditioning.

The following are explanations, by item:

1. Air conditioning only a portion of the residence is common in some residences and saves energy compared to air conditioning the whole occupied space.
2. Heating is seldom needed.
3. Consistently warm temperatures and high power costs make solar water heating very attractive. Solar water heating is widely used. Water heating is often 35 percent or more of the residential energy use. Substantial energy savings come from solar water heating.
4. Limiting solar gains and providing ventilation is the energy focus for windows. Window *U*-factor has little impact. Window air tightness is of little value when the important feature of the windows is their ability to be operable and provide ventilation.
5. High efficiency lighting makes sense with tropical energy prices.
6. This references the “cool roof” provisions. This is similar to an option in Hawaii’s code and the Puerto Rico Energy Center’s analysis. Insulation is less valuable in mild climates where the outside temperature is often comfortable as an inside temperature.
7. Even flat roofs need to drain.

8. Ventilation provided by tropical winds makes occupied spaces more comfortable. 14 percent of the floor area of the room is an option for unconditioned residences in Hawaii's new energy code.
9. When bedroom walls facing two directions are available, ventilation on both walls will be more effective.
10. Interior doors should not block bedroom ventilation. This is similar to Hawaii's new energy code and recommended by the Puerto Rico Energy Center.
11. Ceiling fans increase comfort without conditioning the air. This is similar to Hawaii's new energy code and recommended by the Puerto Rico Energy Center.

R401.3 Certificate (Mandatory). A permanent certificate shall be completed by the builder or registered design professional and posted on a wall in the space where the furnace is located, a utility room or an approved location inside the building. Where located on an electrical panel, the certificate shall not cover or obstruct the visibility of the circuit directory label, service disconnect label or other required labels. The certificate shall list the predominant *R*-values of insulation installed in or on ceiling/roof, walls, foundation (slab, basement wall, crawlspace wall and floor) and ducts outside conditioned spaces; *U*-factors for fenestration and the solar heat gain coefficient (SHGC) of fenestration, and the results from any required duct system and building envelope air leakage testing done on the building. Where there is more than one value for each component, the certificate shall list the value covering the largest area. The certificate shall list the types and efficiencies of heating, cooling and service water heating equipment. Where a gas-fired unvented room heater, electric furnace or baseboard electric heater is installed in the residence, the certificate shall list "gas-fired unvented room heater," "electric furnace" or "baseboard electric heater," as appropriate. An efficiency shall not be *listed* for gas-fired unvented room heaters, electric furnaces or electric baseboard heaters.

❖ This section is intended to increase consumer awareness of the energy-efficiency ratings for various building elements in the home. The builder or registered design professional has to complete the certificate and place it on or inside the electrical panel (see Commentary Figure R401.3). The permanent certificate shall not cover or obstruct the visibility of the circuit directory label, service disconnect label or other required labels.

The certificate must disclose the building's *R*-values, fenestration *U*-factors and fenestration SHGC, HVAC equipment types and efficiencies. The energy efficiency of a building as a system is a function of many elements considered as separate parts of the whole. It is difficult to have a proper identification and analysis of a building's energy efficiency once the building is completed because many of the elements may not be readily accessible.

This information is also valuable for existing structures undergoing alterations and additions to help determine the appropriate sizing for the mechanical systems. This is meant to be a simple certificate that is easy to read. The certificate does not contain all the information required for compliance and cannot be substituted for information on the required construction documents. Instead, the certificate is meant to provide the housing owner, occupant or buyer with a simple-to-understand overview of the home's energy efficiency. Where there is a mixture of insulation and fenestration values, the value applying to the largest area is specified. For example, if most of the wall insulation was R-19, but a limited area bordering the garage was R-13, the certificate would specify R-19 for the walls. (In contrast, plans and overall compliance would need to account for both *R*-values.)

The code specifies the minimum information on the certificate, but does not prohibit additional information being added so long as the required information is clearly visible. For example, a builder might choose to list energy-efficiency features beyond those required by the code.

SECTION R402
BUILDING THERMAL ENVELOPE

R402.1 General (Prescriptive). The *building thermal envelope* shall meet the requirements of Sections R402.1.1 through R402.1.5.

Exception: The following low-energy buildings, or portions thereof, separated from the remainder of the building by *building thermal envelope* assemblies complying with

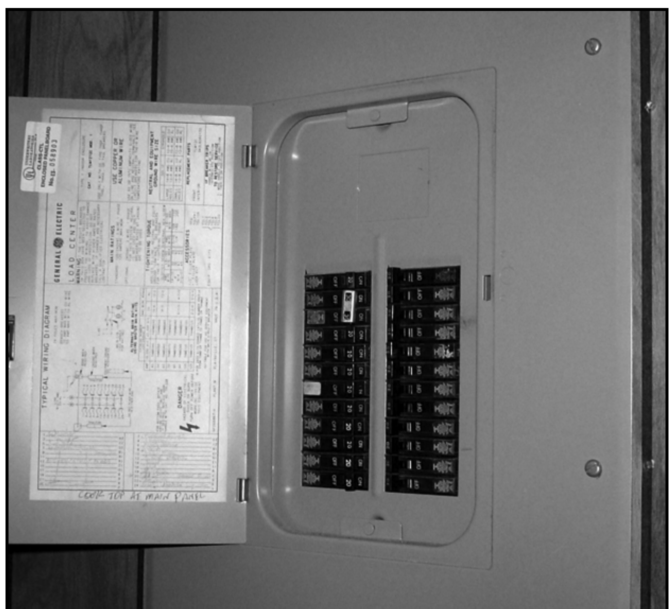


Figure R401.3
CERTIFICATE

this section shall be exempt from the *building thermal envelope* provisions of Section R402.

1. Those with a peak design rate of energy usage less than 3.4 Btu/h · ft^2 (10.7 W/m^2) or 1.0 watt/ft^2 of floor area for space-conditioning purposes.
2. Those that do not contain *conditioned space*.

❖ The provisions of Section R402 are detailed requirements of insulation levels, the performance of openings (fenestrations) and air-leakage and moisture-control provisions that serve to establish the building's energy efficiency. When combined with the "systems" requirements (Section R403) and the electrical power requirements (Section R404), these three sections provide the total package of energy conservation that the code requires.

The term "building thermal envelope" is defined in Section R202 as being "the basement walls, exterior walls, floor, roof and any other building elements that enclose conditioned spaces." This boundary also includes the boundary between conditioned space or provides a boundary between conditioned space and exempt or unconditioned space. Therefore, when combined with the definition of "Conditioned space," the code has defined the boundaries of the building that will be regulated by this section. The building thermal envelope is a key term and resounding theme used throughout the energy requirements. It defines what portions of the building structure bound conditioned space and are thereby covered by the insulation and infiltration (air leakage) requirements of the code. The building thermal envelope includes all building components separating conditioned spaces (see commentary, "Conditioned space") from unconditioned spaces or outside ambient conditions and through which heat is transferred. For example, the walls and doors separating an unheated garage (unconditioned space) from a living area (conditioned space) are part of the building envelope. The walls and doors separating an unheated garage from the outdoors are not part of the building thermal envelope. Walls, floors and other building components separating two conditioned spaces are not part of the building envelope. For example, interior partition walls, the common or party walls separating dwelling units in multiple-family buildings and the wall between a new conditioned addition and the existing conditioned space are not considered part of the building envelope.

Unconditioned spaces (areas having no heating or cooling sources) are considered outside the building thermal envelope and are exempt from these requirements (see Section R202). A space is conditioned if it is heated or cooled directly; communicates directly with a conditioned space; or is indirectly supplied with heating, cooling or both through uninsulated walls, floors, uninsulated ducts or HVAC piping. Boundaries that define the building envelope include the following:

- Building assemblies separating a conditioned space from outdoor ambient weather conditions.
- Building assemblies separating a conditioned space from the ground under or around that space, such as the ground around the perimeter of a slab or the soil at the exterior of a conditioned basement wall. Note that the code does not specify requirements for insulating basement floors or underneath slab floors (except at the perimeter edges).
- Building assemblies separating a conditioned space from an unconditioned garage, unconditioned sunroom or similar unheated/cooled area.

The code specifies requirements for ceiling, wall, floor, basement wall, slab-edge and crawl space wall components of the building envelope. In some cases, it may be unclear how to classify a particular part of a building. For example, skylight shafts have properties of a wall assembly but are located in the ceiling assembly. In these situations, a determination needs to be made and approved by the code official prior to construction so that the proper level of insulation can be installed to complete the building thermal envelope. Generally, skylight shafts and other items that are vertical or at an angle of greater than 60 degrees (1.1 rad) from the horizontal would typically use the wall insulation value.

The exception exempts certain buildings from the thermal envelope requirements of Section R402. The obvious one is any building that does not contain a conditioned space. The other type of building is a low-energy building (design rate of energy usage less than 1 watt/ft^2). For these spaces, insulation and rated fenestration are not cost effective.

R402.1.2 Insulation and fenestration criteria. The *building thermal envelope* shall meet the requirements of Table R402.1.2, based on the climate zone specified in Chapter 3.

❖ This section serves as the basis for the code's general insulation and fenestration requirements. Therefore, this is the first place to determine what the requirements for the building thermal envelope will be. There are specific requirements for certain assemblies and locations that are addressed in Sections R402.2 and R402.3. First, this section mandates compliance with the proper component insulation and fenestration requirements of Table R402.1.2. However, once that general requirement is established, Sections R402.1.3, R402.1.4 and R402.1.5 provide three possible means of showing that the building thermal envelope will comply. Any of the three methods may be used at the discretion of the designer. The three options and their advantages are discussed in the commentary with the subsections. In general, the later subsections will provide the designer with more options and flexibility, but they are also more complex than using Table R402.1.2 on an individual component basis.

Table R402.1.2 lists the minimum *R*-value and maximum *U*-factor and SHGC requirements for different portions of the building thermal envelope, including basement and exterior walls, floor, ceiling and any other building elements that enclose conditioned space. Using the table begins with determining the climate zone for the proposed location from Table R301.1 or Figure R301.1. Once the climate zone has been determined, each of the *R*-value, *U*-factor or SHGC requirements must be met for the applicable component (e.g., ceilings, walls, floors, etc.).

Maximum fenestration *U*-factor is the first column in Table R402.1.2 that must be complied with (see definition for "Fenestration" in Chapter 2). Except as modified or exempted by Section R402.3, each fenestration product in the proposed building must not exceed the maximum *U*-factor requirement presented in the table for a particular climate zone. For example, a single-family residence located in Climate Zone 5 would require installation of glazed fenestration products with a maximum *U*-factor of 0.32. This would include all glazing in the walls of the building thermal envelope (e.g., vertical windows); skylights in the roof would be limited to a maximum *U*-factor of 0.55. The proposed glazing *U*-factor should be called out in the building plans either on the floor plan or in a window schedule. This will provide the necessary information to the field inspector, who will then need to verify that what is on the plans is installed in the field.

Fenestration products that do not have labels on them must use the default *U*-factors contained in Table R303.1.3(1) or R303.1.3(3) (see commentary, Section R303.1.3). Note that the lowest default *U*-factor included in the table for glazed fenestration is listed at 0.55 for a "nonmetal or metal-clad double-pane window." This *U*-factor will not meet the requirements of the code in Climate Zones 2 and higher.

TABLE R402.1.2. See below.

❖ Table R402.1.2 serves as the basis for establishing the building thermal envelope requirements based on the text of Section R402.1.2 and sets the performance level for each of the individual components listed. See the commentary for Sections R402.1.2, R402.2 and R402.3 for additional discussion related to the components in the table. The simplest compliance approach is to meet these requirements directly. Note that the requirements do not change based on the area of the components of the residence. These same requirements apply to changes in existing buildings; for example, additions.

A few specifics of Table R402.1.2 may benefit from clarification.

When applying the fenestration requirements of this table, it is important to remember the definition of

TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13+5[h]	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20+5 or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

For SI: 1 foot = 304.8 mm.

a. R-values are minimums. *U*-factors and SHGC are maximums. When insulation is installed in a cavity which is less than the label or design thickness of the insulation, the installed *R*-value of the insulation shall not be less than the *R*-value specified in the table.

b. The fenestration *U*-factor column excludes skylights. The SHGC column applies to all glazed fenestration. Exception: Skylights may be excluded from glazed fenestration SHGC requirements in climate zones 1 through 3 where the SHGC for such skylights does not exceed 0.30.

c. "15/19" means R-15 continuous insulation on the interior or exterior of the home or R-19 cavity insulation at the interior of the basement wall. "15/19" shall be permitted to be met with R-13 cavity insulation on the interior of the basement wall plus R-5 continuous insulation on the interior or exterior of the home. "10/13" means R-10 continuous insulation on the interior or exterior of the home or R-13 cavity insulation at the interior of the basement wall.

d. R-5 shall be added to the required slab edge *R*-values for heated slabs. Insulation depth shall be the depth of the footing or 2 feet, whichever is less in Climate Zones 1 through 3 for heated slabs.

e. There are no SHGC requirements in the Marine Zone.

f. Basement wall insulation is not required in warm-humid locations as defined by Figure R301.1 and Table R301.1.

g. Or insulation sufficient to fill the framing cavity, R-19 minimum.

h. The first value is cavity insulation, the second value is continuous insulation, so "13+5" means R-13 cavity insulation plus R-5 continuous insulation.

i. The second *R*-value applies when more than half the insulation is on the interior of the mass wall.

"Fenestration" and that it includes items such as doors, glass blocks and other items as well as windows. Therefore, any door located in the building thermal envelope would still be subject to these limitations. Although vertical fenestration (vertical windows and doors) and skylights have a separate column for *U*-factor, the SHGC applies to both. This is reinforced by the provisions of Note b.

The ceiling *R*-value requirements are precalculated for insulation only and already assume a credible *R*-value for other building materials such as air films, interior sheathing and exterior sheathing. The only *R*-value for ceiling insulation that may be used to meet the requirements is that installed between the conditioned space and the vented airspace in the roof/ceiling assembly. This is typically not an issue because most insulation is installed directly on top of the gypsum board ceiling and the ceiling location represents the building thermal envelope. Insulation installed in the ceiling must meet or exceed the required insulation level. The "conditioned attic" requirements of the code may be viewed as an acceptable alternative if approved by the code official. These minimum ceiling *R*-values would still be applicable where the provisions of Section R806.4 of the IRC were used to create a conditioned attic assembly. In those cases, the location of the insulation and air barrier (building thermal envelope) are simply located at the roof instead of at the ceiling line. See the commentary to Sections R402.2.1 and R402.2.2 for additional information regarding ceiling insulation requirements.

The *R*-values presented under the "wall" columns represent the sum of the insulation materials installed between the framing cavity and, if used, the insulating sheathing. See Section R402.1.2 regarding how to compute the *R*-value. Insulating sheathing must have an *R*-value of at least R-2 to be considered. The R-2 limitation comes from the definition of "Insulating sheathing." The *R*-value of noninsulative interior finishes, such as sheet rock, or exterior coverings (e.g., wood structural panel siding) is not considered when determining whether the proposed wall assembly meets the requirements. For example, in Commentary Figure R402.1.2, the *R*-value of the cavity insulation installed between framing (R-13) is added to the insulating sheathing installed on the outside of the studs (R-6) resulting in an R-19 wall. The R-19 total insulation value can then be compared to the *R*-value requirement for the specific climate zone in Table R402.1.2 to determine compliance.

The insulation *R*-value requirement for exterior walls assumes wood framing. Walls framed using steel studs or constructed of materials such as a concrete masonry unit (CMU) are addressed in Sections R402.2.5 and R402.2.6. In residences with more than one type of wall (frame or mass) or more than one type of below-grade wall (conditioned basement or crawl space), the requirement for each component is taken from the appropriate column in Table R402.1.2.

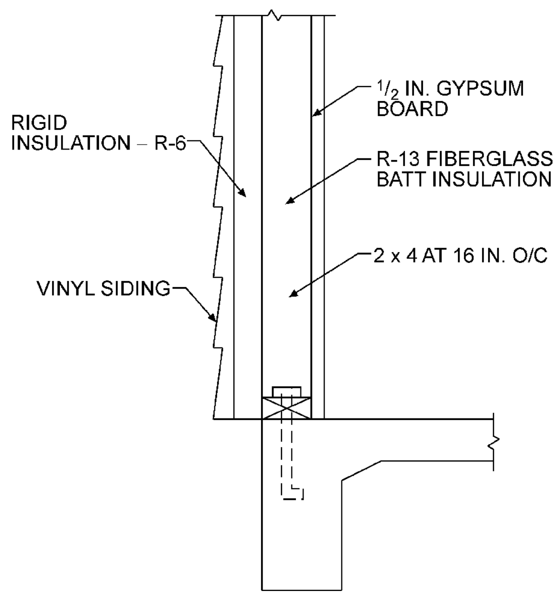
Mass walls are defined and have additional requirements in Section R402.2.5. Mass walls are intended to be above-grade walls and do not include basement walls, which have a separate entry in the table.

Note a reminds the code user which level of performance is required. Therefore, when dealing with *R*-values, a higher number would be better. When dealing with *U*-factors, the lower the number, the better the performance.

In accordance with Note c, for basement walls and crawl space walls, the two numbers separated by a "/" represent the values for continuous and cavity insulation; either will meet the code's requirements. For example, in Climate Zone 6, the wall can either be covered with continuous insulation to a minimum level of R-15 or, if some type of framing is used (such as a wood-frame wall used to finish out a basement), R-19 insulation must be installed in the cavity. This higher level of cavity insulation adjusts for the bridging or reduction in energy efficiency that the framing elements would create.

In accordance with Note d, heated slabs require R-5 insulation in Climate Zones 1, 2 and 3 and R-15 slab edge insulation in Climate Zones 4 and above. This R-15 insulation is the result of R-5 being "added" to the R-10 insulation level specified in the table for Climate Zones 4 through 8.

In accordance with Note g, where R-30 under-floor insulation is required, less insulation may be used if the framing cavity is filled, down to a minimum of R-19. This recognizes that extending the framing solely to hold more insulation can cost more than it is worth.



For SI: 1 inch = 25.4 mm.

Figure R402.1.2
EXTERIOR *R*-VALUES

R402.1.3 *R*-value computation. Insulation material used in layers, such as framing cavity insulation, or continuous insulation shall be summed to compute the corresponding component *R*-value. The manufacturer's settled *R*-value shall be used for blown insulation. Computed *R*-values shall not include an *R*-value for other building materials or air films. Where insulated siding is used for the purpose of complying with the continuous insulation requirements of Table R402.1.2, the manufacturer's labeled *R*-value for insulated siding shall be reduced by R-0.6.

❖ This section indicates how the *R*-value in Table R402.1.2 is to be determined. Table R402.1.2 specifies the required *R*-values for the insulation products, the nominal *R*-value. This is the *R*-value of the insulation products only. Although other products and features such as finish materials, air films and airspaces may contribute to overall energy efficiency, when determining the *R*-value in the code, these additional items are not considered and do not contribute to the nominal *R*-value. For example, if a wall had R-13 cavity insulation, gypsum board with an *R*-value of almost R-1 and exterior siding that has an *R*-value of R-1, the overall wall *R*-value is simply R-13 because the gypsum board and the exterior siding do not contribute to the *R*-value for purposes of determining code compliance. Where there is more than one layer of insulation, the *R*-values for the layers are summed. For example, a wall with R-13 batts within the framing cavity and R-4 insulated sheathing would be treated as an R-17 wall (13 + 4 = 17). It is only insulation materials that may be summed to determine the component's *R*-value.

R402.1.4 *U*-factor alternative. An assembly with a *U*-factor equal to or less than that specified in Table R402.1.4 shall be permitted as an alternative to the *R*-value in Table R402.1.2.

❖ For residences built with common insulation products, the most direct method of compliance is often via the *R*-values in Table R402.1.2. As an alternative, compliance can be demonstrated by calculating the *U*-factor for a component. Table R402.1.4 gives *U*-factors that are deemed to be equivalent to the *R*-values in the prescriptive tables. Unlike the *R*-values in Table R402.1.2, which consider only the insulation, *U*-factors consider all the parts of the construction. *U*-factors for a wall might include exterior siding, gypsum board and air films, all of which would be excluded from the *R*-value computation by Section R402.1.2; for example, whether wall framing is 16 or 24 inches (406 or 610 mm) on center matters in computing the *U*-factor. Whether framing is metal or wood can also have a significant impact on *U*-factor.

U-factors are well suited to several applications. Construction types that limit the amount of framing or include thermal breaks as part of their design may benefit from *U*-factor calculations. Components with complex or nonuniform geometries can use testing to establish *U*-factors. Compliance with the "total UA alternative" or tradeoff approach in Section R402.1.4 requires the use of the *U*-factor tables.

Example of *U*-factor calculation in Table R402.1.4:

WALL COMPONENT	CAVITY	STUDS, PLATES	HEADERS
	***R*-value**	***R*-value**	***R*-value**
Outside air film	0.25	0.25	0.25
Plywood siding	0.59	0.59	0.59
Continuous insulation	5	5	5
Plywood sheathing	0.83	0.83	0.83
Wood studs	—	4.38	4.38
Cavity insulation	13	—	—
$^1/_2$″ Gypsum board	0.45	0.45	0.45
Inside air film	0.68	0.68	0.68
Sum of thermal resistance	20.8	12.18	12.18

The above table includes the *R*-values for the cavity and framing (studs, plates and headers). The *U*-factor is 1/*R*-value. To calculate the *U*-factor for the combination of the cavity and framing at 16 inches on-center spacing, calculate the *U*-factor based on the weighting factors of 75-percent cavity, 21-percent studs and plates, and 4-percent headers (78-percent cavity, 18-percent studs and plates and 4-percent headers for 24 inches on-center spacing). An assembly with a *U*-factor equal to or less than that calculated in this table must be permitted as an alternative to an assembly in Table R402.1.2.

The *U*-factor for the above assembly may be calculated as shown below:

$$U = \frac{0.75}{20.8} + \frac{0.21}{12.18} + \frac{0.04}{12.18} = 0.057$$

Example of *U*-factor alternative:

WALL COMPONENT	CAVITY	STUDS, PLATES	HEADERS
	***R*-value**	***R*-value**	***R*-value**
Outside air film	0.25	0.25	0.25
Plywood siding	0.59	0.59	0.59
Continuous insulation	13.1	13.1	31.1
Plywood sheathing	0.83	0.83	0.83
Wood studs	—	4.38	4.38
Cavity insulation	0.91	—	—
$^1/_2$″ Gypsum board	0.45	0.45	0.45
Inside air film	0.68	0.68	0.68
Sum of thermal resistance	16.81	20.28	20.28

In the above assembly, the R-13 cavity insulation is removed and a value of 0.91 is assumed for the airspace in the stud cavity. The continuous insulation is increased to 13.1. The framing spacing is increased to 24 inches (610 mm) on center.

The *U*-factor for the above assembly may be calculated as shown below:

$$U = \frac{0.78}{16.81} + \frac{0.18}{20.28} + \frac{0.04}{20.28} = 0.057$$

The *U*-factor from the above assembly is equal to or less than that specified in Table R402.1.4.

It should be noted that the *U*-factor alternative could be used for all or part of a wall. Thus, the prescriptive *R*-values in Section R402.1.2 can be applied to one segment of the wall, and the *U*-factors in this section can be used to determine the construction of another segment of the wall. One possible combination would be to apply the prescriptive requirements of Table R402.1.2 for the portion of the exterior wall thermal envelope with structural sheathing, and the *U*-factor alternative (Table R402.1.4) for the portion of the exterior wall thermal envelope that does not have structural sheathing. Note h of Table R402.1.2 could be applied to 40 percent of the wall when structural sheathing is present, allowing a reduction in the *R*-value of R-3 for this segment.

Where approved by the code official in accordance with Section R102, alternative methods of construction, materials and insulation systems may also be used instead of the prescriptive *R*-values of Table R402.1.2. For example, designers may substitute greater stud spacing, insulated plates and insulated headers in walls as an alternative to the prescribed cavity or continuous insulation.

R402.1.5 Total UA alternative. If the total *building thermal envelope* UA (sum of *U*-factor times assembly area) is less than or equal to the total UA resulting from using the *U*-factors in Table R402.1.4 (multiplied by the same assembly area as in the proposed building), the building shall be considered in compliance with Table R402.1.2. The UA calculation shall be done using a method consistent with the ASHRAE *Handbook of Fundamentals* and shall include the thermal bridging effects of framing materials. The SHGC requirements shall be met in addition to UA compliance.

❖ This alternative allows one portion of the building to make up for another. It recognizes that there may be reasons for less insulation in some parts of the building, which can be compensated for by more insulation in other parts of the residence. The key concept is that the overall building thermal flow (UA) meets the code. This concept could allow a ceiling to make up for a wall or vice versa. As a practical matter, whether a building will comply by this method can sometimes be estimated quickly. A large area that is significantly over the required *R*-value will make up for a small area only mildly under the required *R*-value. Likewise, it will sometimes be obvious that a small area that mildly exceeds the requirement will not make up for a large area well below the requirement.

This section allows for such tradeoffs but only if the total UA for the proposed building is below the aggregate UA calculation using the required values in Table R402.1.4 and the same assembly areas as the actual building. In other words, under this alternative, components with varying insulating values can be "traded off" with one another as the builder sees fit, as long as the total UA calculation for the entire building equals or is less than a calculation for that same house using the same assembly areas and the maximum UA values from Table R402.1.4.

The UA is the sum of the component *U*-factors times each assembly area. The maximum allowable UA is the UA for a proposed design as if it was insulated to meet exactly the individual component *U*-factor requirements. This tradeoff provision allows the type of insulation and installed fenestration to vary, which permits significant design flexibility. The desire for tradeoffs in construction is common because of unexpected problems or design conflicts, and a UA trade-off analysis is usually calculated with the assistance of electronic compliance tools, depending on

TABLE R402.1.4
EQUIVALENT *U*-FACTORS[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR	SKYLIGHT *U*-FACTOR	CEILING *U*-FACTOR	FRAME WALL *U*-FACTOR	MASS WALL *U*-FACTOR[b]	FLOOR *U*-FACTOR	BASEMENT WALL *U*-FACTOR	CRAWL SPACE WALL *U*-FACTOR
1	0.50	0.75	0.035	0.084	0.197	0.064	0.360	0.477
2	0.40	0.65	0.030	0.084	0.165	0.064	0.360	0.477
3	0.35	0.55	0.030	0.060	0.098	0.047	0.091[c]	0.136
4 except Marine	0.35	0.55	0.026	0.060	0.098	0.047	0.059	0.065
5 and Marine 4	0.32	0.55	0.026	0.060	0.082	0.033	0.050	0.055
6	0.32	0.55	0.026	0.045	0.060	0.033	0.050	0.055
7 and 8	0.32	0.55	0.026	0.045	0.057	0.028	0.050	0.055

a. Nonfenestration *U*-factors shall be obtained from measurement, calculation or an approved source.
b. When more than half the insulation is on the interior, the mass wall U-factors shall be a maximum of 0.17 in Climate Zone 1, 0.14 in Climate Zone 2, 0.12 in Climate Zone 3, 0.087 in Climate Zone 4 except Marine, 0.065 in Climate Zone 5 and Marine 4, and 0.057 in Climate Zones 6 through 8.
c. Basement wall *U*-factor of 0.360 in warm-humid locations as defined by Figure R301.1 and Table R301.1.

the jurisdiction. For example, the Department of Energy (DOE) has online compliance software for the code called REScheck, which can be downloaded from the DOE website at www.energycodes.gov. REScheck, if approved by the jurisdiction as compliant with the code, can be used to perform a UA tradeoff analysis.

This section explicitly prohibits the tradeoff of SHGC requirements, requiring that the "SHGC requirements be met in addition to UA compliance." As a result, glazed fenestration must comply with the SHGC values shown in Table R402.1.2 even if the *U*-factor is modified by trading off against some other component.

The requirements of this section establish specific additional requirements for any tradeoff. First, the baseline house must have the same assembly areas as the proposed house (e.g., the same area of each assembly—fenestration, skylights, ceiling, wall and floor). Second, the calculation should be done consistent with the *ASHRAE Handbook of Fundamentals*. Third, the calculation must include the thermal bridging effects of framing materials. To meet these requirements, the calculation method must either specifically combine the actual framing and insulation paths (with their specific areas and *U*-values) or use framing factors such as those found in the *ASHRAE Handbook of Fundamentals* for all framed building components (Note: this is not necessary for fenestration, which is a whole product value). To illustrate this approach, assume 1,000 square feet (93 m^2) of wall, of which 250 square feet (23 m^2) is framing (assuming 0.81 *U*-factor) and 750 square feet (70 m^2) is cavity (R-13 insulation). The baseline (general code requirement) and proposed opaque wall UAs are computed as follows:

- Baseline Opaque Wall for Climate Zone 2 = (0.082 x 1000) = 82. (The 0.082 value used in the calculation is taken from Table R402.1.4.)
- Proposed Opaque Wall UA = (0.81 x 250) + (0.077 x 750) = 78. (The 0.81 value used in the calculation was given above as an assumption. The 0.077 value is determined based on the *R*-value of 13; that is, 1 ÷ 13 = 0.077.)

Similar computations would be done for each assembly (such as fenestration or ceilings) and the baseline and proposed values then totaled and compared. If the baseline is greater than or equal to the proposed values, the house satisfies the UA alternative. The home still must meet all other prescriptive requirements, including the fenestration SHGC in Table R402.1.2, the air leakage requirements of Section R402.4 and the moisture-control requirements of Section R402.5.

It also should be noted that this alternative is limited to UA tradeoffs for the building's thermal envelope. The 2015 code does not authorize or establish any basis for HVAC tradeoffs associated with its UA tradeoff option. HVAC performance is simply not addressed under the code prescriptive or UA tradeoff paths. It is addressed only in Section R405 under the "Simulated Performance Alternative." As a result, the code limits these simplified tradeoffs to UA envelope tradeoffs and defers any more complex tradeoffs exclusively to the "Simulated Performance Alternative" in Section R405. If the builder wishes to factor in HVAC performance for tradeoffs, Section R405 can be used and is permitted based on Section R101.3, accepting Section R405 as a compliance option.

Documentation acceptable to the local building department generally must be submitted to the appropriate authority to certify acceptable component UA tradeoffs.

UA alternative example (for calculating standard and proposed designs):

Building areas and *U*-factors (for single-family, Zone 5 from Table R402.1.4)

Standard (Code) Design	**Proposed Design**
Exterior Wall 1050 ft^2 U_w = -0.057	Exterior Wall 1050 ft^2 U = 0.0451
Glazed doors and windows 192 ft^2 U_g = 0.32	Glazed doors and windows 192 ft^2 U = 0.40
Opaque exterior door 38 ft^2 U_g = 0.32	Opaque exterior door 38 ft^2 U = 0.35
Roof 1500 ft^2 U_r = 0.026	Roof 1500 ft^2 U_r = 0.026
Floor (slab) 1500 ft^2 U = 0.033	Floor (slab) 1500 ft^2 U_{fe} = 0.033

UA Standard = (0.057 × 1050) + (0.32 × 192) + (0.32 × 38) + (0.026 × 1500) + (0.033 × 1500) = 222

UA Proposed = (0.0451 × 1050) + (0.40 × 192) + (0.35 × 38) + (0.026 × 1500) + (0.033 × 1500) = 225

UA Proposed > UA Standard; therefore design fails to meet code requirements.

R402.2 Specific insulation requirements (Prescriptive). In addition to the requirements of Section R402.1, insulation shall meet the specific requirements of Sections R402.2.1 through R402.2.13.

❖ This section contains specific requirements to be followed for the individual items listed in the subsections. Although Section R402.1 and Tables R402.1.2 and R402.1.4 provide the general basis for complying with the energy requirements of this chapter, Section R402.2 provides additional details regarding the actual construction of the assemblies or modifications that may affect the general requirements. Relying on the principle that specific requirements apply over general requirements will help ensure that these specific provisions are properly followed.

R402.2.1 Ceilings with attic spaces. Where Section R402.1.2 would require R-38 insulation in the ceiling, installing R-30 over 100 percent of the ceiling area requiring insulation shall be deemed to satisfy the requirement for R-38 wherever the full height of uncompressed R-30 insulation extends over the wall top plate at the eaves. Similarly, where Section R402.1.2 would require R-49 insulation in the ceiling, installing R-38 over 100 percent of the ceiling area requiring insulation shall be deemed to satisfy the requirement for R-49 insulation wherever the full height of uncompressed R-38 insulation extends over the wall top plate at the eaves. This reduction shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the total UA alternative in Section R402.1.5.

❖ The required ceiling *R*-value found in the code is based on the assumption that standard truss or rafter construction was being used. Where raised-heel trusses or other methods of framing that do not permit the ceiling insulation to be installed to its full depth over the entire area are used, the code permits the installation of a lower *R*-value insulation. The general assumption is that ceiling insulation will be compressed at the edges and, if special construction techniques are used, the level of insulation required can be reduced.

Insulation installed in a typical roof assembly will be full height throughout the center portions of the assembly and will taper (be compressed) at the edges as the roof nears the top plate of the exterior wall system [see Commentary Figure R402.2.1(1)]. The slope of the roof causes this tapering, which is further amplified by any baffling installed to direct ventilation air from the eave vents up and over the insulation. Because of this tapering, the installed *R*-value near the plate lines will be less than the rated *R*-value for the insulation. This is caused by compression (compressed insulation has a lower *R*-value than insulation installed to its full thickness) and the limited space between the floor of the attic and the roof sheathing near the exterior plate line. Thus, a typical installation, on average, will have a lower *R*-value than that of the rated insulation. Because of this, the code will allow installation of a lower insulation value if it can be installed full thickness, to its rated *R*-value, over the plate line of the exterior wall. This allowance recognizes that a partial thermal “bypass” has been made more efficient by using insulation with the full *R*-value at the eaves. The full insulation *R*-value is sometimes achieved by what is termed an “energy truss” or “advanced framing.” This can be achieved by using an oversized truss or raised-heel truss as shown in Commentary Figure R402.2.1(2). Another way to achieve the full *R*-value would be by use of insulation with a higher *R*-value per inch at the eaves. The use of the options permitted by this section allows substituting R-30 for R-38 insulation, and R-38 may be substituted for R-49 insulation to meet the requirements of the code. When using the conditioned attic requirements of the code, the same option of using a reduced *R*-value would apply if the insulation was installed directly under the roof deck, rather than on the attic floor. The insulation would be permitted to meet the lesser *R*-value, presuming the full *R*-value was met over the eaves. Of course, this situation would also presume that the attic space beneath the insulation was not vented.

Note that this text applies only to the *R*-value portion of the code; there is no reduction in requirements if the *U*-factor alternative or the total UA alternative is used. In those cases, the reduced thickness must be

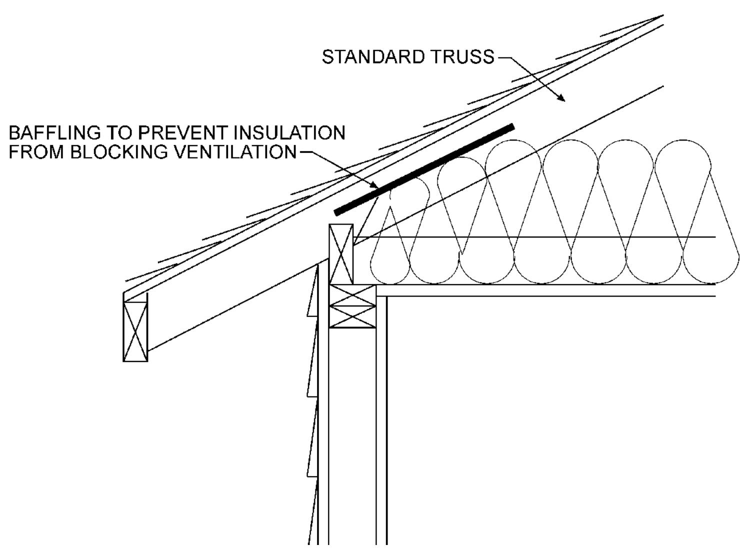


Figure R402.2.1(1)
TYPICAL ROOF ASSEMBLY

accounted for in the calculations. In addition, if the residence had more than one separate attic space, it is possible this section could apply to one attic space, but not another.

R402.2.2 Ceilings without attic spaces. Where Section R402.1.2 would require insulation levels above R-30 and the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, the minimum required insulation for such roof/ceiling assemblies shall be R-30. This reduction of insulation from the requirements of Section R402.1.2 shall be limited to 500 square feet (46 m^2) or 20 percent of the total insulated ceiling area, whichever is less. This reduction shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the total UA alternative in Section R402.1.5.

❖ In situations where the ceiling is installed directly onto the roof rafters and no attic space is created, this section will allow a reduced level of ceiling insulation for a limited area. This section addresses the construction of what are typically called “cathedral” or “vaulted” ceilings, which result in that portion of the home not having an attic area above the ceiling. See the definition of “Attic” in Chapter 2 of the code. Based on the use of solid sawn lumber (2 × 8, 2 × 10 or 2 × 12) in conventional construction, as the ceiling *R*-value requirement increases, it may be impossible to install the required ceiling insulation from Table R402.1.2 in the available cavity depth. In addition, the ventilation requirements of Section R806.3 of the IRC or Section 1203.2 of the IBC further reduce the available space by requiring a minimum space of 1 inch (25 mm) between the insulation and the roof sheathing. Therefore, when the depth of the cavity will not permit the required insulation level, this section permits a reduction to R-30 ceiling insulation instead of the normally required R-38 or R-49 requirement from Table R402.1.2. This will generally result in reducing the required insulation level instead of having to increase the depth of the framing members. This section in the code recognizes that increases in framing size done only to accommodate higher *R*-values are an expensive way to achieve a limited increase in *R*-value.

It is important to note that this section applies only to areas that have a required insulation level above R-30 (Climate Zones 4 through 8). Further, the reduction is limited to portions of ceiling assemblies that do not exceed 500 square feet (46 m^2) or 20 percent of the ceiling area. The intent is that the 500-square-foot (46 m^2) or 20-percent limitation be the total aggregate exempted amount of the building’s thermal envelope (ceiling) that can use this reduction. It is not the intent that a home could have multiple areas that were each under the 500-square-foot (46 m^2) or 20-percent limit but would aggregate to more than that amount. In situations that cannot meet these limitations [homes in Climate Zones 1 through 3 or homes needing more than 500 square feet (46 m^2) of reduced ceiling insulation], the depth of the rafters would have to be increased to meet the table’s required insulation level, or other design changes or means of compliance would be necessary. This provision does not apply if the *U*-factor alternative or the total UA alternative is being used. In those cases, the reduced insulation level might be accomplished, but it would be accounted for with additional insulating components in the case of the *U*-factor alternative or with added insulation elsewhere in the case of the total UA alternative.

R402.2.3 Eave baffle. For air-permeable insulations in vented attics, a baffle shall be installed adjacent to soffit and eave vents. Baffles shall maintain an opening equal or greater than the size of the vent. The baffle shall extend over

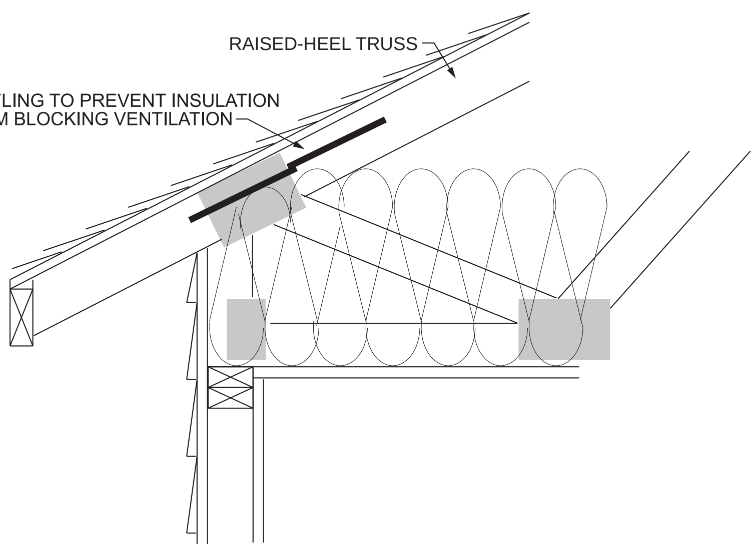


Figure R402.2.1(2)
RAISED-HEEL TRUSS

the top of the attic insulation. The baffle shall be permitted to be any solid material.

❖ For air-permeable insulations in vented attics, a baffle shall be installed adjacent to soffit and eave vents. This will help prevent wind from degrading the attic insulation performance. Baffles serve to keep vents open, insulation in place and keep the wind from blowing through the insulation and reducing its effectiveness.

R402.2.4 Access hatches and doors. Access doors from conditioned spaces to unconditioned spaces such as attics and crawl spaces shall be weatherstripped and insulated to a level equivalent to the insulation on the surrounding surfaces. Access shall be provided to all equipment that prevents damaging or compressing the insulation. A wood- framed or equivalent baffle or retainer is required to be provided when loose-fill insulation is installed, the purpose of which is to prevent the loose-fill insulation from spilling into the living space when the attic access is opened, and to provide a permanent means of maintaining the installed *R*-value of the loose-fill insulation.

Exception: Vertical doors that provide access from conditioned to unconditioned spaces shall be permitted to meet the fenestration requirements of Table R402.1.2 based on the applicable climate zone specified in Chapter 3.

❖ The portion of a ceiling used for an attic access door is a weak part of the building thermal envelope. The purpose of this provision is to ensure that measures are taken to prevent large loss of energy through this opening.

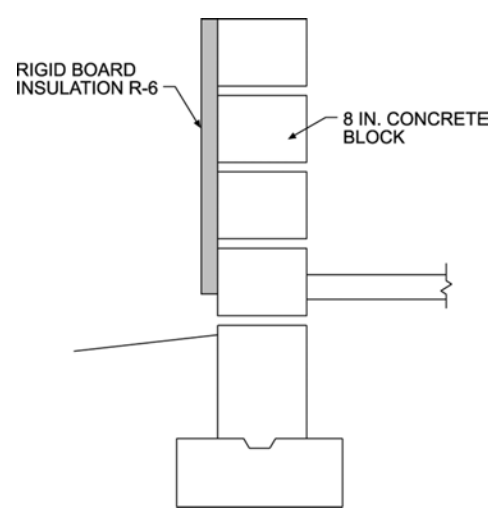
R402.2.5 Mass walls. Mass walls for the purposes of this chapter shall be considered above-grade walls of concrete block, concrete, insulated concrete form (ICF), masonry cavity, brick (other than brick veneer), earth (adobe, compressed earth block, rammed earth) and solid timber/logs, or any other walls having a heat capacity greater than or equal to 6 Btu/ft^2 × °F (123 kJ/m^2 × K).

❖ The code uses a simple definition for mass walls. Walls made of the specified materials and mass are mass walls. Mass walls may meet the lower mass wall *R*-value (as compared to frame wall values) specified in their respective climate zones because of the energy-conserving characteristics of mass walls. Note that the difference between the wood-frame *R*-value is greatest in southern climates. This recognizes that the thermal "averaging" provided by mass walls is most effective in warmer climates. In the very northern climates where there is almost continual heating during parts of the year, the thermal mass is of limited value. The code simply lists the types of walls that are considered as being "mass" walls. There is no additional limitation or characteristic specified for the walls that would be applicable when using the code.

In general terms, the heat capacity is a measure of how well a material stores heat. The higher the heat capacity, the greater the amount of heat stored in the material. For example, a 6-inch (152 mm) heavy-weight concrete wall has a heat capacity of 14 Btu/ft^2 × °F (620 J/m^2 × K) compared to a conventional 2-inch by 4-inch wood-framed wall with a heat capacity of approximately 3 Btu/ft^2 × °F (138 J/m^2 × K). Tables R402.1.2 and R402.1.4 are used to determine the insulation or equivalent *U*-factor requirements for mass walls. To use the tables, first consult either Table R301.1 or Figure R301.1 to determine the climate zone of the proposed project. The *R*-value for the assembly is then given for the mass wall in Table R402.1.2 or the *U*-factor is given in Table R402.1.4.

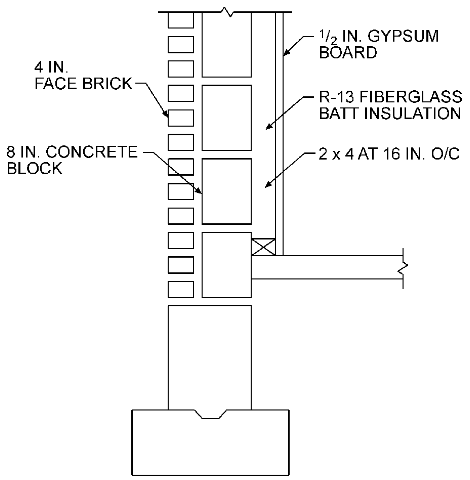
When dealing with the mass walls, the insulation location is important. Note i of Table R402.1.2 indicates that the second *R*-value, which is the higher *R*-value for mass walls in each climate zone, is applicable when more than half of the insulation is on the interior of the mass wall. The first values listed in Table R402.1.2 are, therefore, based on the installation of the majority of the insulation ("at least 50 percent") being located on the exterior side of the wall or being integral to the wall. Likewise, Note b of Table R402.1.4 provides lower maximum *U*-factors for mass walls with more than 50 percent of the insulation on the interior of the wall.

For an example of a wall assembly that has insulation on the exterior of the wall (between the mass wall and the exterior), see Commentary Figure R402.2.5(1). Concrete masonry units with insulated cores or masonry cavity walls are examples of integral insulation. For mass walls with the insulation installed on the interior (an insulated furred wall located between the conditioned space and the mass wall), see Commentary Figure R402.2.5(2). As shown, these two figures would be examples of mass walls that meet or exceed the general requirements of this section and Table R402.1.2 for Climate Zones 1 through 4, except for those in Marine Zone 4.



For SI: 1 inch = 25.4 mm.

Figure R402.2.5(1)
EXTERIOR INSULATION



For SI: 1 inch = 25.4 mm.

Figure R402.2.5(2)
INTERIOR INSULATION

R402.2.6 Steel-frame ceilings, walls and floors. Steel-frame ceilings, walls, and floors shall meet the insulation requirements of Table R402.2.6 or shall meet the *U*-factor requirements of Table R402.1.4. The calculation of the *U*-factor for a steel-frame envelope assembly shall use a series-parallel path calculation method.

❖ The insulation requirements of Table R402.1.2 are based on conventional wood-frame construction methods. Because the code also includes provisions applicable to steel-framing methods, this chapter has been written to include this material. Table R402.2.6 specifies combinations of cavity and continuous insulation for steel framing that are equivalent to the specified wood-frame component *R*-values in Table R402.1.2.

Table R402.1.2 cannot be used directly for steel-frame components. When using Table R402.2.6, all listed options comply; the code user can choose any option on the list that corresponds to the correct *R*-value in the left-hand column. Steel has a much higher thermal conductivity (ability to transfer heat) than wood. Therefore, steel-frame cavities require a higher *R*-value or include a requirement for insulated sheathing that acts as a thermal break or both.

Instead of using this table, the code user could choose to calculate or measure a *U*-factor for a building component and show compliance based on meeting the *U*-factor requirement in Table R402.1.4. The code user could use the total UA tradeoff in Section R402.1.4 or even the performance-based approach in Section R405 to show compliance based on the overall building, even if the steel-frame wall did not meet the code requirements directly. Other combinations of cavity insulation and continuous insulation not shown in Table R402.2.6 would also be allowed; however, if a combination from the table is used, no additional calculation is necessary.

R402.2.7 Walls with partial structural sheathing. Where Section R402.1.2 would require continuous insulation on exterior walls and structural sheathing covers 40 percent or less of the gross area of all exterior walls, the continuous insulation *R*-value shall be permitted to be reduced by an amount necessary to result in a consistent total sheathing thickness, but not more than R-3, on areas of the walls covered by structural sheathing. This reduction shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the total UA alternative in Section R402.1.5.

❖ The provisions of this section are intended to deal with a practical situation that occurs when structural sheathing is used over a portion of the outside wall, such as at the corners for horizontal bracing. In those

TABLE R402.2.6
STEEL-FRAME CEILING, WALL AND FLOOR INSULATION (*R*-VALUE)

WOOD FRAME *R*-VALUE REQUIREMENT	COLD-FORMED STEEL EQUIVALENT *R*-VALUE[a]
Steel Truss Ceilings[b]	
R-30	R-38 or R-30 + 3 or R-26 + 5
R-38	R-49 or R-38 + 3
R-49	R-38 + 5
Steel Joist Ceilings[b]	
R-30	R-38 in 2 × 4 or 2 × 6 or 2 × 8 R-49 in any framing
R-38	R-49 in 2 × 4 or 2 × 6 or 2 × 8 or 2 × 10
Steel-framed Wall, 16″ on center	
R-13	R-13 + 4.2 or R-19 + 2.1 or R-21 + 2.8 or R-0 + 9.3 or R-15 + 3.8 or R-21 + 3.1
R-13 + 3	R-0 + 11.2 or R-13 + 6.1 or R-15 + 5.7 or R-19 + 5.0 or R-21 + 4.7
R-20	R-0 + 14.0 or R-13 + 8.9 or R-15 + 8.5 or R-19 + 7.8 or R-19 + 6.2 or R-21 + 7.5
R-20 + 5	R-13 + 12.7 or R-15 + 12.3 or R-19 + 11.6 or R-21 + 11.3 or R-25 + 10.9
R-21	R-0 + 14.6 or R-13 + 9.5 or R-15 + 9.1 or R-19 + 8.4 or R-21 + 8.1 or R-25 + 7.7
Steel-framed Wall, 24″ on center	
R-13	R-0 + 9.3 or R-13 + 3.0 or R-15 + 2.4
R-13 + 3	R-0 + 11.2 or R-13 + 4.9 or R-15 + 4.3 or R-19 + 3.5 or R-21 + 3.1
R-20	R-0 + 14.0 or R-13 + 7.7 or R-15 + 7.1 or R-19 + 6.3 or R-21 + 5.9
R-20 + 5	R-13 + 11.5 or R-15 + 10.9 or R-19 + 10.1 or R-21 + 9.7 or R-25 + 9.1
R-21	R-0 + 14.6 or R-13 + 8.3 or R-15 + 7.7 or R-19 + 6.9 or R-21 + 6.5 or R-25 + 5.9
Steel Joist Floor	
R-13	R-19 in 2 × 6, or R-19 + 6 in 2 × 8 or 2 × 10
R-19	R-19 + 6 in 2 × 6, or R-19 + 12 in 2 × 8 or 2 × 10

a Cavity insulation *R*-value is listed first, followed by continuous insulation *R*-value.
b. Insulation exceeding the height of the framing shall cover the framing.

cases, the thickness of the portion of the wall with structural sheathing could be different than the portion of the wall without sheathing. The code therefore allows a reduction of R-3 in the required insulation of the sheathed portion to facilitate some flexibility in the choice of insulation. This option is only allowed in the application of the prescriptive table, Table R402.1.2, and not when utilizing the *U*-factor alternative or the UA alternative.

R402.2.8 Floors. Floor framing-cavity insulation shall be installed to maintain permanent contact with the underside of the subfloor decking.

> **Exception:** The floor framing-cavity insulation shall be permitted to be in contact with the topside of sheathing or continuous insulation installed on the bottom side of floor framing where combined with insulation that meets or exceeds the minimum wood frame wall *R*-value in Table 402.1.2 and that extends from the bottom to the top of all perimeter floor framing members.

❖ Floors that are a part of the building thermal envelope, such as those over a crawl space or an unconditioned garage, are required to meet or exceed the floor *R*-value requirements listed in Table R402.1.2. The insulation *R*-value requirements range from R-13 in warm climates to R-38 in extremely cold climates. Insulation must be installed between the floor joists and must be well supported with netting, wire, wood strips or another method of support so that the insulation does not droop or fall out of the joist cavities over time. Some floor insulation has a tendency to sag or drop with time. This sag or drop exposes the subfloor directly to the temperature beneath the floor. Sagging also has a tendency to open airflow paths to parts of the floor, producing cold spots and negating the value of the floor insulation in the effected section of the floor. Even small areas that lack insulation or allow air circulation between the floor insulation and the subfloor can have a marked effect on the energy efficiency of the floor. This section specifies that floor insulation must be installed so it will maintain "permanent contact" with the subfloor (meaning over the useful life of the residence).

If a floor of a building extends over outside air, such as over an open carport, the floor is still insulated to the "floor" requirement of Table R402.1.2 rather than being treated as part of the exterior envelope card meeting the same *R*-value as for ceilings.

The exception provides a specific configuration for insulating a floor. Requiring insulation in floors to be in direct contact with the underside of subfloor decking is one insulating option. Another option is to have an airspace between the floor sheathing and the top-of-cavity insulation where this cavity insulation is in direct contact with the top side of sheathing or continuous insulation installed on the underside of the floor framing and is combined with perimeter insulation that meets or exceeds the *R*-value requirements for walls. This second option leads to fewer cold spots yet does not change the heat loss as long as the cavity insulation is in direct contact with sheathing or continuous insulation below it. It also facilitates services to be enclosed in the thermal envelope. An example of this configuration is illustrated in Commentary Figure R402.2.8.

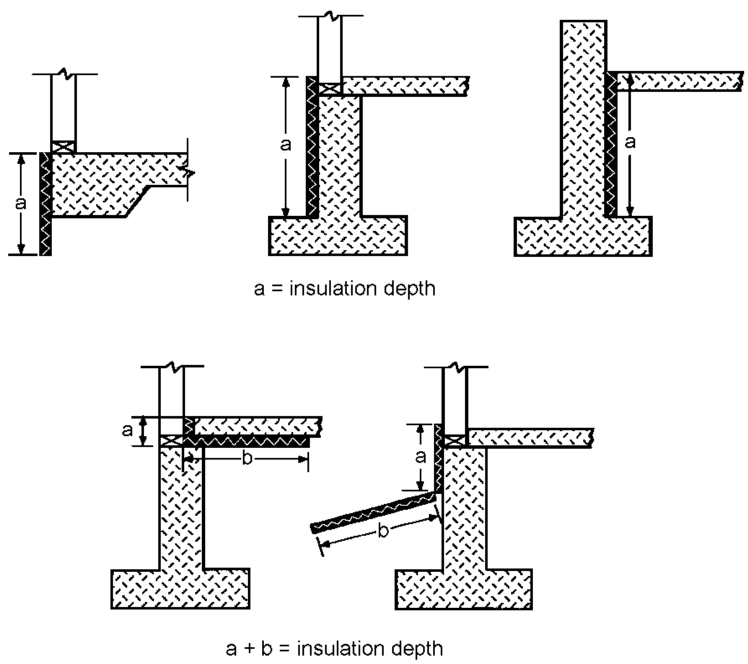


Figure R402.2.8
SLAB INSULATION METHODS

R402.2.9 Basement walls. Walls associated with conditioned basements shall be insulated from the top of the *basement wall* down to 10 feet (3048 mm) below grade or to the basement floor, whichever is less. Walls associated with unconditioned basements shall meet this requirement unless the floor overhead is insulated in accordance with Sections R402.1.2 and R402.2.8.

❖ The walls of conditioned basements must be insulated to meet the requirements of Table R402.1.2. Each wall of a basement must be considered separately to determine whether it is a basement wall or an exterior wall. It is a basement wall if it has an average below-grade wall area of 50 percent or more. A wall that is less than 50 percent below grade is an exterior wall and must meet the insulation requirements for walls. Most walls associated with basements will be at least 50 percent below grade and, therefore, must meet basement wall requirements.

Walkout basements offer a challenge in determining compliance with the code. A walkout basement [see Commentary Figures R402.2.9(1) and (2)] may have a back wall that is entirely below grade, a front wall or the walkout portion that is entirely above grade and two sidewalls with a grade line running diagonally. In this case, the back wall must meet the requirements for basement walls, the front wall would need to meet the requirements for walls (either framed wall or mass wall, as applicable) and the side walls would need to be evaluated to determine whether they were 50 percent or more below grade and, therefore, basement walls.

Basement insulation must extend up to 10 feet (3048 mm) under the ground, or at least as far as the basement wall extends under the ground. Heat flow into the ground occurs all along the buried portion of the wall, as well as along the above-ground portion of

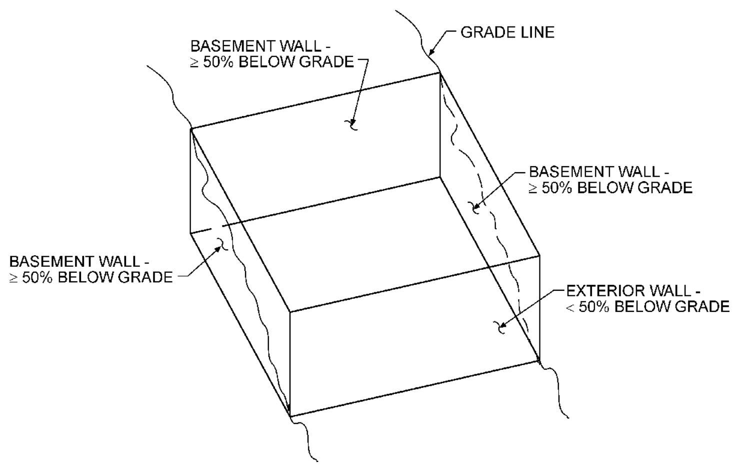


Figure R402.2.9(1)
WALKOUT BASEMENT

Figure R402.2.9(2)
EXTERIOR BASEMENT INSULATION

the wall. Heat flow below 10 feet (3048 mm) is greatly diminished so the code requires basement insulation only down to 10 feet (3048 mm), or the depth of the basement wall.

The code does not specify whether the insulation is to be placed on the inside or outside of a basement wall. In some localities moisture considerations may suggest the type and location for insulation.

The last part of this section allows insulating unconditioned basement walls as an alternative to insulating the floor above the unconditioned basement. Therefore, it essentially shifts the location of the building thermal envelope from the floor to the basement walls. Although not required, insulating the unconditioned basement walls makes a good deal of sense if a basement is likely to be conditioned at some time after construction.

Because the rim joist between floors is a part of the building envelope, this must be insulated also if the basement is conditioned.

When applying the provisions of this section, it is important to review the definitions for both “Above grade wall” and “Basement wall” in Section R202. For code users who also deal with commercial buildings, remember that the rule for residential buildings is 50 percent above or below grade and not the 85-percent minimum below grade with 15-percent maximum above-grade area that is applicable under Section C402.2.2 for commercial construction.

R402.2.10 Slab-on-grade floors. Slab-on-grade floors with a floor surface less than 12 inches (305 mm) below grade shall be insulated in accordance with Table R402.1.2. The insulation shall extend downward from the top of the slab on the outside or inside of the foundation wall. Insulation located below grade shall be extended the distance provided in Table R402.1.2 by any combination of vertical insulation, insulation extending under the slab or insulation extending out from the building. Insulation extending away from the building shall be protected by pavement or by not less than 10 inches (254 mm) of soil. The top edge of the insulation installed between the *exterior wall* and the edge of the interior slab shall be permitted to be cut at a 45-degree (0.79 rad) angle away from the *exterior wall.* Slab-edge insulation is not required in jurisdictions designated by the *code official* as having a very heavy termite infestation.

❖ The perimeter edges of slab-on-grade floors must be insulated to the *R*-values listed in Table R402.1.2. These requirements apply only to slabs 12 inches (305 mm) or less below grade. The listed *R*-value requirements in the table are for unheated slabs. A heated slab must add another R-5 to the required insulation levels based on Note d of Table R402.1.2.

The insulation must extend downward from the top of the slab or downward to the bottom of the slab and then horizontally in either direction until the distance listed in Table R402.1.2 is reached. See Commentary Figure R402.2.10 for examples on how the distance is measured. Most of the heat loss from a slab will occur in the edge that is exposed directly to the outside air. The insulation must be installed to the top of the slab edge to prevent this heat loss. Slab insulation may be installed on the exterior of the slab edge or between the interior wall and the edge of the interior slab as in a nonmonolithic slab. In this type of installation, the exposed insulation could cause problems with tack strips for carpeting. Therefore, the

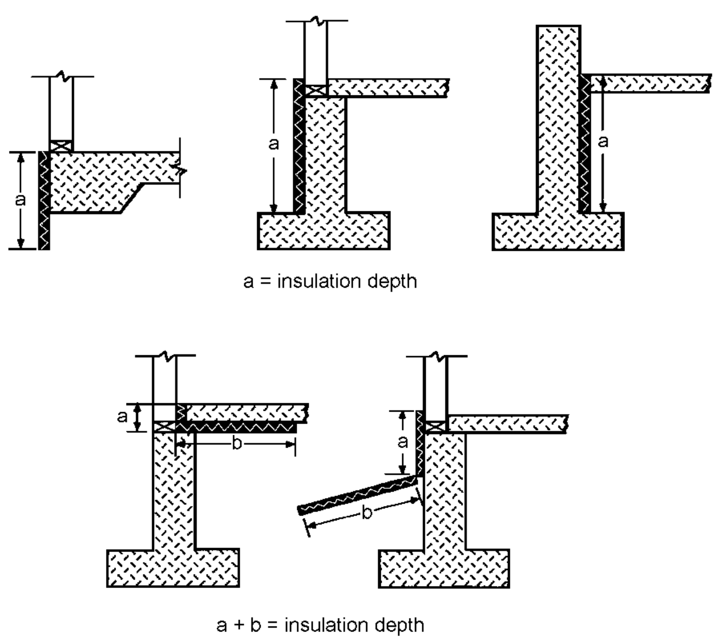


Figure R402.2.10
SLAB INSULATION METHODS

insulation is allowed to be cut at a 45-degree angle away from the exterior of the wall. If a monolithic slab and foundation is being used, the required insulation would obviously need to be installed on the exterior and then either extended to the required depth or turned out to the exterior and protected by either some type of pavement or a minimum of 10 inches (254 mm) of soil. Insulation that is exposed on or near the surface is easily damaged. This protection method ensures that the insulation remains in place and provides the intended energy savings.

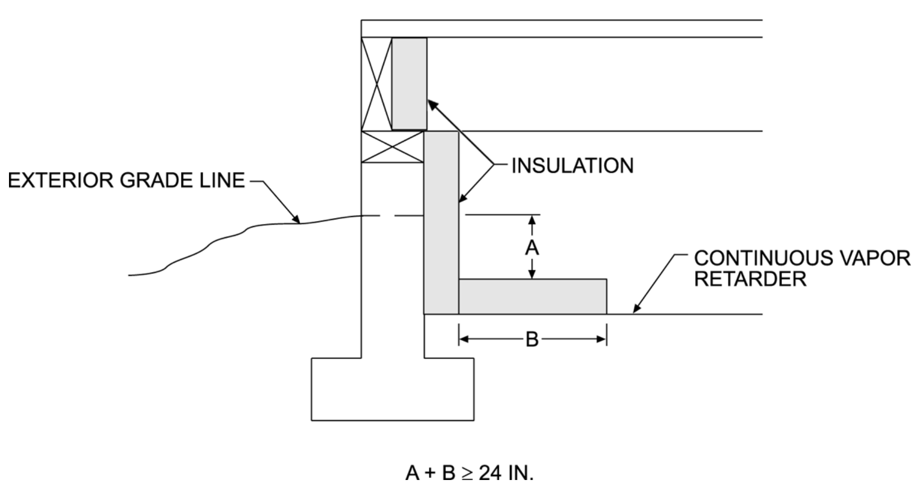
In areas with very heavy termite infestation, slab perimeter insulation need not be installed in accordance with Table R402.1.2. These areas are identified in Figure 301.2(6) of the IRC or Figure 2603.9 of the IBC or by the jurisdiction, based on the local history and situation. It is important to understand that this exemption from the slab insulation provisions are for any area with heavy termite infestations. The fact that this is an exemption and does not contain any requirement for a compensating increase of insulation at other locations is important.

The requirements of Section R402.1.4 could still be used in areas that do not have a heavy termite infestation to eliminate the slab edge insulation if desired. Typically, slab perimeter insulation can be traded off entirely in these climates by increasing the ceiling or wall insulation *R*-values or by using glazing with a lower *U*-factor.

R402.2.11 Crawl space walls. As an alternative to insulating floors over crawl spaces, crawl space walls shall be permitted to be insulated when the crawl space is not vented to the outside. Crawl space wall insulation shall be permanently fastened to the wall and extend downward from the floor to the finished grade level and then vertically and/or horizontally for at least an additional 24 inches (610 mm). Exposed earth in unvented crawl space foundations shall be covered with a continuous Class I vapor retarder in accordance with the *International Building Code* or *International Residential Code*, as applicable. All joints of the vapor retarder shall overlap by 6 inches (153 mm) and be sealed or taped. The edges of the vapor retarder shall extend not less than 6 inches (153 mm) up the stem wall and shall be attached to the stem wall.

❖ The code allows for the insulation of crawl space walls instead of insulating the floor between the crawl space and the conditioned space. In essence, the code user is defining the thermal boundary as either the floor or the crawl space wall. Because the ground under the crawl space is tempered by the thermal mass of the dirt, the temperature of the crawl space is usually more favorable than the outside temperature. This is a popular practice for freeze protection of plumbing pipes in colder climates because it is common to install plumbing in the crawl space. The heat transferred through the uninsulated floor to the crawl space helps keep the crawl space temperature above freezing when the outside air temperature drops below freezing. To comply with this provision, the crawl space must be mechanically vented or supplied with conditioned air from the living space. IBC Section 1203.3 and its subsections address this crawl space ventilation requirement.

The code also requires installation of insulation from the sill plate downward to the exterior finished grade level and then an additional 24 inches (610 mm) either vertically or horizontally (see Commentary Figure R402.2.11). Under this insulation scenario, the rim joist is considered part of the conditioned envelope and must be insulated to the same level as the exterior wall. The insulation must be attached securely to the crawl space wall so that it does not fall off. The code also requires installing a continuous Class I vapor retarder on the floor of the crawl space



For SI: 1 inch = 25.4 mm.

Figure R402.2.11
CRAWL SPACE WALL INSULATION

to prevent ground-water vapor from entering the crawl space. A Class I vapor retarder is defined in the IBC as a material with a permeance of 0.1 perm or less (see the definition of "Vapor retarder class" in the IBC). The vapor retarder is to be installed with all joints overlapped and sealed or taped to provide continuity. Also, the vapor retarder must extend up the crawl space wall and be secured to the wall with an appropriate attachment, such as an approved mastic or a treated wood nailer.

R402.2.12 Masonry veneer. Insulation shall not be required on the horizontal portion of the foundation that supports a masonry veneer.

❖ For exterior foundation insulation, the horizontal portion of the foundation that supports a masonry veneer need not be insulated. For slab-edge insulation installed on the exterior of the slab, the code allows the insulation to start at the bottom of the masonry veneer and extend downward. This is essentially a matter of practicality and accommodates the construction of a "brick ledge" without the need for insulating the foundation at the point where the masonry would bear on that foundation.

R402.2.13 Sunroom insulation. *Sunrooms* enclosing conditioned space shall meet the insulation requirements of this code.

Exception: For *sunrooms* with *thermal isolation*, and enclosing conditioned space, the following exceptions to the insulation requirements of this code shall apply:

1. The minimum ceiling insulation *R*-values shall be R-19 in *Climate Zones* 1 through 4 and R-24 in *Climate Zones* 5 through 8.
2. The minimum wall *R*-value shall be R-13 in all *climate zones*. Walls separating a *sunroom* with a *thermal isolation* from *conditioned space* shall meet the *building thermal envelope* requirements of this code.

❖ With the amount of glass in sunrooms, it is imperative the insulation requirements of the code be complied with to ensure minimal current requirements. The exceptions also tighten the requirements per zone to minimize energy usage.

R402.3 Fenestration (Prescriptive). In addition to the requirements of Section R402, fenestration shall comply with Sections R402.3.1 through R402.3.5.

❖ This section contains specific requirements that affect the requirements for individual items listed in the subsections. Although Section R402.1 and Tables R402.1.2 and R402.1.4 provide the general basis for complying with the energy requirements of this chapter, Section R402.3 provides additional details regarding the application of the provisions or modifications that may affect the general fenestration requirements. Relying on the general code policy that specific requirements apply over general requirements will help ensure that these specific provisions are properly applied.

The term "fenestration" in this section refers to opaque doors and the light-transmitting areas of a residential building's wall, floor or roof, generally window, skylight and nonopaque door products (see the definition of "Fenestration" in Chapter 2). Prior to the 2006 edition, the residential energy provisions of the code applied only to buildings with 15 percent or less of glazing areas (fenestration). The code's prescriptive requirements varied depending on the type of residential occupancy, but did include limitations on the amount of fenestration (maximum of 25 percent for one- and two-family dwellings and 30 percent for R-2, R-4 or townhouses). These earlier versions of the code established whole building performance requirements, with fenestration performance requirements as a derivative value dependent on window area, overall envelope area and the performance of other assemblies (e.g., walls, ceilings, floors). The code establishes specific simplified prescriptive requirements (without area considerations) for fenestration products in Table R402.1.2—specifically, fenestration *U*-factors, skylight *U*-factors and glazed fenestration SHGCs. The elimination of these fenestration area limitations helped to greatly simplify the application of the code's envelope requirements.

The fenestration requirements of the code are critical to the overall energy efficiency of the residence. First, unlike opaque assemblies, glazed fenestration can transmit a substantial amount of heat through the glazing into the living space in both the summer and winter, resulting in a unique concern about solar heat gain (and, as a result, necessitating SHGC requirements). Second, the insulating value (*U*-factor) of typical fenestration is much higher than that of a typical wall. For example, a good low emissivity (low-E), insulated glass wood or vinyl fenestration product will have less than one-fourth the insulating value of an equivalent area of R-13 insulated opaque wall. These issues have an effect not only on energy use, but overall occupant comfort, condensation and other issues.

In accordance with Section R303.1.3, the *U*-factor and SHGC for each fenestration product must be obtained from a label attached to the product certifying that the values were determined in accordance with NFRC procedures by an accredited, independent lab or from a limited default table.

R402.3.1 *U*-factor. An area-weighted average of fenestration products shall be permitted to satisfy the *U*-factor requirements.

❖ Section R402.3.1 permits using the calculated area-weighted average *U*-factor of all fenestration products in the building to satisfy the fenestration *U*-factor requirements set by Table R402.1.2 or R402.1.4. As a result, if all fenestration products (window, door or skylight) do not meet the specific value, the user can still achieve compliance if the weighted average of all products is equal to or less than the specified value.

This option permits the use of some windows that have values lower than the prescriptive general requirement, as long as these poorly performing windows are offset by windows with values better than the requirement.

When applying this area-weighted option, it is important to remember that the term "fenestration" includes windows, skylights, doors with glazing and opaque doors, all of which would be included in the average calculation.

Using the *U*-factor requirement of 0.35 for Climate Zone 6 as an illustration, this section provides two options for compliance. The simplest option is to ensure that all windows and doors have labeled NFRC values of 0.35 or less. This approach is also more likely to ensure adequate performance and comfort throughout the home. Alternatively, a weighted average may be taken of the values from all windows and doors to see if the weighted average is less than or equal to 0.35.

As a simple example, assume 100 square feet (9.3 m^2) of 0.32 windows, 100 square feet (9.3 m^2) of 0.36 windows and one 20-square-foot (1.8 m^2) 0.40 *U*-factor door $[(100 \times 0.32) + (100 \times 0.36) + (20 \times 0.40)]/(100 + 100 + 20) = 0.345$ (weighted average *U*-factor). Therefore, because the weighted average *U*-factor is less than the required 0.35, the fenestration in this example would be in compliance with the code.

In accordance with Section R303.1.2, the *U*-factor for each fenestration product must be obtained from a label attached to the product certifying that the *U*-factor was determined in accordance with NFRC procedures by an accredited, independent lab. In the absence of an NFRC-labeled *U*-factor, a value from the limited default tables [Tables R303.1.3(1) and R303.1.3(2)] must be used. The provisions of Section R402.4.5 should be reviewed when using the area-weighted average in the tradeoff options (see commentary, Section R402.5).

R402.3.2 Glazed fenestration SHGC. An area-weighted average of fenestration products more than 50-percent glazed shall be permitted to satisfy the SHGC requirements.

Dynamic glazing shall be permitted to satisfy the SHGC requirements of Table R402.1.2 provided the ratio of the higher to lower labeled SHGC is greater than or equal to 2.4, and the *dynamic glazing* is automatically controlled to modulate the amount of solar gain into the space in multiple steps. *Dynamic glazing* shall be considered separately from other fenestration, and area-weighted averaging with other fenestration that is not dynamic glazing shall not be permitted.

Exception: *Dynamic glazing* is not required to comply with this section when both the lower and higher labeled SHGC already comply with the requirements of Table R402.1.2.

❖ Under Table R402.1.2, all glazed fenestration products in Climate Zones 1 through 3 must have an SHGC equal to or less than 0.30 (there is no requirement in Climate Zones 4 through 8). This requirement is intended to control unwanted solar gain in cooling-dominated climates to increase comfort, reduce air-conditioning energy and peaks, reduce HVAC sizing and reduce energy costs.

Similar to Section R402.3.1, Section R402.3.2 allows some latitude for individual product variability by permitting this performance requirement to be met using an area-weighted average of all of the fenestration products that are more than 50-percent glazed. The 50-percent glazing threshold is established to exclude doors or other fenestration products that are either completely or largely opaque from the equation. The reason for this exclusion is that opaque elements do not allow solar heat gain as glazing does. The area-weighted calculation approach is explained in an example with Section R402.3.1. An additional example for SHGC is as follows:

Window 1	SHGC - 0.24	200 ft^2
Window 2	SHGC - 0.32	100 ft^2
Window 3	SHGC - 0.30	100 ft^2
Sliding glass door	SHGC - 0.40	40 ft^2

$[(200\ ft^2 \times 0.24) + (100\ ft^2 \times 0.32) + (100\ ft^2 \times 0.30) + (40\ ft^2 \times 0.40)]/440\ ft^2$

$440\ ft^2$ = SHGC - 0.29 Average

Using the figures in the example, even though Window 2 and the sliding glass door both have SHGC values that exceed the 0.25 limitation of Table R402.1.2 for Climate Zones 1 through 3, this design will comply because the weighted average is 0.34.

In accordance with Section R303.1.3, the SHGC for each glazed fenestration product must be obtained from a label attached to the product certifying that the SHGC was determined in accordance with NFRC procedures by an accredited, independent lab. In the absence of an NFRC-labeled SHGC, a value from the limited default table [Table R303.1.3(1)] must be used.

It is important to note that the SHGC requirement must be met by the fenestration product on a standalone basis. The code does not permit the alternative of a "permanent solar shading device" such as eave overhangs or awnings, as was permitted by other energy codes and previous versions of the code, to assist in code compliance.

R402.3.3 Glazed fenestration exemption. Up to 15 square feet (1.4 m^2) of glazed fenestration per dwelling unit shall be permitted to be exempt from *U*-factor and SHGC requirements in Section R402.1.2. This exemption shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the Total UA alternative in Section R402.1.5.

❖ In addition to using the area-weighted average approach (Sections R402.3.1 and R402.3.2) to allow maximum compliance flexibility for builders, the code allows up to 15 square feet (1.4 m^2) of the building's total glazed fenestration area to be exempt from the *U*-factor and SHGC requirements listed in Table

R402.1.2. All other glazing must meet or exceed the designated *U*-factor and SHGC requirements. The exempted glazing area should be designated on the building plan, either on the floor plan or in a window schedule. This will give the necessary information to the field inspector who will then need to verify that what is on the plans is installed in the field. This exemption allows the use of ornate or unique window, skylight or glazed door assemblies in a building without going to another compliance approach. The area, the *U*-factor and SHGC of the exempt product(s) should be excluded from the area-weighted calculations that may be performed under Sections R402.3.1 and R402.3.2. In addition, the exception provided by this section would also allow this 15 square feet (1.4 m^2) of glazing to be excluded from the limits of Section R402.5. Note that this exemption does not apply where the basis for the thermal envelope was the *U*-factor alternative in Section R402.1.4 or the total UA alternative in Section R402.1.4. In these cases, the amount of insulation does not need to be exempted.

R402.3.4 Opaque door exemption. One side-hinged opaque door assembly up to 24 square feet (2.22 m^2) in area is exempted from the *U*-factor requirement in Section R402.1.2. This exemption shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the total UA alternative in Section R402.1.5.

❖ Similar to the exemption provided in Section R402.3.3 to enhance design flexibility, the code allows one side-hinged opaque door to be exempt from fenestration *U*-factor requirements as contained in Table R402.1.2, as well as the limitations of Section R402.5. Although the code does not define it, an opaque door is generally considered to be a fenestration product with an overall glazing area of less than 50 percent. The opaque door exemption allows builders to use an ornate or otherwise *U*-factor noncompliant entrance door assembly in a building without going to another compliance approach. The area and the *U*-factor of the exempt product should be excluded from the area-weighted calculations under Section R402.4.1.

R402.3.5 Sunroom fenestration. *Sunrooms* enclosing *conditioned space* shall meet the fenestration requirements of this code.

Exception: For *sunrooms* with *thermal isolation* and enclosing *conditioned space* in *Climate Zones* 2 through 8, the maximum fenestration *U*-factor shall be 0.45 and the maximum skylight *U*-factor shall be 0.70.

New fenestration separating the *sunroom* with *thermal isolation* from *conditioned space* shall meet the *building thermal envelope* requirements of this code.

❖ This section simply reminds the user that sunrooms enclosing conditioned spaces are subject to code requirements. The exception tightens the maximum fenestration *U*-factor for Climate Zones 4 through 8. The maximum skylight *U*-factor shall be 0.70. Given the amount of glass in a sunroom, this section of the code tightens up the fenestration requirements and minimizes energy usage.

R402.4 Air leakage (Mandatory). The *building thermal envelope* shall be constructed to limit air leakage in accordance with the requirements of Sections R402.4.5 through R402.4.4.

❖ Sealing the building envelope is critical to good thermal performance of the building. The seal will prevent warm, conditioned air from leaking out around doors, windows and other cracks during the heating season, thereby reducing the cost of heating the residence. During hot summer months, a proper seal will stop hot air from entering the residence, helping to reduce the air-conditioning load on the building. Any penetration in the building envelope must be thoroughly sealed during the construction process, including holes made for the installation of plumbing, electrical and heating and cooling systems (see Commentary Figure R402.4). The code lists several areas that must be caulked, gasketed, weatherstripped, wrapped or otherwise sealed to limit uncontrolled air movement. Most of the air sealing will be done prior to the installation of an interior wall covering because any penetration will be noticeable and accessible at this time. The code allows the use of airflow retarders (house wraps) or other solid materials as an acceptable method to meet this requirement. To be effective, the building thermal envelope seal must be:

- Impermeable to airflow.
- Continuous over the entire building envelope.
- Able to withstand the forces that may act on it during and after construction.
- Durable over the expected lifetime of the building.

It is unlikely that the same type of barrier will be used on all portions of the building's thermal envelope. Therefore, joints between the various elements, as well as joints or splices within products (such as the overlap in separate pieces of house wrap), must be effectively addressed to provide the continuity needed to perform as desired.

R402.4.1 Building thermal envelope. The *building thermal envelope* shall comply with Sections R402.4.1.1 and R402.4.1.2. The sealing methods between dissimilar materials shall allow for differential expansion and contraction.

❖ Air infiltration is a major source of energy use because the incoming air usually requires conditioning. The uncontrolled introduction of outside air (infiltration) creates a load that varies with time. Ventilation, the controlled introduction of fresh air, is more manageable and provides a more controlled air quality. Uncontrolled infiltration also has a tendency to create or aggravate moisture problems, providing an additional reason to limit infiltration.

R402.4.1.1 Installation. The components of the *building thermal envelope* as listed in Table R402.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in Table R402.4.1.1, as applicable to the method of construction. Where required by the *code official*, an *approved* third party shall inspect all components and verify compliance.

❖ The provisions of this section are intended to reduce the energy loss to infiltration and to improve insulation installation.

The code allows all materials that are commonly used as sheathing to be part of the thermal envelope, including interior drywall. By the definition of an air barrier, gypsum board should be considered, as should exterior sheathing. The solid sheathing is not enough; for the air barrier to be effective the joints and openings must be sealed. The code does not require the air barrier on the inside of the air-permeable insulation.

In some cases, inspection of the air barrier is better performed by individuals with more expertise than the staff of the authority having jurisdiction might have. Therefore, the code gives the code official authority to require third-party inspectors.

Note that the line item in the table regarding fireplaces requires gaskets on fireplace doors. All wood-burning fireplaces are a source of air leakage. Loss of energy through these units can be reduced with gasketed doors and a requirement that combustion air be brought directly from the outdoors to the firebox. Gaskets on the fireplace doors will help to minimize air leakage into the firebox. Air that leaks past a poorly gasketed fireplace door, or a door that is simply left open, will flow up the chimney aided by the chimney draft. During the majority of the year the fireplace will not be operating. The combination of well-gasketed doors and a well-sealed flue damper will prevent air leakage through what is effectively an enormous hole in the thermal envelope of the building.

However, it should be noted that the difficulty with this requirement is that most factory-built fireplaces tested in accordance with the code-required test standard for factory-built fireplaces, UL127, are not tested and listed with doors. Therefore, there is a significant safety hazard in adding gasketed doors to a factory-built fireplace tested and manufactured in accordance with UL127, without doors. That hazard would be overheating of the unit and high likelihood of causing fires. This provision in Table R402.4.1.1 for gasketed fireplace doors is a general provision to prevent air leakage and was not intended to prohibit the use of factory-built fireplaces listed for use without doors, in violation of that listing. The specific requirements of the test standard UL127, the product listing and the manufacturer's instructions would prevail for factory-built fireplaces. Keep in mind that Section R402.4.3 requires tight fitting dampers for all fireplaces as well, which will prevent air leakage.

TABLE R402.4.1.1. See page R4-23.

❖ This table contains the list of items that are required to be inspected if the visual inspection option for demonstrating building air tightness given in Section R402.4.1.1 is chosen.

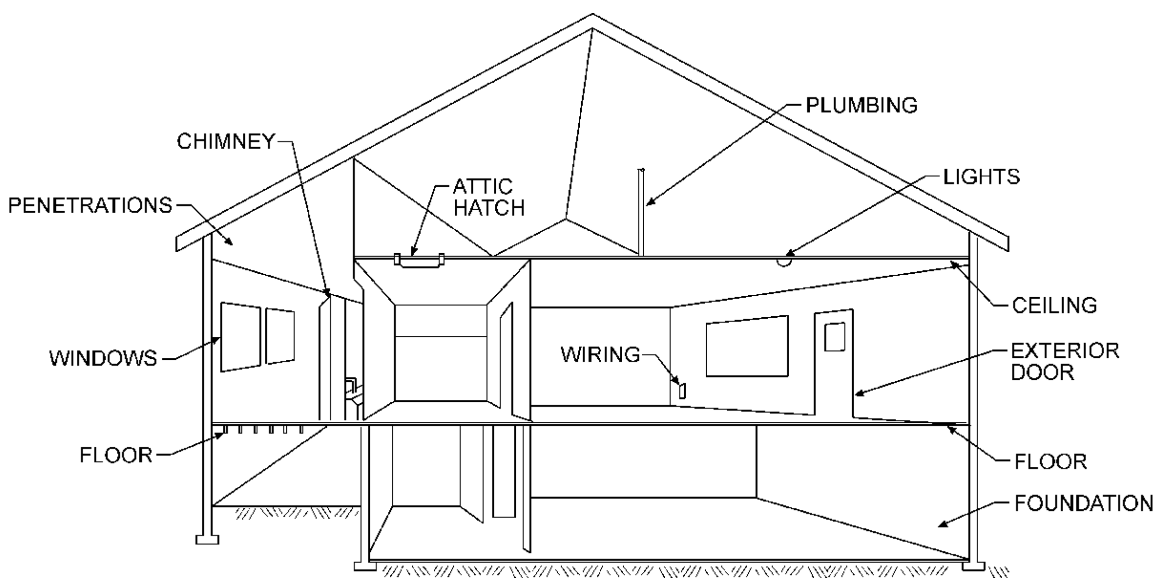


Figure R402.4
TYPICAL SOURCES OF AIR LEAKAGE IN THE HOME

TABLE R402.4.1.1
AIR BARRIER AND INSULATION INSTALLATION

COMPONENT	AIR BARRIER CRITERIA[a]	INSULATION INSTALLATION CRITERIA
General requirements	A continuous air barrier shall be installed in the building envelope. The exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed.	Air-permeable insulation shall not be used as a sealing material.
Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier shall be sealed. Access openings, drop down stairs or knee wall doors to unconditioned attic spaces shall be sealed.	The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.
Walls	The junction of the foundation and sill plate shall be sealed. The junction of the top plate and the top of exterior walls shall be sealed. Knee walls shall be sealed.	Cavities within corners and headers of frame walls shall be insulated by completely filling the cavity with a material having a thermal resistance of R-3 per inch minimum. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.
Windows, skylights and doors	The space between window/door jambs and framing, and skylights and framing shall be sealed.	
Rim joists	Rim joists shall include the air barrier.	Rim joists shall be insulated.
Floors (including above garage and cantilevered floors)	The air barrier shall be installed at any exposed edge of insulation.	Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of subfloor decking, or floor framing cavity insulation shall be permitted to be in contact with the top side of sheathing, or continuous insulation installed on the underside of floor framing and extends from the bottom to the top of all perimeter floor framing members.
Crawl space walls	Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.	Where provided instead of floor insulation, insulation shall be permanently attached to the crawlspace walls.
Shafts, penetrations	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.	
Narrow cavities		Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
Garage separation	Air sealing shall be provided between the garage and conditioned spaces.	
Recessed lighting	Recessed light fixtures installed in the building thermal envelope shall be sealed to the drywall.	Recessed light fixtures installed in the building thermal envelope shall be air tight and IC rated.
Plumbing and wiring		Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
Shower/tub on exterior wall	The air barrier installed at exterior walls adjacent to showers and tubs shall separate them from the showers and tubs.	Exterior walls adjacent to showers and tubs shall be insulated.
Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical or communication boxes or air-sealed boxes shall be installed.	
HVAC register boots	HVAC register boots that penetrate building thermal envelope shall be sealed to the subfloor or drywall.	
Concealed sprinklers	When required to be sealed, concealed fire sprinklers shall only be sealed in a manner that is recommended by the manufacturer. Caulking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings.	

a. In addition, inspection of log walls shall be in accordance with the provisions of ICC-400.

R402.4.1.2 Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate not exceeding five air changes per hour in Climate Zones 1 and 2, and three air changes per hour in Climate Zones 3 through 8. Testing shall be conducted in accordance with ASTM E 779 or ASTM E 1827 and reported at a pressure of 0.2 inch w.g. (50 Pascals). Where required by the *code official*, testing shall be conducted by an *approved* third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the *code official*. Testing shall be performed at any time after creation of all penetrations of the *building thermal envelope*.

During testing:

1. Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed, beyond the intended weatherstripping or other infiltration control measures.
2. Dampers including exhaust, intake, makeup air, backdraft and flue dampers shall be closed, but not sealed beyond intended infiltration control measures.
3. Interior doors, if installed at the time of the test, shall be open.
4. Exterior doors for continuous ventilation systems and heat recovery ventilators shall be closed and sealed.
5. Heating and cooling systems, if installed at the time of the test, shall be turned off.
6. Supply and return registers, if installed at the time of the test, shall be fully open.

❖ The purpose of this code section is to test the building or dwelling unit to demonstrate the building's air tightness. A blower door test, which is a house pressurization test, should be done with a blower door at a pressure of 0.2 inches water gauge [50 Pascals (1psf)]. The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding 5 ACH50, or five air changes per hour at 50 Pascals (1 psf) in Climate Zones 1 and 2, and 3 ACH50, or three air changes per hour at 50 Pascals (1 psf), in Climate Zones 3 through 8. The ACH50 is a common measurement made when doing air infiltration tests and, therefore, a reasonable metric for use in the code. Testing can be conducted by an approved third party, if allowed by the code official. This requires that HVAC ducts not be sealed during the test. In this context, "sealed" is intended to mean sealed off from the interior of the house. The maximum is 5ACH50, or five air changes per hour at 50 Pascals (1 psf).

R402.4.2 Fireplaces. New wood-burning fireplaces shall have tight-fitting flue dampers or doors, and outdoor combustion air. Where using tight-fitting doors on factory-built fireplaces listed and labeled in accordance with UL 127, the doors shall be tested and listed for the fireplace. Where using tight-fitting doors on masonry fireplaces, the doors shall be listed and labeled in accordance with UL 907.

❖ All wood-burning fireplaces are a source of air leakage. Loss of energy through these units can be reduced with gasketed doors and a requirement that combustion air be brought directly from the outdoors to the firebox. Gaskets on the fireplace doors will help to minimize air leakage into the firebox. Air that leaks past a poorly fitted fireplace door, or a door that is simply left open, will flow up the chimney aided by the chimney draft. Throughout the majority of the year, the fireplace will not be in use. The combination of tight-fitting doors and a tight flue damper will prevent air leakage through what is effectively an enormous hole in the thermal envelope of the building. However, not all factory-built fireplaces are tested for use with doors; therefore, in some cases installing doors on the fireplace would violate the unit's listing and could create a fire hazard. Doors on factory-built fireplaces are required to be tested and listed for the fireplace in accordance with UL 127. The manufacturers' instructions for factory-built fireplaces should be followed and such instructions could prohibit the installation of doors. Doors on masonry fireplaces are required to be listed and labeled in accordance with UL 907. The code also allows tight-fitting flue dampers for fireplaces to deal with the issue of air loss.

Lastly, this section and Section R1006 of the IRC require factory-built and masonry fireplaces to be equipped with a direct outdoor combustion supply. The provisions of Section R1006.2 of the IRC would prevent the installation of a fireplace with the firebox floor below finished grade.

R402.4.3 Fenestration air leakage. Windows, skylights and sliding glass doors shall have an air infiltration rate of no more than 0.3 cfm per square foot (1.5 L/s/m^2), and swinging doors no more than 0.5 cfm per square foot (2.6 L/s/m^2), when tested according to NFRC 400 or AAMA/WDMA/CSA 101/I.S.2/A440 by an accredited, independent laboratory and *listed* and *labeled* by the manufacturer.

Exception: Site-built windows, skylights and doors.

❖ Windows, skylights and doors should be tested and labeled by the manufacturer as meeting the air infiltration requirements. The intent of this section is to effectively complete the sealing of the building's thermal envelope by providing specific testing and performance criteria for windows, skylights and doors. This testing and labeling requirement provides an easy method for both the builder and the inspector to demonstrate compliance with the code. While "site built" fenestration is exempted from these requirements, units would have to be "durably sealed" to limit infiltration according to the requirements in Section R402.4.1.

R402.4.4 Rooms containing fuel-burning appliances. In Climate Zones 3 through 8, where open combustion air ducts provide combustion air to open combustion fuel burning appliances, the appliances and combustion air opening shall be located outside the building thermal envelope or enclosed in a room, isolated from inside the thermal envelope. Such rooms shall be sealed and insulated in accordance with the envelope requirements of Table R402.1.2, where the walls, floors and ceilings shall meet not less than the basement wall *R*-value requirement. The door into the room shall be fully gasketed and any water lines and ducts in the room insulated in accordance with Section R403. The combustion air duct shall be insulated where it passes through conditioned space to a minimum of R-8.

Exceptions:

1. Direct vent appliances with both intake and exhaust pipes installed continuous to the outside.
2. Fireplaces and stoves complying with Section R402.4.2 and Section R1006 of the *International Residential Code*.

❖ The entire set of provisions in the code for air leakage is of little value when a combustion air duct is installed, open to the conditioned space, virtually placing a large hole through the thermal envelope. Blower door testing as now required by the code cannot be accomplished with a combustion air opening inside the thermal envelope. Testers regularly block such openings as this is the only way they can pressurize the home; only to be opened after the test is completed. Ideally, direct vent, sealed combustion appliances solve the problem. Where less efficient, open combustion fuel burning appliances are used, it is reasonable and proper to isolate the appliances and the required combustion air from inside the thermal envelope.

R402.4.5 Recessed lighting. Recessed luminaires installed in the *building thermal envelope* shall be sealed to limit air leakage between conditioned and unconditioned spaces. All recessed luminaires shall be IC-rated and *labeled* as having an air leakage rate not more than 2.0 cfm (0.944 L/s) when tested in accordance with ASTM E 283 at a 1.57 psf (75 Pa) pressure differential. All recessed luminaires shall be sealed with a gasket or caulk between the housing and the interior wall or ceiling covering.

❖ To correctly apply this provision, it is important to realize that it deals only with recessed lights that are installed in the building thermal envelope. Therefore, lights that are located so that all sides of the luminaire are surrounded by conditioned space would not fall under this section's requirements. For example, a light located in a soffit would not be regulated if the soffit was below a ceiling that served as the building's thermal envelope. Additionally, a light installed in the floor/ceiling assembly between a first-floor living room and a bedroom above it would be exempted.

Because of their typical location of installation, recessed lighting fixtures pose a potential fire hazard if incorrectly covered with insulation. In addition, the ceiling or a barrier directly above it often serves as the air leakage or moisture barrier for the home.

Therefore, holes cut through the ceiling to install these fixtures also act as chimneys that transfer heat loss and moisture through the building envelope into attic spaces. The heat loss resulting from improperly insulated recessed lighting fixtures can be significant.

Recessed lighting fixtures must be insulation contact (IC) rated lights, which are typically double-can fixtures, with one can inside another (see Commentary Figure R402.4.5). The outer can (in contact with the insulation) is tested to make sure it remains cool enough to avoid a fire hazard. An IC-rated fixture should have the IC rating stamped on the fixture or printed on an attached label.

Recessed lights must also be tightly sealed or gasketed to prevent air leakage through the fixture into the ceiling cavity.

R402.5 Maximum fenestration *U*-factor and SHGC (Mandatory). The area-weighted average maximum fenestration *U*-factor permitted using tradeoffs from Section R402.1.5 or R405 shall be 0.48 in Climate Zones 4 and 5 and 0.40 in Climate Zones 6 through 8 for vertical fenestration, and 0.75 in Climate Zones 4 through 8 for skylights. The area-weighted average maximum fenestration SHGC permitted using tradeoffs from Section R405 in Climate Zones 1 through 3 shall be 0.50.

❖ This section is intended to clarify the application of the fenestration performance maximums and to set reasonable performance levels for these products when using the tradeoffs of Section R402.1.5 or R405.

This section does not define the minimum code requirements for fenestration *U*-factors that are set in Table R402.1.2. Rather, this section sets limits on the tradeoffs allowed based on the total UA calculations

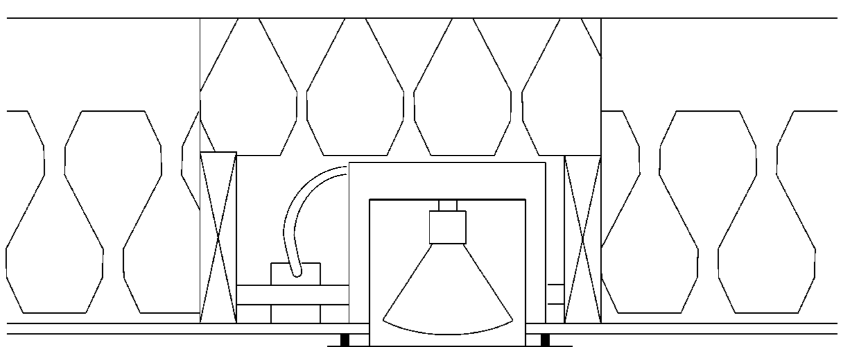


Figure R402.4.5
IC-RATED RECESSED LIGHT

(see Section R402.1.4) or the simulated performance option found in Section R405. This section is in contrast to the basic principle used in Section R402.1.5. Although that section allows a *U*-factor that does not meet the general code requirements to be offset by the increased efficiency of another part of the residence, this section establishes a limitation on the level of efficiency that can be compensated for.

Note that this section does not set a limit on individual products because Sections R402.3.1 and R402.3.2 are not affected. Rather, this section sets an overall limit on the weighted average of those products. These limits are often called “hard limits” or “maximum tradeoff” limits.

In situations where the code is applied to only a portion of the residence, such as only to the addition but not the existing residence, the weighted average could be calculated for just the addition (see commentary, Sections R402.3.1 and R402.3.2).

The thermal properties (*U*-factor) of skylights are different than those of window products. After installation, they perform differently than windows and are, therefore, rated differently. As a result, even the highest rated skylights cannot achieve the same level of *U*-factor performance as windows and glass doors. Therefore, the code provides different values for these “maximum” limits in the tradeoff.

The SHGC provisions are limited in the cooling-dominated climate zones. Therefore, where solar heat gain through the fenestration can affect the cooling load, comfort and efficiency, a “hard limit” of 0.5 would be applied when using Section R405.

SECTION R403
SYSTEMS

R403.1 Controls (Mandatory). At least one thermostat shall be provided for each separate heating and cooling system.

❖ This provision ensures that a separate thermostat is installed for each system. As an example, if separate systems are installed so that one serves the downstairs and one serves the upstairs of a two-story residence, two separate thermostats would be required, one regulating each level. This allows for greater flexibility, control and energy savings than would be possible if both systems were controlled by a single thermostat.

R403.1.1 Programmable thermostat. The thermostat controlling the primary heating or cooling system of the dwelling unit shall be capable of controlling the heating and cooling system on a daily schedule to maintain different temperature set points at different times of the day. This thermostat shall include the capability to set back or temporarily operate the system to maintain *zone* temperatures down to 55°F (13°C) or up to 85°F (29°C). The thermostat shall initially be programmed by the manufacturer with a heating temperature set point no higher than 70°F (21°C) and a cooling temperature set point no lower than 78°F (26°C).

❖ This code section provides each household an opportunity for energy savings by requiring a programmable thermostat that allows changing the temperature setpoints automatically throughout the day.

R403.1.2 Heat pump supplementary heat (Mandatory). Heat pumps having supplementary electric-resistance heat shall have controls that, except during defrost, prevent supplemental heat operation when the heat pump compressor can meet the heating load.

❖ Heat pump systems must have controls that prevent supplementary electric resistance heater operation when the heating load can be met by the heat pump alone. Typically, these controls will be thermostats that will have a “heat pump” designation on them. The make and model of the thermostat should be called out on the building plans so the inspector can verify that what is installed in the field matches the plans. Because change-outs in the field are common, the instructions that come with the thermostat can also be checked to verify that the thermostat is designed for use with a particular heat pump. To limit the hours of use of the electric-resistance heating unit and provide the most cost-efficient operation of the equipment, the specific control language is included in this section.

R403.2 Hot water boiler outdoor temperature setback. Hot water boilers that supply heat to the building through one- or two-pipe heating systems shall have an outdoor setback control that lowers the boiler water temperature based on the outdoor temperature.

❖ This section provides a requirement that gives each household with a hot water boiler an opportunity for energy savings by requiring a setback that will lower the temperature of the water based on ambient conditions.

R403.3 Ducts. Ducts and air handlers shall be in accordance with Sections R403.3.1 through R403.3.5.

❖ The five subsections of Section R403.3 provide the requirements of this chapter, which apply to the ducts and air handlers used in residential buildings.

R403.3.1 Insulation (Prescriptive). Supply and return ducts in attics shall be insulated to a minimum of R-8 where 3 inches (76 mm) in diameter and greater and R-6 where less than 3 inches (76 mm) in diameter. Supply and return ducts in other portions of the building shall be insulated to a minimum of R-6 where 3 inches (76 mm) in diameter or greater and R-4.2 where less than 3 inches (76 mm) in diameter.

> **Exception:** Ducts or portions thereof located completely inside the *building thermal envelope.*

❖ HVAC ductwork located outside of the conditioned space must have insulation with minimum *R*-values of R-8 or R-6, depending on the size of the duct. This includes both supply and return ducts. For areas other than attics, the values are R-6 and R-4.2. Energy losses are less in smaller ducts, therefore the *R*-value of the insulation is lower for ducts less than 3 inches in diameter.

The exception addresses the fact that ductwork in the thermal envelope is already protected from energy loss by virtue of being in the thermal envelope.

R403.3.2 Sealing (Mandatory). Ducts, air handlers and filter boxes shall be sealed. Joints and seams shall comply with either the *International Mechanical Code* or *International Residential Code*, as applicable.

Exceptions:

1. Air-impermeable spray foam products shall be permitted to be applied without additional joint seals.
2. For ducts having a static pressure classification of less than 2 inches of water column (500 Pa), additional closure systems shall not be required for continuously welded joints and seams, and locking-type joints and seams of other than the snap-lock and button-lock types.

❖ Ducts must be sealed in accordance with the duct sealing requirements of either the IMC or the code. Joints and seams that fail in a duct system can result in increased energy use because the conditioned air will be delivered to an unconditioned space or to a building space where it is not needed, such as a wall or floor assembly, crawl space or attic, instead of to a room or area inside the conditioned envelope. Return-air ductwork installed in basements or concealed building spaces may conduct chemicals or other products that produce potentially harmful fumes. Because the return air operates under negative pressure, any leaks could draw fumes, moisture, soil gases or odors from the surrounding area and direct them into the house. Therefore, sealing of return-air ductwork is also a requirement.

Duct tightness must be checked by leakage testing of the ducts at the end of construction or at the time of rough in. The pass/fail criteria for leakage rate is more stringent if the rough-in test time is chosen. This is simply because it is probably that some of the ductwork will be disturbed during subsequent construction and, therefore, have a higher leakage rate than what was tested.

R403.3.2.1 Sealed air handler. Air handlers shall have a manufacturer's designation for an air leakage of no more than 2 percent of the design air flow rate when tested in accordance with ASHRAE 193.

❖ This section of the code requires that air handlers have a manufacturer's designation for an air leakage of not more than 2 percent of the design flow rate when tested in accordance with ASHRAE 193. Energy conservation measures in the air-conditioning industry have driven the manufacturers of systems and components to establish compliance with leakage limits in ducts and air-handling units. The standards set by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) form the basis for testing. Establishing an air-handler leakage rate, given the availability of a uniform test procedure, is prudent since any leakage in the air-handling unit contributes to waste of energy. The magnitude of leakage has a direct bearing on energy use and indoor air quality.

R403.3.3 Duct testing (Mandatory). Ducts shall be pressure tested to determine air leakage by one of the following methods:

1. Rough-in test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (25 Pa) across the system, including the manufacturer's air handler enclosure if installed at the time of the test. All registers shall be taped or otherwise sealed during the test.
2. Postconstruction test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (25 Pa) across the entire system, including the manufacturer's air handler enclosure. Registers shall be taped or otherwise sealed during the test.

Exception: A duct air leakage test shall not be required where the ducts and air handlers are located entirely within the building thermal envelope.

A written report of the results of the test shall be signed by the party conducting the test and provided to the *code official*.

❖ Duct tightness must be checked by leakage testing at the end of construction or at the time of rough-in. This affords some flexibility to the builder. The test at the end of construction, if failed, could be more difficult to correct. However, the test after rough-in is more stringent as noted in the commentary to Section R403.3.4.

R403.3.4 Duct leakage (Prescriptive). The total leakage of the ducts, where measured in accordance with Section R403.3.3, shall be as follows:

1. Rough-in test: The total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m^2) of conditioned floor area where the air handler is installed at the time of the test. Where the air handler is not installed at the time of the test, the total leakage shall be less than or equal to 3 cubic feet per minute (85 L/min) per 100 square feet (9.29 m^2) of conditioned floor area.
2. Postconstruction test: Total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m^2) of conditioned floor area.

❖ The pass/fail criteria for the tested duct leakage rate is more stringent if the rough-in test time is chosen. This is simply because it is probable that some of the ductwork will be disturbed during subsequent construction and, therefore, have a higher leakage rate than what was tested.

R403.3.5 Building cavities (Mandatory). Building framing cavities shall not be used as ducts or plenums.

❖ Building framing cavities shall not be used as ducts or plenums. Stud bays and other building cavities that are exposed to the differing outside temperatures cannot be used as supply air ducts. In addition, these spaces are limited to use for return air only because the negative pressures in the return air plenum with respect to surrounding spaces will decrease the likelihood of spreading smoke to other spaces via the plenum. In addition, for many of the same reasons that sealing (Section R403.2.2) is required, building cavities are a very inefficient means of distributing air.

R403.4 Mechanical system piping insulation (Mandatory). Mechanical system piping capable of carrying fluids above 105°F (41°C) or below 55°F (13°C) shall be insulated to a minimum of R-3.

❖ Heat losses during mechanical fluid distribution impact building energy use both in the energy required to make up for the lost heat and in the additional load that can be placed on the space-cooling system if the heat is released to air-conditioned space. These losses can be effectively limited by insulating the mechanical system piping that conveys fluids at extreme temperatures.

R403.4.1 Protection of piping insulation. Piping insulation exposed to weather shall be protected from damage, including that caused by sunlight, moisture, equipment maintenance and wind, and shall provide shielding from solar radiation that can cause degradation of the material. Adhesive tape shall not be permitted.

❖ Proper protection of piping insulation exposed to the weather elements is necessary to prevent damage, including that due to sunlight, moisture, equipment maintenance and wind.

R403.5 Service hot water systems. Energy conservation measures for service hot water systems shall be in accordance with Sections R403.5.1 through R403.5.4.

❖ A review of the definition of "Service water heating" in Chapter 2 is appropriate before applying these requirements. Any time the system is set up to circulate the water through it, the piping is required to be insulated as listed in Section R403.5.2.

R403.5.1 Heated water circulation and temperature maintenance systems (Mandatory). Heated water circulation systems shall be in accordance with Section R403.5.1.1. Heat trace temperature maintenance systems shall be in accordance with Section R403.5.1.2. Automatic controls, temperature sensors and pumps shall be accessible. Manual controls shall be readily accessible.

❖ When the distribution piping is heated to maintain usage temperatures, such as in circulating hot water systems or systems using pipe heating cable, the system pump or heat trace cable must have conveniently located manual or automatic switches or other controls that can be set to optimize system operation or turn off the system during periods of reduced demand. The simplest of these devices is an automatic time clock. Notice, however, that the code will accept either a readily accessible manual switch or an automatic means to turn off the circulating pump.

R403.5.1.1 Circulation systems. Heated water circulation systems shall be provided with a circulation pump. The system return pipe shall be a dedicated return pipe or a cold water supply pipe. Gravity and thermo-syphon circulation systems shall be prohibited. Controls for circulating hot water system pumps shall start the pump based on the identification of a demand for hot water within the occupancy. The controls shall automatically turn off the pump when the water in the circulation loop is at the desired temperature and when there is no demand for hot water.

❖ Demand-activated circulation is an efficient energy conservation strategy, given that the code, the *International Plumbing Code*® (IPC®) and the IRC require that the hot water piping in automatic temperature maintenance systems in new buildings be insulated with pipe insulation. This means the water in the circulation loop will stay hot for a very long time—up to 45 minutes for $^{3}/_{4}$-inch nominal pipe and up to 2 hours for 2-inch nominal pipe—even if the circulating pump is shut off. If this is the case, there is no reason to run the pump when the water is still hot and no reason to run the pump when no one is in the building or when no one is demanding hot water. The only time it makes sense to run the pump is shortly before hot water is needed, hence the requirement that the pump be controlled on-demand.

R403.5.1.2 Heat trace systems. Electric heat trace systems shall comply with IEEE 515.1 or UL 515. Controls for such systems shall automatically adjust the energy input to the heat tracing to maintain the desired water temperature in the piping in accordance with the times when heated water is used in the occupancy.

❖ The requirements for heat trace are partly to ensure that the systems can be operated in the most energy-

TABLE R403.6.1
WOLE-HOUSE MECHANICAL VENTILATION SYSTEM FAN EFFICACY

FAN LOCATION	AIR FLOW RATE MINIMUM (CFM)	MINIMUM EFFICACY (CFM/WATT)	AIR FLOW RATE MAXIMUM (CFM)
Range hoods	Any	2.8 cfm/watt	Any
In-line fan	Any	2.8 cfm/watt	Any
Bathroom, utility room	10	1.4 cfm/watt	< 90
Bathroom, utility room	90	2.8 cfm/watt	Any

For SI: 1 cfm = 28.3 L/min.
a. When tested in accordance with HVI Standard 916

efficient manner consistent with providing heated water to the occupancy. The referenced standards are included to ensure that installed systems are safe for the intended application. The energy consequences of using heat trace are very reasonable. An example is an analysis of a small (100-foot-long) loop. The energy requirements of keeping the trunk line hot, which is the same as keeping the supply portion of the loop hot in a circulating system, are 701 kWh per year, assuming 12 hours at high temp (115°F) and 12 hours at economy temp (105°F). This is equivalent to operating the loop about 3 hours per day, but with hot water available 24 hours a day/7 days a week in the supply trunk. This is a significant savings when water heating is done electrically or with a similarly expensive fuel. If the branches are also traced, heated water can be delivered even more quickly to the fixtures using only 1,682 kWh per year, which is the same energy as running the loop a little more than 6 hours a day.

R403.5.2 Demand recirculation systems. A water distribution system having one or more recirculation pumps that pump water from a heated water supply pipe back to the heated water source through a cold water supply pipe shall be a *demand recirculation water system*. Pumps shall have controls that comply with both of the following:

1. The control shall start the pump upon receiving a signal from the action of a user of a fixture or appliance, sensing the presence of a user of a fixture or sensing the flow of hot or tempered water to a fixture fitting or appliance.
2. The control shall limit the temperature of the water entering the cold water piping to 104ºF (40ºC).

❖ The purpose of this section is to clarify the requirements for installing circulation pumps in applications that use a cold water supply pipe to circulate the water back to the water heater. Demand recirculation water systems are significantly more energy efficient than other recirculation systems and are inherently safer when the cold water supply is used as the return. The greater safety comes from the fact that the controls specified for demand recirculation water systems limit the flow of water from the hot water supply into the cold water supply to only minutes a day and because they limit the temperature of the water that is allowed to go into the cold water supply.

R403.5.3 Hot water pipe insulation (Prescriptive). Insulation for hot water pipe with a minimum thermal resistance (*R*-value) of R-3 shall be applied to the following:

1. Piping $^3/_4$ inch (19.1 mm) and larger in nominal diame-ter.
2. Piping serving more than one dwelling unit.
3. Piping located outside the conditioned space.
4. Piping from the water heater to a distribution manifold.
5. Piping located under a floor slab.
6. Buried piping.
7. Supply and return piping in recirculation systems other than demand recirculation systems.

❖ This section simply prescribes conditions where hot water piping needs to be provided with a minimum R-3 insulation.

R403.5.4 Drain water heat recovery units. Drain water heat recovery units shall comply with CSA B55.2. Drain water heat recovery units shall be tested in accordance with CSA B55.1. Potable water-side pressure loss of drain water heat recovery units shall be less than 3 psi (20.7 kPa) for individual units connected to one or two showers. Potable water-side pressure loss of drain water heat recovery units shall be less than 2 psi (13.8 kPa) for individual units connected to three or more showers.

❖ Drain water heat recovery is often a cost-effective way to add to energy efficiency by recapturing hot water energy that is literally “going down the drain.” The proposed standards have already been in use by designers for 10 years and the resulting ratings are in use by a variety of energy efficiency programs. Commercial (i.e., nonmultiunit residential) applications are engineered systems while multiunit residential applications are nonengineered and straightforward.

CSA B55.2 standard is for fabrication and material quality of DWHR units. The CSA B55.1 standard is for testing and labeling of DWHR unit efficiency and pressure loss at 2.5 gpm (9.5 lpm).

R403.6 Mechanical ventilation (Mandatory). The building shall be provided with ventilation that meets the requirements of the *International Residential Code* or *International Mechanical Code*, as applicable, or with other approved means of ventilation. Outdoor air intakes and exhausts shall have automatic or gravity dampers that close when the ventilation system is not operating.

❖ Mechanical ventilation is the alternative to having natural ventilation. Both natural and mechanical ventilation can be provided to a space. Unlike natural ventilation, mechanical ventilation does not depend on unpredictable air pressure differentials between the indoors and outdoors to create airflow. The volume of air supplied to a space must be approximately equal to the volume of the air removed from the space. Otherwise, the space will be either positively or negatively pressurized and the actual ventilation flow rate will be equivalent to the lower rate of either the air supply or air exhaust.

The requirements of this section are intended to reduce infiltration into the building when ventilation systems are off. Infiltration speeds up natural cooling or warming of the space during off hours and can increase the energy use required to maintain normal temperatures.

Any outdoor air inlets or outlets serving fans, boilers and other HVAC systems equipped with an on/off switch that either introduces outside air into a building or exhaust air outside of a building must have dampers that automatically close when the fan is shut off. These dampers may be either gravity type or motorized, regardless of whether the fan is supplying or exhausting air. One of the most common such dampers that is seen on homes is the gravity-type backdraft damper on a clothes dryer exhaust duct.

R403.6.1 Whole-house mechanical ventilation system fan efficacy. When installed to function as a whole house mechanical ventilation system fans shall meet the efficacy requirements of Table R403.6.1.

Exception: Where whole house mechanical ventilation fans are integral to tested and listed HVAC equipment, they shall be pow-ered by an electronically commutated motor.

❖ This section of the code is applicable to whole-house mechanical ventilation systems that meet the efficacy requirements of Table R403.6.1. To reduce the amount of energy consumed by residential mechanical ventilation systems is to address the power consumption of the fans that are powering the system. This is important because these fans will operate many hours per day. The table offers energy efficacy levels for exhaust fans that are the same levels as current ENERGY STAR ventilation fan specifications.

R403.7 Equipment sizing and efficiency rating (Mandatory). Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other *approved* heating and cooling calculation methodologies. New or replacement heating and cooling equipment shall have an efficiency rating equal to or greater than the minimum required by federal law for the geographic location where the equipment is installed.

❖ Once the building's thermal envelope is properly insulated and sealed, it will often allow for the reduction of equipment size from what has typically been installed using a "rule-of-thumb" method or other means of estimating. A properly sized system will operate more efficiently, help improve occupant comfort and extend the equipment's service life. Section M1401.3 of the IRC stipulates that the heating and cooling equipment must be sized based on the building loads calculated in accordance with the ACCA Manual J. This manual contains a simplified method of calculating heating and cooling loads. It includes a room-by-room calculation method that allows the designer to determine the required capacities of the heating and cooling equipment. In addition, it provides a means to estimate the airflow requirements for each of the areas in the house. This estimate can be used in sizing the duct system for the types of heating and cooling units that use air as the medium for heat transfer. Other approved methods may be used with the code official's approval.

Though not required by the code, the calculated airflows would provide a means to evaluate the installation of the mechanical system. By providing the proper airflow to the various portions of the building, the system can operate more efficiently and can help prevent spaces from being too hot or too cold.

R403.8 Systems serving multiple dwelling units (Mandatory). Systems serving multiple dwelling units shall comply with Sections C403 and C404 of the IECC—Commercial Provisions in lieu of Section R403.

❖ The criteria in Section R403 primarily address standalone mechanical systems in single-family houses. However, for buildings, many residential building projects such as townhouses will have more complicated mechanical systems that may consist of a single system serving multiple dwelling units.

R403.9 Snow melt and ice system controls (Mandatory). Snow- and ice-melting systems, supplied through energy service to the building, shall include automatic controls capable of shutting off the system when the pavement temperature is above 50°F (10°C), and no precipitation is falling and an automatic or manual control that will allow shutoff when the outdoor temperature is above 40°F (4.8°C).

❖ Snow melt equipment is being installed at a greater frequency in residential projects in communities with high snow accumulation. Previously, the code only required that the building be built to a certain level of efficiency; however, there was no limit placed on the energy use for snow melt, which can be twice the energy use per square foot of the building.

This section does not restrict the use or sizing of snow melt, but it does require that controls be installed on the equipment so that the system will operate more efficiently. The automatic controls provide efficient operation by keeping the system in an idle mode until light snow begins to fall and allowing adequate warm-up before a heavy snowfall. Systems that only use manual controls require the building owner to manually turn on the system when it starts to snow or to leave the system running in the snow-melting mode, using significantly more energy. Chapter 50, Snow Melting and Freeze Protection, of the 2003 *ASHRAE Applications Handbook* states that using a manual switch to operate snow melt equipment may not melt snow effectively; thus, snow will accumulate. This requirement is also referenced in ANSI/ASHRAE/IESNA Standard 90.1, Section 6.4.3.8, Freeze protection and Snow/Ice Melting Systems.

R403.10 Pools and permanent spa energy consumption (Mandatory). The energy consumption of pools and permanent spas shall be in accordance with Sections R403.10.1 through R403.10.3.

❖ Because of the heating and filtering operations involved with pools and inground permanently installed spas, they provide a good opportunity to save energy by limiting heat loss or pump operation. This section provides the scoping requirements for the pool and spa heaters, time switches and pool covers that can make the operation more energy efficient. These features would provide energy savings for residential pools if their owners use them. The requirements of this section were added to the code in order to help coordinate with requirements found in ASHRAE 90.1 and to help reduce the energy used by these pools and inground permanently installed spa systems.

R403.10.1 Heaters. The electric power to heaters shall be controlled by a readily *accessible* on-off switch that is an integral part of the heater mounted on the exterior of the heater, or external to and within 3 feet (914 mm) of the heater. Operation of such switch shall not change the setting of the heater thermostat. Such switches shall be in addition to a circuit breaker for the power to the heater. Gas-fired heaters shall not be equipped with continuously burning ignition pilots.

❖ An accessible on-off switch allows heaters to be turned off when heat is not needed or when the pool or spa may not be used for a period of time.

R403.10.2 Time switches. Time switches or other control methods that can automatically turn off and on according to a preset schedule shall be installed for heaters and pump motors. Heaters and pump motors that have built-in time switches shall be in compliance with this section.

Exceptions:

1. Where public health standards require 24-hour pump operation.
2. Pumps that operate solar- and waste-heat-recovery pool heating systems.

❖ The use of a time switch or other control method to control the heater and pumps provides an easy system for pool and spa operations and energy savings. The application of Exception 1 is dependent on the requirements of the health department in the jurisdiction. Because these are often public pools and spas, the health department may require continuous filtering or circulation. Exception 2 grants a credit for using other systems that help the pool and spa operate more efficiently. Therefore, when solar- and waste-heat-recovery systems are used to heat the pool, the exception eliminates the time-switch requirement.

R403.10.3 Covers. Outdoor heated pools and outdoor permanent spas shall be provided with a vapor-retardant cover or other *approved* vapor-retardant means.

Exception: Where more than 70 percent of the energy for heating, computed over an operation season, is from site-recovered energy, such as from a heat pump or solar energy source, covers or other vapor-retardant means shall not be required.

❖ Where energy is used to heat a pool or a spa, a cover is required to help hold in the heat and keep it from being lost to the surrounding air. The level of protection or insulation that the cover must provide depends on the temperature to which the pool is heated. Any time a pool or spa is heated, the code will require a vapor-retardant pool cover. This type of cover is not required to provide any minimum level of insulation value. It simply will help hold some of the heat in, much like placing a lid on a pot. In situations where the pool is heated above 90°F (32°C), the cover must be insulated to the specified R-12 level. The exception is similar to that found in Section R403.10.2.

R403.11 Portable spas (Mandatory). The energy consumption of electric-powered portable spas shall be controlled by the requirements of APSP-14.

❖ This section coordinates the code with the *International Swimming Pool and Spa Code*® (ISPSC®). Both codes rely on APSP-14 for energy conservation requirements for portable spas. The standard addresses efficiency requirements for water heating equipment and water circulation pumps.

R403.12 Residential pools and permanent residential spas. Residential swimming pools and permanent residential spas that are accessory to detached one- and two-family dwellings and townhouses three stories or less in height above grade plane and that are available only to the household and its guests shall be in accordance with APSP-15.

❖ This section coordinates the code with the ISPSC. Both codes rely on APSP-15 for energy conservation requirements for residential pools and permanent residential spas. The standard addresses efficiency requirements for water heating equipment and water circulation pumps.

SECTION R404
ELECTRICAL POWER AND LIGHTING SYSTEMS

R404.1 Lighting equipment (Mandatory). Not less than 75 percent of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps or not less than 75 percent of the permanently installed lighting fixtures shall contain only high-efficacy lamps.

Exception: Low-voltage lighting.

❖ Lighting accounts for roughly 12 percent of the energy used in residences relying on incandescent bulbs. Thus, this requirement is a substantial energy saver. Incandescent lighting—still used in the vast majority of residences—is the least energy efficient of all light types.

One more efficient lighting option is the compact fluorescent light (CFL). CFLs use about 80 percent less energy than standard incandescent lighting. Limiting this requirement to 75 percent of the lamps in a residence ensures there will be plenty of exceptions for situations where a CFL might not work as well, such as dimmable fixtures.

R404.1.1 Lighting equipment (Mandatory). Fuel gas lighting systems shall not have continuously burning pilot lights.

❖ Continuously burning pilots waste energy; therefore, the code does not use them.

SECTION R405
SIMULATED PERFORMANCE ALTERNATIVE (PERFORMANCE)

❖ Section R405 describes an alternative way to meet the code's goal of effective energy use based on showing that the predicted annual energy use of a proposed design is less than or equal to that of the same home if it had been built to meet the prescriptive criteria in Sections R402 and R403. Section R406 does not prescribe a single set of requirements; rather, it provides a process to reach the energy-efficiency goal based on establishing equivalence with the intent of the code. Because of the level of detail required in the analysis, this method of design is not often used for residential buildings; however, with the changes that have been made in Section R402 and in newer editions of the DOE's REScheck software, Section R405 may become a more popular means of demonstrating code compliance. This section may allow designers to show that many of their current plans meet the overall code requirements even though individual components of the home fall below required code compliance levels.

When using this section and other performance options, the terms "standard reference design" and "proposed design" are used extensively. These terms can create confusion for some users, but they really are very easy to understand. The "proposed design" is exactly that. It is the building as it is proposed to be built, including building size and room configurations, window and wall assemblies, mechanical equipment, orientation, etc. It is essentially the building as it is shown on the construction documents (plans and specifications). The "standard reference design" is the same building configuration and orientation as the proposed design, but instead of matching the plans for the building as it will actually be built, the standard design is shown to only meet the minimum requirements of the code. For example, the standard reference design building in Climate Zone 4 would require that the walls and roof be insulated to a level of R-13 and R-38, respectively, based on the requirements in Table R402.1.2 (*U*-factors of 0.082 and 0.030 in accordance with Table R402.1.4). On the other hand, the proposed design may show that the intent is to install R-19 insulation in the walls and R-49 in the roof. Therefore, if everything else in the two buildings was identical, it would be easy to see in this example that the proposed design does exceed what is required by the code in the standard reference design.

There are two fundamental requirements for using the code. First, Section R405 compliance is based on total estimated annual energy usage across the major energy-using systems in a residential building: envelope, mechanical and service water heating. Note that Section R405 does not include lighting in the analysis process. Second, Section R405 compares the energy use of the proposed design to that of a standard reference design. As mentioned above, the standard reference design is the same building design as that proposed, except that the energy features required by the code (insulation, windows, HVAC, infiltration) are modified to meet the minimum prescriptive requirements in Sections R402 and R403. The standard reference design is used only for comparison and is never actually built.

Section R405 sets both general principles and specific guidelines for use in computing the estimated annual energy cost of the proposed and standard reference designs.

These guidelines constitute a large portion of Section R405 and are easily seen in Table R405.5.2(1). They are necessary to maintain fairness and consistency between the proposed and standard designs. Although the simulated performance alternative method is the most complex method, it gives the design professional the flexibility to introduce exterior walls, roof/ceiling components, etc., that do not meet the requirements of the prescriptive performance approach in Sections R402 and R403 but are considered acceptable where the annual energy use of the proposed building is equal to or less than that of the standard reference design building. Envelope features that lower energy consumption (window orientation, passive-solar features or the use of "cool" reflective roofing products in cooling-dominated climates) and mechanical and service water-heating systems that are more efficient than those required by the minimum prescriptive requirements in Sections R402 and R403 are used to offset the potentially high thermal transmittance of an innovative exterior envelope design in this instance.

The simulated performance alternative also allows energy supplied by renewable energy sources on the building site to be discounted from the total energy consumption of the proposed design building. Because renewable energy obtained on the site comes from nondepletable sources such as solar radiation, wind, plant byproducts and geothermal sources, its use is not counted as part of the proposed building's energy use. The definition of "Energy cost" in Section R202 and the provisions of Section R405.3 should be reviewed when dealing with renewable energy. Renewable energy that is purchased from an off-site source cannot be excluded and would be included within the definition of "energy cost."

R405.1 Scope. This section establishes criteria for compliance using simulated energy performance analysis. Such analysis shall include heating, cooling and service water heating energy only.

❖ This section simply indicates that the performance analysis can include not only building envelope performance (as is limited in Section R402.1.4) but that the tradeoffs can also include the energy used for heating, cooling and service water heating. The provisions of this section do not include an allowance for lighting energy to be included. If a designer wished to include lighting, it would be done under the alternative materials and methods provisions of Section R102 (see commentary, Section R102).

Section R405.1 establishes the terms of performance-based comparison for residential buildings. Under the Section R405 Simulated Performance approach, the candidate building (proposed design) is evaluated based on the cost of energy used. In simple terms, Section R406 states: build the residence any way as long as it is designed to use no more energy than a home built exactly to the minimum requirements in Sections R402 and R403.

This performance option can also be used to take advantage of energy-efficiency improvements that are only partly reflected in the total UA (sum of *U*-factor times the assembly area) of the residence, which is found in Section R402.1.4. For example, in a cooling climate, reduction in ceiling UA will save more energy than an equal reduction in slab UA. This energy savings occurs because cooling climates have ground temperatures that approach comfortable indoor temperatures, diminishing the value of slab insulation for such climates. In contrast, the ceiling insulation in cooling climates usually receives higher solar loads during the warmest part of the day, increasing the value of ceiling insulation. Therefore, in cooling climates, a change in ceiling UA (perhaps adding more ceiling insulation) may have a substantially greater impact on energy use than the same UA change in slab-edge insulation.

A variety of calculation methods can be used to show compliance under the simulated performance alternative approach. The calculations can be complex; for example, a detailed building energy simulation tool covering all aspects of building energy use. Much of Section R405 deals with establishing guidelines for defining aspects of the various sophisticated calculations that form the basis of the annual energy-use comparison. Alternatively, the analysis can be a simple calculation or correlation focused on one aspect of energy use. Where a method of analysis does not calculate, model or estimate a specific energy-using feature, it cannot be used for tradeoffs based on that specific feature. For example, software using degree-day-based climate and building envelope calculations does not specifically account for water heater energy use. Therefore, this type of software cannot be used to take credit for a high-efficiency water heater. Note, however, that software using degree-day-based climate and building envelope calculations accounts for changes in insulation levels; therefore, it could be used for an insulation tradeoff under the simulated performance approach.

The use of Section R405 to show compliance is not required by all homes with special features designed to save energy. Very energy-efficient designs may not give credit for all of the design's features to show compliance. For example, a highly energy-efficient, passive solar home may be so well insulated and have such low glazing *U*-factors that those items alone may be sufficient to show compliance with the energy-related requirements in the code by using only UA computations or by meeting the prescriptive requirements of Sections R402 and R403. Because of these very efficient elements, compliance may be shown by using the prescriptive provisions or the easier UA computations instead of a more complex evaluation, which would include the other energy-using subsystems in the building.

R405.2 Mandatory requirements. Compliance with this section requires that the mandatory provisions identified in Section R401.2 be met. All supply and return ducts not completely inside the *building thermal envelope* shall be insulated to a minimum of R-6.

❖ This section serves as a reminder of the requirements found in Section R101.3. When using Section R405, compliance with the various mandatory provisions in this chapter is still required. The sections that must be complied with separately include items that often cannot be effectively modeled. When using Section R405, it is important to review the provisions of Section R402.5, which place "hard limits" on the fenestration *U*-factors and SHGC that may be used for tradeoffs (see commentary, Section R402.5).

R405.3 Performance-based compliance. Compliance based on simulated energy performance requires that a proposed residence (*proposed design)* be shown to have an annual energy cost that is less than or equal to the annual energy cost of the *standard reference design.* Energy prices shall be taken from a source *approved* by the *code official,* such as the Department of Energy, Energy Information Administration's *State Energy Price and Expenditure Report. Code officials* shall be permitted to require time-of-use pricing in energy cost calculations.

Exception: The energy use based on source energy expressed in Btu or Btu per square foot of *conditioned floor area* shall be permitted to be substituted for the energy cost. The source energy multiplier for electricity shall be 3.16. The source energy multiplier for fuels other than electricity shall be 1.1.

❖ The general procedure is to show that the annual energy cost for the building is less than the annual energy cost of a building that just meets the prescriptive requirements. The applicant must estimate the annual energy cost for two buildings: the one to be built and the standard reference design building. Because the two are compared on the basis of annual energy costs, designs that have lower demand charges or use energy when rates are lower may be able to gain an advantage using Section R405. It is also common to equate energy sources on the basis of cost because energy bills are the principal motivator for energy efficiency. An annual energy analysis could be used to compare a wide variety of energy-using features and conservation opportunities for the candidate building. The annual energy use can be used to trade off insulation; window/door areas; *U*-factors; HVAC equipment efficiency; water heating efficiency; infiltration control measures; duct insulation and sealing; pipe insulation and renewable energy technologies; or new energy technologies. Appliances not regulated by the code (refrigerators, dishwashers, clothes-washing machines, residential lighting) are not eligible for tradeoffs under this chapter.

The approach in this section is targeted for use in residences with energy-saving features that are not reflected in the UA or overall U-factor. Examples of features that lower energy consumption but not U-factor include high-efficiency HVAC systems; windows predominantly oriented toward the south; passive solar features; highly reflective ("cool") roofing products in cooling-dominated climates; and renewable energy sources such as photovoltaic, geothermal heat pumps and wind farms.

A building will comply with the requirements of the code and be acceptable when the annual energy cost of the proposed design is less than or equal to the annual energy cost of the standard design. The following sections will provide additional information and guidance related to the standard reference design and the design to which it is compared.

The purpose of the exception is to allow the use of source energy as an alternative metric to energy cost for compliance with the performance provisions.

Adding source energy as an alternative to energy cost offers many benefits to compliance, as follows:

- Using cost will be a liability to the home builder if home buyers do not achieve the savings listed in the compliance documentation.
- Energy cost changes frequently. This means that a home that complies today may not comply a few months from now if costs change.
- Energy cost focuses attention on first-year energy costs, which misses the point of an energy code where features that are generally life-cycle cost effective to the homeowner are added to save energy and make homes more comfortable over the life of the home, not to reduce first cost.

The source multipliers of 3.16 and 1.1 are from the 2002 *DOE Core Databook*. One way to think of this is that electric energy utilized at the site requires 3.16 times the source energy to produce the electricity at power plants and distribute via power lines to homes. This is because the efficiency of power plants is much less than 100 percent and there are losses in transmission and distribution as well. Other fuels, such as natural gas and fuel oil, have less source energy losses and a lower source energy multiplier.

Standard Reference Design

This section reiterates the simulated performance approach's strong reliance on principles established in Sections R402 and R403 as the foundation for the baseline level of energy efficiency established in the code. Therefore, all tradeoffs are judged against the prescriptive requirements of the standard reference design. Accordingly, insulation levels for the standard design building are set by the prescriptive requirements in Section R402 and are generally based on the values in Table R402.1.4. To discourage designers from picking a combination for the standard design that results in an inflated energy budget, thus permitting easy compliance by the proposed design (i.e., gaming), general principles and specific guidelines are given for various energy-using systems of the building [see Table R405.5.2(1)].

The entries in Table R405.5.2(1) for the envelope and fenestration requirements assist the code user in defining the standard reference design without bias. This is especially true in southern climates, where air-conditioning requirements are significant. In these cooling-dominated climates, where *U*-factor requirements are relatively high, residences with very large window areas and virtually no wall insulation can comply with the code through the use of windows with very low *U*-factors. This results in excessive air-conditioning costs in these climates because unshaded windows, dominated by solar heat gain, are required to meet only the code thermal-resistance and solar heat gain requirements. As a result, it is possible to construct residences in these climates with limited wall insulation, as long as windows with high thermal resistance and low SHGC are used.

The Table R405.5.2(1) entries for the building's thermal envelope components and fenestration are necessary to pin down the overall energy consumption of the standard design as described in Section R402. Without the guidance provided by these entries, the areas and *U*-factors of the windows and building thermal envelope could assume a multitude of different values and still satisfy Section R402 requirements. Furthermore, different values for these components would result in different overall energy cost levels for the standard design. The annual energy cost of the standard design represents the maximum "budget" the proposed design must meet. Without specific details of the standard reference design's features and components, this budget becomes a moving target and will allow a designer to pick a combination for the standard design that results in a very large energy budget, thus permitting the proposed design to easily comply with Section R405 but not meet the energy conservation levels intended in the code.

Proposed Design

In general, the proposed design is the building that will be constructed exactly as it is shown in the plans and construction documents. Therefore, most of the entries for Table R405.5.2(1) will be "as proposed." There are, however, some sections that must match what is required or used for the standard reference design. The proposed design must be similar in many characteristics to the standard design. Otherwise, it may not provide an "apples-to-apples" comparison, thereby limiting the value of this method in demonstrating that the proposed design truly is more efficient. Some of the items that must be comparable include:

1. The standard and proposed designs must use the same energy sources (fuels) for the same function. For example, a gas-heated standard design cannot be compared to an electrically heated proposed design.
2. The areas of the building components (ceiling, wall and floor), including the building's shape, configuration and orientation, must all remain the same in both the standard and proposed designs.
3. Both the standard and proposed designs must assume the same outdoor and comfort indoor climate conditions.
4. Both the standard and proposed designs must assume the same occupant diversity and usage patterns; for example, the same thermostat set points, water usage, internal gains, etc.

The exception in Section R405.3 is important to understand because some jurisdictions may require the comparison to be done on the basis of "site energy" versus "annual energy cost." Because of the fact that utility charges for various types of energy can change over time, some code officials may prefer that the comparison be made based on the amount of energy delivered to the home instead of the cost of that energy.

The code establishes the effective use of site energy as opposed to primary (a.k.a., source) energy as a goal and then delineates specific criteria, both prescriptive and performance based, for meeting that goal. Primary energy is defined as the amount of energy delivered to a sector adjusted to account for the energy sources used to produce the energy (e.g., energy used to generate electricity). Included also is the energy lost in delivering the fuel to a customer; for instance, the electricity lost in the transmission and distribution of electricity. Site (delivered) energy is the amount of energy delivered to a household. Energy generation, transmission and distribution losses are not included. Primary energy is useful to show the ultimate resource impact of sectoral energy demand with respect to global particulate contributions of carbon dioxide, for example. Site energy is necessary if one wants to know what is going on inside the building. In this case, fuel choice does matter; oil-heated homes may consume more site energy than electrically heated homes, for instance.

From an economist's perspective, using energy cost instead of primary or site energy is preferable. Deregulation will affect the choice of fuels and households will decide what to consume. This view assumes that competitive pressures will ultimately equalize prices. This primary-versus-site debate centers on electricity, but losses are also associated with other energy sources. For example, one could take distillate fuel oil all the way back to the refinery, even factoring in energy losses in the fuel delivery trucks. So while Section R405 will generally require the comparison to be based on the annual energy cost for the homeowner, some jurisdictions prefer to know the amount of energy delivered and not the cost. Regardless of which comparison basis is used, it is clearly the intent of Section R405 to require the effective use of energy.

This exception permits equating different energy sources on the basis of the site energy. Site energy is energy use measured at the building boundary. For designs under Section R405, site energy is input to the heating, cooling-service and water-heating equipment.

As mentioned earlier, it is common to equate energy sources on the basis of cost because energy bills are the principal motivator for energy efficiency and, over time, the market will move to the more economical energy source. The results of using either energy cost or delivered "site energy" tend to be similar. The use of tradeoffs based on energy costs may be preferable in cooling-dominated climates. The cost of a unit of gas is commonly much less than the same unit of electricity; therefore, equating fossil fuels and electricity in terms of heat content may not reflect the interest of the building owner based primarily on the applicable utility rate structures and tariffs. In southern climates, the use of site-energy-based tradeoffs tends to overcredit changes in heating energy use and undercredit changes in cooling energy use. The intent of the code to "achieve the effective use of energy" (see Section R101.3) can be preserved through the use of an annual energy cost or site-energy-based comparison. The use of site energy, or delivered energy, as the basis for the comparison under Section R405 requires the approval of the code official.

R405.4 Documentation. Documentation of the software used for the performance design and the parameters for the building shall be in accordance with Sections R405.4.1 through R405.4.3.

❖ This section provides a list of the minimum information needed to demonstrate compliance with code requirements. The three subsections in Section R405.4 list the minimum level of information needed for this purpose. Because much of the information and software used for the performance option must be approved by the code official, the jurisdiction should be consulted to see if any additional information may be required (see commentary, Section R405.6.2).

A review of the code requirements of Section R104 should also be included when looking at Section R405.4. The construction documents must contain the data necessary to confirm that the results of the design have been incorporated into the construction documents and also to allow assessment of compliance. This is of particular importance when coupled with performing a comprehensive plan review given the sometimes very lengthy and sophisticated submittals required by the energy-efficiency method (see commentary, Section R104). Though not listed in the code, some state laws may require that the design of the building construction and, in this case, the development of a comparative building-energy analysis be done by a registered design professional in accordance with the licensing laws of the state where the work takes place.

In such states, the code official should consider and enforce the requirement to coordinate with state licensing laws that often establish thresholds for when the services of a registered design professional are required.

R405.4.1 Compliance software tools. Documentation verifying that the methods and accuracy of the compliance software tools conform to the provisions of this section shall be provided to the *code official.*

❖ This section is essentially a general requirement that where software is used to demonstrate compliance under Section R405, the software be shown to provide accurate comparisons and results. Many of the software systems that may be used will be familiar and readily acceptable to the code official. Where a less commonly used software is proposed for use, the code official will need to be shown that the software performs its intended function and is accurately comparing the standard reference and proposed designs.

R405.4.2 Compliance report. Compliance software tools shall generate a report that documents that the *proposed design* complies with Section R405.3. A compliance report on the *proposed design* shall be submitted with the application for the building permit. Upon completion of the building, a compliance report based on the as-built condition of the building shall be submitted to the *code official* before a certificate of occupancy is issued. Batch sampling of buildings to determine energy code compliance for all buildings in the batch shall be prohibited.

Compliance reports shall include information in accordance with Sections R405.4.2.1 and R405.4.2.2. Where the *proposed design* of a building could be built on different sites where the cardinal orientation of the building on each site is different, compliance of the *proposed design* for the purposes of the application for the building permit shall be based on the worst-case orientation, worst-case configuration, worst-case building air leakage and worst- case duct leakage. Such worst-case parameters shall be used as inputs to the compliance software for energy analysis.

❖ The approved software should be able to demonstrate that the proposed design has an annual energy cost that is either less than or equal to that of the standard reference design. The code requires that a compliance report be submitted on two occasions: at the time of permit application, to verify that the proposed design complies with the code; and at the end of the project before the certificate of occupancy is issued, to verify that the "as-built" building complies with the code.

R405.4.2.1 Compliance report for permit application. A compliance report submitted with the application for building permit shall include the following:

1. Building street address, or other building site identification.
2. A statement indicating that the *proposed design* complies with Section R405.3.
3. An inspection checklist documenting the building component characteristics of the *proposed design* as indicated in Table R405.5.2(1). The inspection checklist shall show results for both the *standard reference design* and the *proposed design* with user inputs to the compliance software to generate the results.
4. A site-specific energy analysis report that is in compliance with Section R405.3.
5. The name of the individual performing the analysis and generating the report.
6. The name and version of the compliance software tool.

❖ Providing the address of the project will not only help in the tracking of the project and various permits, but it also ensures that the calculations run were for the intended project and not based on a project that may not be applicable. While it may be possible to run a calculation based on a stock set of plans [see orientation provisions in Table R405.5.2(1)], the best way to provide a truly accurate comparison is to provide a site-specific evaluation, as required in Item 4.

Item 2 provides the primary information from which approval will be granted. A summary must be submitted showing how the annual energy cost of the proposed design compares to the annual energy cost of the standard design. The comparison summary must include, as a minimum, annual energy cost by design (standard versus proposed) and could include the fuel type (electric versus gas versus renewable sources) if it was a part of a trade-off.

Besides showing the actual comparison between the two designs, Item 3 requires an inspection checklist that can be used by the inspector to ensure that the proposed design matches what is actually constructed in the field. This checklist addresses the details of construction on which the comparison was conducted. See Section R405.4.3, Item 1, for the equivalent requirement for the standard reference design. These two sections not only ensure that the comparison is accurate but also provide information so that the comparison can be run again and verified if needed. While it would be best if the checklist included information for all of the items listed in Table R405.5.2(1), it is only necessary that the information is provided for items that are compared or for which trade-offs are based or taken.

Because various versions of software can include different inputs or evaluations, it is important that both the name and version of the software be provided. Changes to new or an updated version of existing software could often provide different results. Listing the software edition helps the code official evaluate the report and also provides the information to conduct a verification review if necessary.

R405.4.2.2 Compliance report for certificate of occupancy. A compliance report submitted for obtaining the certificate of occupancy shall include the following:

1. Building street address, or other building site identification.
2. A statement indicating that the as-built building complies with Section R405.3.
3. A certificate indicating that the building passes the performance matrix for code compliance and listing the energy saving features of the buildings.
4. A site-specific energy analysis report that is in compliance with Section R405.3.
5. The name of the individual performing the analysis and generating the report.
6. The name and version of the compliance software tool.

❖ The items required for the compliance report for obtaining the certificate of occupancy are basically the same as those required for the permit application, except that the report is based on the "as-built" condition of the building. During the course of construction, changes in the windows, type of insulation, equipment or building dimensions are all required to be documented and approved. The changes must be approved based on compliance with the code and the original design. At the end of the day, however, one must verify that the changes made did not have a negative impact on the performance of the building, as analyzed before the permit application.

R405.4.3 Additional documentation. The *code official* shall be permitted to require the following documents:

1. Documentation of the building component characteristics of the *standard reference design.*
2. A certification signed by the builder providing the building component characteristics of the *proposed design* as given in Table R405.5.2(1).
3. Documentation of the actual values used in the software calculations for the *proposed design.*

❖ The items in this section are not automatically required as those of Sections R405.4.1 and R405.4.2 but are instead only required when the code official wishes them to be. Item 1 provides information related to the standard reference design similar to what Section R405.4.2.2, Item 2, provides for the proposed design. Having this information allows the code official or designer to easily replicate the calculations if additional verification reviews or changes are needed.

Item 2 can be useful in a couple of ways. It can be used not only by the inspector, similar to the checklist in Section R405.4.3, Item 2, but it helps to ensure that items that may not be seen by or visible to the inspector have been installed as proposed. This certification can essentially be considered the same as the builder stating the as-built structure complies with the proposed and originally approved design plans.

Item 3 provides for a possible need to check input values for computer programs utilized. This enables the plan checker to readily verify compliance with the basic requirements of the code.

R405.5 Calculation procedure. Calculations of the performance design shall be in accordance with Sections R405.5.1 and R405.5.2.

❖ The provisions of this section simply ensure that comparisons between the standard reference design and the proposed design are accurate and reflect an "apples-to-apples" comparison.

R405.5.1 General. Except as specified by this section, the *standard reference design* and *proposed design* shall be configured and analyzed using identical methods and techniques.

❖ Items that are not involved in the tradeoffs must be comparable between the standard reference design and the proposed design. This helps to ensure that the energy savings are truly based on the differences from Table R405.5.2(1) that are being evaluated. Though it should go without saying, the same calculation method or software must be used to estimate the annual energy usage for space heating and cooling of the standard design and the proposed design. The calculation tool must be approved by the code official. A jurisdiction may want to make known the methods it prefers for comparing annual energy use. The code official retains the authority to determine whether a specific set of computations for a particular residence is acceptable. The use of Section R405 is optional; therefore, the applicant is free to choose the method for achieving compliance (see commentary, Sections R101.3 and R401.2). Regardless, the calculation procedure used to evaluate the standard design must also be used to evaluate the proposed design.

R405.5.2 Residence specifications. The *standard reference design* and *proposed design* shall be configured and analyzed as specified by Table R405.5.2(1). Table R405.5.2(1) shall include, by reference, all notes contained in Table R402.1.2.

❖ While the majority of Section R405 addresses the process to evaluate the standard design and proposed design, this section serves as the backbone of Section R405 and the information on which the comparisons are conducted. Tables R405.5.2(1) and R405.5.2(2) provide the list of items that are compared and establish not only the requirements for the standard design but also give a good view of what items may be included and evaluated for tradeoffs. The determination of requirements and application of the various items is fairly easy to follow due to the way the components are listed in separate rows of the table. Under Section R405, only these items may differ between the proposed and standard reference design. As discussed in the commentary to Section R405.1, if there are any additional components or features for which a designer wishes to make a tradeoff, the approval of such items would need to be based on Section R102.

The information that is determined for Tables R405.5.2(1) and R405.5.2(2) would be the type of information needed for both Sections R405.4.2.2, Item 2, and R405.4.3, Item 1.

TABLE R405.5.2(1). See page R4-41.

❖ As discussed in the commentary to Section R405.5.2, this table serves as the backbone of the requirements for Section R405. By comparing the annual energy cost of a standard reference design to that of a proposed design, designers may trade off the efficiency of one element or component for an increased efficiency in another.

The column dealing with "building components" helps to distinguish what building elements may be considered and included in the performance option of Section R405. The column labeled "Standard Reference Design" provides details used to determine the annual energy cost serving as the maximum energy cost that the proposed design could use. This column simply states how the standard design home is to be configured and treated in the simulations that will compare it to the proposed design home. This column simply ensures that comparisons between the two designs truly are based on a plan that meets the intended performance of the code. The "Proposed Design" column represents the home for which compliance is trying to be determined. As indicated, most of the items in a proposed design will be "as proposed." There are a few entries in this column where the proposed design must use the same values as the standard design. These items are restricted so that a fair comparison is provided and so that the design parameters may not simply be changed in an attempt to show improved efficiency. Additional comments about the table or specific component requirements are as follows:

Walls, roofs and fenestration: Similar to Sections R402.1 and R402.3, this table separates the impact of solar gains for fenestration such as windows or energy loss through windows and doors from the impact of wall *U*-factors. The provisions simply ensure that each component of the building's thermal envelope is evaluated separately.

Walls, floors, ceilings and roofs: To avoid gaming the comparison, the areas of these items must be the same in both designs. No valid comparison of the proposed and standard designs can be made if the size of the two designs is not equal.

Foundations: This section explicitly requires the foundation and on-grade floor type be the same for both designs. Without this provision, the possibility for the designer to select a less energy-efficient foundation or floor type (including modeling a floor system over a heated space) for the standard design and a more energy-efficient foundation type for the proposed design is left open. Under this circumstance, heat loss for the proposed design would be much less significant because of the lower heat loss through the foundation. The resulting loss "credit" results in less insulation being required for the proposed design. This type of credit is prohibited because the designer may not have intended to use the unfavorable foundation in the first place.

Doors: The amount of door area and the orientation for the door are specified. Whether the door is glazed or opaque is not a consideration for the standard design because the area of glazing is dealt with under a separate entry. By requiring the door to be on the north orientation, the effects of SHGC on a glazed door are minimized.

Glazing: This requirement exists in response to strong evidence showing that glazing area and geometry have some impact on the building's overall thermal transmittance, and that solar heat gain through windows constitutes a large portion of the air-conditioning load (typically 25 percent) in southern climates.

The area limitations help to ensure that the glazing areas are not manipulated to affect the efficiency of the various designs. The proposed glazing area limitation of 18 percent of the conditioned floor area of the residence is identical to the requirement of the Home Energy Rating System Council Guidelines (Version 2) for its standard design, and is equal to the maximum window area that was allowed by ASHRAE Standard 90.2-1993 for its standard design.

The code language, found in Note a, indicating that the glazing area includes the sash, framing and glazing is needed for completeness and clarification. The NFRC guidelines on window labeling require that window performance ratings be based on the full window system product. In other words, the *U*-factor, SHGC, visible light transmittance, air leakage and other properties of the window must be based on the combined impacts of both the glazing and its associated opaque constituents (defined here as "sash").

Orientation significantly affects the annual energy consumption on a building and is critical to achieving an optimum passive solar design. This section recognizes that building energy consumption is affected by orientation and that an orientation change of the glazing could be a way to manipulate the standard reference design so that it uses an increased amount of energy or gains an increased advantage by limiting solar heat gain.

Experimental evidence using eight cardinal exposures with equal glazing areas for the standard design as input for simulation programs shows that the procedure is inconvenient with very small increases in accuracy. Due to this, the four cardinal exposures are sufficient for achieving solar neutrality on the standard design. Because the percentage of glass-area facing in a particular orientation can vary significantly on a proposed design, the actual orientations are needed for accuracy. The difference in a large amount of glazing facing directly south, versus southwest, will significantly increase annual energy use, peak loads and the time the peak loads occur. The trend is that the more passive solar techniques are applied to the building, the more important the orientation becomes.

The section establishes an SHGC standard of 0.4 for glazed fenestration products in climates with significant cooling loads. Specifically, this requirement applies to warmer climates (Climate Zones 1 through 3). As a result, this requirement applies throughout much of the southern region of the United States in Oklahoma, Arkansas, Tennessee and North Carolina and extending as far north as the warmer parts of California and Nevada. Although Table R402.1.2 does not require an SHGC in Climate Zones 4 through 8, this table establishes a requirement of 0.40 for these climate zones. When applying the SHGC provisions of the standard design, remember the application of Note e in Table R402.1.2 for Climate Zone 3, Marine.

This section explicitly addresses interior shading and limits considering the benefits of it on the performance of windows in residences. The term “interior shading” hours and the values to be used are specified. Most homeowners use some form of interior window treatment, such as drapes, blinds or shades, on their windows. In addition to their decorative aspects, drapes and curtains have been traditionally used by homeowners to control privacy and daylight, provide protection from overheating and reduce the fading of fabrics. To most effectively reduce solar heat gain, the drapery used to block the sunlight should have high reflectance and low transmittance. A densely woven, light-colored fabric would achieve this objective. Drapes can reduce the SHGC of clear glass from 20 to 70 percent, depending on the color and openness of the drapery fabric. The impact of drapery on solar heat gain is proportionally lessened if the window glass is shaded or tinted. The main disadvantage of drapes and other interior devices as solar control measures is that once the solar energy has entered a window, a large proportion of the energy absorbed by the shading system will remain inside the house as heat gain. Interior devices are thus most effective when they are highly reflective, with minimum absorption of solar energy. Interior shading devices, such as blinds and shades, primarily provide light and privacy control but also can have an impact on controlling solar heat gain. They include horizontal Venetian blinds, mini blinds, vertical slatted blinds of various materials, a wide variety of pleated and honeycomb shades and roll-down shades. White- or silver-colored blinds, coupled with clear glass, have the greatest potential for reducing solar heat gains. Some manufacturers have offered window-unit options that include mini blinds mounted inside sealed or unsealed insulating glass. The blinds, in the sealed dust-free environment, can be operated with a magnetic lever without breaking the air seal. Blinds in the unsealed glazing unit are protected as well but can be easily removed for cleaning or repair. These between-glass shading devices have a lower shading coefficient than equivalent blinds mounted on the interior. They also provide additional insulating value to the double glass by reducing convective loops in the airspace.

Unlike the other strategies to reduce heat gain, interior shades generally require consistent and active intervention by the homeowner. It is unlikely that anyone would operate all shades in a consistent, optimal pattern, as an analysis assumes they are to be operated. A value of 0.7 is proposed for summer conditions to approximate the condition of predominantly closed, medium-colored interior draperies. The winter value is increased to 0.85 to not unduly penalize winter heating performance. Variance from these values is specifically not allowed. It is possible to install motorized and automated shading systems, but these are quite costly and not yet in common use. When contemplating the use of high-performance glazing for the necessary solar control as opposed to just using interior shading, there are two important benefits: there is less need for operating the shades and the window is rarely covered, resulting in a clear view and daylight at all times. Of course, shades also provide privacy and darkness when desired so they may be closed part of the day in any case, but the high-performance glazing means there is less need to operate them in a particular manner to achieve significant reductions in energy use. Because of the uncertainty of actual application and more limited benefits of the interior shades, the code will generally require the proposed design to use the same values as the standard reference design.

Permanent, exterior-mounted shading devices for the standard design are considered atypical and, therefore, are not required or allowed to be included. Where credit is taken in the proposed design for these devices, the code official must approve and confirm the installation of the actual shading device proposed.

Skylights: This is intended to reduce the complexity of the design requirements as applied to skylight areas in the standard design. If this section was not included, ceilings and skylights would also require detailed treatment as in Section R402.3 and the glazing section above to fully specify the standard design.

Air exchange rate: This section establishes conditions under which air-leakage reduction can be claimed reliably. Without using an actual measurement, it often is not practical to document infiltration reduction measures beyond those in the standard design because the code (see Section R402.4) already assumes a fairly comprehensive air-sealing regimen. Where the test reports that the anticipated building infiltration performance is not achieved as was assumed in the permit application, infiltration must be lowered or some other means used to make up the increased energy use attributable to the deficiency in infiltration rates. Note that "tight" buildings may require mechanical ventilation to improve occupant comfort. Controlling ventilation rates reduces cooking odors, damp musty smells, stale air and elevated levels of carbon dioxide. Ventilation also helps reduce concentrations of air-borne contaminants off-gassed from building materials and related to other household activities.

Internal gains: The calculations for both the standard and proposed designs must assume the same internal loads. Where the simulation tool allows specification of internal gains, the total heat gains (sensible + latent) are to be calculated based on this equation in both the standard and proposed designs (the code does not distinguish between sensible and latent gains). This equation makes internal gains a function of the conditioned area and the number of bedrooms.

Heating systems: This section simply requires that the heating and cooling equipment in the standard design meet the minimum efficiency requirements that are currently required at the time of the evaluation.

This section contains general guidelines for the proposed design for any annual energy analysis under Section R405. The standard and proposed designs must use the same energy sources (fuels) for the same function. For example, a gas-heated standard design cannot be compared to an electrically heated proposed design. For a fossil-fuel-heated building, the standard design must assume the applicable minimum efficiency as dictated by the code and the National Appliance Energy Conservation Act (NAECA).

Service water heating: Where the simulation tool or calculation models water heating energy, domestic service water-heating calculations must assume a set point of 120°F (49°C), with a daily usage of 30 gallons (113 L) per unit plus 10 gallons (37.8 L) per bedroom.

Thermal distribution systems [see Table R405.5.2(2)]: Research and practice in the past few years has shown that the major component of heating and cooling system efficiency stems from air leakage in hot and cold air distribution systems (primarily ducts, but also air-handler cabinets). The research has been conducted by ASHRAE; Lawrence-Berkley National Laboratory; Brookhaven National Laboratory; Electric Power Research Institute; Gas Research Institute; Florida Solar Energy Center; and numerous other research organizations and national utilities. Many, if not most, utilities in the nation now offer customers duct-leakage diagnosis and repair efforts as part of their energy conservation and demand side management programs. The Sheet Metal and Air-Conditioning Contractors National Association (SMACNA) has published test procedures in outlining the methods and air distribution systems through duct-system pressurization testing (see the SMACNA *HVAC Air Duct Leakage Test Manual*), and a number of calibrated pressurization test equipment manufacturers are now producing equipment for sale in the market.

Technical questions regarding the energy impacts and mechanisms of specific leak types in certain locations remain; however, there is no question the elimination of air leakage results in energy inefficiency in duct systems being limited to conduction gains and losses through the ducts themselves.

The virtual elimination of these leaks also results in much-improved heating- and cooling-system efficiencies (on the order of 95- to 99-percent efficient as opposed to 75- to 80-percent efficient). There is no technical disagreement that, once air leakage is no longer in question, air distribution system efficiency can be determined through straightforward engineering calculations using conduction heat-transfer equations, unencumbered by the complexities of air-leakage flows. A conservative assumption is that the ductwork in the standard design is 50-percent inside and 50-percent outside the conditioned space; however, the arrangement of ductwork in the standard design must be representative of that proposed.

Unless directly heated and cooled, attics and crawl spaces are unconditioned spaces. The specified distribution system efficiency (DSE) is to be used in the standard design where the designer wishes to take advantage of the impacts from improved DSEs in the proposed design and the entire distribution system is substantially leak free. Proposed designs use specified system efficiencies based on the proportion of ducts inside and outside a substantially leak-free conditioned system. It is acceptable for the proposed design to use system efficiencies other than those given where such factors result from a code-official-approved, post-construction duct system performance test. [Note that Table R405.5.2(2) is titled "Default Distribution System Efficiencies" and that Note a of that table indicates that the values are for untested distribution systems.] The provisions in this section are a mechanism that allows builders to take credit for substantially leak-free duct systems where they are installed.

R405.6 Calculation software tools. Calculation software, where used, shall be in accordance with Sections R405.6.1 through R405.6.3.

❖ See the commentary to Section R405.6.1.

TABLE R405.5.2(1)
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Above-grade walls	Type: mass wall if proposed wall is mass; otherwise wood frame.	As proposed
	Gross area: same as proposed	As proposed
	U-factor: as specified in Table R402.1.4	As proposed
	Solar absorptance = 0.75	As proposed
	Emittance = 0.90	As proposed
Basement and crawl space walls	Type: same as proposed	As proposed
	Gross area: same as proposed	As proposed
	U-factor: from Table R402.1.4, with insulation layer on interior side of walls	As proposed
Above-grade floors	Type: wood frame	As proposed
	Gross area: same as proposed	As proposed
	U-factor: as specified in Table R402.1.4	As proposed
Ceilings	Type: wood frame	As proposed
	Gross area: same as proposed	As proposed
	U-factor: as specified in Table R402.1.4	As proposed
Roofs	Type: composition shingle on wood sheathing	As proposed
	Gross area: same as proposed	As proposed
	Solar absorptance = 0.75	As proposed
	Emittance = 0.90	As proposed
Attics	Type: vented with aperture = 1 ft^2 per 300 ft^2 ceiling area	As proposed
Foundations	Type: same as proposed	As proposed
	Foundation wall area above and below grade and soil characteristics: same as proposed	As proposed
Opaque doors	Area: 40 ft^2	As proposed
	Orientation: North	As proposed
	U-factor: same as fenestration from Table R402.1.4	As proposed
Vertical fenestration other than opaque doors	Total area[h] = (a) The proposed glazing area, where the proposed glazing area is less than 15 percent of the conditioned floor area (b) 15 percent of the conditioned floor area, where the proposed glazing area is 15 percent or more of the conditioned floor area	As proposed
	Orientation: equally distributed to four cardinal compass orientations (N, E, S & W).	As proposed
	U-factor: as specified in Table R402.1.4	As proposed
	SHGC: as specified in Table R402.1.2 except that for climates with no requirement (NR) SHGC = 0.40 shall be used.	As proposed
	Interior shade fraction: 0.92-(0.21 × SHGC for the standard reference design)	0.92-(0.21 × SHGC as proposed)
	External shading: none	As proposed
Skylights	None	As proposed
Thermally isolated sunrooms	None	As proposed
Air exchange rate	Air leakage rate of 5 air changes per hour in climate zones 1 and 2, and 3 air changes per hour in climate zones 3 through 8 at a pressure of 0.2 inches w.g (50 Pa). The mechanical ventilation rate shall be in addition to the air leakage rate and the same as in the proposed design, but no greater than $0.01 \times CFA + 7.5 \times (N_{br} + 1)$ where: CFA = conditioned floor area N_{br} = number of bedrooms Energy recovery shall not be assumed for mechanical ventilation.	For residences that are not tested, the same air leakage rate as the standard reference design. For tested residences, the measured air exchange rate[a]. The mechanical ventilation rate[b] shall be in addition to the air leakage rate and shall be as proposed.

(continued)

TABLE R405.5.2(1)—continued
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Mechanical ventilation	None, except where mechanical ventilation is specified by the proposed design, in which case: Annual vent fan energy use: kWh/yr = 0.03942 × *CFA* + 29.565 × (N_{br} +1) where: *CFA* = conditioned floor area N_{br} = number of bedrooms	As proposed
Internal gains	IGain = 17,900 + 23.8 × *CFA* + 4104 × N_{br} (Btu/day per dwelling unit)	Same as standard reference design.
Internal mass	An internal mass for furniture and contents of 8 pounds per square foot of floor area.	Same as standard reference design, plus any additional mass specifically designed as a thermal storage element[c] but not integral to the building envelope or structure.
Structural mass	For masonry floor slabs, 80 percent of floor area covered by R-2 carpet and pad, and 20 percent of floor directly exposed to room air.	As proposed
	For masonry basement walls, as proposed, but with insulation required by Table R402.1.4 located on the interior side of the walls	As proposed
	For other walls, for ceilings, floors, and interior walls, wood frame construction	As proposed
Heating systems[d, e]	As proposed for other than electric heating without a heat pump, where the proposed design utilizes electric heating without a heat pump the standard reference design shall be an air source heat pump meeting the requirements of Section C403 of the IECC-Commercial Provisions. Capacity: sized in accordance with Section R403.7	As proposed
Cooling systems[d, f]	As proposed Capacity: sized in accordance with Section R403.7.	As proposed
Service water heating[d, e, f, g]	As proposed Use: same as proposed design	As proposed gal/day = 30 + (10 × N_{br})
Thermal distribution systems	Duct insulation: From Section R403.2.1 A thermal distribution system efficiency (DSE) of 0.88 shall be applied to both the heating and cooling system efficiencies for all systems other than tested duct systems. For tested duct systems, the leakage rate shall be 4 cfm (113.3 L/min) per 100 ft^2 (9.29 m^2) of *conditioned floor* area at a pressure of differential of 0.1 inches w.g. (25 Pa).	As tested or as specified in Table R405.5.2(2) if not tested. Duct insulation shall be as proposed.
Thermostat	Type: Manual, cooling temperature setpoint = 75°F; Heating temperature setpoint = 72°F	Same as standard reference

For SI: 1 square foot = 0.93 m^2, 1 British thermal unit = 1055 J, 1 pound per square foot = 4.88 kg/m^2, 1 gallon (US) = 3.785 L, °C = (°F-32)/1.8, 1 degree = 0.79 rad.

a. Where required by the *code official*, testing shall be conducted by an *approved* party. Hourly calculations as specified in the ASHRAE *Handbook of Fundamentals*, or the equivalent shall be used to determine the energy loads resulting from infiltration.

b. The combined air exchange rate for infiltration and mechanical ventilation shall be determined in accordance with Equation 43 of 2001 ASHRAE *Handbook of Fundamentals*, page 26.24 and the “Whole-house Ventilation” provisions of 2001 ASHRAE *Handbook of Fundamentals*, page 26.19 for intermittent mechanical ventilation.

c. Thermal storage element shall mean a component not part of the floors, walls or ceilings that is part of a passive solar system, and that provides thermal storage such as enclosed water columns, rock beds, or phase-change containers. A thermal storage element must be in the same room as fenestration that faces within 15 degrees (0.26 rad) of true south, or must be connected to such a room with pipes or ducts that allow the element to be actively charged.

d. For a proposed design with multiple heating, cooling or water heating systems using different fuel types, the applicable standard reference design system capacities and fuel types shall be weighted in accordance with their respective loads as calculated by accepted engineering practice for each equipment and fuel type present.

e. For a proposed design without a proposed heating system, a heating system with the prevailing federal minimum efficiency shall be assumed for both the standard reference design and proposed design.

f. For a proposed design home without a proposed cooling system, an electric air conditioner with the prevailing federal minimum efficiency shall be assumed for both the standard reference design and the proposed design.

g. For a proposed design with a nonstorage-type water heater, a 40-gallon storage-type water heater with the prevailing federal minimum energy factor for the same fuel as the predominant heating fuel type shall be assumed. For the case of a proposed design without a proposed water heater, a 40-gallon storage-type water heater with the prevailing federal minimum efficiency for the same fuel as the predominant heating fuel type shall be assumed for both the proposed design and standard reference design.

(continued)

TABLE R405.5.2(1)—continued
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

h. For residences with conditioned basements, R-2 and R-4 residences and townhouses, the following formula shall be used to determine glazing area:
$AF = A_s \times FA \times F$
where:
AF = Total glazing area
A_s = Standard reference design total glazing area.
FA = (Above-grade thermal boundary gross wall area)/(above-grade boundary wall area + 0.5 x below-grade boundary wall area).
F = (Above-grade thermal boundary wall area)/(above-grade thermal boundary wall area + common wall area) or 0.56, whichever is greater.
and where:
Thermal boundary wall is any wall that separates conditioned space from unconditioned space or ambient conditions.
Above-grade thermal boundary wall is any thermal boundary wall component not in contact with soil.
Below-grade boundary wall is any thermal boundary wall in soil contact.
Common wall area is the area of walls shared with an adjoining dwelling unit.
L and *CFA* are in the same units.

TABLE R405.5.2(2)
DEFAULT DISTRIBUTION SYSTEM EFFICIENCIES FOR PROPOSED DESIGNS[a]

DISTRIBUTION SYSTEM CONFIGURATION AND CONDITION	FORCED AIR SYSTEMS	HYDRONIC SYSTEMS[b]
Distribution system components located in unconditioned space	—	0.95
Untested distribution systems entirely located in conditioned space[c]	0.88	1
"Ductless" systems[d]	1	—

For SI: 1 cubic foot per minute = 0.47 L/s, 1 square foot = 0.093 m^2, 1 pound per square inch = 6895 Pa, 1 inch water gauge = 1250 Pa.
a. Default values given by this table are for untested distribution systems, which must still meet minimum requirements for duct system insulation.
b. Hydronic systems shall mean those systems that distribute heating and cooling energy directly to individual spaces using liquids pumped through closed-loop piping and that do not depend on ducted, forced airflow to maintain space temperatures.
c. Entire system in conditioned space shall mean that no component of the distribution system, including the air-handler unit, is located outside of the conditioned space.
d. Ductless systems shall be allowed to have forced airflow across a coil but shall not have any ducted airflow external to the manufacturer's air-handler enclosure.

R405.6.1 Minimum capabilities. Calculation procedures used to comply with this section shall be software tools capable of calculating the annual energy consumption of all building elements that differ between the *standard reference design* and the *proposed design* and shall include the following capabilities:

1. Computer generation of the *standard reference design* using only the input for the *proposed design.* The calculation procedure shall not allow the user to directly modify the building component characteristics of the *standard reference design.*
2. Calculation of whole-building (as a single *zone*) sizing for the heating and cooling equipment in the *standard reference design* residence in accordance with Section R403.6.
3. Calculations that account for the effects of indoor and outdoor temperatures and part-load ratios on the performance of heating, ventilating and air-conditioning equipment based on climate and equipment sizing.
4. Printed *code official* inspection checklist listing each of the *proposed design* component characteristics from Table R405.5.2(1) determined by the analysis to provide compliance, along with their respective performance ratings (*R*-value, *U*-factor, SHGC, HSPF, AFUE, SEER, EF are some examples).

❖ This section states the general capabilities for the calculation software and its ability to evaluate the effects of building parametrics, system design, climatic factors, operational characteristics and mechanical equipment on annual energy usage.

There are a number of different software programs available to perform these calculations. The complexity of the programs will often depend on the amount of parameters that may be varied between the designs. The phrase in the base section that the software must be capable of evaluating the consumption of "all building elements that differ" between the two designs is important because it is the differences between the standard design and the proposed design that determine whether the proposed design is acceptable.

To ensure that the comparisons are made only on the items that are being traded, Item 1 looks to keep the software from allowing any manipulation that would help to reduce the energy costs of the standard design.

R405.6.2 Specific approval. Performance analysis tools meeting the applicable provisions of Section R405 shall be permitted to be *approved.* Tools are permitted to be *approved* based on meeting a specified threshold for a jurisdiction. The *code official* shall be permitted to approve tools for a specified application or limited scope.

❖ Though this section may be viewed as accepting a reduced level of efficiency, the intent is really more in line with the provisions of Section R102. An alternative program for evaluating the energy efficiency of a building using performance criteria can be substituted here. However, that alternative must meet the performance criteria of Section R405.

R405.6.3 Input values. When calculations require input values not specified by Sections R402, R403, R404 and R405, those input values shall be taken from an *approved* source.

❖ This section simply requires that any additional input information required by the calculation software be approved by the code official. Through the use of the phrase "approved source," the code official would be able to review the source of the information that is being used for inputting information. This will help to ensure that the selected values are reasonable for the situation and not just an estimate.

SECTION R406 ENERGY RATING INDEX COMPLIANCE ALTERNATIVE

R406.1 Scope. This section establishes criteria for compliance using an Energy Rating Index (ERI) analysis.

❖ The Residential Provisions of the code allow for varying methods for demonstrating compliance. This includes a prescriptive and simulated performance option in addition to allowing efficiency programs designed to go above the minimum code levels, as "deemed to comply" programs. These above-code programs must be approved by the code official to be used in the jurisdiction. Alternative programs that depend on an Energy Rating Index (ERI) have been approved as an alternative code or above-code program in at least six states and in over 130 jurisdictions. These types of programs typically take the form of a Home Energy Rating System (HERS) program. Under the current code there is no guidance on setting ERI scores, which will lead to inconsistent application of these types of programs based on climate zones.

This section provides an ERI with established rating numbers to allow alternative programs using an ERI to be designed to meet these criteria. The section provides guidelines for the development of the index, requirements for documentation to be provided to ensure compliance and a requirement that an approved third party verify that the building complies with the applicable ERI.

R406.2 Mandatory requirements. Compliance with this section requires that the provisions identified in Sections R401 through R404 be labeled as mandatory and Section R403.5.3 be met. The building thermal envelope shall be greater than or equal to levels of efficiency and Solar Heat Gain Coefficient in Table 402.1.1 or 402.1.3 of the 2009 *International Energy Conservation Code*.

Exception: Supply and return ducts not completely inside the building thermal envelope shall be insulated to a minimum of R-6.

❖ As with Section R405.2 for the performance-based alternative, minimum requirements have been established in the code for all buildings. The sections that must be complied with separately include items that often cannot be effectively modeled. When using Section R406, it is important to review the provisions of Section R402.5, which place "hard limits" on the fenestration *U*-factors and SHGC that may be used for trade-offs (see commentary, Section R402.5).

R406.3 Energy Rating Index. The Energy Rating Index (ERI) shall be a numerical integer value that is based on a linear scale constructed such that the *ERI reference design* has an Index value of 100 and a *residential building* that uses no net purchased energy has an Index value of 0. Each integer value on the scale shall represent a 1-percent change in the total energy use of the rated design relative to the total energy use of the *ERI reference design*. The ERI shall consider all energy used in the *residential building*.

❖ To avoid confusion in the application of different ERI programs, the parameters for the index are established here. The reason is simple and logical—to allow a clear understanding of the meaning of the index and to be able to uniformly apply the requirements of the code.

R406.3.1 ERI reference design. The *ERI reference design* shall be configured such that it meets the minimum requirements of the 2006 *International Energy Conservation Code* prescriptive requirements.

The proposed *residential building* shall be shown to have an annual total normalized modified load less than or equal to the annual total loads of the *ERI reference design*.

❖ The reference house is based on a home built to the 2006 IECC, which is consistent with ERI-based programs that are used today.

R406.4 ERI-based compliance. Compliance based on an ERI analysis requires that the *rated design* be shown to have an ERI less than or equal to the appropriate value listed in Table R406.4 when compared to the *ERI reference design*.

TABLE R406.4
MAXIMUM ENERGY RATING INDEX

CLIMATE ZONE	ENERGY RATING INDEX
1	52
2	52
3	51
4	54
5	55
6	54
7	53
8	53

❖ Based on the energy conservation levels set by the 2015 IECC, the ERI required for the rated design (i.e., the proposed building) are set as shown.

R406.5 Verification by approved agency. Verification of compliance with Section R406 shall be completed by an *approved* third party.

❖ In order to ensure proper application of the parameters of the ERI chosen and the proper use of computer software, this option for energy conservation requires a third party to review the proposed design to ensure compliance with the code. The approved third party should be knowledgeable in the energy code, the ERI system and the use of computer software for design. By stating the agency or individual must be a "third party," the code is requiring financial independence, with no possible conflicts of interest.

R406.6 Documentation. Documentation of the software used to determine the ERI and the parameters for the residential building shall be in accordance with Sections R406.6.1 through R406.6.3.

❖ See the commentary to Section R405.4.

R406.6.1 Compliance software tools. Documentation verifying that the methods and accuracy of the compliance software tools conform to the provisions of this section shall be provided to the *code official*.

❖ See the commentary to Section R405.4.1.

R406.6.2 Compliance report. Compliance software tools shall generate a report that documents that the ERI of the *rated design* complies with Sections R406.3 and R406.4. The compliance documentation shall include the following information:

1. Address or other identification of the residential building.
2. An inspection checklist documenting the building component characteristics of the *rated design*. The inspection checklist shall show results for both the *ERI reference design* and the *rated design*, and shall document all inputs entered by the user necessary to reproduce the results.
3. Name of individual completing the compliance report.
4. Name and version of the compliance software tool.

Exception: Multiple orientations. Where an otherwise identical building model is offered in multiple orientations, compliance for any orientation shall be permitted by documenting that the building meets the performance requirements in each of the four (north, east, south and west) cardinal orientations.

❖ See the commentary to Section R405.4.2.

R406.6.3 Additional documentation. The *code official* shall be permitted to require the following documents:

1. Documentation of the building component characteristics of the *ERI reference design*.
2. A certification signed by the builder providing the building component characteristics of the *rated design.*
3. Documentation of the actual values used in the software calculations for the *rated design*.

❖ See the commentary to Section R405.4.3.

R406.7 Calculation software tools. Calculation software, where used, shall be in accordance with Sections R406.7.1 through R406.7.3.

❖ See the commentary to Sections R405.6.1 through R405.6.3.

R406.7.1 Minimum capabilities. Calculation procedures used to comply with this section shall be software tools capable of calculating the ERI as described in Section R406.3, and shall include the following capabilities:

1. Computer generation of the *ERI reference design* using only the input for the *rated design*.

   The calculation procedure shall not allow the user to directly modify the building component characteristics of the *ERI reference design*.
2. Calculation of whole building, as a single *zone*, sizing for the heating and cooling equipment in the *ERI reference design* residence in accordance with Section R403.7.
3. Calculations that account for the effects of indoor and outdoor temperatures and part-load ratios on the performance of heating, ventilating and air-conditioning equipment based on climate and equipment sizing.
4. Printed *code official* inspection checklist listing each of the *rated design* component characteristics determined by the analysis to provide compliance, along with their respective performance ratings.

❖ See the commentary to Sections R405.6.1 through R405.6.3.

R406.7.2 Specific approval. Performance analysis tools meeting the applicable sections of Section R406 shall be *approved*. Tools are permitted to be *approved* based on meeting a specified threshold for a jurisdiction. The *code official* shall approve tools for a specified application or limited scope.

❖ See the commentary to Sections R405.6.1 through R405.6.3.

R406.7.3 Input values. When calculations require input values not specified by Sections R402, R403, R404 and R405, those input values shall be taken from an approved source.

❖ See the commentary to Sections R405.6.1 through R405.6.3.

Chapter 5 [RE]: Existing Buildings

General Comments

New for the 2015 IECC Residential Provisions is a separate chapter dealing with alterations, repairs, additions and change of occupancy of existing buildings. These provisions, for the most part, originated in Chapter 1 of the 2012 IECC Residential Provisions; however, the 2015 edition contains options dealing with situations where compliance with the code for additions is difficult. The provisions now allow an energy-neutral method for difficult-to-comply projects, essentially mandating simply that the building with the addition uses no more energy than the existing building. This will allow projects to take advantage of energy-efficient alterations on the existing building to offset compliance difficulties with features on the addition. Requirements for alterations are provided, giving specific details and exceptions for the building envelope, heating and cooling systems, hot water systems, and lighting. Finally, the code allows that repairs be done without consideration of compliance with this code.

Purpose

The purpose of this chapter is to provide requirements for the unique circumstances involved with existing building additions, alterations and repairs.

SECTION R501 GENERAL

R501.1 Scope. The provisions of this chapter shall control the *alteration*, repair, addition and change of occupancy of existing buildings and structures.

❖ The scope of this chapter includes specific circumstances related to changes to existing buildings. This chapter provides a roadmap when dealing with different types of projects—alterations, repairs, additions and changes of occupancy.

R501.1.1 Additions, alterations, or repairs: General. Additions, alterations, or repairs to an existing building, building system or portion thereof shall comply with Section R502, R503 or R504. Unaltered portions of the existing building or building supply system shall not be required to comply with this code.

❖ For commentary on additions, see Section R502; for alterations, see Section R503; and for repairs, see Section R504.

R501.2 Existing buildings. Except as specified in this chapter, this code shall not be used to require the removal, *alteration* or abandonment of, nor prevent the continued use and maintenance of, an existing building or building system lawfully in existence at the time of adoption of this code.

❖ This section addresses the fact that, in general, the code does not affect existing buildings. It will permit an addition to be made to an existing building without requiring the existing building to conform to the code. In such a case, the addition is expected to comply with the current code, but it will not require changes for the existing portion. Therefore, the code does not apply retroactively to existing buildings. When an existing building is modified by an addition, alteration, renovation or repair, Section R502, R503 or R504 will provide the guidance and requirements for such changes.

R501.3 Maintenance. Buildings and structures, and parts thereof, shall be maintained in a safe and sanitary condition. Devices and systems that are required by this code shall be maintained in conformance to the code edition under which installed. The owner or the owner's authorized agent shall be responsible for the maintenance of buildings and structures. The requirements of this chapter shall not provide the basis for removal or abrogation of energy conservation, fire protection and safety systems and devices in existing structures.

❖ The code is designed to regulate new construction and new work and is not intended to be applied retroactively to existing buildings except where existing envelope, lighting, mechanical or service water heating systems are specifically affected by Section R502, R503 or R504. Maintenance of building systems and components in accordance with the effective code at the time of their installation is required, but such systems and components need not be upgraded or modified to meet the code.

R501.4 Compliance. *Alterations*, *repairs*, *additions* and changes of occupancy to, or relocation of, existing buildings and structures shall comply with the provisions for *alterations*, *repairs*, *additions* and changes of occupancy or relocation, respectively, in the *International Residential Code*, *International Building Code*, *International Fire Code*, *International*

Fuel Gas Code, *International Mechanical Code*, *International Plumbing Code*, *International Property Maintenance Code*, *International Private Sewage Disposal Code* and NFPA 70.

❖ Compliance with the provisions of other *International Codes*® (I-Codes®), such as the IBC, should not be ignored. The I-Codes are intended to be a coordinated set of construction codes. This section clarifies the relationship between this chapter of the code and the IRC, IBC, *International Fire Code*® (IFC®), *International Fuel Gas Code*® (IFGC®), *International Mechanical Code*® (IMC®), *International Plumbing Code*® (IPC®), *International Property Maintenance Code*® (IPMC®), *International Private Sewage Disposal Code*® (IPSDC®) and NFPA 70.

When alterations and repairs are made to existing mechanical and plumbing systems, the provisions of the I-Codes and NFPA 70 for alterations and repairs must be followed. Those codes indicate the extent to which existing systems must comply with the stated requirements. Where portions of existing building systems, such as plumbing, mechanical and electrical systems, are not being altered or repaired, those systems may continue to exist without being upgraded as long as they are not hazardous or unsafe to building occupants.

R501.5 New and replacement materials. Except as otherwise required or permitted by this code, materials permitted by the applicable code for new construction shall be used. Like materials shall be permitted for repairs, provided hazards to life, health or property are not created. Hazardous materials shall not be used where the code for new construction would not permit their use in buildings of similar occupancy, purpose and location.

❖ There are two options for materials used in repairs to an existing building. Generally, the materials used for repairs should be those that are presently required or permitted for new construction under the I-Codes. It is also acceptable to use materials consistent with those that are already present, except where those materials pose a hazard. This allowance follows the general concept that any repair should not make a building more hazardous than it was prior to the repair. It is generally possible to repair a structure, its components and its systems with materials consistent with those materials that were used previously. However, where materials now deemed hazardous are involved in the repair work, they may no longer be used. For example, the code identifies asbestos and lead-based paint as two common hazardous building materials that cannot be used in the repair process. Certain materials previously considered acceptable for building construction are now known to threaten the health of occupants.

R501.6 Historic buildings. No provision of this code relating to the construction, *repair, alteration,* restoration and movement of structures, and *change of occupancy* shall be mandatory for *historic buildings* provided a report has been submitted to the code official and signed by the owner, a registered *design professional*, or a representative of the State Historic Preservation Office or the historic preservation authority having jurisdiction, demonstrating that compliance with that provision would threaten, degrade or destroy the historic form, fabric or function of the *building*.

❖ In some aspects, this is a bit of a continuation of the "existing building" provisions, but it goes even further—historic buildings are exempt. In earlier editions of the code, this exemption applied only to the exterior envelope of such buildings and to the interior only in those cases where the ordinance explicitly designated elements of the interior. With the current text, historic buildings are exempt from all aspects of the code. This exemption, however, is not without conditions. The most important criterion for application of this section is that the building must be specifically classified as being of historic significance by a qualified party or agency. Usually this is done by a state or local authority after considerable scrutiny of the historical value of the building. Most states and many local jurisdictions have authorities such as a landmark commission.

Because of the unique issues involved, historic buildings are exempt from the requirements of the code. This exemption could be extended to include all parts that are "historic," including additions, alterations and repairs that would normally be addressed by Section R502 or R503. If the proposed addition, alteration or renovation is not "historic," then the provisions of Section R502 or R503 should be applied. Consideration of energy conservation and compliance with the code is still of value in historic buildings. In exempting historic buildings, the code is simply recognizing that energy efficiency may be difficult to accomplish while maintaining the "historic" nature of the building.

SECTION R502
ADDITIONS

R502.1 General. Additions to an existing building, building system or portion thereof shall conform to the provisions of this code as those provisions relate to new construction without requiring the unaltered portion of the existing building or building system to comply with this code. Additions shall not create an unsafe or hazardous condition or overload existing building systems. An addition shall be deemed to comply with this code where the addition alone complies, where the existing building and addition comply with this code as a single building, or where the building with the addition uses no more energy than the existing building. Additions shall be in accordance with Section R502.1.1 or R502.1.2.

❖ Simply stated, new work must comply with the current requirements for new work. Any addition to an existing system involving new work is subject to the requirements of the code. Additions can place additional loads or different demands on an existing system and those loads or demands could necessitate changing all or part of the existing system. Additions and alterations must not cause an existing system to be any less in compliance with the code than it was before the changes.

Additions to existing buildings must comply with the code when the addition is within the scope of the code and would not otherwise be exempted. Additions include new construction, such as a conditioned bedroom, sun space or enclosed porch added to an existing building. Additions also include existing spaces converted from unconditioned or exempt spaces to conditioned spaces. For example, a finished basement, an attic converted to a bedroom or a carport converted to a den are additions. The addition of an unconditioned garage would not be considered within the scope of the code because the code applies to heated or cooled (conditioned) spaces.

Although not specifically defined in the code, building codes typically define an "addition" as any increase in a building's habitable floor area (which can be interpreted as any increase in the conditioned floor area). For example, an unconditioned garage converted to a bedroom is an addition. If a conditioned floor area is expanded, such as a room made larger by moving out a wall, only the newly conditioned space must meet the code. A flat window added to a room does not increase the conditioned space and thus is not an addition by this definition. If several changes are made to a building at the same time, only the changes that expand the conditioned floor area are required to meet the code. The addition (the newly conditioned floor space) complies with the code if it complies with all of the applicable requirements in Chapter 4 [RE]. For example, requirements applicable to the addition of a new room would most likely include insulating the exterior walls, ceiling and floor to the levels specified in the code; sealing all joints and penetrations; installing a vapor retarder in unventilated frame walls, floors and ceilings; identifying installed insulation *R*-values and window *U*-factors; and insulating and sealing any ducts passing through unconditioned portions or within exterior envelope components (walls, ceilings or floors) of the new space.

R502.1.1 Prescriptive compliance. Additions shall comply with Sections R502.1.1.1 through R502.1.1.4.

❖ The basic premise of this section is that the addition alone, and not the remainder of the building, must comply with the code.

R502.1.1.1 Building envelope. New building envelope assemblies that are part of the addition shall comply with Sections R402.1, R402.2, R402.3.1 through R402.3.5, and R402.4.

> **Exception:** Where nonconditioned space is changed to conditioned space, the building envelope of the addition shall comply where the UA, as determined in Section 402.1.4, of the existing building and the addition, and any alterations that are part of the project, is less than or equal to UA generated for the existing building.

❖ The exception is the key to this section. Again, the insulation, sealing and air infiltration barriers required in the code for new construction apply to the addition. However, the exception provides some guidance regarding the circumstance where nonconditioned space becomes conditioned space. A typical example of this would be enclosing an attached garage to become a family room. The baseline for the entire building including the existing building would be the UA of the existing building. That is the sum of the *U*-values for the walls, windows and doors multiplied by the respective areas of each of those components. Accordingly, the total sum of the UA for the completed building including the newly conditioned garage must be less than the UA for the existing building. This ensures that, regardless of how well insulated the existing building is, the addition will not make the building envelope less energy efficient.

Example: An existing house has a total UA of 222 (using the "Standard" Design as the existing house from the example in commentary Section R402.1.4). A 20-foot by 10-foot garage is proposed to be converted to a family room. For the example, assume the newly renovated garage has a 20-square-foot window.

The total UA of the existing building is 222 as calculated in Section R402.1.4. For the building with the new family room, we are using R-20 wall insulation in the cavity, with R-13 continuous insulation. Floor insulation is increased to R-38. The total UA for that combination of exterior wall values is 234, which is greater than 222. Therefore, some additional insulation will be required in order for the newly created conditioned space to meet the code.

EXISTING BUILDING	EXISTING BUILDING PLUS NEW FAMILY ROOM
Exterior Wall: 1,050 ft^2 U_w = 0.057 Glazed doors and windows: 192 ft^2 U_g = 0.32	Exterior Wall: 1,170 ft^2 850 ft^2 @ U_w = 0.057 320 ft^2 @ U_w = 0.032 Glazed doors and windows: 222 ft^2 @ U_g = 0.32
Opaque Exterior Door: 38 ft^2 U_g = 0.32 Roof: 1,500 ft^2 U_r = 0.026 Floor (slab): 1,500 ft^2 U_s = 0.033	Opaque Exterior Door: 19 ft^2 U_g = 0.32 Roof: 1,700 ft^2 1,500 ft^2 @ U_r = 0.026 200 ft^2 @ U_r = 0.022 Floor: 1,700 ft^2 1,500 @ U_s = 0.033 200 ft^2 @ U_s = 0.028

R502.1.1.2 Heating and cooling systems. New heating, cooling and duct systems that are part of the addition shall comply with Sections R403.1, R403.2, R403.3, R403.5 and R403.6.

> **Exception:** Where ducts from an existing heating and cooling system are extended to an addition, duct systems with less than 40 linear feet (12.19 m) in unconditioned spaces shall not be required to be tested in accordance with Section R403.3.3.

❖ Heating and cooling systems for additions are required to meet the current code for additions. The key to this section, again, is the exception that allows relaxation on duct-testing requirements. This accommodates a simple addition where there is a short reach with the ductwork in an attic or crawl space to the conditioned spaces in the addition.

R502.1.1.3 Service hot water systems. New service hot water systems that are part of the addition shall comply with Section R403.5.

❖ There is no relaxation of requirements for construction of new service hot water systems in additions.

R502.1.1.4 Lighting. New lighting systems that are part of the addition shall comply with Section R404.1.

❖ There is no relaxation of requirements for construction of new lighting systems in additions.

R502.1.2 Existing plus addition compliance (Simulated Performance Alternative). Where nonconditioned space is changed to conditioned space, the addition shall comply where the annual energy cost or energy use of the addition and the existing building, and any alterations that are part of the project, is less than or equal to the annual energy cost of the existing building when modeled in accordance with Section R405. The addition and any alterations that are part of the project shall comply with Section R405 in its entirety.

❖ Section R405 provides the performance alternative for compliance with the code. This section simply states that this performance alternative can be used in the design of an addition as well. The difference here is that the "standard design" is the existing building, rather than the standard building modeled from compliance with the code as used in Section R405.

SECTION R503
ALTERATIONS

R503.1 General. *Alterations* to any building or structure shall comply with the requirements of the code for new construction. *Alterations* shall be such that the existing building or structure is no less conforming to the provisions of this code than the existing building or structure was prior to the *alteration*.

Alterations to an existing building, building system or portion thereof shall conform to the provisions of this code as they relate to new construction without requiring the unaltered portions of the existing building or building system to comply with this code. Alterations shall not create an unsafe or hazardous condition or overload existing building systems. *Alterations* shall be such that the existing building or structure uses no more energy than the existing building or structure prior to the *alteration*. Alterations to existing buildings shall comply with Sections R503.1.1 through R503.2.

❖ Alterations include renovations, which implies that something is changed in the structure. For example, the removal, rearranagement or replacement of partition walls in an office building is an alteration because of, in part, possible impact on the means of egress, fire resistance or other life safety features of the building. Conversely, the replacement of damaged trim pieces on a door frame is considered a repair, not an alteration.

Basically, alterations are to conform to the requirements for a new structure, except as specifically stated in this section. For example, a new window installed where there was none will be required to have the *U*-factor rating and SHGC rating required for fenestration in the code, even if the insulation in the walls is not in conformance with the code. With this basic intent in mind, Sections R503.1.1, R503.1.2, R503.1.3, R503.1.4 and R503.2 address specific systems in the code that could be part of an alteration.

R503.1.1 Building envelope. Building envelope assemblies that are part of the alteration shall comply with Section R402.1.2 or R402.1.4, Sections R402.2.1 through R402.2.13, R402.3.1, R402.3.2, R402.4.3 and R402.4.5.

> **Exception:** The following alterations need not comply with the requirements for new construction provided the energy use of the building is not increased:
>
> 1. Storm windows installed over existing fenestration.
> 2. Existing ceiling, wall or floor cavities exposed during construction provided that these cavities are filled with insulation.
> 3. Construction where the existing roof, wall or floor cavity is not exposed.
> 4. Roof recover.
> 5. Roofs without insulation in the cavity and where the sheathing or insulation is exposed during reroofing shall be insulated either above or below the sheathing.
> 6. Surface-applied window film installed on existing single pane fenestration assemblies to reduce solar heat gain provided the code does not require the glazing or fenestration assembly to be replaced.

❖ The exceptions to this section are the key to these provisions. Alterations involving exterior walls and roofs are required to meet the requirements for a new building unless one of these exceptions apply.

The exceptions address situations where the alteration or repair of a structure or element is not required to comply with the provisions of the code. Typically, such situations would be a normal part of ongoing maintenance of the building, would improve the building's energy performance, or would not present an opportunity for improved energy savings. All of these exceptions are tied to the fact that they are permitted, provided "the energy use of the building is not increased."

Exception 1 is a fairly self-evident provision. Because of the limited nature of the work, there is little opportunity to make additional changes. This helps to reinforce the statement from the main paragraph that the intent is not to make "the unaltered portions(s) of the existing building or building system" comply with the code. In this case, the addition of a storm window over an existing window will only improve performance of the existing fenestration.

Exception 2 is important for a couple of the limitations that it contains. The provision only applies when the ceiling, wall or floor cavity is "exposed during construction." If the cavity is not opened up, then there is no requirement to do anything. If the cavity is exposed, the requirement will only be to "fill" it with insulation. Therefore, the level of insulation is not required to comply with the building thermal envelope requirements but is instead only required to be "filled" with any type of insulation and not to any specific *R*-value.

Exception 3 will exempt the need to make changes to the building thermal envelope because the building cavities are not exposed.

Exception 4 is straightforward. A roof recover is an alteration but does not impact the building envelope.

Exception 5 applies to roofs that are part of the building envelope and typically would have below-deck or above-deck insulation. The second sentence of Exception 4 permits the code-required insulation to be above or below the deck. For a typical single-family home (with nonconditioned space), the ceiling is the building thermal envelope and the roof is not; therefore, Exception 5 would not apply. However, if during reroofing the existing ceiling cavities are exposed, then Exception 3 would apply.

Exception 6 is straightforward as well. Surface film used to provide a lower SHGC rating is acceptable for windows that do not otherwise need to be replaced.

R503.1.1.1 Replacement fenestration. Where some or all of an existing fenestration unit is replaced with a new fenestration product, including sash and glazing, the replacement fenestration unit shall meet the applicable requirements for *U*-factor and SHGC as provided in Table R402.1.2.

❖ Replacement windows and doors are required to meet the requirements of the code for new construction, with no exceptions.

Replacing only a glass pane in an existing sash and frame would not fall under this provision if the *U*-factor and SHGC are equal to or lower than the values prior to the replacement. In situations where the existing values are not known or where the replacement is more than just replacing the glass pane, the provisions may be applicable. It is often common practice when fenestration is replaced to remove only the sash and glazing of an existing window and replace them with an entirely new fenestration product. Sometimes the existing frame also is removed, but many times the new fenestration product is custom made to fit in the existing space left after the sash and glazed portions are removed. In essence, the new fenestration is installed in or over the existing frame. Whether the existing frame is removed or not, these types of replacements are regulated by this section.

Section R503.1.1.1 requires that each fenestration unit replaced in a residence not exceed the maximum fenestration *U*-factor and SHGC for the applicable climate zone. This requirement applies to all replacement windows, even if the existing frame is not removed (e.g., the new window is placed inside the old frame), so long as the sash and glazing are replaced. In addition, remember that the definition of "Fenestration" includes doors, which must meet the same *U*-factor requirements as windows. Therefore, the replacement of a door also would have to meet these requirements.

When dealing with replacement fenestration, the code official should be consulted to explain how this requirement will be applied. For simple ease of application for both the code official and the installer, the *U*-factor and SHGC requirements could be applied to each fenestration unit. Therefore, the *U*-factor and SHGC required for each unit would be the values listed directly in Table R402.1.2. However, if acceptable to the code official and additional information is available regarding the performance of the remaining existing windows in the home, it may be reasonable to permit the use of the area-weighted values of Sections R402.3.1 and R402.3.2 or the exemptions of Sections R402.3.3 and R402.3.4 to the replaced fenestration unit.

In accordance with Section R102.1, the *U*-factor and SHGC for each replacement fenestration product must be obtained from a label attached to the product certifying that the values were determined in accordance with NFRC procedures by an accredited, independent laboratory. In the absence of an NFRC-labeled *U*-factor or SHGC, a value from the limited default tables [see Tables R303.1.3(1) through R303.1.3(3)] must be used. The NFRC procedures do include applicable methods to test various replacement products.

R503.1.2 Heating and cooling systems. New heating, cooling and duct systems that are part of the alteration shall comply with Sections R403.1, R403.2, R403.3 and R403.6.

Exception: Where ducts from an existing heating and cooling system are extended, duct systems with less than 40 linear feet (12.19 m) in unconditioned spaces shall not be required to be tested in accordance with Section R403.3.3.

❖ Heating and cooling systems for additions are required to meet code requirements for new construction for alterations. The key to this section is the exception that allows relaxation on duct testing requirements. This accommodates a simple alteration where there is a short reach with the ductwork in an attic or crawl space to the conditioned spaces in the alteration.

R503.1.3 Service hot water systems. New service hot water systems that are part of the alteration shall comply with Section R403.4.

❖ Service hot water systems in an alteration must meet the requirements of the code for new construction, with no exceptions.

R503.1.4 Lighting. New lighting systems that are part of the alteration shall comply with Section 404.1.

Exception: Alterations that replace less than 50 percent of the luminaires in a space, provided that such alterations do not increase the installed interior lighting power.

❖ Alterations involving lighting systems can be relaxed somewhat when fewer than 50 percent of the luminaires are being replaced. However, in keeping with the primary intent of the code for alterations, the final product cannot use more energy than the building that is being renovated. The code does not allow an increase in lighting power.

R503.2 Change in space conditioning. Any nonconditioned or low-energy space that is altered to become *conditioned space* shall be required to be brought into full compliance with this code.

Exception: Where the simulated performance option in Section R405 is used to comply with this section, the annual energy cost of the proposed design is permitted to be 110 percent of the annual energy cost otherwise allowed by Section R405.3.

❖ When nonconditioned spaces are converted to conditioned space, the impact on the community energy resources is the same as that for new construction. As such, they should be required to meet the minimum standards set by the code for new construction.

The exception recognizes the fact that full compliance with this code for existing buildings is extremely difficult and costly. Conditions such as slab edges, structural thermal bridges, and window configurations cannot be practically remedied in many cases. Therefore, an alternate compliance path allows a 10-percent higher total building performance value. This could result in the preservation and adaptive reuse of more existing buildings, which itself is a significant energy conservation measure.

SECTION R504 REPAIRS

R504.1 General. Buildings, structures and parts thereof shall be repaired in compliance with Section R501.3 and this section. Work on nondamaged components necessary for the required *repair* of damaged components shall be considered part of the *repair* and shall not be subject to the requirements for *alterations* in this chapter. Routine maintenance required by Section R501.3, ordinary repairs exempt from *permit*, and abatement of wear due to normal service conditions shall not be subject to the requirements for *repairs* in this section.

❖ This section and Section R504.2 detail examples of what a repair is. A repair is work not required to comply with the alterations provisions of the code. Section R503.2 provides some specific work that is considered repairs. This is done simply to clarify the code on these specific issues; the list is not intended to be comprehensive—other work could also be considered repairs, as described in this section.

R504.2 Application. For the purposes of this code, the following shall be considered repairs:

1. Glass-only replacements in an existing sash and frame.
2. Roof repairs.
3. Repairs where only the bulb and/or ballast within the existing luminaires in a space are replaced provided that the replacement does not increase the installed interior lighting power.

❖ See the commentary to Section R504.1.

SECTION R505 CHANGE OF OCCUPANCY OR USE

R505.1 General. Spaces undergoing a change in occupancy that would result in an increase in demand for either fossil fuel or electrical energy shall comply with this code.

❖ When a building undergoes a change of occupancy, energy-using systems (envelope, mechanical, service water heating, electrical distribution or illumination) must be evaluated to determine the effect the change of occupancy has on system performance and energy use. For example, if a mercantile building were converted to a restaurant, additional ventilation would be required for the public based on the increased occupant load. If an existing system serves an occupancy that is different from the occupancy it served when the code went into effect, the mechanical system must comply with the applicable code requirements for a mechanical system serving the newer occupancy. Depending on the nature of the previous occupancy, changing a building's occupancy classification could result in a change to the mechanical, service water heating, electrical distribution or illumination systems or any combination of these.

Buildings undergoing a change of occupancy must meet the applicable requirements of the code when peak demand is increased. For example, if a hotel is converted to multiple-family residential use and the conversion results in an increase in the building's peak connected load (space conditioning, lighting or service water heating), the entire building must be brought into compliance.

When the occupancy changes in a portion of an existing building (residential or commercial) and the new occupancy results in an increase in the peak demand for either fossil fuel or electrical energy supply, the portion of the building associated with the new occupancy must meet the code.

When a permittee claims that a change in occupancy will not increase the peak design rate of energy use for the building, it is the applicant's responsibility to demonstrate that the peak load of the converted building will not exceed the peak load of the original building. Without supporting documentation, the peak load generally must be assumed to increase with a change in occupancy.

It is also important that users realize that under the code there can be a difference between the change of occupancy (the way a building is used) and what the IBC deals with when a change of occupancy classification occurs. Therefore, if a storage building that has no heating or cooling is modified so that the building is heated to prevent stock items from freezing, the IBC would not consider this as a change of occupancy because the occupancy classification would still be Group S-1. The code, however, would consider this a change in occupancy because the way the building is used would change and it would result in an increase in the demand for energy.

R505.2 General. Any space that is converted to a dwelling unit or portion thereof from another use or occupancy shall comply with this code.

Exception: Where the simulated performance option in Section R405 is used to comply with this section, the annual energy cost of the proposed design is permitted to be 110 percent of the annual energy cost otherwise allowed by Section R405.3.

❖ This is a specific example of a change in occupancy. See commentary to Section R505.1.

The exception recognizes the fact that full compliance with the code for existing buildings is extremely difficult and costly. Conditions such as slab edges, structural thermal bridges and window configurations cannot be practically remedied in many cases. Therefore, an alternate compliance path allows a 10-percent higher total building performance value. This could result in the preservation and adaptive reuse of more existing buildings, which itself is a significant energy conservation measure.

Chapter 6 [RE]: Referenced Standards

General Comments

Chapter 6 [RE] contains a comprehensive list of standards that are referenced in the Residential Provisions of this code. It is organized to make locating specific document references easy.

It is important to understand that not every document related to energy conservation is qualified to be a "referenced standard." The International Code Council (ICC)® has adopted a criterion that referenced standards in the *International Codes*® (I-Codes®) and standards intended for adoption into the I-Codes must meet to qualify as a referenced standard. The policy is summarized as follows:

- Code references: The scope and application of the standard must be clearly identified in the code text.
- Standard content: The standard must be written in mandatory language and be appropriate for the subject covered. The standard cannot have the effect of requiring proprietary materials or prescribing a proprietary testing agency.
- Standard promulgation: The standard must be readily available and developed and maintained in a consensus process such as those used by ASTM or ANSI.

The ICC Code Development Procedures CP #28, of which the standards policy is a part, are updated periodically. A copy of the latest version can be obtained from the ICC offices.

Once a standard is incorporated into the code through the code development process, it becomes an enforceable part of the code. When the code is adopted by a jurisdiction, the standard also is part of that jurisdiction's adopted code. It is for this reason that the criteria were developed. Compliance with this policy means that documents incorporated into the code are developed through the use of a consensus process, are written in mandatory language and do not mandate the use of proprietary materials or agencies. The requirement for a standard to be developed through a consensus process means that the standard is representative of the most current body of available knowledge on the subject as determined by a broad range of interested or affected parties without dominance by any single interest group. A true consensus process has many attributes, including but not limited to:

- An open process that has formal (published) procedures allowing for the consideration of all viewpoints.
- A definitive review period that allows for the standard to be updated and/or revised.
- A process of notification to all interested parties.
- An appeals process.

Many available documents related to mechanical system design and installation and construction, though useful, are not "standards" and are not appropriate for reference in the code. Often, these documents are developed or written with the intention of being used for regulatory purposes and are unsuitable for use as a standard because of extensive use of recommendations, advisory comments and nonmandatory terms. Typical examples include installation instructions, guidelines and practices.

The objective of ICC's standards policy is to provide regulations that are clear, concise and enforceable; thus the requirement for standards to be written in mandatory language. This requirement is not intended to mean that a standard cannot contain informational or explanatory material that will aid the user of the standard in its application. When the standard's promulgating agency wants such material to be included, however, the information must appear in a nonmandatory location, such as an annex or appendix, and be clearly identified as not being part of the standard.

Overall, standards referenced by the code must be authoritative, relevant, up to date and, most important, reasonable and enforceable. Standards that comply with the ICC's standards policy fulfill these expectations.

Purpose

As a performance-based code, the *International Energy Conservation Code*® (IECC®) contains numerous references to documents that are used to regulate materials and methods of construction. The references to these documents within the code text consist of the promulgating agency's acronym and its publication designation (for example, ACCA Manual J) and a further indication that the document being referenced is the one that is listed in this chapter. This chapter contains all of the information that is necessary to identify the specific referenced document. Included is the following information on a document's promulgating agency (see Commentary Figure 6 [RE]):

- The promulgating agency (the agency's title).
- The promulgating agency's acronym.
- The promulgating agency's address.

For example, a reference to ASTM E 283 indicates that this document can be found in Chapter 6 [RE] under the heading ASTM. The specific standards designation is E 283. For convenience, these designations are listed in alphanumeric order. This chapter identifies that ASTM E 283 is titled *Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen*, the applicable edition (i.e., its year of publication) is 2004 and it is referenced in one section of the code.

This chapter will also indicate when a document has been discontinued or replaced by its promulgating agency. When a document is replaced by a different one, a note will appear to tell the user the designation and title of the new document.

The key aspect of the manner in which standards are referenced by the code is that a specific edition of a specific standard is clearly identified. In this manner, the requirements necessary for compliance can be readily determined. The basis for code compliance is, therefore, established and available on an equal basis to the building official, contractor, designer and owner.

This chapter lists the standards that are referenced in various sections of this document. The standards are listed herein by the promulgating agency of the standard, the standard identification, the effective date and title, and the section or sections of this document that reference the standard. The application of the referenced standards shall be as specified in Section R106.

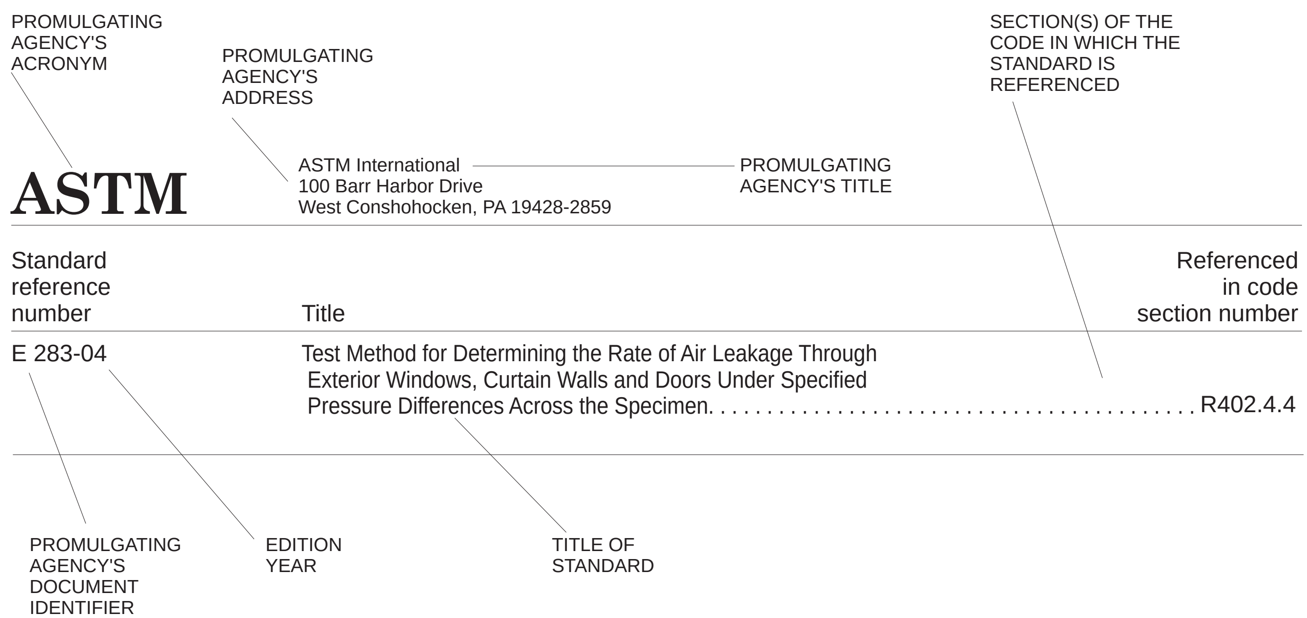


Figure 6 [RE]
REFERENCED STANDARDS

This chapter lists the standards that are referenced in various sections of this document. The standards are listed herein by the promulgating agency of the standard, the standard identification, the effective date and title, and the section or sections of this document that reference the standard. The application of the referenced standards shall be as specified in Section 106.

AAMA

American Architectural Manufacturers Association
1827 Walden Office Square
Suite 550
Schaumburg, IL 60173-4268

Standard reference number	Title	Referenced in code section number
AAMA/WDMA/CSA 101/I.S.2/A C440—11	North American Fenestration Standard/ Specifications for Windows, Doors and Unit Skylights	R402.4.3

ACCA

Air Conditioning Contractors of America
2800 Shirlington Road, Suite 300
Arlington, VA 22206

Standard reference number	Title	Referenced in code section number
Manual J—2011	Residential Load Calculation Eighth Edition	R403.7
Manual S—13	Residential Equipment Selection	R403.7

APSP

The Association of Pool and Spa Professionals
2111 Eisenhower Avenue
Alexandria, VA 22314

Standard reference number	Title	Referenced in code section number
APSP 14—11	American National Standard for Portable Electric Spa Energy Efficiency	R403.10.1, 403.11
APSP 15a—2013	American National Standard for Residential Swimming Pool and Spa Energy Efficiency	R403.12

ASHRAE

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329-2305

Standard reference number	Title	Referenced in code section number
ASHRAE—2013	ASHRAE Handbook of Fundamentals	R402.1.5, Table R405.5.2(1)
ASHRAE 193—2010	Method of Test for Determining the Airtightness of HVAC Equipment	R403.3.2.1

ASTM

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2859

Standard reference number	Title	Referenced in code section number
C 1363—11	Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus	R303.1.4.1
E 283—04	Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen	R402.4.4

ASTM—continued

E 779—10	Standard Test Method for Determining Air Leakage Rate by Fan Pressurization	R402.4.1.2
E 1827—11	Standard Test Methods for Determining Airtightness of Building Using an Orifice Blower Door	R402.4.1.2

CSA

CSA Group
8501 East Pleasant Valley
Cleveland, OH 44131-5575

Standard reference number	Title	Referenced in code section number
AAMA/WDMA/CSA 101/I.S.2/A440—11	North American Fenestration Standard/Specification for Windows, Doors and Unit Skylights	R402.4.3
CSA 55.1—2012	Test Method for measuring efficiency and pressure loss of drain water heat recovery units	R403.5.4
CSA 55.2—2012	Drain water heat recover units	R403.5.4

DASMA

Door and Access Systems Manufacturers Association
1300 Sumner Avenue
Cleveland, OH 44115-2851

Standard reference number	Title	Referenced in code section number
105—92(R2004)—13	Test Method for Thermal Transmittance and Air Infiltration of Garage Doors	R303.1.3

ICC

International Code Council, Inc.
500 New Jersey Avenue, NW
6th Floor
Washington, DC 20001

Standard reference number	Title	Referenced in code section number
IBC—15	International Building Code®	R201.3, R303.2, R402.1.1, R501.4
ICC 400—12	Standard on the Design and Construction of Log Structures	Table R402.5.1.1
IECC—15	International Energy Conservation Code®	R101.4.1, 403.8
IECC—09	2009 International Energy Conservation Code®	R406.2
ECC—06	2006 International Energy Conservation Code®	R202, R406.3.1
IFC—15	International Fire Code®	R201.3,R501.4
IFGC—15	International Fuel Gas Code®	R201.3,R501.4
IMC—15	International Mechanical Code®	R201.3, R403.3.2, R403.6, R501.4
IPC—15	International Plumbing Code®	R201.3,R501.4
IPSDC—15	International Private Sewage Disposal Code®	501.4
IPMC—15	International Property Maintenance Code®	501.4
IRC—15	International Residential Code®	R201.3, R303.2, R402.1.1, R402.2.11, R403.3.2, R403.6, R501.4

IIEEE

The Institute of Electrical and Electronic Engineers, Inc.
3 Park Avenue
New York, NY 1016-5997

Standard reference number	Title	Referenced in code section number
515.1—2012	IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Commercial Applications	R403.5.1.2

NFPA

National Fire Protection Association.
1 Batterymarch Park
Quincy, MA 02169-7471

Standard reference number	Title	Referenced in code section number
70—14	National Electrical Code	R501.4

NFRC

National Fenestration Rating Council, Inc.
6305 Ivy Lane, Suite 140
Greenbelt, MD 20770

Standard reference number	Title	Referenced in code section number
100—2009	Procedure for Determining Fenestration Products *U*-factors—Second Edition	R303.1.3
200—2009	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence—Second Edition	R303.1.3
400—2009	Procedure for Determining Fenestration Product Air Leakage—Second Edition	R402.4.3

UL

UL LLC
333 Pfingsten Road
Northbrook, IL 60062

Standard reference number	Title	Referenced in code section number
127—11	Standard for Factory Built Fireplaces	R402.4.2
515—11	Electrical Resistance Heat Tracing for Commercial and Industrial Applications including revisions through November 30, 2011	R403.5.1.2

US-FTC

United States-Federal Trade Commission
600 Pennsylvania Avenue NW
Washington, DC 20580

Standard reference number	Title	Referenced in code section number
CFR Title 16 (May 31, 2005)	R-value Rule	R303.1.4

WDMA

Window and Door Manufacturers Association
2025 M Street, NW Suite 800
Washington, DC 20036-3309

Standard reference number	Title	Referenced in code section number
AAMA/WDMA/CSA 101/I.S.2/A440—11	North American Fenestration Standard/Specification for Windows, Doors and Unit Skylights	R402.4.3

Appendix RA: Recommended Procedure for Worst-case Testing of Atmospheric Venting Systems Under R402.4 or R405 Conditions ≤ $5ACH_{50}$

(This appendix is informative and is not part of the code.)

General Comments

Energy efficiency improvements often have a direct impact on the building pressure boundary affecting the safe operation of combustion equipment. Under certain conditions, reduced natural-air leakage coupled with the installation of atmospheric combustion appliances will reduce air exchange to the outside of a building and potentially contribute to poor indoor air quality and health problems due to spillage, inadequate draft, or carbon monoxide concerns.

Purpose

This appendix is intended to provide guidance to builders, code officials and home performance contractors for worst-case testing of atmospheric venting systems to identify problems that weaken draft and restrict combustion air. Worst-case vent testing uses the home's exhaust fans, air-handling appliances and chimneys to create worst-case depressurization in the combustion appliance zone (CAZ). This appendix is basically a distilled version of predominant combustion safety test procedures for atmospherically vented appliances found in readily available home performance programs across the country, such as EPA's *Healthy Indoor Environments Protocols*, EPA's *Home Performance with Energy Star*, DOE's *Workforce Guidelines for Home Energy Upgrades*, HUD's *Community Development Block Grants and Weatherization Assistance Programs*, BPI's *Technical Standards for the Building Analyst Professional*, and RESNET's *Interim Guidelines for Combustion Appliance Testing and Writing Work Scopes*. This is intended to take the combustion safety test procedures that are used most commonly by these home performance, weatherization, and beyond-code programs, and reduce them to their simplest and most straightforward form for the purpose of combustion safety in field assessment through the use of building diagnostic tools.

SECTION RA101 SCOPE

RA101.1 General. This appendix is intended to provide guidelines for worst-case testing of atmospheric venting systems. Worst-case testing is recommended to identify problems that weaken draft and restrict combustion air.

SECTION RA201 GENERAL DEFINITIONS

COMBUSTION APPLIANCE ZONE (CAZ). A contiguous air volume within a building that contains a Category I or II atmospherically vented appliance or a Category III or IV direct-vent or integral vent appliance drawing combustion air from inside the building or dwelling unit. The CAZ includes, but is not limited to, a mechanical closet, a mechanical room, or the main body of a house or dwelling unit.

DRAFT. The pressure difference existing between the *appliance* or any component part and the atmosphere that causes a continuous flow of air and products of *combustion* through the gas passages of the *appliance* to the atmosphere.

Mechanical or induced draft. The pressure difference created by the action of a fan, blower or ejector that is located between the *appliance* and the *chimney* or vent termination.

Natural draft. The pressure difference created by a vent or *chimney* because of its height and the temperature difference between the *flue* gases and the atmosphere.

SPILLAGE. Combustion gases emerging from an appliance or venting system into the combustion appliance zone during burner operation.

SECTION RA301 TESTING PROCEDURE

RA301.1 Worst-case testing of atmospheric venting systems. Buildings or dwelling units containing a Category I or II atmospherically vented appliance; or a Category III or IV direct-vent or integral vent appliance drawing combustion air from inside of the building or dwelling unit, shall have the Combustion Appliance Zone (CAZ) tested for spillage, acceptable draft and carbon monoxide (CO) in accordance with this section. Where required by the *code official*, testing shall be conducted by an *approved* third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the *code official*. Testing shall be performed at any time after creation of all penetrations of the *building thermal* envelope and prior to final inspection.

Exception: Buildings or dwelling units containing only Category III or IV direct-vent or integral vent appliances that do not draw combustion air from inside of the building or dwelling unit.

The enumerated test procedure as follows shall be complied with during testing:

1. Set combustion appliances to the pilot setting or turn off the service disconnects for combustion appliances. Close exterior doors and windows and the fireplace damper. With the building or dwelling unit in this configuration, measure and record the baseline ambient pressure inside the building or dwelling unit CAZ. Compare the baseline ambient pressure of the CAZ to that of the outside ambient pressure and record the difference (Pa).
2. Establish worst case by turning on the *clothes dryer* and all exhaust fans. Close all interior doors that make the CAZ pressure more negative. Turn on the air handler, where present, and leave on if, as a result, the pressure in the CAZ becomes more negative. Check interior door positions again, closing only the interior doors that make the CAZ pressure more negative. Measure net change in pressure from the CAZ to outdoor ambient pressure, correcting for the base ambient pressure inside the home. Record "worst case depressurization" pressure and compare to Table RA301.1(1).

   Where CAZ depressurization limits are exceeded under worst-case conditions in accordance with Table RA301.1(1), additional combustion air shall be provided or other modifications to building air-leakage performance or exhaust appliances such that depressurization is brought within the limits prescribed in Table RA301.1(1).
3. Measure worst-case spillage, acceptable draft and carbon monoxide (CO) by firing the fuel-fired appliance with the smallest Btu capacity first.
   a. Test for spillage at the draft diverter with a mirror or smoke puffer. An appliance that continues to spill flue gases for more than 60 seconds fails the spillage test.
   b. Test for CO measuring undiluted flue gases in the throat or flue of the appliance using a digital gauge in parts per million (ppm) at the 10-minute mark. Record CO ppm readings to be compared with Table RA301.1(3) upon completion of Step 4. Where the spillage test fails under worst case, go to Step 4.
   c. Where spillage ends within 60 seconds, test for acceptable draft in the connector not less than 1 foot (305 mm), but not more than 2 feet (610 mm) downstream of the draft diverter. Record draft pressure and compare to Table RA301.1(2).
   d. Fire all other connected appliances simultaneously and test again at the draft diverter of each appliance

**TABLE RA301.1(1)
CAZ DEPRESSURIZATION LIMITS**

VENTING CONDITION	LIMIT (Pa)
Category I, atmospherically vented water heater	–2.0
Category I or II atmospherically vented boiler or furnace common-vented with a Category I atmospherically vented water heater	–3.0
Category I or II atmospherically vented boiler or furnace, equipped with a flue damper, and common vented with a Category I atmospherically vented water heater	–5.0
Category I or II atmospherically vented boiler or furnace alone	
Category I or II atmospherically vented, fan-assisted boiler or furnace common vented with a Category I atmospherically vented water heater	
Decorative vented, gas appliance	
Power-vented or induced-draft boiler or furnace alone, or fan-assisted water heater alone	–15.0
Category IV direct-vented appliances and sealed combustion appliances	–50.0

For SI: 6894.76 Pa = 1.0 psi.

**TABLE RA301.1(2)
ACCEPTABLE DRAFT TEST CORRECTION**

OUTSIDE TEMPERATURE (°F)	MINIMUM DRAFT PRESSURE REQUIRED (Pa)
< 10	–2.5
10 – 90	(Outside Temperature ÷ 40) – 2.75
> 90	–0.5

For SI: 6894.76 Pa = 1.0 psi.

for spillage, CO and acceptable draft using procedures 3a through 3c.

4. Measure spillage, acceptable draft, and carbon monoxide (CO) under natural conditions—without *clothes dryer* and exhaust fans on—in accordance with the procedure outlined in Step 3, measuring the net change in pressure from worst case condition in Step 3 to natural in the CAZ to confirm the worst case depressurization taken in Step 2. Repeat the process for each appliance, allowing each vent system to cool between tests.
5. Monitor indoor ambient CO in the breathing zone continuously during testing, and abort the test where indoor ambient CO exceeds 35 ppm by turning off the appliance, ventilating the space, and evacuating the building. The CO problem shall be corrected prior to completing combustion safety diagnostics.
6. Make recommendations based on test results and the retrofit action prescribed in Table RA301.1(3).

TABLE RA301.1(3)
ACCEPTABLE DRAFT TEST CORRECTION

CARBON MONOXIDE LEVEL (ppm)	AND OR	SPILLAGE AND ACCEPTABLE DRAFT TEST RESULTS	RETROFIT ACTION
0 – 25	and	Passes	Proceed with work
$25 < \times \leq 100$	and	Passes	Recommend that CO problem be resolved
$25 < \times \leq 100$	and	Fails in worst case only	Recommend an appliance service call and repairs to resolve the problem
$100 < \times \leq 400$	or	Fails under natural conditions	**Stop!** Work shall not proceed until appliance is serviced and problem resolved
> 400	and	Passes	**Stop!** Work shall not proceed until appliance is serviced and problem resolved
> 400	and	Fails under any condition	**Emergency!** Shut off fuel to appliance and call for service immediately

Appendix RB: Solar-ready Provisions—Detached One- and Two-family Dwellings, Multiple Single-family Dwellings (Townhouses)

(The provisions contained in this appendix are not mandatory unless specifically referenced in the adopting ordinance.)

General Comments

This appendix is intended to support future potential improvements for detached one- and two-family dwellings, and multiple single-family dwellings for solar electric and solar thermal systems. This appendix does not require the installation of conduit, prewiring, or preplumbing. It does not require any specific physical orientation of the residential building. It does not require any increased load capacities for residential roofing systems. It does not require the redesign of plans.

Many building departments have been mandated by local regulations to accelerate permits and inspections for solar installation. Having important information and documentation available to the building department, solar contractor and homeowner will assist in supporting the accelerated working environment many municipalities have mandated.

The U.S. Department of Energy's (DOE) SunShot Initiative has set a goal to make solar energy cost competitive with other forms of energy by the end of the decade, which would reduce installed costs of solar energy systems by about 75 percent. This initiative, combined with increased pressures on our energy supply and demand, is expected to drive greater adoption of renewable energy systems on residential buildings.

Purpose

This appendix is intended to identify the areas of a residential building roof, called the solar-ready zone, for potential future installation of renewable energy systems. The ability to plan ahead for possible future solar equipment starts with documenting necessary solar-ready zone information on the plans, some of which may already be required in permit construction requirements. This appendix also requires the builder to post specific information about the home for use by the homeowner(s).

The documentation of solar-ready zones and roof load calculations (already performed during the design phase) will assist building departments as well as any future solar contractors seeking to install renewable energy systems on the roof. The builder/designer is knowledgeable on the intricacies of each model and plan and can easily identify unobstructed roof areas as well as spaces where conduit, wiring and plumbing can be routed from the roof to the respective utility areas. This will save building departments and solar designers time and effort when installing future solar systems. If a homeowner wishes to install a solar energy system later, this documentation can save thousands of dollars in labor, installation, design and integration of the solar system into the house.

SECTION RB101 SCOPE

RB101.1 General. These provisions shall be applicable for new construction where solar-ready provisions are required.

SECTION RB102 GENERAL DEFINITION

SOLAR-READY ZONE. A section or sections of the roof or building overhang designated and reserved for the future installation of a solar photovoltaic or solar thermal system.

SECTION RB103 SOLAR-READY ZONE

RB103.1 General. New detached one- and two-family dwellings, and multiple single-family dwellings (townhouses) with not less than 600 square feet (55.74 m^2) of roof area oriented between 110 degrees and 270 degrees of true north shall comply with Sections RB103.2 through RB103.8.

Exceptions:

1. New residential buildings with a permanently installed on-site renewable energy system.

2. A building with a solar-ready zone that is shaded for more than 70 percent of daylight hours annually.

RB103.2 Construction document requirements for solar-ready zone. Construction documents shall indicate the solar-ready zone.

RB103.3 Solar-ready zone area. The total solar-ready zone area shall be not less than 300 square feet (27.87 m^2) exclusive of mandatory access or set back areas as required by the *International Fire Code*. New multiple single-family dwellings (townhouses) three stories or less in height above grade plane and with a total floor area less than or equal to 2,000 square feet (185.8 m^2) per dwelling shall have a solar-ready zone area of not less than 150 square feet (13.94 m^2). The solar-ready zone shall be composed of areas not less than 5 feet (1524 mm) in width and not less than 80 square feet (7.44 m^2) exclusive of access or set back areas as required by the *International Fire Code*.

RB103.4 Obstructions. Solar-ready zones shall be free from obstructions, including but not limited to vents, chimneys, and roof-mounted equipment.

RB103.5 Roof load documentation. The structural design loads for roof dead load and roof live load shall be clearly indicated on the construction documents.

RB103.6 Interconnection pathway. Construction documents shall indicate pathways for routing of conduit or plumbing from the solar-ready zone to the electrical service panel or service hot water system.

RB103.7 Electrical service reserved space. The main electrical service panel shall have a reserved space to allow installation of a dual pole circuit breaker for future solar electric installation and shall be labeled "For Future Solar Electric." The reserved space shall be positioned at the opposite (load) end from the input feeder location or main circuit location.

RB103.8 Construction documentation certificate. A permanent certificate, indicating the solar-ready zone and other requirements of this section, shall be posted near the electrical distribution panel, water heater or other conspicuous location by the builder or registered design professional.

INDEX

A

B

C

D

E

F

G

H

I

L

M

O

P