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Energy Code Enforcement Training Manual

Covering the Washington State
Energy Code and the Ventilation
and Indoor Air Quality Code

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Introduction

This manual is designed to provide building department personnel with specific inspection and plan review skills and information on provisions of the 1991 edition of the Washington State Energy Code (WSEC). It also provides information on provisions of the new stand-alone Ventilation and Indoor Air Quality (VIAQ) Code.

WHY AN ENERGY CODE?

Nearly a third of all the energy used in the U.S. is consumed through some form of tempering our indoor climate -- through space heating or cooling, water heating, and lighting. Of the energy used in buildings, nearly 75% is dedicated to heating and air conditioning systems. Furthermore, many studies indicate that much more energy is consumed than is necessary to do the job.

The intent of the WSEC is to reduce the amount of energy used by requiring energy-efficient construction. Such conservation reduces energy requirements, and, as a result, reduces the use of finite resources, such as gas or oil. Lowering energy demand helps everyone by keeping electricity costs down. (It is less expensive to use existing electrical capacity efficiently than it is to develop new and additional capacity needed to heat or cool inefficient buildings.)

The measures required or recommended in the WSEC are not intended to require unnecessary or unreasonable expense. Lengthy cost-analysis has been conducted on the paths and options presented in the Code and explained in this manual. Every attempt has been made to develop a practical and effective approach to energy-efficient construction.

THE VIAQ CODE

The new VIAQ Code (effective July, 1991) is a natural companion to the energy code. Whether energy-efficient or not, all homes have potential indoor air quality problems. Studies have shown that indoor air is often more polluted than outdoor air! The VIAQ Code provides a means of exchanging stale air for fresh, without compromising energy savings, by setting standards for a controlled ventilation system. It also offers requirements meant to prevent indoor air pollution from building products or radon.

HOW TO USE THE MANUAL

This manual is intended to act as a day-to-day reference for code enforcers, but is meant to supplement, not supplant, other sources of information and training currently available to Washington's code enforcement personnel (see below). As much as possible, the manual reflects the most recent information and clarifications arising from interaction with code officials and inspectors in the field.

The WSEC is presented first, including a general information section, a residential compliance section, and a "commercial" (or non-residential) compliance section. The VIAQ Code is presented next, again beginning with general information, followed by a unit on administrative requirements, a unit on residential

✓ **NOTE**

Essentially, this manual presents general information first before providing specific information, separates residential from "commercial" requirements, and offers more simple options before more complex ones. It also attempts to provide background information helpful to understanding the WSEC and VIAQ Codes. As a result of this organization, and due to additional training issues, it was not possible to follow the Codes' organization exactly. For example, although the Code presents the Systems Analysis Compliance Path first, the training manual presents the Prescriptive Path first. This is both because it is the simplest to understand, and because it will likely be the path most used.

We realize this may confuse those who may refer to Code Chapter numbers rather than path names to refer to a particular compliance path. However, to keep it straight, WSEC Chapters are referred to as a "Code Chapter" in the text, for example "Code Chapter 3," or "WSEC Chapter 3." In addition, paths are always referred to by name.

Finally, specific Code references in the manual are made by Section number, and usually appear in brackets, for example [Section 101].

requirements and a unit on non-residential requirements. The manual includes substantial appendices, such as resources, tables, sample worksheets, and other data necessary to enforce the code.

The following unit-by-unit summary will help provide the reader with an overview of this publication.

WSEC-- General Information

Unit 1: Presents requirements governing Code administration and enforcement as they are presented in WSEC Chapter 1. This includes information on the intent and scope of the Code, and in particular, its application to existing buildings. In addition, general information on other enforcement issues, such as conflicts with other codes, reference standards recognized by the Code, and sources defining technical terms found in the Code, is provided.

Unit 2: In order to effectively administer and enforce the Code, it is important to understand the basic principles that serve as its foundation. This unit discusses heat transfer, the factors that can affect it, heat

energy measurement, and heat flow analysis, as it is applied in the WSEC.

Unit 3: Presents the WSEC's design criteria for the thermal performance of buildings as established in WSEC Chapter 3. These criteria are used to determine minimum insulation for a building envelope and to size heating and cooling (HVAC) systems. Climate zones are defined.

Unit 4: Draws together general requirements instituted by the Code, including minimum requirements for the installation of the thermal components of the building envelope; minimum requirements for moisture and air leakage control; and minimum performance requirements for building mechanical systems, water heating, and lighting. These requirements apply no matter what compliance path is being used, although most of these are established in WSEC Chapter 5, which presents the Component Performance Compliance Path. Requirements that apply only to non-residential occupancies are referred to in this unit but actually discussed in Units 9, 10, and 11.

WSEC -- Residential Compliance

Unit 5: Explains how residential buildings can comply using the Prescriptive Path, based on Code Chapter 6. The path is the simplest of three possible paths available to show compliance with the WSEC's thermal performance requirements for the building envelope. Although the least flexible path of the three, the Prescriptive Path does offer over 50 options -- it is expected to be the compliance path of choice for most residential situations. In addition, this unit describes a prescriptive method for verifying residential heating load sizing (Code Chapter 9). It is intended to be used for *compliance purposes only*. (See Unit 6 for proper sizing of the heating system.)

Unit 6: Explains how residential buildings can comply using the Component Performance Path, based on Code Chapter 5. In addition, it provides an in-depth example of design heat load calculations for proper sizing of the heating system.

Unit 7: Explains how residential buildings can comply using the Energy Systems Analysis Path, based on Code Chapter 4. The Path is the most flexible and the most complex of three possible paths available to show compliance with the WSEC's thermal performance requirements for the building envelope. In addition, this unit provides a summary of software suggested for use, including those listed in Code Chapter 8.

Unit 8: Offers suggestions that can help facilitate transition to the 1991 version of the WSEC and the new VIAQ Code. These are applicable no matter what type of occupancy is being considered. Also provides an overview of submittal, plan review, and site inspection for residential occupancies.

WSEC -- "Commercial" Compliance

Unit 9: Introduces the "commercial" code, essentially WSEC requirements for "other than Group R" or non-residential occupancies. This unit focuses on thermal performance of the building envelope, and presents Prescriptive, Component Performance, and Systems Analysis requirements for the envelope.

Unit 10: Presents mechanical and service water systems requirements as they apply to all non-Group R occupancies.

Unit 11: Presents electrical power and lighting requirements as they apply to all non-Group R occupancies.

VIAQ Code

Unit 12: Introduces the VIAQ Code and summarizes important aspects of the Code, including its intent and scope, permitted alternatives, and resolutions for conflicts with other codes. It also discusses the scope of the code official's responsibility for permit submittal, inspection, and enforcement.

Unit 13: Summarizes the requirements of the VIAQ Code as they apply to Group R (residential) occupancies. This unit also provides a basis for understanding these requirements, including an overview of residential ventilation, as well as background information on indoor air quality and radon.

Unit 14: Summarizes the requirements of the VIAQ Code as they apply to non-Group R (or "commercial") occupancies.

✓ NOTE

Although a reading of the entire manual is suggested for an effective understanding of the WSEC and the VIAQ Code, an understanding of all requirements specifically applicable to Group R occupancies would minimally include a reading of Units 1 through 8, and Units 12 and 13.

An understanding of all WSEC and VIAQ requirements specifically applicable to non-Group R occupancies would minimally include a reading of Units 1 through 4, Units 9 through 12, and Unit 14. Although Chapter 8 focuses mainly on enforcement issues for Group R occupancies, it also provides general suggestions for effective enforcement that apply no matter what occupancy is being considered.

Appendices

The appendices provide information supporting material in the text as well as data useful in determining compliance.

Appendix A (Resources): Includes a list of organizations and groups providing administrative and technical assistance, other technical resources, a listing of references used in the manual, and product resources.

Appendix B (WSEC Tables): Includes tables applicable to Group R occupancies -- Code Tables 6-1 through 6-6 (Prescriptive), Code Table 5-1 (Component Performance), and pre-approved Component Performance packages. Also includes tables covering other than Group R occupancies -- Code Tables 6-7 (Prescriptive), and Code Table 5-2 (Component Performance).

Appendix C (Component U-Values): Includes WSEC default U-value tables

listed in WSEC Chapter 10, ASHRAE window standards, the State Building Code Council's list of window and door tested values; ASHRAE U-Values for selected materials, and the "zone" method for calculating metal framing U-Values.

Appendix D (Weather Data): Includes the 1986 edition of the *Recommended Outdoor Design Temperatures for Washington State* by the Puget Sound Chapter of ASHRAE.

Appendix E (Checklists and Worksheets): Includes WSEO-EES sample checklists that can be used to determine Prescriptive or component Performance compliance, a worksheet for use with WATTSUN, and the WSEO Code Program Checklist.

Appendix F (Radon Information): Requirements matrix and Washington State Department of Health's Radon Fact Sheet.

Appendix G (Directory of Acronyms): A glossary of acronyms used in this manual.

OTHER RESOURCES

This manual was developed by WSEO as part of the Energy Codes Enforcement Training Program. In addition to this manual, a certification program (administered by WABO) and training programs (offered by WSEO-EES offices) are available. These are discussed in more detail in Chapter 8.

✓ NOTE

Constructive comments on the manual or other training resources are welcomed and should be addressed to

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✓ **HOTLINES**

- ⇒ **Washington State Energy Code & Ventilation Code - *Technical Assistance***
staffed by WSEO to respond to technical questions from Building Department personnel and professional firms. **1-800-235-TA4U(8248)**
 - ⇒ **Commercial/Industrial Energy Questions - *Electric Ideas Clearinghouse***
staffed by WSEO to respond to technical questions, provide product information and supply class schedules on commercial and industrial topics. **1-800-872-3568**; FAX 1-800-872-3882; Electronic Bulletin Board 1-800-762-3319
 - ⇒ **Residential Energy Questions - *WSEO-Energy Extension Service***
staffed by WSEO to respond to questions from the general public on energy conservation matters. **1-800-962-9731**
 - ⇒ **Residential Circuit Rider - *WSEC Training***
Building Departments should contact Jim Bowman or Gary Nordeen in Seattle, or David Hales in Spokane for training for their staff. Professional organizations can arrange training by contacting Bruce Carter in Seattle, or David Hales in Spokane. Seattle - 1-206-296-5640; Spokane - 1-509-456-6150.
 - ⇒ **Washington State Energy Code & Ventilation Code - *Interpretations***
staffed by ICBO to respond to requests for interpretations from building departments (*only*).
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Unit 1: Administration and Enforcement

This unit draws together information useful to building officials and others using the Washington State Energy Code (WSEC). It presents Code requirements governing administration and enforcement as they are presented in WSEC Chapter 1. This includes information on the intent and scope of the Code, and in particular, its application to existing buildings.

In addition, the unit provides general information on other enforcement issues, such as conflicts with other codes, reference standards recognized by the Code, and sources defining technical terms found in the Code.

INTENT

[Section 101.2]

The Washington State Energy Code (WAC 51-11) establishes energy standards for new or altered residential and commercial buildings and structures. The standards relate to thermal, mechanical, lighting, and service water heating energy usage and electrical distribution systems and equipment. For residential construction, minimum and maximum standards are set. For commercial construction, only minimum standards are set.

The Code is intended to provide flexibility and permit alternate approaches and techniques to achieve compliance with its requirements. There are three paths available to show compliance with the Code's thermal performance requirements for the "building envelope." A building need only meet the requirements of one path to show compliance with the Code. In addition, there are general requirements that apply to all buildings covered by the Code, regardless of the compliance path chosen.

The three compliance paths provided in the Code are:

- ⇒ Prescriptive Requirements
- ⇒ Component Performance
- ⇒ Systems Analysis

In the Prescriptive Path, a "standard design" must be used. (There are no trade-offs.) In the Systems Analysis and Component Performance Paths, the standard design is compared to a proposed design, which may differ due to allowable trade-offs. For example, using trade-offs, more insulation may be substituted for less efficient windows.

✓ DEFINITIONS

The **building envelope** consists of all components comprising the building shell, and is defined by the Code to include: "the elements of a building which enclose *conditioned* spaces through which thermal energy (heat) may be transferred to or from the exterior or to or from spaces exempted [from compliance] by the Code." Exempted spaces are treated as if they are part of the exterior of the building.

(continued, next page)

✓ DEFINITIONS (continued)

Conditioned space is defined in the Code as one that is provided with either heated and/or cooled air or that is capable of being maintained at temperatures over 50°F during the heating season. This includes adjacent spaces separated by an uninsulated component such as basements, utility rooms, garages, or corridors.

Heated space is defined by the Code as "space, within a building, which is provided with a positive heat supply." According to the Code, this includes finished living space within a basement or basement space with registers or heating devices designed to supply heat (whether finished or not). It does not include, however, heating systems that are designed to heat a given space to less than 50°F.

The **standard design** is the design of the building being evaluated for compliance, if all components of the proposed building envelope were built to Code, that is, matched values of the Code exactly, given fuel and climate variables.

It is also sometimes referred to in industry literature or in the Code itself as the "Code House," the "Base Case," or the "Code Reference House." Component values of the standard design are considered "target" values.

The three paths are explained in depth in this manual, but the significant aspects of each approach are summarized below.

Prescriptive Requirements

- ⇒ Utilizes tables that provide minimum R-values (or maximum U-values) for components of the building envelope. (See Unit 2, this manual, for an in-depth discussion of R- and U-values.)
- ⇒ For residential construction, may require calculations for sizing the heating system, only. (However, prescriptive heating system sizing, *for compliance purposes only*, is provided in Code Chapter 9.)

The Prescriptive Requirements approach (Code Chapter 6) is the simplest way to comply. It may be used for all occupancies. Prescriptive requirements vary by occupancy, climate zone, fuel type, ratio of glazing to floor area, and construction type. Over 50 prescriptive options are provided. With this approach, insulation values,

window performance standards, and furnace efficiencies are prescribed. No flexibility in the prescribed values is allowed, although heating system sizing requirements can be traded off for higher heating system efficiencies under certain conditions. (This is true for all three paths. See "HVAC Equipment Capacity Requirements," Unit 4.) When prescribed values are met, the building complies. No further calculations are necessary to show compliance.

Component Performance

- ⇒ Requires a comparison of the total building envelope heat loss rate of a proposed design to the standard design.
- ⇒ Utilizes tables that provide maximum U-values for the standard design by specific component.
- ⇒ Allows trade-offs of component efficiencies as long as the total heat loss (for the proposed envelope) is equal or lower.

- ⇒ Requires calculations using standard engineering equations.

Under the Component Performance compliance approach (Code Chapter 5), each component (e.g., wall, floor, roof/ceiling) of the building envelope is compared against target values specified by the Code. Trade-offs among envelope thermal components are allowed as long as the *overall rate of heat loss* (for the proposed envelope) is equal to or less than the overall rate of heat loss for the standard design.

Systems Analysis

- ⇒ Requires a comparison of the estimated annual heat loss of a proposed design to the estimated annual heat loss of the standard design.
- ⇒ Requires calculations of heat gains and losses through envelope.
- ⇒ Requires complex analysis not practically done manually. (A computer is recommended.)

The Systems Analysis approach (Code Chapter 4) compares the annual energy use per square foot (sometimes called an "energy budget") for a proposed design to the energy budget of the standard design of the same building. An equivalent or lower annual energy consumption for the proposed design indicates compliance.

While considering the overall heat loss rate of the standard building (essentially derived using the Component Performance Path) this approach goes further, and takes into account heat gains, such as incidental solar heating equipment or occupants. Thus, it allows the greatest flexibility when modifying the building or mechanical

components of the proposed design from the standard design. It also makes for lengthy mathematical analysis. This path is usually performed with one of a number of computer programs.

SCOPE

[Section 101]

The "Scope" section of the Code:

- ⇒ Describes buildings to which the Code does not apply.
- ⇒ Describes how the Code applies to existing buildings, including historic buildings, and altered or repaired structures.
- ⇒ Resolves conflicts with other codes and within the Code.
- ⇒ Describes the extent of the code official's responsibility and authority regarding plan and specification submittals, inspections, and enforcement.
- ⇒ Describes identification and other requirements for materials and equipment.

Spaces Covered (General)

The Code regulates residential ("R-Occupancy") and non-residential buildings ("Other than R-Occupancy") designed primarily for human occupancy. It can also include *parts* of buildings that are primarily for use by people. In a mixed use building, if the area designed for human occupancy takes up 10% or less of the area of any floor of the building, the Code allows the building official to consider the major use of the building its occupancy type.

Unit 1: Administration & Enforcement

✓ EXAMPLE

In the case of a factory with lounge area, if the lounge takes up 10% or less of the floor area, the building may simply be considered (for WSEC purposes) an industrial occupancy if the building official permits it. If the lounge takes up more than 10% of the floor area, the lounge area must meet requirements for that use.

Seasonal Buildings. The Code does not divide buildings into classifications based on seasonal use. Housing constructed for summer vacation occupancy or seasonal labor is required to meet the Code.

Spaces Not Covered. There are some cases that do not need to comply with the building envelope requirements of the Code, such as:

- ⇒ When the amount of "non-renewable energy" used for space heating (or cooling) purposes, at design peak usage, is less than 3.4 Btus or 1.0 watt per square foot of floor area [Section 101.3.1.1]. This includes spaces where the heating system using the non-renewable fuel is a back-up.
- ⇒ When the space is not *heated or cooled* by a non-renewable energy source [Section 101.3.1.2].

✓ CHANGE

The '86 version of the WSEC made the distinction between "low-rise residential" and all other occupancies, including residential occupancies more than three stories above-grade. In general, the '91 Code treats all residential or R-occupancies the same. This includes high-rise apartments and hotels.

There are exceptions to this general change, however. Effective July 1992, there are options within the Prescriptive Path where glazing efficiency specifications can be modified for buildings less than three stories in height. More specific information on these options is provided in Unit 5, which explains the Prescriptive Path.

✓ DEFINITION

According to the Code, **non-renewable energy sources** are "all energy sources that are not renewable energy sources, including natural gas, oil, coal, wood, liquified petroleum gas, steam, and any utility-supplied electricity." (Code Chapter 2). Note that wood is considered "non-renewable." This classification is Code-specific. Typically, wood has been considered a *renewable* form of energy. The reason for this unusual classification is to avoid excluding wood-heated buildings from Code compliance.

✓ CHANGE

The '86 WSEC defined energy sources as being "depletable" or "non-depletable." In 1991, they are described as non-renewable or renewable energy sources. In general, non-renewable is used in place of the term depletable, and renewable is used in place of the term non-depletable. Renewable energy sources include: incoming solar radiation; energy from wind, waves or tides; energy from lake or pond thermal differences; or energy from the internal heat of the earth.

Existing Buildings

[Section 101.3.2]

Under "Existing Buildings" the Code specifically addresses additions, historic buildings, changes of occupancy or use, and alterations and repairs to the building envelope or heating system. The Code extends quite a bit of discretion to the building official regarding these structures.

Additions

[Section 101.3.2.1]

A new addition must comply with the Code, but any parts of the existing building that are not altered do not have to comply. If the addition is less than 750 square feet, it may not fully comply with the Code. However, improvements must then be made to the original part of the structure to compensate for any deficiencies in the addition.

Compliance shall then be demonstrated by Systems Analysis or Component Performance. (Compliance can be prescriptive only if there are no trade-offs being made with the existing structure.)

Historic Buildings

[Section 101.3.2.2]

Historic buildings covered by the Code are those listed on local, state, or federal historic registries or buildings determined by the building official to be eligible for listing.

✓ EXCEPTION

Additions to historic buildings may be treated more liberally. In the case of historic buildings, the code official can accept alternatives to full compliance that result in a reasonable degree of energy efficiency.

Change Of Occupancy Or Use

[Section 101.3.2.3.]

The Code requires that buildings converted from commercial to residential occupancy must comply. Buildings converted from residential to commercial occupancy must comply if new or increased heating and cooling are provided. Commercial buildings undergoing a change in use that requires heating or cooling where formerly there has been none must comply. Commercial buildings with heating or cooling systems that will not be altered with the change in use need not comply. All buildings undergoing a change of use, must comply with lighting standards, unless existing lighting is not altered. (General lighting standards are provided in Unit 4. Lighting requirements specific to non-Group R occupancies are covered in Unit 11.)

Alterations and Repairs

[Section 101.3.2.4 - 101.3.2.8.]

Under alterations and repairs, the Code addresses the building envelope, mechanical systems, service water heating, and lighting systems. If these systems are replaced or altered, they must be brought up to new Code levels.

When an alteration or repair is made to an existing building, the code official must determine under which code the structure was originally built. If the building was originally built under the 1991 WSEC, then any changes must comply, without exception, to the Code [Section 101.3.2.4]. If the building was built under a previous code, it must meet at least the standards for the shell set by the code under which it was built. In the case of an existing building, where an *initial* tenant alteration is taking place, this alteration must comply with the 1991 WSEC.

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Structural Changes. In general, the Code's insulation and air sealing requirements apply only when the alterations or repairs expose framing cavities; that is, when an exterior wall, ceiling, or floor is opened up. If the framing is exposed, it must be insulated to its full capacity (allowing for ventilation in the case of the attic). [Section 101.3.2.5]

Even when structural changes do not expose framing cavities, however, there may be Code standards to be met, if the alteration includes replacing windows. The Code specifies efficiencies for replacement windows in an exception to Section 101.3.2.5. These requirements are discussed in Unit 4.

✓ EXCEPTION

According to Section 101.3.2, in addition to alterations and repair where framing cavities are not exposed, or windows are not replaced, there are circumstances where alterations or repair may occur without having to make the whole building meet the Code. This is where the building official determines that full compliance is not practical or possible due to physical, or economic constraints.

Less than full compliance is also permitted when the energy efficiency is improved and the change is necessary on the basis of health and safety. In either case, the code official is called upon to exercise good judgement in making the decision.

Regardless of circumstances, any changes in the envelope must improve the energy efficiency of the building and individual building envelope components undergoing alterations or repairs should (as much as reasonable, given exception cited above) meet the energy efficiency requirements for

those components as specified in Tables 5-1, 5-2 in Code Chapter 5 or Tables 6-1 through 6-6 or 6-7 in Code Chapter 6.

Mechanical Systems. Section 101.3 covers alterations and repair to mechanical systems as well. Again, only the parts of the system that are being replaced or modified need to meet the Code.

If a furnace is being replaced, nothing has to be done to the duct work for energy reasons. If new duct work is being added, it must be insulated as required by the Code.

When actual equipment replacements are in order, the Code specifies minimum mechanical system efficiencies in Section 503, and service water heating efficiencies in Section 504. (See Table 1.1.)

Table 1.1: Mechanical Equipment Requirements

Heat Pumps	HSPF = 6.8
Central Combustion Heating	AFUE = 78%
Hot Water Heating	NAECA Label (a)

(a) NAECA stands for National Appliance Energy Conservation Act. Although labelling showing compliance with the 1987 Act is specified by the Code, current industry practices do not include NAECA labelling. For the purposes of the Code, it is assumed that all appliances manufactured after July 1, 1991 meet NAECA requirements.

Lighting Systems. Lighting systems are covered by the Code [Section 505] during alterations and repair, under the following circumstances:

- ⇒ When lighting systems are altered or replaced in buildings constructed to the 1991 Code.
- ⇒ When lighting systems are altered or replaced in buildings constructed to a previous code but are part of a "substantial remodel."

✓ **DEFINITION**

A **substantial remodel** is defined as any alteration to or restoration of a building within a twelve-month period "the cost of which exceeds sixty percent of the current replacement value of the particular building." [Code Chapter 2]

- ⇒ Remodeling of an entire floor or an entire tenant space that includes a new lighting system with or without a new ceiling grid or suspension system shall require compliance of a lighting power budget.
- ⇒ Compliance with switching budgets [Section 505.2] is required when new wiring is being run related to adding fixtures and/or fixtures are being relocated to a new circuit.

✓ **EXCEPTION**

Remodeling of any size area with or without putting a new ceiling grid or suspension system when reusing existing fixtures and/or adding new ones shall not require compliance with the lighting power budget *as long as the installed wattage is maintained or reduced.*

Materials and Equipment

[Section 102]

All materials and equipment need to be "identified in order to show compliance."

As to method of identification, the Code is specific regarding window and door efficiency ratings. In Section 502.1.5.1, it requires that "doors and glazing shall be identified with a label that states an overall product U-value that is no less than the actual tested U-value." (See Figure 1.1.)

For other materials and equipment, labels can provide information which the building official will need to enforce the Code, such as during the field inspection when make and model numbers of the installed material or equipment must be matched to those named in submittal documents. In addition, labels can provide efficiency information such as tested rating and capacity (in the case of mechanical equipment).

The Code requires that labels for materials and equipment requiring preventive maintenance must refer the operator to the maintenance manual. This manual must be provided for any equipment that requires preventive maintenance for efficient operation. [Section 102.2]

Figure 1.1: Typical Window Efficiency Label

THERMAL PERFORMANCE CLASS

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Alternative Practices. Alternate materials, construction methods, designs, or insulating systems not specifically mentioned in the Code may be used. However, the building official must approve these as meeting the intent of the Code. [Section 103]

Plans And Specifications

[Section 104]

When required by the building official, plans and specifications must be submitted showing dates and details. The required information includes U-values, R-values, equipment types, sizes, controls, and efficiencies, heat loss calculations, material types, and supporting calculations to show compliance. When compliance is by Systems Analysis, calculations prepared by a Washington licensed architect or engineer may be required by the building official for all types of occupancies. [Sections 104.1-104.2]

It is also the building official's prerogative to accept the professional stamp of a state licensed engineer or architect in lieu of a plan and specification check. The building official does not have to accept stamped plans or specifications and has the right to question any submittals. The architect or engineer must stipulate that the design meets the Code to the best of their knowledge, understanding, and belief. [Section 104.2]

Inspections/Enforcement

[Section 105.1-3]

The Code states that all construction or work for which a permit is issued shall be inspected by the building official. All construction or work shall remain accessible and exposed for inspection purposes until approved by the building official.

Work may not continue past any point indicated in each successive inspection without first obtaining the approval of the building official.

A wall insulation inspection is required and takes place by the building official after wall insulation and air vapor retarder sheet or film materials are in place, and before wall covering is installed.

✓ CHANGE

The 1986 Code allowed contractor self-certification of work. This is no longer permissible.

Liability

[Section 107]

According to the Code, nothing contained in it "is intended to create or form the basis for any liability on the part of any city or county or its officers, employees or agents for any injury or damage resulting from the failure of a building to conform to the provisions of this Code."

Conflicts

[Section 108]

With Other Codes. In general, when there are conflicts between the WSEC and other codes, such as the *UBC*, *UMC* or *UPC*, other codes take precedence over the WSEC. The only exception is WSEC's requirement for duct work insulation. It takes precedence over the *UMC* requirement.

Within the Code. When there are conflicts between different sections of the Code, the more restrictive requirement shall govern. When there are conflicts between a general

and a specific requirement, the specific requirement applies.

UNDERSTANDING THE CODE

Amendments To The Code

The Code undergoes revisions on a regular basis. However, in between time, amendments are considered necessary for clarification of the standards. These are mailed regularly to local jurisdictions, or are available from ICBO, WSEO, or SBCC.

✓ NOTE

Interpretations are available that provide more in-depth discussions of some provisions of the Code. They are advisory in nature and are available through the State Building Code Council (SBCC).

Terminology in the Code

[Section 201]

Code Chapter 2 provides definitions. In addition, wherever appropriate throughout this manual, annotated definitions are presented for your greater understanding.

Terms not defined in WSEC Chapter 2 (or in this manual) may be found in the *UBC*, *UMC*, or other construction codes. Webster's unabridged dictionary can be used for additional clarification.

Reference Standards

[Section 701]

In various sections through the Code, you will find designations such as RS-1 or RS-11. These numbers designate references listed in Code Chapter 7. The references are publications by accredited, authoritative

agencies recognized by the Code (also listed). These publications contain information that forms the basis for such things as testing of construction materials, engineering standards and methodology, mechanical system equipment testing, or installation standards.

The reference standards, or portions thereof, listed in Code Chapter 7 and referred to in the Code, are considered part of the Code. In general, the training manual refers to a reference publication by its Code Reference Standard designation (e.g. "RS-4") as well as its title.

✓ EXAMPLE

RS-4 refers to ASHRAE Standard 55-81 "Thermal Environmental Conditions for Human Occupancy," published by American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. This reference is incorporated as the Code's standard for determining design relative humidity when air conditioning is provided.

✓ NOTE

Code information is available at the following hotlines:

For Builders and Building Officials: WSEC Technical Assistance is available at 1-800-235-TA4U, Monday through Friday, 8 a.m. to 5 p.m.

For the general public: WSEO Energy Hotline (1-800-962-9731) is available Monday through Friday, 8 a.m. to 5 p.m.

Building officials may also use the ICBO hotline for questions regarding the WSEC.

For More Background

Effective administration and enforcement of the Code requires a thorough understanding of the Code and the rationale behind it. For

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that reason, Unit 2 presents a review of the energy concepts and calculations that provide the basis for the Code. Unit 3 of

this manual establishes design criteria for the thermal performance of buildings.

Unit 2: Understanding the Code

In order to effectively administer and enforce the Code, it is important to understand the basic principles that serve as its foundation. This unit discusses heat transfer, the factors that can affect it, heat energy measurement, and heat flow analysis, as it is applied in the WSEC.

HEAT TRANSFER

The Code's intent is to limit the unwanted flow of energy out of, or into, a building. Heat is one form of energy. It can be transmitted by a temperature difference between two materials or between two spaces. When there is a temperature difference, heat is always transferred from the warmer area to the colder one. This transfer can take place through:

Conduction. The movement of heat through a solid material, such as when heat applied to the bottom of a frying pan travels up through the handle. The R-value of an insulation material is its *resistance* to conductive heat loss. (See a fuller discussion of R-value later in this unit.) We install insulation in walls and ceilings to reduce the conductive heat loss from houses.

Convection. The movement of heat from one location to another by the movement of a fluid such as air. Forced convection is at work when a fan or circulator moves warm air or water from one part of a building to another. Natural convection occurs when air moves from one room to another due to a temperature difference. Infiltration and exfiltration of air through the building envelope transfers heat into or out of the building envelope by convection.

Radiation. The movement of heat from a warmer to a cooler body by the transfer of heat waves or radiation. Radiative heat

transfer does not affect the air between the heat-emitting and the heat-absorbing objects. Nor does it affect objects not in direct line with the heat source. For example, a wood stove will warm the side of your body facing the stove, but not the side facing away.

While all three methods of heat transfer are involved in heat flow to and from a space, the language used in the Code generally describes the flow as if conduction were the only transfer operating. This is a traditional simplification to allow standard measurement and analysis.

Trying to measure convective heat losses tends to be complicated. It is only in the more complex Systems Analysis Path that convective heat losses due to infiltration are actually calculated to some extent. In the Prescriptive and Component Performance Paths, convective losses are recognized but dealt with through simplifying assumptions.

But what about radiation? Heat losses by radiation are almost impossible to predict. Because such heat losses depend on the temperature of the objects the radiating surfaces "see" or radiate to, the amount of heat loss from a building due to radiation can vary very much. It would depend on whether trees, cars, or other buildings or objects are in the proposed building's "line

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of sight." This is hardly measurable in any meaningful way.

Because of this, and because radiation is part of a complex mix of radiation, conduction, and convection, heat losses or gains from radiation are typically ignored. In fact, only the Systems Analysis Path accounts for radiation explicitly, when it considers and calculates solar gains.

Factors Affecting Heat Transfer

There are several major factors that affect heat loss or gain in a building. Basically,

they include the structure's ability to resist heat loss (or gain, in a cooling environment), the level of air flow into and out of the building, climate, and internal heat gains. The WSEC attempts to account for these factors as much as is practicable.

Ability to Resist Heat Loss. In short, the building shell or envelope is what divides the inside of a structure from the outside. Its ability to keep warmth in, and cold out, is a major focus of the WSEC requirements. (See Figure 2.1.)

FIGURE 2.1: Structure's Ability to Resist Heat Loss (or Gain)

These components make up the building envelope and represent potential sources of conductive heat loss.

How does the WSEC account for this?

1. It requires an overall standard of thermal performance for the building envelope.

✓✓ In the Systems Analysis and Component Performance Paths, performance is calculated based on components' individual efficiencies. Trade-offs of thermal values between components are okay, as long as overall thermal performance meets Code target.

✓✓ In the Prescriptive Path, the performance standard is assumed to be met if individual components' efficiencies match Code's specifications exactly. Trade-offs are not okay, and calculations are not necessary.

2. It sets general insulation standards that apply no matter which compliance path is chosen.

The thermal properties of each component of the building envelope, such as windows or walls, contribute to the overall building's capacity to retain or lose heat. In general, when measuring the thermal performance or efficiency of these building elements, it is the *rate of conductive heat loss* that is being measured. This is expressed in U-values, R-values, or other tested ratings.

In the Component Performance and Systems Analysis Paths, thermal properties of individual components of the building envelope are analyzed and can be traded off, as long as the overall rate of heat loss of the proposed design is estimated to be equal to or lower than that of the standard design. In the Prescriptive Path, thermal properties of individual components are set, and cannot be traded-off. Thus, the potential heat loss through each component of the building envelope will match exactly the heat loss through components of the standard design.

In addition, the Code institutes general requirements, including insulation practices, that aim to reduce conductive heat loss through the building envelope, which apply no matter what compliance path is chosen. (See Unit 4 of the training manual, for these and other general requirements.)

Air Flow Into and Out of the Building.

The WSEC seeks to regulate the introduction of unconditioned outside air as much as possible. It sets standards for air leakage control and mechanical ventilation to reduce the potential for *convective* heat loss. (See Figure 2.2.)

Regardless of the compliance path used to determine envelope thermal performance, convective heat loss must be considered when sizing the heating system. Standard design heat load calculations account for

some losses due to infiltration and ventilation.

✓ NOTE:

The Systems Analysis and Component Performance Paths require standard design heat load (DHL) calculations for determining if the proposed system is sized to comply. DHL calculations may be required by the building official in the Prescriptive Path, as well. However, if the building official allows it, the Code offers the use of default values from Code Chapter 9 in the Prescriptive Path. It is important to note that this is provided as a compliance check only. Standard engineering practice recommends DHL (and DCL) calculations for proper sizing.

In addition, some aspects of convective heat loss due to infiltration are calculated for the proposed design when using the Systems Analysis Path. In the Component Performance Path, losses due to infiltration or ventilation in the standard and proposed designs are assumed to be equal. This is true in the Prescriptive Path, also, where this assumption has been used when developing prescriptive options.

Again, there are general requirements that aim to maintain a continuous air barrier and thus reduce convective heat loss. These apply no matter what compliance path is chosen. (See Unit 4 for air leakage control requirements.)

Climate. In all three paths, the indoor design temperature is set by the WSEC at 70°F for heating and 78°F for cooling. Obviously, climate will affect the design's capacity to maintain these indoor temperatures (see Figure 2.3, next page). Actual weather data is used in the Systems Analysis Path. The WSEC attempts to take outdoor temperature into account in the

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FIGURE 2.2: Level of Air Flow Into and Out of the Building

Air leakage and mechanical ventilation represent sources of convective heat loss.

How does the WSEC account for this?

1. It requires proper sizing of heating/cooling systems.

✓✓ In the Systems Analysis and Component Paths, standard design heat load (DHL) calculations are required.

✓✓ In the Prescriptive Path, standard DHL calculations may be required, or default values from Code Chapter 9 can be used as a compliance check.

2. In the Systems Analysis Path, some calculation of infiltration is done when determining the building's annual energy budget.

3. It sets general requirements aimed to reduce convective heat loss through building envelope components, mechanical systems, etc.

ALSO . . . the VIAQ Code establishes maximum and minimum performance standards for ventilation, independent of infiltration.

FIGURE 2.3: Climate

Climate factors, such as typical outdoor temperatures in a given location, will affect the heat loss or gain in a building.

How does the WSEC account for this?

1. It sets an indoor design temperature.
2. It takes outdoor weather into account.

✓✓ In the Systems Analysis Path, computer analysis uses typical meteorological year data (TMY).

✓✓ In the Component Performance and Prescriptive Paths, requirements are based on climate zones set by the Code.

Component Performance and Prescriptive Paths by setting up different requirements for two separate geographical zones based on climate.

Internal Gains and Thermal Mass.

Internal gains are potential sources of heat gain in a building. For example, when operating, appliances produce a certain amount of heat; occupants produce heat (see Figure 2.4, next page). Thermal mass is essentially the capacity to store heat, and is the means by which a building may utilize heat when it is needed (and not necessarily when it is produced).

In the Systems Analysis path, certain internal heat gains are estimated for the proposed design and used to offset potential heat loss. These calculations are not required (nor are heat gains considered) for the Prescriptive or Component Performance Paths.

A certain amount of thermal mass is implicitly assumed in all compliance paths. However, unusual (and additional) thermal mass can be credited when using the Systems Analysis path. This credit can be used to offset potential heat loss.

Unit 2: Understanding the Code

WSEC specifies internal heat gains for Group R occupancies in Section 402.1.3. (The Code assumes that internal gains in multi-family units will provide up to 1,500 Btu/hr; and that such gains in single-family units will provide up to 3,000 Btu/hr. Btus are discussed in the next section.) For non-Group R occupancies, internal gains are calculated using computer analysis.

Internal gains become more significant as the energy-saving characteristics of the building shell increase or as the size of the building decreases. In large commercial buildings, however, internal gains are also significant contributors to the cooling load.

Heat Energy Measurement

Heat energy is usually described in terms of Btus (British Thermal Units), watts, or kilowatts. Because the Code deals with the transfer of heat energy over a period of time, it uses units that measure the rate of energy use or energy transfer. In this sense, the Code describes heat flow in units of Btus per hour (Btu/hr) or kilowatts per hour (kWh). These units are related. A single watt equals 3.413 Btus; therefore 1 kWh equals 3,413 Btu/hr. Similarly, if a machine consumes 5 kW in an hour, its power consumption is 5 kWh or 17,065 Btu/hr (that is, 5×3413).

Figure 2.4: Internal Gains and Thermal Mass

Internal gains and thermal mass are potential sources of heat gain in a building.

The WSEC accounts for this in the Systems Analysis Path, only:

1. For Group R occupancies, internal gains assumptions are specified, and are based on whether the residence is multi-family or single-family. For non-Group R occupancies, internal gains are calculated using computer analysis.
2. For all occupancies, more than typical amounts of thermal mass can be credited to offset heat loss in calculating the annual energy budget.

HEAT FLOW ANALYSIS

To determine the design heat loss for a building, we must account for the following:

- ⇒ Different heat loss rates through different components;
- ⇒ Time;
- ⇒ Surface area; and
- ⇒ Temperature difference.

However, for simplicity, (and because it isn't necessary) the Code does not call for full-blown heat loss calculations (accounting for time, area, *and* temperature) in all cases. In addition to actual heat loss, there are interim values that can be used to compare the energy performance of a proposed design versus the Code's standard design. These include rates of heat loss using factors of time, temperature difference, or area, or rates using a combination of these factors. An example of the latter would be the rate of Btus lost per unit area per unit time ($\text{Btu}/\text{ft}^2/\text{hr}$).

The WSEC specifies the values to be compared when evaluating the design envelope. They can vary depending on the path or type of occupancy. The WSEC also specifies the value to be used when determining whether the heating system is sized properly.

The main thing to remember is that like values must be compared to like. For example, the rate of heat loss per hour estimated for the proposed design must be compared to the rate of heat loss per hour estimated for the standard design. It should not be compared to a different value for the standard design, such as the annual heat loss.

Conductive Heat Loss Through Shell

Because the different materials in an insulated assembly touch each other, conduction describes the heat loss through solid (or opaque) components of the building envelope. The heat loss analysis required by the WSEC for building envelopes complying through Component Performance compares *rates* of conductive heat loss. The heat loss analysis required for envelope designs complying through Systems Analysis compares the annual heat loss (offset by credits for heat gains present).

No matter which path used, heat loss analysis begins by determining heat loss rates through different components. These rates are expressed in U-values, R-values, and for slabs F-values. These values will be used to determine an overall rate of heat loss for the envelope, or to calculate the actual heat loss expected for the envelope.

U-Values. A U-value is a coefficient of thermal transmittance. It tells us how easily heat is transferred through a material or assembly of materials. It is expressed as the time rate of heat flow per unit area and unit temperature difference between the warm and cold sides of a given assembly (such as a uniformly constructed opaque wall section). Thus, *it is a rate showing how fast heat flows*. Typically, this would be indicated as the number of Btus lost through one square foot of surface area, in one hour, when there is one °F temperature difference across the surface (Btu/ft^2 per hr per °F). U-values are derived by testing and measurement and are then published for use in calculations.

✓ EXAMPLE 2.1

The thermal efficiency of windows is often described in U-values. If a window has a U-value of .56 it means that each hour .56 Btus of heat will be transferred across one ft² of window from the warm side of the window to the cold side for each degree (1°F) of temperature difference. By multiplying the area (A) of the window (let's say it's 5 ft²) by the temperature difference (Delta T) by the U-value of the window, we find the conductive heat loss per hour (Qc).

Assuming a temperature difference of 20°F, we find that 56 BTUs are lost per hour through this window.

$$Q_c = U \times A \times \Delta T$$

$$56 = .56 \times 5 \times 20$$

Conductivity (k) is the thermal transmittance per 1" thickness of material. Conductance (C) is the thermal transmittance of the actual thickness of the material. For example, the conductivity of soft wood is about 0.8 Btu/hr per °F per inch thickness. The conductance of a 2 x 4 stud is more like 0.23 Btu/hr/°F per given thickness (3.5"). Generally, as thickness goes up, conductance goes down. As conductance (and the U-value) of a material decreases, its ability to insulate increases.

A U-value is the conductance through a given assembly including air films (dead air space) on either side of the material.

U-values are often used to measure the heat transmission through an assembly made up of several materials.

The UA represents the heat loss rate per unit temperature difference for a given assembly of given area. It is obtained by multiplying the U-value for a given material or assembly by the surface area (A) of the assembly. The UA is therefore expressed in

units of Btu/hr per °F. The UAs derived for individual assemblies or components of a building envelope can be combined to find a total UA for the building envelope. (But don't add U-values themselves, see "Caution," next page.)

R-Values. Some building components, such as walls, floors, or ceilings, are given R-values instead of U-values. If the U-value or conductance is how fast heat flows, then the *R-value measures the resistance, or how slowly heat flows*. This is a measure of how many hours it will take for one Btu of heat to pass through one square foot surface of a material when there is one degree of temperature difference. Generally, as thickness of a given material goes up, the R-value increases. The higher the R-value, the better an insulator the material is.

R-values and U-Values are reciprocal. That is, if one is known, the other can be determined. This is important, since the analysis required by the Code will often require conversion of R-values to U-values. (See Example 2.2)

✓ Example 2.2: R- & U-Values are Reciprocal

$$U = 1/R$$

and

$$R = 1/U$$

It is easy then to determine the U-value of an R-11 fiberglass batt:

$$U = 1/R$$

$$= 1/11$$

$$= 0.0909$$

or, rounded off, .091

NOTE: Later in this unit, an example is used to demonstrate the use of this formula and others presented.

When heat flows through layered materials, the R-values can be added together to get the total resistance to heat flow at a given point. R-values in a single assembly should be added up *before* converting them to a single U-value.

Adding R-Values. Several materials go into a section of a wall, floor, or ceiling. Each of these materials has its own R- or U-value. Table 3A from Chapter 23 of the ASHRAE 1989 *Handbook of Fundamentals* lists values for the most common building materials. (Table 3A is duplicated in Appendix C of this manual.) Also see the Super GOOD CENTS *Residential Construction Reference Manual*. See the example and Figure 2.5 on the next page for an illustration of how to calculate the overall U-value for an assembly.

F-Values. For simplification, conductive heat loss through slabs are expressed in "F"

values instead of U-values. An F-value is the rate of perimeter heat loss per unit temperature difference and per unit perimeter length. The primary difference between an F-value and a U-value is that the heat loss factor (UA) of the slab is determined by multiplying the F-value of the slab material by the perimeter length in linear feet, rather than by area (as UA-values of other components are figured). However, the product of the F-value and the perimeter of a slab, in linear feet, is expressed in the same units as the UA and can be combined with UA values of other assemblies to determine a heat loss per unit temperature difference for a designed structure. (See Example 2.3.)

Like U-values, F-values decrease as the insulating value of the material increases. Table 10-2 (Code Chapter 10) provides default "F" values for various slab insulation levels. (See Appendix C.)

✓ CAUTION

Don't Add U-Values! Despite the fact that U-values are the reciprocal of R-values, and R-values can be added, U-values can never be added together for heat flow through materials in sequence.

Suppose instead of adding the R-values, the separate U-values for all these materials were added together. When U-values are added, the result is a larger number. However, a larger U-value indicates less insulation. Clearly this is not the case.

Thus the rule is to total up R-values, before converting them to a U-value.

✓ NOTE

In the majority of cases, U- or F-values will *not* actually be calculated. The Code requires that the default U- or F-values listed in Code Chapter 10 be used if the proposed practice is listed. If the proposed practice deviates significantly from practices listed in Code Chapter 10, then these values can be calculated using methods described in this unit.

If you were to use the methods described below to determine U-values for assemblies or practices listed in Code Chapter 10, you would find that the U-values you get are slightly different than the default values listed for those practices. This is because the methods used to derive the default U-values in Code Chapter 10 take into consideration some factors not accounted for in the methods used here. The methods presented here are less complex, but are accepted by the Code, and would provide acceptable values.

✓ EXAMPLE :

In the wall section shown, the heat will meet a total R-value resistance of 21.73 where it flows through the insulated cavity. This includes the R-values of all layers of materials at that point in the wall: the inside air film, drywall, insulation, sheathing, felt, siding, and outside air film. However, the heat will meet less resistance where it flows through the stud. Total R-value for the wall section at this point is 9.61. Similar calculations are shown for the ceiling and floor.

Figure 2.5: Calculating U-Values

✓ Example 2.3

A slab-on-grade has R-10 perimeter insulation, so the F-Value is 0.54. The slab perimeter length is 50 feet. Then:

$$\begin{aligned} UA &= F\text{-value} \times P \\ UA &= .54 \times 50 \\ UA &= 27 \text{ Btu/hr}^\circ\text{F} \end{aligned}$$

Developing Values for Components

Since a building envelope is made up of various components, each with its own set of thermal properties, heat loss analysis of the entire envelope consists in part of determining a combined (UA) or *average* (Uo) heat loss rate for the envelope based on heat loss rates calculated or assumed for individual components.

In introducing U-values above, the manual provides a method of obtaining the UA. It is important to distinguish the UA from the Uo. The Uo is the overall or average heat transmission of the gross area of the exterior building envelope. The Uo-value applies to the combined effect of the time rate of heat flows through the various parallel paths of heat transmission.

Averaging U-Values. Heat flow in a building is never through a single material or a single uniformly constructed component. More often, several heat flows running parallel to each other need to be averaged to get the overall transmittance through a single component. The wall is again a good example because it has one heat flow through the stud, one through the cavity, a third path through windows, and perhaps a fourth through doors. In this case, the designer must determine the areas and total R-values of two or more cross sections. Then he must convert them to U-values and average them.

Converting R-values to U-Values. Using the reciprocal formulas presented above, R-values can be converted to U-values. In Example 2.4 (below), R-values of the same wall section as in Figure 2.5 are converted to U-values.

Computing U-Value With Framing Factor. To provide an accurate overall U-value for opaque components, the framing factor should be considered. The framing factor accounts for the fact that wall, ceiling, or floor components are partly framing and partly insulated cavity. How much area the framing takes up depends on the spacing of the studs or joists. Typically, the area of a 16 inch on-center wall includes 20% framing, and 80% insulated cavity.

When there are windows and doors in the wall, the additional framing from solid headers, trimmers, and jack studs can easily bring the framing factor up to 23% of the wall area. Although every house is a little different, standards such as those provided in Table 2.1 (next page) are used for simplification. (See Example 2.5 for an example of a calculation using the framing factor.)

✓ Example 2.4: Converting R-Values to U-Values in Wall Example

$$U = 1/R$$

$$R_{\text{CAVITY}} = 21.73$$

$$U_{\text{CAVITY}} = \frac{1}{21.73} = 0.046$$

$$R_{\text{STUD}} = 9.61$$

$$U_{\text{STUD}} = \frac{1}{9.61} = 0.104$$

At the cavity the U-value is 0.046; at the stud the U-value is 0.104.

Table 2.1: Framing Factors

	STANDARD FRAMING	INTERMEDIATE FRAMING	ADVANCED FRAMING
Studs & Plates	.19	.18	.13
Insulated Cavity	.77	.78	.83
Headers	.04	.04	.04

✓ **Example 2.5: Figuring the U_o for Wall Example Using Framing Factor (a)**

1. The framing factor is used in deriving the rate of heat loss of the gross wall area shown in Figure 2.5. The first step derives the average U-value for the opaque wall area using the framing factor for the wall. The next step shows the heat loss rate through the entire wall area. That is, this entire wall area loses 88.95 Btus each hour for every one °F of temperature difference between the inside and outside temperature. Finally, this rate is applied to a typical design temperature condition. If the temperature difference is 30°F, then the heat loss is 2,668 Btus/hr.

$$U_o = [U_{\text{framing}} \times \%FR] + [U_{\text{cavity}} \times (1 - \%FR)]$$

where %FR stands for the framing factor.

$$U_o = [0.104 \times 0.23] + [0.046 \times 0.77] = [0.0239] + [0.0354] = 0.0593 \text{ Btu/hr} \cdot \text{F} \cdot \text{ft}^2$$

2. If the building has 1500 ft² of opaque wall area:

$$U_{\text{AWALL}} = U \times A = 0.0593 \times 1500 = 88.95 \text{ Btu/hr} \cdot \text{F}$$

3. The heat loss rate per hour at a temperature difference of 30°F is then:

$$Q = U \times A \times \Delta T = 0.0593 \times 1500 \times 30 = 2668 \text{ Btu/hr through the wall.}$$

Putting it All Together

Subscripts are used with U- and F- values associated with specific components and their respective areas and perimeters. Thus

$$\text{Total UA} = U_w A_w + U_c A_c + F_s P_s$$

might be used to indicate that the total UA is equal to: the U-value of the wall assembly (U_w) times the wall area (A_w) plus the U-value of the ceiling (U_c) times the ceiling area (A_c) plus the F-value of the floor slab (F_s) times the perimeter of the slab (P_s).

To understand these concepts better, consider the following, Example 2.6.

✓ **EXAMPLE 2.6:**

Assume we have a house with four sides. (See Figure 2.6, below.) If the walls of the house are all made of the same material and constructed in a similar fashion, then they will have similar U-values (U_w). If the ceiling of the house is made of a different material in a different way, then it will have a different U-value (U_c). In similar fashion, the U-value of the floor could be represented as U_f . Now, if the respective areas of the top, bottom, and sides of the house are represented by A_w , A_c , and A_f , then the following would be true:

$$UA_{HOUSE} = U_c A_c + U_f A_f + U_w A_w$$

where UA equals the Btus lost per hr per °F for the whole house;

$$U_o = \frac{U_c A_c + U_f A_f + U_w A_w}{A_c + A_f + A_w}$$

where U_o equals the average Btus lost per hour per °F per unit area;

$$Q = UA_{HOUSE} \times \Delta T$$

where Q equals the Btus lost per hour for the whole house, and Delta T represents the difference in temperature between the inside and the outside of the house; and

$$\text{Annual heat loss} = UA_{HOUSE} \times \text{heating degree days} \times 24 \text{ hr}$$

where heating degree days represent the sum of the average differences in temperature between the inside of the house and the outside temperature over the whole year at a given weather site. This provides the total estimated Btus lost from the house over the period of one year.

Figure 2.6: Sample House for Calculation

✓ NOTE

When determining the area(s) to be used in heat loss calculations, note that the Code calls for measurement of the **gross area**.

In doing calculations for residential occupancies, the "gross area" will have to be broken down to "gross" areas for individual components. Definitions for gross conditioned floor area, gross exterior wall area, gross floor area, and gross roof/ceiling area are provided in Code Chapter 2. The essential point is that these areas are always measured from the exterior or outside surfaces.

The **gross wall area** includes windows, doors, and their related framing, as well as the sections of insulated wall. In a two-story house, this will include the area between the first-story wall and the second-story wall.

The **gross floor area** includes the entire square footage of conditioned space, not just the floor over unheated spaces. This is used when calculating acceptable glazing area. In heat loss calculations *only floor area that is part of the envelope is included*.

When defining the **glazing area**, the Code requires that it includes the glazing, sash, and frame. This includes windows, clerestories, skylights, sliding and swinging glass doors, and glass block walls located in the shell of the conditioned space. For doors where the daylight opening area is less than 50% of the door area, the glazing area is the daylight opening area. For all other doors, the glazing area is the door area.

Analysis of Air Leakage or Potential Convective Heat Loss

To size a heating system properly or perform a Systems Analysis compliance calculation, convective heat transfer must be determined.

As noted above, heat loss by convection is commonly called infiltration or air leakage. Occupants in some homes will think of uncomfortable drafts. Infiltration is not always noticeable, however, and can cause significant heat losses without creating obvious discomfort.

Convective heat loss occurs when warm house air is forced out, usually from the upper part of the house (exfiltration), and by cold incoming air, usually in the lower part (infiltration). The rate of transfer increases when the wind blows against the building or when the temperature difference between the inside and outside air increases.

Air Changes per Hour. An air change (AC) occurs each time the total volume of air in the house is replaced. If it only takes one hour for this to happen, there is one air change per hour (ACH). Houses have been measured from less than 0.1 ACH to well over 5 ACH. It is difficult to determine accurately how many air changes per hour occur in a home. A number of factors can affect the actual air infiltration rate:

- ⇒ The protection of the terrain around the house (i.e., bushes, trees, hills, etc.);
- ⇒ The number of angles and corners of the house;
- ⇒ The extent and quality of air leakage control measures taken during construction of the house;
- ⇒ The type of mechanical equipment in the house (i.e., fans, heating or cooling systems, see Example 2.7, below); and

- ⇒ The weather the house sees (i.e., wind speed, air pressure, temperature).

Average ACH Ranges. ACH rates are not constant; they vary with the season or with occupant activity. The greatest air change rates generally occur in the summer, when the windows are likely to be open; and in the winter, when the heating system is running and the largest temperature difference between the inside and outside occurs. However, an average must be used to compute heat loss rate by infiltration. Typical homes in the U.S. seem to range from 0.3 to 1.5 ACH.

The Code specifies "an ACH of 0.35 for thermal calculations only." [Section 402.1.5]. What this basically means is that, for the purpose of doing Systems Analysis (which is the only path that calculates the thermal effects of infiltration), the Code assumes a .35 ACH for the standard design. For design heat load calculations used to size heating equipment for buildings using the Prescriptive or Component Performance Paths, the WSEO recommends assuming an ACH of 0.6.

Calculating Infiltration Losses. The heat lost due to air infiltration (convection) can be determined using the following formula:

$$Q_i = .018 \times V \times \text{ACH} \times \Delta T$$

In addition to ACH and temperature difference (ΔT), the equation calls for a constant (.018) and the volume of the space (V). The constant .018 represents the specific heat of air, which is the measure of how much heat the air can hold at a given humidity. Although altitude and humidity can affect the specific heat of air, it is assumed constant as a simplification. The volume of the house is derived from the ceiling height multiplied by the heated floor area.

Since this calculation (for envelope compliance) is done as part of Systems Analysis, it is not done manually, but with the help of a computer program dedicated to analyzing overall thermal performance.

The formula is the basis for proper sizing of the heating system, as well. Sizing the heating system requires knowing the design heat load. The design heat load is the amount of heat the building will lose per hour at the average coldest outside temperature, while maintaining an indoor temperature of 70°F. Thus it is the amount of heat the heating system must be able to produce. An in-depth example of design heat load calculation is included in Unit 6,

✓ EXAMPLE 2.7

An example of how the type of mechanical equipment in a building can affect the ACH is the difference between air leakage in a house with duct work running outside the heated space and one that is electrically heated with zonal units inside the heated space. Research shows that houses with duct work running outside the building envelope typically suffer a loss of 15% in heating efficiency due to air leakage. The ACH rate increases in such a system when the furnace distribution fan goes on. (The fan pressurizes the duct work and increases the volume of air escaping through duct leaks.) On the other hand, a house with baseboard electrical heaters located on the inside of the building envelope would not experience this increase because there is no change in the driving force across the effective leakage area.

Unit 2: Understanding the Code

which covers the Component Performance Approach. Since design heat load calculations can be required regardless of the path used, this example should be consulted for all paths.

Efficiency Comparisons Required by the Code

The values or rates of heat loss that are used in the Code to determine compliance are the same as those demonstrated in Figure 2.7 (and illustrated previously in Example 2.6). In enforcing the Code however, you may not need to determine all of the values. Specific value comparisons are required, depending on the path, occupancy, or purpose. Here's a quick summary of the comparisons the Code requires:

- ⇒ **UA values** of the proposed and standard designs are compared to determine *residential* Component Performance compliance.

- ⇒ **Uo values** of the proposed and standard designs are compared to determine *non-residential* component performance compliance.

- ⇒ The **heat loss rate (Q)** including conductive, infiltration, and duct losses is the foundation for design heat load calculations used for sizing heating equipment and determining compliance.

- ⇒ **Annual heat loss values** of the proposed and standard designs are compared in Systems Analysis compliance, including credit for any heat gains present.

Overall value comparisons are not required for the Prescriptive Path (although a building official may require calculating Q for the purpose of sizing the heating system). Keep in mind that value comparisons are implicit in prescriptive compliance. U- or R-values of individual components must meet required efficiencies.

Figure 2.7: Summary of Equations Used by WSEC

$$UA = U_w \times A_w + U_c A_c + \text{etc.}$$

where UA equals the Btus lost per hour per °F temperature difference for entire structure;

$$U_o = \frac{U_w A_w + U_c A_c + \text{etc.}}{A_w + A_c + \text{etc.}}$$

where Uo equals the average Btus lost per hour per °F temperature difference per unit area (ft²)

$$Q = UA \times \Delta T$$

where Q equals the Btus lost per hour for the entire structure; and

$$\text{Annual heat loss} = UA \times \text{heating degree days} \times 24 \text{ hr}$$

where the annual heat loss represents the estimated Btus lost per year for the entire structure.

Unit 3: Design Requirements

This unit presents the design criteria for the thermal performance of buildings as established in WSEC Chapter 3. These criteria are used to determine minimum insulation for a building envelope and to size heating and cooling (HVAC) systems. A building that is designed to be both heated and cooled must meet the more stringent of the heating or cooling requirements for the exterior envelope. [Sections 301.1, 301.2]

THERMAL DESIGN PARAMETERS

[Section 302]

Insulation requirements and the size of heating and cooling equipment are based upon the following design parameters:

- ⇒ Indoor design temperatures are 70°F maximum for heating and 78°F minimum for cooling. An exception states that other design temperatures may be used in equipment selection if it results in lower energy use. [Section 302.2.1]
- ⇒ Indoor design relative humidity for heating shall not exceed 30%. When comfort air conditioning is provided, the design relative humidity within the comfort envelope as defined in ASHRAE Standard 55-81 "Thermal Environmental Conditions for Human Occupancy" [RS-4], must be selected for minimum total HVAC system energy use. [Section 302.2.2]. (Readers are referred to the detailed ASHRAE standard, but generally, this "comfort envelope" represents a range of 40% to 60% relative humidity.)
- ⇒ The outdoor design temperatures for heating and cooling shall be from the 0.6% column for winter and the 0.5% column for summer from "Recommended Outdoor Design Temperatures, Washington State, ASHRAE," published by the Puget

Sound Chapter of ASHRAE.

[Section 302.1] A portion of the 1986 table is shown in Table 3.1.

The entire table is in Appendix D.

To use this table, first locate the community where the building is planned. In Aberdeen, for example, a building should be designed for a winter temperature of 28°F and a summer temperature of 81°F with a corresponding 62°F "wet bulb" temperature.

✓ DEFINITION

A **dry bulb temperature** is taken independent of humidity. A **wet bulb temperature** is found using a special type of wet-wicked thermometer.

Correlating the wet bulb temperature with the dry bulb temperature yields the relative humidity in a space. As relative humidity in a space increases, wet and dry bulb temperatures for the space tend to converge.

CLIMATIC ZONES

The Code's requirements vary depending on where the building is located. The state is divided into two climatic zones [Section 302.3], as follows:

Unit 3: Design Requirements

- ⇒ ZONE 1. All counties not included in Climate Zone 2. Okanogan, Pend, Oreille, Spokane, Stevens, and Whitman Counties.
- ⇒ ZONE 2. Adams, Chelan, Douglas, Ferry, Grant, Kittitas, Lincoln, The map in (Figure 3-1) shows Zones 1 and 2 by counties.

Figure 3.1: Recommended Outside Design Temperatures (a)

Station	Elev./Ft	Summer		Winter 0.6%	Annual Degree Days
		Design Dry Bulb 0.5%	Design Wet Bulb 0.5%		
Aberdeen	12	81	62	28	5316
Aberdeen 20NNE	435	83	63	25	5539
Anacortes	30	72	61	24	5168
Anatone	3570	89	63	-4	7345
Appleton	2335	92	65	11	7345
Alder Dam					5820
Auburn	80	84	67	25	
Battleground	295	91	68	19	5263
Bellevue	200	83	67	24	
Bellingham AP	150	76	66	19	
Bellingham 2N	140	78	67	17	5738

(a) Excerpt ASHRAE-Puget Sound Chapter "Recommended Outdoor Design Temperatures," 4/86

Figure 3.1: Climate Zones

✓ **CHANGES**

The 1986 WSEC allowed jurisdictions to establish alternate zones based on a 6,000 degree-day threshold for areas with local variations in weather data. The 1991 WSEC no longer offers this option. All buildings must meet the climate zone requirements as defined above.

Under the 1986 Code, Chelan and Douglas Counties were in Zone 1. In the 1991 Code these counties are now in Zone 2.

The 1986 WSEC set standards for ventilation for minimum ventilation requirements for all occupancies. In 1991, a stand-alone ventilation and indoor air quality code was instituted.

VENTILATION

[Section 303]

Minimum ventilation standards for all occupancies are included in the 1991 Washington State Ventilation and Indoor

Air Quality Code (VIAQ Code) (WAC 51-13). See Units 12, 13, and 14 of this manual for a discussion of the VIAQ Code as it applies to residential and commercial buildings.

Unit 4: General Requirements

This unit draws together general requirements instituted by the WSEC. These requirements apply no matter what compliance path is being used. Understanding these general requirements is extremely important in facilitating efficient plan checking and field inspections.

For the most part, the WSEC's general requirements appear in Code Chapter 5, which presents the Component Performance Compliance Path. For example, Code Section 502 provides general thermal performance criteria for "Group R" (residential) occupancies and "other than Group R" (non-residential) occupancies.

Some general requirements appearing in Code Chapter 5 and explained in this unit apply only to residential occupancies. If so, this is noted. Some general requirements appearing in Code Chapter 5 apply only to non-residential occupancies. For convenience, these requirements are referenced in this unit but are not discussed in depth until Units 9, 10, and 11, which focuses on requirements for non-residential occupancies.

In addition, there are general requirements applicable to all occupancies that cover practices more typically found in "commercial" construction. These requirements are introduced here in Unit 4, with more detailed discussions following in Units 9, 10, and 11.

General requirements summarized in this unit are listed in Table 4.1 with Code section references. Basically, they reflect:

- ⇒ Minimum requirements for the installation of the thermal components of the building envelope [Section 502].
- ⇒ Minimum requirements for moisture and air leakage control [Section 502].
- ⇒ Minimum performance requirements for building mechanical systems [Section 503], water heating [Section 504], and lighting [Section 505].

THERMAL DESIGN OF THE BUILDING ENVELOPE

General requirements for the thermal design of the building envelope address practices and materials for insulation, glazing and doors, moisture control, air leakage control, including recessed lighting.

Insulation

Section 502 establishes the criteria for insulation material [502.1.4.1]. The Code refers to the *UBC* for use limitations and

flame and smoke ratings. Substantial contact of the insulation with the surface being insulated is required.

Clearances. Section 502.1.4.3 states that insulation shall be installed with "clearances according to manufacturers' specifications," and "so that required ventilation is unobstructed." The amount of attic or ceiling ventilation is governed by the *UBC* Section 3205(c). The WSEC specifically

Table 4.1: Summary of General Requirements (a)

AREA OF CONSTRUCTION	CODE REFERENCE
Insulation	Section 502.1.4
Clearances	502.1.4.3
Access Hatches & Doors	502.1.4.4
Roofs & Ceilings	502.1.4.5
Walls	502.1.4.6
Floors	502.1.4.7
Slab-On-Grade	502.1.4.8
Radiant Slabs	502.1.4.9
Below-Grade Walls	502.1.4.10
Glazing & Doors	Section 502.1.5
Testing Standards	502.1.5.1
Labelling Requirement	502.1.5.1
Moisture Control	Section 502.1.6
Vapor Retarders	502.1.6.1 to 502.1.6.
Ground Covers	502.1.6.7
Space Heating Types	Section 502.2.2
Air Leakage Control	Section 502.4
Windows and Doors	502.4.2 and 502.4.3
Recessed Lighting	502.4.4
Mechanical Systems	Section 503
Heating and Cooling Load Calculations	503.2 and 503.2.1
System Sizing Limits	503.2.2
HVAC Equip. Performance	503.4
Standard Conditions	503.4.1.1
Heat Pump Efficiency	503.4.2.2
Combustion Efficiency	503.4.3
Cooling Efficiency	503.4.4 to 503.4.5
HVAC Controls	503.8
Thermostats	503.8.1 to 503.8.1.3
Zoning	503.8.3
Setback	503.8.3.4(1)
Heat Pumps	503.8.3.5
Duct Insulation	503.9
Duct Construction	503.10
Duct Sealing	503.10.2
Pipe Insulation	503.11
Service Water Heating	Section 504
Water Heater Efficiency	504.2.1
Controls	504.3
Swimming Pools	504.5
Hot Water Conservation	504.8
Electrical Lighting	Section 505
Switching	505.2(b)

(a) There are additional requirements specific to "commercial" buildings. They are not cited here, but are discussed in Chapters 9, 10, 1 and 11.

Figure 4.1: Roof Ventilation

calls for a minimum 1" of vented air space in single rafter joist vaulted ceiling cavities [Section 502.1.6.3]. Crawl space vents placed in the rim joist must also be baffled. (See "Floor Insulation.")

Insulation may be tapered to permit ventilation depending upon the compliance chosen.

Roof Venting. Figure 4.1 shows several types of roof venting. The most effective ventilation splits the vent area between the ridge and eave vents. In addition, Figure 4.2

illustrates two ways to insure the eave venting is not closed off by insulation. Clearly, loose-fill insulation must be baffled so it will not spill out into a soffit or obstruct bird block venting. Batt insulation must also be baffled, since it can interfere with bird blocks as well. In addition, baffling batt ends prevents air from blowing into the batt, chilling them and the ceiling below. Such air flow contributes to heat loss, condensation, and mold growth.

Eave Vents. The Code requires that where eave vents are installed, the openings need

Figure 4.2: Eave Venting

Unit 4: General Requirements

to be baffled to deflect the incoming air above the insulation. The baffles are to be manufactured of material resistant to wind-driven moisture and installed to the requirements of Section 502.1.4.5.

Raising the Roof. Raising the roof framing (called "Advanced" or "Adv." framing in the WSEC) makes it possible to maintain full insulation depth (and R-value) over the wall plate. (See Figure 4.3.) This practice is required by some prescriptive options and may be used as a trade-off to improve thermal efficiency in component performance or systems analysis compliance. Using rigid insulation with a higher R-value or tapering the insulation around the perimeter are also acceptable alternatives depending on the compliance path chosen.

Ceiling. Loose-fill insulation may be used when the slope of the ceiling is not greater than 3 feet in 12 feet and there is a minimum of 30" of clearance from the top of the bottom chord of the truss or ceiling joist to the roof sheathing at the ridge [Section 502.1.4.5]. (See Figure 4.4.) Clearly, a typical vaulted ceiling and many types of scissor trusses would not meet this requirement.

Ceiling Plenums. Although more typical of "commercial" construction, this practice is governed by Section 502.1.3, which applies to all occupancies. The Code requires that the U-value for the roof/ceiling assembly be derived from the materials from the roof up. The ceiling and the plenum space are not considered for thermal transmittance purposes. In computing the gross area of the building, however, the dimensions are based on the interior face of the upper plenum surface.

Access Hatches. Access hatches from the heated space to an unheated area must be

Figure 4.3: Getting Full Attic Insulation

Figure 4.4: Loose-fill Insulation

Figure 4.5: Attic Hatch and Catwalk

weatherstripped [Section 502.1.4.4] and insulated to a level that is the equal to the level of the adjacent surfaces. Weatherstripping access doors into an attic or crawl space will reduce the air leakage and heat loss from the heated space. When loose-fill insulation is used, the Code requires a retainer or baffle around the opening of the access to prevent the insulation from spilling into the living area. The Code specifically calls for a wood or equivalent baffle. (See Figure 4.5a.)

Provision must be made for access to equipment in a manner that prevents the compression or damage to the insulation. An example would be construction of a catwalk over blown insulation to provide access to an attic fan. (See Figure 4.5b.)

Wall Insulation. Wall insulation needs to fill the entire cavity with no compression or voids. To avoid potential problems with dry wall application and face-stapled insulation, other methods of compliance are available. Unfaced batts used with either polyethylene or a perm-rated paint as a vapor retarder are acceptable practices.

Metal Framing. Heat flow through metal-framed assemblies is different from heat flow through those with wood framing.

✓ CHANGE

Under the 1991 WSEC, inset stapling is not allowed: All faced insulation must be face-stapled to avoid compression [Section 502.1.4.6].

Section 502.1.1 of the WSEC identifies four ways to determine U-values for assemblies constructed with metal framing. Although metal framing is more typical of "commercial" construction, one of the methods listed below is to be applied to metal framing in all occupancies. (See Unit 9 for more specific information on metal framing.)

- ⇒ Laboratory or field measurement; or
- ⇒ Using Appendix E (Thermal Bridge in Sheet Metal Construction) from ASHRAE Standard 90.1-1989, "Efficient Design of New Buildings Except New Low-Rise Residential Buildings;" or
- ⇒ Using the zone method as described in Chapter 22 of the 1989 *ASHRAE Handbook of Fundamentals*; or
- ⇒ Using effective framing/cavity R-values provided in the Code itself (See Table 4.2).

Unit 4: General Requirements

TABLE 4.2: Default Values For Metal Framing

Wall Framing	Default U-values Cavity Insulation	
	R-11	R-19
2 x 4 @ 16" o.c.	5.50	-
2 x 4 @ 24" o.c.	6.60	-
2 x 6 @ 16" o.c.	-	7.60
2 x 6 @ 24" o.c.	-	8.55

Floor Insulation. Floors must be insulated in a permanent manner, with the insulation in substantial contact with the floor surface. This is to avoid any cold air movement between the two, which would reduce the effectiveness of the insulation. Floor insulation must have supports spaced no more than 24" on center. The supports must be installed in a permanent manner with no compression of the insulation.

As shown in Figure 4.6, floor insulation must be placed so that it does not block air flow through foundation vents. Vents placed in the rim joist must have a permanently placed baffle installed at an angle of 30 degrees from the horizontal, to divert air flow below the lower surface of the floor insulation.

Floors Over HVAC Plenums. There are no requirements for insulating floors over heated basements, heated garages, or underfloor areas used as HVAC plenums. Underfloor areas used as HVAC plenums must comply with Section 1008 of the *UMC* and the foundation walls must be insulated to the level required for the other walls in the structure.

Figure 4.6: Foundation Vent Baffle

✓ **NOTE**

Under the VIAQ Code Section 502.1, crawl space plenums must meet special radon mitigation requirements. (See Unit 13 of this manual for more information.)

Slab-On-Grade. Any concrete slab within conditioned space must be insulated at the perimeter. It is important that this insulation maintains a thermal break at the slab edge. (See Figure 4.7.)

✓ **CHANGE**

The 1991 WSEC defines a slab "on-grade" (and subject to on-grade perimeter insulation requirements) if its top surface is less than 24" below the final exterior grade.

Insulation of a slab-on-grade can be accomplished by one of four methods (See Figure 4.8 a - d, next page):

Figure 4.7: Slab-on-Grade Thermal Breaks

- ⇒ For interior slab insulation, the insulation must extend 24" down from the top of the slab (a); or
- ⇒ Run down the slab edge and back under the slab for a developed total length of 24" (b).
- ⇒ For exterior slab insulation, the insulation must extend downward on the outside of the foundation wall a

minimum of 24" or to frost line (c) [Section 502.1.4.8]. Above-grade insulation must be protected; or

- ⇒ For exterior insulation of monolithic slabs, the insulation must extend downward from the top of the slab to the bottom of the footing (d).

See Figure 4.9 (next page) for specific examples.

Figure 4.8: Slab-on-Grade Insulation

Figure 4.9: Slab-on-Grade

Insulation used for slab construction must be a water-resistant material manufactured for this purpose. A cover, flashing, or parging must protect the insulation from moisture and physical damage above-grade. It may also be necessary to prevent termite access to the building. (See "Moisture Control," this unit.)

Radiant Slabs. If the slab-on-grade will have a radiant heating system installed, a

minimum of R-10 insulation (all zones) is required under the slab [Section 502.1.4.9]. The entire area of radiant slab in contact with the ground must be thermally isolated.

Below-Grade Wall Insulation. When the insulation is placed on the exterior (cold side), it must be labeled for below-grade installation. Any exterior insulation extending above-grade must be protected.

✓ **CHANGE**

Previous versions allowed an exception eliminating insulation requirements for unfinished basements. This exception is no longer allowed in the WSEC. Any basement with a positive heat source must have insulated walls. If the basement is to remain unheated, then the floor above must be insulated to meet the minimum required value of the appropriate option. (To be "unheated," no positive heat source can be provided to the basement; there can be no provisions for heat from duct work or electrical wiring "stubbed" for future heaters.)

✓ **NOTE**

The formula to figure slab losses uses "F" values; not "U" values. F-values are a measure of conductive heat loss and are discussed in that section in Unit 2 of this manual. Table 10-2 [Code Chapter 10] provides default "F" values for various slab insulation levels.

Figure 4.10: Below-Grade Walls

The insulation must extend from the top of the below-grade wall to the top of the footing [Section 502.1.4.10] (see Figure 4.10a). Insulation for below-grade walls may also be placed on the interior (warm

side) of the walls. It must extend from the top of the below-grade wall to the top of the below-grade floor level [Section 502.1.4.10]. (See Figure 4.10b.)

✓ DEFINITION

Sections of "below-grade walls" that extend up to 24" above-grade may be considered part of the below-grade wall. They can be insulated to the level of the below-grade wall. Anything more than 24" above finished grade, however, must be considered "above-grade," and must be insulated to above-grade wall standards.

Glazing And Doors

Windows are qualified by tested U-values. Section 502.1.5 states specific thermal testing procedures for the testing of glazing products and doors. If the windows or doors have not been tested by the Code-specified ASTM or AAMA tests, a default U-value provided in the Code can be used [Sections 1006 and Code Table 10-6]. Values are provided for manufactured glazing, and for non-manufactured glazing. (See Table 4.3.) Non-manufactured fixed-lite glazing products must have wood frames, a minimum 1/2" air space, and be built on site. For glazing kits, such as a solarium kit, the manufactured glazing values must be used.

Replacement Glazing. Where glass and sash are being replaced in a residential occupancy, a maximum "area-weighted U-value" of .40 is required in a building with electric resistance heat. Glazing with a maximum U-value of 0.65 (for Zone 1) and 0.60 (for Zone 2) are sufficient for the other

TABLE 4.3: Glazing Default Values (a)

Manufactured Glazing Products:	
Single Glazing (all)	U = 1.20
Double glazing: Aluminum or Steel-framed	U = 0.90
Wood or Vinyl-Framed	U = 0.75
Non-Manufactured Site-Built Glazing Products:	
Air-filled	U = 0.60
Argon-filled	U = 0.55
Low-e, Air-filled	U = 0.50
Low-e, Argon-filled	U = 0.40
(a) Excerpted from WSEC [Section 1006.1].	

(non-electric) fuel types. (This does not apply if only the glass is being replaced, in the case of a broken lite.) If storm windows are added, they do not have to be tested, but will have an assumed U-value of 0.90.

✓ DEFINITION

Area-weighted U-value (AWU) is the U-value multiplied by the area. The AWU is the average for all the glazing; it must meet the code specifications. By setting a maximum AWU value when replacing windows, the Code allows for some flexibility but maintains an overall thermal standard for glazing in the structure.

AWU-values for glazing can provide some flexibility when determining compliance with the Prescriptive Path. A more in-depth discussion of AWU-values and a method to calculate them are found in this manual's discussion of the Prescriptive Path (Unit 5).

✓ CHANGES

The Code no longer uses window Class values to show thermal efficiency. Windows and doors must now be labeled with an overall product U-value not less than the actual tested U-value.

Effective July 1, 1992, NFRC (National Fenestration Rating Council) tested ratings are acceptable to qualify glazing under the WSEC, as long as "Model Size AA has been tested and listed therein."

Doors. Code Table 10-6 provides default U-values for wood and steel doors (Table 4.4). However, if more than 50% of the door is glazing, the entire door must be treated like glazing. For doors with less than 50% glazing, the glazing area should be treated separately from the opaque area of the door. The glazing area must meet code glazing requirements; the opaque area must meet the WSEC's requirements for doors.

Table 4.4: Default U-Values for Wood and Steel Doors

Nominal Thickness, Inches	Description	No Storm Door	Wood Storm Door ^c	Metal Storm Door ^d
Wood Doors^b				
1-3/8	Panel door with 7/16" panels ^e	0.57	0.33	0.37
1-3/8	Hollow core flush door	0.47	0.30	0.32
1-3/8	Solid core flush door	0.39	0.26	0.28
1-3/4	Panel door with 7/16" panels ^e	0.57	0.33	0.36
1-3/4	Hollow core flush door	0.46	0.29	0.32
1-3/4	Panel door with 1-1/8" panels ^e	0.39	0.26	0.28
1-3/4	Solid core flush door	0.33	0.28	0.25
2-1/4	Solid core flush door	0.27	0.20	0.21
Steel Doors^b				
1-3/4	Fiberglass or mineral wool core w/steel stiffeners, no thermal break ^f	0.60	----	----
1-3/4	Paper honeycomb core without thermal break ^a	0.56	----	----
1-3/4	Solid fire rated mineral fiberboard core without thermal break ^f	0.38	----	----
1-3/4	Polystyrene core without thermal break (18 gage commercial steel)	0.35	----	----
1-3/4	Polyurethane core without thermal break (18 gage commercial steel) ^f	0.29	----	----
1-3/4	Polyurethane core without thermal break (24 gage commercial steel) ^f	0.29	----	----
1-3/4	Polyurethane core w/thermal break & wood perimeter (24 gage commercial steel)	0.20	----	----
1-3/4	Solid urethane foam core with thermal break	0.19	0.16	0.17
<p>Note: All U-factors for exterior doors in this table are for doors with no glazing, except for the storm doors which are in addition to the main exterior door. Any glazing area in exterior doors should be included with the appropriate glass type and analyzed. Interpolation and moderate extrapolation are permitted for door thicknesses other than those specified.</p> <p>^a Values are based on a nominal 32 by 80 in. door size with no glazing</p> <p>^b Outside air conditions: 15 mph wind speed, 0°F temperature; inside air conditions: natural convection, 70°F air temperature.</p> <p>^c Values for wood storm door are for approximately 50 percent glass area.</p> <p>^d Values for metal storm door are for any percent glass area.</p> <p>^e 55 percent panel area</p> <p>^f ASTM C 236 hotbox data on a nominal 3 by 7 ft door size with no glazing.</p> <p>The U-factors in the table are for exterior wood and steel doors. The values given for wood doors were calculated, and those for steel doors were taken from hot box tests (Sabine et al. 1975; Yellot 1965) or from manufacturer's test reports. An outdoor surface conductance of 6.0 Btu/h x ft² x °F was used, and the indoor surface conductance was taken as 1.4 Btu/h x ft² x °F for vertical surfaces with horizontal heat flow. All values given are for exterior doors without glazing. If an exterior door contains glazing, the glazing should be analyzed as a window.</p>				

MOISTURE CONTROL

The control of moisture movement is important when constructing an energy-efficient building. To reduce the chance of moisture entering framing cavities, vapor retarders are required in walls, floors, and sometimes ceilings. Vapor retarders must meet a "permeance" rating of "one perm dry cup" or less.

The vapor retarder may be installed in a variety of ways. Acceptable vapor barriers include polyethylene, kraft- or foil-faced batts, perm-rated paint, or tongue-and-groove plywood flooring -- as long as the perm rating is one or less, and it meets other requirements for the particular component, such as strength. (For example, an under-floor vapor barrier can be 4-mil poly, while a ground vapor barrier needs to be at least 6-mil.)

Floors. Floors separating conditioned from unconditioned spaces are required to have a vapor retarder installed [Section 502.1.6.2]. Common construction practices sometimes use materials that comply with the Code. For example, a floor constructed with 3/4" tongue-and-groove exterior grade plywood flooring glued to joists meets the Code, because the perm rating of the plywood meets the "one perm" or less requirement.

Ceilings. Ceilings need to have a vapor retarder installed if the ventilated space above the insulation averages less than 12" [Section 502.1.6.3]. (See Figure 4.11.) Vaulted ceilings and some scissor trusses will not meet this minimum so a vapor retarder will be necessary in those cases.

Vapor retarders are not required when all the insulation is installed between the roof

Figure 4.11: Ceiling Requiring Vapor Retarder

✓ DEFINITION

According to the Code Chapter 2, "permeance is the ability of a material of specified thickness to transmit moisture in terms of amount of moisture transmitted per unit time for a specified area and differential pressure... Permeance may be measured using ASTM E-96-72 or other approved dry cup method as specified in RS-1[ASHRAE *Handbook of Fundamentals*]."

A rating of one perm means 1 grain of water vapor will diffuse through 1 square foot of material each hour when there is a pressure differential of 1 inch of mercury.

membrane and the structural roof deck [Section 502.1.6.5].

Walls. The Code requires that walls have a vapor retarder installed on the warm side of the wall during winter. As stated above, the Code does not allow inset-stapling of faced batt insulation. Inset-stapling not only compresses the insulation, it also provides paths for moisture movement. This movement can be reduced by stapling the

facings to the stud or joist, as the Code requires. [Section 502.1.6.6]

Ground. Moisture from below the house is addressed by requiring a ground cover on the crawl space floor. A 6-mil, black, polyethylene cover or approved equal is specified [Section 502.1.6.7]. All joints must overlap a minimum of 12" and the cover must reach the foundation wall as shown in Figure 4.12.

✓ EXCEPTIONS

The WSEC allows a wall vapor barrier to be located one-third of the way in from the warm side. This is based on R-value, not distance. For example, in an R-27 wall, with stud framing on the exterior insulated to R-19, and horizontal strapping on the interior, insulated to R-8, the vapor barrier could be sandwiched between the studs of the "exterior" framing, and the strapping.

The ground cover may be omitted in crawl spaces if the crawl space has a concrete slab floor with a minimum thickness of 3-1/2".

Figure 4.12: Crawl Space Floor with Ground Cover

AIR LEAKAGE

The Code's air leakage requirements [Section 502.4] apply only to building sections and openings that separate conditioned and unconditioned spaces. Thus, doors entering into an unheated storage area are covered, but doors between rooms within the conditioned space are not.

The Code specifically calls for air tightening (by caulking and weatherstripping) three types of sites:

- ⇒ Joints between any of the major components in the exterior envelope of the building. Major leakage can occur, for example, where the wall meets the foundation, where the wall meets the ceiling/roof system, where two walls come together (as at a corner or band joist), or where walls meet doors or windows, or exterior ceilings and skylights.
- ⇒ Any penetration through any component in the exterior shell. This may be as small as a cable TV wire or as large as a plumbing stack or chimney. Penetrations through

floors over unheated spaces must be included.

- ⇒ All other such openings.

This last category encourages the Code official or builder to think carefully about the potential leakage through any unspecified spots. The Code does not spell out acceptable sealing techniques. Regarding materials, it tells the official that these areas can be "sealed, caulked, gasketed, or weatherstripped." (See Figure 4.13.)

Specific Air Leakage Control

In addition to these general air leakage requirements, the code sets specific requirements for two areas with high air leakage potential: windows and doors, and recessed lighting.

Windows and Doors. Leakage through windows and doors is addressed in section of 502.4.3. Site-built windows are provided with their own leakage requirements [Section 502.4.3(c)]. They must have stops and good sealant or caulking on all fixed lites. Movable sashes must be closed against weatherstripping by a closer latch.

✓ Note

The Code does not say exactly where the seal is to be applied. Should it be on the interior or the exterior side of the joint or opening?

Exterior application has the benefit of preventing liquid moisture from getting into the wall, but raises concerns about trapping moisture from the inside. Interior application will reduce the transport of house air into the wall.

Because house air is usually warmer and holds more water vapor, interior application may help reduce condensation from occurring in the shell. Interior application is also more easily verified by visual inspection. It is up to the Code official to determine what makes an acceptable seal.

Figure 4.13: Critical Areas for Air Leakage Control

✓ Exception

UBC supersedes the WSEC for any opening that must be protected by a fire-rated assembly, effectively "exempting" it from the air sealing requirement.

Note that this exemption has been applied to the door between the heated space and the unheated garage in a residence. A fire-rated door may be weatherstripped, as long as the weatherstripping in no way interferes with the automatic closing of the door.

Recessed Lighting. The 1991 WSEC includes specific requirements for recessed lighting when installed in the exterior shell [section 502.4.4]. These requirements address insulation and air leakage issues. Three types of lights or installation methods for recessed lighting are allowed:

- ⇒ The light must be "IC"-rated with no penetrations in the exterior can and sealed or gasketed to prevent air leakage into the unconditioned space. This is sometimes referred to

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as a "prescriptive can." (See Figure 4.14a.)

- ⇒ A light that is "IC"-rated may be installed in the exterior shell if it is installed in a box constructed of 1/2" gypsum wallboard or other approved material that may be sealed for air leakage. This is sometimes called the "sealed enclosure" method of compliance. (See Figure 4.14b.)
- ⇒ The light is "IC"-rated and has been tested and certified that air leakage is less than 2 cfm at 75 pascals. The light must be labelled showing that it has been tested. This is a "performance-tested can." (See Figure 4.14c.)

Figure 4.14: Recessed Light Cans

✓ DEFINITION

"IC-rated" is a UL listing indicating that the can light has been tested and approved for installation in direct contact with and covered by insulation.

✓ CHANGES

The original code allowed non-"IC-rated" cans to be installed in sealed enclosures as long as minimum clearances were maintained. Subsequent interpretation has eliminated this option because of conflict with the National Electrical Code.

The "sealed enclosure" method of compliance as it is presented here is actually a modification of the 1991 WSEC, and is effective July 1, 1992.

BUILDING MECHANICAL SYSTEMS

This section covers the Code's general requirements for heating and cooling systems, including design and equipment standards. In addition, requirements for duct and pipe insulation are discussed.

For more specific information on systems typically used in "commercial" or non-Group R occupancies, and for additional requirements specific to those occupancies, see Unit 10. In particular, information is provided in Unit 10 on air- and water-source heat pumps, combustion heating equipment, packaged and unitary

equipment, applied cooling equipment, air economizer cycles, balancing, and zoning.

Space Heating Types

The following two categories comprise all space heating types defined by the Code:

Electric Resistance. Space heating units, which include baseboard units, radiant units, forced air units, and electric boilers, acting either as the primary or secondary heating system (unless the primary system is a heat pump).

Other. All gas, wood, oil, and propane space heating systems, unless electric resistance is used as a secondary heating system, and all heat pump space heating systems. If electric resistance is used as a secondary system, *and* if the primary system is not a heat pump system, the building must comply as if it were electrically heated.

HVAC Equipment Capacity Requirements

The Code requires that the heating system be sized no greater than 150% of the design heat load [Section 503.2.2]. (See exceptions below.) The design heat load is determined through a series of calculations. An in-depth example of design heat load calculation is included in Unit 6 of this manual, which covers the Component Performance Path. Since design heat calculations can be required regardless of the path used, this example should be consulted for all paths.

HVAC Equipment Efficiency Standards

Central oil, natural gas, or propane residential heating systems must have a minimum AFUE of 78% (.78). There are some exceptions to this requirement, although only the first is actually called out as an "exception" in the Code:

✓ EXCEPTIONS:

There are three exceptions to the Code's limitation of heating system size to no more than 150% of the design heat load, including:

1. For combination units: When heating and cooling equipment are combined, such as with an heat pump that provides electric heating and cooling, or gas-pack units that provides gas heating and electric cooling, compliance need only be demonstrated for one, that is either the heating or the cooling capacity of the unit. (However, the Code states in Section 501.1 that the more stringent heating or cooling requirements must be met. Thus, compliance needs to be demonstrated for the larger load.)

2. For relatively small equipment: For oil or gas heating units with a capacity of 56,000 Btus/hr or less, design load requirements can be traded off if higher efficiency equipment is installed. The trade off allowed is 1% greater efficiency (AFUE) over the Code-specified minimum of 78% system efficiency for each 5,000 Btu/hr the equipment exceeds the design load.

EXAMPLE: A house with a design heat load of 30,000 Btu/hr may install a 55,000 Btu/hr gas furnace with an AFUE of 83%. Normally 150% of design heat load would limit the system to $30,000 \times 150\% = 45,000$, but by increasing the furnace efficiency by 5% the unit is allowed to exceed the design load by 25,000 Btu/hr, as long as the total unit size remains under 56,000 Btus/hr. **Note: Furnaces with AFUEs between 81-88% are rare; as a result, a furnace with an AFUE of 88% or greater may be required to satisfy this exception.**

3. For standby or duplicate equipment for emergency or other use: These systems are exempted as long as controls are installed to prevent the primary and standby equipment from operating simultaneously (sometimes referred to as a "lock out").

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- ⇒ Residential systems that are oversized must have a higher AFUE (This is only applicable to small equipment, see exceptions to the Code's sizing limitation, above.)
- ⇒ One Prescriptive Path option allows a 74% AFUE appliance; and
- ⇒ System Analysis compliance allows the designer to trade off system efficiency.

For non-central systems powered by any of these same fuels, such as a wall-mounted room furnace, the systems must minimally have an intermittent ignition device or meet NAECA efficiency levels [Section 503.4.3]. (See efficiency rating definitions, next page.)

Electrically-driven heat pump systems must meet both an HSPF of 6.8 and Coefficient of Performance (COP) of 3.0 at 47°F. When calculating the COP for field-assembled unitary heat pumps consisting of one or more components, energy used by auxiliary equipment such as compressors, pumps, fans, and control equipment must be

included in the total energy input, but supplemental heaters may not. If compliance is met by the cooling load, the cooling efficiency tables should be checked [Code Tables 5-8 through 5-10]. However, the minimum efficiencies for the heating equipment must also be met.

Verifying System Sizing and Efficiency. Data from the equipment supplier or from a national certification or rating program is adequate to demonstrate compliance. This data should specify efficiencies at the standard operating conditions noted in the Code.

Equipment covered by the Code is listed below in Table 4.5. The table refers to the appropriate Code tables to be used in determining the minimum efficiency and the standard conditions under which that efficiency should be measured.

Code Tables 5-7 through 5-9 state minimum requirements for heat pumps and electrically-driven cooling equipment. These are excerpted in Table 4.6, page 4-20.

Figure 4.5: HVAC Equipment Covered by WSEC

<u>Type of Equipment</u>	<u>Reference for Efficiency</u>	<u>Reference for Rating Conditions</u>
Heat Pumps	Code Table 5-7	Code Table 5-4
Packaged and Unitary Electric Cooling Equipment	Code Table 5-8	Code Tables 5-5, 5-6
Central Combustion Heating Equipment	Minimum 78 AFUE* [503.4.3]	Not listed
*Required AFUE will be higher if system is oversized.		

✓ DEFINITIONS

The Code specifies residential HVAC equipment efficiencies in the following terms:

The **Coefficient of Performance (COP)** is an efficiency rating for heat pumps and electrically-driven cooling equipment. It is the ratio of the useful heat output delivered by the complete heat pump unit (excluding supplementary heating) to the corresponding rate of energy input, in consistent units (usually watts) and under the Air Conditioning and Refrigeration Institute's (ARI) standard rating conditions. [Sections 503.4.1.1 and 503.4.2; Code Table 5-7 for heating]

Basically, the COP gives the instantaneous efficiency of the equipment in its heating mode at the specific outdoor temperature at which it is measured. It is the efficiency rating to check for water- or ground-source heat pumps. For air-source heat pumps, the COP is checked at 47°F. Since the COP is a measure of the efficiency at a given instant, and air temperatures vary so much, air-source heat pump efficiency is generally rated using an HSPF, which provides an average or seasonal efficiency.

The **Heating Season Performance Factor (HSPF)** measures the total Btus of heat produced by a heat pump during its normal annual usage period, divided by the total electrical input in watt hours for that same time period. HSPFs of standard (heating) equipment range from just over 5 to just over 9.

The **Energy Efficiency Ratio (EER)** measures the cooling capacity in Btus/hr divided by the power input in watts for electrically-driven cooling equipment. It is measured under a specific set of conditions for the type of equipment being tested. Sections A and H of the ARI Directory of Certified Unitary Air-Conditioners and Air Source Heat Pumps provide standard test conditions. The ARI directory often lists SEER instead of EER. The SEER is a seasonally adjusted figure computed by dividing the total cooling Btus for the annual usage period by the electrical input in watt hours for the same period. Values run from as low as 7 to as high as 15.

Steady-State Efficiency is the combustion efficiency of the heat production process. That is, the total fuel energy input minus the stack losses from incomplete combustion, sensible heat in exhausted dry combustion byproducts, and both sensible and latent heat in exhausted wet combustion byproducts.

The **Annual Fuel Utilization Efficiency (AFUE)** is used for combustion heating equipment and is specified according to DOE specifications. It measures the amount of energy delivered in the form of usable heat, as a percentage of the total energy input of the fuel consumed. An AFUE is more revealing than the steady-state efficiency a service person can check during a tune-up, because it includes pilot and off-cycle losses. In this sense, an AFUE is more of a seasonal average.

The AFUE does not take into consideration any inefficiency introduced to the heating system due to poor installation or losses from duct work. AFUEs apply to all central residential-sized furnaces (with inputs of less than 225,000 Btus/hr).

A higher COP, HSPF, EER, SEER, or AFUE indicates greater efficiency.

✓ CHANGE

The 1986 WSEC set minimum EERs for all electric HVAC cooling equipment. In the 1991 version of the WSEC, this is changed. For most equipment under 65,000 Btu/hr, SEERs are set. [Code Table 5-8].

Table 4.6: Minimum Requirements for Heat Pumps and Electrically-Driven Cooling Equipment *

A. Heat Pumps - Heating Mode			
SOURCE	MINIMUM COP		MINIMUM HSPF
Air Source:			
Split System	3.0 ¹		6.8
Single Package System	3.0 ¹		6.6
Water Source	3.8 ¹		-----
Ground Water Source	3.0 ¹		-----

B. Electric HVAC Equipment (Including Heat Pumps) - Cooling Mode			
STANDARD RATING CAPACITY	AIR COOLED		EVAP/WATER COOLED
	SEER	EER	EER
Under 65,000 Btu/hr. (19,050 watts)			
A. Split System	10.0 ¹	-----	-----
B. Single Package	9.7 ¹	-----	9.3 ¹
65,000 Btu/hr. & over (residential only)	-----	8.9 ¹	10.5 ¹

C. WATER CHILLING PACKAGES							
TYPE OF COMPONENT	COMPRESSOR TYPE	CONDENSING MEANS					
		AIR		WATER		EVAPORATIVE	
		EER	COP	EER	COP	EER	COP
Condenser Included	Centrifugal or rotary	8.00	2.34	13.80	4.04	-----	-----
	Reciprocating	8.40	2.36	12.00	3.51	-----	-----
Condenserless	Reciprocating	9.90	2.90	12.00	3.51	-----	-----
Compressor condenser units 65,000 Btu/hr (19 kW) & over ²	Positive displacement	9.50	2.78	12.50	3.66	12.50	3.66

D. HYDRONIC HEAT PUMPS			
Water source under 65,000 Btu/hr (19 kW)	Centrifugal or rotary	9.00	2.64
Water source 65,000 Btu/hr (19 kW) & over	Centrifugal or rotary	9.40	2.75.

¹ See Code Tables 5-7 to 5-9 for Important footnotes and Tables 5-4 to 5-6 for rating conditions.

¹ See Code Tables 5-7 to 5-9 for important footnotes and Tables 5-4 to 5-6 for rating conditions.

✓ NOTE

WHY IS SIZING SO IMPORTANT? Designed with higher R-values and a lower air leakage rate, Code-standard homes should require smaller heating units. Properly sized, smaller heating systems offer the following advantages:

- ⇒ Reduced first cost to builder and/or owner.
- ⇒ Increased operating efficiency, which results in energy and costs savings (including maintenance as well as operating costs).
- ⇒ Lowered peak demand (electric heating) on utility generating capacity, which may affect rates.

Smaller heating systems do require more time to bring a completely cold house up to temperature. If the system is sized within the range the Code calls for, however, comfort can be maintained in typical operating conditions. Furthermore, once the comfort level is reached, the system cycles normally as the higher thermal values slow heat loss from the home. Cycling on and off frequently, as happens in a leakier house, reduces operating efficiency of some types of systems, and causes more wear to the equipment.

Builders should acquaint owners with the benefits and operating characteristics of their properly sized system. Building officials should encourage proper sizing and not require more heating capacity than is actually needed.

HVAC Controls

Temperature. The Code sets some requirements for temperature and humidity controls [Section 503.8]. Each heating or cooling system must have at least one thermostat. Where floors or zones do not have separate thermostats to control heating and/or cooling, some other simple way must be available to vary the amount of heating or cooling supplied to areas without thermostats. Operable grilles on registers will meet this requirement but balancing duct dampers located in a crawl space will not as they are not "readily accessible" [Section 503.8.3.1]. In multi-family dwellings, each unit must meet these same requirements [Section 503.8.3.2].

When the thermostat is used to control heating only, it must have an adjustable range from 55°F to 75°F. When used for

cooling only, it must have an adjustable range from 70°F to 85°F.

All thermostats used for both heating and cooling must have a range between 55°F and 85°F and provide for separate operation of heating and cooling equipment. This requires that the thermostat be set so the maintained temperature for cooling is at least 10°F above that for heating; e.g., 68°F for heating and 78°F for cooling [Section 503.8.1.3]. This separation of set point temperatures helps prevent simultaneous operation of both heating and cooling equipment. It also prevents rapid switching between modes, which would be inefficient.

Residential Setback Control. There must be a readily accessible means for reducing the energy required for heating or cooling during periods of non-use or reduced need. [Section 503.8.3.4]

Heat Pump Controls. Programmable thermostats are required for all residential heat pumps [Section 503.8.3.5].

Thermostats are required to have a minimum of two programmable setback periods per day and be capable of limiting the use of supplemental heat during the warm-up period. These are commonly referred to as "ramping" type thermostats. A "ramping" thermostat keeps the heat pump from using supplemental or strip heat when not necessary.

Humidity. When energy is used to add humidity to building air, the humidity may only be controlled when at 30% or less. That is, new energy cannot be used to humidify the air when it is above 30% relative humidity. The building official may permit exceptions to this when special considerations require closer control of humidity levels [Section 503.8.2], such as in a hospital, or computer room.

The HVAC Distribution System

The Code requires insulation for ducts and piping carrying heated or cooled air or liquids through uninsulated spaces. The amount and nature of the insulation depends on the exact application.

Duct Insulation. Whenever ducts, plenums, or other enclosures containing heated or

cooled air are installed in an unheated space, they must be insulated. Recent studies indicate that poorly sealed and insulated ducts running through uninsulated spaces can reduce the delivered heat efficiency by as much as 40%. The quality of the workmanship is as important as the amount of insulation. The Code, however, does not require insulation if the ducts are located within the conditioned space.

Insulation Thickness. The thickness of the insulation used depends on several factors: the climate zone, where the ducts are installed, the R-value of the material, the occupancy type, and the application (whether heating, cooling, or both).

Table 4.7 provides an excerpt of the Code Table 5-11, which presents duct insulation requirements. To use the table, match the duct locations in the planned building with those in the table, choosing appropriate climate zone and occupancy type. Insulation requirements are listed in the table using letter keys, such as "C, V, and W". The keys are defined in notes provided with the table. "C,V, and W" indicates that the insulation required must be equal to an R-7, and that a vapor barrier and a weatherproof barrier be installed.

In some cases the duct insulation requirements are different for heating and

✓ CHANGE

The 1991 WSEC version of Table 5-11 has added separate duct insulation requirements for heating and cooling ducts installed in Group R occupancies. The required insulation level for ducts installed in attics, crawl spaces, or in exterior walls, floors, or ceilings is R-8. Check Code Table 5-11 for insulation levels for ducts installed in other locations.

✓ NOTE

Footnote 2 of Code Table 5-11 requires that vapor barriers be installed on conditioned air supply ducts in geographic areas where the average of the July, August, and September mean dewpoint temperature exceeds 60°F. However, calculations by the Puget Sound Chapter of ASHRAE for selected cities around the state, show no dewpoint temperatures higher than 53°F.

Table 4.7: Duct Insulation Requirements

DUCT LOCATION	CLIMATE ZONE	INSULATION TYPES MECHANICALLY COOLED	INSULATION TYPES HEATING ONLY	GROUP R OCCUPANCY HEATING OR COOLING DUCTS
On roof or on exterior of building	I II	C, V ² and W (R-7) D, V ² and W (R-10)	C and W (R-7) D and W (R-10)	E and W (R-8) D and W (R-10)
Attic, garage, crawl space, in walls ¹ , in floor/ceiling ¹	I II	B and V ² (R-5) C and V ² (R-7)	B (R-5) C (R-7)	E (R-8) E (R-8)
Within the conditioned space or in heated basements		None Required	None Required	None Required
In cement slab or in ground		A (R-2)	B (R-5)	B(R-5)

Note: Where ducts are used for both heating and cooling, the minimum insulation shall be as required for the most restrictive condition.

¹ Insulation may be omitted on that portion of a duct which is located within a wall or floor-ceiling space where both sides of this space are exposed to conditioned air and where this space is not ventilated or otherwise exposed to unconditioned air.

² Vapor barriers shall be installed on conditioned air supply ducts in geographic areas where the average of the July, August, and September mean dewpoint temperature exceeds 60°F.

INSULATION TYPES: Minimum densities and out-of-package thickness.

A. 0.5-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket or equivalent to provide an installed total thermal resistance of at least R-2.

B. 2-inch 0.60 lb/cu. ft. mineral or glass fiber blanket 1.5-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket. 1.5-inch 3 to 7 lb/cu. ft. mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-5.

C. 3-inch 0.60 lb/cu. ft. mineral or glass fiber blanket 2-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket. 2-inch 3 to 7 lb/cu. ft. mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-8 7.

D. 4-inch 0.60 lb/cu. ft. mineral or glass fiber blanket 3-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket. 3-inch 3 to 7 lb/cu. ft. mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-10.

E. 3.5 inch 0.60 lb/cu. ft. mineral or glass fiber blanket, 2.5 inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-8.

V. Vapor barrier, with perm rating not greater than 0.5 perm, all joints sealed.

W. Approved weatherproof barrier.

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cooling. Ducts that are used for both heating and cooling must be insulated according to the strictest requirement. Requirements for other ducts are shown on the table.

With either heating or cooling ducts, sealing the seams and joints is required when they are installed outside the conditioned space [Section 503.10.2].

The Code calls for the seams and joints to be "taped and sealed with a material approved by the building official." (See Figure 4.15.) Remember that insulation is not required for ducts installed within wall, floor, or ceiling spaces that are located between adjacent heating spaces. [Footnote 1 of Code Table 5-11]

Figure 4.15: Duct Sealing

Pipe Insulation. Section 503.11 states all piping shall be insulated in accordance with Code Table 5-12. If water pipes are outside of the conditioned space then the pipe insulation requirement is R-3 for all non-recirculating hot and cold pipes. (See pipe insulation requirements for service water heating, below.)

✓ NOTE

Although recent modifications in the Code may be confusing, current understanding of the Code's intent is that it:

- ⇒ Requires all pipes serving non-Group R occupancies to be insulated to Code Table 5-12;
- ⇒ Requires pipes serving residential occupancies *that are outside the conditioned space* to be insulated to R-3 (for freeze protection); and
- ⇒ Requires recirculating hot water pipes be insulated to Table 5-12.

SERVICE WATER HEATING

Water Heaters. All storage water heaters must meet the requirements of the 1987 NAECA and be so labelled [Section 504.2.1]. As stated earlier, industry practice does not include NAECA labelling at this time. If appliances are manufactured after July 1991, they must meet the requirements of the NAECA, and presumably meet the WSEC standard. (See Figure 4.16 for proper installation.)

All electric water heaters on concrete floors or in unheated spaces must be placed on an incompressible, insulated surface (R-10).

The Code sets standards for insulation of unfired hot-water storage tanks [Section 504.2.2] and, for the first time, combination service water heating/space heating boilers [Section 504.2.3]. Both of these situations are almost exclusively of concern to those working with other than Group R-3 occupancies. See Unit 10 for more information.

Automatic Controls. Water heaters must have automatic controls capable of adjustment within the acceptable temperature range. (Scalding protection should be provided.) The temperature must be set to 120°F. [Section 504.3] (Commercial applications, such as a restaurant or hospital, may have to run water at higher temperatures for health code compliance.)

Piping Insulation. According to Section 504.7, which governs piping insulation for service water systems, recirculating and

non-recirculating piping "shall be thermally insulated in accordance with Section 503.11 and Table 5-12." According to Section 503.11, non-recirculating hot and cold water pipes outside the conditioned space must be insulated to R-3 minimum. Code Table 5-12 provides pipe sizes and temperatures for recirculating service hot and cold water pipes.

Shutdown. A separate switch for electric water heater or a separate valve to the main burner of all other water heaters must be

Figure 4.16: Energy Conserving Hot Water Features

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installed to allow the system to be turned off [Section 504.4].

Swimming Pools. All pool heaters must have separate on/off switches capable of operation without adjusting the thermostat setting. The controls must be capable of providing for a maximum design water temperature down to 65°F.[Section 504.5.1] Heated pools must have pool covers approved by the building official [Section 504.5.2]. Pool piping must be insulated in accordance with Code Table 5-12 [Section 504.7].

Hot Water Conservation. Showers and lavatories used for other than safety reasons must be equipped with flow control devices or specially manufactured shower heads or aerators. Water flow must be limited.

✓ CHANGE

Section 504.8.1 of the 1991 WSEC specifies that water flow be limited to a maximum of 3 gallons per minute (gpm) per shower head or faucet measured at maximum pressure with both hot and cold turned on. However, the SBCC has revised this requirement, effective July 1, 1992, by deleting the specific value (3 gpm), and citing instead the Water Conservation Act.

ELECTRICAL POWER AND LIGHTING

All lighting controls, except automatic controls or those for special purpose applications, which require trained operators; or those that would pose a safety or security problem, shall be installed so as to be readily accessible. [Section 505.2(a)]

The maximum lighting power controlled from a single switch must not exceed that provided by a 20 ampere circuit loaded to 80% [Section 505.2(b)].

Sections 505.2(c) through (g) apply to all buildings, but are almost exclusively relevant to "commercial" construction. These and other non-residential lighting requirements including lighting budgets and switching are presented in Unit 11 of this manual.

Unit 5: Prescriptive Path (Residential)

This unit explains how residential buildings can comply using the Prescriptive Path, based on Code Chapter 6 [Sections 601 through 604].

As stated in Unit 1, the Prescriptive Path is only one of three possible paths to show compliance with the WSEC's thermal performance requirements for the building envelope. In addition, there are general requirements that apply to all buildings covered by the Code, regardless of the compliance path chosen. For example, the proposed design must meet general requirements for mechanical system controls [Section 503.8], water temperature control [Section 504.3] and lighting switching [Section 505.2]. (See Unit 4 for a summary of general requirements.)

Of the three compliance paths offered, the Prescriptive Path is the simplest. It is also the least flexible. However, it does offer over 50 prescriptive options and provides sufficient opportunity for compliance for most residential situations. If a design is complex or unusual, however, the path may not be suitable. See Unit 6 for a discussion of the Component Performance Path, and Unit 7 for a discussion of Systems Analysis. Code compliance for commercial structures is discussed in Units 9, 10, and 11.

The Code provides a prescriptive method for sizing heating loads (Code Chapter 9). This method is only applicable when the Prescriptive Path is being used to determine envelope compliance. It is discussed in this unit.

PREScriptive TABLES

The requirements for residential construction using the Prescriptive method of compliance are outlined in Code Tables 6-1 to 6-6 [Sections 625 through 630 in revised editions]. The tables are based on climatic zones within the state, fuel type used for space conditioning, and construction type.

The tables listed below in Table 5.1 (and included in Appendix B) may be used for all Group R occupancies, but some option paths available to log home construction are limited to buildings less than three stories. (Also, see "Changes" next page.)

Building designs complying under the Prescriptive Path must have a minimum

Table 5.1: Guide to the Prescriptive Tables

	<u>Frame Construction Electric</u>	<u>Frame Construction Other Fuel</u>	<u>Log Construction Electric</u>	<u>Log Construction Other Fuel</u>
Zone 1	6-1	6-2	6-5	6-6
Zone 2	6-3	6-4	6-5	6-6

✓ CHANGES

The 1986 version of the WSEC gave "credit" for the thermal value of the entire assembly, which includes air films. This is no longer true.

In the 1991 version of the WSEC, Tables 6-1 through Tables 6-4 each provided two options specifically applicable to frame construction buildings less than three stories in height ("low-rise"). A recent SBCC ruling, effective July 1, 1992, has changed this. Options VII and VIII of these tables, previously only applicable to low-rise buildings, are now available to buildings of any height. At the same time, maximum glazing U-values allowed by Options VII and VIII have been decreased. Instead, footnotes to these options specify glazing U-values that are higher than specified in the option, if the building is three stories or less. Effectively, this modification creates eight new options for frame construction buildings less than three stories. (See "Low-Rise Frame Construction," below.)

level of installed insulation in walls, ceilings, or roofs, and floors. The prescriptive tables list minimum acceptable R-values for various components. These values are for the total nominal or "face value" of the batt, loose-fill, and/or rigid insulation that is installed. The framing that interrupts the insulation layer, the sheathing, finish materials, and the air films are not figured in. For example, an attic with R-11 batts between 2x4 ceiling trusses, plus an additional R-27 loose-fill on top, is considered an R-38 ceiling for the purpose of prescriptive compliance.

Using the Tables

In order to select the proper Code table to use, the builder or code official must know the climate zone, type of heating system, and construction type. (See Example 1.)

Frame Construction. Option paths in the four tables for non-log structures (Code Tables 6-1 to 6-4) vary depending upon the amount of glazing in the structure. (See Example 2.)

Maximum glazing areas range from 10% to 30% of the conditioned floor space. Once the appropriate option is chosen, the thermal

performance for the remaining components of the envelope are determined. If a given

structure exceeds the glazing limit for an option, then it must comply with the component requirements for the next highest option.

✓ EXAMPLE 1

Suppose the design being considered is a gas-heated frame house to be located in Olympia. According to the map provided in Unit 3, Olympia is located in Zone 1. Reviewing the list of prescriptive tables provided above, the appropriate choice would be Code Table 6-2, for Zone 1, using "other fuels" (non-electric). If the building were to be of log construction, then Code Table 6-6 (using the Zone 1 section) would be the appropriate table.

✓ EXAMPLE 2

The amount of glazing in the structure is the percentage representing the ratio of glazing to conditioned floor area. A 1,000 square foot house with 158 square foot of windows (rough openings) has a percentage of glazing to floor area of 15.8%.

$$\frac{158}{1000} = 0.158 = 15.8\%$$

The U-values and R-values listed are the minimum requirements for each option. Once an option is selected all of the minimum requirements must be met. (See Example and Table 5.2, below. The table

excerpts material from Code Table 6-1. Also, see the discussion of area-weighted U-values for windows and doors, later in this unit, for an exception.)

✓ EXAMPLE

In Example 2, we found the building to have a glazing to floor ratio of 15.8%. Assuming it were electrically heated and located in Zone 1, the building would have to meet standards set in Code Table 6-1 (Below in Table 5.2).

The appropriate minimum requirements are found in Option V of the table, since the percentage of glazing exceeds the glazing to floor area ratio set in Option IV (15%). Reading across the table, requirements of Option V, and those that must be met for this particular building to comply using the Prescriptive Path, include:

Glazing U-Value:	0.39
Doors U-Value:	0.20
Ceiling:	R-38
Vaulted Ceiling:	R-30
Wall Above Grade:	R-21
Wall Below Grade:	R-21 (interior); R-10 (exterior)
Floor:	R-30
Slab-on-Grade:	R-10

Table 5-2: Residential Prescriptive Options for Zone 1, Electric Resistance Heat (a)

Option	Glazing % Floor Area	Glazing U-value	Doors	Ceiling ²	Vaulted Ceiling ³	Wall Above Grade	Wall*int ⁴ Below Grade	Wall*ext ⁴ Below Grade	Floor ⁵	Slab ⁶ On Grade
I.	10%	0.46	0.40	R-38	R-30	R-21	R-21	R-10	R-30	R-10
II.	12%	0.43	0.20	R-38	R-30	R-19	R-19	R-10	R-30	R-10
III.	12%	0.40	0.40	R-38	R-30	R-21	R-21	R-10	R-30	R-10
IV.*	15%	0.40	0.20	R-38	R-30	R-19	R-19	R-10	R-30	R-10
V.	18%	0.39	0.20	R-38	R-30	R-21	R-21	R-10	R-30	R-10
VI.	32%	0.36	0.20	R-38	R-30	R-21	R-21	R-10	R-30	R-10
VII.	25%	0.32	0.20	R-38	R-30	R-19+R-5	R-21	R-10	R-30	R-10
VIII	30%	0.29	0.20	R-38	R-30	R-19+R-5	R-21	R-10	R-30	R-10

(a) Note: This is an excerpted table, please see Appendix B for the complete table, including important footnotes. Excerpted from the WSEC Table 6-1. Modified by SBCC ruling, effective July 1, 1992.

Low-Rise Frame Construction. As stated above, footnotes in Tables 6-1 through 6-4 effectively create eight new options for buildings less than three stories in height.

✓ EXAMPLE

Taking the example once again of the electrically heated home in Zone 1, we can see how this works, using Table 5.2, above: If the home has a glazing to floor area ratio of 22% to 25%, the home would minimally need to comply with Option VII in Code Table 6-1. This option requires a maximum glazing U-value 0.32. However, if the building is less than three stories, a footnote specifies that its glazing U-value can be as high as 0.35.

Log Construction. Option paths in the two tables for log structures (Code Tables 6-5 and 6-6) vary on the basis of average log thickness. Again, all the table values are minimum requirements that must be met. (See Table 5.3, below, which excerpts material from Code Table 6-5.)

Thermal Equivalency. In theory, each option in a prescriptive table, if followed precisely, should produce a structure of equivalent thermal performance to all the other options. As glazing area or log

thickness are varied, individual component values are adjusted to maintain thermal equivalency.

PRESCRIPTIVE ENVELOPE REQUIREMENTS

Ceiling Insulation

Although the basic ceiling insulation requirements are R-38 for ceilings below vented attics and R-30 for single-rafter, joist vaulted ceilings, the range of minimum prescribed values for ceiling insulation is from R-30 to R-60 [Section 602.1]. Values differing from the basic requirements, such as R-60, include a requirement for an advanced framing system (denoted by "Adv" in tables). Advanced framing is a special framing system or modified truss in the roof structure. The system provides a means for maintaining the full specified R-value for the ceiling to the outside of the wall top plate. (See Figure 5.1.)

Wall Insulation

Wall insulation is required for all exterior walls, as well as for any wall that separates unheated and heated space, such as the wall next to an unheated garage. The Code

Table 5.3: Prescriptive Options for Electrically Heated Log Homes in Zone 1 (a)

Option	Average ² Log Thickness	Glazing % Floor Area	Glazing U-value	Doors U-value	Ceiling ³	Vaulted ⁴ Ceiling	Floor ⁵	Slab ⁶ On Grade
I. ⁷	5.5"	15%	0.31	0.14	R-60 Adv	R-38	R-38	R-10
II. ⁷	7.5"	15%	0.40	0.20	R-60 Adv	R-38	R-30	R-10
III. [*]	9.6"	15%	0.40	0.20	R-38	R-30	R-30	R-10

(a) Note: This is excerpted from Code Table 6-5, please see Appendix B for the complete table, including important footnotes.

requires minimum insulating values ranging from R-15 to R-28.5 for all above-grade exterior walls as determined by the appropriate option path.

The Code automatically accepts three wall configurations as meeting the prescriptive requirements for an R-19 wall [Section 602.2], including (see Figure 5.2 next page):

- ⇒ 2" x 4" framed wall with installed R-11 batt and R-5 insulated sheathing (Option 1 in Figure 5.2), or
- ⇒ 2" x 4" framed wall with installed R-13 batt and R-3.2 insulated sheathing (Option 2), or
- ⇒ 2" x 6" framed wall with installed R-19 batt (Option 3).

Figure 5.1: Standard vs. Advanced Roof Framing

STANDARD

ADVANCED

Unit 5: Prescriptive Path (Residential)

In all other cases, the *nominal* R-value of the insulation layer(s) must equal that required by the Code. Some R-value requirements for wall insulation are given as a sum of two values (for example, R-19 + R-5). This indicates a requirement for R-19 wall cavity insulation, plus R-5 foam sheathing. Alternative practices providing a nominal insulation value of at least R-24 are acceptable, however. (See Figure 5.3.)

The nominal values used for prescriptive compliance ignore framing factors, air

films, and the thermal resistance of other building materials. Therefore, converting these R-values to U-values will not yield the same values as the default U-values provided in Code Chapter 10 (for use in Component Performance calculations; see Unit 5).

Basement Walls. Below-grade exterior walls surrounding conditioned space must be insulated to not less than the nominal R-value specified for below-grade walls in Tables 6-1 to 6-6 [Section 602.3].

Figure 5.2: Acceptable R-19 Walls

Below-grade interior walls require R-values similar to above-grade wall values. (See Figure 4.10; also, see definition of "below-grade walls," in Unit 4.)

Exterior insulation R-value requirements depend on the location. Zone 1 houses require R-10. Zone 2 houses require R-12 when the insulation is placed on the exterior side of a below-grade wall.

Figure 5.3: R-24 Wall

✓ NOTE

Below-grade walls may be insulated on the exterior or interior side of the wall. There are advantages and disadvantages to both approaches.

Exterior application doesn't rob space from the building's interior, and increases thermal benefits by incorporating the mass of the concrete wall. However, the insulation material used for exterior application tends to cost more. Exterior insulation also requires protection from damage and is more difficult to install without breaking.

Interior insulation does eat up floor space, but is less expensive. It is less vulnerable to damage, and easier to install.

Floor Insulation

Insulation requirements for floors over an unheated space vary from R-19 to R-38, depending on the prescriptive option. This includes floors over unheated basements, unheated garages, and vented crawl spaces [Section 602.5]. Floor insulation must meet the general requirements in Section 502.1.4.7. (See Unit 4.)

Slabs-on-Grade. The builder must insulate the edges of any slab floors poured on grade or less than 24 inches below grade. The insulation must be R-10 for all prescriptive options. (See Figures 4.7, 4.8, and 4.9 in Unit 4.)

✓ **NOTE**

In the colder climates of Zone 2, the practice of insulating the perimeter of the crawl space rather than the floor, or of splitting the insulation between the perimeter and the floor, may be desired. However, neither of these practices are included in Prescriptive Path compliance. When using these approaches, compliance will need to be determined using the Component Performance Path.

There is a new "pre-approved" Component Performance package that includes perimeter/floor insulation. However, it's only available at the discretion of the building official and for electrically heated buildings. (See "Alternatives to Prescriptive Options," this unit.)

Also note that perimeter or perimeter/floor insulation may result in a radon vent requirement per the VIAQ Code. This is because it is likely that crawl space vents will need to be closed in the winter to get any value out of the insulation.

Doors And Windows

Glazing Area. The glazing area must not exceed the percentage of gross floor area specified for the appropriate option in the Prescriptive Tables. [Section 602.7.1]

Glazing U-Value. The total glazing area must have an average AWU- value less than or equal to the specified option value. [602.7.2]. (U-values for glazing must be determined in accordance with general requirements of Section 502.1.5.1; see Unit 4.) If the U-values for all glazing in a building are below the U-value required by a prescriptive option, then no calculations are required. If compliance requires an average AWU, however, then the areas and the U-values for all glazing must be included with the building permit application. The acceptance of an average AWU is an exception to the general rule that each component must not exceed the prescribed value of a given prescriptive option in order to qualify under that option. (See Figure 5.6.)

Single Glazing. Single glazing may be used for ornamental, security, or architectural purposes. The area of single glazing, however, is limited to no more than 1% of

the total floor area. For the purpose of Code compliance the area of single glazing must be doubled when included in the percentage of total glazing area allowed in the prescriptive tables. [Section 602.7.2]. Thus, in a particular option, if glazing is limited to 15% of the total floor area, and single glazing is actually 1% of the total floor area, only 13% would be available for other glazing. When the AWU calculation is used to show compliance, the single glazing does not have to be included in the calculation.

If the single glazing is included with other glazing in an AWU calculation, and the overall AWU value is acceptable, then the single glazing area may, in fact, be more than 1% of the total floor area. In this case, the single glazing is not doubled, since the "price" for single glazing is already "paid" in the AWU calculation.

✓ **CHANGE**

In earlier versions of the WSEC, skylights needed to be treated as single glazing, and doubled when included in the percentage of total glazing area allowed in the prescriptive tables. This is no longer the case.

Figure 5.6: Windows - Area Weighted Average U-Values

The example below shows how to find the average AWU-value for all glazing: The UA for each window is calculated. By dividing the total UA for all the windows by the total window area, the average AWU is found. In this case, the average AWU is .40.

Typically, there may be several windows in a structure with the same U-value. You can save time by adding the total area these windows represent; then multiplying the total area by the U-value to find the UA for these windows. This UA can be used as if it were for a single window in the calculation.

Zone 1 - Electric Heat Total Conditioned Floor Area = 20' x 50' = 1000 ft²

Window	Area (ft ²)	x	U-Value	=	AU
1	20'	x	0.35	=	7.00
2	15'	x	0.35	=	5.25
3*	Exempt as long as area < 1% of floor area				
4†	4	x	0.40	=	1.60
5	15	x	0.35	=	5.25
6	20	x	0.35	=	7.00
7	15	x	0.35	=	5.25
8†	42	x	0.48	=	20.16
Total	131 ft ²			=	51.51

$$AWU = \frac{51.51}{131} = 39.32$$

$$\text{Glazing \%} = \frac{\text{glazing area}}{\text{floor area}} = \frac{131 + 12^*}{1000} = 14.2\%$$

* Window #3 area must be doubled to determine the % glazing area.

† The 1/2 lite in one door (#4) is less than 50% of the door area and therefore only the glazed area is counted as glazing. The glazing in the sliding glass door (#8) is greater than 50% of the door area, so the entire door rough opening is counted as glazing.

Unit 5: Prescriptive Path (Residential)

Exterior Doors. Doors that are less than 50% glazing, including fire doors, must have an area-weighted average U-value (AWU) for the opaque portion of the door not exceeding the values given in the prescriptive tables [Section 602.6]. The glazing portion of the door, or the entire door area (*if it contains more than 50% glazing*) must comply with the glazing requirements.

Alternatives To Prescriptive Options

Because Prescriptive options offered in the Code fail to reflect some common building practices especially in Zone 2, the WSEO has suggested four alternative Component Compliance Packages (see Table 5.4).

These alternate options have been developed using the target values of Code Table 5-1, and Component Performance Equations 1 and 3. They offer trade-offs not available in the Prescriptive Path, but do not require area take-off calculations usually

required by the Component Performance Path. In a sense, they are "pre-approved" design options that comply through the Component Performance Path. However, they work just like Prescriptive options. That is, no trade-offs may be made between each package -- each package must be matched in its entirety.

✓ NOTE

These packages are for electrically heated homes and may only be used at the discretion of the building official.

Key advantages to these packages are:

- ⇒ All four packages assume wood or ornamental doors;
- ⇒ No foam sheathing is required for walls; and

Table 5.4: Component Compliance Packages for Electrically Heated Homes

Package	Glazing % Floor Area	Glazing U-Factor	Door U-Factor	Attic Ceiling	Vaulted Ceiling	Above Grade Wall	Below Grade Walls Int	Ext	Floor	Slab
Zone I										
A	15%	.38	.40/19*	R38	R30	R21 Int**	R19	R10	R30	R10
Zone II										
B	12%	.36	.40/19*	R38	R30	R21 Int**	R21	R12	R30	R10
C	15%	.36	.40/19*	R49	R30	R21 Int**	R21	R12	R30	R10
D	12%	.33	.40/19*	R49	R30	R21 Int**	R21	R12	†R19F +R-11P	R10
* One door (up to 24 ft ²) may have U-Factor = .40 or less; remaining doors must have U-Factor = .19 or less.										
** R21 Int = R21 Intermediate framing; 16" o.c. stud spacing, R-10 insulated headers, full insulation at corners and interior wall intersections with exterior walls, all structurally unnecessary framing eliminated.										
† Indicates an R-19 floor combined with R-11 perimeter insulation in the crawl space										
Refer to Chapter 5 of the Energy Code for other requirements, including building envelope (Section 502), mechanical system (Section 503), and service water heating (Section 504).										

- ⇒ Combination floor and foundation perimeter insulation is included in one Zone 2 package.

The disadvantage is that these paths may require the structure to meet a higher level of energy efficiency than required by the Prescriptive Path, and in some cases a higher level of energy efficiency than if a standard Component Performance calculation were done.

It is important to remember that general requirements (as outlined in Unit 4), must be met no matter which compliance path is chosen, and this applies to situations in which these packages are used for compliance.

HEATING AND COOLING SYSTEMS

General requirements for mechanical systems must be met regardless of compliance path used. These are found in Code Section 503, and discussed in Unit 4.

System Sizing

The Prescriptive Path is often chosen for its simplicity; no heat loss (or gain)

calculations are required to show compliance. Calculations may be required for determining proper system size, however. This is at the discretion of the code official. If the code official approves, structures that otherwise have met compliance prescriptively, may size their heating systems prescriptively as well, according to Section 900. The system size calculated using the values from Section 900 would be used instead of a detailed design heat load calculation. (See Table 5.5.)

Table 5.5: HVAC Sizing Prescriptive Check (a)

To check the size of the intended heating system, multiply the square footage of heated area by the appropriate number from the columns below. This will yield the maximum Btu/hr for the heating system.

	Zone I	Zone II
Electric Resistance	21	29
Electric Resistance (Forced Air)	24	32
Other Fuels (Forced Air)	27	39

(a) Excerpted from Section 900.

✓ EXAMPLE

A 1,000 square foot house in Zone 2, with electric resistance forced-air heating, would not have to submit a design heat load calculation if the designed furnace capacity is 32,000 BTU/hr or less (unless required by the building official).

$$1,000 \text{ ft}^2 \times 32 \text{ BTU/hr.ft}^2 = 32,000 \text{ Btus/hr}$$

The size of the house is the variable. In a given zone with a given fuel type, a larger house will have a larger size limit.

The values in Section 900 are given in Btus/hr regardless of fuel type. However, since electrical heating systems would typically be sized in KW, it may be necessary to convert the capacity figure to kW. In the above example, since 1 kW = 3,413 Btus, the design heat load expressed in electric heat is 9.38 kW (32,000/3,413).

Unit 5: Prescriptive Path (Residential)

✓ CHANGE

In the past, design heat load calculations to document compliance with the Code's system sizing requirement were specified by the Code, no matter what compliance path was chosen. However, as noted above, the 1991 Code now allows as an option a prescriptive method of documenting such compliance. This option is available at the discretion of the building official and is not intended as a method of sizing. Proper sizing is discussed in Unit 4, and a detailed design heat load calculation for residential applications is provided in Unit 6.

medium-, or high-efficiency equipment. Table footnotes define the minimum values of these specifications. See Table 5.6, which provides these values.

✓ CHANGE

After January 1, 1992, the 1987 National Appliance Energy Conservation Act will no longer allow the manufacture of appliances with efficiencies less than those designated in Table 5.6 as "Medium" (that is, with an AFUE rating of less than 78%, if a combustion appliance, or with an HSPF of less than 6.8, if a heat pump).

System Efficiency

The general combustion appliance efficiency requirements for Group R occupancies is a minimum AFUE of .78 [Section 503.4.3]. Minimum heat pump efficiencies are given in Code Table 5-7. (See Unit 4 for a more in-depth discussion of system efficiency general requirements).

Code Prescriptive Tables 6-2, 6-4, and 6-6 allow some trade-offs of these standard efficiencies against other components. The options involved require either low-,

Table 5.6: Prescriptive Efficiencies for Heating Systems

Rating	AFUE (combustion)	HSPF (heat pumps)
Low	74%	6.35
Med*	78%*	6.80*
High	88%	7.70

* Required efficiency for component performance compliance.

Unit 6: Component Performance Approach (Residential)

This unit explains how residential buildings can comply using the Component Performance Path, based on Code Chapter 5. In addition, it provides an in-depth example of design heat load calculations (DHL) for proper sizing of the heating system. While the unit follows the order of the code, in actual practice, the builder, designer, or code official must first determine what the heating fuel will be. All other decisions follow from this.

It is important to note that in addition to providing calculations for permit compliance through Component Performance, Code Chapter 5 provides many general requirements for the thermal design of the envelope, and for building mechanical systems. For simplicity, a summary of all general requirements, including those appearing in Code Chapter 5, is provided in Unit 4 of this training manual. With the exception of specific requirements associated with design heat load calculations, they are not repeated here.

COMPONENT PERFORMANCE PATH

As stated in Unit 1, the Component Performance Path is one of three paths to show compliance with the Code's thermal performance requirements for the building envelope. In addition, there are general requirements that apply to all buildings covered by the Code, regardless of the compliance path chosen. (See Unit 4.)

Component Performance Compliance is determined by:

- ⇒ Figuring the heat loss rate for each component (U_o);
- ⇒ Multiplying each by its respective area (A); and
- ⇒ Summing the total house heat loss rate per unit temperature difference (UA).

This process is performed for the proposed design and for the standard design. If the potential heat loss rate (UA) for the proposed design is equal to or less than the standard design, the proposed design complies.

✓ NOTE

Unit 2 provides background information on heat loss and heat loss rates. This includes a discussion of the meaning of U -, U_o -, UA -, and R - values, and how they are applied in the Code. The discussion provides the basis for understanding calculations required by the Component Performance path. If you haven't read Unit 2 yet, it is strongly suggested you do so, before studying this Unit.

COMPONENT PERFORMANCE TABLES

Tables at the end of Code Chapter 5 provide the minimum R -values and maximum U -values for various components. These values are used to figure the overall thermal transmittance (U_o). Code Table 5-1 [Section 530, revised editions] gives maximum or target U_o for Group R occupancies. Code Table 5-2 [Section 531, revised editions] states the reference U_o values for non-residential structures. (See Unit 9 for a

Unit 6: Component Performance Approach (Residential)

discussion of Component Performance compliance for commercial structures.)

Other tables list minimum characteristic requirements for various components. These include standard rating conditions, heating system efficiency, duct and pipe insulation levels, and lighting power budgets. Some of these tables apply to residential structures, others to non-residential (or commercial) structures, still others to both. The text of the Code and subsequent interpretations often modify or clarify the information in the tables. Most of these tables are discussed in Unit 4.

The values in Code Table 5-1 are assembly values; that is, they include the insulation, sheathing, interior finish materials, air films, and any other material that makes up the component. This is different from values in Code tables provided for the Prescriptive Path (Code Chapter 6, discussed in this manual in Unit 5) where values are nominal insulation levels. That is, if the Prescriptive Table calls for R-30, the value of the insulation alone must be R-30.

EQUATIONS & TRADE-OFFS

The Code states that the U_o of any single component may be increased as long as the U_o of some other component(s) is decreased

enough to balance the first [Section 502.1.1] In this way the U_o for the whole building will be equal to or less than the U_o of the standard design.

Equations for use in computing trade-offs are provided at the end of Section 502. Equations 1 and 3 are for Group R occupancy. Equations 4 and 5 are for other than Group R occupancy. (For information on calculations for commercial buildings, see Unit 9.) Equation 2 is used for all occupancies.

Equation 1 provides information about the potential thermal performance of the proposed design if it were built with target U -values, that is, of the standard design.

The equation calculates the "target" UA allowed by the Code ($UA = U_o \times \text{area}$). This is the amount of heat loss per unit degree difference that would take place in the building, if each component is built with target U -values. These target U -values are specified by the Code in Table 5-1. Areas used in the calculation for components in the building are taken off from the proposed design. (Glazing is the one exception: Its area is fixed and provided in Code Table 5-1.)

✓ EQUATION 1:

$$UA_T = U_w A_w + U_{bgw} A_{bgw} + U_g A_g + U_f A_f + U_{rc} A_{rc} + U_{cc} A_{cc} + U_d A_d + F_s P_s$$

where UA_T = the target UA for the building envelope; U -values are target values set by the Code for individual components; and the area is taken off from the proposed design. Subscripts identify U_o -values and areas for individual components of the building envelope. For example, U_w represents the U_o -value of the wall, while A_w represents the wall area; U_{bgw} represents the U_o -value of the below-grade wall. (F_s represents the F -value of the slab, while P_s represents the perimeter (in linear feet) for the slab; for more information on F -values, see Unit 2.)

Equation 2 provides information about the U-values of each component in the proposed design. This information is then used in calculating Equation 3.

In actuality, the equation calculates the U-value of a particular parallel path through a given component, based on the R-values of materials used in the path. As discussed in Unit 2, it is rare that a component will have only one parallel path. Each section of a component with a unique parallel path will have a unique U-value. In the example discussed at length in Unit 2, a wall component has a different U-value for the section through the insulated cavity, than it does through the stud.

✓ **EQUATION 2:**

$$U = \frac{1}{r_o + R_1 + R_2 \dots r_i}$$

The "R" stands for R-values of various materials in the section. In a wall, this might be siding, sheathing, insulation or stud, and interior finish materials. Note that a dead air space (represented by "r" in the equation) resists heat flow: U-values for air films on either side are specified by the code as follows:

$r_o = .17$ for all exterior surfaces in winter (used for heating loads)

$r_i = .25$ for all exterior surfaces in summer (used for cooling loads)

$r_i = .61$ for interior horizontal surfaces with heat flow up (ceiling); $r_i = .92$ for interior horizontal surfaces with heat flow down (floors)

$r_i = .68$ for interior vertical surfaces (walls)

Note: For information on converting R-values to U-values, see Unit 2.

By repeating the calculation defined in Equation 2 to find the individual U-values of each parallel path in a component, we find all of the U-values represented by a given component. These U-values can then be used to find the U_o . The U_o is the average U-value through a gross component area with different parallel paths. Thus the U_o value of the wall (expressed as U_{wall}) is equal to the U-value through the insulated cavity times the percentage of cavity area in the wall plus the U-value through the framing times the percentage of framing area in the wall or:

$$U_w = (U_{cavity} \times \%A_{cavity}) + (U_{framing} \times \%A_{framing})$$

✓ **NOTE**

As stated in Unit 2, in the majority of cases, U- or F-values will not actually be calculated. *The Code requires that the default U- and F-values listed in Code Chapter 10 be used if the proposed practice is listed.* Thus, the calculations required in Equation 2 will only be done if the proposed practice deviates significantly from practices listed in Code Chapter 10.

Equation 3 provides information about the potential thermal performance for the proposed design with component U-values as they are intended to be built. This thermal performance is then measured against the target thermal performance determined in Equation 1. (The design is in compliance if potential thermal performance is the same as or better than expected using target U-values, that is, if the UA for the proposed design, is the same as or less than the target UA value for the standard design.)

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✓ EQUATION 3

$$UA = U_{AW} + U_{BGW} + U_{AG} + U_{AF} + U_{RC} + U_{CC} + U_{AD} + F_{SP}$$

The equation calculates the UA for the *proposed* design. Essentially Equation 3 repeats the process of Equation 1, using all the major components of the proposed building.

The areas used in Equation 3 will be the same areas used in Equation 1, unless the design calls for a glazing area different from the amount fixed in Equation 1 and Code Table 5-1. (Keep in mind that if the glazing area changes, the opaque wall area will change as well.)

U-values in Equation 3 are for *proposed* practices. Thus, U-values used in Equation 3 may be different from U-values used in Equation 1. If the proposed practice for a component is the same as used to derive target U-values in Code Table 5-1, then the U-value for that component is assumed to be the same. If the proposed practice is different from the practice used to derive target U-values in Code Table 5-1, then U-values for the components in the proposed design can be found using the most appropriate of the two following methods:

If the practice is listed in the table of default U-values for that component (provided in Code Chapter 10), then the default U-value for that practice *must* be used; or

The U-values for components can be calculated using Equation 2. (The use of

Equation 2 should follow standard engineering practices and any calculation must be done in accordance with Chapters 19 through 27 of the *ASHRAE Handbook of Fundamentals*.

✓ NOTE

The Code addresses envelope assemblies containing metal framing [Section 502.1.1]. Because metal studs are a better conductor of heat than wood studs are, heat loss through an assembly containing metal framing is much higher. The Code states that U-values of assemblies with metal framing may be calculated by one of four methods [and includes a table [Section 502.1.1] that shows an accurate R-value of insulation installed in metal stud walls. (See Unit 4 for general metal framing requirements, and Unit 9 for more details. This practice is more common in non-residential construction.)

Worksheets

Worksheets to compute the above equations are provided in Appendix E. Figures 6.1a-e, show a proposed design using a sample house plan. Figures 6.2a and 6.2b walk you through the equations by using an example of a gas heated house to be built in Zone 1 to illustrate a worksheet (pages one and two) completed for the proposed design. See Appendix E for an example of the same house using Wattsun 5.2 to show compliance.

Figure 6.1: Proposed Design Example

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Figure 6.1: Proposed Design Example (continued)

(c)

(d)

Figure 6.1: Proposed Design Example (continued)

Figure 6.2a: Heat Loss Calculation Worksheet Example

Method A (below-grade wall/slab heat-loss tradeoffs)

- For each wall that differs in depth, perform a separate calculation using Steps 2 & 3. Sum the totals.
- Determine wall area from the slab surface to the top of the mud sill. Exclude door and glazing areas and insert them into the designated boxes below for both Base case and Proposed heatloss.
- Find the appropriate wall depths in Table 1 and insert the corresponding wall values into the Base case box(es). Multiply the corresponding wall U-value by the area derived in Step #1.
- Measure the perimeter distance in linear feet for each slab under a wall with a different Table 1 depth. Insert the slab F-value from Table 1 corresponding to each wall listed in Step #3.

BASE CASE HEATLOSS

B.G. wall #1	192 (Ft)	x U .041	=	7.87
B.G. slab #1	24 (L. Ft)	x F .64	=	15.36
B.G. wall #2	560 (Ft)	x U .037	=	20.72
B.G. slab #2	70 (L. Ft)	x F .57	=	39.90
TOTAL COLUMN →				83.85

PROPOSED HEATLOSS

Use Chapter 10, page 81, U & F-values for this calculation ¹. and the same BASE CASE area/L. ft. measurements.

B.G. wall #1	192 (Ft)	x U .064	=	12.29
B.G. slab #1	24 (L. Ft)	x F .57	=	13.68
B.G. wall #2	560 (Ft)	x U .056	=	31.36
B.G. slab #2	70 (L. Ft)	x F .42	=	29.40
TOTAL COLUMN →				86.73

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Table 1 (Below grade wall/slabs)**Insulated interior wall**

2' depth: walls	U.043
slab	F.69
3.5' depth: walls	U.041
slab	F.64
7' depth: walls	U.037
slab	F.57

Insulated exterior wall

2' depth: walls	U.070
slab	F.60
3.5' depth: walls	U.064
slab	F.57
7' depth: walls	U.056
slab	F.42

("Depth" indicates the total concrete wall depth including not more than 6" of above grade)

¹ Proposed U- and F-values come from Code Default Table 10-1. See Appendix C.

Figure 6.2b: Heat Loss Calculation Example (part 2)

Permit No. _____

1991 WSEC Chapter 5, Residential Compliance Form

Heat source: OTHER (Gas, oil, propane, wood, heat pumps) Zone 1

Standard Case Dwelling

Sample

Component		Ft2 or perimeter L. feet		Uo	=	UA
Maximum UA allowed	Roof/Ceilings	(1)	1069 (Ft2)	x .036	=	38.48
	Cathedral Ceilings	(2)	550 (Ft2)	x .034	=	18.70
	Framed Floor	(3)	440 (Ft2)	x .041	=	18.04
	Gross Wall		2086 (Ft2)			
	Glazing (15% x cond. fir. Ft2)	(4)	404 (Ft2)	x .65	=	262.60
	Doors	(5)	57 (Ft2)	x .40	=	22.80
	Framed Wall (G. wall - (4+5))	(6)	1625 (Ft2)	x .062	=	100.75
	Below grade walls:					
or	Interior	The UA value for either of these wall types must be derived using Method A in the instructions. Insert the value into the appropriate box at right.				= 83.85
	Exterior					=
	Slab on grade	(7)	(L. feet)	x .54	=	21.60
Add 1 - 7 for cross check w/ proposed →						266.82

Proposed Dwelling Calculation

UA value for the proposed dwelling		Component	Area/Perimeter	Uo	1	UA
Roof/Ceilings	Ceiling #1 (R-38 Blown)		1069 (F12)			
	Skylight(s) #1	(1)	NONE (F12)	x	=	
Floor	Net ceiling #1 (Cells - Sky)	(2)	1069 (F12)	x .031	=	33.14
	Ceiling #2 (R-30 U-Value)		550 (F12)			
Glazing & Doors	Skylight(s) #2	(3)	NONE (F12)	x	=	
	Net ceiling #2 (Cells - Sky)	(4)	550 (F12)	x .034	=	18.70
Wall Sections	Framed floor	(5)	440 (F12)	x .041	=	18.04
	Slab on grade	(6)	40 (L. Feet)	x .54	=	21.60
	Glazing (Vinyl Arco)		236 (F12)	x .49	=	115.64
	Glazing (Vinyl Low E)		125 (F12)	x .41	=	51.25
	Glazing (Vinyl Tested)		75 (F12)	x .45	=	33.75
	Glazing (_____)		(F12)	x	=	
	Door (Wood Frame / 1 1/2")		40 (F12)	x .39	=	15.60
	Door (Fiberglass Test)		17 (F12)	x .10	=	1.70
	Wall #1 (R-19.50 Lwp)		2086 (F12)			
	Glazing & doors #1	(7)	493 (F12)			
Wall Sections	Net wall #1 (Wall#1 - G & D)	(8)	1593 (F12)	x .062	=	98.77
	Wall #2 (_____)		(F12)			
	Glazing & doors #2	(9)	(F12)			
	Net wall #2 (Wall#2 - G & D)	(10)	(F12)	x	=	
	Below grade slab		See Instructions, Method A		=	86.73
Add 1 - 10 for cross check w/base				1000 912		

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Proposed UA
(Add this column)

Standard Case UA
(add this column)

Name _____
Street _____
Lot _____
City _____
Phone () _____
Notes: _____

If the Proposed UA value is less than or equal to the Base Case UA value, the dwelling design complies with the 1991 WSEC.

Page 2

- 1 These values come from the appropriate tables in Code Chapter 10.
2 The proposed house is in compliance because the proposed UA (494.92) is less than the standard UA (566.82).

AIR LEAKAGE

The Component Performance Compliance equations do not address heat loss due to air leakage or infiltration. (Trade-offs for air leakage rates for thermal envelope compliance are available only when using the Systems Analysis Path; see Unit 7.)

For designs using the Component Performance path, the assumption is made that both the proposed and standard designs have the same ACH rate. In addition, the Code requires general air leakage control measures. (See Unit 4.)

DESIGN HEATING AND COOLING LOAD

The calculation required for approval of the heating or cooling equipment size is called the design heat load (DHL) or design cooling load (DCL) calculation [Section 503.2.2]. The calculation determines the minimum amount of heat (Btus) the system must add (or remove) from the building each hour to maintain comfort. Thus, the proper size for the heating or cooling system is determined. The calculation must use standard engineering procedures, but the Code does not require an engineer to do them for residential structures.

The calculation is based on the same equations used for Component Performance compliance, but with a couple of differences. In calculating compliance for Component Performance, the builder or code official looks at heat transfer by way of conduction through a number of exterior components. In figuring a design heat (or cooling) load, heat losses from duct work located outside the conditioned space are also considered. In addition, the calculation will take into account the heat transfer into or out of the building due to air leakage and ventilation.

Finally, there is a third significant difference, which stems from the inclusion of climate data in the calculations.

The Component Performance Compliance calculation yields a heat loss rate through each component and for the whole building for each square foot of surface, at a single degree (1°F) of temperature difference between the inside and the outside. The design heat load calculation determines what the whole building's heating or cooling need will be at a specific design temperature difference. In this way the building is fitted to its climate.

As stated in Unit 3, the Code specifies an indoor design temperature of 70°F [Section 302] and an outdoor design temperature taken from the 0.6% column in the table of "Recommended Outdoor Design Temperatures, Washington State" (see Appendix D).

Heat And Cooling Load Calculation

Appendix E provides worksheet(s) to compute the design heating and cooling load. Figure 6.3 (next page) walks you through the calculation for design heating load, using the same example design used above. This time, we will further assume the house will have a central forced air gas furnace with duct work in an unheated crawl space. The house will be located in Bellingham.

Using The Computer For Component Performance

Although a computer program is not necessary to show compliance with the WSEC, it is recommended for the complex Systems Analysis Path. Code Chapter 8 provides a list of software programs that can be used for this purpose. (The list is

Unit 6: Component Performance Approach (Residential)

Figure 6.3: Design Heat Load Calculation Example

1997 WSEC Residential Design Heat Load Form

Climate Zone 1

Instructions:

Sample

A. The following steps will determine the maximum heating system size:

1. Structural loss, value (1): May be taken directly from the Proposed UA box on page 2.
2. Air leakage loss, Value (2): This is the volume (F13) of the conditioned space in the dwelling.
3. Climate Factor, ΔT : The local ASHRAE climate factor is 52 F. for your jurisdiction. (Call WEES if unsure.)¹
4. Duct Loss, value (3): Insert value from BTU/Hr. Box (a).
5. Calculate values a, b, and c by multiplying the numbers in each horizontal row.
6. Add values a, b, and c.
7. Multiply the sum from Step #6 by 1.5 to obtain the maximum heating system output for the building.
8. If the heating system is electric, divide the BTU/hr. value from Step #7 by 3413 to get kWatt output.

Heat loss path	Values	ΔT	ACH	Factors	BTU/Hr.
Structural loss	(1) <u>495²</u> (BTU/Hr/F)	x <u>52</u>			= <u>25,740</u> (a)
Air leakage loss	(2) <u>22,000</u> (F13)	x <u>52</u>	x .60 <u>3</u>	x 0.018	= <u>12,355</u> (b)
Duct losses	(3) <u>25,740</u> (BTU/Hr)			x .10	= <u>2,574</u> (c)

Permit No. _____

Name _____

Street _____

Lot# _____

City _____

County _____

Phone# _____

Manufacturer _____

Type of system _____

Model # _____

Heating output _____ (kW) (BTU/hr.)

Design Heat Load
(a+b+c) → 40,669
(BTU/Hr.)

Maximum Heating Output
(Gas, oil, propane, wood)
(Design Heat Load X 1.5) → 61,004
(BTU/Hr.)

OR

Maximum Heating Output
(Electric, heat pumps)
(BTU/hr. / 3413) → 17.87
(kWatts)

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¹ The outdoor design temperature for Bellingham from the ASHRAE weather data (see Appendix D) is 18°F. Interior design temperature from Code Chapter 3 is 70°F. $\Delta T = 70^\circ - 18^\circ = 52^\circ$

² From Component Performance worksheet - Figure 6.2(b) proposed UA.

³ WSEO recommended ACH for the design heat load calculation.

Unit 7.) These same programs can be used, if desired, to perform calculations for the Component Performance Path.

The WATTSUN computer program is available from WSEO and has been developed to do Component Performance, Design Heat Load, and other calculations. The program is customized to show compliance with the WSEC as well as with other Northwest regional codes.

WATTSUN 5.2 (and later versions) has the standard design U-values from Code Table 5-1 and the default U-values from Code Chapter 10 built into the program as well as

other Code requirements. After entering the requested data for a proposed design, the program will perform the calculations outlined above and indicate whether the proposed house has complied or not. It will also determine heating system size.

Worksheets for collecting and entering WATTSUN data are included in Appendix E.

In addition, many heating contractors have software programs supplied by heating equipment manufacturers that can perform design heat load calculations.

Unit 7: Systems Analysis (Residential)

This unit explains how residential buildings can comply using the Systems Analysis Path, based on Code Chapter 4 [Sections 402.1 - 402.6]. In addition, it provides a summary of software suggested for use, including those listed in Code Chapter 8.

As stated in Unit 1, Systems Analysis is only one of three possible paths to show compliance with the WSEC's thermal performance requirements for the building envelope. In addition, there are general requirements that apply to all buildings covered by the Code, regardless of the compliance path chosen. For example, the proposed design must meet general requirements for mechanical system controls [Sections 503.8], water temperature control [Section 504.3] and lighting switching [Section 505.2]. (See Unit 4 for a summary of general requirements.)

Of the three compliance paths offered, Systems Analysis is the most flexible and most complex. See Unit 5 for a discussion of the Prescriptive Path, and Unit 6 for a discussion of the Component Performance Path. Compliance for commercial structures is discussed in Units 9, 10, and 11.

SYSTEMS ANALYSIS PATH

This approach builds on the Component Performance Approach. It starts with a heat loss calculation, but goes one step further. In Systems Analysis, the building heat gains are also calculated. Systems Analysis allows the builder to trade off the effects of heat gains, increased thermal mass, mechanical system efficiency, infiltration rates, and thermal performance of envelope components. As an example, if a building has substantial gains from internal sources or passive solar, then the home may experience a greater heat loss without increasing its use of a non-renewable energy source. This allows additional flexibility in the envelope design.

Since a complete analysis of gains, particularly solar gains, can be complicated and lengthy, Systems Analysis is done with a computer program.

When Systems Analysis Makes Sense

The builder or designer should first try the two simpler paths to see if the building complies through either the trade-offs allowed by the Component Performance Approach, or through the simple requirements of the Prescriptive Requirements Approach. Some minor adjustments in the building design may resolve any potential conflict with the Code requirements of these paths. If the Prescriptive or Component Performance requirements remain too rigid, however, then the flexibility of Systems Analysis may be necessary to show that the building will use the same or less energy than an identical one built in simple conformance to the Code.

Custom homes, incorporating unique envelope design features, are often candidates for Systems Analysis approach. Architects and more experienced design professionals are likely to be involved in this type of project. They are often more

Unit 7: Energy Systems Analysis (Residential)

familiar with the type of computer analysis demanded by the path.

Systems Analysis may also be used to take credit for renewable energy resources, such as solar, wind, etc. (See the Code definition for renewable energy sources [Section 201.1].)

Systems Analysis design can sometimes provide a solution for a rather common problem: when unapproved field changes are made in the building and result in non-compliance. Two such examples might be the installation of the wrong windows or a cathedral ceiling framed with insufficiently sized members to accommodate the required insulation. A Systems Analysis approach to the building with these potential problems may show that it can still comply. Or, it could reveal a change still available in another component, such as a more efficient heating system, which would put the building back in compliance.

This practice should not be encouraged, but it can be used in a pinch. Nor is it the responsibility of the code official to solve the problem. As in all cases, it is the contractor's responsibility to show compliance; this is simply a path he may choose to use.

There is the danger that the Systems Analysis will not show compliance. If this situation occurs and a redesign by another approach is still inadequate to show compliance, the contractor will have to rebuild the non-complying component.

ENERGY BUDGET

Compliance with this chapter requires an analysis of the annual energy usage of the proposed design [Section 402.2].

Like the Component Performance compliance path, the applicant must submit plans for the proposed building. From these plans, an estimate is made of the building's annual energy consumption, sometimes called the "energy budget." This is expressed in Btus or kWh per square foot of conditioned floor area per year. Then an estimate of the annual energy consumption of the same building is made as though all of its components were built exactly to Code. This "standard design" will have the same dimensions or layout, floor area, and operating characteristics as the proposed design, but it will meet the component U- or R-values and the equipment efficiency requirements of Code Chapter 5 (summarized in this manual in Unit 6).

The final test is to compare the two estimates. As long as the proposed design's energy use is no greater than that of the standard design's, the building complies by Systems Analysis [Section 402].

As stated above, the "energy budget" developed in Systems Analysis includes gains, as well as losses.

Standardized Input Values For Calculating Budget

For residential construction the Code establishes standardized input values for calculating the annual space heating budget [Section 402.1.3]. (See, Table 7.1)

Other Values

Glazing. Glazing in the standard design must be modeled with equal areas facing north, east, south, and west.

Infiltration. Infiltration levels used for purposes of thermal calculations only are

Table 7.1: Standardized Input Values

Thermostat	
Thermostat set point, heating	65° F.
Thermostat set point, cooling	78° F.
Thermostat night set back	65° F.
Thermostat night set back period	0 hrs
Internal Gain	
R-3 occupancy (single family)	3,000 Btu/hr
R-1 occupancy (multifamily/unit)	1,500 Btu/hr
Other Parameters	
Domestic hot water set point	120°F.
Domestic hot water consumption	20 gal/person/day
Minimum Heat Storage	
Calculated by using standard engineering practice for the actual building or as approved	
Site Weather Data	
Typical meteorological year (TMY) or ersatz TMY data for the closest appropriate TMY site or as approved	
Heating System Efficiency	
Electric Resistance Heat	1.00
Heat Pumps	6.80 HSPF
Other Fuels	0.78 AFUE

prescribed at 0.35 air changes per hour [Sections 402.1.5].

Heating Season Performance Factors (HSPF). HSPFs for heat pumps used for compliance with this section must be calculated using procedures consistent with U.S. DOE Test Procedures [Section 402.2].

Variables in Proposed Design

The "proposed" building may vary any of the following parameters:

- ⇒ Overall Thermal transmittance (U_o) of the building or individual components;
- ⇒ Heat storage capacity;
- ⇒ Glazing orientation, area, and shading coefficients; and
- ⇒ Heating system efficiency.

Other energy saving measures may also be included in the proposed mode. (See discussion of "Energy Saving Measures and Credits," below.)

ENSURING A FAIR COMPARISON

The Code spells out the minimum level of detail required in calculations of energy consumption by the standard and proposed designs. To ensure a fair comparison, the Code requires that the buildings be "of similar design." As defined in Section 402 of the Code this means that the proposed and standard designs must:

- ⇒ **Use the same energy source for the same functions.**

This means that, if an energy source is going to be used for water heating in the proposed design, the same energy source for water heating must be used in the standard design. An example would be a proposed design that uses more solar energy and less gas or oil than the standard design.

To compare annual energy usage, all energy sources must be converted to common units before being totaled. The conversion should be done in terms of energy content as

Unit 7: Energy Systems Analysis (Residential)

delivered to the building site. It cannot include any factors for generation or transmission losses occurring elsewhere. In particular, comparisons of electrical and fuel use should be made on the basis of 1 kWh = 3,413 Btus.

- ⇒ **Have equal floor area and the same ratio of envelope to floor area.** For example, if the proposed design is a geodesic dome, the standard design must be a geodesic dome.

This requirement applies to heated or cooled spaces and does not include outside or unconditioned spaces in the two buildings. If the proposed design is to include an unheated, but tempered, sunspace, then the interfacing wall must be insulated and should be treated as an extension of the adjacent walls (as a Trombe wall would be). An unheated sunspace is not included in the floor space of the standard design (although internal gains due to this unheated sunspace can be credited). If the sunspace will be heated by a conventional non-renewable resource then the standard design must include a similar space.

- ⇒ **Have equal environmental requirements.**

The buildings must have the same temperature control points and must be equally able to meet them. In other words, one building cannot be controlled to 72°F for heating and cooling while the other is controlled to 70°F for heating and 78°F for cooling. Also, the amount of outside air supplied at minimum levels must be equal. Other conditions affecting the comfort or usefulness of the space must also be equal. For example, lighting levels must be equivalent, as must the provision of

auxiliary services such as domestic hot water.

- ⇒ **Use the same climate data.**

Obviously, the same weather conditions must be used to evaluate the energy consumption in the two designs.

- ⇒ **Have equal occupancy.**

This means simply that the two buildings must be occupied by the same numbers of people, doing the same things, during the same times.

- ⇒ **Have the same usage schedule.**

The building and all its subsystems must be operated on the same schedule. It is not valid to compare one building occupied 24 hours per day to another unoccupied for 14 hours per day.

- ⇒ **Use the same assumptions in calculating the energy use of building energy systems.**

Assumptions about operating practices in the buildings or interactions between systems should be kept the same to ensure legitimate comparison. Even though "credits" can be gained to offset heat loss through the use of higher efficiencies in the proposed design, assumptions about how the energy is going to be used must remain constant.

- ⇒ **Employ heat pumps equally.**

If the proposed design uses electrically driven heat pumps, then the standard design must also employ heat pumps of at least equal capacity. Both sets of heat pumps must meet the minimum performance requirements given in Chapter 4 of the

Code, though one may be more efficient than the other.

Finally, there is one significant difference between the two designs that is likely to occur. In general, the Code indicates that the standard design for R-occupancy buildings must have the same component areas as the proposed design. This prevents the comparison of a one-story house to a two-story house of the same conditioned floor area. It would also disallow comparison to a house with the same floor plan, but higher ceilings. On the other hand, the Code permits a difference in the window area of the two designs. The Code states that the standard design house window area will equal 15% of the floor area; no more, no less. The proposed design can adjust the window (and, therefore, wall) area up or down from this 15%. If the estimated consumption improves for the proposed design, the house qualifies.

CALCULATION AND ANALYSIS PROCEDURES

Annual Energy Usage.

A full year energy simulation is not required for Group R occupancies, including one- or two-family dwellings or multi-family units. A full year energy simulation as required for Non- Group R occupancies is discussed in Unit 9.

The Code allows a simpler analytic technique, such as WATTSUN, or an approved alternate, provided the technique used adequately represents the energy use by both the standard and proposed design.

In addition to WATTSUN, the Code suggests other software programs for use in Systems Analysis (see discussion of software, below).

Alternate calculation techniques are allowed, if approved by the building official and if they follow accepted engineering practices and standards. [See Sections 402.1.2 & 402.5 exception]

The description of "buildings of similar design" above make it clear that even if a simpler analysis technique is used, the Code requires it to provide a good representation of the building as it will be occupied and operated.

ENERGY SAVING MEASURES AND "CREDITS"

Renewable Resource. The procedures outlined in this chapter may be used to take credit for renewable energy resources. Energy from renewable resources may be excluded from the comparative analysis of a standard and proposed design [Section 402.1.1]. Renewable resources include solar, geothermal, wind and other sources defined in Chapter 2 of the Code [Section 201].

✓ CHANGE

The 1986 version of the WSEC had a limit on the credit that could be taken for renewable resources. This limit has been removed in the 1991 version.

Internal Heat Gains. Heat gains from lighting, appliances, and occupants are "credited" through a simple assumption that these heat sources will, in a single-family residence, produce 3,000 Btu/hr. The Code assumes that in a multi-family unit, these heat sources will provide 1,500 Btu/hr. [Section 402.1.3] These values are to be input when calculating the annual space heating budget. Other heat gains, such as passive solar and thermal mass may affect the annual energy budget.

Unit 7: Energy Systems Analysis (Residential)

Passive Solar Credit. Demonstrated passive solar gains are "credited" Btu for Btu. That is, for each Btu produced through the use of passive solar features, a Btu of heat loss is offset. However, if the building relies on 8% or more south-facing or equivalent glazing to achieve compliance, then a sun chart or approved documentation must be provided depicting actual site shading. Also, sufficient thermal mass is required to adequately store this energy for use when solar gain is absent. The Code requires an equivalent heat storage capacity of at least 45 Btu/°F for each square foot of south-facing glass for compliance under this section [Section 402.1.4].

Thermal Mass. As discussed above, additional thermal mass beyond typical light framed construction may help qualify a building for solar gains that can offset heat loss. Examples of additional thermal mass would include logs, a concrete slab floor, or a massive masonry fireplace within the building envelope.

DOCUMENTATION

If applicants use Systems Analysis, they must submit an energy analysis comparison report. This report should outline the characteristics of the two buildings and their operating systems with enough technical detail so that code official can follow the analysis. The analysis will usually compare simulations of the performance of the standard and proposed designs. All assumptions and data used in the simulations must be included. Computer printouts from the simulation usually contain this data, but it should be summarized in a report or on a submittal form. The report must:

- ⇒ Compare the total annual energy use of both designs; and

- ⇒ Show a simulation using accepted techniques and practices. [Section 402.6]

RESIDENTIAL ENERGY ANALYSIS SOFTWARE

Systems Analysis or "Energy Budget" design most commonly uses computer software. Essentially the software will combine target rates of heat loss as set in Code Table 5-1 (Component Performance), other standard values required by the Code, and climate data and other variables, to come up with an annual energy budget for the standard design. The proposed design must meet or better this energy budget.

Most of the software is programmed with built-in values. The software combines built-in values with those input by the designer. Built-in values vary with the software. They may include the U-values for the various composite components, for assumed internal gains, and for solar gains from glazing. Some software requires the designer to calculate the appropriate structural component areas and determine corresponding R-values from the plan. At a minimum, areas for the various components must be taken off the plans. A plan review take-off sheet should be used by the designer and submitted along with a print-out for plan review.

There are many micro-computer based programs available that can be used for Systems Analysis compliance. Most of the programs listed below in Table 7.2 and described in Table 7.3 depend upon simulations of weather and building characteristics to estimate useful passive solar and internal appliance heating gains and the auxiliary energy use of the building.

All of these programs are used to analyze building energy and solar performance. Some work well for people unfamiliar with computers; others take skill. Programs listed here are from WSEC Chapter 8 and are suggested for energy analysis compliance for Group R occupancies. The

WATTSUN 5.2 program includes customized weather data and input screens to show compliance with the '91 WSEC and contains the default U-values from Code Chapter 10 as well as the target thermal properties specified by the Component Performance Path.

Table 7.2: Recommended Software for Residential Systems Analysis Calculations*

<u>Program Name</u>	<u>Operating System</u>	<u>Type of Program</u>	<u>Address</u>	<u>Cost</u>
CALPAS 3**	MS DOS	Passive Solar Heating/Cooling Simulation	Berkeley Solar Group 455 Santa Clara Ave. Oakland, CA 94610 (510) 839-7600	\$795
DATA CAL**	MS DOS	Spreadsheet UA Calculations	Sunrise Energy, Inc. 5708 43rd Ave. E. Tacoma, WA 98443 (206) 593-6483	\$130
DOE 2	MS DOS	Building Energy Load Simulation	Acrosoft International, Inc. 9745 E. Hampton Av Suite 230 Denver, CO 80231 (303) 368-922	\$495-695
F-LOAD	APPLE, CP/M, MS DOS	Building Energy Load Simulation	F-Chart Software 4406 Fox Bluff Rd. Middleton, WI 53562 (608) 836-85365	\$425
MICROPAS**	MS DOS, CP/M	Passive Solar Heating/Cooling Simulation Graphics	Enercomp 123 C Street Davis, CA 95616 (916) 568-2485	\$795
SUNDAY 3.0**	CP/M 2.0, MS DOS	Passive Solar Heating/Cooling Simulation	Ecotope 2812 E. Madison St. Seattle, WA 98112 (206) 322-3753	\$125
WATTSUN 5.2**	MS DOS	Passive Solar Heating Model, U and UA Tradeoff Calculations (Code Chapter 5)	WSEO P.O. Box 43165 Olympia, WA 98504 Attn: Hank Date (206) 586-5045	\$65***

*This list is not intended to be exclusive. Other programs may also be acceptable.
 **BPA approved for Super Good Cents Programs
 ***Free to local governments. Others \$65 (plus tax in state).

Unit 7: Energy Systems Analysis (Residential)

Table 7.3: Computer Program Descriptions

Program	Comments
CALPAS 3	Command driven, hourly weather simulation program (365 day year). Certified by the California Energy Commission for Title 24 Energy Code compliance. Will require a large amount of run time unless your computer has a special math processor. Technical background in both thermal analysis and computers is required. Outputs hourly, monthly and annual summaries of heating and cooling loads, and solar and internal gains.
DATAACAL	Calculated approach to Energy code compliance for residential and small commercial using the Component Performance. Outputs comprehensive report showing all calculations, including cavity v.s. stud/joist UA calculations. Input assembly U values; default values available in manual. Anticipates code changes since code values can be modified by user. Program built to do City of Tacoma Code.
DOE2	Menu-driven microcomputer version of the mainframe DOE-2.1D program. Performs energy use analysis for residential and commercial buildings. Can provide full-year, hour-by-hour analysis for multiple zones. Includes two cities' hourly Test Reference Year (TRY) and/or Test Meteorological Year (TMY) data; additional weather files available. Requires basic knowledge of building thermal performance.
F-LOAD	Menu-driven, monthly weather simulation for building energy analysis. Calculates building heat loss coefficient. Outputs monthly and annual energy load, useful solar and internal gains and life-cycle cost economics.
MICROPAS	Hourly weather simulation program. Year condensed to 42 representative days for quicker calculation times. Certified by the California Energy Commission for compliance with Title 24 Energy Code compliance. Multiple building zones for modeling sunspaces, Trombe walls, etc. Technical background is required because user must derive the building heat loss coefficient. Outputs hourly, monthly and annual summaries of heating and cooling loads, solar and internal gains and graphics.
SUNDAY 3.0	Menu-driven hourly weather simulation program. Models single zone buildings on a daily base. Will calculate heating, cooling, and ventilation as well as heat loss coefficients. Includes built in thermal mass calculator and an extensive library of U and R values for building components that can be modified by the user. Outputs monthly and annual heating/cooling loads as well as solar and internal gains.
WATTSUN 5.2	Menu-driven correlation program based on Sunday monthly algorithms. Building thermal values chosen from menus. Outputs building heat loss coefficient and annual heating load estimate. Easily trades off building components thermal values or costs. Automatically checks <i>Super GOOD CENTS</i> (1991), WSEC (1991), or Oregon State Code (1990), Idaho Residential Energy Code, Tacoma Energy Code (1987), King County Standards and others for thermal performance compliance, figures heating system size and life cycle cost data (when costs entered). Very easy to use. Includes data for 33 Northwest locations.

Unit 8: Effective Enforcement -- Submittal, Plan Review, and Inspection

This unit offers suggestions that can help facilitate transition to the 1991 version of the WSEC version (and the new VIAQ Code). These are applicable no matter what type of occupancy is being considered. In addition, the unit provides an overview of submittal requirements for Group R occupancies, as well as a practical review of steps that can be taken to ease submittal, plan review, and site inspection for these occupancies.

Although the unit is addressed to building department personnel, it can be helpful to anyone interested in understanding the enforcement process.

IMPLEMENTING THE NEW CODE(S)

Developing accountability, technical expertise, and uniformity can significantly improve the likelihood of successful enforcement of any new building code. Here are some suggestions:

Establish Accountability

Establishing accountability within a jurisdiction is an important aspect of making any new code work. In regard to the WSEC and the VIAQ Code, this means making changes in jurisdictional Code paperwork that reflect new documentation requirements and other changes in the Energy Code. It also means publicizing these changes through the normal means: press releases, industry newsletters, and public or staff meetings. Publicity would be directed toward elected officials, department personnel, and members of the shelter industry.

Develop Technical Expertise

The higher the level of technical expertise regarding the 1991 WSEC the greater the chance of enforcement without frustration and miscommunication. Certification and

various training opportunities are available for building department personnel who enforce the code, and for members of the shelter industry, who must apply the code.

Certification. WSEC Certification of building officials is offered through a test administered twice a year by WABO. Certification formally recognizes building department personnel who have attained a high level of personal knowledge in the area of energy codes and standards. WABO's Energy Code Certification Program qualifies "Inspectors" and "Plan Reviewers."

Circuit Rider Program. The Washington State Energy Office/Energy Extension Service offers workshops on the details of the 1991 WSEC (and the VIAQ Code) for building officials and others involved in the building industry.

Workshops currently offered to building department staff include: Code Overview, Plan Review, Site Inspection, Component Performance and Design Heat Loss Calculations, and Mechanical Ventilation and Indoor Air Quality. Other topics may be offered if identified by department staff as

Unit 8: Effective Enforcement

an area of particular need. The workshops generally take 2 to 2-1/2 hours and are available upon request of your jurisdiction. In addition to training on specific technical aspects of the Code, benefits include exposure to a uniform, state-wide "interpretation" of the WSEC, and an opportunity for building officials to share common Code problems and potential solutions. Call Jim Bowman at 206/296-5636 to arrange.

Such workshops cannot take the place of in-house staff training (when the size of the building department warrants it). At in-house training meetings, staff can develop a greater understanding of the Code they must convey to builders and others. In-house training also deepens staff commitment to enforcement.

For builders and others involved in the shelter industry, WSEO offers "Shelter Industry Training" in support of local code jurisdictions implementing the 1991 WSEC. Orientation meetings will be followed by more specific technical sessions. The training will primarily cover areas of the new code that differ from the 1986 version, explain compliance options, and give local jurisdictions an opportunity to present any specific requirements. Typical training duration is 5 to 6 hours. Such workshops should reduce the amount of time spent briefing builders "one-on-one" out in the field. They can also indicate to the shelter industry that your jurisdiction seriously intends to enforce the code, that the jurisdiction is committed to educating members of the shelter industry, and that the Code is a state-wide mandate (further increasing accountability).

Joint training sessions sponsored by the jurisdiction and by local building groups are especially encouraged, since it "invests"

builders in the Code, and members are more motivated to attend. Call Bruce Carter at 206/296-5632 to arrange.

Independent Study. In addition to the Circuit Rider Program, an independent study course has been developed specifically to prepare building department personnel for the energy code certification exam. The correspondence course covers plan review and field inspection of both residential and non-residential construction. Trainees complete the course at their own pace. This course is in the process of being updated to reflect changes in the WSEC.

Hotlines and Other Resources.

Administrative and technical assistance, including several hotlines, are available through various organizations. They are listed in detail in Appendix A. Also listed are various libraries lending energy and code-related material, WSEC (and VIAQ Code) fact sheets and other related publications. Resources for information about energy-related products are included as well.

Develop Jurisdictional Uniformity

You can encourage uniform enforcement throughout the state by sharing paperwork and forms used for enforcement and by regularly discussing enforcement approaches at staff meetings within your jurisdictions and at regional meetings. Regional meetings can provide opportunities for staff of neighboring jurisdictions to discuss enforcement problems, solutions, and interpretations.

Engaging the shelter industry in regional discussions of policy and interpretations will also increase uniformity, as well as encourage cooperation and reduce local builder resistance.

PAPERWORK

Some method of documenting submittal, plan review, and site inspection is necessary to fulfill the intent of the WSEC. Consistent use of forms can aid compliance by helping to:

- ⇒ *Educate* -- Using forms may seem to take up more time, but actually can help to educate the builder in less time than it would take to explain the entire WSEC book. Forms can speed up the process by referencing Code sections that are applicable.
- ⇒ *Document* -- Forms can be used to document detailed requirements, provide a paper trail, and help to catch problems in the planning stage, before they cause more trouble in the field.
- ⇒ *Commit* -- Forms that include applicable Code requirements make sure that the requirements won't be overlooked, and make the applicant accountable. By looking "official," they help show that the intent to enforce is serious.
- ⇒ *Simplify* -- Standardized forms can help ease the process by providing written direction. They can answer the question: "Just tell me what to do."
- ⇒ *Unify* -- Forms make consistent treatment more likely. They can reduce wasted time and frustration on both the official's and the applicant's part.

Form Organization. Forms can be organized in several ways. In general, they are best organized by inspection phase or by building trade. When organized by

inspection phase, (i.e. foundation, framing, insulation, and final), there is an assumption that inspections will be combined. When based on building trade, (i.e. mechanical, building, plumbing, and electrical), there is an assumption that inspections will be separate and specialized.

WSEO Checklists. Although you are not required to use them, a series of forms have been designed by the Washington State Energy Office - Energy Extension Service specifically for use in *residential* compliance with the WSEC (and VIAQ Code). They are referenced in this unit where appropriate and samples are included in Appendix E. Because most jurisdictions combine inspections, the WSEO checklists are organized by inspection (but keep in mind that the Code does not require this approach.)

The checklists are customized for the WSEC. The ones used for a particular project will be determined by climate zone type, construction type, type of fuel, and compliance path chosen. Radon issues (such as a proposed building located in a high risk area) will also affect the forms package. (See Unit 13 of this manual.)

The checklists provide a systematic way of dealing with submittal requirements for both electric and non-electric designs (whether new construction or alterations; whether log or frame) including ventilation, design heat load, and qualification by the Prescriptive or Component Performance Paths. (It is assumed Systems Analysis compliance will be documented using computerized printouts.)

The intent is to simplify the Code enforcement process, while providing an adequate "paper trail." Using the WSEO checklists, the same set of paperwork for a

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particular project can be used for all three phases of enforcement; that is, for submittal, plan review, and inspection. The forms are intended to be self-explanatory, and include information on the requirements of a particular path. As a result, the checklists can be useful as an educational tool for the builder.

If you decide to use the WSEO checklists, make sure you have the latest edition. The samples in Appendix E are not intended for actual use. Camera-ready packages of the forms suitable for your location are available by contacting the Energy Extension Service, 1-800-962-9731.

SUBMITTAL

A complete and properly designed submittal package can enhance your effectiveness and avoid miscommunication and frustration.

In the initial contact with the applicant, try to:

- ⇒ Explain the plan review and inspection process;
- ⇒ Provide the applicant with forms to be used for compliance;
- ⇒ Explain how the forms will be used;
- ⇒ Use the forms as a tool to explain submittal requirements;
- ⇒ Provide the applicant with information on the jurisdiction's submittal requirements;
- ⇒ Provide a quick check of the plans (if available at this time; if not, try to do so at the earliest opportunity.)

Keep it Simple. Keeping the administrative process as simple as possible is an important aspect of administering the WSEC. Important new standards, including new inspection requirements and expanded prescriptive options, could get buried under a siege of paperwork. This is something to avoid. Provide only the forms that the applicant will need for the particular project being proposed. It's important to explain how you plan to use the forms. Using the WSEO checklists or similar forms can help. Figure 8.1 shows how such a form can be used in the submittal stage for a non-electrically heated frame house located in Zone 2, using the Prescriptive Path to comply.

Provide Information in Writing. It's best to provide a written copy of your jurisdiction's submittal requirements, for the applicant's convenient referral later.

Review Plans Early On. When the applicant submits documentation for the project, a quick check of the plans will assure that the applicant has included all the necessary information. Check if the plans :

- ⇒ Are complete (For example, are window schedules complete? Is every component accounted for?);
- ⇒ Are checkable (Can the plans be read and understood?);
- ⇒ Include all necessary calculations, specifications, mechanical plans, window and door schedules, and furnace sizing calculations; and
- ⇒ Include obvious errors, omissions, bad assumptions, or unique details that may require additional information.

Figure 8.1: Using the WSEO Code Checklist for Submittal

Permit # _____

'91 WSEC Residential Compliance Form**Sample****Instructions:**

1) Carefully review the requirements of each of the options below. Choose an option that best suits your dwelling design. Glazing percentage typically determines which option to choose. Your building must match the selected option requirements without exceptions or substitutions.

2) In the shaded areas on the pages that follow, make checks in the circles next to the requirements of your option (the option numbers are listed next to the requirements). Disregard components or equipment that don't apply to your project. Your permit will be processed more efficiently if you provide all of the requested information. Department staff can help you with general questions about this form.

Can't comply? If none of the Prescriptive (Chapter 6) Options are acceptable, consider the Component Performance (Chapter 5) Approach. The main advantage is flexibility to juggle individual R and U-values as long as an overall maximum value isn't exceeded. Note that the overall Component Performance requirements are no less stringent than the Prescriptive requirements. Calculations may be performed with a **Component Performance (Chapter 5) Form**, or by using an acceptable computer program such as **WATTSUN 5.2**.

Plan Review*(For official use only)*

The selected Option is appropriate for this dwelling design.

YES ☐
NO ☐

Option ____ may be a better choice.

Notes: _____

Approved by: _____

Date: _____

	OPT I	OPT II	OPT III	OPT IV	OPT V	OPT VI	OPT VII (x 2 Stories)	OPT VIII (x 2 Stories)
	☐	☐	☐	☒ 1	☐	☐	☐	☐
Furnace AFUE	.78	.78	.88	.78	.74	.78	.78	.78
H. Pump HSPF	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Glazing max:								
% of floor	10%	12%	17%	17%	17%	21%	25%	30%
U-value	0.70	0.65	0.65	0.60	0.50	0.50	0.45	0.40
Door U-value¹ (or R-value)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)
Ceilings:								
with attics	R-38	R-38	R-38	R-38	R-38	R-38	R-38	R-38
vaulted	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30
Walls:								
or above grade	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
below grade								
interior	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
exterior	R-12	R-12	R-12	R-12	R-12	R-12	R-12	R-12
Floor	R-25	R-25	R-25	R-30	R-30	R-30	R-30	R-30
Slab on grade	R-10	R-10	R-10	R-10	R-10	R-10	R-10	R-10

Footnote:

1) Glazing and door U-values may be weighted to meet the option U-value requirement.

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¹ The applicant has indicated the intention of using prescriptive option IV.

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If you can, provide this quick check while the applicant is still present. You'll catch problems when they are easier to deal with.

Prepare the Applicant for Plan Review.

At the time of permit request, the applicant must provide certain items of information. The "Quick Checklist" (below) can be helpful in summarizing for the applicant the items that must be submitted at this time. Once the plans and this information are accepted, the project is ready for plan review.

PLAN REVIEW

Plan review is an essential component in the successful inspection and completion of a construction project. The more thorough the plan review, the more information you can pass on to the builder, and the better the chance the applicant will understand the

Code requirements that affect the project. Also, the more systematic the plan review, the easier it is on you and the applicant. You can minimize notes by using reference numbers that apply to the standard forms you use. (Some jurisdictions have mechanized the process by using printed labels). Whatever the system you use, make sure it works in the field. Field personnel will be more likely to use the system (and forms) conscientiously if they have had input in designing the system.

Don't forget to use hotlines and other resources listed in Appendix A during the plan review process. Referring the applicants to these resources can save you time (and headaches later).

Figure 8.2 outlines the steps in a typical plan review.

✓✓✓ QUICK CHECKLIST OF ITEMS NEEDED AT PERMIT REQUEST ✓✓✓

Compliance Approach: Information on the method to be used to show compliance for the design. (Does the applicant plan to comply using the Prescriptive, Component Performance, or Systems Analysis path? If Prescriptive Path, which option?)

Documentation: For projects complying using Component Performance and Systems Analysis Paths, documentation of heat loss calculations. Projects using Systems Analysis may need to provide additional documentation (e.g. sun charts) if the project calls for "credits" for solar gain and thermal mass.

Drawings: Plan views, elevation views, and building cross sections (including wall, floor, slab, and roof).

Mechanical plan: Information showing location, layout, and equipment selected for HVAC and service water heating; also design heat load calculations and selected furnace size (If using the Prescriptive Path, will the applicant be able to use the prescriptive alternative to document sizing compliance?)

Window schedule: Information showing manufacturer, model number, tested U- value, and total square footage.

Door schedule: Information showing door selection and U-value. May be done on the plans in lieu of a schedule.

Compliance Review

The compliance review begins with determining the fuel type and compliance path chosen by the builder. The compliance path will determine what is required in the building envelope to meet the Code's

standard for thermal performance. The method of review will then vary, depending on the path chosen. (Make sure that all components of the envelope are included in the evaluation, no matter what compliance path is used.)

Figure 8.2: Plan Review Flow Chart

¹ Provide submittal requirements and all necessary items.

² Note corrections on plans and plan correction sheet(s). Complete plan review worksheet.

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Prescriptive Path. Builders often choose a prescriptive option for residential construction. If the applicant has completed the submittal paperwork correctly, you will be able to determine Prescriptive Compliance by checking the vertical section view for proper insulation levels and the window schedule or the plan view for glazing compliance. The ratio of glazing area to floor area should be checked to determine compliance.

Component Performance. If the builder has chosen compliance under Component Performance, a spot check of various areas should be done to assure that the areas used for compliance match those on the plans. U-values shown for compliance should be checked against the default values for similar building sections found in Code Chapter 10. Verify that heat loss calculations done conform with those required by the WSEC. Check to see if they were done properly; is the reported total heat loss the sum of all the losses? (See Unit 2 for background information on heat loss; and Unit 6 for a detailed example of Component Performance calculations.)

Systems Analysis. If Systems Analysis is chosen for compliance, the compliance printout should be checked to verify that the software used is approved for WSEC compliance. A list of suggested software can be found in Table 7.2 of this manual. If some other software has been used, check to make sure it meets the Code's modelling requirements (as discussed in Unit 7). Areas used for compliance on the computer printout should be spot checked against the plans.

General Requirements. Reviewing the plan for general compliance, that is, for meeting requirements that apply no matter what compliance path chosen, should

include a verification of insulation practices, air sealing, attic and crawl space ventilation, vapor retarders and moisture control, VIAQ requirements. (For a review of general requirements, see Unit 4; general ventilation requirements are discussed in Unit 12.)

A careful review will emphasize window compliance, since glazing is so critical to the overall building performance. (In addition to general glazing requirements provided in Unit 4, glazing requirements specific to Prescriptive Compliance are provided in Unit 5. Also, an updated SBCC listing of tested U-value information for windows is included in Appendix C.)

Mechanical Review

Review of the specified heating equipment includes checking for maximum capacity as well as minimum efficiency. (For a review of general mechanical requirements, see Unit 4; for mechanical requirements specific to non-Group R occupancies, see Unit 10. Required Design Temperatures are discussed in Unit 3. Also, see Washington State Weather Data in Appendix D.)

Sizing Review. A design heat load calculation should verify compliance with the 150% of the design heat load sizing limitation (or meets guidelines for exceptions discussed in Unit 4 of the manual.) In lieu of a design heat load calculation, heating system sizing limits may be derived by using the values found in Code Chapter 9 (if the Prescriptive Path is used for compliance.)

Verify that the design heat load calculation includes accurate area take-offs and recognizable U-values. Also check for the presence of heat loss from duct work.

Efficiency Review. The equipment must meet minimum efficiency levels set by the WSEC. To determine equipment efficiency, standard equipment references must be consulted. Combustion equipment Annual Fuel Utilization Efficiency (AFUE) can be found in the *GAMA Consumer's Directory of Certified Furnace and Boiler Ratings*. The GAMA listings are issued twice yearly,

in April and in October, and includes a water heating section. The Directory is available at a small charge. (See Appendix A for GAMA's address.)

Table 8.1 is excerpted from the gas furnace section of a typical GAMA Directory. Complete instructions are provided in the opening pages of the publication.

Table 8.1: GAMA Directory (excerpt)

Model Number	Foot Note	Type	Input Btu/hr	Heating Capacity, Btu/hr	AFUE, %
58GS025	1,2	UI	25,000	20,000	79.3
58GSC030-BB	1,8	UI	40,000	32,000	76.0
58GSC030-BB	1,2,8	UI	40,000	32,000	83.0
58GP050-AA,-BA,-CA		UI	50,000	38,000	65.3
58GP050-AA,-BA,-CA	1	UI	50,000	38,000	68.9
58GSC045-CB	1,8	UI	60,000	49,000	76.0
58GP075-AA-BA-CA		UI	75,000	57,000	65.3
58GS075-AA-BA-CA	1	UI	75,000	57,000	68.9
58GP075-AA-BA-CA	2	UI	75,000	57,000	75.4
58GS075-AA-BA-CA	1,2	UI	75,000	57,000	78.8
58SSB060-BC-CC	1,3	UI	71,000	58,000	81.6
58GSC065-CB	1,8,	UI	80,000	65,000	76.0
58GSC065-DB	1,8,	UI	80,000	65,000	76.0
58GSC065-CB-1	1,8,	UI	80,000	65,000	76.0
58SX040-CC	1,3,4,5	UN	44,000	40,000	91.3
58GSC045-CB	1,8	UN	60,000	48,000	76.3
58SSB060-BC,-CC	1,3	UN	71,000	58,000	80.9
58SSL060-BC	1,3	UN	71,000	58,000	80.9
58SX060-CC	1,3,4,5	UN	66,000	61,000	91.3

- 1 Electronic Ignition (No Standing Pilot).
- 2 Electro-Mechanical Vent Damper(s) Specified by the Furnace Manufacturer.
- 3 Power Combustion or Power Vent.
- 4 Condensing Type.
- 5 Direct Vent (Includes Venting and Combustion Air Systems).

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✓ CHANGE

Increased AFUE values for furnaces equipped with automatic flue dampers, allowed under the 1986 WSEC, are no longer allowed unless the furnace has been tested in that condition and the rating appears in the GAMA directory.

Heat pump equipment efficiency may be verified in the *ARI Directory of Certified Heating and Cooling Equipment*. Table 8.2 is excerpted from the ARI Directory. Note

that manufacturers' model numbers for both inside and outside coils are required to check compliance. ARI directories are updated and published twice yearly. Published by the Air Conditioning and Refrigeration Institute, they are available without charge on a regular and automatic basis to jurisdictions upon receipt of a written request. (See Appendix A for the Institute's address.)

VIAQ Code Compliance. As part of the mechanical review, you will be checking for

Table 8.2: ARI Directory (excerpt)

Unitary Systems Manufacturers										
ARI STANDARD RATINGS										
Foot Note(s)	Model Designation	Cooling		High Temperature		Heating		Low Temperature		Sound Rating (dbs)
		Capacity (MBtuh)	Btuh/ Watt	Capacity (MBtuh)	COP 47*	HSFF Btuh/ Watt	Capacity (MBtuh)	COP 17*		
CARRIER AIR CONDITIONING (CONTINUED)										
Carrier North American Operations										
TYPE:	HRCU-A-CB	SEER								
	Outdoor Unit	Indoor Unit								
	38QNO1532	40DO014	12.0	7.95	12.4	2.38	5.30	6.9	1.58	7.8
	38QNO1532	40AQ018	13.0	8.50	13.3	2.68	5.85	7.3	1.68	7.8
	38QNO1532	40DO018	13.0	8.40	13.1	2.58	5.75	7.3	1.68	7.8
	38QNO1532	40AQ024	13.4	8.60	13.5	2.72	5.95	7.4	1.70	7.8
	38QNO1532	40DO024	13.5	8.95	13.2	2.70	5.95	7.2	1.72	7.8
	38QNO1532	40RC018	13.8	9.30	13.1	2.78	6.10	7.1	1.78	7.8
	38QNO1833	40AQ018	16.5	7.85	17.5	2.70	6.05	10.1	1.90	8.0
	38QNO1833	40DO018	16.7	7.90	17.2	2.60	6.00	10.0	1.84	8.0
	38QNO1833	40DO024	17.2	8.00	17.6	2.70	6.10	10.1	1.90	8.0
	38QNO1833	40AQ024	17.3	8.00	17.8	2.70	6.15	10.1	1.90	8.0
	38QNO1833	40RC018	17.4	8.00	17.6	2.70	6.10	10.2	1.90	8.0
	38QNO1833	40RC024	17.6	8.05	17.8	2.70	6.20	10.2	1.90	8.0
	38QNO2430 31	40AQ024	21.6	7.85	25.0	2.84	5.90	13.4	1.78	8.0
	38QNO2430 31	40DO024	22.0	8.15	24.6	2.70	6.00	13.2	1.78	8.0
	38QNO2430 31	40RC024	22.4	7.85	25.2	2.52	5.80	13.4	1.68	8.0
	38QNO2430 31	40AQ030	22.6	8.10	25.4	2.72	5.95	13.6	1.80	8.0
	38QNO2430 31	40RC030	22.6	8.10	25.4	2.52	5.80	13.6	1.68	8.0
	38QNO2430 31	40DO030	23.0	7.95	26.0	2.74	6.05	14.0	1.78	8.0
	38QNO3033	40RC030	29.0	8.05	32.0	2.80	6.05	18.0	1.80	8.2
For explanation of FOOTNOTES: * = WAST * = 1" *** Section F page F.1										
TYPE:	HRCU-A-CB	SEER								
	Outdoor Unit	Indoor Unit								
	38QNO3033	40AQ030	29.0	7.95	32.4	2.72	6.15	18.4	1.78	8.2
	38QNO3033	40DO030	29.6	7.90	32.8	2.68	6.10	18.7	1.68	8.2
	38QNO3033	40AQ036	30.1	8.10	32.8	2.80	6.10	18.6	1.82	8.2
	38QNO3033	40GB GH036	32.0	8.10	34.0	2.88	6.15	19.0	1.90	8.2
	38QNO3033	40AQ036	32.6	8.20	34.4	2.80	6.20	19.8	1.96	8.0
	38QNO3033	40GB GH042	34.4	8.50	35.0	2.90	6.40	20.2	2.02	8.0
	38QNO3033	40GB GH036	35.0	8.60	35.2	3.00	6.65	20.2	2.06	8.2
	38QNO4031	40GB GH042	41.0	7.90	45.0	2.76	6.45	26.2	2.06	8.0
	38QNO4031	40GB GH048	41.5	8.30	45.0	2.80	6.45	26.2	2.02	8.0

compliance with the VIAQ Code along with compliance with the WSEC. Keep in mind that VIAQ standards are new, and many builders will be unfamiliar with them. For more detailed information on general and occupancy-specific VIAQ Code requirements, see Units 12, 13, and 14.

Floor plans should reflect the location and manufacturer of source-specific and whole-house ventilation equipment, including the fresh air intake(s). Location and type of automatic control for the whole house system should be noted. Duct work runs and insulation (particularly for ventilation equipment) should also be noted. This assists both the field inspector and the builder if the duct runs are long and appear as if they might not conform to the requirements of VIAQ Code Table 3-3. Note insulation levels for fresh air inlet ducts running in heated space if the builder elects the integrated forced air furnace/ventilation option.

Airflow and sone ratings for ventilation equipment can be verified using the fan list in Table 8.3 (next page), or by checking published manufacturers' specifications. The Home Ventilating Institute's *Certified Products Directory 11d*, can also be used to check sone ratings and in many cases, airflow ratings. (The HVI Directory can help you when determining if the design meets the VIAQ Code's performance standards, but won't be able to tell you if the fan meets VIAQ Code prescriptive airflow ratings. See discussion of this issue in Unit 13, "Prescriptive Standards of the VIAQ Code.")

Plumbing Review

Plumbing considerations in plan review include water tank efficiency, pipe insulation, and water conservation

measures. Water tanks should meet the requirements of the National Appliance Energy Conservation Act of 1987 (NAECA). (For general plumbing requirements, see Unit 4. For requirements specific to non-Group R occupancies, see Unit 10.)

✓ NOTE

Although the Code requires that water tanks be labelled as meeting NAECA requirements, current industry practice does not include such labelling. Since the NAECA requires that all appliances manufactured after July 1, 1991 meet its requirements, it is reasonable to assume that appliances manufactured since that date meet the WSEC as well.

Plan Review Checklist

Using the same checklist completed for submittal can help guide the plan reviewer through the process and can assure uniformity, accuracy, and even decrease review time. Figure 8.3 shows how the WSEO checklist used for submittal can be used at the plan review stage. In this illustration, the mechanical compliance portion of the checklist is used. The building official compares the plan with the information provided in the original submittal. The same example used in Figure 8.1 (a non-electric home located in Zone 2, using the Prescriptive Path to comply) is used.

The checklist can be used to identify the component values that must be met. (This can be useful for field inspectors as well. Notes made on a completed plan review checklist can be carried into the field by the inspector and used during the inspection process.)

Unit 8: Effective Enforcement

Table 8.3: Fans Listing Airflow at 0.25" water gauge (w.g.)

This list is not intended as an endorsement of any specific product, nor does it list all fans that may meet the requirement.

Manufacturer	Model No.	Sone Rating	Cfm (at .25" w.g.)
Airmart	2584*	2.5	82
	2511*	2.5	95
Broan	360†	1.5	90
	S90†	1.5	84
	362	2.0	178
	684	2.5	65
	S130	2.5	109
	S120L(L)	2.5	107
Dayton Electric	4C833*	2.2	85
	4C714*	2.3	158
Fasco Industries	710†	1.3	85
	761	2.0	60
	763	2.5	81
	768	2.5	80
Kanalflokt, Inc	KK100†	1.4	103
	KK200†	1.5	194
NuTone	QT-80†	1.5	62
	QT-200	2.0	175
	QT-140L(L)	2.0	110
	QT-110	2.5	96
	QT-150	2.5	115
	671	2.5	77
Penn Ventilator	Z6†	1.3	85
	Z5†	1.5	95
	ZT	2.2	85
	ZJ1	2.3	158
Reversomatic	EB55*	2.0	53
	B60	2.3	53
	QB80	2.4	53

* indicates a heat-light-vent combination unit, (L) indicates a light-vent combination unit.

† indicates that the fan meets sone rating requirement for wholehouse fan mounted at the building envelope.

Other fans exceeding 1.5 sones may be used as wholehouse fans if they are remotely mounted more than 4 feet from the pick up grill.

Figure 8.3: Using the WSEO Checklist for Plan Review

COMPLIANCE REQUIRED

2

1991 WSEC RESIDENTIAL COMPLIANCE FORM

INSPECTION APPROVED

3

IMPORTANT: Please supply information in the shaded boxes and check the appropriate circles. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

INSULATION PHASE

1

Walls, including rim joists, shall be insulated without compression to R-19 (All Options, Table 6-4).

27

Skylight wall insulation is installed and equivalent to the required wall R-values above.

28

Interior below grade wall insulation shall be R-19 (All Options, Table 6-4).

29

Exterior below grade wall insulation, if not insulated on the interior, shall be R-12 (Table 6-4).

30

Exterior slab on grade insulation, if not located on the interior, shall be R-10 (Table 6-4).

31

Exterior Slab or wall insulation shall be approved for below grade use.

32

Vaulted ceilings shall be insulated without compression to R-30 (All Options, Table 6-4).

Vapor retarders shall be installed toward the warm surface as represented below (502.1.6):

Select one option for floors, walls, and appropriate ceilings:

Floors:

☒ Plywood w/ exterior glue

☐ Poly (≥ 4 Mil)

☐ Backed batts

Walls:

☒ Poly plastic (≥ 4 Mil)

☐ Face-stapled, backed batts

☐ Low-perm paint

Ceilings:

☒ Not required where ventilation space averages > 12" above insulation.

☐ Face-stapled backed batts

☐ Poly plastic (≥ 4 mil)

☐ Low-perm paint

Heating system efficiency and sizing requirements shall be met as represented below (S. 503):

33

Heat pump efficiency, as listed in the ARI directory, shall be met as follows:

☐ Split system, air source heat pump: HSPF ≥ 6.8, COP ≥ 3.0.

☐ Single package, air source heat pump: HSPF ≥ 6.6, COP ≥ 3.0.

☐ Water source heat pump: COP ≥ 3.8.

☐ Ground source heat pump COP ≥ 3.0.

34

Central heating system AFUE rating, as listed in the GAMA Directory, shall be:

☒ ≥ .78 (Options I, II, IV, VI, VII, VIII)

☐ ≥ .88 (Option III)

☐ ≥ .74 (Option V)

37

Non-central, combustion heating systems shall have intermittent ignition.

38

Maximum heating system output (150% of design heat load) is 65,000 KW or BTU/hr.

39

High efficiency forced-air furnace (≤ 56,000 BTU/hr. output) may exceed 150% of DHL because: ☐ GAMA listed AFUE is ≥ 78 + 1 per each 5000 BTU/hr output that it exceeds the DHL.

Heating system requirements will be met with following system (S.503.4.1.1):

Mr. HOT STUFF Model # XYZ Max. output 65,000 KW or BTU/Hr.

Type GAS HSPF _____ and/or COP _____

WSEC Insulation phase requirements:

Inspected by: _____ Date _____

FINAL PHASE

40

Envelope Floors shall be insulated without compression, and with support ≤ 24" O.C. to (Table 6-4):

☐ R-25 (Options I, II, III)

☒ R-30 (Options IV, V, VI, VII, VIII)

41

Door systems shall meet U.40 (All Options, Table 6-4).

Door types are (1) _____ (2) _____ (3) _____

42

Non-vaulted, attic ceilings shall be insulated without compression to R-38 (All Options, Table 6-4)

43

Exposed foam insulation shall be protected with metal or plastic flashing or equivalent material that extends below grade (S. 502.1.4.8).

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- 1 Right column indicates house as proposed by builder.
2 Checks in column (far left) indicate required compliance as determined by plan reviewer.
3 Inspection column (center) remains unchecked until verified by field inspection.

A thoroughly reviewed and noted set of plans can greatly reduce confusion, frustration, and costly mistakes in the field. Remember, for complicated or "exotic" projects, or whenever you are in doubt about the conditions or practices being proposed, the WSEC gives the building official the authority to require that plans be submitted and stamped by a design professional licensed in the state.

SITE INSPECTION

The real measure of WSEC compliance lies in the site inspection. Inspection provides visual verification that materials are provided and installed in accordance with the Code.

By now the WSEO checklist used to process submittal and plan review (if you've chosen to use it) has become a "customized" inspection list. It will be clear to the inspector what the requirements are, and what was intended in the plans to meet those requirements. The inspector will be able to compare the permitted details to what he sees in the field. It is important to note that there may be differences between the component planned, and the component actually installed. These differences are not significant unless they affect the thermal performance of the component. Substituting a different brand, for instance, is not important, if the thermal performance of the component matches that in the original proposal.

Figure 8.4 demonstrates how the inspector can use the WSEO checklist out in the field. The same house used in the previous examples is shown here. In this case, the window portion of the checklist is illustrated.

The WSEO checklist can act as a reminder of items to verify and to the contractor of when to call for an inspection. It is the responsibility of the permit holder to schedule required inspections.

Timing is Everything. Keep in mind that WSEC and VIAQ requirements add to the number of items to be checked on normal UBC inspections. Additional time should be allowed for verification of energy code items on routine UBC visits. An additional wall insulation inspection is required as well, and should be scheduled. Figure 8.5 shows the typical flow of inspection procedures.

The inspections required for the WSEC are as follows:

Foundation/Slab: This inspection should be done after performing the following -- plumbing groundwork, electrical groundwork, footings/reinforcement/placement, sub-slab gravel for radon mitigation (required in higher radon risk areas only) and sub-slab (exterior below-grade) insulation.

The energy code inspection should verify the required sub-slab insulation, thermal breaks in slabs that run between heated and unheated areas, below-grade wall exterior insulation, and the radon gravel and soil gas membrane, if radon prescriptive requirements are called for.

Framing: This inspection should be done after the following are completed -- rough-in plumbing, rough-in mechanical, rough-in electrical, structural framing, and energy framing requirements.

Figure 8.4: Using the WSEO Checklist for Site Inspection

1991 WSEC RESIDENTIAL COMPLIANCE FORM

**COMPLIANCE
REQUIRED**

**INSPECTION
APPROVED**

IMPORTANT: Please supply information in the shaded boxes and check the appropriate circles. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

FRAMING PHASE (Continued)

Sample

Glazing/skylights by type

See the Washington glazing directory

No.	Manufacturer	Frame material	# Layers	Model #	Area (Ft ²)	Uo value	Tested?
1	Window World	Aluminum	2	W-100	100	U .35	Yes ☑
2	Skyline Windows	Aluminum	2	S-200	40	U .35	Yes ☑
						U ____	Yes ○
						U ____	Yes ○
						U ____	Yes ○
						U ____	Yes ○
						U ____	Yes ○
						U ____	Yes ○
						U ____	Yes ○
						U ____	Yes ○
10 Single Glazing (No more than 1% of heated floor area before doubling, S. 602.7.2)						U ____	Yes ○
Type:	No:	Area:	X 2			U ____	Yes ○
Type:	No:	Area:	X 2			U ____	Yes ○
11 Untested Glazing (Use only default U-values in Chapter 10, S.1006.1)							
Type:	No:	Area:				U ____	
Type:	No:	Area:				U ____	
TOTAL GLAZING AREA (Add entire column) →							

Maximum allowed glazing area(S. 602.7.1) is derived by taking the the total glazing area of 232 Ft² and dividing by the total conditioned floor area of 1740 Ft². Multiply this number by 100. This value can't exceed the glazing percentage for your selected option:

☐ ≤ 10%(Option I)
 ☐ ≤ 12%(Options II)
 ☒ ≤ 17%(Option III, IV, V)
 ☐ ≤ 21%(Option VI)
 ☐ ≤ 25%(Option VII)
 ☐ ≤ 30%(Option VIII)

Glazing % = 13.3%

13 Glazing documentation Insufficient, U-values shall be justified by Mr. testing report.

Glazing air leakage(S. 502.4.3 (c)) measures shall be met as follows :

- Fixed site-built: stops with sealant.
- Operating site-built: weatherstripped with closer

Concealed Insulation shall be placed: 1) Behind shower/tub 2) Behind partition studs/corner

Standard air leakage caulking is complete and installed in the following locations (S. 502.4.3):

- Between Sole plate/subfloors
- Wiring/plumbing/duct register penetrations
- Rim joists/mud sills (heated lower floors)
- Partition stud penetrations
- Light fixture/ flue penetrations
- Around window and door frames

Page 3 of 5

Figure 8.5: Typical Inspection Flow

Footnotes denote other energy-related inspections occurring at the particular inspection.

1 Ground cover

2 Under-slab insulation

3 Window size/type, infiltration control/caulking, mechanical sizing

4 Wall insulation, vapor retarder

5 Ceiling/crawlspace, gaskets or weatherstripping

The energy code inspection should look for compliance with air sealing, attic ventilation baffling, glazing area and efficiency, heating equipment, crawl space ventilation, recessed lighting and ventilation and indoor air quality requirements.

Insulation: This inspection should be done after insulation is installed in walls, but *before* drywall goes up.

This energy inspection should verify insulation in the walls (including interior below-grade insulation), vapor barrier placement, and heating system efficiency (if not verified on framing). Contractor self-certification of energy code compliance for insulation is no longer acceptable. Wall insulation must be verified by inspection before closure of the wall. If the design

includes vaulted ceilings, they should be inspected at the same time for insulation compliance.

Final: This inspection should be done after the following are completed -- finished plumbing, mechanical, electrical, and final energy requirements.

The final energy inspection should verify floor insulation, ceiling insulation (non-vaulted ceilings), doors, crawl space ground cover/vapor retarder, plumbing insulation, furnace and ventilation system operation, HVAC controls, water heater compliance, water conservation requirements, solid fuel combustion equipment air requirements, and radon consumer information and radon monitor.

Unit 9: Energy Code Requirements for Non-Group R Occupancies

Units 9, 10, and 11 of this manual present WSEC requirements specific to non-Group R occupancies (referred in the Code as "other than Group R occupancies"). They include requirements covering the building shell (this unit), mechanical and service water systems (Unit 10), and electrical power and lighting (Unit 11). These requirements are sometimes called the "commercial code," but in actuality apply to buildings that are not commercial, strictly speaking, such as schools, industrial facilities, jails, garages, and hospitals. These buildings may include living quarters, but nonetheless are covered by the "commercial code."

In general, the Code's building shell requirements are less stringent for non-Group R occupancies than for residential or Group R occupancies, while the mechanical systems and the electrical power and lighting requirements are significantly more complex.

In addition to the Code's requirements specific to non-Group R occupancies, there are general requirements that apply to all occupancies, regardless of the compliance path chosen. These are covered in Unit 4 of this manual. For example, air leakage control requirements as outlined in Unit 4 will apply to both residential *and* "commercial" buildings. General requirements presented in Unit 4 include two construction practices that are typically more common in "commercial" construction, but are not distinguished in the Code as to their application. These include metal framing and the use of ceiling return air plenums. See Unit 4 for a discussion of these requirements. Additional information on metal framing is also provided below.

For WSEC requirements regarding alterations and repair of existing buildings, including historic, multi-use, and others, see Unit 1 of this manual.

✓ CHANGE

In general, the 1991 version of the WSEC contains very few differences from the previous version in requirements specific to non-Group R occupancies. The main exception is the upgrading of ventilation requirements for these occupancies. (As of 1991, these requirements are no longer in the body of the WSEC, but part of a new stand-alone VIAQ Code; see Unit 14.)

The "commercial code" is undergoing review at this time, however, through a process authorized by the legislature. New requirements for non-Group R occupancies are expected to be published some time in the future.

✓ NOTE

A complete understanding of requirements applicable to non-Group R buildings, would minimally include a reading of Units 1 through 4 of this manual, Units 9 through 12, and Unit 14 (which covers the VIAQ Code's requirements for "commercial" buildings).

THERMAL PERFORMANCE OF THE BUILDING ENVELOPE

This unit presents building shell or envelope requirements for non-Group R occupancies. As with residential buildings, there are three paths available to show compliance with the Code's thermal performance requirements for the building envelope: Prescriptive, Component Performance, or Systems Analysis.

PRESCRIPTIVE REQUIREMENTS

Requirements for non-Group R occupancies using the Prescriptive method of compliance are established in Code Table 6-7 (see Appendix B).

Building designs complying under the Prescriptive Path must have a minimum level of installed insulation in walls, ceilings or roofs, and floors, depending on the climate zone in which the building will be located. Code Table 6-7 lists minimum acceptable R-values for various components. These values are for the total nominal or "face value" of the insulation that is installed. They do not represent the value of the total assembly, and thus do not include the R-value of finish materials, or air films, for example.

✓ CHANGE

In the 1986 WSEC, the Prescriptive method was restricted to buildings with less than 10,000 square feet gross floor area. As of the 1991 WSEC, this is no longer the case.

In non-Group R occupancies, the maximum glazing area is a percentage of the gross exterior wall area. This is different from the WSEC's requirements for residential buildings, which figures maximum glazing

area as a percentage of the heated floor area. The glazing must be insulated glass with either a minimum 1/2" air space or an approved storm sash. When doors are 50% or more glazing they are included in the glazing area. Doors may be single glazed, but then that area is counted twice in figuring the glazing percentage. (For more information and an example of this calculation, see "Doors and Windows," in Unit 5, which explains the Prescriptive Path for residential occupancies.)

COMPONENT PERFORMANCE

Using the Component Performance approach allows builders to trade higher insulation levels of one component for lower values in another part of the building. The resulting average heat loss rate per square foot per degree of temperature difference (U_o) of the proposed design is then compared to that of the same building built to the Code component levels, in other words, to the standard design. As long as the proposed design has a heat loss rate per square foot equal to or lower than the standard design, the building complies with the Code's thermal requirements. (See Unit 2 for a more detailed discussion of U_o -values.)

Component Performance Tables. Tables at the end of Code Chapter 5 provide the minimum or maximum values for various components. These values are used to figure the U_o . Code Table 5-2 [Section 531, revised edition] states the target U_o for commercial or non-Group R structures. Code Table 5-2 is included in this manual in Appendix B.

Unlike the Prescriptive Approach, the Component Performance path distinguishes

between non-Group R occupancies of three stories or less and those over three stories. This is reflected in Code Table 5-2, which provides different target U_o values based on this variable. This distinction is based on the fact that the larger the building, the less direct the relationship between its energy consumption and the envelope.

Equations. Equations for use in computing trade-offs are provided at the end of Section 502. Equations 4 and 5 are for "other than Group R" occupancies. Equation 2 is used for *all* occupancies.

Equation 4 provides information about the potential thermal performance of the proposed design as if it were built with

target U -values, that is, about the standard design.

The equation calculates the "target" U_o allowed by the Code. This is the average heat loss per hour per degree Fahrenheit per unit area ($\text{Btu/hr-}^{\circ}\text{F-ft}^2$) that would take place in the building, if each component is built with target U -values specified by the Code in Table 5-2.

This fairly simple calculation requires only the gross floor, wall, and ceiling areas, and the perimeter length of the slab.

Equation 2 provides information about the U -values of each component in the proposed design. This information is then used in calculating Equation 5.

✓ EQUATION 4:

$$U_o = \frac{U_w A_w + U_f A_f + U_c A_c + F_s P_s}{A_w + A_f + A_c + P_s}$$

where:

U_o = the target combined thermal transmittance of the gross exterior wall, floor, and roof/ceiling assembly area.

U_w = the thermal transmittance value of the gross wall area as found in Code Table 5-2.

A_w = gross wall area, including glazing, doors, and below-grade wall, as well as above-grade opaque wall area.

U_f = the thermal transmittance value of the floor area found in Code Table 5-2.

A_f = floor area over unconditioned space.

U_c = the thermal transmittance value of the ceiling area found in Code Table 5-2.

A_c = ceiling area.

F_s = concrete slab component F -value found in Code Table 5-2

P_s = lineal feet of concrete slab perimeter.

Unit 9: Non-Group R Occupancy Energy Code Requirements

Equation 2 has already been discussed in Unit 6 of this manual, which covers the Component Performance Approach for residential buildings. See that discussion for more detail.

Equation 5 provides information about the potential thermal performance for the proposed design with component U-values as they are intended to be built. This

✓ Equation 2:

$$U = \frac{1}{r_o + R_1 + R_2 \dots r_i}$$

✓ NOTE

It is important that these two equations include all the same factors. This is confusing in the Code. Specifically, Equation 4 as printed in the Code applies the values from Code Tables 5-2 and 5-3 only to "opaque above-grade wall," yet the tables themselves say the value includes glazing. In order to keep the two equations on equal footing, it is essential that the U-value and area used in Equation 4 cover the gross wall area, including glazing, doors, and below-grade walls, as well as above-grade opaque wall. To be clear and consistent, Equation 5 should identify opaque above-grade wall with a different designation, such as U_{ABG} and A_{ABG} , for "above-grade wall." Otherwise any comparison between the two as they stand will unfairly penalize the proposed building. Make sure below-grade wall is accounted for in the standard design equation if it is included in the proposed design.

✓ Equation 5 (modified for clarity):

$$U_o = \frac{U_{ABW}A_{ABW} + U_{BGW}A_{BGW} + U_GA_G + U_{FA}F + U_{RC}A_{RC} + U_{CC}A_{CC} + U_{DA}D + F_sP_s}{A_{ABW} + A_{BGW} + A_G + A_F + A_{RC} + A_{CC} + A_D + P_s}$$

Where:

U_o = the combined thermal transmittance of the gross exterior wall, floor, and roof/ceiling assembly area.

U and A on the right hand side of the equation stand for the heat loss rate and the area, respectively, of each component in the building, as designated by the subscript.

The subscripts, in order of appearance above are:

- ABW = above grade opaque wall.
- BGW = below-grade opaque wall.
- G = glazing (window or skylight).
- F = floor.
- RC = roof/ceiling.
- CC = cathedral ceiling.
- D = opaque door.
- S = concrete slab

Values used for slabs are noted differently because they are correlated with the perimeter length of the slab rather than a square foot area.

- F_s = concrete slab component F-factor.
- P_s = lineal ft. of concrete slab perimeter.

NOTE: Where more than one type of wall, window, roof/ceiling, door, and skylight is used, the U and A terms for those items shall be expanded into sub-elements such as:

$$U_{W1}A_{W1} + U_{W2}A_{W2} \dots \text{etc.}$$

thermal performance is then measured against the target thermal performance determined in Equation 4. (The design is in compliance if potential thermal performance is the same as or better than expected using target U-values, that is, if the U_o for the proposed design, is the same as or less than the target U_o value for the standard design.)

The equation for the proposed U_o is slightly more complicated, because it must reflect each unique type of floor, wall, or ceiling construction. That is, if the building has

both an insulated flat ceiling and a cathedral ceiling, the different ceiling areas must be identified separately in the equation. If the ceiling is all of one type (e.g. flat), but has areas that use different materials, those areas must also be identified separately.

Example. Figures 9.1, 9.2a, 9.2b, and 9.2c walk you through the equations, using an example of a "spec office building." The proposed design is presented in Figure 9.1. Figures 9.2 (a, b, and c) illustrate the calculations completed for compliance.

Figure 9.1: "Spec Office Building"

- B-2 Office Building
- 3 Stories - 10 feet floor-to-floor
- R-7 Slab-On Grade Floor
- Windows
 - 24% of Gross Wall Area
 - Aluminum Frame
 - 1/2 Inch Air Space
 - No thermal Break
- Walls
 - 2 X 4 Wood Frame
 - R-11 Batt Insulation
 - 4 Inch Face Brick Exterior
 - 5/8 Inch Drywall Interior
- Roof
 - R-30 Rigid Insulation
 - 5/8 Inch Plywood Deck
 - Built-Up Roof

Unit 9: Non-Group R Occupancy Energy Code Requirements

Figure 9.2(a): U/UA Calculation - Spec Building/Wall Element

Washington State
Energy Code 1991
(non-residential)

Form 2c

ENVELOPE U-VALUE WORKSHEET

Project I.D. "SPEC" OFFICE

Element: WALL

Sketch of element:

Framing Factor (if applicable)=

Note: Make copies of this form for every building element.

Material	Thickness (inches)	R-Value per Inch	R-Value Solid	R-Value Cavity
OUTSIDE Air Film	—	—	0.17	0.17
FACE BRICK	4"	0.11	0.44	0.44
BATT INSULATION	3.5"	—	—	11.00
WOOD FRAMING	3.5"	1.25	4.38	—
DRYWALL	5/8"	0.90	0.56	0.56
INSIDE Air Film	—	—	0.68	0.68
Sum of R-Values			6.23	12.85
U=1/R			0.161	0.078
Framing Factor			.20	
Solid U-Value x Framing Factor			a) 0.0322	
U=1/R				
(1 - Framing Factor)				.80
Cavity U-Value x (1 - Framing Factor)				b) .0624
Sum of Adjusted U-Values (a+b)				.095
Area of Element (Net area after openings such as doors, windows, and skylights have been subtracted)				6840

Note: Effective R-Values may be used for framed walls from the handout of framing R-values instead of using the framing factor calculation.

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Figure 9.2(b): U/UA Calculation - Spec Building/Roof Element

**Washington State
Energy Code 1991
(non-residential)**

Form 2c

ENVELOPE U-VALUE WORKSHEET

Project I.D. "Spec" Office

Element: Roof

Sketch of element:

Framing Factor (if applicable)=

Note: Make copies of this form for every building element.

[illegible]

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Figure 9.2(c): U/UA Calculation - Total/Targeted & Proposed

STANDARD BUILDING DESIGN

Area of Wall (A_w) = $300 \times 30 = 9000 \text{ ft}^2$
Area of Roof (A_r) = $50 \times 100 = 5000 \text{ ft}^2$
Perimeter of Slab (P_s) = $(2 \times 50') + (2 \times 100') = 300 \text{ ft}$

Inserting U-values from Code Table 5.2 and the dimensions above into Equation 4:

$$U_o = \frac{(0.25 \times 9000) + (0.035 \times 5000) + (0.56 \times 300)}{9000 + 5000 + 300}$$
$$= 0.181 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

PROPOSED BUILDING DESIGN

Area of Wall (A_w) (less 24% glazing) = $.76 \times 9000 = 6840 \text{ ft}^2$
Area of Glazing (A_g) (24%) = $.24 \times 9000 = 2160 \text{ ft}^2$
Area of Roof (A_r) = 5000 ft^2
Perimeter of Slab (P_s) = 300 ft
U-Value for Specified Glazing (U) = $0.72 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$

Inserting these values and the calculated U-Values (Figures 9.2 (a) & (b)) into Equation 5.

$$U_o = \frac{(0.095 \times 6840) + (0.72 \times 2160) + (0.031 \times 5000) + (0.56 \times 300)}{9000 + 5000 + 300}$$
$$= 0.177 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

PROPOSED (U_o) is less than the STANDARD (U_o)

Therefore the PROPOSED BUILDING DESIGN COMPLIES.

Glazing U-Values. The Code identifies standard procedures for determining glazing and door U-values. The standard procedure involves testing according to one of the following tests: AAMA 1503.1 or either ASTM C236-87 or C976-82. In the latter two cases, the test must be conducted under winter horizontal heat flow conditions using a 15 mph wind speed perpendicular to the exterior surface of the glazing. [Section 502.1.5.1] The Code Revisor is currently

reviewing a proposal including an exception which will allow ratings by the National Fenestration Rating Council (NFRC) procedure (adopted June 28, 1991) if model size AA is tested and listed.

There is an exception, however, for commercial or non-Group R occupancies. Code Section 505.1.5.2 allows alternative glazing U-values to be taken from Table 13 of Chapter 27 of the 1989 ASHRAE

Handbook of Fundamentals, or they can also be calculated by a procedure given in that same chapter. Chapter 22 of ASHRAE *Fundamentals* provides an acceptable table of door U-values (Table 6). These tables are excerpted in Appendix C.

Alternative Wall U-Values. The Code allows maximum U-values of walls in buildings of three stories or less to be increased to those of buildings over three stories (as given in Code Table 5-2) if:

- ⇒ The mechanical supply of outside air and exhaust of building air is automatically shut off and the duct closed for at least eight hours a day when the building is not occupied; or
- ⇒ If the heating system meets a minimum level of efficiency, which varies according to the heating fuel [Section 502.3.3]. In the case of gas or oil furnaces or boilers, the minimum combustion efficiency for a central system is 85%. For room and space heaters it is 80%. For heat pumps, the coefficient of performance (COP) must not be less than those in Code Table 5-7 (See Appendix B). Additionally a heat pump must meet the other conditions of Section 503.4.2.
- ⇒ If both the above criteria are met, the Code allows the wall U-values to increase by another 0.05.

The Code further allows that walls with a weight of 30 lb/ft² or greater may increase the calculated value of the thermal resistance by 25% for determining compliance as long as the heating and cooling set point temperatures in the conditioned spaces are separated by at least 5°F. The temperature control must prevent

new energy from being used to heat above or cool below the respective set point temperatures. The 25% increase only applies to masonry walls exposed to inside air as measured face to face, without including the thermal resistance of air films on either face or any additional exterior wall elements. If the wall is made from hollow core masonry block, the cores must be filled with grout, concrete, or insulating material of a minimum 2.25 R-value.

Metal Framing. The heat flow through metal-framed components is just different enough that most of the standard assumptions result in a somewhat inaccurate number to represent the heat loss rate. This in turn creates three possible problems:

- ⇒ Heating and cooling load calculations result in inappropriate equipment selection (usually too small);
- ⇒ Computer modeling done for energy studies seriously misstate the behavior of the building; and/or
- ⇒ Optimistic energy savings projections based on building shell improvements overestimate the benefits and lose credibility for energy conservation projects.

Since building components are usually not made all of one material, we need a way to estimate the relative contribution of each different material to the overall heat loss rate. As discussed in Unit 4, we normally identify the separate parallel heat flow paths (i.e. through the cavity or through the framing); determine the R-value of each layer in the path; derive the U-value of the whole path; then average the whole assembly according to proportionate areas for each Uo path. While not perfectly

Unit 9: Non-Group R Occupancy Energy Code Requirements

accurate, this is a satisfactory procedure for the most part. It breaks down, however, when a highly conductive material, such as a metal stud, makes up a path. In this case there is significant heat flow laterally, or sideways, as well as straight out through the component. That is to say, the heat flow through the area where the metal stud exists is much greater than the proportionate area would suggest.

If the component uses metal framing, but has non-metal surfaces, the simplest, and perhaps least precise, way to compensate for this is to multiply the insulation of the layer of the wall with metal framing by correction factors provided in Code Section 502.1.1 (and repeated below in Table 9.1; see Example below). There is another

Table 9.1: Default U-values for Metal Framing

Wall Framing	Cavity Insulation	
	R-11	R-19
2 x 4 @ 16" o.c.	5.50	-----
2 x 4 @ 24" o.c.	6.60	-----
2 x 6 @ 16" o.c.	-----	7.60
2 x 6 @ 24" o.c.	-----	8.55

method to correct for metal elements in the wall, called the "Zone Method." It is more complex, and explained in detail in Appendix C.

Figure 9.3: Using Metal Framing Correction Factors

If we apply the correction factors to a metal framed wall with R-11 insulation, 5/8" drywall on the interior and 4" brick on the exterior, metal studs increases the heat loss of the wall 44% over a similarly built wall with wood studs or 75% over the same wall without accounting for the metal studs.

$$\begin{aligned}
 Q &= U_o \times A \times (T_i - T_o) \\
 &= 0.136 \times 100 \times (70 - 0) \\
 &= 952 \text{ Btu/hr}
 \end{aligned}$$

SYSTEMS ANALYSIS

The final approach to show compliance takes the heat loss comparison of Component Performance one step further. The proposed building's annual space heating/cooling and water heating energy use (in kWh/ft²/yr or Btus/ft²/yr) is compared to annual energy use of the standard building. This analysis not only considers the losses of the building, but also any energy gains that occur. The "gains" include internal gains from processes, occupants, solar, or equipment. Energy contributed by renewable energy sources (such as active or passive solar systems) may be excluded from the proposed building load. The proposed building may also benefit from improved heating or cooling equipment with efficiencies beyond the required code levels. In this sense, Systems Analysis considers the total energy use of the building, including *all* its systems. [Section 401.1]

This analysis is complicated enough to require a computer to perform it. The analysis is done for both the standard design and the proposed design. The calculation procedure in the analysis must simulate the performance of the building and its operating systems through a full year cycle (8,760 hours of operation). [Section 402.4] This must be detailed enough to evaluate the following criteria [Sections 402.4-402.5]:

- ⇒ Hourly data for the building's location for climate factors such as temperatures, solar radiation, wind, and humidity. The applicant must select data that will give long-term average performance rather than simply choosing statistics from a random historic year. In this sense, it will represent annual seasonal

variations. Typical Meteorological Year (TMY) data for the closest TMY site is preferred, unless some other approved, more suitable data is available.

- ⇒ All the characteristics of the building that affect its thermal transfer and storage capacity; including its orientation, size, shape, mass (and thus storage capacity), as well as air, moisture, and heat transfer characteristics.
- ⇒ Details about how the building is operated in terms of temperature, humidity, ventilation, lighting, and control differences for occupied versus unoccupied periods.
- ⇒ The design capacities and efficiencies of the mechanical equipment; not only under the design load condition, but also when operating under partial load conditions. If it is available, manufacturer's data or comparable field test data must be used for all systems.
- ⇒ The loads on the building. Building loads are determined by the internal heat generation, which, in turn, is affected by the number of occupants in the building during both occupied and unoccupied use, the operation of equipment, and heat produced by lighting.

The comparison must use standard engineering procedures. When comparing the two designs, the analysis assumes the same energy sources for the same functions, the same floor area and ratio of envelope to floor area, the same operational and occupancy schedule, identical climate data, and environmental requirements. [Section

Unit 9: Non-Group R Occupancy Energy Code Requirements

402.2] (See "Ensuring a Fair Comparison," in Unit 4.)

Some items that can differ between the proposed and standard designs include efficiency ratings of insulation, glazing, or heating/cooling equipment; the orientation, area, and shading coefficient of glazing; and the heat storage capacity of the building.

While this method is the most complicated, it is potentially the most accurate. The designer can optimize the design of the building more carefully. Systems Analysis is most appropriate for very large or complex designs, or for simple designs that can benefit significantly from the use of a renewable energy resource.

Unit 10: Building Mechanical and Service Water Systems for Non-Group R Occupancies

Building mechanical and service water system requirements are established in WSEC Code Sections 503 and 504. Section 503 covers heating and cooling system requirements, including specific requirements on load calculations, efficiency, design and equipment, as well as duct and pipe insulation. Section 504 covers requirements for design and equipment selection for service water heating. This includes boilers, storage tanks, piping, insulation, and controls.

Many of these requirements are general and apply to all occupancies. Although they may be referred to here, they are covered in-depth in Unit 4 of this manual. Some, however, apply only to commercial or non-residential buildings. They are discussed in this unit. This unit's discussion of Code requirements regarding HVAC system hardware will divide into three areas:

- ⇒ Requirements for the actual space conditioning equipment;
- ⇒ Requirements that affect the distribution system (including fans or pumps), such as economizer cycles, variable air volume (VAV) systems, transport factors, duct or pipe insulation, etc.; and
- ⇒ Requirements for the system controls.

The Code does not necessarily follow this order in presenting these requirements. They are organized in this way for this discussion for simplification only. Keep in mind that in many cases, these requirements tend to overlap. For example, how a design deals with distribution requirements regarding economizers will affect control design as well.

MECHANICAL SYSTEMS

Table 10.1 (next page) presents a list of the various Code sections that affect the design of mechanical systems.

✓ EXCEPTION

The Code allows the code official to approve exemptions from these requirements in special cases. For example, the Code clearly identifies hospitals, laboratories, thermally sensitive equipment, and computer rooms as special cases, but not the only ones. [Section 503.1]

Heating And Cooling Load Calculation

From the Code enforcement perspective it is important that the plan reviewer understand basic heat loss/gain calculations that are used to establish design heating and cooling loads. These loads, in turn, are used to size the installed HVAC equipment. The Code addresses the following areas relating to the specification of heating and cooling equipment by the permit applicant or contractor:

Table 10.1: Sections Affecting Mechanical System Design

201.1	Important Definitions	
302	Design Criteria	
	302.1	Exterior Design Conditions
	302.2	Interior Design Conditions
	302.3	Climate Zones
	WAC	Mechanical Ventilation
501.1	Existence of Mechanical System Is Basis for Envelope Requirements	
503	Building Mechanical Systems	
503.2	Calculation of Heating and Cooling Loads	
	503.2.1	Procedures
	503.2.2	Sizing Limits
		Exceptions
503.3	Simultaneous Heating and Cooling	
		Exceptions
503.4	HVAC Equipment Performance Requirements	
	503.4.1	Equipment Components
	503.4.2	HVAC System Heating Equip. Heat Pump-Heating Mode
	503.4.3	HVAC System Combustion Equipment
	503.4.4	Packaged and Unitary HVAC System Equipment
	503.4.5	Applied HVAC System Components, Electrically Operated
	503.4.6	HVAC System Equipment - Heat Operated, Cooling Mode
503.5	Transport Energy	
	503.5.1	All-Air Systems
	503.5.2	Other Systems
503.6	Balancing	
503.7	Cooling with Outdoor Air	
		Exceptions
503.8	Controls	
	503.8.1	Temperature Control
	503.8.2	Humidity Control
	503.8.3	Zoning for Temperature Control
503.9	Air Handling Duct System Insulation	
503.10	Duct Construction	
503.11	Piping Insulation	

- ⇒ Design parameters (outside and inside design temperatures, minimum levels of thermal performance, etc.);
- ⇒ Equipment sizing limitations; and
- ⇒ Equipment performance requirements.

The inspector must also be able to verify the installation of the approved equipment in the field.

The Code requires a load calculation for approval of the heating and cooling equipment size. The code official may require an engineer or architect stamp to authenticate the calculations for the sizing and performance of equipment and control systems. When required this must be performed by a licensed architect or engineer. [Section 104]

For heating design load calculations, Code Section 302 specifies an indoor design temperature of 70°F and an outdoor design temperature taken from the 0.6 percent column in the WINTER portion of the Puget Sound Chapter of ASHRAE's publication, "Recommended Outdoor Design Temperatures, Washington State." (See Appendix D.) The cooling design load calculations use an indoor design temperature of 78°F and an outdoor design dry bulb (DB) and wet bulb (WB) temperature taken from the 0.5 percent column in the SUMMER portion of the same publication. (See Unit 3 for definitions of dry bulb and wet bulb temperatures.)

These calculations shall be performed in accordance with good engineering practice and include both infiltration and ventilation air changes. The preferred methods are the

ASHRAE procedures, especially Chapters 24, 25, and 26 from ASHRAE's *Handbook of Fundamentals*. The *Handbook* is the authoritative resource on design load calculations and should be included in the library of every building department. Other generally accepted methods include *Manual J* from ACCA [Air Conditioning Contractors of America], SMACNA [Sheet Metal and Air Conditioning Contractors National Association, Inc.] publications, and the Carrier *Air Conditioning Design Book*.

Although similar in concept to calculating heating and cooling loads for residential buildings, the calculations for commercial buildings tend to be more complex. In Unit 2 of this manual, we discussed the major factors that affect heat loss or gain in a building, including: the structure's ability to resist heat loss or gain, the level of air flow into and out of the building, climate, and internal heat gains.

In commercial buildings, internal gains, latent heat, system selection, and VIAQ requirements can significantly affect the complexity of compliance calculations.

Internal heat gains produced by people, lights, appliances (primarily computers), stack effect, and solar heat gain from large expanses of glass significantly affect cooling requirements. Additionally, latent heat, the heat contained in the moisture evaporated into the air, will affect cooling needs in a commercial building. The latent load often requires psychrometric mixed air and coil calculations.

The type of system selected may also affect the magnitude of the load, or call for simultaneous heating and cooling. Then too, the Code calls for partial load operation calculations in non-residential buildings (in

addition to total load calculations.) Finally, the ventilation requirements contained in the VIAQ Code can also have a significant impact on heating and cooling system sizing.

Heating And Cooling System Sizing

Obviously, the system must be large enough to meet the calculated design load. To provide a margin of safety, the system specification can exceed the design load calculations, but it can be no larger than 150% of the design loads. This size limitation requirement applies to the heating and cooling equipment separately.

While the Code requires design load calculations in all cases, it does allow exceptions, even to the 150% limit under certain conditions. (See Unit 4 for exceptions.)

HVAC EQUIPMENT PERFORMANCE

Section 503.4

For someone unfamiliar with the variety of HVAC systems used in non-residential construction, reading the Code can be a confusing experience. The following basic descriptions may provide some guidance. In an attempt to build from the more to less familiar, and from less to more complex, the manual will begin with heating systems, then move on to a variety of cooling systems.

Perhaps the first thing to clarify is that the term "air conditioning" means more than the cooling system it typically describes in residential buildings. Providing "conditioned" air can include heating, humidification, dehumidification, and filtering, as well as cooling.

Section 503.4 describes efficiency requirements for the various HVAC systems that may be encountered in commercial buildings. (See definitions of efficiency ratings, next page.) Heating system efficiencies include minimum COPs and/or HSPFs for heat pumps (air-, water-, or ground-source and hydronic units), and minimum steady-state efficiencies (not AFUEs) for combustion systems. EERs or SEERs are used, according to condensing means, for unitary electric cooling equipment, whether single packaged or central. The applied electrically-operated cooling components used in custom engineered systems must meet EER and COP requirements, again according to the condensing means. Finally, minimum COPs are given for applied heat-operated cooling systems, as would be used in engineered systems. While many of the non-residential building requirements are unchanged from the 1986 WSEC, some system efficiency requirements are increased in the 1991 Code.

Generally, neither the designer nor the code official is involved with actually calculating performance figures (like COP or EER) for HVAC equipment. When selecting equipment or checking plans, each needs to be aware of the criteria, however, to be assured the efficiency figures listed by the supplier meet the code criteria.

The efficiency requirements are specified for each system in Code Tables 5-7 to 5-10. The rating conditions at which those efficiency ratings are derived are presented in Code Tables 5-3 to 5-6. Where equipment efficiency levels are specified, documentation must show approved data to satisfy these requirements. The necessary information can be furnished by the equipment supplier, or certified under a nationally recognized certification program such as those conducted by the

Air-Conditioning and Refrigeration Institute (ARI) or the Gas Appliance Manufacturer's Association (GAMA). (For resources, see Appendix A.)

Code Tables 5-7 to 5-10 are summarized in Table 10.2 (next page).

✓ **DEFINITIONS**

Heating Equipment:

AFUEs are not used for other than group R occupancies. The Code requires instead a minimum steady-state efficiency (see below).

Steady-State Efficiency is the combustion efficiency of the heat production process. That is, the total fuel energy input minus the stack losses from incomplete combustion, sensible heat in exhausted dry combustion byproducts, and both sensible and latent heat in exhausted wet combustion byproducts.

The **Coefficient of Performance (COP)** is an efficiency rating for heat pumps and electrically-driven cooling equipment. It is the ratio of the useful heat output delivered by the complete heat pump unit (excluding supplementary heating) to the corresponding rate of energy input, in consistent units (usually Btu/h/(watts x 3.412)) and under the Air Conditioning and Refrigeration Institute's (ARI) standard rating conditions. [Sections 503.4.1.1 and 503.4.2; Code Table 5-7 for heating]

The **Heating Season Performance Factor (HSPF)** measures the total Btus of heat produced by a heat pump during its normal annual usage period, divided by the total electrical input in watt hours for that same time period. HSPFs of standard (heating) equipment range from just over 5 to just over 9.

Basically, the COP gives the instantaneous efficiency of the equipment in its heating mode at the specific outdoor temperature at which it is measured. It is the efficiency rating to check for water- or ground-source heat pumps. For air-source heat pumps, the COP is checked at 47°F. Since the COP is a measure of the efficiency at a given instant, and air temperatures vary so much, the HSPF, which provides an average or seasonal efficiency, is frequently considered a more accurate rating for air-source heat pump efficiency.

Cooling Equipment

The **Energy Efficient Ratio (EER)** measures the cooling capacity in Btus/hr divided by the power input in watts for electrically-driven cooling equipment. It is measured under a specific set of conditions for the type of equipment being tested. Sections A and H of the ARI Directory of Certified Unitary Air-Conditioners and Air Source Heat Pumps provide standard test conditions. The ARI directory often lists SEER instead of EER. The SEER is a seasonally adjusted figure computed by dividing the total cooling Btus for the annual usage period by the electrical input in watt hours for the same period. Values run from as low as 7 to as high as 15.

✓ **CHANGE**

The 1986 WSEC set minimum EERs for all electric HVAC cooling equipment. In the 1991 version of the WSEC, this is changed. For most equipment under 65,000 Btu/hr, SEERs are set. [Code Table 5-8].

Unit 10: Non-Group R Mechanical Systems & Services

Table 10.2: Electrically-Driven Heating and Cooling Equipment - Minimum Requirements (a)

A. Heat Pumps - Heating Mode (Code Table 5-7)			
SOURCE	MINIMUM COP		MINIMUM HSPF
Air Source:			
Split System	3.0 ²		6.8
Single Package System	3.0 ²		6.8
Water Source	3.8 ³		---
Ground Water Source	3.0 ⁴		---

B. Electric HVAC Equipment (Including Heat Pumps) - Cooling Mode (Code Table 5-8 modified - see Appendix B)			
STANDARD RATING CAPACITY	AIR COOLED		EVAP/WATER COOLED
	SEER	EER	EER
Under 65,000 Btu/hr. (19,050 watts)			
A. Split System	10.0	---	---
B. Single Package	9.7	---	9.3
65,000 Btu/hr. & over (residential only)	---	8.9 ⁴	10.5 ¹

C. WATER CHILLING PACKAGES (Code Table 5-9)							
TYPE OF COMPONENT	COMPRESSOR TYPE	CONDENSING MEANS					
		AIR		WATER		EVAPORATIVE	
		EER	COP	EER	COP	EER	COP
Condenser Included	Centrifugal or rotary	8.00	2.34	13.80	4.04	----	----
	Reciprocating	8.40	2.36	12.00	3.51	----	----
Condenserless	Reciprocating	9.90	2.90	12.00	3.51	----	----
Compressor condenser units 65,000 Btu/hr (19 kW) & over ²	Positive displacement	9.50	2.78	12.50	3.66	12.50	3.66

D. HYDRONIC HEAT PUMPS (Code Table 5-9)			
Water source under 65,000 Btu/hr (19 kW)	Centrifugal or rotary	9.00	2.64
Water source 65,000 Btu/hr (19 kW) & over	Centrifugal or rotary	9.40	2.75.

(a) This table contains information excerpted from several tables; see Code Tables 5-7 to 5-10 for important footnotes and Tables 5-4 to 5-6 for rating conditions.

Table 10.2: Electrically-Driven Heating and Cooling Equipment - Minimum Requirements (cont.)

E. Heat Operated Cooling Equipment (Code Table 5-10) (b)	
Heat Source	Minimum COP
Direct Fired (gas, oil)	0.48
Indirect Fired (steam, hot water)	0.68
where: $\text{Minimum COP} = \frac{\text{Net Cooling Output}}{\text{Total Heat Input}^1}$	
¹ electrical auxiliary inputs excluded	
(b) This section of Table 10.2 provides Code Table 5-10 in its entirety.	

HEATING EQUIPMENT

The heating equipment discussed in this unit include combustion systems (furnaces and boilers), and heat pumps (air-, water-, or ground water-source).

Combustion Systems

The simpler systems one finds in smaller commercial buildings may not be all that different from those seen in residential buildings. While boilers are more commonly used for heating, the plans may call out a gas-fired furnace or a heat pump. Where rates are attractive the designer might specify an electric boiler or a gas-fired unit with oil-fired back-up.

Non-residential occupancy requirements for central combustion heating systems are unchanged from the 1986 Code. In these systems combustion is used for the production of heat. In any combustion process, a fuel (normally composed of hydrogen and carbon and referred to as a hydrocarbon) is combined with oxygen (normally obtained from air) in the presence

of a flame. Furnaces use a combustion process to heat an air stream directly. Boilers use a combustion process to heat water or produce steam directly, which is then piped through the conditioned space or through an air stream delivered to the conditioned space.

The combustion process releases heat and forms combustion by-products. The by-products normally consist of carbon dioxide, nitrogen and oxygen, water, and carbon monoxide. Combustion efficiencies are defined as 100% minus the percentage of the fuel input (measured in Btus/hr) that is not used to heat air or water, or to produce steam. The fuel energy not used to produce heat are contained in the combustion byproducts. These losses are classified as:

- ⇒ Dry products, like carbon dioxide, nitrogen, or oxygen, exiting the furnace or boiler at a temperature higher than the initial combustion air temperature;
- ⇒ Wet products, like water, exiting the furnace or boiler at a temperature

higher than the initial combustion air temperature; and

- ⇒ Combustibles, like carbon monoxide, exiting the furnace or boiler without being burned.

All commercial gas and oil-fired central heating systems must show a minimum combustion efficiency of not less than those shown in Code Table 5-3.

The Code divides the equipment into two groups according to input capacities of the equipment and the type of system.

Furnaces. The required minimum efficiency is 1% higher for furnaces if their capacity is *greater* than 225,000 Btus/hr (i.e. 75%). Furnace input capacities can be obtained directly from the equipment nameplate. These capacities are reported directly as Btus per hour or M.B.H. (thousands of Btus per hour). Efficiencies for those rated at 225,000 Btu/hr *or less* must be measured in accordance with applicable Federal Department of Energy procedures.

Boilers. Boiler efficiency requirements increase 1% (again to 75%) when the unit capacity is *greater* than 300,000 Btu/h. Boiler input capacities can be obtained directly from the equipment nameplate. For water boilers, capacities are reported just as for furnaces. For steam boilers, capacities may be reported like those for furnaces or may be given as boiler horsepower. One horsepower equals 33,475 Btus per hour. The labelled values on the equipment may represent either input or output but should be identified as such.

Heat Pumps

Heat pumps operate on the refrigeration cycle to provide both heating and cooling for a conditioned space. They are classified as either air-source, water-source, or ground water-source, depending on the source from which they take the heat energy. They can be either a split system, in which the two fan-coil units, the air handler and the control may be in different cabinets, or single package units, where all the components are in one cabinet.

In the heating mode, a refrigerant is circulated through a heat exchanger in the heat source where it picks up heat, evaporating the refrigerant. This could be a separate coil in outdoor air, in water, or in a loop carrying brine circulated in the ground. Then the refrigerant is compressed, which raises the temperature, and "pumped" to another heat exchanger in the building heat distribution system where the refrigerant condenses and thereby gives off heat. Figure 10.1 provides a schematic for an air-source heat pump in the heating mode.

Water-source heat pumps operating in the heating mode remove heat from a water stream (rather than an air stream) and transfer it to an indoor air stream. The water source may be either a geothermal well or a closed water loop. The schematic of the water-source heat pump operating in the heating mode is pictured in Figure 10.2. The primary difference is the source at the remote heat exchanger.

Code Table 5-7 (see Table 10.2A, earlier) requires minimum efficiencies for heat pumps when used for heating. Though not stated, this table covers all "unitary" heat pumps (see definition in "Cooling Equipment" discussion, later in this unit) used for heating regardless of condensing

Figure 10.1: Schematic for an Air-Source Heat Pump

Figure 10.2: Schematic for a Water-Source Heat Pump

source or number of components. The table also covers hydronic heat pump components that are not part of a factory assembled and tested system, but are selected and applied by a designing engineer. Since the source temperatures for water- and ground water-source are relatively stable, COPs are sufficiently accurate indicators of overall efficiency. Because air temperatures vary so much, air-source heat pump efficiency is generally rated using the HSPF. The HSPF takes into consideration such things as the effect of the defrost mechanism and the fact that the heat pump is considerably less efficient when the outdoor temperature is 17°F rather than 47°F.

The efficiency requirements apply whether the supplementary back-up heat is electricity or some other source. Systems covered by this include individual room units, such as are commonly found in offices or hotel rooms, as well as typical split systems with condensing and evaporating coils in different locations. When water-source (hydronic) heat pump components are used in conjunction with cooling in a custom engineered system, Code Table 5-9 sets the minimum COP. Since there is no way of knowing all the

components in the system, no HSPF is specified.

Rating Conditions

In order to compare different models and makes of equipment on a uniform and equal basis, the Code specifies the conditions under which the manufacturer's determine their COPs or HSPFs (and EERs and SEERs). Basically, Code Table 5-4 sets the temperature of the air entering the HVAC system from the conditioned space, and the temperature of the source material entering the coil at the other end of the refrigeration system, whether the source is air or water. The temperatures specified for air-source heat pumps represent temperatures that are approximately 10°F above the respective coil temperatures.

It is important to remember that these temperatures are only to provide a common ground for comparing efficiency, and that efficiency of the equipment, and resulting output, will be different at other temperatures. For example, these ratings do not mean that the source water temperatures must be 70°F or 50°F where water- or ground water-source equipment is installed.

✓ CHANGE

Heat pump efficiencies for the heating mode have been increased in the 1991 version of WSEC. Water- or ground-source heat pump COPs are increased to 3.8 and 3.0 respectively. Air-source heat pumps must meet a minimum COP of 3.0 and an HSPF of 6.8 for split systems or 6.6 for single package systems.

✓ CHANGE

The Code accidentally contradicts itself in the tables governing water- or ground water-source heat pump efficiencies. Specifically, Code Table 5-4 sets the standard rating conditions used when deriving the COP. Code Table 5-7, however, uses different entering water temperatures. These are the temperatures that the Air Conditioning and Refrigeration Institute uses to rate these systems. Since this is a uniform and accepted nationally recognized practice, this is preferred. Water-source heat pumps are rated with 70°F water entering the evaporator (outdoor) coil. Ground-source heat pumps are rated with 50°F water entering the evaporator coil.

It does mean that the selected equipment must be able to meet those required COPs if the specified entering water temperatures existed. It also means that a different efficiency should be used to calculate the system's output capacity where the entering water temperature is less (or more) than those specified in Code Table 5-7's footnotes.

If this difference is not considered, the heat pump (refrigeration) portion of the system may be incorrectly sized. If undersized, it will require more input by the back-up heat. When the back-up heat is electric, this will be more expensive and less efficient. If the heat pump system is oversized, the result is less effective use of the equipment.

COOLING EQUIPMENT

The cooling load is dominant in most non-residential buildings. In addition, the great variety of cooling system options introduce a fair amount of complexity. We can begin to understand the differences by breaking the systems into two groups - unitary systems and engineered systems.

Unitary systems are those made up of components assembled and tested by the manufacturer and designed to work together. They are commonly "direct expansion," or "DX", systems. Engineered systems are designed by a qualified HVAC professional, most likely a mechanical engineer, from components or assemblies available on the market. The manufacturers of these components have not determined whether they work together suitably. That is the responsibility of the designer. Engineered systems are frequently called "built-up" systems, and are commonly "chilled water" systems involving cooling towers.

Unitary Systems

Unitary systems themselves can be divided into two groups as well. First, "single package" or "packaged" unitary systems are those in which all the components to the system are within one cabinet, such as a room air conditioner. A typical heat pump with the evaporating coil and the condensing coil located in separate assemblies in different locations is a good example of the second type, a "split" system.

Because it is familiar and simple, the room air conditioner is a good starting illustration. All of the components are within the cabinet -- fans, filters, controls, the evaporating (indoor) coil, the condensing (outdoor) coil, and the compressor. If the unit also contains an electric or fuel-fired heating element and serves only one room or zone, it fits the description of a "packaged terminal air conditioner." If there is a reversing valve instead of a heating element, it becomes a "packaged terminal heat pump." Neither of these are connected to ductwork. Fans within the unit distribute conditioned air to the space through grilles or diffusers on the unit. They may also be called "unit heaters" or "unit air conditioners."

The room air conditioner uses the vapor compression cycle to remove heat from the space. Refrigerant picks up heat from the building and expands (i.e. changes from liquid to gas) at the evaporating fan/coil, then rejects the heat on the outer side at the condensing fan/coil. This is the reverse of the operation of a heat pump in the heating mode described above. When the refrigerant expands in an evaporator right in the stream of air delivered to or in the conditioned space, it is a "direct expansion" or "DX" system.

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Another way to distinguish between systems is how heat is removed at the condensing end of the cycle. In an air-source heat pump or typical air conditioner, a fan draws outdoor air over the condensing coil to remove the heat at the condenser. This is shown in Figure 10.3. Other systems may use water to cool the condensing coil, or spray water on the coil while blowing air across it (evaporative). Figure 10.4 provides a diagram of an evaporative-cooled system. Water- or evaporative-cooled condensers are frequently remotely located from the rest of the unit, making it a split system.

Unitary systems can be larger or made differently. Figure 10.5 shows a long, horizontal unitary system mounted on the roof top, connecting with duct work through the envelope. All of the components are on the building exterior, so it is still a packaged

system. Other packaged systems are entirely inside the building - some vertical units run as large as 50 tons (600,000 Btus). When ducts or pipes supply conditioning to areas other than the space or room where the equipment is located, the system is a "central" air conditioning system. A central system has one system delivering one temperature air to all the spaces served.

Ducting, as well as zoning, can limit the size of the unitary system. Sometimes several, smaller, separate units are installed to serve zones with different requirements instead of one large system with a lot of ducting. There may be one system for each floor, or there can be several systems on each floor.

All electrically powered unitary cooling equipment must meet the efficiency requirements stated in Code Table 5-8 (see

Figure 10.3: Air-Cooled Condenser System Schematic

Figure 10.4: Evaporative-Cooled Condenser System Schematic

Table 10.2B, earlier). This includes all the equipment described above. Section 503.4.4.1 clearly indicates the requirements

are for systems conditioning space for human occupation, not for equipment providing refrigeration for food or for florist

Figure 10.5: Roof Mounted Unitary System

or nursery coolers. The table groups the systems according to whether they are single package or split, and according to the means used to condense the refrigerant. Remember, when the system is a heat pump that also provides heating, it must also meet the requirements of Code Table 5-7.

The EERs and SEERs are tied to Code Table 5-5 for the standard rating conditions. The 80°F (DB)/67°F (WB) condition for air entering from the space is essentially 80°F, 50% relative humidity. The 95°F (DB)/75°F (WB) ambient conditions for air-cooled condensers is essentially 95°F, 40% relative humidity.

✓ CHANGE

The required minimum efficiencies in Code Table 5-8 are different from those required in the 1986 Code. Since the printing of the Code, the SBCC has corrected Table 5-8 to align state requirements with the NAECA requirements and to allow less stringent requirements for non-residential systems. A revised version of this table appears in Appendix B. The SBCC now recommends an EER of 8.2 on commercial systems over 65,000 Btu/hr. (See Table 4.6 in Unit 4 of this manual).

Engineered Systems

As there is a limit to how large an area a unitary system covers, there can also be a limit to how many individual systems a designer wants to install in a given building. At some point it will be more practical to put in a custom engineered system.

Engineered systems are frequently split systems, though some of the components in the systems may be factory assembled packaged units. Regardless, the designer selects the components, and engineers

determine how they work together. For this reason, the units are sometimes called "applied" components.

Frequently these engineered systems involve "chilled water" systems, or "chillers," and cooling towers. In chiller systems, the refrigeration cycle is removed one step further from the space being conditioned. That is, the conditioned air still drops heat to a heat exchanger in the duct work or in the space itself. The loop running through the heat exchanger is circulating chilled water instead of a refrigerant. At the other end of the loop, the water rejects the heat to a heat exchanger in a refrigeration cycle. From there the refrigeration cycle moves it first to a compressor, then to a condenser coil. See Figure 10.6.

How the system rejects the heat at the condensing coil and the type of compressor determine exactly what sort of engineered system it is (and what requirements it must meet in Code Table 5-9). Compressors can be reciprocating (piston), centrifugal, rotary, or screw type.

As before, the condensing coil can be cooled by air, water, or the evaporative process. When the system includes a cooling tower, a second water loop may circulate between the condensing coil and the tower. Figure 10.7 illustrates two types of cooling towers. In one type, the open loop tower (a), the condenser water itself is sprayed through the air and water that has not evaporated is recollected at the tower. In a closed loop system (b), the condenser water loop circulates through the cooling tower where water from the cooling tower sprays over it. It is possible, however, that the refrigerant condensing coil itself is cooled directly by a water source or by an air stream sprayed with water (evaporative).

Figure 10.6: Chilled Water System Refrigeration Cycle

Figure 10.7: Two Types of Cooling Towers

Code Table 5-9 governs the efficiency requirements of the components in built-up systems (see Table 10.2C, earlier). Checking compliance with the efficiency requirements involves four steps. First, find out if the capacity is less than 65,000 Btus/hr. Next, identify the type of compressor in the component. The Code sets up two categories: centrifugal and rotary or reciprocating. Screw compressors are included with rotary compressors. Then, check the documentation to see whether the compressor manufacturer includes the condenser when determining the EER or COP. Often remote condensers are not included, so there is a "condenserless" category in the table. Finally, read down the column under the means used at the condensing coil to find the minimum EER or COP.

The lower half of Code Table 5-9 provides the minimum cooling COPs and EERs for engineered, water-source (hydronic) heat pump systems. (The heating efficiencies are still governed by Code Table 5-7.)

These efficiencies are based on the rating conditions in Code Table 5-6. The fouling factors account for scaling or corrosion that occurs in water-to-water heat exchangers where one loop is run in a tube inside the shell of the other loop. Dirt acts as an insulator reducing the effectiveness of the heat exchange. The ambient air conditions, which affect air- or evaporative-cooled systems, once again reflect 95°F, 40% relative humidity.

The same rating conditions apply whether determining the COP or the EER. This means, if one is known, the other can be easily derived. The EER equals the COP multiplied by 3.413 Btus/watt. Specific compliance with Code requirements must be determined from manufacturers'

information. For air-cooled condenser chiller systems, the manufacturer may quote a COP. The documentation must indicate whether this COP includes the condenser fans (condenser included) or does not (condenserless). For water-cooled condensers, the manufacturer may quote a compressor in kW per ton. This can be converted to a COP by taking the reciprocal of the kW per ton and multiplying it by 3.516 kW per ton. That is, 1/kW per ton x 3.516 kW per ton.

✓ **EXAMPLE**

A manufacturer rates their compressors at 1.172 kW/ton, the COP of the unit is 3.0.

$$\frac{1}{1.172} \times 3.516 = 2.99999$$

Heat-Operated Cooling Equipment

All the cooling systems described to this point have been systems that work by mechanically compressing the refrigerant from the evaporator. Yet, when the cooling load is large, it may be more practical to use a different system, an "absorption" system. Here the refrigerant (e.g., water) again removes heat from the conditioned space in an evaporator. Then the refrigerant is actually absorbed or adsorbed by another chemical solution (such as a 61% lithium bromide solution).

The choice of refrigerant/absorber solution combination and the temperatures at which they are maintained control how the refrigerant vapor goes into the absorber solution. This essentially replaces the compressor's function in mechanical refrigeration. In order to keep the system running the absorber solution must be

concentrated. So, it is heated, boiling off the refrigerant again. A condenser then cools the refrigerant, which is then returned to the conditioned space to start the process all over again. While it seems contradictory, the system applies heat to provide cooling; hence, "heat-operated cooling equipment." This same process runs gas-operated refrigerators, typically used where electricity is not available.

Minimum COP values for heat operated cooling are given in Code Table 5-10. (See Table 10.2E, earlier.) The schematic of the chiller system is pictured in Figure 10.8.

Checking Ratings

Sometimes manufacturers' data is not supplied with plans, or perhaps, the installed equipment is not exactly that specified. It's useful to have a place to find equipment ratings without holding up a job for documentation. The Air-Conditioning and Refrigeration Institute (ARI) publishes a *Directory of Certified Unitary Products* and a *Directory of Certified Applied Air Conditioning Products*. These guides are published semi-annually and are available to building jurisdictions free of charge. (See Appendix A.)

The most recent publication should be used for compliance data. The directory numbers can be checked directly against the Code requirements.

Figure 10.8: Heat-Operated Cooling System Schematic

DISTRIBUTION SYSTEM

How the distribution system is arranged and controlled to provide conditioning also provides several opportunities to save energy. This ranges from how duct work is designed to provide heating and cooling, to the energy consumption of the fans or pumps used to move the energy around. This manual will specifically address Code requirements regarding:

- ⇒ Simultaneous heating and cooling
- ⇒ Economizer cycles
- ⇒ Air transport factors
- ⇒ Balancing
- ⇒ Insulation requirements

Simultaneous Heating And Cooling Section 503.3

In many existing non-residential buildings the space conditioning system is set up in such a way that energy is consumed to heat air that has already been cooled, such as a "constant volume reheat" system. In other systems two ducts are used, one carrying heated air, the other carrying cooled air. When a room needs neither to be cooled or heated, the system mixes air from both ducts to provide a neutral temperature. The Code does intend to prevent equipment from both heating and cooling the air in a single temperature control zone at the same time. Variable air volume (VAV) or single zone constant volume systems generally satisfy this requirement.

Specifically, the Code requires, in each temperature control zone, thermostatic controls installed and operated to sequence the use of heating and cooling energy to

satisfy the thermal and/or humidity requirement of the zone. Controls shall prevent:

- ⇒ Reheating (heating air that is cooler than system mixed air);
- ⇒ Recooling (cooling air that is warmer than system mixed air);
- ⇒ Mixing or simultaneous supply of warm air (warmer than system return air mixed air) and cold air (cooler than system mixed air);
- ⇒ Other simultaneous operation of heating and cooling systems to one zone.

Mixed air is defined as return air mixed with the minimum ventilation air requirement as required in Chapter 3 of the VIAQ Code. Mixed air is illustrated in Figure 10.9.

Some confusion may enter here since this section of the WSEC refers to Section 303, which in turn sends the reader to the 1991 VIAQ Code for ventilation air requirements. In some cases the minimum air flows for non-residential occupancies have changed from the 1986 WSEC ventilation requirements. The minimum outdoor air requirements vary according to occupant density and use of the space. They are given in VIAQ Code Table 3-4. The VIAQ Code specifically states that in no case will outdoor air quantities be less than 5 cfm per person and that the maximum outdoor air quantity used to calculate the heating/cooling loads shall not be more than three times the value in VIAQ Code Table 3-4.

The Code permits the following four exceptions to the simultaneous heating and cooling requirements above:

Figure 10.9: Air Flow Schematic Illustrating Mixed Air

1. Variable Air Volume (VAV) Systems.

These systems are designed to reduce the amount of supply air to a zone as the cooling requirements of that zone are reduced. As the cooling load drops off, eventually the supply air flow rate will drop to a level that will maintain the minimum ventilation air required by VIAQ Code Table 3-4. At this point, any further reduction in the cooling load must be overcome by reheating the supply air to satisfy the zone HVAC load requirements.

VAV systems are acceptable, provided the the system can:

- ⇒ Reduce minimum air flow to thirty percent or less of the peak supply volume, but not less than the larger of the following:
- ⇒ The minimum ventilation requirement as per VIAQ Code Table 3-4; or

⇒ 0.5 cfm/ft² of conditioned area served before reheating, recooling, or mixing the return air.

2. Recovered or Renewable Energy.

Simultaneous heating and cooling is permitted, if the energy for reheating, or providing warm air in mixing systems, is provided entirely from recovered energy that would otherwise be wasted, or from renewable energy sources (see Code Chapter 2 for definition of renewable energy sources). However, this system must also comply *without exception* to the requirement for cooling with outdoor air (Section 503.7), which states the system must be able to automatically use as much as 100% of its fan system capacity to cool with outdoor air if that will result in lower usage of new energy.

3. Special Humidity Needs. Simultaneous heating and cooling is permitted, if specific humidity levels are required to satisfy process needs.

4. Special Pressurization or Contamination Requirements. Finally, simultaneous heating and cooling is permitted, if special pressurization relationships or cross-contamination requirements make variable air volume systems impractical (such as some areas of hospitals and laboratories).

In these cases, supply air temperatures shall be reset by representative building load or by outside air temperature. That is, the zone cooling load can be indirectly determined from representative building loads or by monitoring outdoor air temperatures. If either method determines that the zone cooling load is reduced, the supply air temperature shall be increased (reset) instead of lowering the supply air volume (variable air volume).

Outdoor Air Economizer Cycle

Section 503.7

An economizer cycle is also known as "free cooling." It matches controls with the distribution system so that energy consumption for cooling is reduced. When the building is in a cooling mode, the economizer compares the return air to the outside air and opens outside air dampers for free cooling whenever the outside air requires less cooling than the return air. The schematic in Figure 10.9 (above) shows a simple arrangement of dampers to introduce outside air into the return air before any additional cooling is added. Dampers control the removal of exhaust air as well.

The cycle can be controlled by an economizer on enthalpy control or on dry bulb temperature control. The dry bulb temperature control is the simpler of the two, since it merely looks at the sensible heat (i.e., temperature) difference between outdoor and HVAC return air. When the

outside air is sufficiently cool, generally below 60° - 65°F, the economizer opens the outside air damper. When the outside air is too hot to provide a cooling benefit, the economizer closes the dampers to reduce the outdoor air to the minimum ventilation requirements (VIAQ Code; see Unit 14 of this manual.) If the outside air is very cold, the outside air dampers may not open more than the minimum required for ventilation, or only slightly. It is possible to use what seems to be very warm outside air to cool. Sometimes internal conditions such as lighting loads or roof solar gains may make the temperature of ceiling plenum return air very high, say 85°F. Then, even 80°F outdoor air can be used for cooling if it is dry enough.

The enthalpy control is more complex in that it measures the total heat of the air entering the coil, that is, both the sensible and the latent heat in the air. Sensible heat is indicated by dry bulb temperature (DB), while latent heat is indicated by relative humidity (RH). Cooling can be accomplished by replacing warm, humid indoor air with dryer outdoor air. The enthalpy control measures both conditions (DB and RH) in the return air duct and outdoors. It then computes which air source would impose the lowest load on the cooling system. If outside air is the smallest load, the controller uses the economizer cycle. If the outdoor air is too humid, however, it would have to be dehumidified before it could be used for cooling. It may be more economical to treat the return air itself.

Whether the control is dry bulb temperature or enthalpy, the key issue is that the control compares the outside air with the air in the return of the HVAC system, then operates the outside air dampers and/or applies cooling from the refrigeration system.

Theoretically, dry bulb economizer control savings will be less than those shown for enthalpy control, except in dry climates. Yet there is some question as to the ability of the enthalpy control to measure relative humidity accurately. In addition, there is some doubt that the relatively few days per year where an enthalpy control can provide savings warrant the extra cost for the control, even in the more humid regions of Washington State.

Operation of the economizer can be made automatic by providing:

- ⇒ Dampers capable of providing 100% outdoor air; and
- ⇒ Local controls that open the outdoor damper first on a rise in discharge or space temperature during the economizer cycle.

Compliance with the WSEC requirement for economizer cycle inclusion can be checked by operating the damper system. Figure 10.9, earlier, illustrates a typical ventilation system. The controls must sequence the chilled water or the direct expansion (DX) coil and dampers properly. The system is manipulated to call for cooling and indicate that outside air is preferred. It complies if the exhaust air and outdoor air dampers are fully opened and the return air damper is closed. If the outdoor damper has opened, then, on a further rise, the cooling coil is turned on.

Some smaller systems may use pressure relief dampers elsewhere in the building for economizer operation instead of exhaust air dampers in the duct system. If the inspector is unaware of this, he may mistakenly conclude there is no economizer.

✓ EXCEPTIONS

Seven exceptions to the code requirement for economizer cycles exist. The exceptions are part of the Code to ensure that including an economizer cycle in an HVAC system design will not increase the system energy consumption compared to a conventional design. The code official may allow exceptions when:

- ⇒ The cooling system has total fan capacities of less than 3,500 cfm or 90,000 Btu/h.
- ⇒ The quality of outdoor air would require extensive treatment to make it suitable and building official approval.
- ⇒ The energy consumed humidifying or dehumidifying the outside air is greater than the energy conserved by using outdoor air cooling, on an annual basis.
- ⇒ The use of outdoor air increases overall building energy consumption by affecting the operation of other systems.
- ⇒ Energy recovered from an internal/external zone heat recovery system exceed the energy conserved by outdoor air cooling on an annual basis.
- ⇒ All space cooling is accomplished by a circulating liquid that transfers space heat directly or indirectly to a heat rejection device such as a cooling tower, without the use of a refrigeration system.
- ⇒ The use of 100% outside air will cause frosting on the coil in a direct expansion system when the compressor is running. In this case controls may be added to reduce the quantity of outside air. The intent is still to use 100% outside air instead of mechanical cooling when it will result in less energy consumption.

Transport Energy

Section 503.5

An additional measure used to describe the efficiency of complex HVAC systems is the Air Transport Factor (ATF). This amounts to a budget for the energy consumption of the fans moving air in the system. The Code requires an ATF of 5.5 or greater. Basically, this means that the energy embodied in the sensible cooling of the space must be at least 5.5 times the energy consumed by the supply and return fans used to cool the space.

Strictly speaking, the ATF is the sensible heat removal, expressed in Btus per hour (Btu/h or Btuh), divided by the supply and return air fan(s)' power input, expressed in Btus per hour. The ATF can be calculated easily with minimal information. The designer needs to know the operating horsepower of all the fans (BHP), the Btus of usable sensible cooling in the design load, and the constant for Btuh/horsepower. The power input to the supply and return fans is equal to the sum of their operating horsepower (that is, *brake horsepower*, or BHP) times the inverse of the motor(s)' efficiency times 2,546 Btuh/horsepower, or:

$$\text{BHP} \times \frac{1}{\text{Eff}} \times 2546$$

It is important to remember that this calculation uses the power consumed to deliver the cooling, not the installed horsepower. Energy for transfer of air through heat recovery devices shall not be included in determining the factor. On the other hand, such energy shall be included when evaluating heat recovery system effectiveness.

This calculation is performed under the design system air flow conditions for

constant volume systems. If a variable air volume system is involved, the calculation may be based on the average operation conditions. Obviously, this works easily for an all-air system. Yet the Code requires that other types of systems -- air and water, all-water, unitary systems with chilled, hot, dual temperature, or condenser water transport systems to space terminals, etc. -- not require greater transport energy than an equivalent all-air system (with an ATF not less than 5.5). A good procedure for any system is to add the power consumption of all fans or pumps that must be operated to provide the cooling at design conditions into the denominator of the equation. The transport energy would include the consumption of both central and terminal fans or pumps, but not that of fans that do not return air to the conditioned space. For example, the pump that circulates chilled water in the distribution system would be added in, while the pump in the condenser water loop would not.

In order for the code official to check compliance in this area, the HVAC design engineer's documentation must show equipment data that demonstrates how he derived the loads, BHP, and so forth.

Typically, the ATF is not calculated for packaged systems such as those covered in Code Table 5-8. Extensive work by the City of Seattle Department of Construction and Land Use has shown that the SEER or EER for equipment less than 10 tons is a satisfactory indicator of the ATF. The EERs for these units already include the total power input, so the fan power has been accounted for. In fact, if it were calculated, the ATF is frequently in the range of 12 to 20, well above the 5.5 the Code requires.

✓ EXAMPLE

A 15-ton air cooled direct expansion packaged cooling system delivers supply air with a 7.5-horsepower fan operating at 7 horsepower. No return air fans are present. The building HVAC design engineer tells you the sensible heat load is 12 tons. Calculate the ATF.

$$\text{ATF} = \frac{(12 \text{ tons})(12,000 \text{ Btuh/ton})}{(7.0 \text{ HP})(2,546 \text{ Btuh/HP})}$$

$$\text{ATF} = 8.1$$

Balancing**Section 503.6**

While not strictly an energy conservation measure, balancing is essential to the proper operation of the equipment. Obviously, energy conserving measures like economizers or prevention of simultaneous heating and cooling depend on air mixing and sequencing of controls. No HVAC system can be properly controlled if it is not properly balanced. The Code specifically requires (Section 503.6) that the system design provide a means to balance air and/or water systems. This includes, but is not limited to, dampers, temperature and pressure test connections, and balancing valves.

Insulation Requirements**Section 503.**

Air Handling Duct System Insulation. All ducts, plenums and enclosures installed in or on buildings must be thermally insulated to meet the requirements of Code Table 5-11. These requirements and exceptions are discussed in Unit 4.

Code Table 5-11 requires where ducts are used for both heating and cooling, the

minimum insulation must satisfy the requirements of the most restrictive condition. Vapor barriers must be installed on conditioned air supply ducts in geographic areas where the average of the July, August, and September mean dew point temperature exceeds 60°F. Calculations performed by the Puget Sound Chapter of ASHRAE for selected cities around the state, however, show no dew point temperatures higher than 53°F. (See the last page of the ASHRAE tables in Appendix C.)

✓ CHANGE

The 1991 Code specifies that duct construction shall be in accordance with the applicable SMACNA and ASHRAE Standards listed in Code Chapter 7, as well as with the *UMC*, as previously specified. High- and medium-pressure duct work must be leak tested in accordance with the applicable standard and show a leakage rate not higher than that specified by the standard. (For supply duct insulation requirements, see Unit 4.)

Piping Insulation [Section 503.11]. All piping installed to serve buildings (and within) should be thermally insulated in accordance with Code Table 5-12.

Insulation thickness in Code Table 5-12 is based on insulation having thermal resistance in the range of 4.0 to 4.6 per inch of thickness on a flat surface at a mean temperature of 75°F. Minimum insulation thickness shall be increased for materials having R-values less than 4.0 per inch, or may be reduced for materials having R-values greater than 4.6 per inch.

To calculate the required thickness for materials with thermal resistance greater or

✓ **CHANGE**

The 1991 WSEC requires non-recirculating water pipes installed outside the conditioned space to have a minimum R-3 insulation, whether hot or cold water. Recirculating systems must meet the requirements of Code Table 5-12. As before, footnote 1 in Table 5-12 requires a 1/2" (.5") increase in insulation thickness for all piping exposed to ambient air.

✓ **EXCEPTION:**

Piping insulation is not required in piping installed within unitary HVAC equipment.

✓ **CHANGE**

Previously the Code specifically excepted the insulation requirement on piping at temperatures between 55°F and 100°F. This has been deleted from the 1991 Code. It would seem that piping in this temperature range within the building still would not need insulation since Code Table 5-12 does not identify it.

Originally the 1991 Code also excepted piping insulation when the heat loss and/or heat gain of the piping, without insulation, does not increase the energy requirements of the building or is used as a component of a designed heating system. Recently, however, the Building Code Council dropped this exception from enforcement effective July 1, 1992. Following this interpretation of the Code, the following piping must be insulated according to Code Table 5-12 and Section 503.11:

- ⇒ All heating system piping, inside or outside conditioned space, but not within in unitary HVAC equipment;
- ⇒ All service hot water piping, recirculating and non-recirculating; and
- ⇒ All non-recirculating service cold water piping located outside the heated space (minimum R-3).

less than R-4.6 per inch, see the equations given in Section 503.11 a and b. Additional insulation with vapor barriers shall be provided to prevent condensation where required.

CONTROLS

Section 503.8

Controls have a significant effect on the energy consumption of the building. The Code addresses temperature and humidity controls, zoning for temperature control, setbacks and shutoff, and controls specific to heat pumps.

Temperature/Humidity

Each HVAC system shall have at least one thermostat for the regulation of temperature.

Thermostat setting requirements, including those for heat pumps, are presented in Unit 4.

A humidistat is necessary if an HVAC system is equipped with a means for adding or removing moisture to maintain specific selected humidities in spaces or zones. This device measures the relative humidity of a mixture of air and water vapor. In humidifying systems, the humidistat can control the HVAC system to increase the zone relative humidity to 30%. It should prevent new energy from being used by the system to increase the zone relative humidity above 30%. (Section 503.8.2) The code official may permit special occupancies to have different relative humidities.

✓ CHANGE

The 1986 WSEC disallowed a humidity control that would use new energy to reduce space humidity below 60%. This has been deleted from the 1991 WSEC.

✓ Definition

For the purposes of this code, a **zone** is defined as a space or group of spaces within a building with sufficiently similar heating and/or cooling requirements, so that comfort conditions can be maintained by a single controlling device.

Zoning for Temperature Control**Section 503.8.3**

At least one thermostat for regulation of space temperature shall be provided for:

- ⇒ Each separate HVAC system; and
- ⇒ Each separate "zone."

The floor space of a commercial building is sometimes divided into HVAC zones. (See definition above) Normally, in commercial buildings, provisions are made for an internal and an external, or perimeter, zone for each exterior exposure. That is, an entire side of uniform exposure may be zoned separately. At a minimum, each floor of a building shall be considered as a separate zone with at least one thermostat.

For example, on a given floor there might be one zone along the glazed south wall of the building, a different zone on the glazed north wall, and yet another zone in between. An area that contains many heat producing pieces of equipment, such as copiers, printers, or large computer banks is likely to be zoned differently from an office or records storage area.

Setback/Shutoff

Each HVAC system shall be equipped with a readily accessible, automatic means of shutting off or reducing the energy used for HVAC during periods of non-use or alternate uses of the building spaces or zones served by the system. The following are examples that meet this requirement:

1. Manually adjustable automatic timing devices; e.g., time clocks. These timing devices will restrict the HVAC equipment to operation during building occupied periods. During unoccupied periods, the HVAC systems shall be shut off by the timing device.

2. Automatic control systems; e.g., energy management systems should be installed on HVAC systems. For unoccupied periods during the cooling season, the control system can increase the zone set point temperature to reduce the HVAC system energy consumption. For unoccupied periods during the heating season, the control system can decrease the zone set point temperature to reduce the HVAC system energy consumption.

Heat Pumps

Special requirements for heat pump controls are identified in Code Section 503.8.3.5. If a heat pump is used, the cut-on and cut-off temperatures for the compression heating must be higher than those for supplementary heating. There must be at least two programmable setbacks per day. The thermostat must be able to limit the use of supplementary heat during the warm-up.

WATER HEATING SYSTEMS

Section 504

By and large the requirements for commercial systems are essentially the same as those for residential as far as WSEC is concerned. (See Unit 4.)

Tank Insulation. Additionally, heat loss from unfired hot water storage tanks must be limited to a maximum of 9.6 Btu/hr/ft² of external tank surface area. The design ambient temperature must be no more than 65°F [Section 504.2.2].

Combination Service Water Heating & Space Heating Boilers [Section 504.2.3]. Service water heating equipment must not be dependent on year round operation of space heating boilers. The Code makes two exceptions to this rule:

1. Systems with service/space heating boilers having a standby loss Btu/h less than:

$$\frac{(13.3 \text{ pmd} + 400)}{n}$$

determined by the fixture count method where:

pmd = probable maximum demand in gallons/hour as determined in accordance with chapter 37 of 1987 ASHRAE HVAC Systems and Applications Handbook.

n = fraction of year when outdoor daily mean temperature exceeds 64.9°F.

The standby loss is to be determined for a test period of 24 hours duration while maintaining a boiler water temperature of 90°F above ambient of 60°F and a five foot stack on the appliance.

2. For systems where the use of a single heating unit will lead to energy savings, such unit shall be utilized.

Pumps. Circulating hot water systems must be controlled so that the circulation pump(s) can be conveniently turned off, manually or automatically, when the hot water system is turned off [Section 504.6].

✓ CHANGE

In public rest rooms lavatories are to be equipped with a metering valve. This valve not only controls flow to a maximum 2.5 gallons/minute, but is also designed to close by spring or water pressure when left unattended (self-closing). Lavatories for the physically handicapped, however, shall not be equipped with self-closing valves.

Unit 11: Electrical Power and Lighting for Non-Group R Occupancies

This unit presents WSEC lighting and electrical power requirements as they apply to commercial or non-residential buildings. The requirements are established in Code Section 505.

The intent of this section of the Code is to make the switching and budgeting of power for lighting building interiors and exteriors more energy efficient. As such it sets restrictions and limits on the use of electrical energy for the purpose of building illumination.

For lighting system requirements specific to the alteration and repair of existing buildings, see Unit 1 of this manual.

SWITCHING

The Code addresses the distribution and use of electrical energy for lighting from the service entrance to the points of use. In addition to promoting efficient energy use, the Code's intent is to allow maximum flexibility. Section 505.2 sets the minimum lighting controls to be installed in any building. The Code encourages additional controls where they can significantly reduce consumption. Figure 11.1 (next page) illustrates WSEC requirements as applied to various lighting switching situations.

The Code spells out seven lighting control requirements in Section 505.2 (a) through (g), which are as follows:

All controls must be readily accessible. This section requires that occupants have access to switches and other manual lighting controls. This means that switches (controls) should be conspicuously and conveniently located in the space served by the lighting system, or at the primary entrance to it. Automatic controls such as occupant-sensing devices, special purpose controls such as stage lighting, lighting for security such as night lights, and those controls whose operation by occupants

would pose a safety problem, such as in a prison, are exempted in this section.

Maximum sizing for single switches. This limits the lighting power controlled by a single switch or automatic control to that of a 20 amp. circuit loaded to no more than 80%. Example 11.1 (page 11-3) demonstrates how to determine this requirement for 100-4 tube fluorescent light fixtures. A master control is allowed so long as individual switches can still function independently.

Designated areas for individual or occupant sensing controls. First, the Code requires a switch or automatic control in all rooms or spaces enclosed by walls or ceiling height partitions with floor area less than 400 square feet. Second, if the space floor area is greater than 400 square feet, the controls must be able to reduce the lighting to 50%, or they must be occupant-sensing devices. Stepped controls that bracket 50% have been deemed to comply with this requirement; for example, "OFF-1/3 2/3-ON" switching of 3-tube fixtures.

Unit 11: Non-Group R Electrical Power and Lighting

Figure 11.1: WSEC Lighting Switching Requirements

ROOM NUMBER	CHARACTERISTICS	REQUIREMENTS ¹
1	LESS THAN 400 ft ² NO WINDOWS	ON-OFF SWITCHING OR OCCUPANCY SENSOR*
2	MORE THAN 400 ft ² NO DAYLIGHTING	BI-LEVEL SWITCHING ON-50%-OFF OR OCCUPANCY SENSOR
3	MORE THAN 400 ft ² NO DAYLIGHTING	BI-LEVEL SWITCHING ON-50%-OFF OR OCCUPANCY SENSOR
4	MORE THAN 400 ft ² WINDOW WALL WIDER THAN 12 FEET	BI-LEVEL EACH ROW PARALLEL OR 2 STEP TO 50%-OFF WITHIN 12' OF DAYLIGHTING REMAINING AREA BI-LEVEL ON-50%-OFF
5	MORE THAN 200 ft ² LESS THAN 400 ft ² DAYLIGHTING?	OCCUPANCY SENSOR* ON-OFF SWITCHING EACH ROW PARALLEL OR 2-STEP-50%-OFF* OR CONTINUOUS DIMMING*
6	LESS THAN 200 ft ² DAYLIGHTING	ON-OFF OR OCCUPANCY SENSOR*
7	MORE THAN 400 ft ² OTHER DAYLIGHTING?	SEPARATE BI-LEVEL EACH ROW "WHERE LIGHT AVAILABLE" OR DAYLIGHTING CONTROLS*; BI-LEVEL FOR REMAINING AREA

*Credit on light budget for this option. (See Table 11.2)

¹20 AMP limitation rule applies in all cases

Occupant sensing devices come in two types -- infrared and ultrasonic. Infrared controls sense the body heat of an occupant. Ultrasonic controls sense movement. Both have sensitivity and time-delay adjustment features to fine tune and limit off-on controlling when the room is occupied.

Designated areas where natural lighting is available. For all building areas greater than 200 square feet, where natural lighting is available, separate controls independent of general lighting are required to control the lights nearest the natural lighting. The Code calls for individual or daylight- or occupant-sensing automatic controls. Each row of lights nearest to a window wall must have a separate switch *or* that natural lighting area must have at least a two-step control that reduces illumination to not more than one-half and to completely off.

In offices and schools where the areas may be large, the daylighting provision extends inward from the window wall 12 feet into the areas, or to the next interior wall if that is less than 12 feet from the window wall. Retail stores require only the row of lights nearest the window walls to meet the provisions.

Display exhibition of specialty lighting must be controlled separately from general lighting.

Exterior building lighting must be on automatic controls. The automatic controls reduce or turn off all lights during daylight hours or periods of non-use, except for those lights required for safety or security reasons. This includes facade lighting, parking lots, driveways, and walkways. Signs and security or safety lights may be manually controlled.

✓ **EXAMPLE 11.1: Determining Switching Requirements for 100 - 4 Lamp Fluorescents**

A plan uses 100-4 lamp (40 watts/lamp) fluorescent fixtures. Assume an additional 10% energy use by the ballasts.

$$\begin{aligned} \text{Fixture watts} &= (4 \text{ lamps} \times 40 \text{ watts}) \times 110\% &= 176 \text{ watts} \\ \text{Since Watts} &= \text{Voltage} \times \text{Amperage}^*, \text{ with wiring at 120 volts:} \\ \text{Amperage} &= \frac{176 \text{ watts/fixture}}{120 \text{ volts}} &= 1.47 \text{ amps/fixture} \end{aligned}$$

Since 20 Amp circuits loaded 80% (or 80% of 20 Amps) = 16 Amps, the number of fixtures allowed per circuit is:

$$\text{Fixtures/circuit} = \frac{16 \text{ amps}}{1.47 \text{ amps/fixture}} = 10.9 \text{ fixtures/circuit}$$

Round *down* to 10 fixtures.

Therefore, for 100 fixtures at 10 fixtures/circuit, at least ten 20 amp circuits or switches must be used.

*NOTE: This example makes two assumptions:

1. Virtually all building lighting systems in the U.S. are either 120V or 277V systems. Although three phase circuits are sometimes used, a given fixture is wired to only one leg, thus making the fixture the equivalent of single phase power. Therefore, the equation here assumes single phase power.

2. The power factor corrections (COS) have been ignored. This assumption is common practice for building lighting systems.

LIGHTING POWER BUDGETS

Section 505.3

All buildings except dwellings must limit the total installed wattage for lights. The lighting power budget is the sum of the power limits computed for all interior and exterior lighting. The installed wattage must not exceed the budget levels established by the Code. The total wattage must include the lamps and ballasts.

Interior Lighting

[Section 505.3.2]

Interior lighting limits are established in Code Table 5-13, excerpted in Table 11-1, which specifies the maximum allowed installed wattage for the various occupancies and is measured in watts per square foot of gross conditioned floor area. The budget is determined by multiplying the gross conditioned floor area by the watts per square foot for the particular occupancy. For special conditions the building official approves, the calculations may be based on the Illuminating Engineering Society Unit Power Density or another similar nationally recognized standard.

To determine the allowed budget for a specific case, the occupancy description that most closely resembles the case ("primary occupancy") is used. If a building has mixed occupancy, each occupancy is calculated separately, then summed to obtain the budget. Common circulation areas are calculated proportionately to the different budgets of the sharing occupancies ("weighted average"). See Example 11.2 on page 11-6.

Exemptions for Automatic Controls. For compliance calculations, the installed wattage may be reduced when automatic lighting controls are installed. That is, each

unit is counted as contributing less wattage than it actually does because of the energy savings the automatic control provides. Several types of automatic controls are available. The Code specifies under what conditions and how much a reduction may be taken with certain types of controls. Table 11.2 (page 11-6) presents the allowed reductions. Example 11.3 (page 11-7) illustrates one possible case. Except where noted, the percentages apply to a single space up to 400 ft² enclosed by ceiling height partitions.

Exterior Lighting

Building perimeter lighting is calculated separately from interior lighting. The building perimeter is allowed 7.5 watts per linear foot. Outdoor parking areas and circulation lighting are allowed an additional 0.05 watts/ft². Parking garages are allowed 0.3 W/ft². Lighting for signs that are not an integral part of the building should not be included in the calculations.

✓ EXCEPTIONS

Because of special needs, lighting for certain areas is excluded from the calculation for the lighting power budget. These are:

- ⇒ Stage lighting, entertainment, or audiovisual presentations;
 - ⇒ Medical and dental task lighting;
 - ⇒ Lighting for the visually handicapped; and
 - ⇒ Kitchens and food preparation areas in restaurants.
-

Figure 11.2 (page 11-7) shows a site plan for the total lighting budget calculation, including perimeter lighting, a parking lot, and the office building. Example 11.4 (page 11-8) shows how to calculate the actual budget.

Table 11.1: Interior Lighting Limits (a)

GROUP OCCUPANCY	DESCRIPTION	LIGHTING POWER BUDGET ² (Watts/ft ²)
A	Assembly w/ stage	1.1
	Stage lighting	Exempt
	Assembly w/o stage: other than B and E	1.1
B	Gasoline Service station	1.7
	Storage garage	0.3
	Office buildings	1.7
	Wholesale stores	2.0
	Police and fire stations	1.7
	Retail stores:	
	less than 6000 s.f.	4.0
	6000 to 20,000 s.f.	3.0
	over 20,000 s.f.	2.0
	Drinking and dining establishments	1.85
	Food preparation task light	Exempt
	Aircraft hangars storage	0.7
	Process plants ³	1.0
E	Factories and workshops ³	1.7
	Storage structures	0.7
E	Schools and daycare centers	1.7
	Audio-visual presentation lighting	Exempt
H	Storage structures	0.7
	Handling areas	1.7
	Paint shops	2.0
	Auto repair shops	1.7
	Aircraft repair hangars	1.7
I	Institutions	1.7
	Administrative support areas	1.7
	Diagnostic, treatment, food service task lighting	Exempt
R	Dwelling units	Exempt
	Food preparation task lighting	Exempt

¹Watts/sq.ft. of room may be increased by two percent per foot of height above 20 feet.

²Emergency exit lighting is exempt from interior lighting budget.

³Lighting that is part of machines or equipment is exempt from this budget.

✓ EXAMPLE 11.2

A 4050 ft² floor has a combination of 1425 ft² of storage area, 1175 ft² of retail area and 850 ft² of common area.

Lighting Power Budget:

for the retail space:	4.0 W/ft ²	x	1775 ft ²	=	7100 W
for the storage space:	0.7 W/ft ²	x	1425 ft ²	=	997.5 W
for the common area:	$\frac{(7100 \text{ W} + 997.5 \text{ W})}{(1775 \text{ ft}^2 + 1425 \text{ ft}^2)}$			=	2.53 W/ft ²
	2.53 W/ft ²	x	850 ft ²	=	2150.9 W

Therefore, the total lighting power budget is the sum of all the component lighting power budgets of the building:

$$\frac{7100 \text{ W} + 997.5 \text{ W} + 2150.9 \text{ W}}{1000 \text{ W/kW}} = 10.25 \text{ kW}$$

Table 11.2: Credits for Automatic Controls

When certain automatic lighting controls are installed, the Code allows a reduction of the installed wattage used to calculate the lighting budget. The extent of reduction is determined by the type of control(s) and the area(s) involved.

Type of Control	% Reduction	Conditions
Occupant-sensing devices	30% for any single space	Single space up to 400 ft ² and enclosed by ceiling height partitions
Daylighting controls	30% if continuous dimming 20% if stepped	Any daylit space
Lumen maintenance controls	10%	Any space
Daylight controls with occupant sensing devices	44% for any single space	single space up to 400 ft ² within daylit space and enclosed by ceiling height partitions
Occupant sensing devices with lumen maintenance controls	37% for any single space	Single space up to 400 ft ² and enclosed by ceiling height partitions

✓ **EXAMPLE 11.3**

Room -- 15 x 20 office	=	300 ft ²
(3) 4-tube fluorescent fixtures at 184 watts each	=	552 W
From Table 5-13 : office buildings	=	1.7 W per ft ²
300 ft ² x 1.7 W/ft ²	=	510 W allowed
552 watts is greater than 510 watts	--	Does not comply
With occupant sensing device (30 percent reduction) (552 W x 30% = 165 W)		552 W - 165.6 W = 386 W
386 W is less than 510 W	--	Space Complies

The Code allows combining interior and exterior budgets, and combining budgets of different major occupancies. These may then be distributed throughout the building, provided that the total building lighting power requirements -- less any credit for automatic controls or daylighting systems --

does not exceed the combined power budget per WSEC. This procedure is not recommended, however, since it creates future problems for lighting power compliance as the size and/or uses of the building changes. (See Example 11.5 later in this unit.)

Figure 11.2: Calculating Total Lighting Budget

✓ **EXAMPLE 11.4: How to Calculate Total Lighting Budget**

BUILDING INTERIOR LIGHTING BUDGET:

$$[\text{watts/ft}^2] \times [\text{area}]$$

1. Code Table 5-13, lighting budget = 1.7 watts/ft².
2. Area (Figure 11.2) = 5000 ft²

$$1.7 \text{ w/ft}^2 \times 5000 \text{ ft}^2 = 8500 \text{ W.}$$

EXTERIOR PERIMETER BUDGET:

$$[\text{watts/LF}] \times [\text{linear feet (LF)}]$$

1. Perimeter unit budget [Section 505.3.4] = 7.5 watts/LF.
2. Perimeter (Figure 11.2) = 300 LF.

$$7.5 \text{ w/LF} \times 300 \text{ LF} = 2250 \text{ W}$$

EXTERIOR PARKING BUDGET:

$$[\text{watts/ft}^2] \times [\text{area}]$$

1. Parking unit budget [Section 505.3.4] = 0.05 watts/ft²
2. Area (Figure 11.2) = 2800 ft²

$$0.05 \text{ w/ft}^2 \times 2800 \text{ ft}^2 = 140 \text{ W.}$$

BUILDING BUDGET

INTERIOR	8500
PERIMETER	2250
<u>PARKING</u>	<u>140</u>
TOTAL	10750

✓ **EXAMPLE 11.5**

A restaurant with an interior budget of 1.85W/ft² "loans" part of its budget, say 0.5 W/ft², to the exterior lighting. Later, the restaurant changes to B 2 office use with an interior budget of 1.7 W/ft². A tenant improvement is initiated to raise the interior lighting level from 1.35 W/ft² to 1.7 W/ft². Should the code official approve it?

If the code official does approve the change without requiring a reduction of lighting in the exterior lighting, the building will not be in compliance. If the code official requires that the exterior lighting be included in the project, there is a tendency to criticize the official as being unreasonable. The best solution is to avoid the problem; do not combine budgets except in unusual cases.

Enforcement

In order for the code official to enforce the lighting requirements, plans must include a lighting plan and a schedule of fixture types and listed wattage. The plan should include fixture placement and type together with controls and circuits for each area. The lighting power panel schedule should also be included, indicating the amperage of the circuit. The code official also needs to

review the calculations for the lighting power budget showing a comparison of the actual installed wattage and the Code allowed maximum for the proposed building. Form 11.1 is a suggested format for simple lighting budget calculations.

Lighting Power Budget vs. Lighting Design

Standard lighting design procedures, such as ASHRAE 90A-1980 and ASHRAE 90.1-1989, include finding the proper level of illumination required for activities in a given area; selecting fixtures to provide that illumination; and positioning those fixtures to use that illumination most effectively.

The Code's lighting requirement is not meant to take the place of standard lighting design procedures. The Code sets a limit on

the amount of energy that can be used to light a given space. It does not set a standard for the lighting levels actually achieved. In fact, very different lighting designs, producing very different illumination levels, can use the same amount of energy. Of course, the efficiency of lighting fixtures selected will determine the amount of energy used. Thus, fixture selection will be an important factor in achieving compliance.

Unit 12: VIAQ Code Administration, Enforcement, and Definitions

The Washington State Ventilation and Indoor Air Quality Code (VIAQ Code) sets forth minimum ventilation requirements for *all* occupancies. This chapter summarizes important aspects of the VIAQ Code, including the Code's intent and scope, permitted alternatives, and resolutions for conflicts with other codes. It also discusses the scope of the code official's responsibility for permit submittal, inspections, and enforcement.

For information on how the VIAQ Code applies to Group R occupancies, see Unit 13. For information on how the Code applies to other than Group R occupancies, see Unit 14.

✓ NOTE

All Code references in Units 12, 13, and 14, including Code Chapters, refer to the VIAQ Code unless specifically noted. In other words, a simple reference to Code Chapter 3, will denote Chapter 3 of the VIAQ Code.

INTENT

The intent of the VIAQ Code is threefold:

- ⇒ Code Chapter 3 provides minimum standards for the design and installation of mechanical ventilation systems. These standards are based on the ASHRAE Ventilation Standard 62-89.
- ⇒ As a means of pollutant source control, Code Chapter 4 establishes requirements for the selection of building materials and solid fuel combustion appliances used within the conditioned space.
- ⇒ Code Chapter 5 sets criteria for minimum radon resistive construction for all Group R Occupancies.

Prior to 1991, the WSEC addressed ventilation and indoor air quality issues on a limited basis. However, with the enactment

of WAC Chapter 51-13, ventilation and indoor air quality requirements have been broadened and significantly changed. In addition, they are now in the form of a stand-alone VIAQ Code. The Code, effective July 1, 1991, is an interim Code and is, as of this writing, undergoing a review that may result in major revisions. Subsequent to the review currently taking place, the VIAQ Code will be subject to reviews on a regular basis. As with the WSEC and most building codes, modifications and interpretations between routine reviews will be released and available to building department personnel. (See "Amendments to the Code," Unit 1.)

The most significant change from previous WSEC ventilation and indoor air quality requirements is the VIAQ Code's inclusion of requirements for mechanical ventilation, pollutant source control, and radon resistive measures for Group R occupancies.

The VIAQ Code is similar in concept to the Northwest Energy Code (NWECC), but has stricter prescriptive requirements. In addition, it applies to all fuel types, not just electrically heated buildings.

SCOPE AND APPLICATION

[VIAQ Chapter 1]

All occupancies must comply with the minimum requirements set forth. [Section 101.3] The provisions of the Code provide flexibility to permit innovative approaches and techniques. Compliance with the ventilation sections of the Code can be demonstrated by on-site testing, by engineered design, or by following prescriptive procedures to attain performance standards.

Existing Buildings

Alterations and Additions. Alterations and additions may be made to existing buildings without making the entire building comply, provided that the alteration or addition complies with the Code. [Sections 101.3.1.1, 101.3.1.2]

Additions with less than 500 sq. ft. of floor area are exempted from the ventilation requirements of Code Chapter 3 unless they contain areas where excess water vapor is produced. High moisture areas, such as kitchens, bathrooms, water closets, indoor pools, and spas must meet the source-specific ventilation requirements of Section 302.2.1 in all cases. The whole-house ventilation requirements for residential occupancies only would apply to additions over 500 sq. ft.

Alterations or additions to existing residential buildings that do not require the construction of foundations, crawl spaces,

slabs, or basements are not required to meet the provisions for radon protection contained in VIAQ Code Chapter 5. Any alteration or addition, regardless of floor area, that *does* involve the construction of a foundation, etc., however, must meet all of the radon resistive construction standards in Code Chapter 5 [Section 101.3.1.1]. Code Chapter 5 applies only to Group R occupancies.

Historical Buildings. Such buildings are exempt from the Code only to the extent necessary to preserve those features essential to their historical appearance or function. [Section 101.3.1.3]

Alternative Materials and Methods

[VIAQ Section 102]

The VIAQ Code gives building officials broad discretionary authority to approve alternative materials and building methods. As long as the building official judges them to be equivalent for the purpose intended, and to meet Code requirements for suitability, effectiveness, safety, and indoor air quality, they may be approved.

Plans And Specifications

[VIAQ Section 103]

The building official has the option to require the submittal of plans and specifications detailing compliance with the VIAQ Code. The building official may also require that plans submitted to document compliance be stamped by an engineer, architect, or other qualified professional licensed to practice in the state.

ENFORCEMENT/INSPECTIONS

[VIAQ Section 104]

The VIAQ Code requires that all pertinent data, features of a building, materials, equipment, and systems as governed by the Code are subject to inspection by the building official. The Code further specifies that these items must be inspected and approved before a building is deemed ready for occupancy. [Section 104.4] The building official may require tests as proof of compliance. For example, required residential ventilation rates in Code Chapter 3 are given as a performance standard. Under some circumstances it may be necessary to require flow testing of a system to show compliance with the standard.

Conflicts With Other Codes

[VIAQ Section 106]

In addition to meeting the requirements of the VIAQ Code, buildings must continue to conform to the State Building Code. Where conflicts arise between the VIAQ Code and any part of the State Building Code including: Uniform Building, Uniform Plumbing, Uniform Mechanical, and Uniform Fire Codes, the provisions of the VIAQ Code shall govern [Section 106.1]. The VIAQ Code, however, is not intended

to abridge any safety or health requirements under any other code.

Finally, the local legislative bodies are directed to enforce the Code and authorized to adopt or issue rules or regulations necessary to achieve effective administration of the Code. [Section 106.2]

Definitions

[VIAQ Chapter 2]

Proper administration and enforcement of the Code requires a thorough understanding of Code provisions, ventilation and indoor air quality concepts and practices, and basic definitions.

Certain terms, phrases, words and their derivatives are defined in Code Chapter 2. Where terms are not defined in this section, the definitions should be taken from Chapter 4 of the *UBC*. Webster's unabridged 3rd edition (1981) may be used for further clarification.

In addition, while providing a summary of requirements as they apply to Group R occupancies, Unit 13 discusses the basis for these requirements, including potential problems the Code seeks to address, and benefits of compliance.

Unit 13: Residential Ventilation and Indoor Air Quality

This unit summarizes the requirements of the VIAQ Code as they apply to Group R occupancies. The unit also provides a basis for understanding these requirements, including an overview of residential ventilation, as well as background information on indoor air quality and radon.

Specific requirements of the VIAQ Code as they apply to Group R occupancies include: standards for ventilation, pollutant source control, and radon resistive construction. The requirements apply to all Group R Occupancies regardless of fuel type or the path used to show WSEC compliance.

Ventilation requirements include "source-specific" and "whole-house" mechanical ventilation for all residential buildings.

Pollutant source control includes the reduction of formaldehyde outgassing from construction materials and the control of combustion by-products from solid fuel combustion appliances.

Radon requirements include a state-wide requirement to supply radon monitors to all single-family and first-floor multi-family residences and radon vents for certain crawl spaces. In addition, the Code sets prescriptive radon measures for designated higher radon risk counties, including sub-slab aggregate.

For a summary of VIAQ Code requirements as they apply to Non-Group R occupancies, see Unit 14 of this manual.

VENTILATION

[VIAQ Code Chapter 3]

Ventilation Requirements for Group R occupancies are incorporated in Code Chapter 3. They include requirements for a "source-specific," or "spot," system to exhaust stale air, moisture, odors, or another contaminant at the site as it is generated, and a "whole-house" mechanical ventilation system to provide fresh air, while generally exhausting stale air.

Requirements for compliance by performance are set forth in Section 302. Compliance may be shown through engineered calculations or performance testing. Requirements for prescriptive compliance are found in Section 303.

What Is Ventilation?

Most people think of ventilation as the exchange of stale inside air with fresh outdoor air. An air exchange occurs naturally when two conditions exist at the same time. There must be a force, such as wind, to push the air. And there must be an opening through which the air can pass, such as a window or a crack.

How much "natural ventilation" actually occurs depends on how large the opening is and how strong the pressure driving the air is. In fact, during the heating season, we usually call this "natural ventilation" by a different name - infiltration- and we pay for it in our heating bills.

All homes have some openings that leak cold air into, or heated air out of, the house. Even when the windows and doors are closed, air can leak in around their frames, around pipes or electrical outlets, or through cracks between the framing and the foundation. The more complicated the house shape, the greater the opportunity for leaks. To reduce the energy penalty these leaks cause, the State Energy Code identifies areas to seal against air leakage. [WSEC Section 502.4, see Unit 4 of this manual.]

Even when the leakage area is small, the actual air exchange can be high if the driving force behind the air is high. Four things can contribute to the driving force:

- ⇒ Weather effects, especially wind;
- ⇒ The temperature difference between the inside and outside;
- ⇒ The height of the house; and
- ⇒ Heating systems or other mechanical equipment that move house air.

Winter weather can make the second and fourth effects very large.

When it's cold outside, the difference between inside and outside air temperatures causes warm air to rise and leak out the top of the house, while cold outside air is drawn in at lower levels. This is called the *stack effect*. In cold weather it is very strong. When heating systems use house air for combustion, then exhaust the air outside, they can drive a large air change. Ventilators, such as clothes dryers, range hoods, and bath fans can also drive an air change.

Natural Ventilation

Depending on natural ventilation for good air to breathe is like living in Alaska and depending on natural lighting to read. For a good part of the year, you're sitting in the dark. Similarly, with "natural ventilation," the air may not change often enough to remove odors, humidity, or other pollutants. When temperatures are mild, there is little stack effect. Even if windows are open, the driving force might not cause much air change. Outside temperatures may be low enough in the spring and fall to discourage window opening.

Unseen Pollutants

Some of the reasons to ventilate, such as odors or humidity, are easy to identify and respond to. Others may not be. Many of the materials we use to build, furnish, or even clean our homes, can release pollutants to the air we breathe without our knowing it. Keeping known pollutants out of the home is the best first step. Regular ventilation is a good second step to protect against pollutants unknown to us.

Natural vs. Mechanical Ventilation

The problem with natural ventilation is the lack of control. How do we know we will have adequate ventilation when and where we need it? We can't determine when the wind will blow or what the temperature will be. If the house is leaky enough to provide good ventilation in the mild spring and fall seasons, it will be too leaky in winter. As a result, the house will become uncomfortable and waste energy.

True ventilation is the *controlled* exchange of stale indoor air with fresh outdoor air. Currently, a tight building shell and a

mechanical ventilation system is the best way we know to provide that control.

⇒ Avoids energy waste and discomfort from excessive air change.

Benefits Of Mechanical Ventilation

A well designed and properly installed ventilation system:

- ⇒ Provides good air quality year round.
- ⇒ Controls when and where (and how much) outdoor air enters the building, thus avoiding drafts and contributing comfort.
- ⇒ Distributes fresh air to the rooms we live in.
- ⇒ Removes moisture or odors from bathrooms, kitchens, and other "wet" rooms.
- ⇒ Gives the occupant the ability to remove stale air from all habitable rooms.

Proper mechanical ventilation and good air leakage control work together and are essential to creating a comfortable, energy-efficient home.

PERFORMANCE VENTILATION STANDARDS

[VIAQ Section 302]

The performance standards established by the VIAQ Code are based on the ASHRAE Standard 62-89: "Ventilation for Acceptable Indoor Air Quality." The standard's underlying assumption is that as contaminated stale air is exhausted from the structure, it can be replaced with better quality outside air (with less moisture and other pollutants).

✓ DEFINITIONS

A **source-specific ventilation system** is defined as a mechanical ventilation system including all fans, controls, and ducting, which is dedicated to exhausting contaminant laden air to the exterior of the building from the room or space in which the contaminant is generated. [Section 202] Source-specific systems are sometimes referred to as "spot" ventilation.

A **whole-house ventilation system** is defined as a mechanical ventilation system including fans, controls, and ducts that replaces, by direct or indirect means, air from habitable rooms with outdoor air. [Section 202]

A **habitable space** is space in a structure for living, sleeping, eating, or cooking. Bathrooms, toilet compartments, laundry areas, closets, halls, storage or utility space and similar areas are not considered habitable space. For the purpose of the Code, a single habitable space may consist of adjoining rooms when one-half of the area of the common wall is open and unobstructed and provides an opening of not less than one-tenth the floor area of the interior room or 25 square feet (whichever is greater). [Section 202]

✓ EXCEPTION

Public corridors are an exception and must meet the ventilation requirements of Section 1205 (c) of the UBC.

✓ DEFINITIONS

CFM or cfm stands for cubic feet per minute and is used to measure the volume of ventilation air required or the capacity of a fan to move air.

Static pressure is a measure of the resistance of air movement through a duct system. Often used as a basis for the design and sizing of duct systems. The static pressure of a duct system is essentially a back pressure the fan must overcome to achieve air movement through the duct.

Water gauge is a scale used to show pressure differences. When you suck on a straw in a glass of water, the water rises in the straw because the pressure in the straw is reduced. The height to which the water rises is a measure of the pressure difference inside and outside the straw. The height of a 1"-diameter column of water is frequently used to describe the static pressure in a duct system. The static pressure of a residential ventilation duct system might typically be .15 inches of water.

A **fan curve** graphically plots variations in fan capacity with different static pressures (see Figure 13.1). This can be useful information for choosing an appropriate fan to provide a required air flow through a given duct system. Fan capacity ratings are given in terms of the volume of air (in cfm) that the fan can move against a given static pressure (in inches of water gauge). For prescriptive compliance, the VIAQ Code requires that all fan capacities be rated at .25 inches of water gauge.

ACH stands for air changes per hour. It is a measure of the ventilation rate of a room or whole structure. If half the volume of air in a room is exchanged for fresh air in one hour, then the room is being ventilated at the rate of 0.5 ACH. The VIAQ requires whole-house ventilation systems be capable of 0.35 to 0.50 ACH.

Figure 13. 1: Fan Curve - Air Flow vs. Static Pressure

Using the ASHRAE standard, the VIAQ Code sets minimum design criteria for ventilation to maintain acceptable indoor air quality. In addition, the VIAQ Code, in coordination with the WSEC, establishes maximum ventilation rates so that occupants do not pay an unnecessary energy penalty.

The Code requires that each dwelling unit or guest room be provided with source-specific and whole-house ventilation systems designed to meet the performance standard specified. [Section 302.2]

Source-Specific Ventilation

[VIAQ Section 302.2.1]

Source-specific ventilation is required in each kitchen, bathroom, water closet, laundry facility, indoor swimming pool, spa, and other rooms where excess moisture or cooking odor is produced. Spot ventilation is illustrated in Figure 13.2 (next page). The minimum effective ventilation capacities required by the Code are contained in Code Table 3-1 (See Table 13.1).

Examination of Code Table 3-1 indicates that the source-specific ventilation requirement may be met with either intermittent or continuous ventilation. Continuously operated systems should run 24 hours a day, 365 days a year, except when the house is unoccupied for long periods of time, such as during a vacation.

Note that the airflow rate required for continuously operated systems is much lower than that required for intermittent systems, as indicated in Code Table 3-1.

✓ NOTE

Previous versions of the WSEC had only required mechanical ventilation in wet rooms when there was no operable window present.

The NWEC requires mechanical ventilation in electrically heated structures, but is less specific in regards to a requirement for ventilation in the laundry area.

The VIAQ Code requires mechanical source specific ventilation in the specified locations of residential occupancies regardless of heating fuel type or the presence of operable windows.

Whole-House Ventilation Systems

[VIAQ Section 302.2]

Whole-house exhaust systems may consist of whole-house exhaust ventilation, ventilation integrated with forced-air systems, or a dedicated heat recovery ventilation system. Whole house ventilation is illustrated in Figure 13.3 (page 13-7).

Each dwelling unit must be equipped with a whole-house ventilation system. Based on ASHRAE *Standard 62-89*, the Code

Table 13.1: Minimum Source-Specific Ventilation Capacity

<u>Mode of Operation</u>	<u>Bathroom</u>	<u>Kitchen</u>
Intermittently operating	50 cfm	100 cfm
Continuous operation	20 cfm	25 cfm
(a) Excerpted from VIAQ Code Table 3-1.		

Figure 13.2: Source-Specific Ventilation

SPOT VENTILATION

Figure 13.3: Whole House Ventilation

WHOLE HOUSE VENTILATION

Unit 13: Residential Ventilation & Indoor Air Quality

requires a system capable of providing at least 0.35 air changes per hour (ACH), but never less than 15 cubic feet per minute (cfm) per bedroom, plus an additional 15 cfm. The standard's intent is to provide at least 15 cfm per occupant, and it uses the number of bedrooms as a means of estimating the number of occupants in a dwelling. In large homes with a lot of common area, the 0.35 ACH rate will usually exceed the 15 cfm requirement and would be used to size ventilation. In smaller houses with a number of small bedrooms, the 15 cfm per bedroom plus 15 cfm requirement may dominate.

Whole-house ventilation systems must also be designed to limit ventilation to no more than 0.5 ACH (see possible exception, below). Thus the range of acceptable ACH provided by the whole system is between 0.35 and 0.5. The lower limit is set to maintain acceptable indoor air quality. The upper limit is imposed to conserve energy and avoid paying an unnecessary energy cost.

As part of the whole-house ventilation requirement, the system must supply fresh outdoor air to all habitable rooms. This outdoor air must be supplied directly to the rooms through outdoor air inlets, integration with a forced air heating system, ducting, or

other equivalent means. Doors and operable windows are deemed by the Code not to meet the outdoor air supply intake requirement.

Controls

[VIAQ Section 302.3]

All ventilation controls are required to be readily accessible except for the case of a continuously operated whole-house system. The control switch for a continuously operated system should be located so it won't be inadvertently shut off.

Source-specific ventilation systems must be controlled by either manual switches, dehumidistats, timers, or other approved means [Section 302.3.1]. Typically, each exhaust fan in a bathroom or other required location would have its own switch, although it can be tied in with the light switch. This is most commonly applied in bathrooms, but is not required. Timers have the advantage of allowing ventilation to continue for a set period after someone leaves a room.

Intermittently operated whole-house ventilation systems must be able to operate continuously at the required capacity. They must have both a manual and automatic control [Section 302.3.2]. These need to be switched separately.

✓ NOTE

The VIAQ Code's "15 cfm per bedroom, plus additional 15 cfm" standard is a simplification the Code uses to estimate potential occupancy in the home, and thereby fulfill the intent of ASHRAE's ventilation standard. (The ASHRAE standard is 15 cfm per occupant.) The requirement does *not* mean that a 15 cfm fan must be installed in each bedroom.

✓ EXCEPTION

A house must be ventilated to the 15 cfm per bedroom requirement, even if by doing so the building would exceed 0.5 ACH. This is an exceptional circumstance that could occur in the case of a very small house with lots of bedrooms.

The Code suggests the use of a clock timer for the automatic control. Timers are preferable to dehumidistats, particularly in colder climates where humidity levels in the winter seldom rise high enough to activate the systems; and in warm, wet climates, where humidity levels are so high that the systems may never shut off. (In the first case, though humidity may be low, ventilation is still needed to remove odors or other contaminants. In the second case, with high outdoor humidity, the additional ventilation won't do much good, since the outdoor air is as moist as the indoor air.)

A programmable timer can be set to provide ventilation on a regular basis based on occupancy patterns.

The VIAQ Code requirement is for an *installed ventilation capacity*. When and for how long the system should be operated is left to the occupant and will differ from one residence to another depending on lifestyle and individual sensibilities. Condensation on windows and lingering unpleasant odors would be an indication the system needs to run more often or for longer periods. Houses with more people, fish tanks, lots of

house plants, and indoor pools or spas would all be candidates for more ventilation. Recent recommendations indicate that a whole-house ventilation system should be run at least six to eight hours a day in a typical house. The run time should coincide with times the building is occupied.

Noise

[VIAQ Section 302.4]

If ventilation fans are too noisy, people don't like to use them. This is especially critical for a whole-house ventilation system that may be run eight or more hours a day. The Code requires that whole-house fans located 4 feet or less from the interior grille must have a "sone" rating of 1.5 sones or less at 0.1 inches of water gauge. (See definition of sone, next page.) Remotely-mounted fans (as in Figure 13.4) installed more than 4 feet from the interior grille and acoustically isolated from structural elements of the building and duct work do not need to meet the sone rating requirement. Whole-house ventilation systems integrated with forced-air heating

Figure 13.4: Remotely-Mounted Fans

✓ **DEFINITION**

A **sone** is an internationally recognized unit of loudness. One sone is equal in loudness to a pure tone of 1,000 cycles per second at 40 decibels above the listener's threshold of hearing. According to the HVI, one sone is basically "equivalent to the sound of a quiet refrigerator running in a quiet kitchen."

Sones are used instead of decibels because sone ratings are more easily compared. This is because sones are figured on a linear scale, while decibels are figured on a logarithmic basis. Thus, two sones are equivalent to doubling one sone, but two decibels are greater than doubling one decibel.

✓ **CHANGE**

NWEC jurisdictions should note the difference in sone rating requirements. The VIAQ requirement for 1.5 sones or less represents a reduction from the NWEC requirement for 2.5 sones or less.

systems and heat-recovery systems are also exempt from the sone rating requirement.

Ventilation Ducts

[VIAQ Section 302.5]

All ventilation ducts must terminate outside the building. The Code does not allow exhaust air to be vented into attics, crawl spaces, or garages.

In order to exhaust air directly outside, rather than spill it into an interior space, ducts should terminate in a roof jack or other end cap allowing a direct connection. Spillage needs to be avoided because it can create moisture problems in these spaces. Exhaust systems designed for intermittent operation must have back-draft dampers.

Exhaust ducts in unconditioned space and ventilation supply ducts in conditioned space must be insulated to a minimum of R-4. This is to minimize condensation. Anytime a temperature difference occurs between the air inside the duct and the air outside the duct, there is a potential for condensation on the warm side of the duct.

Outdoor Air

[VIAQ Section 302.6]

A mechanical system must be used to supply outdoor air directly to all habitable spaces. The system may use exhaust fans, supply fans, or both. The exhaust fans create a negative pressure that draws fresh air through air inlets.

Mechanical ventilation systems bring replacement fresh air into buildings through outdoor air inlets [Section 302.6.1]. Inlets must be screened or otherwise protected from entry of insects, leaves, or other material. Outdoor air inlets must not take air from the following areas:

- ⇒ Closer than 10 feet to an appliance outlet, unless the outlet is 3 feet or more above the inlet.
- ⇒ Where objectionable odor, fumes, or flammable vapors can be picked up.
- ⇒ A hazardous or unsanitary location.
- ⇒ A room or space containing any fuel-burning appliance.

⇒ Closer than 10 feet from a vent opening to a plumbing drainage system unless the vent opening is at least 3 feet above the air inlet.

⇒ Attic, crawl spaces, or garages.

Individual Outdoor Air Inlets. When individual room outdoor air inlets are used, they must have a controllable and secure opening. (See Figure 13.5.) The total opening area must not be less than 4 square inches. Outdoor air inlets should be placed to avoid drafts. The Code also requires the inlets be tested by an as yet undetermined approved agency to a nationally recognized standard. [Section 302.6.2]

Where outdoor air supplies are separated from exhaust points by doors, provision must be made to ensure air flow by undercutting doors, installation of grilles, transoms, or similar means where permitted by the *UBC*. [Section 302.6.4] Typically, most builders will undercut doors. An individual air inlet is required to have a

minimum 4 square inch area. Undercutting a 30" door by 3/4" should provide adequate airflow.

✓ CHANGE

Under the NWECA individual room inlets were only required in the bedrooms plus one additional inlet. The VIAQ Code requires inlets for *all* habitable rooms. (Adjoining rooms may be considered a single habitable space for the purposes of the Code, if it meets certain conditions. See definition of "habitable space," earlier.)

Integrated Outdoor Air. When outdoor ventilation air is integrated with a forced-air system, the air connection to the return air stream must be equivalent to a 6"-diameter duct and be located to avoid thermal shock to the furnace heat exchanger [Section 302.6.3]. If the furnace air handler is used to draw in the fresh air, the problem is to find a point close enough to the air handler to insure adequate ventilation while still

Figure 13.5: Outdoor Air Inlets

Figure 13.6: Connecting Duct to Return Plenum

buffering the heat exchanger. Figure 13.6 illustrates an integrated outdoor air supply and shows how you can connect the duct to the plenum return.

The duct must also have a flow control device to insure that the 0.35 to 0.5 ACH standard is met under normal operating conditions.

Compliance Through Performance [Section 302.1]

The builder may decide to demonstrate compliance with the performance standard through engineering calculations or performance testing. Documentation of calculations must be submitted as required.

Any performance testing must be done in accordance with recognized test methods.

Performance Testing. On-site testing would be done after the ventilation system is installed and is operational. Any system meeting the general requirements of Section 302, and shown by testing to provide the required ventilation rates for source-specific and whole-house ventilation would be deemed in compliance. The advantage of this type of compliance is that there is no question the system installed is meeting the standard. The disadvantage of this compliance approach is that if the system fails to pass the test at this stage of construction, alterations in the system may be difficult and expensive.

✓ NOTE

How Do You Measure Airflow In Residential Buildings?

IN-DUCT AIRFLOW MEASUREMENTS can be done using a Pitot tube, a flow grid, or a hot-wire anemometer:

- ⇒ **Pitot Tube:** Air velocity can be accurately and easily measured using a Pitot tube and a low-pressure gauge. The Pitot tube is inserted into the air stream in the duct. The pressure gauge is attached to the Pitot tube allowing a measurement of static pressure and total pressure in the duct. The difference between these two pressures is the velocity pressure that is used to calculate the airflow rate.

Pressures and/or airflows within the ducts must be large enough to allow an accurate measurement. Pitot tubes and sensitive low-pressure gauges are relatively inexpensive.

- ⇒ **Flow Grid:** Flow grids use the same principle as Pitot tubes in that they measure the pressures within ducts. Flow grids are available in various sizes and are placed in a section of duct (the flow grid diameter must match the diameter of the duct). A low-pressure gauge is attached to the pressure taps provided on the outside of the flow grid. The pressure reading is used to find the air flow rate using tables provided with each flow grid device.

Flow rates of less than about 20 cfm cannot be measured accurately with flow grids. Flow grids are relatively inexpensive.

- ⇒ **Hot-Wire Anemometer:** Hot-wire anemometers measure airflow rates using a probe containing a heated element that is inserted into the ducts. These devices can be used for very low flows.

Accuracy of these devices depends upon their calibration and operator skill. Good quality units can be relatively expensive.

AIRFLOW MEASUREMENTS OUTSIDE OF DUCTS can be done using a flow hood, a hot-wire anemometer, or a vane anemometer:

- ⇒ **Flow Hood:** Flow hoods are used to measure airflows at supply, return, and exhaust grilles. These devices are fitted over the grille or register to capture and direct the air across openings or through a rotating vane. These devices can have acceptable accuracy, depending upon the unit, calibration, application, and air velocity.

Most flow hoods cannot accurately measure low airflow rates. These units can be relatively expensive.

- ⇒ **Hot-Wire Anemometer:** See above. Since these devices do not measure pressures, they can be used to measure air velocities in open air streams, such as across the face of a grille or register.

They can be accurate for very low flows. Air turbulence and lack of operator skill can create significant errors. Relatively expensive.

- ⇒ **Vane Anemometer:** These devices use a rotating vane (or propeller) to measure air velocity. They are commonly used to measure air velocities in open air streams and for face velocities at grilles or registers. Accuracy is affected by turbulence, calibration, application, and operator skill.

Some of these devices are accurate for low flows. Good quality, accurate units can be relatively expensive.

✓ **Note (continued)**

MEASURING VENTILATION WITH TRACER GAS quantifies the actual ventilation rate in rooms or buildings over various periods of time:

- ⇒ **Decay:** In the most common tracer gas method, a harmless, inert, tracer gas is thoroughly mixed with the air in a room or building. While the ventilation system is operated in a typical manner, the tracer gas is measured continuously or at various time intervals. The ventilation rate is determined by plotting the dilution of the tracer gas over a period of time (the more rapidly the tracer gas concentration is diluted, the higher the ventilation rate).

The accuracy of this method depends upon the precision of the tracer gas measurements, air mixing, sample locations, and test duration.

Tracer gas tests can be performed with active instrumentation using Sulphur Hexafluoride (SF₆), Carbon Dioxide (CO₂), and other inert tracers. Longer term ventilation tests, such as more than a week, are typically conducted with passive devices, such as Perfluorocarbon Tracer (PFT) kits.

A BLOWER DOOR, or fan door, measures the air flow through the building envelope at a series of specific pressures. The standard reference index is the ACH at 50 pascals (50 pa), though in some areas the actual cfm at 50 pa is becoming the more commonly referred to number, because the ACH at 50 pa does not reveal much about the air flow through the envelope. For example, a 1500 square foot home and a 3000 square foot home could both have an ACH of 7 at 50 pa, but the latter would be experiencing twice as much actual cfm.

Then, too, there is some dispute about what a measurement at an induced pressure (50 pa) tells us about the actual air flow under normal circumstances (which will involve varying pressures). For these reasons the blower door is an excellent tool for measuring the relative leakiness of the envelope and diagnosing trouble spots, but the tracer gas measurement generally reveals much more about the actual ventilation (i.e. dilution of pollutants) in the building.

Engineering Calculations. These may be used to show compliance and avoid testing. To insure compliance, the building official would need to review the submitted calculations and inspect the installed system to assure that it was installed as designed. An engineered system would include a sizing calculation, duct system design, duct system static calculation, and fan selection. Most packaged or pre-engineered systems come fully documented. In addition, most licensed HVAC contractors should be able to provide necessary design documentation.

More information on duct design can be found in the *ASHRAE Handbook of Fundamentals* (Chapter 33); *Manual D* published by the Air Conditioning Contractors Association; and from the

Sheet Metal and Air Conditioning Contractors National Association (SMACNA). (See Appendix A.)

Example 13.1 walks you through an engineered calculation for performance compliance, using a whole house system.

PRESCRIPTIVE VENTILATION STANDARDS

[VIAQ Section 303]

The VIAQ Code also offers a prescriptive path for compliance with its mechanical ventilation requirements. This approach may be used for intermittently operated systems only. [Section 303.1] Continuously operated systems must comply under Section 302 of the Code.

Example 13.1: Calculating Airflow Through a Duct System

How do you know whether the fan installed is actually delivering the air flow desired? The best way is to measure the flow with one of the devices described earlier. A second way is to calculate the flow by considering the fan's ability to move air against pressure (shown by a fan curve or a table as shown in Figure 13.1) and the amount of resistance to flow (static pressure) the duct system will supply. The grille, the terminal fitting (e.g. roof jack), the type of duct, as well as the length and number of bends all add resistance to the air flow.

Suppose we have a fan with the flow vs. pressure characteristics shown previously in Figure 13.1(a). How much duct can be attached and maintain an adequate flow rate for a 1500 ft² three bedroom house?

1. First determine the Code required flow rate for the fan. It must be capable of a flow equal to (a) 15 cfm/bedroom plus another 15 cfm or (b) the flow that would produce 0.35 ACH (but not more than 0.5 ACH).

(a) $(3 \text{ bedrooms} \times 15) + 15 = 60 \text{ cfm minimum}$

(b) $0.35 \times 1500 \times 8 = 4200 \text{ ft}^3/\text{hour}; \frac{4200 \text{ ft}^3/\text{h}}{60 \text{ min./h}} = 70 \text{ cfm}$ (with a maximum of 100 cfm for 0.5 ACH.)

So the Code would require a fan with an installed capacity of 70 cfm. The prescriptive table (VIAQ Code Table 3-2) would require a minimum 80 cfm.

2. Next determine the static pressure the fan can overcome and move 70 cfm. Fan (a) in Figure 13.1 can push against 0.175" w.g.

3. Assuming 4" diameter duct, determine the resistance external to the fan - that is, the duct and any fittings. The only manufacturer we can find who lists the static pressure of their roof jack indicates about 0.25" w.g. at 70 cfm. That already exceeds the ability of the fan. This means purchasing a stronger fan, or installing larger duct and fittings which create less resistance.

Fan (c) is able to move 90 cfm against 0.5" w.g.. That falls nicely within the range allowed.

4. Subtracting the roof jack resistance: $(0.5 - 0.25) = 0.25"$

that is, 0.25" w.g. remains for the duct, back draft damper, and grille. Unfortunately, there is very little data available for the grilles or dampers. Their contribution could easily range from 0.05 to 0.17, leaving between 0.2 and 0.07 for the duct.

5. Checking the duct friction charts in ACCA's Manual D we find flexible metal duct will contribute about 0.22" w.g. resistance in 100 feet of duct. Finding the allowable length is simply a matter of comparing ratios. Let "X" represent the length to be determined. Taking the worse case:

$$\frac{0.07}{X} = \frac{0.22}{100}$$

$$0.22X = 7$$

$$X = 31.8'$$

As long as the length of straight duct run was not greater than 31.8', the fan should provide the design air flow. Remember each 90° elbow is equal to 10 lineal feet of the same duct, so the length of the run must be reduced accordingly. If this installation has one elbow, slightly over 20' of duct could be run. Two elbows would drop the duct length to just over 10'.

In its prescriptive path the VIAQ Code determines limits to the ventilation system for the builder. Flexibility in the design of the system and selection of equipment is sacrificed for ease of compliance. The Code prescriptively sizes the system, and specifies the duct work and fan selection.

Source-Specific Fans

[VIAQ Section 303.1.1]

To comply prescriptively, source-specific exhaust fans for bathrooms, laundries, and similar areas must have a minimum fan flow rating not less than 50 cfm at .25 inches of water gauge. Kitchen exhaust fans must have a minimum fan flow rating of 100 cfm at .25" of water gauge. Manufacturers' fan flow ratings shall be determined as per the Air Movement and Control Association (AMCA) 210.

Whole-House Ventilation

[VIAQ Section 303.1.2]

Whole-House Exhaust Ventilation. Using the prescriptive path, the whole-house ventilation system is sized according to Code Table 3-2. (Excerpted in this manual in Table 13.2). The Table establishes minimum and maximum *exhaust* fan flow rates based on the number of bedrooms.

Dwelling units with more than four bedrooms must calculate the ventilation rate based on the 0.35 to 0.50 ACH performance standard [Section 303.1.2 (a)]. (In other words, you cannot prescriptively size a fan system for a five-plus bedroom house using Code Table 3-2; also, this method may not be the best choice when sizing a large house with few bedrooms.)

The exhaust fan must meet the prescribed fan flow rate at 0.25 inches of water gauge.

Table 13.2: Whole House Exhaust Fan Prescriptive Requirements (a)

Number of Bedrooms	CFM Minimum	CFM Maximum
2 or less	50	75
3	80	120
4	100	150

(a) Excerpted from VIAQ Code Table 3-2

✓ CHANGE

For jurisdictions used to enforcing the NWECA, these fan flow rates are higher than those required by NWECA. The fan rating is also higher: Fans must be tested at 0.25" of water gauge instead of 0.10".

✓ NOTE

Although the Code also specifies that the *HVI Directory* can be used to determine fan flow ratings, this is not true for prescriptive compliance, as of this writing. This is because fans listed in the *HVI Directory* have been tested at 0.10" of water gauge. As stated above, the VIAQ Code's prescriptive requirement is that fans be tested at 0.25" of water gauge. (See Table 8.3 in Unit 8 for fans listed at 0.25" water gauge.)

Integrated Forced-Air/Ventilation Systems. Integrated systems must have a 6" diameter or equivalent outdoor air inlet connecting the outside terminal element to the return plenum of the forced air system. The outdoor air inlet must be equipped with a damper or other device that regulates the air flow to not less than 0.35 ACH but not more than 0.50 ACH under normal operating conditions. [Section 303.1.2 (b)]

✓ NOTE

Prescriptive requirements for systems integrated with forced-air heating will still require testing of the air flow to know where to set the damper.

- ⇒ All duct and fitting sizes must be 4" in diameter or greater;
- ⇒ Maximum duct lengths shall not exceed those specified in VIAQ Table 3-3; and
- ⇒ Terminal fittings must have a net free area greater than or equal to the duct size.

Dedicated Heat Recovery Ventilation Systems. Duct work in heat recovery ventilation systems must not be less than 6" in diameter. Balancing dampers must be installed on the inlet and exhaust sides. Flow grids must be installed on the supply and return. The minimum system sizing must be based on VIAQ Code Table 3-2. Heat recovery systems are exempt from maximum flow rates. [Section 303.1.2 (c)]

A properly installed duct system conforming to VIAQ Code Table 3-3 should never produce a static pressure exceeding 0.25 inches of water gauge. Coupled with a prescriptive fan rated at 0.25 inches water gauge, the system should deliver the required ventilation.

Exhaust Ducts

[VIAQ Section 303.2]

The ventilation duct system is prescriptively designed using VIAQ Code Table 3-3 (excerpted in Table 13.3, below). Prescriptive requirements for source-specific and whole-house exhaust ducts are:

System characteristics of prescriptive source-specific and whole-house ventilation systems not addressed in Section 303 must comply with the general requirements of Section 302 [Section 303.1]. This includes the use and placement of outdoor air inlets, sone ratings, controls, duct insulation, and air distribution.

Table 13.3: Prescriptive Exhaust Duct Sizing (a)

Fan Test Maximum CFM@.25W.G.	Maximum Flex Diameter	Maximum Length Feet	Maximum Smooth Diameter	Maximum Length Feet	Maximum Elbows*
50	4"	25	4"	70	3
50	5"	90	5"	100	3
50	6"	>100(b)	6"	>100(b)	3
80	4"	Not allowed	4"	20	3
80	5"	15	5"	100	3
80	6"	90	6"	>100(b)	3
100	5"	Not allowed	5"	50	3
100	6"	45	6"	>100(b)	3
125	6"	15	6"	>100(b)	3
125	7"	70	7"	>100(b)	3

* For each additional elbow subtract 10' from length.
 (a) Excerpted from VIAQ Code Table 3-3.
 (b) ">" Means "greater than". **Note:** This essentially limits the length to 100 feet.

INDOOR AIR QUALITY

[VIAQ Code Chapter 4]

Pollutant Source Control

The Code institutes measures for the reduction of formaldehyde. All structural components of the house such as softwood plywood, particle board, wafer board, and oriented strand board must be identified as "EXPOSURE 1," "EXTERIOR," OR "HUD-APPROVED." The materials used in products with these labels release much lower levels of formaldehyde than unlabelled products, such as interior grade plywoods, etc.

Solid Fuel Burning Appliances and Fireplaces

[VIAQ Section 401]

The use of solid fuel combustion appliances and fireplaces can adversely affect indoor air quality (becoming a health hazard) and contribute to energy inefficiency. If an appliance or fireplace is allowed to draw combustion air from inside the conditioned space, large volumes of heated air will be lost to the outside.

The same appliances, dependent upon inside air for combustion, may under some circumstances, such as when a strong exhaust fan is turned on or when wind blows down the chimney, allow smoke and other combustion by-products to flow into the house. This is called "backdrafting." (See Figure 13.7.)

In order to minimize heat loss and reduce the backdrafting potential, the Code requires that solid fuel combustion appliances and fireplaces meet the following requirements (See Figures 13.8 a and b):

Figure 13.7: Backdrafting

CAUSED BY REDUCED
AIR PRESSURE RELATIVE
TO OUTSIDE

WIND CAN
INITIATE IT

Doors. All appliances such as wood stoves and most fireplaces must have tight-fitting glass or metal doors [Sections 401.2a, 401.3c]. The Code does not define tight-fitting. Fireplaces may use a flue draft induction fan in place of doors.

Combustion Air. Solid fuel combustion appliances such as wood stoves must have a combustion air duct connected directly to the appliance. There is no minimum duct size requirement. [Section 401.2b] Manufacturer's recommendations should be followed.

For site-built fireplaces, a combustion air duct must run from outside the conditioned space of the house directly to the firebox. The duct must have an area of at least 6 square inches and be provided with an outside air duct damper [Section 401.3b]. "Zero clearance" and "factory-built" fireplaces should follow manufacturer's recommendations for the size and type of combustion air duct, but are still required to provide outside combustion air.

Figure 13.8: Solid Fuel Appliance Requirements

✓ **EXCEPTIONS: [VIAQ Section 401.2b]**

Combustion air does not have to be supplied directly to the appliance when:

- ⇒ The unit is tested and certified by an industry testing agency to meet the performance requirements of the test required by the Department of Housing and Urban Development (HUD) Mobile Home Construction and Safety Standard regarding carbon monoxide backdrafting.

NOTE: The HUD standard referenced in the VIAQ Code exception above references a UL test that assumes outside combustion air. This is in conflict with the intent of the VIAQ Code exception. Essentially, it would allow a stove to qualify for use without outside combustion air by passing a test that uses outside combustion air. As a result, the Washington State Building Code Council has ruled that using the HUD standard is not acceptable for qualification for the VIAQ exception. Wood stove manufacturers have challenged this interpretation. Until further interpretation is provided, the exception is not actually available.

- ⇒ The appliance is installed in an unheated space and is part of a central heating system. In this case, UMC requirements need to be met. The UMC may require combustion air be supplied to the area where the appliance is located.
- ⇒ The appliance is installed in an existing building (that is, one permitted before the VIAQ Code went into effect) and the existing construction prohibits direct connection. This case requires a 4" (minimum) duct be installed providing combustion air to the room containing the appliance. The duct must bring the air as close as possible to the appliance. The duct must also have a barometric damper or approved equivalent to minimize heat loss to the outside.

Flue Dampers. Fireplaces must provide a tight-fitting flue damper operated by a readily accessible manual or approved automatic control [Section 401.3a].

Gas Log Fireplaces. Fireplaces with gas logs must be installed in compliance with the *UMC* Chapter 803 [Section 401.3c].

✓ **NOTE**

A reading of *UMC* Chapter 803 would imply that gas log fireplaces do not have to have a tight-fitting door, or an outside source for combustion air. However, the *VIAQ* Code intends that, for gas-log fireplaces, *UMC* Chapter 803 and *VIAQ* provisions 401.3(b) and (c) be met.

RADON RESISTIVE CONSTRUCTION STANDARDS

[*VIAQ* Code Chapter 5]

Radon is an odorless, colorless, radioactive gas, which rises naturally from the soil. Research has documented the negative effects of exposure to radon on health. As a result, the *VIAQ* Code requires measures to protect public health through monitoring and reducing radon entry into new residential occupancies. Some of these requirements apply state-wide; others are specific to particular counties or types of construction.

Application

[Section 501.2]

This section establishes minimum radon resistive construction standards for all Group R Occupancies. The requirements must be adopted and enforced by all jurisdictions in the state. All areas of the state must comply with the requirements of Section 502. Some areas of the state have

been determined to be at higher risk for radon exposure. These must comply with the additional requirements of Section 503. (See Figure 13.9.) The designated counties are: Ferry, Grant, Okanogan, Pend Oreille, Skamania, Spokane, Stevens, and Wahkiakum.

State-Wide Radon Requirements

[Section 502]

Monitoring. The Code requires the builder to provide a three-month etched track radon monitor to all new homes and first floor dwelling units in multi-family residences [Section 502.2]. The Code does not require the builder to perform monitoring or ensure that it has taken place. Monitoring and mitigation, if needed, are the responsibility of the homeowner.

The monitor will give occupants the increased capacity to assess their risk of exposure to radon. Instructions on how to use the monitor and how to understand the test results must also be provided by the builder at the time of final inspection. [Section 502.2.1]. This information may be obtained from the Washington State Department of Health or the Washington State Energy Office. (See "Radon and Your New Home" in Appendix F.)

✓ **NOTE**

It is not the intent of the Code to imply that the builder and/or building official are liable if testing shows radon problems in the building.

Pending legislation will shift the responsibility for supplying the radon monitor and information from the builder to the local jurisdictions. This change is effective July 1, 1992.

Figure 13.9: High Risk Counties (a)

(a) Darker counties must comply with VIAQ Code Section

Crawl Spaces. All new residential construction must meet the *UBC* Section 2516(c) for crawl space ventilation [Section 502.1.2].

If the crawl space meets any of the following conditions specified in Sections 502.1.2 and 502.1.3, then the Code requires that a radon vent be installed:

- ⇒ The crawl space ventilation is less than 1 square foot for every 300 square feet of crawl space area; or
- ⇒ The crawl space has operable vents; or
- ⇒ The crawl space functions as a supply or return plenum for an HVAC system.

Radon Vent [Section 503.2.6]. A radon vent is a pipe that keeps unwanted gases out of the home by evacuating them to the outdoors, much like a plumbing vent.

When a radon vent must be installed, the Code requires a continuous sealed pipe that runs from beneath the ground cover in the crawl space to a point outside the building. (See Figure 13.10.) The radon vent must:

- ⇒ Have a minimum 3" diameter or as approved;
- ⇒ Be constructed of PVC schedule 40 or ABS or approved equivalent smooth walled pipe;
- ⇒ Terminate no less than 12" above the eave;

Unit 13: Residential Ventilation & Indoor Air Quality

- ⇒ Terminate more than 10 feet horizontally from chimneys or operable windows;
- ⇒ Be sloped to drain;
- ⇒ Be protected from blockage by snow;
- ⇒ Be visibly labeled "Radon Vent;" and
- ⇒ Be located within the thermal envelope to the extent practicable.

The radon vent as required by the Code for crawl spaces is intended primarily to

facilitate future mitigation measures that might be deemed necessary after radon testing. The radon vent may be eliminated if an active depressurization system is installed to provide mitigation. See the exception in Section 503.2.6.

Fan. Vent installation must provide a location for the possible installation of an in-line fan at a future date. The fan location must be as near as possible to the vent's exit point from the structure or it must be outside the structure. The fan and any downstream piping must be isolated from

Figure 13.10: Radon Vent

indoor air. This prevents radon in the vent from leaking into living space. The builder must decide where the fan would be located if it were needed; provide an electrical box there; and provide access to that area. [Section 503.2.7]

The Code requires installation of the fan only when the crawl space is used as a return or supply air plenum.

Crawl Space Plenums. When a crawl space is used as a return or supply plenum, the Code requires the following additional measures:

- ⇒ Installation of 4" of graded aggregate on the floor of the crawl space. [Section 503.2.2]
- ⇒ A soil-gas retarder membrane, such as 6-mil polyethylene or equivalent, placed over the aggregate. If there is no concrete slab to seal for an air barrier, seal this membrane at all seams and penetrations and to the perimeter wall. [Sections 503.2.4 & 503.2.5]
- ⇒ An in-line fan must be installed and activated. The fan must be capable of moving at least 100 cfm rated at 1.0 inches of water gauge. [Section 502.1.3] (See Figure 13.11, next page.)

High-Risk Radon Prescriptive Requirements

[Section 503]

The provisions of this section are required only in the designated higher risk counties. These requirements are designed to reduce radon entry into residences and to prepare for future mitigation, if desired. The prescriptive measures address slab-on-grade and basement construction, areas where radon is most likely to enter the house.

Concrete Slabs. Concrete slabs in direct contact with the building envelope and the ground in Group R Occupancies must be:

- ⇒ Placed over a minimum 4"-thick layer of aggregate [Section 503.2.2];
- ⇒ Placed *directly* on top of a soil-gas retarder membrane [Section 503.2.4];
- ⇒ Sealed to limit the movement of soil-gas into indoor air, at all joints or penetrations that will become inaccessible later [Section 503.2.5]; and
- ⇒ Connected directly to a radon vent. [Section 503.2.6]. The vent must meet the same specifications listed for a radon vent under crawl spaces, including possible fan location and wiring. Installation of a fan is not required.

✓ DEFINITION

A **soil gas retarder** is a flexible sheet material, like 6-mil polyethylene, which will limit the flow of gas from the soil into the building. When placed under a slab, all air sealing is at the slab level. However, if there is no slab, as with a crawl space plenum, this membrane should be sealed along all seams, penetrations, and to the foundation for the radon vent to work properly.

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Figure 13.11: Requirements for Crawlspaces as HVAC Plenums

Separate Aggregate Areas [Section 503.2.8]. Aggregate areas should be as continuous as possible. Where areas are separated by footings or other barriers, two options are available:

- ⇒ A separate radon vent must be installed into each distinct area; or
- ⇒ Separate areas may be considered a single area if a minimum 3" diameter connection joining the areas is provided for every 30' of barrier.

The Code does not limit the total area of sub-slab aggregate that may be vented with a single stack. Research indicates, however, that venting of areas larger than 3,000 square feet with a single stack becomes ineffective. A good practice would be to provide multiple stacks for very large slabs.

The intent of placing aggregate under a slab is to provide a porous material through which a pressure gradient may more easily be maintained under the slab. (See Figure 13.12.) The radon, if present, collects under the slab, stopped by the soil-gas retarder membrane and the sealed slab, and vents to the exterior through the radon vent pipe, which provides the path of least resistance. The possible installation of an in-line fan will enhance the pressure gradient and ensures radon removal.

Below Grade Sealing. All penetrations in the slab and joints in the slab or other floor systems and below-grade walls, which will not be accessible at the final inspection, must be sealed. Sealants must be approved by the building official and be manufactured for the intended use. Placement and tooling must be in accordance with manufacturer's

Figure 13.12: Sub-Slab Aggregate

✓ **NOTES**

The aggregate used under the slab must meet one of the following gradation specifications:

- ⇒ Comply with UBC Standard 26-2 and be 3/4" - No. 4 size aggregate or larger as listed in Table 26-2-A, "Grading Requirements for Concrete Aggregates."
- ⇒ Meet the Washington State Department of Transportation specification 9-03.1(3) "Coarse Aggregate for Portland Cement Concrete." Aggregate size shall be Grade 5 or larger.
- ⇒ Screened and washed consistent with UBC Standard 26-2 with 100% of the gravel passing a 1" sieve and less than 2% passing a No. 4 sieve.

These and other radon prescriptive requirements for concrete slabs do not apply to non-Group R occupancies (e.g. garages).

specifications and result in no gaps or voids after curing. [Section 503.2.5]

Concrete block walls in below grade areas are considered unsealed surfaces. Block walls and any penetrations that will not remain accessible must be sealed to create a continuous air barrier to limit the transport of soil gas into the indoor air. [Section 503.2.9]

A summary of the radon requirements is provided in Table 13.4.

Alternative Methods. As previously mentioned in Unit 12, the VIAQ Code allows for the possibility of alternative methods of design or construction. The alternative must meet the intent of the Code, be at least equivalent to the prescribed practice in suitability, effectiveness, safety, and indoor air quality, and be approved by the building official. [Section 102.1] This provision has been used by a number of jurisdictions to approve alternative methods for radon control.

Table 13.4: Washington State Radon Requirements

Building Condition	Location	Monitor in Residence	Radon Vent Pipe	Activated ¹ System	Aggregate	Soil Gas Retarder Membrane
Crawlspace with Ventilation 1/300 or more	Statewide	YES	----	----	----	----
Crawlspace with Ventilation < 1/300 or Operable Vents	Statewide	YES	YES	----	----	NO ²
Crawlspace used as Return or Supply Plenum	Statewide	YES	YES	YES	YES	YES ³ (sealed)
Basement Slabs/ Slabs-on-Grade	High Risk ⁴ Counties	YES	YES	----	YES	YES (seal not req. ⁵)
Basement Slabs/ Slabs-on-Grade	Other Counties	YES	----	----	----	----
¹ Sealed membrane, sealed joints, continuously operating fan ² No soil gas retarder is required per se, but a ground moisture cover of 6 mil black polyethylene, or equivalent material, is required by the WSEC. ³ Unless there is a concrete slab which has been properly sealed. ⁴ Ferry, Grant, Okanogan, Pend Oreille, Skamania, Spokane, Stevens, Wahkiakum. ⁵ Assumes sealing is done on the slab.						

Unit 14: Ventilation Requirements for Non-Group R Occupancies

This unit summarizes mechanical ventilation criteria and minimum ventilation performance standards for all occupancies other than residential, as presented in VIAQ Code Section 304.

In the past, ventilation requirements for these occupancies were established in the *UBC* and the *WSEC*. The *UBC* is still used to determine minimum requirements for operable areas providing natural ventilation. The *WSEC* addresses related issues of energy efficiency in complying with ventilation requirements (See *WSEC* Section 503 or Unit 10 of this manual.) The *VIAQ* Code now specifies minimum outdoor air quantities. The outdoor air quantities presented for each occupancy type in Table 14.1 (see next page) are from Code Table 3-4 and must be used as minimum required values. In no case, however, shall the outdoor air quantities provided be less than 5 cfm per person.

✓ CHANGE

The values in Table 14.1 are different from previous versions of the *WSEC* and reflect the more recent *ASHRAE Standard 62-89*.

When a mechanical system is used to supply the outdoor air, the system must be capable of supplying the quantities of air specified by Table 14.1 based upon the greater of either the occupant densities in the table or the design occupant density. The outdoor air must be ducted directly to every air handling unit in each zone not provided with sufficient operable area for natural ventilation [Section 304.1].

HEATING COOLING DESIGN LOADS

[Section 304.1]

The maximum outdoor air quantities used as the basis for calculating the heating and cooling design loads must not exceed three times the quantities specified in Code Table 3-4 (again, see Table 14.1).

✓ EXCEPTION

If outdoor air quantities other than those specified in Code Table 3-4 are used or required because of special occupancy or process requirements, source control of air contamination, health and safety or other standards, the required outdoor air quantities must be used as the basis for calculating heating and cooling design loads.

ADDITIONAL REQUIREMENTS

[Section 304.1]

In addition to general ventilation requirements for non-residential construction, the *VIAQ* Code sets specific ventilation and air quality standards for some situations typically associated with commercial construction, including: parking garages, automotive repair buildings, and mechanical refrigerating equipment and storage. It also calls out the issue of combustion air.

Parking Garages. Open parking garages as defined in *UBC* 709(b) are not required to provide additional ventilation.

Unit 14: Non-Group R Ventilation Requirements

All other parking garages used for storing or handling of automobiles under their own power and all loading platforms in bus terminals must provide ventilation at the rate of 1.5 cfm per square foot of gross floor area. Building officials may approve alternative systems designed to exhaust a minimum 14,000 cfm for each operating vehicle. These systems must be based on the anticipated instantaneous movement rate of vehicles but not less than 2.5% (or one vehicle) of the garage capacity.

Automatic carbon monoxide sensing systems may be submitted for approval.

Automotive Repair Buildings. Exhaust extension ducts are required in all buildings used for automotive repair. Extension ducts must be provided for each repair stall and

must terminate outside the building. Extension ducts longer than 10 feet must mechanically exhaust 300 cfm.

Any connecting offices or waiting rooms must be supplied with conditioned air under positive pressure.

Mechanical Refrigerating Equipment and Storage. Mechanical refrigerating equipment and rooms storing "refrigerates" (refrigerants) must conform to the requirements of Chapter 15 of the *UMC*.

Combustion Air. Combustion air requirements must conform to the requirements of Chapter 6 of the *UMC*.

Table 14.1: Outdoor Air Requirements for Ventilation¹ of Commercial Facilities (VIAQ 3-4)

Application	Estimated Maximum ² Occupancy P/1000 ft ² or 100 m ²	Outdoor Air Requirements cfm/person
Dry Cleaners, Laundries ³		
Commercial laundry	10	25
Commercial dry cleaner	30	30
Storage, pick up	30	35
Coin-operated laundries	20	15
Coin-operated dry cleaner	20	15
Food and Beverage Service		
Dinning rooms	70	20
Cafeteria, fast food	100	20
Bars, cocktail lounges ⁴	100	30
Kitchens (cooking) ²³	20	15
Garages, Repair, Service Stations		
Enclosed parking garage ⁵		1.50 cfm/ft.sq.
Auto repair rooms		1.50 cfm/ft.sq.
Hotels, Motels, Resorts, Dormitories ⁶		
Bedrooms		30 cfm/room*
Living rooms		30 cfm/room*
Bath		35 cfm/room*
Lobbies	30	15

* These numbers, reflecting ASHRAE Standard 62-89, correct assumed typographical errors.

Table 14.1: Outdoor Air Requirements for Ventilation¹ of Commercial Facilities (continued)

Application	Estimated Maximum ² Occupancy P/1000 ft ² or 100 m ²	Outdoor Air Requirements cfm/person
Conference rooms	50	20
Assembly rooms	120	15
Dormitory sleeping area ⁸	20	15
Gambling casinos ⁴	120	30
Offices		
Office space ⁹	7	20
Reception area	60	15
Telecommunication centers and data entry areas	60	20
Conference rooms	50	20
Public Spaces		
Corridors and utilities		0.05 cfm/ft.sq.*
Public restroom, cfm/wc or urinal ¹⁰		50
Lockers and dressing rooms		0.5 cfm/ft.sq.*
Smoking lounge ¹¹	70	60
Elevators ¹²		1.0 cfm/ft.sq.
Retail Stores, Sales Floors, and Show Room Floors		
Basement and street	30	0.3 cfm/ft.sq.
Upper floors	20	0.2 cfm/ft.sq.
Storage rooms	15	0.15 cfm/ft.sq.
Dressing rooms		0.20 cfm/ft.sq.
Malls and arcades	20	0.20 cfm/ft.sq.
Shipping and receiving	10	0.15 cfm/ft.sq.
Warehouses	5	0.05 cfm/ft.sq.
Smoking lounge ¹¹	70	60
Specialty Shops		
Barber	25	15
Beauty	25	25
Reducing salons	20	15
Florists ¹³	8	15
Clothiers, furniture		.30 cfm/ft.sq.
Hardware, drugs, fabric	8	15
Supermarkets	8	15
Pet shops		1.00 cfm/ft.sq.
Sports and Amusement ¹⁴		
Spectator areas	150	15
Game rooms	70	25
Ice arenas (playing areas)		0.50 cfm/ft.sq.
Swimming pools (pool and deck area) ¹⁵		0.50 cfm/ft.sq.
Playing floor (gymnasium)	30	20

* These numbers, reflecting ASHRAE Standard 55-89, correct assumed typographical errors.

Unit 14: Non-Group R Ventilation Requirements

Table 14.1: Outdoor Air Requirements for Ventilation¹ of Commercial Facilities (continued)

Application	Estimated Maximum² Occupancy P/1000 ft² or 100 m²	Outdoor Air Requirements cfm/person
Ballrooms and discos	100	25
Bowling alleys (seating areas)	70	25
Theaters¹⁶		
Ticket booths	60	20
Lobbies	150	20
Auditorium	150	20
Stages, studios	70	15
Transportation¹⁷		
Waiting rooms	100	15
Platforms	100	15
Vehicles	150	15
Workrooms		
Meat processing ¹⁸	10	15
Photo studios	10	15
Darkrooms	10	0.50 cfm/ft.sq.
Pharmacy	20	15
Bank vaults	20	15
Duplicating, printing ¹⁹		0.50 cfm/ft.sq.
INSTITUTIONAL FACILITIES		
Education		
Classroom	50	15
Laboratories ²⁰	30	20
Training shop	30	20
Music rooms	50	15
Libraries	20	15
Locker rooms		0.50 cfm/ft.sq.
Corridors		0.10 cfm/ft.sq.
Auditoriums	150	15
Smoking lounges ¹¹	70	60
Hospitals, Nursing and Convalescent Homes		
Patient rooms ²¹	10	25
Medical procedure	20	15
Operating rooms	20	30
Recovery and ICU	20	15
Autopsy rooms ²²		0.50 cfm/ft.sq.
Physical Therapy	20	15
Correctional Facilities		
Cells	20	20
Dining halls	100	15
Guard station	40	15

Table 14.1: Outdoor Air Requirements for Ventilation¹ of Commercial Facilities (continued)

1. Derived from ASHRAE Standard 62-1989.
2. Net occupiable space.
3. Dry-cleaning process may require more air.
4. Supplementary smoke-removal equipment may be required.
5. Distribution among people must consider worker location and concentration of running engine; stands where engines are run must incorporate systems for positive engine exhaust withdrawal. Contaminant sensors may be used to control ventilation.
6. Independent of room size.
7. Installed capacity for intermittent use.
8. See also food and beverage service, merchandising, barber and beauty shops, garages.
9. Some office equipment may require local exhaust.
10. Mechanical exhaust with no recirculation is recommended.
11. Normally supplied by transfer air, local mechanical exhaust; with no recirculation recommended.
12. Normally supplied by transfer air.
13. Ventilation to optimized plant growth may dictate requirements.
14. When internal combustion engines are operated for maintenance of playing surfaces, increased ventilation rates may be required.
15. Higher values may be required for humidity control.
16. Special ventilation will be needed to eliminate special storage effects.
17. Ventilation within vehicles may require special considerations.
18. Spaces maintained at low temperatures (-10oF to + 50oF) are not covered by these requirements unless the occupancy is continuous. Ventilation from adjoining spaces is permissible. When the occupancy is intermittent, infiltration will normally exceed the ventilation requirements.
19. Installed equipment must incorporate positive exhaust and control of undesirable contaminants.
20. Special contamination control systems may be required for processes or functions including laboratory animal occupancy.
21. Special requirements or codes and pressure relationships may determine minimum ventilation rates and filter efficiency.
22. Air shall not be recirculated into other spaces.
23. Makeup air for hood exhaust may require more ventilating air.

Appendix A: Resources

Administrative & Technical Assistance	A-2
Other Technical Resources	A-3
Reference Listings	A-4
Product Resources	A-5

Administrative and Technical Assistance

Table A-1 lists organizations and individuals available to answer your administrative and technical questions regarding the WSEC and the VIAQ Code. Areas of expertise are provided to

help you determine who to contact. If you need a copy of the 1991 State Energy Code and the 1991 VIAQ Code contact the Washington Association of Building Officials (see below).

Table A.1: Administrative & Technical Assistance

Organization	Contact	Area of Expertise
Washington Association of Building Officials P.O. Box 7310 Olympia, WA 98507	Blair Patrick Executive Director 206/586-6725	Full range of code-related questions.
Association of Washington Cities/Washington Assoc. of Counties 4719 Brooklyn Ave. N. Seattle, WA 98104	Mike McCourt 206/543-9050	WSEC program support, including builders' incentives; technical assistance payments; enforcement payments.
Washington State Energy Office (WSEO) 809 Legion Way SE MS FA-11 Olympia, WA 98504-1211	John Devine (Olympia) 206/956-2095 Hank Date (Olympia) 206/956-2031 Tim Nogler (Olympia) 206/956-2094 Marvin Young (Olympia) 206/956-2138 Dave Kohler (Spokane) 509/456-6150 Julie Palakovich (Olympia) 206/956-2098 Janice Hogan (Olympia) 206/956-2060 Jeanne Irving (Olympia) 206/956-2061	Technical assistance, residential. Program and administrative assistance.
WSEO/Electric Ideas Clearinghouse 809 Legion Way SE MS FA-111 Olympia, WA 98504-1211	1-800/872-3568	Technical assistance, commercial.

Table A.1: Administrative & Technical Assistance (continued)

Organization	Contact	Area of Expertise
WSEO/Energy Extension Service 914 E. Jefferson #300 Seattle, WA 98122	Chuck Eberdt (Seattle) Jim Bowman Bruce Carter Gary Nordeen 1-800/962-9731	Training/technical information on energy-efficient residential construction practices.
WSEO/Energy Extension Service N.1212 Washington, # 106 Spokane, WA 99201-2041	Mike Nuess (Spokane) David Hales 1-800/962-9731	Training/technical information on energy-efficient residential construction practices.
State Building Code Council (SBCC) 9th & Columbia Bldg. Olympia, WA 98504-4151	Don Kaiser 206/586-3423	Interpretations
International Conference of Building Officials (ICBO) 12505 Bel-Red Road, #208 Bellevue, WA 98005	Chuck Williams 206/451-9541	Interpretations

Other Technical Resources

Bonneville Power Administration. The BPA publishes material related to energy codes in the Pacific Northwest and energy-efficient construction practices. For most recent publications, contact BPA, P.O. Box 3621, Portland, OR 97208; 1-800/622-4520.

Puget Sound Chapter - ASHRAE. The Puget Sound Chapter of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. has published a 1986 edition of *Recommended Outdoor Design Temperatures, Washington State*. The publication may be purchased from the Chapter at: AGC Building, 1200

Westlake Ave. N. Ste. 414, Seattle, WA 98109; 206/283-1222.

Oregon State University Energy Extension. The OSU Energy Extension Office sells video tapes on energy-efficient construction. For purchase information and a tape catalog, contact the OSU Energy Extension at: OSU, 344 Batcheller Hall, Corvallis, OR 97331-2401; 503/754-3004. Video tapes produced by OSU include cable programs, training programs, and recorded events.

Libraries. The Washington State Energy office in Olympia, both the Spokane and Seattle WSEO/Energy Extension Service

Appendix A: Resources

offices, and the ICBO office lend materials related to the Code and to energy-efficient construction. (Refer to Table A-1 for addresses and phone numbers.).

Fact Sheets. The WSEO/Energy Extension Service (see addresses and phone numbers above) has published fact sheets specifically designed to explain technical and program aspects of the WSEC and the VIAQ Code. (See Table A-2.)

Table A.2: WSEO-EES Code Fact Sheets

Additions and Remodels
Air Leakage Control
Fireplace and Wood Stove Requirements
HVAC System Requirements
Mechanical Ventilation Prescriptive Requirements
What You Need to Know to Meet the Energy Code in Zone 1
What You Need to Know to Meet the Energy Code in Zone 2
Why Mechanical Ventilation?
Radon Control for Higher Risk Counties
Radon Control for Crawl Spaces
Tips for Complying with the Energy Code

Reference Listing

Air Conditioning and Refrigeration Institution (ARI)
1501 Wilson Blvd. 6th Floor
Arlington, VA 22209-2403
Attn: Publications Department

ARI publishes the *Directory of Certified Unitary Air-Source Heat Pumps*, as well as directories for other HVAC equipment, twice yearly. Available free on request from jurisdictions.

Air Conditioning Contractors of America (ACCA)
1513 16th St. N.W.
Washington, DC 20036
202/483-9370

GAMA Efficiency Certification Program
ETL Testing Laboratories, Inc.
Industrial Park, Route 11
Cortland, NY 13045
607/753-6711

GAMA publishes the *Consumer's Directory of Certified Furnace and Boiler Efficiency Ratings* twice yearly in April and October. Available for a small charge.

Home Ventilating Institute of America, Inc. (HVI)
Div. of Air Movement Control Assoc. (AMCA)
30 W. University Dr.
Arlington Heights, IL 60004
312/394-0150

Publishes *Certified Home Ventilating Products Directory: Air Delivery and Sound Levels*

Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA)
8224 Old Courthouse Rd.
Tysons Corner
Vienna, VA 22180

Product Resources

Puget Sound Power and Light

PSP&L publishes *Product Guide for Builders*. Available in service area only; call
1-800/562-1482

Product Resource Center

200 1st Ave. W Suite 803
Seattle, WA 98119
1-800/222-9231
206/281-1715 (Seattle)

Answers product-related questions.
Publishes lists of appropriate products/materials for meeting code requirements.

Iris Communications

P.O. Box 1647
Tualatin, OR 97062
503/620-0881

Iris publishes the *Energy Source Directory* and produces customized construction guides for builders.

Appendix B: WSEC Tables

Residential

Code Tables 6-1 through 6-6 (Prescriptive)	B-2
Code Table 5-1 (Component Performance)	B-8
Pre-Approved Component Packages	B-9

Commercial

Code Table 6-7 (Prescriptive)	B-11
Code Table 5-2 (Component Performance)	B-12
Code Table 5-8 (Electric HVAC Equipment - Cooling)	B-13

TABLE 6-1 PRESCRIPTIVE REQUIREMENTS¹ FOR RESIDENTIAL OCCUPANCIES

HEATING BY ELECTRIC RESISTANCE ZONE I									
OPTION	GLAZING % FLOOR AREA	GLAZING U-VALUE	DOORS U-VALUE	CEILING ²	VAULTED CEILING ³	WALL ABOVE GRADE	WALL ⁴ BELOW GRADE	WALL ⁴ BELOW GRADE	FLOOR ⁵ SLAB ⁶ ON GRADE
I.	10%	0.46	0.40	R-38	R-30	R-21	R-21	R-10	R-10
II.	12%	0.43	0.20	R-38	R-30	R-19	R-19	R-10	R-10
III.	12%	0.40	0.40	R-38	R-30	R-21	R-21	R-10	R-10
IV.*	15%	0.40	0.20	R-38	R-30	R-19	R-19	R-10	R-10
V.	18%	0.39	0.20	R-38	R-30	R-21	R-21	R-10	R-10
VI. ⁷	21%	0.36	0.20	R-38	R-30	R-21	R-21	R-10	R-10
VII. ⁷	25%	0.32	0.20	R-38	R-30	R-19+R-5 ⁸	R-21	R-10	R-10
VIII. ⁷	30%	0.29	0.20	R-38	R-30	R-19+R-5 ⁸	R-21	R-10	R-10

*Reference Case

¹ Minimum requirements for each option listed. For example, if a proposed design has a glazing ratio to the conditioned floor area of 19%, it shall comply with all of the requirements of the 21% glazing option (or higher). Proposed designs which cannot meet the specific requirements of a listed option above, may calculate compliance by Chapters 4 or 5 of this Code.

² Requirement applies to all ceilings except single rafter or joist vaulted ceilings. "Adv" denotes Advanced Framed Ceiling.

³ Requirement applicable only to single rafter or joist vaulted ceilings.

⁴ Below grade walls shall be insulated either on the exterior to a minimum level of R-10, or on the interior to the same level as walls above grade. Exterior insulation installed on below grade walls shall be a water resistant material, manufactured for its intended use, and installed according to the manufacturer's specifications. See section 602.2.

⁵ Floors over crawl spaces or exposed to ambient air conditions.

⁶ Required slab perimeter insulation shall be a water resistant material, manufactured for its intended use, and installed according to manufacturer's specifications. See section 602.4.

⁷ The following options shall be applicable to buildings less than three stories: 0.35 maximum for glazing area of 25% or less; 0.32 maximum for glazing areas of 30% or less.

⁸ This wall insulation requirement denotes R-19 wall cavity insulation plus R-5 foam sheathing.

TABLE 6-2 PRESCRIPTIVE REQUIREMENTS¹ FOR RESIDENTIAL OCCUPANCIES

HEATING BY OTHER FUELS ZONE 1

OPTION	HVAC ⁹ EQUIP. % EFFIC.	GLAZING FLOOR AREA	GLAZING U-VALUE	DOORS U-VALUE	CEILING ²	VAULTED CEILING ³	WALL ABOVE GRADE	WALLint ⁴ BELOW GRADE	WALExt ⁴ BELOW GRADE	FLOOR ⁵	SLAB ⁶ ON GRADE
I.	Med.	10%	0.70	0.40	R-30	R-30	R-15	R-15	R-10	R-19	R-10
II.	Med.	12%	0.65	0.40	R-30	R-30	R-15	R-15	R-10	R-19	R-10
III.	High	21%	0.75	0.40	R-30	R-30	R-19	R-19	R-10	R-19	R-10
IV.*	Med.	21%	0.65	0.40	R-30	R-30	R-19	R-19	R-10	R-19	R-10
V.	Low	21%	0.60	0.40	R-30	R-30	R-19	R-19	R-10	R-19	R-10
VI. ⁷	Med.	25%	0.45	0.40	R-38	R-30	R-19	R-19	R-19	R-25	R-10
VII. ⁷	Med.	30%	0.40	0.40	R-30	R-30	R-19	R-19	R-10	R-25	R-10

*Reference Case

¹ Minimum requirements for each option listed. For example, if a proposed design has a glazing ratio to the conditioned floor area of 19%, it shall comply with all of the requirements of the 21% glazing option (or higher). Proposed designs which cannot meet the specific requirements of a listed option above, may calculate compliance by Chapters 4 or 5 of this Code.

² Requirement applies to all ceilings except single rafter or joist vaulted ceilings. "Adv" denotes Advanced Framed Ceiling.

³ Requirement applicable only to single rafter or joist vaulted ceilings.

⁴ Below grade walls shall be insulated either on the exterior to a minimum level of R-10, or on the interior to the same level as walls above grade. Exterior insulation installed on below grade walls shall be a water resistant material, manufactured for its intended use, and installed according to the manufacturer's specifications. See section 602.2.

⁵ Floors over crawl spaces or exposed to ambient air conditions.

⁶ Required slab perimeter insulation shall be a water resistant material, manufactured for its intended use, and installed according to manufacturer's specifications. See section 602.4.

⁷ The following options shall be applicable to buildings less than three stories: 0.50 maximum for glazing areas of 25% or less; 0.45 maximum for glazing areas of 30% or less.

⁸ This wall insulation requirement denotes R-19 wall cavity insulation plus R-5 foam sheathing.

⁹ Minimum HVAC Equipment efficiency requirement. "Low" denotes an AFUE of 0.74. "Med." denotes an AFUE of 0.78. "High" denotes an AFUE of 0.88.

TABLE 6-3 PRESCRIPTIVE REQUIREMENTS¹ FOR RESIDENTIAL OCCUPANCIES**HEATING BY ELECTRIC RESISTANCE ZONE 2**

OPTION	GLAZING % FLOOR AREA	GLAZING U-VALUE	DOORS U-VALUE	CEILING ²	VAULTED CEILING ³	WALL ABOVE GRADE	WALLint ⁴ BELOW GRADE	FLOOR ⁵ WALLext ⁴ BELOW GRADE	SLAB ⁶ ON GRADE
I.	10%	0.38	0.20	R-38	R-30	R-21	R-21	R-30	R-10
II.	12%	0.40	0.20	R-38	R-30	R-19+R-5 ⁸	R-21	R-25	R-10
III.*	15%	0.40	0.20	R-38	R-30	R-19+R-5 ⁸	R-21	R-30	R-10
IV.	18%	0.38	0.20	R-38	R-30	R-19+R-5 ⁸	R-21	R-30	R-10
V.	21%	0.35	0.20	R-38Adv	R-38	R-19+R-5 ⁸	R-21	R-30	R-10
VI. ⁷	25%	0.30	0.20	R-49Adv	R-38	R-19+R-5 ⁸	R-21	R-30	R-10
VII. ⁷	30%	0.28	0.20	R-60Adv	R-38	R-21+R-7.5 ⁹	R-21	R-30	R-10

***Reference Case**

¹ Minimum requirements for each option listed. For example, if a proposed design has a glazing ratio to the conditioned floor area of 19%, it shall comply with all of the requirements of the 21% glazing option (or higher). Proposed designs which cannot meet the specific requirements of a listed option above, may calculate compliance by Chapters 4 or 5 of this Code.

² Requirement applies to all ceilings except single rafter or joist vaulted ceilings. "Adv" denotes Advanced Framed Ceiling.

³ Requirement applicable only to single rafter or joist vaulted ceilings.

⁴ Below grade walls shall be insulated either on the exterior to a minimum level of R-10, or on the interior to the same level as walls above grade. Exterior insulation installed on below grade walls shall be a water resistant material, manufactured for its intended use, and installed according to the manufacturer's specifications. See section 602.2.

⁵ Floors over crawl spaces or exposed to ambient air conditions.

⁶ Required slab perimeter insulation shall be a water resistant material, manufactured for its intended use, and installed according to manufacturer's specifications. See section 602.4.

⁷ The following options shall be applicable to buildings less than three stories: 0.33 maximum for glazing area of 25% or less; 0.31 maximum for glazing areas of 30% or less.

⁸ This wall insulation requirement denotes R-19 wall cavity insulation plus R-5 foam sheathing.

⁹ This wall insulation requirement denotes R-21 wall cavity insulation plus R-7.5 foam sheathing.

TABLE 6-4 PRESCRIPTIVE REQUIREMENTS¹ FOR RESIDENTIAL OCCUPANCIES

HEATING BY OTHER FUELS ZONE 2											
OPTION	HVAC ⁹ EQUIP. EFFIC.	GLAZING % FLOOR AREA	GLAZING U-VALUE	DOORS U-VALUE	CEILING ²	VAULTED CEILING ³	WALL ABOVE GRADE	WALLint ⁴ BELOW GRADE	WALLext ⁴ BELOW GRADE	FLOOR ⁵	SLAB ⁶ ON GRADE
I.	Med.	10%	0.70	0.40	R-36	R-30	R-19	R-19	R-12	R-25	R-10
II.	Med.	12%	0.65	0.40	R-38	R-30	R-19	R-19	R-12	R-25	R-10
III.	High	17%	0.65	0.40	R-38	R-30	R-19	R-19	R-12	R-25	R-10
IV.*	Med.	17%	0.60	0.40	R-38	R-30	R-19	R-19	R-12	R-30	R-10
V.	Low	17%	0.50	0.40	R-38	R-30	R-19	R-19	R-12	R-30	R-10
VI.	Med.	21%	0.50	0.40	R-38	R-30	R-19	R-19	R-12	R-30	R-10
VII. ⁷	Med.	25%	0.40	0.40	R-38	R-30	R-19	R-19	R-12	R-30	R-10
VIII. ⁷	Med.	30%	0.35	0.40	R-38	R-30	R-19	R-19	R-12	R-30	R-10

***Reference Case**

- Minimum requirements for each option listed. For example, if a proposed design has a glazing ratio to the conditioned floor area of 19%, it shall comply with all of the requirements of the 21% glazing option (or higher). Proposed designs which cannot meet the specific requirements of a listed option above, may calculate compliance by Chapters 4 or 5 of this Code.
- Requirement applies to all ceilings except single rafter or joist vaulted ceilings. "Adv" denotes Advanced Framed Ceiling.
- Requirement applicable only to single rafter or joist vaulted ceilings.
- Below grade walls shall be insulated either on the exterior to a minimum level of R-10, or on the interior to the same level as walls above grade. Exterior insulation installed on below grade walls shall be a water resistant material, manufactured for its intended use, and installed according to the manufacturer's specifications. See section 602.2.
- Floors over crawl spaces or exposed to ambient air conditions.
- Required slab perimeter insulation shall be a water resistant material, manufactured for its intended use, and installed according to manufacturer's specifications. See section 602.4.
- The following options shall be applicable to buildings less than three stories: 0.45 maximum for glazing areas of 25% or less; 0.40 maximum for glazing areas of 30% or less.
- This wall insulation requirement denotes R-19 wall cavity insulation plus R-5 foam sheathing.
- Minimum HVAC Equipment efficiency requirement. 'Low' denotes an AFUE of 0.74. 'Med.' denotes an AFUE of 0.78. 'High' denotes an AFUE of 0.88.

Appendix B: WSEC Tables

THE WASHINGTON STATE ENERGY CODE • WAC 51-11 • EFFECTIVE JULY 1, 1991

TABLE 6-5 LOG HOMES PRESCRIPTIVE REQUIREMENTS¹
HEATING BY ELECTRIC RESISTANCE

OPTION	AVERAGE ² LOG THICKNESS	GLAZING % FLOOR AREA	GLAZING U-VALUE	DOORS U-VALUE	CEILING ³	VAULTED ⁴ CEILING	FLOOR ⁵	SLAB ⁶ ON GRADE
<u>CLIMATE ZONE 1</u>								
I. ⁷	5.5"	15%	0.31	0.14	R-60 Adv	R-38	R-38	R-10
II. ⁷	7.5"	15%	0.40	0.20	R-60 Adv	R-38	R-30	R-10
III.*	9.6"	15%	0.40	0.20	R-38	R-30	R-30	R-10
<u>CLIMATE ZONE 2</u>								
IV. ⁷	6.7"	15%	0.31	0.14	R-60 Adv	R-38	R-38	R-10
V. ⁷	8.7"	15%	0.40	0.14	R-60 Adv	R-38	R-38	R-10
VI. ⁷	9.8"	15%	0.40	0.20	R-60 Adv	R-38	R-30	R-10
VII. ⁷	10.5"	15%	0.40	0.20	R-49 Adv	R-38	R-30	R-10
VIII.*	13.5"	15%	0.40	0.20	R-38	R-30	R-30	R-10

* Reference Case • (highlighted in redline)

¹ For Group R Occupancy use Table 6-5 for only the portion of floor area using log/solid timber walls. Use Tables 6-1 to 6-4 for all other portions of the floor area. Minimum requirements are for each option listed. Interpolations between options is not permitted. Proposed designs which cannot meet the specific requirements of a listed option above, may calculate compliance by Chapters 4 or 5 of this Code.

² Required minimum average log thickness.

³ 'Adv' denotes Advanced Framing. Requirement applies to all ceilings except single rafter joist vaulted ceilings.

⁴ Requirement applicable only to single rafter joist vaulted ceilings.

⁵ Floors over crawl spaces or exposed to ambient air conditions.

⁶ Required slab perimeter insulation shall be water-resistant material, manufactured for its intended use, and installed according to manufacturer's specifications.

⁷ These options shall be applicable to buildings less than three stories.

THE WASHINGTON STATE ENERGY CODE • WAC 52-11 • EFFECTIVE JULY 1, 1991TABLE 6-6 LOG HOMES PRESCRIPTIVE REQUIREMENTS¹
HEATING BY OTHER FUELS

OPTION	AVERAGE ² LOG THICKNESS	GLAZING % FLOOR AREA	GLAZING U-VALUE	DOORS U-VALUE	CEILING ³	VAULTED ⁴ CEILING	FLOOR ⁵	SLAB ⁶ ON GRADE
CLIMATE ZONE 1								
I. ⁷	3.5"	21%	0.40	0.39	R-49 Adv	R-38	R-30	R-10
II.	4.4"	21%	0.40	0.40	R-38	R-30	R-19	R-10
III.	5.2"	21%	0.50	0.40	R-38	R-30	R-19	R-10
IV.	6.5"	21%	0.60	0.40	R-38	R-30	R-19	R-10
V.	7.0"	21%	0.60	0.40	R-38	R-30	R-19	R-10
VI.*	8.2"	21%	0.65	0.40	R-38	R-30	R-19	R-10
CLIMATE ZONE 2								
VII. ⁷	3.5"	17%	0.31	0.14	R-60 Adv	R-38	R-38	R-10
VIII. ^{7,8}	3.5"	17%	0.40	0.40	R-60 Adv	R-38	R-30	R-10
IX. ⁷	4.6"	17%	0.40	0.40	R-60 Adv	R-38	R-30	R-10
X.	5.4"	17%	0.40	0.40	R-38	R-30	R-30	R-10
XI.	6.8"	17%	0.50	0.40	R-38	R-30	R-30	R-10
XII.*	9.0"	17%	0.60	0.40	R-38	R-30	R-30	R-10

* Reference Case • (highlighted in redline)

¹ For Group R Occupancy use Table 6-6 for only the portion of floor area using log/solid timber walls. Use Tables 6-1 to 6-4 for all other portions of the floor area. Minimum requirements are for each option listed. Interpolations between options is not permitted. Proposed designs which cannot meet the specific requirements of a listed option above, may calculate compliance by Chapters 4 or 5 of this Code.

² Required minimum average log thickness.

³ 'Adv' denotes Advanced Framing. Requirement applies to all ceilings except single rafter joist vaulted ceilings.

⁴ Requirement applicable only to single rafter joist vaulted ceilings.

⁵ Floors over crawl spaces or exposed to ambient air conditions.

⁶ Required slab perimeter insulation shall be water-resistant material, manufactured for its intended use, and installed according to manufacturer's specifications.

⁷ These options shall be applicable to buildings less than three stories.

⁸ For this option, minimum HVAC system efficiency is an AFUE of 0.88.

Appendix B: WSEC Tables

TABLE 5-1 TARGET COMPONENT VALUES FOR GROUP R OCCUPANCY

Fuels	Climate Zone	Electric Resistance		Other Fuels	
		1	2	1	2
<u>Component</u>					
Glazing & Floor Area		15%	15%	15%	15%
Glazing U-Factor		U = 0.400	U = 0.400	U = 0.650	U = 0.600
Doors		U = 0.200 (R = 5)	U = 0.200 (R = 5)	U = 0.400 (R = 2.5)	U = 0.400 (R = 2.5)
Ceilings:					
Attic		U = 0.031 (R = 38)	U = 0.031 (R = 38)	U = 0.036 (R = 30)	U = 0.031 (R = 38)
Single Rafter/ Joist Vaulted		U = 0.034 (R = 30)	U = 0.034 (R = 30)	U = 0.034 (R = 30)	U = 0.034 (R = 30)
Walls		U = 0.058 (R = 19A)	U = 0.044 (R = 19+5A)	U = 0.062 (R = 19)	U = 0.062 (R = 19+5)
Floors		U = 0.029 (R = 30)	U = 0.029 (R = 30)	U = 0.041 (R = 19)	U = 0.029 (R = 30)
Slab on Grade		F = 0.54 (R = 10)	F = 0.54 (R = 10)	F = 0.54 (R = 10)	F = 0.54 (R = 10)
Slab R-Value					
<u>Below Grade Interior</u>					
Wall R-Value		(R = 19)	(R = 19)	(R = 19)	(R = 19)
2' Depth: Walls		U = 0.043	U = 0.043	U = 0.043	U = 0.043
Slab		F = .69	F = .69	F = .69	F = .69
3.5' Depth: Walls		U = 0.041	U = 0.041	U = 0.041	U = 0.041
Slab		F = 0.64	F = 0.64	F = 0.64	F = 0.64
7' Depth: Walls		U = 0.037	U = 0.037	U = 0.037	U = 0.037
Slab		F = 0.57	F = 0.57	F = 0.57	F = 0.57
<u>Below Grade Exterior</u>					
Wall R-Value		(R = 10)	(R = 12)	(R = 10)	(R = 12)
2' Depth: Walls		U = 0.070	U = 0.061	U = 0.070	U = 0.061
Slab		F = 0.60	F = 0.60	F = 0.60	F = 0.60
3.5' Depth: Walls		U = 0.064	U = 0.057	U = 0.064	U = 0.057
Slab		F = 0.57	F = 0.57	F = 0.57	F = 0.57
7' Depth: Walls		U = 0.056	U = 0.050	U = 0.056	U = 0.050
Slab		F = 0.42	F = 0.42	F = 0.42	F = 0.42

Component Compliance Packages for Electric Resistance Heat

Alternatives to the Prescriptive Paths of the 1991 WSEC

	Glazing as % of Floor Area	Glazing U-Factor	Door U-Factor	Attic Ceiling	Vaulted Ceiling	Above Grade Wall	Below Grade Walls Int Ext	Floor	Slab
Package A Climate Zone I	15%	.38	.40/.19*	R38	R30	R21 Int**	R19 R10	R30	R10
Package B Climate Zone II	12%	.36	.40/.19*	R38	R30	R21 Int**	R21 R12	R30	R10
Package C Climate Zone II	15%	.36	.40/.19*	R49	R30	R21 Int**	R21 R12	R30	R10
Package D Climate Zone II	12%	.33	.40/.19*	R49	R30	R21 Int**	R21 R12	R19 _{Floor} + R10 _{Perimeter}	

* One door (up to 24 ft²) may have U-Factor = .40 or less; remaining doors must have U-Factor = .19 or less.

** R21 Int = R21 Intermediate framing; 16" oc stud spacing, R10 insulated headers, full insulation at corners and interior wall intersections with exterior walls, all structurally unnecessary framing eliminated.

Refer to Chapter 5 of the Energy Code for other requirements, including building envelope (Section 502), mechanical system (Section 503), and service water heating (Section 504).

Component Compliance Packages

What Are They

These Component Compliance Packages for electrically heated homes are an alternative to the Prescriptive Paths found in Chapter 6 of the 1991 Washington State Energy Code. They were created by the Washington State Energy Office to provide trade-offs not found in the Prescriptive Paths. These alternate paths use the target component values of Table 5-1, and equations 1 and 3 of Chapter 5. Houses that follow these packages will use no more energy for heating than an identical structure built to one of the Prescriptive Paths. The Energy Office has determined that houses using these Component Compliance Packages will comply with the Chapter 5 Component Performance approach.

How Do They Work

The Component Compliance Packages work just like the Prescriptive Paths. Houses that follow the prescribed component requirements for a path will comply with the Energy Code. No trade-offs may be made between the paths -- each path must be followed in its entirety.

Pros & Cons

The advantage to these packages is that Component Performance compliance can be demonstrated with the ease of a Prescriptive Path. The area take-offs needed for a standard Component Performance trade-off are not necessary with this method. Key advantages to these packages are:

- All four packages assume wood or ornamental doors
- No foam sheathing is required for walls
- Combination floor and foundation perimeter insulation is included in one zone 2 package

The disadvantage is that these paths are more restrictive than the Prescriptive Paths, and in some cases more restrictive than if a standard Component Performance calculation was undertaken. The Component Performance and Energy Budget methods also allow greater flexibility in meeting the code.

Cautions

Remember that all of the other requirements for residential buildings found in Chapter 5 of the code apply to houses that use this method. For example, ducts in unheated spaces must be insulated to R8, vapor retarders must be installed, recessed light restrictions apply, etc. These requirements are found in Section 502, Building Envelope Requirements; Section 503, Building Mechanical Systems; and Section 504, Service Water Heating.

Although this variation on code compliance is not explicitly outlined in the Energy Code itself, WSEO is confident that houses using these packages will comply with Chapter 5 if the standard calculations are done. Please call the Washington State Energy Code Toll-Free Line at 1-800-235-8248 if you have any questions about the Component Compliance Packages.

**TABLE 6-7 OTHER THAN GROUP R OCCUPANCIES PRESCRIPTIVE
REQUIREMENTS**

COMPONENT	ZONE I	ZONE II
SPACE CONDITIONING SYSTEM TYPE	ANY	ANY
ROOF/CEILINGS	R-30	R-30
EXTERIOR WALLS	R-11	R-11
FLOORS OVER UNCONDITIONED SPACE	R-11	R-11
BELOW GRADE WALLS	R-4	R-5
SLAB ON GRADE FLOORS ¹	R-7	R-10
GLAZING TYPE	Double ²	Double ²
MAXIMUM TOTAL GLAZING AREA (% of Gross Exterior Wall Area)	32%	22%

¹Insulation shall be a water-resistant material, manufactured for its intended use, and installed to manufacturer's specifications.

²'Double' denotes a minimum air space between glazing of 1/2 inch.

TABLE 5-2 COMPONENT REQUIREMENTS FOR OTHER THAN GROUP R OCCUPANCIES

BUILDINGS OF THREE CONDITIONED STORIES OR LESS					
Zone	Ceilings	Walls (Includes Glazing)	Floors	Slab on Grade ¹	
	Uo	Uo	Uo	Installed R-Value	Installed F-Value
I.	0.035	0.25	0.05	7	0.56
II.	0.035	0.20	0.05	10	0.54

¹ Insulation shall be water-resistant material manufactured for this use.

BUILDINGS OVER THREE CONDITIONED STORIES					
Zone	Ceilings	Walls (Includes Glazing)	Floors	Slab on Grade ¹	
	Uo	Uo	Uo	Installed R-Value	Installed F-Value
I.	0.08	0.30	0.08	7	0.56
II.	0.06	0.25	0.08	10	0.54

¹ Insulation shall be water-resistant material manufactured for this use.

Table 5-8 MINIMUM EFFICIENCY FOR ELECTRIC HVAC EQUIPMENT, COOLING

STANDARD RATING CAPACITY	<u>AIR COOLED</u>		<u>EVAP/WATER COOLED</u>
	SEER	EER	EER
Under 65,000 Btu/hr. (19,050 watts)			
A. Split System	10.0	-----	-----
B. Single Package ³	9.7	-----	9.3 ¹
65,000 Btu/hr. and over	-----	8.9 ²	10.5 ¹

¹ @ 80°F dry bulb / 67°F wet bulb² @ 95°F dry bulb³ Prior to January 1, 1993, a minimum value of 8.0 SEER may be used.

Appendix C: Component U-Values

WSEC Default U-Values (Code Chapter 10)	C-2
ASHRAE Window Standards*	C-24
SBCC Window & Door List (Tested U-Values)	C-26
ASHRAE U-Values for Selected Materials*	C-62
Zone Method of Computing Metal Framing U-Values**	N.A.

*These tables have been reprinted from the ASHRAE *Handbook of Fundamentals*, 1989 ED., with the permission of ASHRAE.

** Unfortunately, as of this printing these fact sheets are not yet available.

CHAPTER 10

**SECTION 1000 -- DEFAULT HEAT-LOSS COEFFICIENTS FOR
SITE-BUILT SINGLE AND MULTIFAMILY HOMES**

SECTION 1001 -- GENERAL

1001.1 Scope: This chapter includes tables of seasonal average heat-loss coefficients for specified nominal insulation. The heat-loss coefficients may also be used for heating system sizing.

1001.2 Description: These coefficients were developed primarily from data and procedures from Standard RS-1, and taken specifically from Standard RS-26, listed in Chapter 7.

Coefficients not contained in this chapter may be computed using the procedures listed in these references if the assumptions in the following sections and Standard RS-26, listed in Chapter 7, are used, along with data from the sources referenced above.

SECTION 1002 -- BELOW GRADE WALLS AND SLABS

1002.1 General: Table 10-1 lists heat-loss coefficients for below-grade walls and floors.

Coefficients for below-grade walls are given as U-values ($\text{BTU}/^\circ\text{F} \cdot \text{hr} \cdot \text{ft}^2$ of wall area). Coefficients for below-grade slabs are listed as F-values ($\text{BTU}/^\circ\text{F} \cdot \text{hr}$ per lineal foot of slab perimeter).

Below-grade wall U-values are only valid when used with the accompanying below-grade slab F-value, and vice versa.

1002.2 Component Description: All below-grade walls are assumed to be eight inch concrete. The wall is assumed to extend from the slab upward to the top of the mud sill for the distance specified in Table 10-1, with six inches of concrete wall extending above grade.

Interior insulation is assumed to be fiberglass batts placed in the cavity formed by 2x4 framing on twenty-four inch centers with one-half inch of gypsum board as the interior finish material. Exterior insulation is assumed to be applied directly to the exterior of the below-grade wall from the top of the wall to the footing. The exterior case does not assume any interior framing or sheetrock.

In all cases, the entire wall surface is assumed to be insulated to the indicated nominal level with the appropriate framing and insulation application. Coefficients are listed for wall depths of two, three and one-half, and seven feet below grade. Basements shallower than two feet should use on-grade slab coefficients.

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Heat-loss calculations for wall areas above grade should use above-grade wall U-values, beginning at the mudsill.

1002.3 Insulation Description: Coefficients are listed for the following four configurations:

1. **Uninsulated:** No insulation or interior finish.
2. **Interior insulation:** Interior 2x4 insulated wall without a thermal break between concrete wall and slab.
3. **Interior insulation with thermal break:** Interior 2x4 insulated wall with R-5 rigid board providing a thermal break between the concrete wall and the slab.
4. **Exterior insulation:** Insulation applied directly to the exterior surface of the concrete wall.

Appendix C: Component U-Values

TABLE 10-1 DEFAULT WALL U-VALUES AND SLAB F-VALUES FOR BASEMENTS

	Below Grade Wall U-value	Below Grade Slab F-value
2-Foot Depth Below Grade		
Uninsulated	0.350	0.59
R-11 Interior	0.066	0.68
R-11 Interior w/th	0.070	0.60
R-19 Interior	0.043	0.69
R-19 Interior w/th	0.045	0.61
R-10 Exterior	0.070	0.60
R-12 Exterior	0.061	0.60
3.5-Foot Depth Below Grade		
Uninsulated	0.278	0.53
R-11 Interior	0.062	0.63
R-11 Interior w/th	0.064	0.57
R-19 Interior	0.041	0.64
R-19 Interior w/th	0.042	0.57
R-10 Exterior	0.064	0.57
R-12 Exterior	0.057	0.57
7-Foot Depth Below Grade		
Uninsulated	0.193	0.46
R-11 Interior	0.054	0.56
R-11 Interior w/th	0.056	0.42
R-19 Interior	0.037	0.57
R-19 Interior w/th	0.038	0.43
R-10 Exterior	0.056	0.42
R-12 Exterior	0.050	0.42

SECTION 1003 -- ON-GRADE SLAB FLOORS

1003.1 General: Table 10-2 lists heat-loss coefficients for heated on-grade slab floors, in units of BTU/°F•hr per lineal foot of perimeter.

1003.2 Component Description: All on-grade slab floors are assumed to be six inch concrete poured directly onto the earth. The bottom of the slab is assumed to be at grade line. Monolithic and floating slabs are not differentiated.

Soil is assumed to have a conductivity of 0.75 BTU/Hr•°F•ft². Slabs two feet or more below grade should use basement coefficients.

1003.3 Insulation Description: Coefficients are provided for the following three configurations:

Two Foot (or four foot) vertical: Insulation is applied directly to the slab exterior, extending downward from the top of the slab to a depth of two feet (or four feet) below grade.

Two Foot (or four Foot) horizontal: Insulation is applied directly to the underside of the slab, and run horizontally from the perimeter inward for two feet (or four feet). The slab edge is exposed in this configuration.

Note: A horizontal installation with a thermal break of at least R-5 at the slab edge should use the vertical-case F-values.

Fully insulated slab: Insulation extends from the top of the slab, along the entire perimeter, and completely covers the area under the slab.

TABLE 10-2 DEFAULT F-VALUES FOR ON-GRADE SLABS

Insulation type	R-0	R-5	R-10	R-15
Uninsulated slab	0.73	--	--	--
2-ft Horizontal (No thermal break)	--	0.70	0.70	0.69
4-ft Horizontal (No thermal break)	--	0.67	0.64	0.63
2-ft Vertical (or Horiz. w/T.B.)	--	0.58	0.54	0.52
4-ft vertical (or Horiz. w/T.B.)	--	0.54	0.48	0.45
Fully insulated slab	--	--	0.36	--

SECTION 1004 -- CRAWLSPACE FLOORS

1004.1 General: Tables 10-3 and 10-4 list heat-loss coefficients for floors over crawlspaces in units of BTU/°F•hr•ft² of floor.

They are derived from procedures listed in standard RS-1, listed in Chapter 7, assuming an average outdoor temperature of 45°F, an average indoor temperature of 65°F, and a crawlspace area of 1350 ft² and one hundred feet of perimeter. The crawlspace is assumed to be two and one-half feet high, with twenty-four inches below grade and six inches above grade.

1004.2 Crawlspace Description: Four crawlspace configurations are considered: vented, unvented, enclosed and heated plenum.

Vented crawlspaces: Assumed to have three air-changes per hour, with at least one ft² of net-free ventilation in the foundation for every three hundred ft² of crawlspace floor area. The crawlspace is not actively heated.

Floors over unheated areas, such as garages, may only use those values which have R-0 perimeter insulation.

Unvented crawlspaces: Assumed to have 1.5 air changes per hour, with less than one ft² of net-free ventilation in the foundation for every three hundred ft² of crawlspace floor area. The crawlspace is not actively heated. Floors over unheated basements may only use those values which have R-0 perimeter insulation.

Heated-plenum crawlspaces: Assumed to have 0.25 air-changes per hour, with no foundation vents. Heated supply air from central furnace is blown into a crawlspace and allowed to enter the living space unducted via holes cut into the floor.

Enclosed floors: Assumes no buffer space, and a covering of one-half inch of T1-11 on the exterior of the cavity exposed to the outside air.

1004.3 Construction Description: Floors are assumed to be either joisted floors framed on sixteen inch centers, or post and beam on four by eight foot squares. Insulation is assumed to be installed under the subflooring between the joists or beams with no space between the insulation and the subfloor. Insulation is assumed to be uncompressed.

Perimeter insulation is assumed to extend from the top of the rim joist to the crawlspace floor and then inward along the ground (on top of the ground cover) for at least twenty-four inches.

Floor coverings are assumed to be light carpet with rubber pad.

**TABLE 10-3 DEFAULT U-VALUES FOR FLOORS OVER VENTED CRAWLSPACE
OR UNHEATED BASEMENT**

<u>Nominal R-value</u>		<u>U-value</u>	
Floor	Perimeter	Post & Beam	Joists
0	0	0.112	0.134
	11	0.100	0.116
	19	0.098	0.114
	30	0.093	0.107
11	0	0.052	0.056
	11	0.048	0.052
19	0	0.038	0.041
	11	0.036	0.038
22	0	0.034	0.037
	11	0.033	0.035
25	0	0.032	0.034
	11	0.031	0.033
30	0	0.028	0.029
	11	0.027	0.028
38	0	0.024	0.025
	11	0.024	0.024

**TABLE 10-4 DEFAULT U-VALUES FOR FLOORS OVER HEATED PLENUM
CRAWLSPACES**

<u>Nominal R-value</u>		<u>U-value</u>
	<u>Perimeter</u>	
	11	0.085
	19	0.075
	30	0.069

Note: Crawlspace used as heated plenums have approximately 30-percent higher heat-loss rate than unvented crawlspaces with the same assumed ACH. Default U-values in Table 10-4 reflect this higher rate of heat loss.

SECTION 1005 -- ABOVE-GRADE WALLS

1005.1 General: Table 10-5 lists heat-loss coefficients for the opaque portion of above-grade walls (BTU/°F•hr•ft²). They are derived from procedures listed in Standard RS-1, listed in Chapter 7, assuming exterior air films at 7.5-mph wind speed.

Insulation is assumed to uniformly fill the entire cavity and to be installed as per manufacturer's directions. All walls are assumed to be finished on the inside with one-half inch gypsum wallboard, and on the outside with either beveled wood siding over one-half inch plywood sheathing or with five-eighths inch T1-11 siding. Insulated sheathing (either interior or exterior) is assumed to cover the entire opaque wall surface.

1005.2 Framing Description: Three framing types are considered, and defined as follows:

Standard: Studs framed on sixteen inch centers with double top plate and single bottom plate. Corners use three studs and each opening is framed using two studs. Headers consist of double 2X or single 4X material with an air space left between the header and the exterior sheathing. Interior partition wall/exterior wall intersections use two studs in the exterior wall.

Standard framing weighting factors:

Studs and plates	.19
Insulated cavity	.77
Headers	.04

Intermediate: Studs framed on sixteen inch centers with double top plate and single bottom plate. Corners use two studs or other means of fully insulating corners, and each opening is framed by two studs. Headers consist of double 2X material with R-10 insulation between the header and exterior sheathing. Interior partition wall/exterior wall intersections are fully insulated in the exterior wall.

Intermediate framing weighting factors:

Studs and plates	.18
Insulated cavity	.78
Headers	.04

Advanced: Studs framed on twenty-four inch centers with double top plate and single bottom plate. Corners use two studs or other means of fully insulating corners, and one stud is used to support each header. Headers consist of double 2X material with R-10 insulation between the header and exterior sheathing. Interior partition wall/exterior wall intersections are fully insulated in the exterior wall.

Advanced Framing Weighting Factors:

Studs and plates	.13
Insulated cavity	.83
Headers	.04

1005.3 Component Description: Default coefficients for three types of walls are listed: single-stud walls, strap walls, and double-stud walls.

Single-Stud Wall: Assumes either 2x4 or 2x6 studs framed on sixteen or twenty-four inch centers. Headers are solid for 2x4 walls and double 2x for 2x6 walls, with either dead-air or rigid-board insulation in the remaining space.

Strap Wall: Assumes 2x6 studs framed on sixteen or twenty-four inch centers. 2x3 or 2x4 strapping is run horizontally along the interior surface of the wall to provide additional space for insulation.

Double-Stud Wall: Assumes an exterior structural wall and a separate interior, non-structural wall. Insulation is placed in both wall cavities and in the space between the two walls. Stud spacing is assumed to be on twenty-four inch centers for both walls.

Appendix C: Component U-Values

TABLE 10-5 DEFAULT U-VALUES FOR ABOVE-GRADE WALLS

2 x 4 Single Wood Stud: R-11 Batt

NOTE:

Nominal Batt R-value:
R-11 at 3.5-inch thickness

Installed Batt R-value:
R-11 in 3.5-inch cavity

Siding Material/Framing Type

R-value Lapped Wood T1-11
of Foam
Board STD ADV STD ADV

0	.088	.084	.094	.090
1	.080	.077	.085	.082
2	.074	.071	.078	.075
3	.069	.066	.072	.070
4	.064	.062	.067	.065
5	.060	.058	.063	.061
6	.056	.055	.059	.057
7	.053	.052	.055	.054
8	.051	.049	.052	.051
9	.048	.047	.050	.049
10	.046	.045	.047	.046
11	.044	.043	.045	.044
12	.042	.041	.043	.042

2 x 4 Single Wood Stud: R-13 Batt

NOTE:

Nominal Batt R-value:
R-13 at 3.63-inch thickness

Installed Batt R-value:
R-12.7 in 3.5-inch cavity

Siding Material/Framing Type

R-value Lapped Wood T1-11
of Foam
Board STD ADV STD ADV

0	.082	.078	.088	.083
1	.075	.072	.080	.076
2	.069	.066	.073	.070
3	.065	.062	.068	.065
4	.060	.058	.063	.061
5	.057	.055	.059	.057
6	.053	.052	.056	.054
7	.051	.049	.052	.051
8	.048	.047	.050	.048
9	.046	.045	.047	.046
10	.044	.043	.045	.044
11	.042	.041	.043	.042
12	.040	.039	.041	.040

2 x 4 Single Wood Stud: R-15 Batt

NOTE:

Nominal Batt R-value:
R-15 at 3.5-inch thickness

Installed Batt R-value:
R-15 in 3.5-inch cavity

Siding Material/Framing Type

R-value of Foam Board Lapped Wood T1-11
STD ADV STD ADV

0	.076	.071	.081	.075
1	.069	.065	.073	.069
2	.064	.061	.068	.069
3	.060	.057	.063	.059
4	.056	.053	.059	.056
5	.053	.051	.055	.052
6	.050	.048	.052	.050
7	.047	.046	.049	.047
8	.045	.044	.047	.045
9	.043	.042	.044	.043
10	.041	.040	.042	.041
11	.039	.038	.041	.039
12	.038	.037	.039	.038

2 x 6 Single Wood Stud: R-19 Batt

NOTE:

Nominal Batt R-value
R-19 at 6-inch thickness

Installed Batt R-Value
R-18 in 5.5-inch cavity

Siding Material/Framing Type

R-value of Foam Board Lapped Wood T1-11
STD INT ADV STD INT ADV

0	.062	.058	.055	.065	.061	.058
1	.058	.055	.052	.060	.057	.055
2	.054	.052	.050	.056	.054	.051
3	.051	.049	.047	.053	.051	.049
4	.048	.046	.045	.050	.048	.046
5	.046	.044	.043	.048	.046	.044
6	.044	.042	.041	.045	.044	.042
7	.042	.040	.039	.043	.042	.040
8	.040	.039	.038	.041	.040	.039
9	.038	.037	.035	.039	.038	.037
10	.037	.036	.035	.038	.037	.036
11	.036	.035	.034	.036	.035	.035
12	.034	.033	.033	.035	.034	.033

Appendix C: Component U-Values

2 x 6 Single Wood Stud: Two R-11 Batts

	R-value of Foam Board	<u>Siding Material/Framing Type</u>					
		Lapped Wood			T1-11		
		STD	INT	ADV	STD	INT	ADV
NOTE:							
Nominal Batt R-value	0	.060	.057	.054	.063	.059	.056
R-22 at 7-inch thickness	1	.056	.053	.051	.059	.056	.053
Installed Batt R-value	2	.053	.050	.048	.055	.052	.050
R-18.9 in 5.5-inch cavity	3	.050	.048	.046	.052	.049	.047
	4	.047	.045	.044	.049	.047	.045
	5	.045	.043	.042	.046	.045	.043
	6	.043	.041	.040	.044	.043	.041
	7	.041	.040	.038	.042	.041	.039
	8	.039	.038	.037	.040	.039	.038
	9	.038	.037	.036	.039	.038	.036
	10	.036	.035	.034	.037	.036	.035
	11	.035	.034	.033	.036	.035	.034
	12	.034	.033	.032	.034	.034	.033

2 x 8 Single Stud: R-25 Batt

	R-value of Foam Board	<u>Siding Material/Framing Type</u>					
		Lapped Wood			T1-11		
		STD	INT	ADV	STD	INT	ADV
NOTE:							
Nominal Batt R-value	0	.051	.047	.045	.053	.049	.046
R-25 at 8-inch thickness	1	.048	.045	.043	.049	.046	.044
Installed Batt R-value	2	.045	.043	.041	.047	.044	.042
R-23.6 in 7.25-inch cavity	3	.043	.041	.039	.044	.042	.040
	4	.041	.039	.037	.042	.040	.038
	5	.039	.037	.036	.040	.038	.037
	6	.037	.036	.035	.038	.037	.036
	7	.036	.035	.033	.037	.035	.034
	8	.035	.033	.032	.035	.034	.033
	9	.033	.032	.031	.034	.033	.032
	10	.032	.031	.030	.033	.032	.031
	11	.031	.030	.029	.032	.031	.030
	12	.030	.029	.028	.031	.030	.029

2 x 6 Single Wood Stud: R-21 Batt

<u>Siding Material/Framing Type</u>							
R-value of Foam Board	Lapped Wood			T1-11			
	STD	INT	ADV	STD	INT	ADV	
<hr/>							
NOTE:							
Nominal BATT R-value	0	.057	.054	.051	.060	.056	.053
R-21 at 5.5-inch thickness	1	.054	.051	.048	.056	.053	.050
Installed Batt R-value	2	.050	.048	.045	.052	.050	.047
R-21 in 5.5-inch cavity	3	.048	.045	.043	.049	.047	.045
	4	.045	.043	.041	.047	.045	.043
	5	.043	.041	.040	.044	.042	.041
	6	.041	.039	.038	.042	.041	.039
	7	.039	.038	.036	.040	.039	.037
	8	.038	.036	.035	.039	.037	.036
	9	.036	.035	.034	.037	.036	.035
	10	.035	.034	.033	.036	.035	.033
	11	.033	.033	.032	.034	.033	.032
	12	.032	.031	.031	.033	.032	.031

2 x 6 Single Wood Stud: R-22 Batt

	<u>Siding Material/Framing Type</u>						
	R-value of Foam Board	Lapped Wood			T1-11		
		STD	INT	ADV	STD	INT	ADV
NOTE:							
Nominal Batt R-value	0	.059	.055	.052	.062	.058	.054
R-22 at 6.75-inch thickness	1	.055	.052	.049	.057	.054	.051
Installed Batt R-value	2	.052	.049	.047	.054	.051	.048
R-20 in 5.5-inch cavity	3	.049	.046	.044	.050	.048	.046
	4	.046	.044	.042	.048	.046	.044
	5	.044	.042	.041	.045	.043	.042
	6	.042	.040	.039	.043	.042	.040
	7	.040	.039	.037	.041	.040	.038
	8	.038	.037	.036	.039	.038	.037
	9	.037	.036	.035	.038	.037	.035
	10	.035	.034	.033	.036	.035	.034
	11	.034	.033	.032	.035	.034	.033
	12	.033	.032	.031	.034	.033	.032

Appendix C: Component U-Values

2 x 6: Strap Wall

<u>Siding Material/Frame Type</u>			
Lapped Wood		T1-11	
STD	ADV	STD	ADV
R-19 + R-11 Batts	.036	.035	.038
R-19 + R-8 Batts	.041	.039	.042

2 x 6 + 2 x 4: Double Wood Stud

			<u>Siding Material/Frame Type</u>			
			Lapped Wood		T1-11	
			STD	ADV	STD	ADV
<u>Batt Configuration</u>						
Exterior	Middle	Interior				
R-19	-----	R-11	.040	.037	.041	.038
R-19	-----	R-19	.034	.031	.035	.032
R-19	R-8	R-11	.029	.028	.031	.029
R-19	R-11	R-11	.027	.026	.028	.027
R-19	R-11	R-19	.024	.023	.025	.023
R-19	R-19	R-19	.021	.020	.021	.020

2 x 4 + 2 x 4: Double Wood Stud

			<u>Siding Material/Frame Type</u>			
			Lapped Wood		T1-11	
			STD	ADV	STD	ADV
<u>Batt Configuration</u>						
Exterior	Middle	Interior				
R-11	-----	R-11	.050	.046	.052	.048
R-19	-----	R-11	.039	.037	.043	.039
R-11	R-8	R-11	.037	.035	.036	.036
R-11	R-11	R-11	.032	.031	.033	.032
R-13	R-13	R-13	.029	.028	.029	.028
R-11	R-19	R-11	.026	.026	.027	.026

Log Walls

	<u>Average Log Diameter</u>	<u>U-value</u>
NOTE:		
R-value of wood:	6-inch	0.148
R-1.25 per inch thickness	8-inch	0.111
Average wall thickness	10-inch	0.089
90% average log diameter	12-inch	0.074
	14-inch	0.063
	16-inch	0.056

Stress Skin Panel

	<u>Panel Thickness</u>	<u>U-value</u>
NOTE:		
R-value of expanded polystyrene:	3 1/2-inch	.071
R-3.85/inch	5 1/2-inch	.048
	7 1/4-inch	.037
	9 1/4-inch	.030
	11 1/4-inch	.025
Framing: 6%		
Spline: 8%		
No thermal bridging between interior and exterior splines		

Single Metal Stud

<u>Nominal Wall Thickness</u>	<u>Nominal Insulation R-Value</u>	<u>Effective Insulation R-Value</u>	<u>Stud Spacing</u>	
			<u>16" O.C.</u>	<u>24" O.C.</u>
4 inch	R-11	R-11	.14	.13
4 inch	R-13	R-12.7	.13	.12
6 inch	R-19	R-18	.11	.10

Appendix C: Component U-Values

SECTION 1006 -- DEFAULT U-VALUES FOR GLAZING AND DOORS

1006.1 Untested Glazing and Doors: Untested glazing and doors shall be assigned the following U-values:

a. Manufactured glazing products:

- single glazing (all): $U = 1.20$;
- double glazing:
 - aluminum or steel framed: $U = 0.90$;
 - wood or vinyl framed: $U = 0.75$;

b. Non-manufactured site built fixed lite glazing products with a minimum of one-half inch airspace in a wood frame only. All products supplied by manufacturers, such as kits for solariums, shall use the default U-values for manufactured glazing products cited above.

- air-filled: $U = 0.60$;
- argon-filled: $U = 0.55$;
- low-e, air-filled: $U = 0.50$;
- low-e, argon-filled: $U = 0.40$;

Products which do not comply with all of these criteria shall use the default U-values listed under manufactured glazing products.

c. For doors, see Table 10-6 on the next page.

TABLE 10-6 TRANSMISSION COEFFICIENTS (U) FOR WOOD AND STEEL DOORS
Btu/hr • ft² • °F

Nominal Door Thickness, Inches	Description	No Storm Door	Wood Storm Door ^c	Metal Storm Door ^d
Wood Doors^b				
1-3/8	Panel door with 7/16 inch panels ^e	0.57	0.33	0.37
1-3/8	Hollow core flush door	0.47	0.30	0.32
1-3/8	Solid core flush door	0.39	0.26	0.28
1-3/4	Panel door with 7/16 inch panels ^e	0.57	0.33	0.36
1-3/4	Hollow core flush door	0.46	0.29	0.32
1-3/4	Panel door with 1-1/8 inch panels ^e	0.39	0.26	0.28
1-3/4	Solid core flush door	0.33	0.28	0.25
2-1/4	Solid core flush door	0.27	0.20	0.21
Steel Doors^b				
1-3/4	Fiberglass or mineral wool core w/ steel stiffeners, no thermal break ^f	0.60	----	----
1-3/4	Paper honeycomb core without thermal break ^f	0.56	----	----
1-3/4	Solid urethane foam core without thermal break ^f	0.40	----	----
1-3/4	Solid fire rated mineral fiberboard core without thermal break ^f	0.38	----	----
1-3/4	Polystyrene core without thermal break(18 gage commercial steel) ^f	0.35	----	----
1-3/4	Polyurethane core without thermal break(18 gage commercial steel) ^f	0.29	----	----
1-3/4	Polyurethane core without thermal break(24 gage commercial steel) ^f	0.29	----	----
1-3/4	Polyurethane core w/ thermal break & wood perimeter(24 gage commercial steel) ^f	0.20	----	----
1-3/4	Solid urethane foam core with thermal break	0.19	0.16	0.17

Note: All U-factors for exterior doors in this table are for doors with no glazing, except for the storm doors which are in addition to the main exterior door. Any glazing area in exterior doors should be included with the appropriate glass type and analyzed. Interpolation and moderate extrapolation are permitted for door thicknesses other than those specified.

^a Values are based on a nominal 32 by 80 in. door size with no glazing.

^b Outside air conditions: 15 mph wind speed, 0 °F air temperature, inside air conditions: natural convection, 70 °F air temperature.

^c Values for wood storm door are for approximately 50 percent glass area.

^d Values for metal storm door are for any percent glass area.

^e 55 percent panel area.

^f ASTM C-236 hollow data on a nominal 3 by 7 ft door size with no glazing.

The U-factors in Table 6 are for exterior wood and steel doors. The values given for wood doors were calculated, and those for steel doors were taken from bar box tests (Sabine et al. 1975; Yellat 1963) or from manufacturer's test reports. An outside surface conductance of 6.0 Btu/ft² • h • °F was used, and the inside surface conductance was taken as 1.4 Btu/ft² • h • °F for vertical surfaces with horizontal heat flow. All values given are for exterior doors without glazing. If an exterior door contains glazing, the glazing should be analyzed as a window.

Appendix C: Component U-Values

SECTION 1007 -- CEILINGS

1007.1 General: Table 10-7 lists heat-loss coefficients for the opaque portion of exterior ceilings below vented attics, vaulted ceilings, and roof decks in units of BTU/°F • hr • ft² of ceiling.

They are derived from procedures listed in RS-1, listed in Chapter 7. Ceiling U-values are modified for the buffering effect of the attic, assuming an indoor temperature of 65°F and an outdoor temperature of 45°F.

1007.2 Component Description: The three types of ceilings are characterized as follows:

Ceilings Below a Vented Attic: Attic insulation is assumed to be blown-in, loose-fill fiberglass with a K-value of 2.6 Hr • °F • ft²/BTU per inch. Full bag count for specified R-value is assumed in all cases. Ceiling dimensions for flat ceiling calculations are forty-five by thirty feet, with a gabled roof having a 4/12 pitch. The attic is assumed to vent naturally at the rate of three air changes per hour through soffit and ridge vents. A void fraction of 0.002 is assumed for all attics with insulation baffles. Standard-framed, unbaffled attics assume a void fraction of 0.008.

Attic framing is either standard or advanced. Standard framing assumes tapering of insulation depth around the perimeter with resultant decrease in thermal resistance. An increased R-value is assumed in the center of the ceiling due to the effect of piling leftover insulation. Advanced framing assumes full and even depth of insulation extending to the outside edge of exterior walls. Advanced framing does not change from the default value.

U-values for flat ceilings below vented attics with standard framing may be modified with the following table:

Roof Pitch	U-Value for Standard Framing	
	R-30	R-38
4/12	.036	.031
5/12	.035	.030
6/12	.034	.029
7/12	.034	.029
8/12	.034	.028
9/12	.034	.028
10/12	.033	.028
11/12	.033	.027
12/12	.033	.027

Vented scissors truss attics assume a ceiling pitch of 2/12 with a roof pitch of either 4/12 or 5/12. Unbaffled standard framed scissors truss attics are assumed to have a void fraction of 0.016.

Vaulted Ceilings: Insulation is assumed to be fiberglass batts installed in roof joist cavities. In the vented case, at least 1.5-inches between the top of the batts and the underside of the roof sheathing is left open for ventilation in each cavity. A ventilation rate of three air changes per hour is assumed. In the unvented or dense pack case, the ceiling cavity is assumed to be fully packed with insulation, leaving no space for ventilation.

Roof Decks: Rigid insulation is applied to the top of roof decking with no space left for ventilation. Roofing materials are attached directly on top of the insulation. Framing members are often left exposed on the interior side.

TABLE 10-7 DEFAULT U-VALUES FOR CEILINGS

Ceilings Below Vented Attics

	<u>Standard Frame</u>	<u>Advanced Frame</u>
Flat Ceiling	Baffled	
R-19	0.049	0.047
R-30	0.036	0.032
R-38	0.031	0.026
R-49	0.027	0.020
R-60	0.025	0.017
Scissors Truss		
R-30 (4/12 roof pitch)	0.043	0.031
R-38 (4/12 roof pitch)	0.040	0.025
R-49 (4/12 roof pitch)	0.038	0.020
R-30 (5/12 roof pitch)	0.039	0.032
R-38 (5/12 roof pitch)	0.035	0.026
R-49 (5/12 roof pitch)	0.032	0.020

Vaulted Ceilings

	<u>16" O.C.</u>	<u>24" O.C.</u>
Vented		
R-19 2x10 joist	0.049	0.048
R-30 2x12 joist	0.034	0.033
R-38 2x14 joist	0.027	0.027
Unvented		
R-30 2x10 joist	0.034	0.033
R-38 2x12 joist	0.029	0.027
R-21 + R-21 2x12 joist	0.026	0.025

Roof Deck

	<u>4x Beams, 48" O.C.</u>
R-12.5 2" Rigid insulation	0.064
R-21.9 3.5" Rigid insulation	0.040
R-37.5 6" Rigid insulation	0.025
R-50 8" Rigid insulation	0.019

SECTION 1008 -- AIR INFILTRATION

1008.1 General: Tables 10-8 and 10-9 list effective air-change rates and heat capacities for heat loss due to infiltration.

The estimated seasonal average infiltration rate in air changes per hour (ACH) is given for standard air-leakage control (see section 502.4 of this Code for air leakage requirements). The effective air-change rate shall be used in calculations for compliance under either the Component Performance or Systems Analysis approaches.

Heat loss due to infiltration shall be computed using the following equation:

$$Q_{\text{infil}} = \text{ACH}_{\text{eff}} * \text{HCP}$$

where:

Q_{infil} = Heat loss due to air infiltration.

ACH_{eff} = The effective air infiltration rate in Table 10-8.

HCP = The Heat Capacity Density Product for the appropriate elevation or climate zone as given below.

TABLE 10-8 ASSUMED EFFECTIVE AIR-CHANGES PER HOUR

<u>Air-Leakage Control Package</u>	<u>Air-Changes per Hour</u>	
	<u>Natural</u>	<u>Effective</u>
Standard	0.35	0.35

TABLE 10-9 DEFAULT HEAT CAPACITY/DENSITY PRODUCT FOR AIR

<u>Zone</u>	<u>Average Elevation</u>	<u>Heat Capacity/Density</u>
1	Mean Sea Level	0.0180 Btu/hr • °F
2	2000	0.0168 Btu/hr • °F
3	3000	0.0162 Btu/hr • °F

SECTION 1009 -- MASS

1009.1 General: Table 10-10 lists default mass-values for residential construction types. All calculations are based on standard ASHRAE values for heat-storage capacity as listed in RS-1, Chapter 22.

Thermal capacity of furniture is ignored, as is heat storage beyond the first four inches of mass thickness. All mass is assumed to be in direct contact with the conditioned space. Concrete separated from the heated volume by other materials must multiply the listed concrete mass value by the result of the following formula:

$$\text{Ln(R-value)} \times (-.221) + 0.5$$

Where:

Ln = Natural log

R-value = R-value of material covering concrete

Note: All default values for covered concrete slabs have been adjusted according to this procedure.

1009.2 Mass Description: Mass is divided into two types: structural, and additional.

Structural Mass: Includes heat-storage capacity of all standard building components of a typical residential structure, including floors, ceilings, and interior and exterior walls in Btu/°F • ft² of floor area. It also assumes exterior wall, interior wall, and ceiling surface area approximately equals three times the floor area.

Additional Mass: Includes any additional building material not part of the normal structure, which is added specifically to increase the building's thermal-storage capability. This category includes masonry fireplaces, water or trombe walls, and extra layers of sheetrock. Coefficients are in Btu/°F • ft² of surface area of material exposed to conditioned space. The coefficient for water is Btu/°F-gallon.

1009.3 Component Description: Light frame assumes one inch thick wood flooring with five-eighths inch sheetrock on ceilings and interior walls, and walls consisting of either five-eighths inch sheetrock or solid logs. Slab assumes a four inch concrete slab on or below grade, with five-eighths inch sheetrock on exterior and interior walls and ceiling, and with separate values for interior or exterior wall insulation. Adjustments for slab covering is based on R-value of material. Additional mass values are based on the density multiplied by the specific heat of the material adjusted for listed thickness.

TABLE 10-10 DEFAULT MASS VALUES

Structural Mass M-value	Btu/°F • Ft ² floor area
-------------------------	-------------------------------------

Light Frame:

Joisted/post & beam floor, sheetrock walls and ceilings	3.0
Joisted/post & beam floor, log walls, sheetrock ceilings	4.0

Slab With Interior Wall Insulation:

Slab, no covering or tile, sheetrock walls and ceilings	10.0
Slab, hardwood floor covering, sheetrock walls and ceilings	7.0
Slab, carpet and pad, sheetrock walls and ceilings	5.0

Slab With Exterior Wall Insulation:

Slab, no covering or tile, sheetrock walls and ceilings	12.0
Slab, hardwood floor covering, sheetrock walls and ceilings	9.0
Slab, carpet and pad, sheetrock walls and ceilings	7.0

Additional Mass M-Value:BTU/°F • Ft² surface area

Gypsum wallboard, 1/2-inch thickness	0.54
Gypsum wallboard, 5/8-inch thickness	0.68
Hardwood floor	1.40
Concrete/Brick, 4 inch-thickness	10.30
Concrete/Brick, 6 inch-thickness	15.40

BTU/°F • gallon

Water, 1 gallon	8.0
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Table 13 Overall Coefficients of Heat Transmission of Various Fenestration Products

Part A: U-Values for Vertical Installation^a, Btu/h·ft²·°F

Glazing Type ^b	Glass Only		Aluminum Frame no thermal break (U _f = 1.9)		Aluminum Frame thermal break (U _f = 1.0)		Wood or Vinyl Frame (U _f = 0.4)	
	Center of Glass	Edge ^c of Glass	Product ^d Type		Product ^d Type		Product ^d Type	
			R	C	R	C	R	C
Single glazing glass	(1.11)	(n/a)	1.31	1.23	1.09	1.10	0.90	0.98
1/8 in. acrylic	(1.03)	(n/a)	1.26	1.16	1.02	1.03	0.84	0.92
Double glass								
1/4 in. air space	(0.57)	(0.66)	0.92	0.78	0.70	0.65	0.54	0.55
3/8 in. air space	(0.52)	(0.62)	0.88	0.74	0.66	0.60	0.50	0.51
1/2 in. and greater air space	(0.49)	(0.59)	0.87	0.72	0.64	0.59	0.49	0.49
Double glass, $\epsilon = 0.40$ on surface 2 or 3								
1/4 in. air space	(0.50)	(0.60)	0.87	0.73	0.65	0.59	0.49	0.50
3/8 in. air space	(0.43)	(0.55)	0.83	0.67	0.60	0.54	0.45	0.45
1/2 in. and greater air space	(0.41)	(0.54)	0.81	0.65	0.58	0.52	0.43	0.42
Double glass, $\epsilon = 0.15$ on surface 2 or 3								
1/4 in. air space	(0.45)	(0.56)	0.84	0.68	0.61	0.55	0.46	0.46
3/8 in. air space	(0.36)	(0.51)	0.78	0.62	0.56	0.48	0.41	0.39
1/2 in. air space	(0.34)	(0.50)	0.76	0.60	0.54	0.46	0.39	0.37
Double glass								
1/4 in. argon space	(0.52)	(0.62)	0.88	0.74	0.66	0.61	0.50	0.51
3/8 in. argon space	(0.48)	(0.59)	0.86	0.71	0.63	0.57	0.48	0.48
1/2 in. and greater argon space	(0.46)	(0.57)	0.82	0.69	0.62	0.56	0.47	0.47
Double glass, $\epsilon = 0.40$ on surface 2 or 3								
1/4 in. argon space	(0.43)	(0.55)	0.83	0.67	0.60	0.54	0.45	0.45
3/8 in. argon space	(0.38)	(0.52)	0.79	0.63	0.57	0.49	0.42	0.40
1/2 in. and greater argon space	(0.36)	(0.51)	0.78	0.62	0.56	0.48	0.41	0.39
Double glass, $\epsilon = 0.15$ on surface 2 or 3								
1/4 in. argon space	(0.36)	(0.51)	0.78	0.62	0.56	0.48	0.41	0.39
3/8 in. argon space	(0.30)	(0.48)	0.74	0.57	0.51	0.43	0.37	0.34
1/2 in. and greater argon space	(0.28)	(0.47)	0.73	0.55	0.50	0.42	0.36	0.33
Double glazing, 1/8 in. acrylic or polycarbonate								
1/4 in. air space	(0.52)	(0.62)	0.89	0.74	0.67	0.61	0.51	0.51
3/8 in. air space	(0.48)	(0.59)	0.86	0.71	0.64	0.57	0.48	0.48
1/2 in. and greater air space	(0.46)	(0.57)	0.85	0.69	0.62	0.56	0.47	0.47
Double glazing, 1/4 in. acrylic or polycarbonate								
1/4 in. air space	(0.48)	(0.59)	0.86	0.71	0.64	0.57	0.48	0.48
3/8 in. air space	(0.44)	(0.56)	0.84	0.68	0.61	0.54	0.46	0.45
1/2 in. and greater air space	(0.42)	(0.54)	0.82	0.66	0.60	0.53	0.45	0.43
Triple glass								
1/4 in. air space	(0.38)	(0.52)	0.79	0.64	0.57	0.50	0.42	0.41
3/8 in. air space	(0.34)	(0.50)	0.76	0.60	0.54	0.46	0.39	0.38
1/2 in. and greater air space	(0.32)	(0.49)	0.75	0.58	0.53	0.45	0.38	0.36
Triple glass, $\epsilon = 0.40$ on surface 2, 3, 4 or 5								
1/4 in. air spaces	(0.35)	(0.50)	0.77	0.61	0.55	0.48	0.40	0.39
3/8 in. air spaces	(0.30)	(0.48)	0.74	0.57	0.52	0.44	0.37	0.35
1/2 in. and greater air spaces	(0.28)	(0.47)	0.72	0.55	0.50	0.41	0.36	0.33
Triple glass or double glass with polyester film suspended in between, $\epsilon = 0.15$ on surface 2, 3, 4, or 5								
1/4 in. air spaces	(0.33)	(0.49)	0.76	0.59	0.53	0.45	0.39	0.37
3/8 in. air spaces	(0.27)	(0.46)	0.72	0.54	0.50	0.41	0.35	0.32
1/2 in. and greater air spaces	(0.24)	(0.45)	0.70	0.52	0.48	0.39	0.34	0.30
Triple glass or double glass with polyester film suspended in between, $\epsilon = 0.15$ on surfaces 2 or 3 and 4 or 5								
1/4 in. air spaces	(0.28)	(0.47)	0.73	0.55	0.53	0.42	0.36	0.33
3/8 in. air spaces	(0.22)	(0.45)	0.69	0.51	0.47	0.37	0.32	0.29
1/2 in. and greater air spaces	(0.19)	(0.44)	0.67	0.48	0.45	0.35	0.31	0.26
Triple glass								
1/4 in. argon spaces	(0.34)	(0.50)	0.77	0.60	0.54	0.46	0.39	0.38
3/8 in. argon spaces	(0.31)	(0.48)	0.74	0.57	0.52	0.44	0.37	0.35
1/2 in. and greater argon spaces	(0.29)	(0.47)	0.73	0.56	0.51	0.42	0.36	0.34
Triple glass, $\epsilon = 0.40$ on surface 2, 3, 4 or 5								
1/4 in. argon spaces	(0.30)	(0.48)	0.74	0.57	0.52	0.44	0.37	0.35
3/8 in. argon spaces	(0.26)	(0.46)	0.72	0.54	0.49	0.41	0.35	0.32
1/2 in. and greater argon spaces	(0.25)	(0.46)	0.71	0.53	0.48	0.39	0.34	0.31

Fenestration

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Table 13 Overall Coefficients of Heat Transmission of Various Fenestration Products (Concluded)

Part A: U-Values for Vertical Installation ^a , Btu/h·ft ² ·°F								
Glazing Type ^b	Glass Only		Aluminum Frame no thermal break (U _f = 1.9)		Aluminum Frame thermal break (U _f = 1.0)		Wood or Vinyl Frame (U _f = 0.4)	
	Center of Glass	Edge ^c of Glass	Product ^d Type		Product ^d Type		Product ^d Type	
			R	C	R	C	R	C
Triple glass or double glass with polyester film suspended in between, ε = 0.15 on surface 2, 3, 4, or 5								
1/4 in. argon spaces	(0.27)	(0.46)	0.72	0.54	0.50	0.41	0.35	0.32
3/8 in. argon spaces	(0.22)	(0.45)	0.69	0.51	0.47	0.37	0.33	0.29
1/2 in. and greater argon spaces	(0.20)	(0.44)	0.68	0.50	0.46	0.36	0.31	0.28
Triple glass or double glass with polyester film suspended in between, ε = 0.15 on surfaces 2 or 3 and 4 or 5								
1/4 in. argon spaces	(0.22)	(0.45)	0.69	0.51	0.47	0.37	0.32	0.29
3/8 in. argon spaces	(0.17)	(0.43)	0.66	0.47	0.44	0.34	0.30	0.25
1/2 in. and greater argon spaces	(0.15)	(0.43)	0.65	0.46	0.43	0.32	0.29	0.24

Part B: U-Value Conversion Table for Sloped and Horizontal Glazing for Upward Heat Flow

Slope	U-Value, Btu/h·ft ² ·°F												
90° (vertical)	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30
45°	0.14	0.25	0.36	0.47	0.57	0.68	0.79	0.90	1.00	1.11	1.22	1.33	1.44
0 (horiz.)	0.19	0.29	0.40	0.51	0.61	0.72	0.82	0.93	1.04	1.14	1.25	1.35	1.46

^aAll U-values are based on standard ASHRAE winter conditions of 70°F indoor and 0°F outdoor air temperature with 15 mph outdoor air velocity and zero solar flux. The outside surface coefficient at these conditions is approximately 5.1 Btu/hr·ft²·°F, depending on the glass surface temperature. With the exception of single glazing, small changes in the interior and exterior temperatures do not significantly affect overall U-values.

^bGlazing layer surfaces are numbered from the outside to the inside. Double and triple refer to the number of glazing lites. All data are based on 1/8 in. glass unless otherwise noted. Thermal conductivities are: 0.53 Btu/h·ft·°F for glass, and 0.11 Btu/h·ft·°F for acrylic and polycarbonate.

^cBased on aluminum spacers data (see Figure 6). Edge of glass effect assumed to extend over the 2.5 in. band around perimeter of each glazing unit as seen in Figure 7.

^dProduct types described in Figure 7.

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
ACI Glass Products							
Aluminum							
SKYLIGHT	9800	2	N	Air	19/32	.82*	OVERALL AREA U-VALUE .38
Aluminum with Thermal Break							
SKYLIGHT	9800	2	Y	Air	19/32	.63*	OVERALL AREA U-VALUE .29
SKYLIGHT	9800	3	N	Air	9/32 +9/32	.59*	OVERALL AREA U-VALUE .27
Acorn Building Components							
Aluminum with Thermal Break							
PROJECTED	4500	2	N	Air	5/8	.60	
SLIDER	2300	2	N	Air	7/16	.63	
SLIDER	2500	2	N	Air	5/16	.65	
SINGLE HUNG	3300	2	N	Air	5/16	.57	
SLIDING DOOR	1200	2	N	Air	3/4	.56	
SLIDING DOOR	800 DORWALL	2	N	Air	5/16	.61	
Aluminum plus Thermal Break plus Aluminum							
SLIDER	2020	2	N	I	2 3/4	.50	
SLIDER	2030	3	N	I	1/4 + 2 1/2	.37	
SINGLE HUNG	2920	2	N	I	2 3/4	.51	
SINGLE HUNG	2930	3	N	I	1/4 + 2 1/2	.39	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Acorn Building Components							
Vinyl							
SLIDER	2600	2	N	Air	9/16	.54	
SINGLE HUNG	3600	2	N	Air	9/16	.54	
Alpine Industries							
Wood							
CASEMENT CASEMENT		2 2	N Y	Argon	5/8 5/8	.39 .32	
SWING DOOR		2	Y	Argon	3/8	.36	
Wood with Ext. Aluminum Clad							
AWNING AWNING		2 2	N Y	Argon	5/8 5/8	.39 .32	
CASEMENT		2	Y	Argon	5/8	.32	
Aluminum							
CASEMENT CASEMENT	320 E 320C	2 2	N N	Argon	1/2 1/2	.59 .65	
SLIDER SLIDER	220 EG 220E	2 2	N N	Argon	9/16 9/16	.60 .65	
SINGLE HUNG	52C	2	N	Argon	9/16	.60	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Y/N Ext.)	Gas	Air Space	U-Val	Product Comment
Alpine Industries							
Aluminum							
GARDEN WINDOW	420	2	N	Air	5/16	.69	
SLIDING DOOR	120	2	N	Argon	1/2	.64	
SLIDING DOOR	120	2	N	Argon	1/2	.66	
SLIDING DOOR	120EG	2	Y	Argon	1/2	.59	
PICTURE	720	2	N	Air	1/2	.59	
Projected	E 320	2	N	Air	9/16	.62	
Aluminum with Thermal Break							
SINGLE HUNG	525	2	N	Argon	5/16	.59	
SKYLIGHT	950	2	N	Air	1/2	.66*	Overall Area U-Value = .39
SKYLIGHT	950	2	Y	Argon	1/2	.59*	Overall Area U-Value = .35
SLIDING DOOR	150	2	N	Air	9/16	.56	
PICTURE	750	2	N	Air	1/2	.52	
Sliding Window	225	2	N	Argon	5/16	.52	
Vinyl							
CASEMENT	380	2	N	Air	25/32	.47	
CASEMENT	380	2	N	Argon	25/32	.37	
CASEMENT	380	2	Y	Argon	25/32	.32	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.)	Gas	Air Space	U-Val	Product Comment
Alpine Industries							
Vinyl							
FIXED	780	2	N	Air	3/4	.5	
SLIDER	280	2	N	Air	23/32	.45	
SLIDER	280	2	N	Argon	1/2	.35	
SLIDER	280	2	Y	Argon	23/32	.32	
SLIDER	280 HP	3	N	Argon	5/8+ 1	.21	
	PLUS			Argon	3/4		
SLIDER	6200 (Series 280)	2	N	Argon	1/2	.35	
SINGLE HUNG							
SINGLE HUNG	580	2	Y	Argon	25/32	.35	
SINGLE HUNG	6200 (Series #580)	2	N	Air	25/32	.47	
SINGLE HUNG	6200 (Series #580)	2	N	Argon	25/32	.39	
SLIDING DOOR							
SLIDING DOOR	180	2	N	Argon	1/2	.48	
SLIDING DOOR	180	2	N	Argon	3/4	.49	
SLIDING DOOR	180	2	Y	Argon	3/4	.40	
PICTURE							
PICTURE	780	2	N	Argon	1/2	.36	
PICTURE	780	2	Y	Argon	25/32	.32	
SLIDER WITH STORM							
SLIDER WITH STORM	280 HP PLUS	3	Y	I	Argon 5/8+ 1 3/4	.20	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Y/N Ext.)	Gas	Air Space	U-Val	Product Comment
Aluma-Glass Industries, Inc.							
Aluminum with Thermal Break							
SLIDER	301	2	N	Air	1/2	.60	
SLIDER	301	2	N	Air	1/2	.60	
SLIDER	601	2	N	Air	1/2	.61	
SLIDER	601	2	Y	Air	1/2	.45	
SLIDING DOOR	900	2	N	Air	3/4	.67	
Vinyl							
CASEMENT	2400	2	N	Air	5/8	.40	
SLIDER	2100	2	N	Air	9/16	.56	
SLIDER	2100	2	Y	Air	9/16	.36	
SINGLE HUNG	2200	2	N	Air	9/16	.56	
American Vinyl Inc.							
Vinyl							
FIXED	500	2	Y	Air	3/4	.36	
SLIDER	500	2	Y	Air	1/2	.40	
SINGLE HUNG	500	2	Y	Argon	9/16	.40	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Y/N Ext.)	Gas	Air Space U-Val	Product Comment
Andersen Corporation						
Wood						
AWNING		2	Y	Argon 9/16	.31	
CASEMENT	PERMA-SHLD	2	Y	Argon 9/16	.30	
DOUBLE HUNG	PERMA-SHLD	2	Y	Argon 7/16	.38	
FIXED	PERMA-SHLD	2	Y	Argon 9/16	.31	
FIXED	PERMA-SHLD FLEXIFRME	2	Y	Argon 11/16	.32	
SKYLIGHT	FIXED STATIONAR Y ROOF	2	Y	Argon 9/16	.41 .44	
PATIO DOOR	FWG 6068L	2	Y	Argon 13/32	.36	
SWING DOOR	HINGED DOOR	2	Y	Argon 7/16	.31	
Wood with External Vinyl Clad						
SLIDER	PERMA-SHLD	2	Y	Air 1/2	.39	
Wood with Internal Vinyl Clad						
SLIDING DOOR	PS510L	2	Y	Argon 9/16	.31	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Y/N Ext.)	Gas	Air Space U-Val	Product Comment
Andersen Corporation						
Aluminum External with Wood Internal						
SKYLIGHT	Operable Roof Window	2	Y	Argon 9/16	.44*	Overall Area U-Value Not Reported
Best Built						
Wood						
CASEMENT	80	2	N	Air 5/8	.36	
CASEMENT	80	2	N	Air 5/8	.36	
CASEMENT	80-R4	3	Y	Argon 1/4+1/4	.24	
DOUBLE HUNG						
Wood with Ext. Aluminum Clad						
DOUBLE HUNG	DW 3648-1	2	Y	Argon 5/16	.33	
CASEMENT						
Wood with Ext. Aluminum Clad						
CASEMENT	CC 1848-2	2	Y	Argon 9/16	.32	
CASEMENT		2	Y	Argon 9/16	.28	
Crystalite, Inc.						
Aluminum						
SKYLIGHT	2650	2	N	Air 5/8	.94*	Overall Area U-Value = .44
SKYLIGHT	2650	2	N	Air 3/4	.79*	Overall Area U-Value = .37
SKYLIGHT	2650	4	N	Air 3/4+1/2	.44*	Overall Area U-Value = .19
SKYLIGHT	2650	4	N	Air 1/2+1/2	.45*	Overall Area U-Value = .21
SKYLIGHT	2650	4	Y	Air 2+4+1/2	.35*	Overall Area U-Value = .15
SKYLIGHT	2650	4	Y	Air 3/4+1/2+3/4"		

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Crystalite, Inc.							
Aluminum							
SKYLIGHT	4040	2	N	Air	2	.72*	Overall Area U-Value = .43
SKYLIGHT	4040	2	N	Air	2	.81*	Overall Area U-Value = .50
SKYLIGHT	4040	2	Y	Argon	7/8	.46*	Overall Area U-Value = .27
Aluminum with Thermal Break							
SKYLIGHT	2650	2	N	Air	2	.82*	Overall Area U-Value = .40
SKYLIGHT	3650	2	N	Air	3/4	.80*	1/8" AT EDGE Overall Area U-Value = .37
Door Distributors, Inc.							
Wood							
SWING DOOR	5001	2	Y	Argon	3/8	.38	
SWING DOOR	5130		N			.41	
Duralite Industries, Inc.							
Aluminum with Thermal Break							
SKYLIGHT	55	2	Y	Air	5/8	.65*	Overall Area U-Value = .36
SKYLIGHT	55	3	N	Air	23	.56*	Overall Area U-Value = .33
Empire Pacific Industries							
Aluminum							
SLIDER	700A	2	N	Air	1/2	.64	
SLIDER	700A	2	N	Argon	1/2	.60	
SINGLE HUNG	700A	2	N	Air	1/2	.65	
SINGLE HUNG	700A	2	N	Argon	1/2	.60	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.)	Gas	Air Space	U-Val	Product Comment
Empire Pacific Industries							
Aluminum							
SLIDING DOOR	850	2	Y	Air	1/2	.65	
PICTURE		2	N	Air	3/4	.60	
Aluminum with Thermal Break							
SLIDER	T-1000	2	N	Air	1/2	.57	
SINGLE HUNG	T-1000	2	N	Air	1/2	.58	
PICTURE	T-1000	2	N	Air	1/2	.59	
Vinyl							
FIXED		2	N	Air	3/4	.49	
SLIDER	4000	2	N	Air	3/4	.50	
SLIDER	4000	2	N	Argon	3/4	.50	
SINGLE HUNG	4000	2	N	Air	3/4	.51	
SINGLE HUNG	4000	2	N	Argon	3/4	.49	
SLIDING DOOR	4000	2	N	Air	3/4	.52	
PICTURE	4000	2	N	Argon	3/4	.45	

* = U-Value of Rough Opening

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STATE BUILDING CODE COUNCILS WINDOW AND OPAQUE DOOR U-VALUE LIST

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Fiberlux Products, Inc.							
Vinyl							
CASEMENT	410	2	N	Air	25/3	.41	
DOUBLE HUNG	1100	2	N	Air	3/4	.48	
DOUBLE HUNG	ULTRAVIEW 1100	2	Y	Air	3/4	.43	
DOUBLE HUNG	ULTRAVIEW 720	2	N	Air	5/8	.55	
DOUBLE HUNG	ULTRAVIEW 720 REINFORCE D	2	N	Air	5/8	.55	
DOUBLE HUNG	950	2	N	Air	5/8	.54	
DOUBLE HUNG	950	2	Y	Air	5/8	.45	
DOUBLE HUNG	950	2	Y	Air	9/16	.36	
DOUBLE HUNG	FACESETTE R	2	Y	Argon	9/16	.42	
FIXED	500	2	N	Air	5/8	.60	
FIXED	500	2	Y	Air	1/4	.58	
SLIDER	1100	2	N	Air	25/32	.52	
SLIDER	ULTRAVIEW 1100	2	Y	Air	25/32"	.44	
SLIDER	ULTRAVIEW 1100	2	Y	Argon	25/32	.42	
SLIDER	ULTRAVIEW 500	2	N	Air	5/16	.59	
SLIDER	500	2	Y	Air	5/16	.56	
SLIDER	500	3	N	I	5/16+	.31	
SLIDER	730	2	N	Air	1 1/2 5/8	.55	

* = U-Value of Rough Opening

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STATE BUILDING CODE COUNCILS WINDOW AND OPAQUE DOOR U-VALUE LIST

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Revision 1

Product Type	Model	Number Glazed Layers	Low Storm E (int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Fiberlux Products, Inc.							
Vinyl							
SINGLE HUNG	500	2	N	Air	5/16	.60	
SINGLE HUNG	500	2	Y	Air	5/16	.44	
SINGLE HUNG	500	2	Y	Air	3/16	.49	
SINGLE HUNG	500	2	Y	Air	5/16	.54	
SINGLE HUNG	500	2	Y	Argon	5/16	.50	
SLIDING DOOR	1200	2	N	Air	3/4	.51	
PICTURE	500	2	N	Air	1/2	.54	
Fleetwood Aluminum Products, Inc.							
Aluminum with Thermal Break							
SLIDING DOOR	3300	2	Y	Argon	5/8	.50	
SLIDING DOOR	Glacier 3000	2	Y	Argon	5/8	.50	
General Products, Inc							
Steel							
STEEL ENTRANCE DR	3068RIE	2	N	Air	1/4	.39	
Hara's Incorporated							
Vinyl							
SLIDER		2	N	Air	9/16	.53	
SLIDER		2	Y	Air	9/16	.43	
SLIDER		2	Y	Argon	9/16	.38	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Y/N Ext.)	Gas	Air Space	U-Val	Product Comment
Hara's Incorporated							
Vinyl							
SINGLE HUNG		2	N	Air	9/16	.54	
SINGLE HUNG		2	Y	Air	9/16	.43	
SINGLE HUNG		2	Y	Argon	9/16	.40	
Hillsdale Sash & Door Co., Inc							
Wood with Aluminum Sill							
SWING DOOR	EG-5001	2	N	Air	3/8	.56	Q-LON Door Seal
SWING DOOR	EG-5001	2	Y	Air	3/8	.52	Q-LON Door Seal
Hope's Architectural Products							
Aluminum							
PROJECTED	210T	2	N	Air	1/4	.62	
Steel							
PROJECTED	1000 ULTRACLAD	2	N	Air	1/4	.64	
PROJECTED	1000 ULTRACLAD	2	Y	Air	1/2	.50	
Hornberg Wood Windows							
Wood							
AWNING		2	N	Air	1/2	.44	
CASEMENT		2	N	Air	1/2	.44	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Hurd Millwork Company							
Wood with Aluminum Clad							
SLIDING DOOR	CHES	2	Y	Air	1/2	.36	HEAT MIRROR 66
SLIDING DOOR	CHES	3	Y	Air	3/4	.36	DG HEAT MIRROR 88
SLIDING DOOR	CHES	4	Y	Inert	3/8+	.24	Unit Contained 2 Heat Mirror Films each with LOWE
SLIDING DOOR	CHES (DG Clear)	2	N	Air	3/4	.52	
Insulate Industries, Inc.							
Vinyl							
SWING DOOR		2	N	Air	7/16	.50	
SWING DOOR		3	Y	Air	1/4+	.38	DG HEAT MIRROR 66
SWING DOOR	DG	3	Y	Air	1/4+	.37	HEAT MIRROR 88
SWING DOOR	DG	4	Y	Inert	3/8+	.25	INSOL 8
Insulate Industries, Inc.							
Vinyl							
SLIDER		2	N	Air	13/16	.41	
SLIDER	3000	2	N	Argon	3/4	.40	
SLIDER	3000	2	Y	Argon	3/4	.36	
SINGLE HUNG	3004	2	N	Argon	3/4	.39	
SINGLE HUNG	3004	2	Y	Argon	3/4	.37	
SLIDING DOOR		2	N	Argon	3/4	.44	
SLIDING DOOR		2	Y	Air	3/4	.38	
SLIDING DOOR	3100	2	N	Air	3/4	.52	
PICTURE	3002	2	N	Argon	3/4	.39	
PICTURE	3002	2	Y	Argon	3/4	.36	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E. (Int. Y/N Ext.)	Gas	Air Space U-Val	Product Comment
Inwood Industries						
Wood						
CASEMENT		2	Y	Argon 5/8	.38	
SLIDER		2	Y	Argon 5/8	.38	
SINGLE HUNG		2	Y	Argon 5/8	.39	
Kawneer Company						
Aluminum						
PROJECTED	6200T	2	N	Air 5/8	.58	
PROJECTED	6200T	2	N	Air 5/8	.58	
PROJECTED	8225T	2	N	Air 1/2	.62	
PROJECTED	8225T	2	N	Air 1/2	.58	
CASEMENT	6200T	2	N	Air 5/8	.59	
CASEMENT	6200T	2	N	Air 5/8	.56	
CASEMENT	6200T	2	Y	Air 5/8	.51	
DOUBLE HUNG	6315T	2	N	Air 5/8	.67	
DOUBLE HUNG	6325T	2	N	Air 5/8	.61	
FIXED	6200T	2	N	Air 5/8	.55	
TOP-HINGED INSWING	6200T	2	N	Air 5/8	.56	
Aluminum with Thermal Break						
FIXED	6315T	2	N	Air 1/2	.57	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.)	Gas	Air Space U-Val	Product Comment
Kawneer Company						
Aluminum with Thermal Break plus Thermal Break plus Aluminum						
CASEMENT	THE PERFORMER	2	N	Air	1/2	.35
Marvin Windows						
Wood						
AWNING	SS34BW	2	N	Air	1/2	.42
CASEMENT	CM34BW	2	N	Air	1/2	.41
CASEMENT	CMADLW	2	N	Air	1/2	.45
CASEMENT	CMEPDW	2	N	Air	1	.37
CASEMENT	MGC 234G	2	N	Air	1/2	.45
DOUBLE HUNG	DHADL	2	N	Air	3/8	.59
DOUBLE HUNG	DHEPDL	2	N	Air	1	.52
DOUBLE HUNG	ETBW 38G	2	N	Air	3/8	.50
DOUBLE HUNG	MAGDHW	2	N	Air	9/16	.49
DOUBLE HUNG	MGET	2	Y	Argon	1/2	.35
DOUBLE HUNG	MGET 34	2	N	Air	1/2	.53
SLIDER	MG	2	Y	Air	1/4	.56
SLIDER	MG	2	Y	Air	1/2	.53
SLIDER	SGBW 38G	2	N	Air	3/8	.53
SLIDING DOOR	MG600PD	2	Y	Argon	1/2	.32
SLIDING DOOR	PDBW 6068	2	N	Air	3/4	.52
SLIDING DOOR		2	N	Air	1/2	.57

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low E (Int. Ext.)	Gas	Air Space	U-Val	Product Comment
Marvin Windows							
Wood							
SWING DOOR	NG6068TD	2	Y	Argon	1/2	.33	
SWING DOOR	TDBW 6068	2	N	Air	1/2	.51	
SWING DOOR		2	N	Air	1/2	.47	
PICTURE		2	N	Air	5/8	.54	
PICTURE	MG	2	Y	Air	5/8	.33	
PICTURE	MG	2	N	Air	1/2	.41	
PICTURE	MGD	2	Y	Air	1/2	.31	
PICTURE		2	N	Air	5/8	.54	
PROJECTED		2	N	Air	1/2	.35	
DBL		2	N	Air	1/4	.50	
CASEMASTER		2	Y	Air	1/2	.36	
DBL		2	N	Air	5/8	.38	
CASEMASTER	MAGTTW	2	N	Air	1/2	.41	
TILT-TURN WINDOW		2	N	Air	1/2	.49	
PROJECTED	MGA 34G	2	N	Air	1/2	.41	
STACK & STRIP	STACK & STRIP	2	Y	Air	1/2	.49	
Mikron Industries							
Vinyl							
SLIDER	180	2	N	Air	3/4	.52	
SLIDER	6200	2	N	Air	13/16	.45	
SLIDER	6200	2	Y	Air	3/4	.31	
SLIDER	6200	2	Y	Air	3/4	.38	
SLIDER	6200A	2	N	Argon	25/32	.37	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Mikron Industries							
Vinyl							
SINGLE HUNG	6200	2	N	Air	25/32	.47	
SINGLE HUNG	6200	2	Y	Air	25/32	.34	
SINGLE HUNG	6200	2	Y	Air	25/32	.39	
SINGLE HUNG	6200A	2	N	Argon	25/32	.39	
SLIDING DOOR		2	Y	Air	3/4	.41	
SLIDING DOOR		2	Y	Air	1/2	.36	
SLIDING DOOR		2	N	Air	3/4	.52	
PICTURE	4975	2	N	Air	3/4	.50	
PICTURE	4975	2	Y	Air	3/4	.39	
PICTURE	4975	2	Y	Air	3/4	.35	
PROJECTED		2	N	Air	3/4	.48	
PROJECTED	4900	2	Y	Air	3/4	.34	
PROJECTED	4900	2	Y	Air	3/4	.39	
Milgard Manufacturing, Inc.							
Aluminum							
SKYWALL	910	2	N	Air	1/2	.67	
PROJECTED	910	2	N	Air	1/2	.68	
PROJECTED	910	2	N	Argon	1/2	.64	
CASEMENT	910	2	N	Air	1/2	.69	
CASEMENT	910	2	N	Argon	1/2	.65	
FIXED	910	2	N	Air	1/2	.65	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low E (Int. Ext.)	Gas	Air Space	U-Val	Product Comment
Milgard Manufacturing, Inc.							
Aluminum							
SLIDER SLIDER	1110	2	N	Air	9/16	.64	
	1110	2	N	Argon	9/16	.55	
SINGLE HUNG SINGLE HUNG	1510	2	N	Air	1/2	.65	
	1510	2	N	Argon	1/2	.60	
GARDEN WINDOW	1800	2	N	Argon	5/16	.67	
SLIDING DOOR SLIDING DOOR	415	2	N	Air	3/4	.68	
	415	2	N	Argon	3/4	.66	
PICTURE	910	2	N	Argon	1/2	.57	
Aluminum with Thermal Break							
SKYWALL SKYWALL PROJECTED PROJECTED	920	2	N	Air	3/4	.55	
	920	2	Y	Argon	3/4	.43	
	920	2	N	Air	3/4	.60	
	920	2	N	Argon	3/4	.54	
PROJECTED	920	2	Y	Argon	3/4	.34	
	920	2	Y	Air	3/4	.50	
CASEMENT CASEMENT CASEMENT	920	2	N	Air	3/4	.60	
	920	2	N	Argon	3/4	.59	
	920	2	Y	Air	3/4	.53	
SLIDER SLIDER SLIDER	1120	2	Y	Air	7/16	.42	
	1120	2	N	Air	1/2	.52	
	1120	2	Y	Argon	1/2	.37	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Milgard Manufacturing, Inc.							
Aluminum with Thermal Break							
SINGLE HUNG	1520	2	N	Argon 3/4		.56	
SINGLE HUNG	1520	2	N	Air 1/2		.58	
SINGLE HUNG	1520	2	Y	Argon 1/2		.37	
SINGLE HUNG	1520	2	Y	Air 1/2		.48	
SKYLIGHT	750	2	N	Air 11/16		.73*	Overall Area U-Value = .37
SKYLIGHT	750	2	N	Argon 11/16		.68*	Overall Area U-Value = .34
SKYLIGHT	750	2	Y	Air 11/16		.63*	Overall Area U-Value = .32
SKYLIGHT	750	2	Y	Argon 11/16		.56*	Overall Area U-Value = .28
SKYLIGHT	780	2	N	Air 3/4		.61*	Overall Area U-Value = .37
SKYLIGHT	780	2	N	Argon 3/4		.61*	Overall Area U-Value = .36
SKYLIGHT	780	2	Y	Air 3/4		.59*	Overall Area U-Value = .35
SKYLIGHT	780	2	Y	Argon 3/4		.45*	Overall Area U-Value = .27
SLIDING DOOR	420	2	Y	Air 5/8		.46	
SLIDING DOOR	420	2	N	Air 5/8		.58	
SLIDING DOOR	420	2	N	Argon 3/4		.57	
SLIDING DOOR	420	2	Y	Argon 3/4		.40	
PICTURE	920	2	N	Air 3/4		.54	
PICTURE	920	2	N	Argon 3/4		.52	
PICTURE	920	2	Y	Argon 3/4		.39	
PICTURE	920	2	Y	Air 3/4		.46	
Aluminum External with Wood Internal							
CASEMENT	3520	2	N	Air 1/2		.57	
CASEMENT	3520	2	Y	Argon 1/2		.39	
SLIDER	3120	2	N	Air 9/16		.57	
SLIDER	3120	2	Y	Argon 9/16		.39	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Milgard Manufacturing, Inc.							
Aluminum External with Wood Internal							
SINGLE HUNG	3220	2	N	Air	9/16	.60	
SINGLE HUNG	3220	2	Y	Argon	9/16	.40	
PICTURE	3320	2	N	Air	1/2	.53	
PICTURE	3320	2	Y	Argon	1/2	.32	
Projected Window	3420	2	Y	Argon	1/2	.38	
Vinyl							
AWNING	5420	2	N	Air	3/4	.49	
AWNING	5420	2	Y	Argon	3/4	.48	
AWNING	5420	2	Y	Air	3/4	.39	
AWNING	5420	2	Y	Argon	3/4	.36	
CASEMENT	5520	2	N	Air	13/16	.38	
CASEMENT	5520	2	N	Argon	13/16	.35	
CASEMENT	5520	2	Y	Air	13/16	.34	
CASEMENT	5520	2	Y	Argon	13/16	.31	
SLIDER	5120	2	N	Air	13/16	.44	
SLIDER	5120	2	N	Argon	13/16	.37	
SLIDER	5120	2	Y	Air	3/4	.38	
SLIDER	5120	2	Y	Argon	3/4	.34	
SINGLE HUNG	5220	2	N	Argon	13/16	.40	
SINGLE HUNG	5220	2	N	Air	13/16	.47	
SINGLE HUNG	5220	2	Y	Air	3/4	.40	
SINGLE HUNG	5220	2	Y	Argon	3/4	.34	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E. (Int. Y/N Ext.)	Gas	Air Space	U-Val	Product Comment
Milgard Manufacturing, Inc.							
Vinyl							
SLIDING DOOR	5620	2	N	Air 3/4		.51	
SLIDING DOOR	5620	2	N	Argon 3/4		.48	
SLIDING DOOR	5620	2	Y	Air 3/4		.42	
SLIDING DOOR	5620	2	Y	Argon 3/4		.39	
PICTURE	5320	2	N	Argon 3/4		.36	
PICTURE	5320	2	N	Air 13/16		.49	
PICTURE	5320	2	Y	Air 13/16		.35	
PICTURE	5320	2	Y	Argon 13/16		.33	
Norco Windows, Inc.							
Wood							
CASEMENT	SG CLEAR	1	N	Air		.95	
DOUBLE HUNG		2	N	Air 1/4		.58	
Wood with External Vinyl Clad							
SLIDING DOOR	PRIMED CONTEMPO	2	N	Air 5/8		.49	
SLIDING DOOR	PRIMED CONTEMPO	2	Y	Argon 5/8		.32	
SLIDING DOOR	PRIMED CONTEMPO	2	N	Air 1/2		.47	
SLIDING DOOR	PRIMED CONTEMPO	2	Y	Argon 1/2		.33	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.)	Gas	Air Space	U-Val	Product Comment
Norco Windows, Inc.							
Wood with Ext. Aluminum Clad							
CASEMENT	NOR'CLAD	2	N	Air	5/8	.57	
CASEMENT	NOR'CLAD	2	Y	Argon	9/16	.35	
CASEMENT	NOR'CLAD	2	Y	Argon	9/16	.31	
CASEMENT	NOR'CLAD	2	N	Air	9/16	.47	
DOUBLE HUNG							
DOUBLE HUNG	NOR'CLAD	2	N	Air	1/4	.66	
DOUBLE HUNG	NOR'CLAD	2	Y	Argon	1/4	.52	
DOUBLE HUNG	NOR'CLAD	2	N	Air	1/4	.62	
DOUBLE HUNG	NOR'CLAD	2	N	Air	1/4+ 2	.38	
DOUBLE HUNG	NOR'CLAD	3	Y	Argon	1/4+ 2	.33	
SLIDER							
SLIDER	NOR'CLAD	2	N	Air	1/4	.59	
SLIDER	SLIDEBY	2	N	Air	1/4+ 2	.39	
SLIDER	SLIDEBY	2	Y	Argon	1/4+ 2	.34	
SLIDER	SLIDEBY	3	Y	Argon	1/4	.54	
SLIDING DOOR							
SLIDING DOOR	NOR'CLAD CONTEMPO	2	Y	Argon	5/8	.33	
Wood with Aluminum Clad							
SWING DOOR	NOR'CLAD CONTEMPO	2	N	Air	5/8	.50	
Wood							
DOUBLE HUNG		2	Y	Argon	1/4	.49	
DOUBLE HUNG		2	Y	Air	1/4+ 2	.40	
DOUBLE HUNG		2	Y	Argon	1/4+ 2	.33	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Y/N Ext.)	Gas	Air Space U-Val	Product Comment
Norco Windows, Inc.						
Wood						
SLIDER	PRIMED SLIDEBY	2	Y	Argon 1/4	.48	
SLIDER	PRIMED SLIDEBY	2	N	Air 1/4	.57	
SLIDER	PRIMED SLIDEBY	2	N	E Air 1/4+ 2	.36	
SLIDER	PRIMED SLIDEBY	2	Y	E Argon 1/4+ 2	.30	
Vinyl						
SLIDER	NOR'CLAD SLIDEBY	2	N	Air 1/4	.66	
Northwest Aluminum Products						
Aluminum						
SLIDER	4530	2	Y	Air 1/2	.39	
SLIDER	525	2	Y	Air 7/16	.56	
SLIDER	525	2	N	Air 9/16	.64	
	525	2	N	Argon 9/16	.60	
SINGLE HUNG	825	2	N	Air 9/16	.65	
SINGLE HUNG	825	2	N	Argon 9/16	.60	
SINGLE HUNG	825 DG	2	Y	Air 7/16	.55	
GARDEN WINDOW	G-870	2	N	Argon 9/16	.68	
GARDEN WINDOW	G870	2	N	Air 1/2	.63	
GARDEN WINDOW	G870	2	Y	Air 1/2	.50	
SKYLIGHT	9130	2	N	Air 3/4	.71*	Overall Area U-Value = .55

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Northwest Aluminum Products							
Aluminum							
SLIDING DOOR	720 DG	2	Y	Air	7/16	.58	
SLIDING DOOR	CLEAR	2	N	Air	7/16	.70	
PICTURE	121	2	N	Argon	1/2	.58	
PICTURE	121	2	N	Argon	1/2	.58	
PICTURE	3128	3	N	Air	3/8+	.40	
PICTURE	3128/3130	2	N	Air	3/8	.56	
PICTURE	3130	3	Y	Air	3/4	.39	
PICTURE	328	2	N	Air	3/4	.53	
PICTURE	328	2	N	Air	3/4	.53	
PICTURE	328	2	N	Air	3/4	.53	
PROJECTED	121/127	2	Y	Air	1/2	.51	PROJECTED WINDOW W/ P.O.B.
PROJECTED W/P.O.B.	1230	3	Y	Air	3/4	.39	VENT
Aluminum with Thermal Break							
CASEMENT	1230	2	N	Air	13/16	.58	
CASEMENT	1230	2	Y	Air	3/4	.49	
SLIDER	3500	2	N	Air	3/4	.60	HEAT MIRROR 88
SLIDER	3500	2	N	Air	3/4	.38	
SLIDER	4530	2	N	Air	9/16	.54	
SLIDER	4530	2	Y	Air	1/2	.39	HEAT MIRROR 88
SLIDER	500	2	N	Air	1/2	.40	
CHINOOK							

* = U-Value of Rough Opening

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Appendix C: Component U-Values

STATE BUILDING CODE COUNCILS WINDOW AND OPAQUE DOOR U-VALUE LIST

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-val	Product Comment
Northwest Aluminum Products							
Aluminum with Thermal Break							
SLIDER	500 CHINOOK	2	N	Air	9/16	.54	
SINGLE HUNG	4830	2	N	Air	9/16	.58	
SINGLE HUNG	4830	3	Y	Air	1/2	.40	
SINGLE HUNG	502 CHINOOK	2	N	Air	1/2	.56	
SKYLIGHT	9130	2	N	Air	3/4	.97*	Overall Area U-Value = .49
SLIDING DOOR	6500	2	N	Air	3/4	.43	HEAT MIRROR 88
SLIDING DOOR	6500 MARLIN	2	N	Air	3/4	.59	
SLIDING DOOR	6530	2	Y	Argon	3/4	.47	
PICTURE	501	2	N	Air	1/2	.54	
PROJECTED	1505	2	N	Air	3/4	.53	
PROJECTED	505	2	N	Air	1/2	.57	
PROJECT-OUT	7505	2	N	Air	1	.27	HEAT MIRROR 88
Vinyl							
CASEMENT	2010	2	N	Air	25/32	.46	
CASEMENT	2010	2	N	Argon	25/32	.38	
CASEMENT	2010	2	Y	Air	23/32	.35	
SLIDER	2050	2	N	Air	25/32	.44	
SLIDER	2050	2	N	Argon	25/32	.36	
SLIDER	2050	2	Y	Air	23/32	.32	

* = U-Value of Rough Opening

STATE BUILDING CODE COUNCILS WINDOW AND OPAQUE DOOR U-VALUE LIST

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Revision 1

Product Type	Model	Number Glazed Layers	Low Storm E (Int. Y/N Ext.)	Gas	Air Space	U-Val	Product Comment
Northwest Aluminum Products							
Vinyl							
SINGLE HUNG	2080	2	N	Air	25/32	.48	
SINGLE HUNG	2080	2	N	Argon	25/32	.39	
SINGLE HUNG	2080	2	Y	Air	23/32	.33	
SLIDING DOOR	1070	2	N	Argon	3/4	.49	
SLIDING DOOR	2070	2	N	Air	3/4	.53	
SLIDING DOOR	2070	2	N	Argon	3/4	.48	
SLIDING DOOR	2070	2	Y	Air	3/4	.41	
SLIDING DOOR	1070	2	N	Air	3/4	.52	
SLIDING DOOR	1070	2	Y	Air	3/4	.36	
PICTURE	2030	2	N	Air	13/16	.50	
PICTURE	2030	2	N	Argon	25/32	.39	
PICTURE	2030	2	Y	Air	3/4	.29	
Northwest Window Works							
Wood							
DOUBLE HUNG		2	Y	Air	5/8	.36	
Pan Abode Cedar Homes							
Wood							
CASEMENT		2	Y	Air	1/2	.38	
SLIDING DOOR		2	Y	Air	5/8	.43	

* = U-Value of Rough Opening

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Appendix C: Component U-Values

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Revision 1

Product Type	Model	Number Glazed Layers	Low Storm E (Int. Y/N Ext.)	Gas	Air Space U-Val	Product Comment
Peachtree Windows and Doors						
Wood with Ext. Aluminum Clad						
CASEMENT	ARIEL	2	Y	Argon 17/32	.34	
DOUBLE HUNG	3648	2	N	Air 17/32	.53	
DOUBLE HUNG	ARIEL 3648	2	Y	Air 17/32	.39	
FIXED	ARIEL	2	Y	Air 17/32	.29	
Aluminum with Internal Wood Clad						
SLIDING DOOR	ARIEL	2	Y	Argon 1/2	.31	
Steel	AVANTI A300		N	N/A	.09	
STEEL PATIO DOOR	PRADO	2	Y	Air 1/2	.27	Adjustable Wood Threshold & Vinyl Wrapped Foam WS
Fiberglass with Urethane Core						
FGLASS ENTRY DOOR	NEWPORT N300		N	N/A	.07	VINYL WRAPPED FOAM WS NEOPRENE SWEEP
Pella Products Company						
Wood						
SWING DOOR	Sequoia	0	N	None	.29	
SWING DOOR	Sherwood	0	N	None	.35	TB Aluminum sill

* = U-Value of Rough Opening

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STATE BUILDING CODE COUNCILS WINDOW AND OPAQUE DOOR U-VALUE LIST

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.)	Gas	Air Space	U-Val	Product Comment
Pella Products Company							
Wood with Ext. Aluminum Clad							
FRCH SLDG	OX26	2	Y	Argon	3/8	.37	EMISSIVITY OF 0.05
PATIO DR	OX26	2	N	Air	15/16	.48	
FRCH SLDG	OX26	2	Y	Air	15/16	.41	
PATIO D	OX26	2	Y	Argon	3/8	.36	EMISSIVITY OF 0.05
FRCH SLDG	OX31	2	Y	Argon	3/8	.34	EMISSIVITY OF 0.05
PATIO D	TTF 705	2	Y	Argon	3/8	.36	EMISSIVITY OF LOW E = .05
SLIDING	3042	2	Y	Air	7/16	.40	EMISSIVITY OF LOW E = .05
PATIO DOOR	3042 Architect	2	Y	Argon	7/16	.39	W/GRID
ENTRANCE DOOR	3042	2	Y	Argon	7/16	.41	EMISSIVITY OF .05
DOUBLE HUNG	322222 Architect	2	Y	Argon	7/16	.37	EMISSIVITY OF 0.05
DOUBLE HUNG	322222TD	2	Y	Air	15/16	.42	EMISSIVITY OF LOW E = .2
DOUBLE HUNG	322222TD	2	Y	Air	15/16	.50	
SLIDING DOOR	OX 26	2	N	Air		.42	
SLIDING DOOR	FRENCH OX 26	2	Y	Air			
SLIDING DOOR	FRENCH	2	Y	Air			
Wood with Aluminum Clad							
SKYLIGHT	1742	2	Y	Argon	5/8	.40	Overall Area U-Value Not Reported
SKYLIGHT	1944	2	Y	Argon	5/8	.35	Overall Area U-Value Not Reported

* = U-Value of Rough Opening

Appendix C: Component U-Values

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STATE BUILDING CODE COUNCILS WINDOW AND OPAQUE DOOR U-VALUE LIST

December 19, 1991
Revision 1

Product Type	Model	Number Glazed Layers	Low Storm E (Int. Y/N Ext.)	Gas	Air Space U-Val	Product Comment
Pozzi Window Company						
Wood with Ext. Aluminum Clad						
SLIDER		2	N	Air	9/16	.55
SLIDING DOOR		2	N	Air	5/8	.54
Puget Sound Windows Inc.						
Vinyl						
SLIDER	ENG'D PROFILES 6000	2	N	Air	13/16	.51
SLIDER	ENG'D PROFILES 6000	2	N	Argon	13/16	.46
SLIDER	Eng'd Profiles 6000	2	Y	Air	13/16	.48
SINGLE HUNG	ENG'D PROFILES 6000	2	N	Argon	13/16	.47
SINGLE HUNG	ENG'D PROFILES 6000	2	Y	Air	13/16	.40
PICTURE	ENG'D PROFILES 6000	2	N	Argon	13/16	.47
PICTURE	ENG'D PROFILES 6000	2	Y	Air	13/16	.39

* = U-Value of Rough Opening

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STATE BUILDING CODE COUNCILS WINDOW AND OPAQUE DOOR U-VALUE LIST

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Revision 1

Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Quantum Wood Windows							
Wood							
CASEMENT/AWNI NG CASEMENT CASEMENT		2	N	Air	5/8	.45	
		2	N	Argon	5/8	.39	
		2	Y	Air	5/8	.33	
DOUBLE HUNG		2	N	Argon	5/8	.40	
SLIDER		2	Y	Argon	5/8	.37	
Seattle Solarium							
Wood with Ext. Aluminum Clad							
SOLARIUM SOLARIUM	SS100 SS100	2	Y	Air	1/2	.30	
		2	Y	Argon	3/4	.37	
Smokey Point Wood Windows							
Wood							
CASEMENT CASEMENT		2	N	Air	1/2	.38	
		2	N	Argon	1/2	.40	
Spectus/Wasington Vinyl							
Wood							
SLIDER W/EXT.STORM		2	N	Air	3/4+ 1/4	.27	
Vinyl							

* = U-Value of Rough Opening

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STATE BUILDING CODE COUNCILS WINDOW AND OPAQUE DOOR U-VALUE LIST

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Y/N Ext.)	Gas	Air Space	U-Val	Product Comment
Spectus/Washington Vinyl							
Vinyl							
CASEMENT	810	2	Y	Air	5/8	.35	
DOUBLE HUNG	710	2	Y	Air	3/4	.38	
SLIDER	530	2	N	Air	3/4	.50	
SLIDER		2	Y	Air	1/2	.35	
SLIDER		2	Y	Air	13/16	.46	
SINGLE HUNG	510	2	Y	Air	1/2	.35	
SINGLE HUNG		2	Y	Air	13/16	.45	
PICTURE	540	2	Y	Air	3/4	.36	
PICTURE	840	2	Y	Air	5/8	.30	
Stanley Door Systems							
Steel							
STEEL	RD-1	2	N	Air	3/16	.33	
ENTRANCE DR							
STEEL	RD-6	2	N	Air	1/4	.49	
ENTRANCE DR							
Sterling Millwork, Inc.							
Wood							
PICTURE		2	N	Air	1/2	.40	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Sunburst Skylights LTD.							
SKYLIGHT	2852	2	Y	Argon	1/2	.31*	OVERALL AREA V-VALUE .19 FLUSH MOUNTED
Timber Windows, Inc.							
Wood							
CASEMENT		2	N	Air	1/2	.37	
PICTURE		2	N	Air	1/2	.44	
Vekaplast Incorporated							
Vinyl							
DOUBLE HUNG		2	N	Air	11/16	.50	
DOUBLE HUNG		2	Y	Air	11/16	.39	
FIXED	PC4W	2	N	Air	1/2	.49	
FIXED	PC4W	2	Y	Air	1/2	.37	
SLIDER	SL1WW	2	Y	Air	1/2	.44	
SLIDER	SL1WW	2	N	Air	3/4	.48	
SLIDER	SL1WW	2	Y	Air	3/4	.42	
SLIDER	SL1WW	2	Y	Air	3/4	.41	
SLIDER	SS3WW	2	N	Air	9/16	.48	
SLIDER	SS3WW	2	N	Air	9/16	.48	
SLIDER	SS3WW	2	N	Argon	13/16	.42	
SLIDER	SS3WW	2	Y	Argon	1/2	.39	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Vekaplast Incorporated							
Vinyl							
SINGLE HUNG		2	N	Air	1/2	.54	
SINGLE HUNG		2	N	Air	9/16	.50	
SINGLE HUNG		2	Y	Air	9/16	.42	
SINGLE HUNG	SH3WW	2	Y	Argon	1/2	.40	
SINGLE HUNG	SH3WW	2	Y	Argon	1/2	.39	
Velux-America Inc.							
Wood							
SKYLIGHT	FSFVHH-4 AL	2	Y	Argon	3/8	.38	Overall Area U-Value Not Reported
SKYLIGHT	FSVHH-4 AL	2	Y	Argon	3/8	.37	Overall Area U-Value Not Reported
SKYLIGHT	TPSVHH-4 AL	2	Y	Argon	3/8	.40	Overall Area U-Value Not Reported
SKYLIGHT	VSVHH-4 AL	2	Y	Argon	3/8	.39	Overall Area U-Value Not Reported
Viking Industries							
Aluminum							
CASEMENT	1619	2	N	Air	3/4	.64	
CASEMENT	1619	2	N	Argon	1/2	.54	
SLIDER	3100	2	N	Air	7/16	.65	
SLIDER	3100	2	N	Argon	9/16	.59	
SINGLE HUNG	3300	2	N	Air	7/16	.65	
SINGLE HUNG	3300 MARK 2	2	N	Argon	17/32	.59	

* = U-Value of Rough Opening

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Product Type	Model	Number Glazed Layers	Low Storm E (Int. Y/N Ext.)	Gas	Air Space U-Val	Product Comment
Viking Industries						
Aluminum						
SLIDING DOOR	3500	2	N	Argon	3/4	.65
SLIDING DOOR	3600-C	2	Y	Air	3/4	.60
PICTURE PICTURE	3600	2	N	Air	1/2	.60
PICTURE PICTURE	3600	2	N	Air	7/16	.65
Vinyl						
CASEMENT	9700	2	N	Air	7/8	.48
CASEMENT	9700	2	N	Argon	7/8	.35
CASEMENT	9700	2	Y	Air	7/8	.36
CASEMENT	9700	2	Y	Argon	7/8	.30
SLIDER	9100	2	N	Air	51/64	.44
SLIDER	9100	2	N	Argon	51/64	.39
SLIDER	9100	2	Y	Air	51/64	.35
SLIDER	9100	2	Y	Argon	51/64	.29
SINGLE HUNG	9300	2	N	Air	51/64	.44
SINGLE HUNG	9300	2	N	Argon	51/64	.40
SINGLE HUNG	9300	2	Y	Air	51/64	.37
SINGLE HUNG	9300	2	Y	Argon	51/64	.31
SLIDING DOOR	9500	2	N	Air	3/4	.52
SLIDING DOOR	9500	2	N	Argon	3/4	.48
SLIDING DOOR	9500	2	Y	Air	3/4	.42
SLIDING DOOR	9500	2	Y	Argon	3/4	.39
PICTURE	9600	2	N	Air	51/64	.45
PICTURE	9600	2	N	Argon	51/64	.40
PICTURE	9600	2	Y	Air	51/64	.35
PICTURE	9600	2	Y	Argon	51/64	.30

* = U-Value of Rough Opening

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Appendix C: Component U-Values

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Revision 1

Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Wells Aluminum, Inc.							
Aluminum with Thermal Break							
SLIDING DOOR	M-1100	2	N	Air	1/2	.59	
SLIDING DOOR	M-1100	2	N	Air	1/2	.59	
Wenco Distributors							
Wood							
CASEMENT	JX-7	2	N	Air	7/16	.55	
CASEMENT	JX-7	2	Y	Argon	7/16	.47	
CASEMENT	NORTH STAR	2	Y	Argon	3/8	.38	
Wood with Ext. Aluminum Clad							
CASEMENT	JX-7	2	N	Air	7/16	.60	
CASEMENT	JX-7	2	Y	Argon	7/16	.50	
Aluminum							
CASEMENT	NORTH STAR	2	N	Air	3/8	.46	
Western Skylights							
Aluminum with Thermal Break							
SKYLIGHT	CD4646G	2	N	Air	5/8	.70*	OVERALL AREA U-VALUE .70
SKYLIGHT	CD48X48	2	Y	Argon	25/32	.43*	OVERALL AREA U-VALUE NOT REPORTED

* = U-Value of Rough Opening

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Revision 1

Product Type	Model	Number Glazed Layers	Low Storm E (Int. Ext.) Y/N	Gas	Air Space	U-Val	Product Comment
Westview Products, Inc.							
Aluminum with Thermal Break							
PICTURE		2	N	Air	5/8	.34	
Windlerce Supply Co.							
Wood							
Wood Horiz. slider		2	Y	Argon	3/4	.37	
Window Products							
Vinyl							
SLIDER		2	N	Air	9/16	.48	
SLIDER		2	N	Argon	9/16	.45	
Window Visions							
Wood							
SLIDER	3300	3	Y	Argon	1/2	.41	

* = U-Value of Rough Opening

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Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values^a

Description	Density, lb/ft ³	Conduc- tivity ^b (k), Btu·in. h·ft ² ·°F	Conduc- tance (C), Btu h·ft ² ·°F	Resistance ^c (R)		Specific Heat, Btu lb·°F
				Per inch thickness (1/k), °F·ft ² ·h Btu·in.	For thick- ness listed (1/C), °F·ft ² ·h Btu	
BUILDING BOARD						
Asbestos-cement board	120	4.0	—	0.25	—	0.24
Asbestos-cement board 0.125 in.	120	—	33.00	—	0.03	—
Asbestos-cement board 0.25 in.	120	—	16.50	—	0.06	—
Gypsum or plaster board 0.375 in.	50	—	3.10	—	0.32	0.26
Gypsum or plaster board 0.5 in.	50	—	2.22	—	0.45	—
Gypsum or plaster board 0.625 in.	50	—	1.78	—	0.56	—
Plywood (Douglas Fir) ^d	34	0.80	—	1.25	—	0.29
Plywood (Douglas Fir) 0.25 in.	34	—	3.20	—	0.31	—
Plywood (Douglas Fir) 0.375 in.	34	—	2.13	—	0.47	—
Plywood (Douglas Fir) 0.5 in.	34	—	1.60	—	0.62	—
Plywood (Douglas Fir) 0.625 in.	34	—	1.29	—	0.77	—
Plywood or wood panels 0.75 in.	34	—	1.07	—	0.93	0.29
Vegetable Fiber Board						
Sheathing, regular density ^e 0.5 in.	18	—	0.76	—	1.32	0.31
Sheathing, regular density ^e 0.75 in.	18	—	0.49	—	2.06	—
Sheathing intermediate density ^e 0.5 in.	22	—	0.92	—	1.09	0.31
Nail-base sheathing ^e 0.5 in.	25	—	0.94	—	1.06	0.31
Shingle backer 0.375 in.	18	—	1.06	—	0.94	0.31
Shingle backer 0.3125 in.	18	—	1.28	—	0.78	—
Sound deadening board 0.5 in.	15	—	0.74	—	1.35	0.30
Tile and lay-in panels, plain or acoustic	18	0.40	—	2.50	—	0.14
. 0.5 in.	18	—	0.80	—	1.25	—
. 0.75 in.	18	—	0.53	—	1.89	—
Laminated paperboard	30	0.50	—	2.00	—	0.33
Homogeneous board from recycled paper	30	0.50	—	2.00	—	0.28
Hardboard ^d						
Medium density	50	0.73	—	1.37	—	0.31
High density, service temp. service underlay	55	0.82	—	1.22	—	0.32
High density, std. tempered	63	1.00	—	1.00	—	0.32
Particleboard ^d						
Low density	37	0.71	—	1.41	—	0.31
Medium density	50	0.94	—	1.06	—	0.31
High density	62.5	1.18	—	0.85	—	0.31
Underlayment 0.625 in.	40	—	1.22	—	0.82	0.29
Waterboard	37	0.63	—	1.59	—	—
Wood subfloor 0.75 in.	—	—	1.06	—	0.94	0.33
BUILDING MEMBRANE						
Vapor—permeable felt	—	—	16.70	—	0.06	—
Vapor—seal, 2 layers of mopped 15-lb felt	—	—	8.35	—	0.12	—
Vapor—seal, plastic film	—	—	—	—	Negl.	—
FINISH FLOORING MATERIALS						
Carpet and fibrous pad	—	—	0.48	—	2.08	0.34
Carpet and rubber pad	—	—	0.81	—	1.23	0.33
Cork tile 0.125 in.	—	—	3.60	—	0.28	0.48
Terrazzo 1 in.	—	—	12.50	—	0.08	0.19
Tile—asphalt, linoleum, vinyl, rubber vinyl asbestos	—	—	20.00	—	0.05	0.36
ceramic	—	—	—	—	—	0.24
Wood, hardwood finish 0.75 in.	—	—	1.47	—	0.68	0.19
INSULATING MATERIALS						
<i>Blanket and Batt^f</i>						
Mineral Fiber, fibrous form processed from rock, slag, or glass						
approx. 3-4 in.	0.3-2.0	—	0.091	—	11	—
approx. 3.5 in.	0.3-2.0	—	0.077	—	13	—
approx. 5.5-6.5 in.	0.3-2.0	—	0.053	—	19	—
approx. 6-7.5 in.	0.3-2.0	—	0.045	—	22	—
approx. 9-10 in.	0.3-2.0	—	0.033	—	30	—
approx. 12-13 in.	0.3-2.0	—	0.026	—	38	—
<i>Board and Slabs</i>						
Cellular glass	8.5	0.35	—	2.86	—	0.18
Glass fiber, organic bonded	4.0-9.0	0.25	—	4.00	—	0.23
Expanded perlite, organic bonded	1.0	0.36	—	2.78	—	0.30
Expanded rubber (rigid)	4.5	0.22	—	4.55	—	0.40

Thermal and Water Vapor Transmission Data

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Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values^a (Continued)

Description	Density, lb/ft ³	Conduc- tivity ^b (k), Btu·in. h·ft ² ·°F	Conduc- tance (C), Btu h·ft ² ·°F	Resistance ^c (R)		Specific Heat, Btu lb·°F
				Per inch thickness (1/k), °F·ft ² ·h Btu·in.	For thick- ness listed (1/C), °F·ft ² ·h Btu	
Expanded polystyrene, extruded (smooth skin surface) (CFC-12 exp.)	1.8-3.5	0.20	—	5.00	—	0.29
Expanded polystyrene, molded beads	1.0	0.26	—	3.85	—	—
	1.25	0.25	—	4.00	—	—
	1.5	0.24	—	4.17	—	—
	1.75	0.24	—	4.17	—	—
	2.0	0.23	—	4.35	—	—
Cellular polyurethane/polyisocyanurate ^b (CFC-11 exp.)(unfaced)	1.5	0.16-0.18	—	6.25-5.56	—	0.38
Cellular polyisocyanurate ^b (CFC-11 exp.)(gas-permeable facers)	1.5-2.5	0.16-0.18	—	6.25-5.56	—	0.22
Cellular polyisocyanurate ⁱ (CFC-11 exp.)(gas-impermeable facers)	2.0	0.14	—	7.20	—	0.22
Cellular phenolic (closed cell)(CFC-11, CFC-113 exp.)	3.0	0.12	—	8.20	—	—
Cellular phenolic (open cell)	1.8-2.2	0.23	—	4.40	—	—
Mineral fiber with resin binder	15.0	0.29	—	3.45	—	0.17
Mineral fiberboard, wet felted						
Core or roof insulation	16-17	0.34	—	2.94	—	—
Acoustical tile	18.0	0.35	—	2.86	—	0.19
Acoustical tile	21.0	0.37	—	2.70	—	—
Mineral fiberboard, wet molded						
Acoustical tile	23.0	0.42	—	2.38	—	0.14
Wood or cane fiberboard						
Acoustical tile	0.5 in.	—	0.80	—	1.25	0.31
Acoustical tile	0.75 in.	—	0.53	—	1.89	—
Interior finish (plank, tile)	15.0	0.35	—	2.86	—	0.32
Cement fiber slabs (shredded wood with Portland cement binder)	25-27.0	0.50-0.53	—	2.0-1.89	—	—
Cement fiber slabs (shredded wood with magnesia oxysulfide binder)	22.0	0.57	—	1.75	—	0.31
<i>Loose Fill</i>						
Cellulosic insulation (milled paper or wood pulp)	2.3-3.2	0.27-0.32	—	3.70-3.13	—	0.33
Perlite, expanded	2.0-4.1	0.27-0.31	—	3.7-3.3	—	0.26
	4.1-7.4	0.31-0.36	—	3.3-2.8	—	—
	7.4-11.0	0.36-0.42	—	2.8-2.4	—	—
Mineral fiber (rock, slag, or glass) ^f						
approx. 3.75-5 in.	0.6-2.0	—	—	—	11.0	0.17
approx. 6.5-8.75 in.	0.6-2.0	—	—	—	19.0	—
approx. 7.5-10 in.	0.6-2.0	—	—	—	22.0	—
approx. 10.25-13.75 in.	0.6-2.0	—	—	—	30.0	—
Mineral fiber (rock, slag, or glass) ^f						
approx. 3.5 in. (closed sidewall application)	2.0-3.5	—	—	—	12.0-14.0	—
Vermiculite, exfoliated	7.0-8.2	0.47	—	2.13	—	0.32
	4.0-6.0	0.44	—	2.27	—	—
<i>Masonry Units</i>						
Brick, common	80	2.2-3.2	—	0.45-0.31	—	—
	90	2.7-3.7	—	0.37-0.27	—	—
	100	3.3-4.3	—	0.30-0.23	—	—
	110	3.5-5.5	—	0.29-0.18	—	—
	120	4.4-6.4	—	0.23-0.16	—	0.19
	130	5.4-9.0	—	0.19-0.11	—	—
Clay tile, hollow						
1 cell deep	3 in.	—	1.25	—	0.80	0.21
1 cell deep	4 in.	—	0.90	—	1.11	—
2 cells deep	6 in.	—	0.66	—	1.52	—
2 cells deep	8 in.	—	0.54	—	1.85	—
2 cells deep	10 in.	—	0.45	—	2.22	—
3 cells deep	12 in.	—	0.40	—	2.50	—
<i>Concrete blocks^h</i>						
Limestone aggregate						
8 in., 36 lb, 138 lb/ft ³ concrete, 2 cores	—	—	—	—	—	—
Same with perlite filled cores	—	—	0.48	—	2.1	—
12 in., 55 lb, 138 lb/ft ³ concrete, 2 cores	—	—	—	—	—	—
Same with perlite filled cores	—	—	0.27	—	3	—

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values* (Continued)

Description	Density, lb/ft ³	Conduc- tivity ^b (k), Btu·in. h·ft ² ·°F	Conduc- tance (C), Btu h·ft ² ·°F	Resistance (R)		Specific Heat, Btu lb·°F
				Per inch thickness (1/k), °F·ft ² ·h Btu·in.	For thick- ness listed (1/C), °F·ft ² ·h Btu	
Normal weight aggregate (sand and gravel)						
8 in., 33-36 lb, 126-136 lb/ft ³ concrete, 2 or 3 cores	—	—	0.90-1.03	—	1.11-0.97	0.22
Same with perlite filled cores	—	—	0.50	—	2.0	—
Same with verm. filled cores	—	—	0.52-0.73	—	1.92-1.37	—
12 in., 50 lb, 125 lb/ft ³ concrete, 2 cores	—	—	0.81	—	1.23	0.22
Medium weight aggregate (combinations of normal weight and lightweight aggregate)						
8 in., 26-29 lb, 97-112 lb/ft ³ concrete, 2 or 3 cores	—	—	0.58-0.78	—	1.71-1.28	—
Same with perlite filled cores	—	—	0.27-0.44	—	3.7-2.3	—
Same with verm. filled cores	—	—	0.30	—	3.3	—
Same with molded EPS (beads) filled cores	—	—	0.32	—	3.2	—
Same with molded EPS inserts in cores	—	—	0.37	—	2.7	—
Lightweight aggregate (expanded shale, clay, slate or slag, pumice)						
6 in., 16-17 lb 85-87 lb/ft ³ concrete, 2 or 3 cores	—	—	0.52-0.61	—	1.93-1.65	—
Same with perlite filled cores	—	—	0.24	—	4.2	—
Same with verm. filled cores	—	—	0.33	—	3.0	—
8 in., 19-22 lb, 72-86 lb/ft ³ concrete, 2 or 3 cores	—	—	0.32-0.54	—	3.2-1.90	0.21
Same with perlite filled cores	—	—	0.15-0.23	—	6.8-4.4	—
Same with verm. filled cores	—	—	0.19-0.26	—	5.3-3.9	—
Same with molded EPS (beads) filled cores	—	—	0.21	—	4.8	—
Same with UF foam filled cores	—	—	0.22	—	4.5	—
Same with molded EPS inserts in cores	—	—	0.29	—	3.5	—
12 in., 32-36 lb, 80-90 lb/ft ³ concrete, 2 or 3 cores	—	—	0.38-0.44	—	2.6-2.3	—
Same with perlite filled cores	—	—	0.11-0.16	—	9.2-6.3	—
Same with verm. filled cores	—	—	0.17	—	5.8	—
Stone, lime, or sand	—	12.50	—	0.08	—	0.19
Gypsum partition tile	—	—	—	—	—	—
3 by 12 by 30 in., solid	—	—	0.79	—	1.26	0.19
3 by 12 by 30 in., 4 cells	—	—	0.74	—	1.35	—
4 by 12 by 30 in., 3 cells	—	—	0.60	—	1.67	—

METALS

(See Chapter 39, Table 3)

ROOFING

Asbestos-cement shingles	120	—	4.76	—	0.21	0.24
Asphalt roll roofing	70	—	6.50	—	0.15	0.36
Asphalt shingles	70	—	2.27	—	0.44	0.30
Built-up roofing	0.375 in.	70	3.00	—	0.33	0.35
Slate	0.5 in.	—	20.00	—	0.05	0.30
Wood shingles, plain and plastic film faced	—	—	1.06	—	0.94	0.31

Spray Applied

Polyurethane foam	1.5-2.5	0.16-0.18	—	6.25-5.56	—	—
Ureaformaldehyde foam	0.7-1.6	0.22-0.28	—	4.55-3.57	—	—
Cellulosic fiber	3.5-6.0	0.29-0.34	—	3.45-2.94	—	—
Glass fiber	3.5-4.5	0.26-0.27	—	3.85-3.70	—	—

PLASTERING MATERIALS

Cement plaster, sand aggregate	116	5.0	—	0.20	—	0.20
Sand aggregate	0.375 in.	—	13.3	—	0.08	0.20
Sand aggregate	0.75 in.	—	6.66	—	0.15	0.20
Gypsum plaster:						
Lightweight aggregate	0.5 in.	45	3.12	—	0.32	—
Lightweight aggregate	0.625 in.	45	2.67	—	0.39	—
Lightweight agg. on metal lath	0.75 in.	—	2.13	—	0.47	—
Perlite aggregate	—	45	1.5	0.67	—	0.32
Sand aggregate	—	105	5.6	0.18	—	0.20
Sand aggregate	0.5 in.	105	11.10	—	0.09	—
Sand aggregate	0.625 in.	105	9.10	—	0.11	—
Sand aggregate on metal lath	0.75 in.	—	7.70	—	0.13	—
Vermiculite aggregate	—	45	1.7	0.59	—	—

MASONRY MATERIALS**Concretes**

Cement mortar	105-135	5.0-10.5	—	0.20-0.10	—	—
Gypsum-fiber concrete 87.5% gypsum,						
12.5% wood chips	51	1.66	—	0.60	—	0.21
Lightweight aggregates including ex-	120	5.5-11.0	—	0.18-0.09	—	—
expanded shale, clay or slate; expanded	100	3.7-5.9	—	0.27-0.17	—	0.20
slags; cinders; pumice; vermiculite;	80	2.5-3.5	—	0.40-0.29	—	0.20
also cellular concretes	60	1.6-1.8	—	0.63-0.56	—	—
	40	0.93-1.11	—	1.08-0.90	—	—

Thermal and Water Vapor Transmission Data

22.9

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values^a (Concluded)

Description	Density, lb/ft ³	Conduc- tivity ^b (<i>k</i>), Btu·in. h·ft ² ·°F	Conduc- tance (<i>C</i>), Btu h·ft ² ·°F	Resistance <i>c</i> (<i>R</i>)		Specific Heat, Btu lb·°F
				Per inch thickness (1/ <i>k</i>), °F·ft ² ·h Btu·in.	For thick- ness listed (1/ <i>C</i>), °F·ft ² ·h Btu	
Perlite, expanded	30	0.75-0.91	—	1.33-1.10	—	0.20
	20	0.63-0.83	—	1.59-1.20	—	—
	50	1.4-1.8	—	0.71-0.56	—	—
	40	0.93	—	1.08	—	0.10
	30	0.71	—	1.41	—	—
Sand and gravel or stone aggregate (oven dried)	20	0.50	—	2.00	—	0.32
	140	8.0-16.0	—	0.13-0.06	—	0.18-0.22
Sand and gravel or stone aggregate (not dried)	140	10.0-20.0	—	0.10-0.05	—	0.19-0.24
Stucco	116	5.0	—	0.20	—	—
SIDING MATERIALS (on flat surface)						
<i>Shingles</i>						
Asbestos-cement	120	—	4.75	—	0.21	—
Wood, 16 in., 7.5 exposure	—	—	1.15	—	0.87	0.31
Wood, double, 16 in., 12 in. exposure	—	—	0.84	—	1.19	0.28
Wood, plus insul. backer board, 0.3125 in.	—	—	0.71	—	1.40	0.31
<i>Siding</i>						
Asbestos-cement, 0.25 in., lapped	—	—	4.76	—	0.21	0.24
Asphalt roll siding	—	—	6.50	—	0.15	0.35
Asphalt insulating siding (0.5 in. bed.)	—	—	0.69	—	1.46	0.35
Hardboard siding, 0.4375 in.	—	—	0.49	—	0.67	0.28
Wood, drop, 1 by 8 in.	—	—	1.27	—	0.79	0.28
Wood, bevel, 0.5 by 8 in., lapped	—	—	1.23	—	0.81	0.28
Wood, bevel, 0.75 by 10 in., lapped	—	—	0.95	—	1.05	0.28
Wood, plywood, 0.375 in., lapped	—	—	1.59	—	0.59	0.29
Aluminum or Steel ^c , over sheathing	—	—	—	—	—	—
Hollow-backed	—	—	1.61	—	0.61	0.29
Insulating-board backed nominal 0.375 in.	—	—	0.55	—	1.82	0.32
Insulating-board backed nominal 0.375 in., foil backed	—	—	0.34	—	2.96	—
Architectural glass	—	—	10.00	—	0.10	0.20
WOODS (12% Moisture Content)^{d,m}						
<i>Hardwoods</i>						
Oak	41.2-46.8	1.12-1.25	—	0.89-0.80	—	0.39 ⁿ
Birch	42.6-45.4	1.16-1.22	—	0.87-0.82	—	—
Maple	39.8-44.0	1.09-1.19	—	0.92-0.84	—	—
Ash	38.4-41.9	1.06-1.14	—	0.94-0.88	—	—
<i>Softwoods</i>						
Southern Pine	35.6-41.2	1.00-1.12	—	1.00-0.89	—	0.39 ⁿ
Douglas Fir-Larch	33.5-36.3	0.95-1.01	—	1.06-0.99	—	—
Southern Cypress	31.4-32.1	0.90-0.92	—	1.11-1.09	—	—
Hem-Fir, Spruce-Pine-Fir	24.5-31.4	0.74-0.90	—	1.35-1.11	—	—
West Coast Woods, Cedars	21.7-31.4	0.68-0.90	—	1.48-1.11	—	—
California Redwood	24.5-28.0	0.74-0.82	—	1.35-1.22	—	—

^aValues are for a mean temperature of 75°F. Representative values for dry materials are intended as design (not specification) values for materials in normal use. Thermal values of insulating materials may differ from design values depending on their in-situ properties (e.g., density and moisture content, orientation, etc.) and variability experienced during manufacture. For properties of a particular product, use the value supplied by the manufacturer or by unbiased tests.

^bTo obtain thermal conductivities in Btu/h·ft·°F, divide the *k*-factor by 12 in./ft.

^cResistance values are the reciprocals of *C* before rounding off *C* to two decimal places.

^dLewis (1967).

^eU.S. Department of Agriculture (1974).

^fDoes not include paper backing and facing, if any. Where insulation forms a boundary (reflective or otherwise) of an airspace, see Tables 2 and 3 for the insulating value of an airspace with the appropriate effective emittance and temperature conditions of the space.

^gConductivity varies with fiber diameter. (See Chapter 20, "Factors that Affect Thermal Performance.") Batt, blanket, and loose-fill mineral fiber insulations are manufactured to achieve specified R-values, the most common of which are listed in the table. Due to differences in manufacturing processes and materials, the product thicknesses, densities, and thermal conductivities vary over considerable ranges for a specified R-value.

^hFor additional information, see Society of Plastics Engineers (SPI) Bulletin U108. Values are for aged, unfaced board stock. For change in conductivity with

age of expanded polyurethane/polyisocyanurate, see Chapter 20, "Factors that Affect Thermal Performance."

ⁱValues are for aged products with gas-impermeable facers on the two major surfaces. An aluminum foil facer of 0.001 in. thickness or greater is generally considered impermeable to gases. For change in conductivity with age of expanded polyisocyanurate, see Chapter 20, "Factors that Affect Thermal Performance," and SPI Bulletin U108.

^jInsulating values of acoustical tile vary, depending on density of the board and on type, size, and depth of perforations.

^kValues for fully grouted block may be approximated using values for concrete with a similar unit weight.

^lValues for metal siding applied over flat surfaces vary widely, depending on amount of ventilation of airspace beneath the siding; whether airspace is reflective of nonreflective; and on thickness, type, and application of insulating backing-board used. Values given are averages for use as design guides, and were obtained from several guarded hot box tests (ASTM C236) or calibrated hot box (ASTM C976) on hollow-backed types and types made using backing-boards of wood fiber, foamed plastic, and glass fiber. Departures of $\pm 50\%$ or more from the values given may occur.

^mSee Adams (1971), MacLean (1941), and Wilkes (1979). The conductivity values listed are for heat transfer across the grain. The thermal conductivity of wood varies linearly with the density and the density ranges listed are those normally found for the wood species given. If the density of the wood species is not known, use the mean conductivity value. For extrapolation to other moisture contents, the following empirical equation developed by Wilkes (1979) may be used:

Table 4 Footnotes (Concluded)

$$k = 0.1791 + \frac{(1.874 \times 10^{-2} + 5.753 \times 10^{-4} M) p}{1 + 0.01M}$$

where p is density based on oven-dry mass in lb/ft³ and M is the moisture content in percent.

ⁿFrom Adams (1971), an empirical equation for the specific heat of moist wood at 75°F is as follows:

$$c_p = \frac{(0.299 + 0.01M)}{(1 + 0.01M)} + \Delta c_p$$

where Δc_p accounts for the heat of sorption and is denoted by

$$\Delta c_p = M (1.921 \times 10^{-3} - 3.168 \times 10^{-5} M)$$

where M is the moisture content in percent by mass.

RECOMMENDED OUTDOOR DESIGN TEMPERATURES WASHINGTON STATE

SECOND EDITION

The tables in Appendix D "Recommended Outdoor Design Temperatures, Washington State" have been reprinted with the permission of the Puget Sound Chapter ASHRAE for this publication only. Additional copies of this document may be obtained from:

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Appendix D: Outside Design Temperatures for Washington

PREFACE

These tables present summer and winter design temperatures for approximately 250 localities in the State of Washington.

The temperatures presented are percentage levels on an annual basis: summer at the 0.1%, 0.5% and 2.0% levels, winter at the median of the annual lows, 0.2% and 0.6% levels. As an example, the summer dry bulb design temperatures for Sea-Tac Airport (SEA) are:

ANNUAL BASIS		TEMPERATURE
% of Year	Hours	
0.1	9	89 F
0.5	44	83 F
2.0	175	76 F

Suggestions in the first edition of this publication for the use of the summer design temperatures were:

1. The 0.1% 9-hour level should be used only for extremely conservative work: sensitive computer installations, heavy internal loads, etc. — the occasional project that must hold the desired temperature regardless of outside conditions. This column may also be used for the sizing of air cooled condensers.

2. The 0.5% 44-hour column is for the average job.

3. The 2.0% 175-hour column is for the promotional job where every corner must be cut and where equipment cost is more important than exact maintenance of temperature.

Dry bulb and wet bulb temperatures were calculated independently and are on a non-coincident basis.

The winter design temperatures also are shown on an annual percentage basis: 0.2% (18 hours) and 0.6% (53 hours). In the first edition of this publication, it was suggested that the three winter values be used as follows:

Median of Extremes
0.2%, 18 hour
0.6%, 53 hour

Residential; large glass areas; light construction
Medium construction; daytime use
Heavy construction

The Washington State Energy Code effective April 1, 1986 requires the 0.5% column for summer design temperatures and the 0.6% column for winter design temperatures.

Temperatures of 41 localities with "a" beside the name were developed from five to 22 years of hourly data, tabulated by computer. Localities marked "b" record only daily maximum and minimum temperatures, and the design levels were developed from seven to 25 years of records, using the graphical method proposed by Loren W. Crow in ASHRAE Research Project 23. Temperatures for other localities (without Weather Stations) were interpolated using contour lines.

Winter temperatures in Washington are highly variable. Annual minimum temperatures may vary plus or minus 20 degrees from the medians listed. The temperatures listed do not represent the most severe conditions. The temperatures of some metropolitan areas show a gradual increase due to growth in energy output.

The source of the annual heating degree days listed in this document is Appendix A of the Washington State Energy Code Training Manual, 1983 edition, WAOENG-83-14, with permission.

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ABBREVIATIONS

AFB	Air Force Base	Mtn	Mountain
AP	Airport	Pt	Point
CO	City Office	Res	Reservoir
Exp	Experiment	RS	Ranger Station
Hts	Heights	Sta	Station
JC	Junior or College	Typical:	"4 (miles) NE"

Appendix D: Outside Design Temperatures for Washington

Station	Elev. Ft.		SUMMER						WINTER			Annual Heating Degree Days
			Design Dry Bulb			Design Wet Bulb			Median of Extremes	Design Dry Bulb		
			0.1%	0.5%	2.0%	0.1%	0.5%	2.0%		0.2%	0.6%	
Aberdeen	12	b	87	81	76	64	62	60	20	24	28	5316
Aberdeen 20 NNE	435	b	89	83	78	65	63	61	17	21	25	5539*
Anacortes	30	b	78	72	67	63	61	59	15	20	24	5168
Anatone	3570	b	94	89	84	66	63	61	-16	-12	-4	7345*
Appleton	2336	b	97	92	86	68	65	62	1	6	11	
Alder Dam												5820*
Auburn	80		90	84	78	70	67	64	11	17	25	
Battleground	295	b	96	91	84	71	68	65	11	15	19	5263
Bellevue	200		89	83	76	69	67	64	14	20	24	
Bellingham AP	150	b	82	76	70	69	66	63	9	14	19	
2 N	140	b	84	78	72	70	67	64	7	12	17	5738
Benton City 2 NW	680	b	102	98	93	72	69	66	0	6	11	5245*
Bickleton	3000	b	97	92	86	68	65	62	-6	-1	4	6859
Blaine	80	b	79	73	67	69	66	63	9	13	17	5724
Bothell 2 N	100	b	89	83	76	69	66	63	7	12	17	5540*
Bremerton	162	b	89	83	76	70	67	64	17	23	29	
Brier	440		88	82	76	69	67	64	14	19	24	
Buckley 1 NE	685	b	89	83	77	69	66	63	10	16	26	5501
Bumping Lake	3440	b	89	83	78	66	63	60	-16	-10	-5	
Burlington	28		83	77	72	69	66	63	10	15	19	
Camas	48		93	87	80	71	68	65	13	17	21	
Castle Rock	50		92	87	82	70	67	64	13	18	23	
Cedar Lake	1560	b	87	80	74	67	64	61	9	15	20	6525
Centralia	185	b	92	87	81	70	67	64	11	16	21	4982
Central Park	20		87	81	76	64	62	60	19	23	27	
Chehalis	178		92	87	81	70	67	64	11	16	21	
Chelan	1120	b	95	89	82	70	67	64	0	5	10	6151
Cheney	2400	b	99	94	88	69	66	63	-9	-3	4	6606*
Chesaw	3960	b	87	81	74	64	61	59	-21	-16	-11	8459*
Chewalah 2 S	1675	b	98	93	87	70	67	64	-21	-15	-9	7188
Chief Joseph Dam	810	b	100	95	89	71	68	65	-4	1	6	6174*
Clallam Bay 1 NNE	30	b	79	74	68	63	61	59	21	25	28	6332
Clarkston	1186	b	100	94	88	70	67	64	-2	2	10	
Clearbrook	64	b	86	80	74	69	66	63	9	14	19	5807
Clearwater	75	b	86	80	75	65	62	60	18	22	26	5835*
Cle Elum	1930	b	97	91	86	69	66	63	-11	-5	1	7020
Clyde Hill	150		89	83	76	69	67	64	14	20	24	
Collax 1 NW	1955	b	99	94	88	69	66	63	-8	-3	2	6319
College Place	800		101	96	90	71	68	65	-6	-2	6	
Colville AP	1874	b	97	92	86	69	66	63	-12	-7	-2	7097
Conconully	2275	b	91	86	80	67	64	61	-17	-12	-7	7521
Concrete	195	b	89	83	78	70	67	64	10	15	19	5162
Connell 4 NNW	1020	b	104	100	95	72	69	66	-5	1	6	
Cougar 5 E	520	b	97	93	87	71	68	65	15	20	25	
Coulee Dam 1 SW	1700	b	99	94	88	70	67	64	-2	3	9	5964*
Coupeville 1 S	50	b	81	76	71	64	62	60	13	18	21	5609
Cushman Dam	760	b	90	85	79	69	66	63	13	18	22	5426
Dallesport AP	222	b	104	99	92	72	70	67	4	9	14	4978
Darrington RS	550	b	91	85	79	70	67	64	3	8	13	5740*
Davenport	2460	b	97	92	86	68	65	62	-8	-2	5	7129

Appendix D: Outside Design Temperatures for Washington

SUMMER									WINTER			Annual Heating Degree Days
Station	Elev. Ft.		Design Dry Bulb			Design Wet Bulb			Median of Extremes	Design Dry Bulb		
			0.1%	0.5%	2.0%	0.1%	0.5%	2.0%		0.2%	0.6%	
Dayton 1 WSW	1557	b	102	97	91	70	67	64	-6	-2	5	5628
Deer Park 2 E	2130	b	97	92	86	69	66	63	-18	-12	-5	7347
Des Moines	50		89	83	76	70	67	64	14	20	25	
Diablo Dam	891	b	93	87	82	69	66	63	5	10	15	6214
Dishman	1950		101	96	90	69	67	64	-4	2	9	
East Bremerton	100		89	83	76	70	67	64	17	23	29	
Edmonds	9		88	82	76	69	67	64	14	19	24	
Electron Headwks	1730	b	88	84	77	68	65	62	6	12	16	
Ellensburg AP	1627	b	95	90	85	68	66	63	-10	-4	2	
CO	1572	b	95	90	85	68	66	63	-8	-2	4	
Elma	68	b	94	88	83	67	64	61	15	20	24	5203
Eltopia 6 W	895	b	102	98	93	71	68	65	-2	4	9	
Elwha RS	360	b	86	81	75	64	62	60	15	20	24	5945*
Enumclaw	742		89	83	77	69	66	63	10	16	26	
Ephrata AP	1259	b	102	97	90	69	67	65	-5	0	7	5603
CO	1250	b	101	96	89	69	67	65	0	5	12	
Everett JC	60	b	85	79	73	69	66	63	13	18	23	5347
Paine AFB	598	a	85	79	73	69	66	63	11	16	21	
Fircrest	300		88	82	75	68	66	63	17	23	29	
Forks 1 E	350	b	86	81	75	69	66	63	15	19	23	5816
Fort Lewis	66	a	90	85	78	70	67	64	12	18	24	
Friday Harbor												5440*
Fruitvale	150		98	94	88	71	68	65	-1	5	11	
Glacier RS	935	b	88	82	76	68	65	62	3	8	13	6510*
Glenoma (Kosmos)	870	b	93	89	83	70	67	64	8	14	18	5678
Goldendale	1650	b	99	94	88	70	67	64	-3	2	7	6284
Grandview	811		101	97	92	72	69	66	0	6	12	
Grapeview	30	b	89	83	77	66	63	60	18	24	30	4873
Grayland 2 S	15	b	80	74	69	63	61	59	20	24	28	5291*
Grays River Hatchery	100	b	91	86	80	70	67	64	16	20	24	
Greenwater	1730	b	89	84	78	68	65	62	3	9	14	
Grotto	849	b	90	84	78	69	66	63	11	16	21	5735*
Harrington 2 S	2260	b	99	94	88	69	66	63	-10	-4	3	
Hartline	1910	b	101	96	90	70	67	64	-4	1	7	6519*
Hatton 8 E	1430	b	103	99	93	71	68	65	-10	-4	1	6035
Holden Village	3220	b	88	81	76	64	62	60	-6	-1	4	8380*
Hoquiam AP	14	b	85	79	74	64	62	60	18	22	26	5085*
Ice Harbor Dam	368	b	104	100	95	72	69	66	6	12	17	
Inchelium 2 NW	1685	b	97	92	86	69	66	63	-10	-5	0	7035*
Issaquah	97		89	83	77	69	67	64	13	19	23	
John Day Dam	186	b	105	100	92	73	70	67	9	14	19	
Kelso AP	26		92	87	82	70	67	64	14	19	24	
Kennewick 10 SW	392	b	101	97	92	71	69	66	2	8	13	4892
Kent	32	b	91	85	78	69	66	63	11	17	21	
Kid Valley	690	b	91	86	80	70	67	64	10	15	20	5769
Kirkland	177		89	83	76	69	67	64	7	12	17	
Lacey	184		90	85	79	68	66	63	7	12	17	
La Center												5480*
Lacrosse 3 ESE	1546	b	103	98	92	70	67	64	-13	-8	-3	5979
La Grande	960	b	93	88	82	70	67	64	13	19	23	

Appendix D: Outside Design Temperatures for Washington

SUMMER								WINTER			Annual Heating Degree Days	
Station	Elev. Ft.		Design Dry Bulb			Design Wet Bulb			Median of Extremes	Design Dry Bulb		
			0.1%	0.5%	2.0%	0.1%	0.5%	2.0%		0.2%		0.6%
Lake Cle Elum	2255	b	93	87	82	68	65	62	-10	-4	1	7539
Lake Forest Park	30		89	83	76	69	67	64	14	20	24	
Lake Kachess	2270	b	92	86	81	67	64	61	-8	-2	3	7687
Lake Keechelus	2475	b	88	82	77	66	63	60	-6	0	5	8279
Lakewood Center	—		88	82	75	68	66	63	17	23	29	
Landsburg	535	b	90	84	77	69	66	63	10	14	18	5854
Larson AFB	1183	a	100	96	90	70	67	64	-6	-1	6	
Laurier	1644	b	98	93	77	70	67	64	-18	-13	-8	7241
Leavenworth	1128	b	99	93	88	70	67	64	-14	-8	-3	6309*
Lemanasky Lake	3500	b	83	78	72	63	61	59	-17	-12	-7	
Lind 3 NE	1630	b	104	100	94	71	68	65	-6	-1	6	6037
Linwood	1900		101	96	90	69	67	64	-3	3	10	
Little Goose Dam	700	b	106	101	95	72	69	66	11	16	22	
Long Beach 3 NNE	25	b	83	77	72	63	61	59	17	21	25	5332
Longmire RS												7253*
Longview	12	b	92	87	82	70	67	64	14	19	24	5064
Lower Granite Dam	640	b	103	98	92	72	69	66	4	9	14	4575*
Lower Monument Dam	460	b	108	103	98	73	70	67	7	13	18	
Lynden	95		80	74	68	69	67	64	9	13	18	
Lynnwood	340		88	82	76	69	67	64	14	19	24	
Malott	815	b	101	96	90	71	68	65	-6	-1	4	
Marietta 3 NNW	10	b	80	74	68	63	61	59	8	13	18	5435*
Marysville	15		85	79	73	69	66	63	13	18	23	
McMillin Res.	579	b	88	83	77	69	66	63	11	17	21	5550
McNary Dam	361	b	104	100	95	72	69	66	0	5	11	
Medical Lake	2350		95	90	84	67	65	62	-9	-3	4	
Medina	26		89	83	76	69	67	64	14	20	24	
Mercer Island	40		89	83	76	68	66	63	15	21	25	
Metaline Falls	2107	b	94	89	83	68	65	62	-11	-6	-1	7325*
Methow 2 W	1165	b	100	94	89	70	67	64	-9	-4	1	6700*
Milton	250		88	82	75	68	66	63	17	23	29	
Monroe	120	b	89	83	77	70	67	64	11	16	21	5133
Montesano 3 NW	40		90	84	79	64	62	60	18	22	25	
Moses Lake 3 E	1208	b	100	96	90	70	67	64	-6	-1	5	6404*
Mt. Adams RS	1960	b	94	89	82	68	65	62	-5	0	6	6973
Mt. Baker Lodge												9060*
Mountlake Terrace	440		89	83	76	69	67	64	12	17	22	
Mt. Pleasant												4960*
Mt. Spokane Summit	5890	b	79	74	68	60	58	56	-15	-9	-2	
Mount Vernon 3 WNW	14	b	83	77	71	69	66	63	11	16	20	
Moxee City 10 E	1550	b	97	93	87	70	67	64	-4	2	8	
Mud Mtn. Dam	1308	b	87	82	76	68	65	62	12	18	23	6067
Nespelem 2 S	1890	b	98	93	87	69	66	63	-14	-9	-4	6899
Newhalem	525	b	95	89	84	70	67	64	9	14	19	5754
Newport	2135	b	97	92	86	69	66	63	-15	-10	-5	7406
Normandy Park	200		89	83	76	68	65	62	14	20	24	
North Head												5205*
Northport	1350	b	97	92	86	70	67	64	-8	-3	2	6588
Oak Harbor	10		79	74	69	64	62	60	8	13	16	
Oakville	85	b	90	85	79	66	63	60	11	16	20	5380
Odessa	1540	b	104	100	94	71	68	65	-5	0	7	6148
Olga 2 SE	80	b	77	71	65	63	61	59	15	20	24	5721
Olympia, Priest Pt.	40	b	90	85	79	68	66	63	12	17	22	5530
AP	195	b	90	85	79	68	66	63	7	12	17	5236
Omak 2 NW	1228	b	95	90	84	70	67	64	-7	-2	3	6806*

Appendix D: Outside Design Temperatures for Washington

SUMMER								WINTER			Annual Heating Degree Days	
Station	Elev. Ft.	Design Dry Bulb			Design Wet Bulb			Median of Extremes	Design Dry Bulb			
		0.1%	0.5%	2.0%	0.1%	0.5%	2.0%		0.2%	0.6%		
Opportunity	1975		101	96	90	69	67	64	-5	1	8	
Oroville	1060	b	98	93	87	70	67	64	-5	0	5	6055*
Othello	1190	b	102	98	92	71	68	65	-3	2	9	5858
Packwood	1060	b	96	90	85	70	67	64	5	11	16	5740*
Palmer 3 SE	920	b	90	84	77	69	66	63	12	18	22	5761
Parkland	301		90	84	77	69	67	64	9	15	20	
Pasco	360		102	96	93	71	69	66	2	8	13	
Plain	1940	b	95	89	84	68	65	62	-14	-9	-3	7424
Pleasant View	1665	b	103	98	92	70	67	64	5	10	16	
Pt. Grenville	100	b	74	68	63	62	60	58	19	23	27	5743*
Pomeroy	1810	b	100	95	89	70	67	64	-9	-5	3	5767
Port Angeles	99	b	80	75	69	62	59	56	19	24	28	5842
Port Orchard	10		89	83	76	70	67	64	17	23	29	
Port Townsend	100	b	81	76	71	63	60	57	17	22	25	5284
Priest Rapids Dam	460	b	106	102	97	73	70	67	2	8	14	
Prosser	675	b	101	97	92	72	69	66	1	7	12	5570
4NE	903	b	100	96	91	71	68	65	0	6	11	5181*
Prindle												4600*
Pullman Exp. Sta.	2545	b	96	91	85	68	65	62	-9	-4	1	6624
Puyallup	50	b	92	86	79	70	67	64	9	15	19	5173
Quilcene 2 SW	123	b	89	83	76	66	63	60	12	18	23	5581
Quillayute AP	179	b	86	81	75	66	63	60	15	19	23	5951
Quinalt RS	220	b	90	84	79	66	63	60	17	21	25	5145*
Quincy 1 NE	1274	b	99	94	88	70	67	64	-8	-3	4	6227
Rainier:												
Carbon River	1735	b	84	78	73	67	64	61	12	18	23	
Longhore	2762	b	91	85	80	67	64	61	4	10	15	7344
Paradise RS	5427	b	77	71	56	60	58	56	-3	3	8	9560*
Raymond	11		87	81	76	64	62	60	20	24	28	
Redmond	53		89	83	76	69	67	64	7	12	17	
Renton	40		89	83	76	69	67	64	14	20	24	
Republic	2610	b	92	87	81	67	64	61	-19	-14	-9	7835*
Richland	357	b	105	101	96	71	69	66	0	6	11	5346*
Rimrock Tieton Dam	2730	b	92	86	82	67	64	61	-8	-2	4	7681
Ritzville	1830	b	103	99	93	70	67	64	-6	-1	6	6386
Rosalia	2400	b	97	92	86	68	65	62	-5	0	6	6818
Ross Dam	1236	b	92	86	81	69	66	63	4	9	14	
Ruff 3 SW												6040*
St. John	1945	b	100	95	89	69	66	63	4	9	15	
Sappho 8 E	760	b	88	83	77	64	62	60	15	19	23	6009*
Satus Pass	2630	b	94	90	84	68	65	62	-1	4	10	
Seattle: Boeing	14	b	89	83	76	68	66	63	15	21	25	
Sea-Tac AP	385	a	89	83	76	68	65	62	14	20	24	5145
CO	19	b	88	82	75	68	66	63	20	26	30	4424*
Jackson Park	335	b	88	82	75	68	66	63	15	21	25	
Maple Leaf	420	b	88	82	75	68	66	63	13	19	23	
U. of Wash.	96	b	90	84	77	69	67	64	16	22	26	4695
Sedro Woolley 1 E	50	b	84	78	73	69	66	63	9	14	19	5356
Selah	1108		98	94	88	71	68	65	-1	5	11	
Sequim	180	b	83	78	72	64	62	60	15	20	23	5645
Shelton	22	b	90	85	79	66	63	60	13	18	23	5241
Shoules	150		85	79	73	69	66	63	13	18	23	
Skamania Fish Hatch	440	b	99	93	86	71	68	65	15	19	24	
Smyrna	560	b	106	102	96	72	69	66	-4	1	8	5860*
Skykomish												5255*

Appendix D: Outside Design Temperatures for Washington

SUMMER								WINTER			Annual Heating Degree Days	
Station	Elev. Ft.	Design Dry Bulb			Design Wet Bulb			Median of Extremes	Design Dry Bulb			
		0.1%	0.5%	2.0%	0.1%	0.5%	2.0%		0.2%	0.6%		
Snohomish	92		87	81	78	69	66	63	11	16	21	5487
Snoqualmie Fall	440	b	89	83	77	69	66	63	12	18	22	
Pass	3020	b	86	80	74	64	62	60	-5	1	6	
South Broadway	1000		98	94	88	71	68	65	-1	5	11	
So. Olympic Tree Farm	580	b	90	84	79	64	62	60	15	20	24	
Spanaway	329		91	85	78	69	67	64	10	16	20	
Spirit Lake												8395*
Spokane AP	2364	a	97	92	86	67	65	62	-9	-3	4	6835
CO	1875	a	101	96	90	69	67	64	-3	3	10	
Fairchild AFB	2437	a	95	90	84	67	65	62	-9	-3	4	
Sprague	1930	b	101	96	90	70	67	64	-8	-2	4	6536
Stampede Pass	3958	b	82	76	71	63	61	59	-4	2	7	9400*
Startup 1 E	170	b	91	85	79	70	67	64	10	15	20	5181
Stehakin 3 NW	1150	b	91	85	80	69	66	63	2	7	12	6795
Stellacoom	50		90	84	77	69	67	64	9	15	21	
Stevens Pass	4070	b	83	77	72	63	61	59	-4	1	6	9307*
Stevenson												5335*
Stockhill Ranch	2200	b	93	88	83	68	65	62	-24	-19	-14	8497
Sumner	72		92	86	79	70	67	64	9	15	19	
Sunnyside	747	b	101	97	91	71	68	65	0	6	12	5361
Tacoma McChord	332	a	90	84	77	69	67	64	9	15	21	4835
CO	267	b	88	82	75	68	66	63	17	23	29	
Tatoosh Island	101	b	68	63	59	61	59	58	24	28	31	5719*
Thompson Place	200		90	85	79	68	66	63	10	15	20	7332
Tieton Intake	2280	b	94	88	83	68	65	62	-6	0	6	
Toledo AP	351	b	89	84	79	69	66	63	7	12	17	
Toppenish	756		100	96	90	71	68	65	-1	5	11	
Trinidad 2 SSE	555	b	104	99	93	72	69	66	1	7	13	5268*
Tukwila	50		89	83	76	69	67	64	14	20	24	
Tumwater	87		90	85	79	68	66	63	7	12	17	
University Place	250		88	82	75	68	66	63	17	23	29	
Upper Baker Dam	690	b	89	83	78	69	66	63	4	9	14	
Vancouver	210	b	94	88	82	70	67	64	14	18	22	4667
Vashon Island	231	b	84	78	71	64	62	60	17	23	28	
Walla Walla AP	1170	a	101	96	90	71	68	65	-6	-2	6	4835
CO	949	b	100	95	89	70	67	64	1	5	13	4805
3 W	800	b	101	96	90	71	68	65	-6	-2	6	5040*
Wapato	850	b	99	95	89	71	68	65	-2	4	10	5239
Washougal 8 ENE	760	b	95	89	82	70	67	64	12	16	21	5225*
Waterville	2620	b	94	88	83	67	64	61	-9	-4	1	7517
Wawawai 2 NW	640	b	103	98	92	72	69	66	4	9	14	
Wellpint	2450	b	98	93	87	68	65	62	-11	-5	1	
Wenatchee AP	1229	b	100	94	89	70	67	64	1	7	13	5799
CO	634	b	98	92	87	69	66	63	-2	4	10	
West Clarkston	825		100	94	88	70	67	64	-2	2	10	
Whidbey Island	32	a	76	71	66	64	62	59	3	8	11	
White River RS	3500	b	87	81	76	64	62	59	1	7	12	
White Swan RS	970	b	100	95	90	71	68	65	-4	2	8	
Whitman Mission	632	b	102	97	91	71	68	65	0	4	11	
Wilton	2160	b	96	91	85	69	66	63	-7	-2	4	6950
Wilapa Harbor	10	b	87	81	76	66	63	60	18	22	26	5078
Wilson Creek	1276	b	101	96	90	71	68	65	-9	-4	3	6232
Wind River	1145	b	96	91	85	70	67	64	5	10	15	6312*
Winthrop 1 WSW	1755	b	96	91	85	69	66	63	-22	-17	-12	7708
Yakima AP	1064	b	98	94	88	71	68	65	-1	5	11	5941

* These entries are 30 year data to 1960. All others are 30 year data to 1970.

Appendix D: Outside Design Temperatures for Washington

TABLE 1**

Average Dewpoint Temperatures (°F)
(A reference for Table 4-16 of the 1986 Washington State Energy Code)

Weather Station	July Dewpt. Years*		August Dewpt. Years*		September Dewpt. Years*		3-Month Average Dewpt.
Olympia AP	52	10	53	10	50	9	52
Quillayute AP	52	8	53	8	50	9	52
Seattle - Tacoma AP	51	4	51	4	48	4	50
Seattle - 2725 Montlake Blvd. East	51	5	53	5	50	5	51
Spokane AP	45	9	45	9	41	9	44
Stampede Pass	44	9	45	9	44	9	45
Walla Walla	No dewpoint data available, 1975 - 1985						
Yakima AP	47	8	47	10	43	8	46

** Data based on Local Climatological Data, Monthly Summaries, National Oceanic and Atmospheric Administration, Environmental Data and Information Service, National Climatic Center, Asheville, North Carolina.

* Number of Years of Data: 1975 - 1985

Appendix E: Sample Checklists and Worksheets

WSEO-EES Sample Checklists

Prescriptive, Residential, Electric, Zone 1	E-2
Component Performance, Residential, Electric, Zone 1	E-9
Component Performance, Residential, Non-Electric, Zone 2	E-18
Prescriptive, Residential, Electric, Zone 2	E-27
Prescriptive, Residential (Log), Electric, Zone 2	E-34
Residential Additions	E-42
Residential Radon (high risk areas)	E-44

WATTSUN Worksheet (Version 5.x)	E-45
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WATTSUN Sample Printout	E-49
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WSEO Code Program Checklist	E-52
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Model WSEC Compliance Forms

The forms in this Appendix are intended to aid compliance with the 1991 Washington State Energy and Ventilation codes. They were designed in a "compliance" format to model a uniform approach to Code compliance. Although the forms were initially conceptualized as a training tool, jurisdictions are using them more and more for enforcement.

Note, however, that the use of these forms is optional and not mandatory.

Each page is stamped "Sample" at the top. Because the forms are routinely refined and updated, the version represented here may not be the current edition. The edit date for any form can be found in the bottom corner. Current copies may be ordered from the Washington Energy Extension Service at 1-800-962-9731. Forms are available for Zones I & II and for "Electric" and "Other" heat sources under the following titles:

- 1) Prescriptive (Chapter 6)
- 2) Prescriptive for Log Dwellings (Chapter 6)
- 3) Component Performance (Chapter 5)
- 4) Component Performance for Additions (Chapter 5)
- 5) Ventilation Requirements for Additions
- 6) Radon Prescriptive Requirements (Applies only in Eight designated counties)

Jurisdiction Logo here

Tip: Reproduce each form type in a different color.

Sample

1991 WSEC Residential Compliance Form Instructions:

About this form: The main purpose of this form is to provide enforcement consistency between inspectors and building jurisdictions. Instead of spending time searching through the WSEC and VIAQ Code, this form will help organize and condense requirements that apply to your project. It is also an excellent tool for learning the residential WSEC requirements.

Page 1. Includes a Table of options, one of which you will select for your particular design. Choose a compliance option that best suits the economics and design of your project.

Pages 2 through 6. Requirements are grouped under **Foundation, Framing, Insulation, and Final Phases**. Each phase lets you know what, and when requirements will be checked by the inspector. **In the shaded areas only**, provide information and check circles that apply to your specific project. Because the form is intended to cover most design variations, many of the listed requirements won't apply to a given project. **Do not** place marks in the two left side columns labeled "COMPLIANCE REQUIRED" and "INSPECTION APPROVED" or in boxes located in non-shaded areas (These are for Department use).

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Design changes: Be sure to get prior approval from the Department if you wish to make changes in your project during construction.

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Code Books: For more requirement detail, refer to the 1991 Washington State Energy Code, First Edition and the 1991 Ventilation and Indoor Air Quality Code, First Edition. Both may be purchased for \$11 from the Washington Association of Building Officials (WABO), P.O. Box 7310, Olympia, Washington 98507

WEES/BOWMAN/JANUARY 92

All Residential Occupancies, Zone 1 Prescriptive (Chapter 6)

Electric Heat source (excluding heat pumps)

Permit # _____

'91 WSEC Residential Compliance Form, Zone 1Prescriptive (Chapter 6) options for all R-Values
Heat source: _____ (oil, gas, electric, wood, etc.)**Sample****Instructions:**

1) Carefully review the requirements of each of the options below. Choose an option that best suits your dwelling design. Glazing percentage typically determines which option to choose. Your building must match the selected option requirements without exceptions or substitutions.

2) In the shaded areas on the pages that follow, make checks in the circles next to the requirements of your option (the option numbers are listed next to the requirements). Disregard components or equipment that don't apply to your project. Your permit will be processed more efficiently if you provide all of the requested information. Department staff can help you with general questions about this form.

Can't comply? If none of the Prescriptive (Chapter 6) options are acceptable, consider the Component Performance (Chapter 5) Approach. The main advantage is flexibility to juggle individual R and U-values as long as an overall maximum value isn't exceeded. Note that the Component Performance requirements are no less stringent than the Prescriptive requirements. Calculations may be performed with a **Component Performance (Chapter 5) Form**, or by using an acceptable computer program such as **WATTSUN 5.2**.

Plan Review*(For official use only)*

The selected Option is appropriate for this dwelling design.

YES ☐
NO ☐

Option ____ may be a better choice.

Notes: _____

Approved by: _____

Date: _____

	OPT I	OPT II	OPT III	OPT IV	OPT V	OPT VI	OPT VII (≤ 2 Stories)	OPT VIII (≤ 2 Stories)
	☐	☐	☐	☐	☐	☐	☐	☐
Glazing max:								
% of floor	10%	12%	12%	15%	18%	21%	25%	30%
U-value ²	0.46	0.43	0.40	0.40	0.39	0.36	0.35	0.32
Door U-value	0.40	0.20	0.40	0.20	0.20	0.20	0.20	0.20
(or R-value)	(R-2.5)	(R-5)	(R-2.5)	(R-5)	(R-5)	(R-5)	(R-5)	(R-5)
Ceilings:								
with attics	R-38	R-38	R-38	R-38	R-38	R-38	R-38	R-38
vaulted	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30
Walls:								
above grade	R-21	R-19	R-21	R-19	R-21	R-21	R-19 ¹	R-19 ¹
below grade								
or interior	R-21	R-19	R-21	R-19	R-21	R-21	R-21	R-21
exterior	R-10	R-10	R-10	R-10	R-10	R-10	R-10	R-10
Floor	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30
Slab on grade	R-10	R-10	R-10	R-10	R-10	R-10	R-10	R-10

Footnote:

1) R5 foam sheathing required in addition to R19 cavity insulation.

2) Glazing and door U-values may be weighted to meet the option U-value requirement.

High Voltage ELECTRIC 2014

INSPECTION
APPROVED

IMPORTANT: Supply information in the shaded area by checking the appropriate circles. Disregard topics that don't describe your building or equipment. DO NOT place checks in the two left columns.

Sample

☐	☐	☒ 1 Slab Insulation (Table 6-1) shall be R-10 and located on the:
☐ A. Exterior (See INSULATION INSPECTION).
OR
☐ B. Interior extending downward from the top slab surface to its undersurface and horizontally under the slab for a total distance of 24", or vertically 24".
☐	☐	☒ 2 Radiant slab Insulation shall have R-10 and extend under the entire slab (S. 502.1.4.9).
☐	☐	☒ 3 Below-grade masonry wall insulation (S. 502.1.4.10) shall be full-depth and located on the:
☐ A. Exterior and rated R-10 (See INSULATION PHASE).
OR
☐ B. Interior (See INSULATION PHASE)
☐	☐	☒ 4 Thermal break(s) shall be placed in the slab (S. 502.1.4.8, 201.1: BUILDING ENVELOPE) between the conditioned and unconditioned spaces checked below, and extend from the top of the slab to the bottom, then underneath toward the conditioned space for a 24" total developed dimension.
☐ Dwelling/garage ☐ Dwelling/connected space ☐ Slab edge and foundation wall.
☐	☐	☒ 5 Radon mitigation system (VIAQ, S. 502.1) shall be installed if one of the following is checked:
☐ A. Net foundation ventilation area is less than 1 Ft ² per 300 Ft ² of crawl space
☐ B. Foundation vents are closable.
☐ C. Under floor plenum acts as supply or return air duct

Inspected by: _____ Date: _____

☐ ☒ **6 All structural panels** such as plywood, particle board, wafer board, and oriented strand board shall be labelled " EXPOSURE I" "EXTERIOR" or "HUD -APPROVED" (VIAQ, S. 401.1).

☐ ☒ **7 Insulation baffles** shall be placed in attics/ceilings to maintain at least 1" ventilation space and extend at least 6" vertically above batts or 12" vertically above loosefill insulation (S. 502.1.4.5).

☐ ☒ **8 Glazing efficiency** required under the selected option shall be (S. 502.1.5, 602.7.2, Table 6-1):

☐ $\leq$ U.46 (Option I) ☐ $\leq$ U.43 (Options II) ☐ $\leq$ U.40 (Option III, IV)

☐ $\leq$ U.39 (Option V) ☐ $\leq$ U.36 (Option VI) ☐ $\leq$ U.35 (Option VII) ☐ $\leq$ U.32 (Option VIII)

Symbols used: = equals > greater than < less than ≥ greater than or equal ≤ less than or equal

WEES/BOWMAN/JANUARY 92

COMPLIANCE
REQUIRED **1991 WSEC RESIDENTIAL COMPLIANCE FORM**

HEAT SOURCE: ELECTRIC ZONE

INSPECTION
APPROVED

IMPORTANT: Please supply information in the shaded boxes and check the appropriate circles. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

FRAMING PHASE (Continued)**Sample** **9 Glazing/skylights by type**

See the Washington glazing directory

No.	Manufacturer	Frame material	# Layers	Model #	Area (Ft ²)	Uo value	Tested?
						U. _____	Yes ☐
						U. _____	Yes ☐
						U. _____	Yes ☐
						U. _____	Yes ☐
						U. _____	Yes ☐
						U. _____	Yes ☐
						U. _____	Yes ☐
						U. _____	Yes ☐
						U. _____	Yes ☐
						U. _____	Yes ☐
						U. _____	Yes ☐

10 Single Glazing (No more than 1% of heated floor area before doubling, S. 602.7.2)

Type: No: Area: X2 U. _____

Type: No: Area: X2 U. _____

11 Untested Glazing (Use only default U-values in Chapter 10, S. 1006.1)

Type: No: Area: U. _____

Type: No: Area: U. _____

TOTAL GLAZING AREA (Add entire column) →

12 Maximum allowed glazing area (S. 602.7.1) is derived by taking the the total glazing area of _____ Ft² and dividing by the total conditioned floor area of _____ Ft². Multiply this number by 100. This value can't exceed the glazing percentage for your selected option:

☐ ≤ 10% (Option I)
 ☐ ≤ 12% (Options II, III)
 ☐ ≤ 15% (Option IV)
 ☐ < 30% (Option VIII)

☐ ≤ 18% (Option V)
 ☐ ≤ 21% (Option VI)
 ☐ ≤ 25% (Option VII)

Glazing % = _____

13 Glazing documentation insufficient, U-values shall be justified by Mfr. testing report. **14 Glazing air leakage** (S. 502.4.3 (c)) measures shall be met as follows :

- 1) Fixed site-built: stops with sealant.
- 2) Operating site-built: weatherstripped with closer

15 Concealed insulation shall be placed: 1) Behind shower/tub 2) Behind partition studs/corner **16 Standard air leakage** caulking is complete and installed in the following locations (S. 502.4.3):

- 1) Between sole plate/subfloors
- 2) Wiring/plumbing/duct register penetrations
- 3) Rim joists/mud sills (heated lower floors)
- 4) Partition stud penetrations
- 5) Light fixture/ flue penetrations
- 6) Around window and door frames

**COMPLIANCE
REQUIRED**

1991 WSEC RESIDENTIAL COMPLIANCE FORM

INSPECTION
APPROVED

IMPORTANT: Supply information and check appropriate circles in the shaded boxes. Disregard topics that don't describe your building or equipment. DO NOT place checks in the two left columns.

FRAMING PHASE (Continued)

Sample

- ☐ ☐ (7) Prescriptive exhaust ventilation exhaust requirements for each dwelling unit (VIAQ, S. 303):

Location	Minimum at .25 w.g.	Mfr./model	Fan label CFM(.1W.G.)
Kitchen fan	100 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Laundry fan	50 CFM		
8 Whole house fan* (choose one)	☐ 50 CFM (1-2 bedrms)		
	☐ 80 CFM (3 bedrms)		
	☐ 100 CFM (4 bedrms)		

Whole house fan: Location _____ Sone rating _____ (≤ 1.5 if attic fan closer than 4' to ceiling)

- ☐ Whole house fan wiring for control routed to central location (*dehumidistat only*).

- ☐ ☐ **19** Whole house fan also serves as a kitchen or bath spot fan. ☐ Yes ☐ No
 (If a spot fan is designated as a whole house fan, the capacity shall be the larger CFM requirement.)

☐ ☐ **20** Whole house fan shall run continuously: Kitchen rate 25CFM: Bath & laundry rate 20CFM.

☐ ☐ **21** Integrated forced-air furnace ventilation (VIAQ Code, S. 303.1.2(b)) shall be synchronized with a whole house fan to supply fresh air to the dwelling: ☐ Yes ☐ No

 - ☐ If yes, a 6" diameter outside air inlet duct w/ motorized damper shall run from the building exterior to the furnace return plenum and limit the ventilation rate to .35 - .5 air change/hour.
 - ☐ Modifications to the above integrated forced air system may require performance testing, in a manner acceptable to the building official, to demonstrate .35 - .5 air change/hour.

- ☐ ☐ ☒ **22** Mechanical ventilation fan ducts shall be $\geq 4'$ and properly sized (VIAQ, Table 3-3).

- ☐ ☒ 23 Fresh air shall be provided for each dwelling unit as follows (VIAQ, S. 302.6.1):
- ☐ Each bedroom: Tested, screened, controllable, through-wall port (≥ 4 Sq. in.) to the exterior.
 - ☐ Each recreation room: One wall port as specified for bedrooms.
 - ☐ Other enclosed "habitable" rooms: One wall port as specified for bedrooms.
 - ☐ Overall living area: One wall port as specified for bedrooms.

- ☐ ☐ ☒ 24 PR ☐ Central forced air furnace which delivers outside makeup air through the ducting system

- ☐ ☒ **25 Recessed lighting fixtures** (S. 502.4.4) shall comply w/ one or more of the following:
- ☐ IC rated, no slots or holes in cans, caulked or sealed between can and ceiling
 - ☐ IC rated with lable certifying an ASTM E283 tested airleakage $\leq$ 2.0 CFM
 - ☐ Any UL listed fixture enclosed by a 1/2" gypboard box or other manufactured box w/ 1/2" clearance to combustables, and 3" clearance to insulation.

WSEC Framing phase requirements:

Inspected by _____ Date _____

COMPLIANCE
REQUIRED **1991 WSEC RESIDENTIAL COMPLIANCE FORM**

Heat source: ELECTRIC Zone: 1

INSPECTION
APPROVED

IMPORTANT: Please supply information in the shaded boxes and check the appropriate circles. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

INSULATION PHASE**Sample**

- ☐ ☐ **26** Exterior slab on grade insulation, if not located on the interior, shall be R-10 (Table 6-1).
- ☐ ☐ **27** Exterior below grade wall insulation, if not located on the interior, shall be R-10 (Table 6-1).
- ☐ ☐ **28** Exterior slab or below grade wall insulation material, shall be approved for below grade use.
- ☐ ☐ **29** Walls, including rim joists, shall be insulated without compression to (Table 6-1):
☐ R-21 batt (Options I, III, V, VI) ☐ R-19 (Option II, IV) ☐ R-19+R-5 foam (Options VII, VIII)
- ☐ ☐ **30** Interior below grade walls shall be insulated to (Table 6-1):
☐ R-21 (Options I, III, V, VI, VII, VIII) ☐ R-19 (Options II, IV)
- ☐ ☐ **31** Skylight wall insulation is installed and equivalent to the required wall R-values above (#28).
- ☐ ☐ **32** Vaulted ceilings shall be insulated without compression to R-30 (Table 6-1, All options)
- ☐ ☐ **33** Vapor retarders shall be installed toward the warm surface as represented below (502.1.6):
 Select one option for floors, walls, and appropriate ceilings:
 Floors: ☐ Plywood w/ exterior glue ☐ Poly (≥ 4 Mil) ☐ Backed batts
 Walls: ☐ Poly plastic (≥ 4 Mil) ☐ Face-stapled, backed batts ☐ Low-perm paint
 Ceilings: ☐ Not required where ventilation space averages $>12"$ above insulation.
☐ Face-stapled backed batts ☐ Poly plastic (≥ 4 mil) ☐ Low-perm paint
- ☐ ☐ **34** Heating system efficiency and sizing requirements shall be met as represented below:
- ☐ ☐ **35** Maximum heating system output (150% of design heat load) is _____ KW (S. 503.2.2).
- ☐ ☐ **36** Heating system requirements will be met with the following system (S.503.4.1.1):
 Mfr. _____ Model # _____ Max. output _____ KW
 Type _____

WSEC Insulation phase requirements:

Inspected by: _____ Date: _____

FINAL PHASE

- ☐ ☐ **37** Envelope floors shall be insulated without compression, and with support $\leq 24"$ o.c. to R-30 (All Options, Table 6-1).
- ☐ ☐ **38** Non-vaulted, attic ceilings shall be insulated without compression to R-38 (All Options, Table 6-1)
- ☐ ☐ **39** Door systems shall meet: ☐ U-40 (Options I, III) ☐ U-20 (Options II, IV, V, VI, VII, VIII, Table 6-1)
 Door types are (1) _____ (2) _____ (3) _____
- ☐ ☐ **40** Exposed foam insulation shall be protected with metal or plastic flashing or equivalent material that extends below grade (S. 502.1.4.8).

COMPLIANCE
REQUIRED **1991 WSEC RESIDENTIAL COMPLIANCE FORM**INSPECTION
APPROVED **IMPORTANT: Disregard topics that don't describe your building or equipment.
DO NOT place checks in the two left columns.****FINAL PHASE (Continued)****Sample**

☐	☐	41 Airflow from habitable rooms to whole-house fan ensured by undercut doors or grilles (VIAQ, S. 302.6.4)
☐	☐	42 Loosefill insulation OK if (S.502.1.4.5):
		1) Maximum ceiling slope ≤ 3 in 12
		2) $\geq 30"$ of clear distance from top of bottom chord to underside of roof sheathing at the roof ridge.
☐	☐	43 6 mil black polyethylene ground cover, lapped 12" at joints and to foundation wall.
☐	☐	44 Clearances shall meet listed minimums between insulation and (S.502.1.4.3):
		1) Chimney 2) Non-IC rated recessed lights: 1/2" to combustibles, 3" to insulation.
☐	☐	45 Attic hatch shall be insulated to required ceiling R-value and is weatherstripped (S.502.1.4.4).
☐	☐	46 Attic access shall have wood dam or equivalent to retain loose fill insulation in attic (S. 502.1.4.4).
☐	☐	47 All exterior doors (except 20 minute doors) shall be weatherstripped (S. 502.4.3).
☐	☐	48 Service hot & cold water piping shall be insulated to R-3 (S. 503.11).
☐	☐	49 Service recirculation hot water piping shall be insulated to Table 5-12 levels.
☐	☐	50 Thermostat provided for each HVAC system with range of 55-75° F (heating) (S.503.8.1).
☐	☐	51 Readily accessible, automatic or manual means provided to restrict or shut-off heating input to each zone or floor during periods not requiring heat (S. 503.8.3.1).
☐	☐	52 Controls for backup heat prohibit simultaneous operation of the primary system (S. 503.2.2(3)).
☐	☐	53 Mechanical ventilation systems shall have proper timers, and/or switches (S. 302.3).
☐	☐	54 Mechanical ventilation ducts shall have insulation $\geq$ R-4 in unconditioned spaces (VIAQ, S. 302.5).
☐	☐	55 Mechanical supply ducts in conditioned spaces shall have $\geq$ R-4 insulation (VIAQ, S. 302.5).
☐	☐	56 Supply ducts shall have volume dampers, or the equivalent, to balance system (S. 503.6).
☐	☐	57 Supply and return air ducts shall have sealed duct joints in unconditioned spaces (S. 503.10.2).
☐	☐	58 HVAC plenums, supply, and return air ducts shall have R-8 insulation (Table 5-11, All options).
☐	☐	59 Electric water heater(s) shall have (S. 504.2.1, 504.3, 504.4):
		1) Separate power shut-off 3) 1987 NAECA Label on tank
		2) Noncompressible R10 pad (unheated spaces only) 4) Temperature setting ≤ 120 F.
☐	☐	60 Showers and lavatories shall limit flow to ≤ 3.0 gallons/minute (S. 504.8.1).
☐	☐	61 Swimming pool(s) (S. 504.5) shall have:
		1) Readily accessible ON/OFF switch (pump, heater) 2) Pool cover 3) Piping insulated to S. 503.11
☐	☐	62 Fireplace(s) (VIAQ, S. 402.3) shall have:
		1) 6 square inch combustion air supplyduct w/ operable damper, directly connected to the fire box
		2) Tight-fitting glass or metal doors; or flue draft induction fan. 3) Tight-fitting flue damper.
☐	☐	63 Solid fuel burning appliance(s) (VIAQ, S. 402.2) shall have:
		1) Tight-fitting glass or metal doors
		2) Outside combustion air source directly connected to the fire box
		Exception: Non-direct, 4" diameter, dampered, combustion air source: allowed only for (1) new stove installations in existing homes where obstructions preclude direct combustion air, or (2) Central heating systems located in unheated spaces.
☐	☐	64 Three-month, etched-track, radon monitor, printed instructions, and an information sheet shall be supplied by the builder to each single-family dwelling and to each ground-floor unit of multi-family dwellings (VIAQ, S. 502.2.1).

WSEC Final phase requirements:

Inspected by: _____

Date: _____

The Component Performance (Chapter 5) Approach. This compliance method allows any combination of building envelope components if their collective heatloss (UA value) doesn't exceed a maximum WSEC budget. The Component Performance approach is a good choice for additions that don't conform to any of the Prescriptive Options. This is true because Component Performance calculations allow credit for heat loss improvements in the existing home. The Prescriptive (Chapter 6) Approach would normally be the first choice for new dwellings since it provides a variety of compliance options, is easier to use, and is no more stringent than The Component Performance Approach. Component Performance calculations may also be performed by computer using programs such as WATTSUN 5.2.

Pages 1, 2, 3. The first two pages provide instructions and forms for performing the Component Performance calculations. The third page sizes the heating system.

Pages 4 to 8. Requirements are grouped under **Foundation, Framing, Insulation, and Final Phases.** Each phase lets you know what, and when requirements will be checked by the inspector. ***In the shaded areas only,*** provide information and check circles that apply to your specific project. Because the form is intended to cover most design variations, many of the listed requirements won't apply to a given project. ***Do not*** place marks in the two left side columns labeled "COMPLIANCE REQUIRED" and "INSPECTION APPROVED" or in boxes located in non-shaded areas (These are for Department use).

Responsibility for Information: Although designated Department staff members will help you with general questions about completing this form, it is ultimately your responsibility to provide detailed information about heating systems, glazing, insulation, and other requested building specifications. Since this form will be evaluated for completeness and accuracy, you can avoid unnecessary permit delays by carefully providing all required information. Disregard items that don't address your particular building or equipment.

Design changes: Be sure to get prior approval from the Department if you wish to make changes in your project during construction.

How the form will be used: This form will ultimately be used for all WSEC field inspections. When it is returned with your permit, relevant boxes under the "COMPLIANCE REQUIRED" column will have been checked by the Building Department. This denotes which WSEC requirements apply to your project. The inspector will inspect your dwelling against these checked items and, when deemed acceptable, place a second check in the "INSPECTION APPROVED" column.

Code Books: For more requirement detail, refer to the 1991 Washington State Energy Code, First Edition and the 1991 Ventilation and Indoor Air Quality Code, First Edition. Both may be purchased for \$11 from the Washington Association of Building Officials (WABO), P.O. Box 7310, Olympia, Washington 98507

WEEB/BOWMAN JANUARY 92

All Residential Occupancies, Zone 1 Component Performance (Chapter 5) Electric Heat source (excluding heat pumps)

Permit No. _____

1991 WSEC Chapter 5, Residential Heat Loss FormHeat source: **ELECTRIC** (except heat pumps), Zone 1**Instructions****Sample**

Overview The Chapter 5 Approach allows any combination of building envelope components as long as the collective heat loss doesn't exceed a maximum limit established by code. The calculations on the lower part of this page may be ignored if below grade wall insulation will either be R-19 on the interior or R-10 on the exterior, or if the basement will not be heated or a habitable space, and the floor above is insulated.

Page 2, Standard Case Dwelling Calculation. Compute areas using outer surfaces for walls, ceilings (less skylights), and floors. Use the rough framed opening areas for doors. The glazing area is derived by multiplying a constant value (.15) by the sum of the conditioned floor areas. (Don't include unheated attached garages, etc.)

Page 2, Proposed Dwelling Calculation. Compute areas using outer surfaces for walls, ceilings, and floors. Use the rough framed opening areas for doors and glazing. Since there are only four boxes on the form for glazing, combine the areas of units with the same U_o value into a single entry. WSEC, Chapter 10, default values must be used for all walls, ceilings, floors, untested doors/glazing, and to determine below-grade wall/slab UA.

The Proposed Dwelling complies if the the Proposed UA doesn't exceed the Base Case UA. Transfer wall, ceiling, floor, glazing, and door values (R and U) to the Check

Method A (below-grade wall/slab heat loss tradeoffs)

1. For each wall that differs in depth, perform a separate calculation using Steps 2 & 3. Sum the totals.
2. Determine wall area from the slab surface to the top of the mud sill. Exclude door and glazing areas and insert them into the designated boxes below for both Standard case and Proposed heatloss.
3. Find the appropriate wall depths in Table 1 and insert the corresponding wall values into the Standard case box(es). Multiply the corresponding wall U-value by the area derived in Step #1.
4. Measure the perimeter distance in linear feet for each slab under a wall with a different Table 1 depth. Insert the slab F-value from Table 1 corresponding to each wall listed in Step #3.

STANDARD CASE HEAT LOSS

B.G. wall #1	(Ft ²)	x U _____	=
B.G. slab #1	(L. Ft)	x F _____	=
B.G. wall #2	(Ft ²)	x U _____	=
B.G. slab #2	(L. Ft)	x F _____	=

TOTAL COLUMN →

PROPOSED HEAT LOSS

Use Chapter 10, page 81, U & F-values for this calculation and the same STANDARD CASE area/L. ft. measurements.

B.G. wall #1	(Ft ²)	x U _____	=
B.G. slab #1	(L. Ft)	x F _____	=
B.G. wall #2	(Ft ²)	x U _____	=
B.G. slab #2	(L. Ft)	x F _____	=

TOTAL COLUMN →

Table 1 (Below grade wall/slabs)**Insulated interior wall Values**

2' depth: walls	U.043
slab	F.69
3.5' depth: walls	U.041
slab	F.64
7' depth: walls	U.037
slab	F.57

Insulated exterior wall

2' depth: walls	U.070
slab	F.60
3.5' depth: walls	U.064
slab	F.57
7' depth: walls	U.056

(*Depth* indicates the total concrete wall depth including not more than 6" of above grade wall.)

Permit No. _____

1991 WSEC Chapter 5, Residential Compliance Form**Heat source: ELECTRIC (Except heat pumps) Zone 1****Sample****Standard Case Dwelling Calculation**

Component	Ft2 or perimeter L. feet	x	Uo	=	UA
Roof/Ceilings	(1) (Ft2)		x .031	=	
Cathedral Ceilings	(2) (Ft2)		x .034	=	
Framed Floor	(3)		x .029	=	
Gross Wall	(Ft2)				
Glazing (15% x cond. flr. Ft2)	(4)		x .40	=	
Doors	(5) (Ft2)		x .20	=	
Framed Wall (G.wall - (4+5))	(6) (Ft2)		x .058	=	
Below grade walls:					
or Interior	The UA value for either of these wall types must be derived using Method A in the instructions. Insert the value into the appropriate box at right.				=
or Exterior					=
Slab on grade	(7) (L. feet)		x .54	=	

Add 1 - 7 for cross check w/ proposed →

Proposed Dwelling Calculation

Component	Area/Perimeter	Uo	UA
Ceiling #1 ()	(Ft2)		
Skylight(s) #1	(1) (Ft2)	x	=
Net ceiling#1 (Ceiling - Sky.)	(2) (Ft2)	x	=
Ceiling #2 ()	(Ft2)		
Skylight(s) #2	(3) (Ft2)	x	=
Net ceiling#2 (Ceiling - Sky.)	(4)	x	=
Framed floor	(5) (Ft2)	x	=
Slab on grade	(6) (L. Feet)	x	=
Glazing ()	(Ft2)	x	=
Glazing ()		x	=
Glazing ()	(Ft2)	x	=
Glazing ()	(Ft2)	x	=
Door ()	(Ft2)	x	=
Door ()	(Ft2)	x	=
Wall #1 ()	(Ft2)		
Glazing & doors #1	(7) (Ft2)		
Net wall #1 (Wall - G & D)	(8) (Ft2)	x	=
Wall #2 ()	(Ft2)		
Glazing & doors #2	(9) (Ft2)		
Net wall #2 (Wall - G & D)	(10) (Ft2)	x	=
Below grade wall	See instructions, Method A		=

Add 1 - 10 for cross check w/base →

Standard Case UA
(add this column)
 Name _____
 Street _____
 Lot _____
 City _____
 Phone () _____
 Notes: _____

If the Proposed UA value is less than or equal to the Base Case UA value, the dwelling design complies with the 1991 WSEC.

 Proposed UA
 (Add this column)

1997 WSEC Residential Design Heat Load Form

Climate Zone 1

Instructions:**Sample****A. The following steps will determine the maximum heating system size :**

1. **Structural loss, value (1):** May be taken directly from the **Proposed UA box** on page 2.
2. **Air leakage loss, Value (2):** This is the volume (Ft³) of the conditioned space in the dwelling.
3. **Climate Factor, ΔT :** The local ASHRAE climate factor is ____ F. for your jurisdiction. (Call WEES if unsure.)
4. **Duct Loss, value (3):** Insert value from **BTU/Hr, Box (a)**.
5. Calculate values a, b, and c by multiplying the numbers in each horizontal row.
6. Add values a, b, and c.
7. Multiply the sum from Step #6 by 1.5 to obtain the maximum heating system output for the building.
8. If the heating system is electric, divide the BTU/hr. value from Step #7 by 3413 to get kWatt output.

Heat loss path	Values	ΔT	ACH	Factors	BTU/Hr.
Structural loss	(1) (BTU/Hr/F)	X			= (a)
Air leakage loss	(2) (Ft ³)	X	x .60	X 0.018	= (b)
Duct losses	(3) (BTU/Hr)			x .10	= (c)

Permit No. _____
 Name _____
 Street _____
 Lot# _____
 City _____
 County _____
 Phone# _____

Manufacturer _____
 Type of system _____
 Model # _____
 Heating output _____ (kW) (BTU/hr.)

Design Heat Load
(a+b+c)

→

_____ (BTU/Hr.)

Maximum Heating Output
(Gas, oil, propane, wood)
(Design Heat Load X 1.5)

→

_____ (BTU/Hr.)

OR

Maximum Heating Output
(Electric, heat pumps)
(BTU/hr. / 3413)

→

_____ (kWatts)

WEES/BOWMAN/JANUARY 92

COMPLIANCE
REQUIRED

1991 WSEC, CHAPTER 5 RESIDENTIAL COMPLIANCE FORM

INSPECTION
APPROVED

IMPORTANT: Supply information in the shaded area by supplying R and U-values, and by checking the appropriate circles. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

Sample**FOUNDATION PHASE**

☐	☐	☐	1 Slab Insulation (Table 5-1) shall be R- _____ and located on the:
☐ A. Exterior (See INSULATION INSPECTION).
OR
☐ B. Interior extending downward from the top slab surface to its undersurface and horizontally under the slab for a total distance of 24", or vertically 24".
☐	☐	☐	2 Radiant slab Insulation shall have R- _____ and extend under the entire slab (S. 502.1.4.9)
☐	☐	☐	3 Below-grade masonry wall insulation (S. 502.1.4.10) shall be full-depth and located on the:
☐ A. Exterior and rated R- _____ (See INSULATION PHASE).
OR
☐ B. Interior (See INSULATION PHASE)
☐	☐	☐	4 Thermal break(s) shall be placed in the slab (S. 502.1.4.8, 201.1: BUILDING ENVELOPE) between the conditioned and unconditioned spaces checked below, and extend from the top of the slab to the bottom, then underneath toward the conditioned space for a 24" total developed dimension.
☐ Dwelling/garage ☐ Dwelling/connected space ☐ Slab edge and foundation wall.
☐	☐	☐	5 Radon Requirements (IAQC, S. 502.1.2, 502.1.3) shall be met if one of the following is checked:
☐ A. Net foundation ventilation area is less than 1 Ft ² per 300 Ft ² of crawl space
☐ B. Foundation vents are closable.
☐ C. Crawl space acts as HVAC supply, or return air plenum.

WSEC Foundation phase requirements:

Inspected by: _____ Date: _____

FRAMING PHASE

☐	☐	☐	6 Insulation baffles shall be placed in attics/ceilings to maintain at least 1" ventilation space and extend at least 6" vertically above batts or 12" vertically above loosefill insulation (S. 502.1.4.5).

Symbols used: = equals > greater than < less than ≥ greater than or equal ≤ less than or equal

WEES/BOWMAN/JANUARY 92

INSPECTION
APPROVED

IMPORTANT: Please supply information in the shaded boxes and check the appropriate circles. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

FRAMING PHASE (Continued)

Sample

[illegible]

COMPLIANCE
REQUIRED ☒

1991 WSEC, CHAPTER 5, RESIDENTIAL COMPLIANCE FORM

INSPECTION
APPROVED ☒

IMPORTANT: Supply Information and check appropriate circles in the shaded boxes. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

FRAMING PHASE (Continued)

Sample

- ☐ ☐ 14 Prescriptive exhaust ventilation exhaust requirements for each dwelling unit (VIAQ, S. 303):

Spot Fans	Minimum (.25 w.g.)	Mfr./model	Fan label (.1WG)
Kitchen fan	100 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Laundry fan	50 CFM		
☐ 50 CFM (1-2 bedrms) ☐ 80 CFM (3 bedrms) ☐ 100 CFM (4 bedrms)			

Whole house fan: Location _____ Sone rating _____ (< 1.5 if attic fan closer than 4' to ceiling)

- ☐ Whole house fan is intended for continuous use.
☐ Whole house fan wiring for control routed to central location (*dehumidistat only*).

- ☐ ☐ 16 Whole house fan also serves as a kitchen or bath spot fan. ☐ Yes ☐ No
 (Spot fan designated as a whole house fan shall meet whole house fan requirements.)
☐ ☐ 17 Spot fan isn't suitable for Whole house fan and must be separate ☐ Yes ☐ No
☐ ☐ 18 Whole house fan shall run continuously: Kitchen(25CFM), Bath & laundry(20CFM) ☐ Yes ☐ No
☐ ☐ 19 Integrated forced-air furnace ventilation (*see footnote*)(VIAQ Code, S. 303.1.2(b)) shall be synchronized with a whole house fan to supply fresh air to the dwelling: ☐ Yes ☐ No
☐ If yes, a 6" diameter outside air inlet duct w/ motorized damper shall run from the building exterior to the furnace return plenum and limit the ventilation rate to between .35 - .5 ACH,
☐ Modifications to the above integrated forced air system may require performance testing, in a manner acceptable to the building official, to demonstrate .35 - .5 Air Changes/Hour.
 *Five bedrooms or larger requires a designed whole house fan system (Rate is .35 - .5 ACH)

- ☐ ☐ 20 Mechanical ventilation fan ducts shall be $\geq$ 4" and properly sized (VIAQ, Table 3-3).

Fresh air supply requirements:

- ☐ ☐ 21 Fresh air shall be provided for each dwelling unit as follows (VIAQ, S. 302.6.1):
☐ Each bedroom: Tested, screened, controllable, through-wall port ($\geq$ 4 Sq. in.) to the exterior.
☐ Each recreation room: One wall port as specified for bedrooms.
☐ Other enclosed "habitable" rooms: One wall port as specified for bedrooms.
☐ Overall living area: One wall port as specified for bedrooms.

- ☐ ☐ 22 OR ☐ Integrated forced air furnace that delivers outside makeup air through the ducting system

WSEC Framing phase requirements:

Inspected by _____ Date _____

INSPECTION
APPROVED

INSULATION PHASE

Sample

- ☐ ☐ **23 Walls**, including rim joists, Shall be insulated without compression to R-_____ (See calculations)

☐ ☐ **24 Below-grade walls** shall be insulated to: Exterior R-_____ or Interior R-_____ (See calculations)

☐ ☐ **25 Slab on grade insulation** shall be R-_____ (See calculations).

☐ ☐ **26 Vaulted ceilings** shall be insulated without compression to R-_____ (See calculations)

☐ ☐ **27 Skylight wall insulation** is installed and equivalent to the required wall R-value (#23) above.

☐ ☐ **28 Vapor retarders** shall be installed toward the warm surface as represented below (502.1.6):
Select one option for floors, walls, and appropriate ceilings:
Floors: ☐ Plywood w/ exterior glue ☐ Poly (≥ 4 Mil) ☐ Backed batts
Walls: ☐ Poly plastic (≥ 4 Mil) ☐ Face-stapled, backed batts ☐ Low-perm paint
Ceilings: ☐ Not required where ventilation space averages $>12"$ above insulation.
☐ Face-stapled backed batts ☐ Poly plastic (≥ 4 mil) ☐ Low-perm paint

☐ ☐ **29 Heating system sizing** requirements shall be met as represented below:

☐ ☐ **30 Maximum heating system output** (150% of design heat load, S. 503.2.2) is _____ KW
Heating system requirements will be met with following system (S.503.4.1.1):
Mfr. _____ Model # _____ Max. output _____ KW
Type _____

Inspected by: _____ Date: _____

FINAL PHASE

- ☐ ☐ **91 Crawl space floors** shall be insulated without compression, and with support $\leq 24"$ O.C. to: R- _____
- ☐ ☐ **92 Non-vaulted, attic ceilings** shall be insulated without compression to: R- _____
- ☐ ☐ **93 Door systems shall meet:** U- _____ (See Calculations)
Door types are (1) _____ (2) _____ (3) _____

COMPLIANCE
REQUIRED

1991 WSEC, CHAPTER 5, RESIDENTIAL COMPLIANCE FORM

INSPECTION
APPROVED IMPORTANT: **DO NOT** place checks in the two left columns.

FINAL PHASE (Continued)

Sample

☐	☐	34 Exposed foam Insulation shall comply as follows (S. 502.1.4.7):
1) Protected with metal or plastic flashing, or other suitable material that extends below grade.
2) Insulation is approved for sub-grade, exterior use and properly installed.
☐	☐	35 Airflow between fresh air ports and whole house fan ensured by undercut doors/grills (VIAQ, S. 302.6.4).
☐	☐	36 Loosefill Insulation OK if (S.502.1.4.5):
1) Maximum ceiling slope not > 3 in 12
2) ≥ 30" of clear distance from top of bottom chord to underside of roof sheathing at the roof ridge.
☐	☐	37 6 mil black polyethylene ground cover, shall be lapped 12" at joints and extend to foundation wall.
☐	☐	38 Clearances shall meet listed minimums between insulation and (S.502.1.4.3):
1) Chimney 2) Non-IC rated recessed lights: 1/2" to combustibles, 3" to insulation.
☐	☐	39 Attic hatch shall be insulated to required ceiling R-value and is weatherstripped (S.502.1.4.4).
☐	☐	40 Attic access shall have wood dam or equivalent to retain loose fill insulation in attic (S. 502.1.4.4).
☐	☐	41 All exterior doors (except 20 minute doors) shall be weatherstripped (S. 502.4.3).
☐	☐	42 Service hot & cold water piping in unconditioned spaces shall be insulated to R-3 (S. 503.11).
☐	☐	43 Service recirculation hot water piping in unconditioned spaces shall be insulated (Table 5-12).
☐	☐	44 Heat pump thermostat shall have programable capability (S. 503.8.3.5).
☐	☐	45 Thermostat provided for each HVAC system with range of 55-75° F(heating) (S.503.8.1.1).
☐	☐	46 Readily accessible, automatic or manual means provided to restrict or shut-off heating input to each zone or floor during periods not requiring heat (S. 503.8.3.1).
☐	☐	47 Controls for backup heat prohibit simultaneous operation of the primary system (S. 503.2.2(3)).
☐	☐	48 Mechanical ventilation system shall have proper timers, and/or switches (VIAQ, S. 302.3).
☐	☐	49 Mechanical ventilation exhaust ducts in unconditioned spaces shall have R-4 ins. (VIAQ, S. 302.5).
☐	☐	50 Mechanical ventilation supply ducts in conditioned spaces shall have R-4 ins.(VIAQ, 302.5).
☐	☐	51 Supply ducts shall have volume dampers, or the equivalent, to balance flows (S. 503.6).
☐	☐	52 Supply and return air ducts shall have sealed duct joints in unconditioned spaces (S. 503.10.2).
☐	☐	53 HVAC plenums, supply, and return air ducts shall have R-8 insulation (Table 5-11, All options).
☐	☐	54 Water heater(s) shall have (S. 504.2.1, 504.3, 504.4):
1) Separate power, or gas shut-off 2) 1987 NAECA label on tank
2) Elect only: non-compressible R-10 pad (unheated spaces, slabs) 4) Temperature setting ≤ 120 F.
☐	☐	55 Showers and lavatories shall limit flow to ≤ 3.0 gallons/minute (S. 504.8.1).
☐	☐	56 Swimming pools(S. 504.5) shall have:
1) Readily accessible ON/OFF switch (pump, heater) 1) Pool cover 3) Piping insulated to S. 503.11
☐	☐	57 All fireplaces (VIAQ, S. 402.3) shall have:
1) 6 square inch combustion air supplyduct w/ accessible damper directly connected to the fire box
2) Tight-fitting glass or metal doors. 3) Tight-fitting flue damper
☐	☐	58 Solid fuel burning appliance(s) (VIAQ, S. 402.2) shall have:
1) Tight-fitting glass or metal doors
2) Outside combustion air source directly connected to the fire box
Exception: Non-direct, 4" diameter, dampered, combustion air source: allowed only for (1) New stove installations in existing homes where obstructions preclude direct combustion air, or (2) Central heating systems located in unheated spaces.
☐	☐	59 Three-month, etched-track radon monitor, printed instructions, and information sheets shall be supplied to the single-family dwelling or first-floor units of multi-family dwellings by the general contractor (VIAQ,S. 502.2.1).

WSEC Final phase requirements:

Inspected by: _____

Date _____

Jurisdiction Logo here

Tip: Reproduce each form type in a different color.

Sample

91 WSEC Residential Compliance Form Instructions:

The Component Performance (Chapter 5) Approach. This compliance method allows any combination of building envelope components if their collective heatloss (UA value) doesn't exceed a maximum WSEC budget. The Component Performance approach is a good choice for additions that don't conform to any of the Prescriptive Options. This is true because Component Performance calculations allow credit for heat loss improvements in the existing home. The Prescriptive (Chapter 6) Approach would normally be the first choice for new dwellings since it provides a variety of compliance options, is easier to use, and is no more stringent than The Component Performance Approach. Component Performance calculations may also be performed by computer using programs such as WATTSUN 5.2.

Pages 1, 2, 3. The first two pages provide instructions and forms for performing the Component Performance calculations. The third page sizes the heating system.

Pages 4 to 8. Requirements are grouped under **Foundation, Framing, Insulation, and Final Phases**. Each phase lets you know what, and when requirements will be checked by the inspector. **In the shaded areas only**, provide information and check circles that apply to your specific project. Because the form is intended to cover most design variations, many of the listed requirements won't apply to a given project. **Do not** place marks in the two left side columns labeled "COMPLIANCE REQUIRED" and "INSPECTION APPROVED" or in boxes located in non-shaded areas (These are for Department use).

Responsibility for Information: Although designated Department staff members will help you with general questions about completing this form, it is ultimately your responsibility to provide detailed information about heating systems, glazing, insulation, and other requested building specifications. Since this form will be evaluated for completeness and accuracy, you can avoid unnecessary permit delays by carefully providing all required information. Disregard items that don't address your particular building or equipment.

Design changes: Be sure to get prior approval from the Department if you wish to make changes in your project during construction.

How the form will be used: This form will ultimately be used for all WSEC field inspections. When it is returned with your permit, relevant boxes under the "COMPLIANCE REQUIRED" column will have been checked by the Building Department. This denotes which WSEC requirements apply to your project. The inspector will inspect your dwelling against these checked items and, when deemed acceptable, place a second check in the "INSPECTION APPROVED" column.

Code Books: For more requirement detail, refer to the 1991 Washington State Energy Code, First Edition and the 1991 Ventilation and Indoor Air Quality Code, First Edition. Both may be purchased for \$11 from the Washington Association of Building Officials (WABO), P.O. Box 7310, Olympia, Washington 98507

WEES/BOWMAN/JANUARY 92

**All Residential Occupancies, Zone 2
Component Performance (Chapter 5)
OTHER heat source (Gas, oil, propane, wood, heat pumps)**

Permit No. _____

1991 WSEC Chapter 5 Residential Heat Loss Form**Heat source: OTHER (gas, oil, propane, heat pumps), Zone 2****Sample****Instructions**

Overview The Chapter 5 Approach allows any combination of building envelope components as long as the collective heat loss doesn't exceed a maximum limit established by code. The calculations on the lower part of this page may be ignored if below grade wall insulation will either be R-19 on the interior or R-12 on the exterior, or if the basement will not be heated or a habitable space, and the floor above is insulated.

Page 2, Standard Case Dwelling Calculation. Compute areas using outer surfaces for walls, ceilings (less skylights), and floors. Use the rough framed opening areas for doors. The glazing area is derived by multiplying a constant value (.15) by the sum of the conditioned floor areas. (Don't include unheated attached garages or basements, etc.)

Page 2, Proposed Dwelling Calculation. Compute areas using outer surfaces for walls, ceilings, and floors. Use the rough framed opening areas for doors and glazing. Since there are only four boxes on the form for glazing, combine the areas of units with the same U_o value into a single entry. WSEC, Chapter 10, default values must be used for all walls, ceilings, floors, untested doors/glazing, and to determine below-grade wall/slab UA.

The Proposed Dwelling complies if the the Proposed UA doesn't exceed the Base Case UA.

Method A (below-grade wall/slab heat loss tradeoffs)

1. For each wall that differs in depth, perform a separate calculation using Steps 2 & 3. Sum the totals.
2. Determine wall area from the slab surface to the top of the mud sill. Exclude door and glazing areas and insert them into the designated boxes below for both Standard case and Proposed heat loss.
3. Find the appropriate wall depths in Table 1 and insert the corresponding wall values into the Standard case box(es). Multiply the corresponding wall U-value by the area derived in Step #1.
4. Measure the perimeter distance in linear feet for each slab under a wall with a different Table 1 depth. Insert the slab F-value from Table 1 corresponding to each wall listed in Step #3.

STANDARD CASE HEAT LOSS

B.G. wall #1	(Ft ²)	x U ____	=
B.G. slab #1	(L. Ft)	x F ____	=
B.G. wall #2	(Ft ²)	x U ____	=
B.G. slab #2	(L. Ft)	x F ____	=
TOTAL COLUMN →			

PROPOSED HEAT LOSS

Use Chapter 10, page 81, U & F-values for this calculation and the same **STANDARD CASE** area/L. ft. measurements.

B.G. wall #1	(Ft ²)	x U ____	=
B.G. slab #1	(L. Ft)	x F ____	=
B.G. wall #2	(Ft ²)	x U ____	=
B.G. slab #2	(L. Ft)	x F ____	=
TOTAL COLUMN →			

WES/BOWMAN/JANUARY 92

Page 1

Table 1 (Below grade wall/slabs)**Insulated interior wall**
Values

2' depth: walls	U.043
slab	F.69
3.5' depth: walls	U.041
slab	F.64
7' depth: walls	U.037
slab	F.57

Insulated exterior wall

2' depth: walls	U.061
slab	F.60
3.5' depth: walls	U.057
slab	F.57
7' depth: walls	U.050

("Depth" indicates the total concrete wall depth including not more than 6" of above grade wall.)

Permit No. _____

1991 WSEC Chapter 5 Residential Heat Loss FormHeat source: **OTHER** (Gas, oil, propane, wood, heat pumps) Zone 2

Standard Case Dwelling

Sample

Component		Ft2 or perimeter L. feet	x	Uo	=	UA	
Maximum UA allowed	Roof/Ceilings	(1) (Ft2)	Uo values are taken from WSEC Table 5 - 1	x .031	=		
	Cathedral Ceilings	(2) (Ft2)		x .034	=		
	Framed Floor	(3) (Ft2)		x .029	=		
	Gross Wall	(Ft2)					
	Glazing (15% x cond. flr. Ft2)	(4)		x .60	=		
	Doors	(5) (Ft2)		x .40	=		
	Framed Wall	(6) (Ft2)		x .062	=		
	Below grade walls:						
	or Interior	The UA value for either of these wall types must be derived using Method A in the instructions. Insert the value into the appropriate box at right.				=	
	or Exterior				=		
Slab on grade	(7) (L. feet)		x .54	=			

Add 1 - 7 for cross check w/ proposed ➔

Proposed Dwelling Calculation

Component		Area/Perimeter	Uo	UA
UA value for the proposed dwelling	Ceiling #1 (_____)	(Ft2)		
	Skylight(s) #1	(1) (Ft2)	x	=
	Net ceiling#1 (a-b=c)	(2) (Ft2)	x	=
	Ceiling #2 (_____)	(Ft2)		
	Skylight(s) #2	(3) (Ft2)	x	=
	Net ceiling#2 (d-e=f)	(4) (Ft2)	x	=
	Framed floor	(5) (Ft2)	x	=
	Slab on grade	(6) (L. Feet)	x	=
	Glazing (_____)	(Ft2)	x	=
	Glazing (_____)	(Ft2)	x	=
Glazing (_____)	(Ft2)	x	=	
Glazing (_____)	(Ft2)	x	=	
Door (_____)	(Ft2)	x	=	
Door (_____)	(Ft2)	x	=	
Wall #1 (_____)	(Ft2)			
Glazing & doors #1	(7) (Ft2)			
Net wall #1 (a-b=c)	(8) (Ft2)	x	=	
Wall #2 (_____)	(Ft2)			
Glazing & doors #2	(9) (Ft2)			
Net wall #2 (d-e=f)	(10) (Ft2)	x	=	
Below grade walls	See Instructions, Method A			=

Add 1 - 10 for cross check w/base ➔

Standard Case UA

(Add this column)

Name _____
 Street _____
 Lot _____
 City _____
 Phone (____) _____
 Notes: _____

If the Proposed UA value is less than or equal to the Base Case UA value, the dwelling design complies with the 1991 WSEC.

Proposed UA

(Add this column)

W.E.S./BOWMAN/JANUARY 92

1991 WSEC Residential Design Heat Load Form

Climate Zone 2

Instructions:**Sample****A. The following steps will determine the maximum heating system size :**

1. **Structural loss, value (1):** May be taken directly from the **Proposed UA box** on page 2.
2. **Air leakage loss, Value (2):** This is the volume (Ft³) of the conditioned space in the dwelling.
3. **Climate Factor, ΔT :** The local ASHRAE climate factor is ____ F. for your jurisdiction. (call WEES if unsure).
4. **Duct Loss, value (3):** Insert value from **BTU/Hr, Box (a)**.
5. Calculate values a, b, and c by multiplying the numbers in each horizontal row.
6. Add values a, b, and c.
7. Multiply the sum from Step #6 by 1.5 to obtain the maximum heating system output for the building.
8. If the heating system is electric, divide the BTU/hr. value from Step #7 by 3413 to get kWatt output.

Heat loss path	Values	ΔT	ACH	Factors	BTU/Hr.
Structural loss	(1) (BTU/Hr/F)	X			= (a)
Air leakage loss	(2) (Ft ³)	X	X .60	X 0.018	= (b)
Duct losses	(3) (BTU/Hr)			X .15	= (c)

Permit No. _____

Name _____

Street _____

Lot# _____

City _____

County _____

Phone# _____

Manufacturer _____

Type of system _____

Model # _____

Heating output _____ (kW) (BTU/hr.)

Design Heat Load
(a+b+c)

→

(BTU/Hr.)

Maximum Heating Output
(Gas, oil, propane, wood)
(Design Heat Load X 1.5)

→

(BTU/Hr.)

OR

Maximum Heating Output
(Electric, heat pumps)
(BTU/hr. / 3413)

→

(kWatts)

WEES/BOWMAN/JANUARY 92

<div style="float: left; width: 150px;"> COMPLIANCE REQUIRED ☒ </div> <div style="float: right; width: 650px;"> 1991 WSEC, CHAPTER 5. RESIDENTIAL COMPLIANCE FORM </div>	
INSPECTION APPROVED ☒	<p>IMPORTANT: Supply information in the shaded area by supplying R and U-values, and by checking the appropriate circles. Disregard topics that don't describe your building or equipment. DO NOT place checks in the two left columns.</p> <div style="text-align: right; background-color: black; color: white; padding: 5px; font-weight: bold; font-size: 1.2em; border-radius: 10px;">Sample</div> <div style="background-color: #cccccc; padding: 5px; margin-top: 10px; font-weight: bold;">FOUNDATION PHASE</div> <div style="margin-top: 10px;"> <div style="display: flex; align-items: flex-start;"> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="flex-grow: 1;"> <p>1 Slab Insulation (Table 5-1) shall be R- _____ and located on the:</p> <div style="margin-left: 20px;"> ☐ A. Exterior (See INSULATION INSPECTION). OR ☐ B. Interior extending downward from the top slab surface to its undersurface and horizontally under the slab for a total distance of 24", or vertically 24". </div> </div> </div> <div style="margin-top: 10px;"> <div style="display: flex; align-items: flex-start;"> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="flex-grow: 1;"> <p>2 Radiant slab Insulation shall have R- _____ and extend under the entire slab (S. 502.1.4.9)</p> </div> </div> <div style="display: flex; align-items: flex-start;"> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="flex-grow: 1;"> <p>3 Below-grade masonry wall insulation (S. 502.1.4.10) shall be full-depth and located on the:</p> <div style="margin-left: 20px;"> ☐ A. Exterior and rated R- _____ (See INSULATION PHASE). OR ☐ B. Interior (See INSULATION PHASE) </div> </div> </div> <div style="margin-top: 10px;"> <div style="display: flex; align-items: flex-start;"> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="flex-grow: 1;"> <p>4 Thermal break(s) shall be placed in the slab (S. 502.1.4.8, 201.1: BUILDING ENVELOPE) between the conditioned and unconditioned spaces checked below, and extend from the top of the slab to the bottom, then underneath toward the conditioned space for a 24" total developed dimension.</p> <div style="margin-left: 20px;"> ☐ Dwelling/garage ☐ Dwelling/connected space ☐ Slab edge and foundation wall. </div> </div> </div> <div style="margin-top: 10px;"> <div style="display: flex; align-items: flex-start;"> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="flex-grow: 1;"> <p>5 Radon Requirements (IAQC, S. 502.1.2, 502.1.3) shall be met if <u>one</u> of the following is checked:</p> <div style="margin-left: 20px;"> ☐ A. Net foundation ventilation area is less than 1 Ft² per 300 Ft² of crawl space ☐ B. Foundation vents are closable. ☐ C. Crawl space acts as HVAC supply, or return air plenum. </div> </div> </div> <div style="margin-top: 20px; border: 1px solid black; border-radius: 10px; padding: 10px; background-color: #f0f0f0;"> <p>WSEC Foundation phase requirements: Inspected by: _____ Date: _____</p> </div> <div style="margin-top: 10px;"> <div style="background-color: black; color: white; padding: 5px; font-weight: bold;">FRAMING PHASE</div> <div style="margin-top: 10px;"> <div style="display: flex; align-items: flex-start;"> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="width: 30px; text-align: center; padding: 5px;"> ☐ </div> <div style="flex-grow: 1;"> <p>6 Insulation baffles shall be placed in attics/ceilings to maintain at least 1" ventilation space and extend at least 6" vertically above batts or 12" vertically above loosefill insulation (S. 502.1.4.5)</p> </div> </div> </div> </div> </div></div></div></div>

Symbols used: = equals > greater than < less than ≥ greater than or equal ≤ less than or equal

WEES/BOWMAN/JANUARY 92

**INSPECTION
APPROVED**

FRAMING PHASE (Continued)

Sample

[illegible]

COMPLIANCE
REQUIRED ☒

1991 WSEC, CHAPTER 5, RESIDENTIAL COMPLIANCE FORM

INSPECTION
APPROVED ☒

IMPORTANT: Supply information and check appropriate circles in the shaded boxes. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

FRAMING PHASE (Continued)

Sample

- ☐ ☐ 14 Prescriptive exhaust ventilation exhaust requirements for each dwelling unit (VIAQ, S. 303):

Spot Fans	Minimum (.25 w.g.)	Mfr./model	Fan label (.1WG)
Kitchen fan	100 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Laundry fan	50 CFM		
☐ 50 CFM (1-2 bedrms) ☐ 80 CFM (3 bedrms) ☐ 100 CFM (4 bedrms)			

- ☐ ☐ 15 Whole house fan
(choose one)

Whole house fan: Location _____ Sone rating _____ (< 1.5 if attic fan closer than 4' to ceiling)

☐ Whole house fan is intended for continuous use.

☐ Whole house fan wiring for control routed to central location (dehumidistat only).

- ☐ ☐ 16 Whole house fan also serves as a kitchen or bath spot fan. ☐ Yes ☐ No

(Spot fan designated as a whole house fan shall meet whole house fan requirements.)

- ☐ ☐ 17 Spot fan isn't suitable for Whole house fan and must be separate ☐ Yes ☐ No

- ☐ ☐ 18 Whole house fan shall run continuously: Kitchen(25CFM), Bath & laundry(20CFM) ☐ Yes ☐ No

- ☐ ☐ 19 Integrated forced-air furnace ventilation (see footnote) (VIAQ Code, S. 303.1.2(b)) shall be synchronized with a whole house fan to supply fresh air to the dwelling: ☐ Yes ☐ No
- ☐ If yes, a 6" diameter outside air inlet duct w/ motorized damper shall run from the building exterior to the furnace return plenum and limit the ventilation rate to between .35 - .5 ACH,
- ☐ Modifications to the above integrated forced air system may require performance testing, in a manner acceptable to the building official, to demonstrate .35 - .5 Air Changes/Hour.

*Five bedrooms or larger requires a designed whole house fan system (Rate is .35 - .5 ACH)

- ☐ ☐ 20 Mechanical ventilation fan ducts shall be $\geq$ 4" and properly sized (VIAQ, Table 3-3).

Fresh air supply requirements:

- ☐ ☐ 21 Fresh air shall be provided for each dwelling unit as follows (VIAQ, S. 302.6.1):

☐ Each bedroom: Tested, screened, controllable, through-wall port ($\geq$ 4 Sq. in.) to the exterior.

☐ Each recreation room: One wall port as specified for bedrooms.

☐ Other enclosed "habitable" rooms: One wall port as specified for bedrooms.

☐ Overall living area: One wall port as specified for bedrooms.

- ☐ ☐ 22 OR ☐ Integrated forced air furnace that delivers outside makeup air through the ducting system

WSEC Framing phase requirements:

Inspected by _____ Date _____

COMPLIANCE
REQUIRED ☒

1991 WSEC, CHAPTER 5, RESIDENTIAL COMPLIANCE FORM

INSPECTION
APPROVED ☒

IMPORTANT: Please supply information in the shaded boxes and check the appropriate circles. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

INSULATION PHASE**Sample**

- ☐ ☐ **23** Walls, including rim joists, shall be insulated without compression to R- _____ (See calculations):
- ☐ ☐ **24** Below-grade walls shall be insulated to: Exterior R- _____ or Interior R- _____ (See calculations)
- ☐ ☐ **25** Slab on grade insulation shall be R- _____ (See calculations).
- ☐ ☐ **26** Vaulted ceilings shall be insulated without compression to R- _____ (See calculations)
- ☐ ☐ **27** Skylight wall insulation is installed and equivalent to the required wall R-value (#23) above.
- ☐ ☐ **28** Vapor retarders shall be installed toward the warm surface as represented below (502.1.6):
Select one option for floors, walls, and appropriate ceilings:
Floors: ☐ Plywood w/ exterior glue ☐ Poly (≥ 4 Mil) ☐ Backed batts
Walls: ☐ Poly plastic (≥ 4 Mil) ☐ Face-stapled, backed batts ☐ Low-perm paint
Ceilings: ☐ Not required where ventilation space averages $>12"$ above insulation.
☐ Face-stapled backed batts ☐ Poly plastic (≥ 4 mil) ☐ Low-perm paint
- ☐ ☐ **29** Heating system efficiency and sizing requirements shall be met as represented below (S. 503):
- ☐ ☐ **30** Heat pump efficiency, as listed in the ARI Directory, shall be:
☐ Split system, air source heat pump: HSPF ≥ 6.8 , COP ≥ 3.0
☐ Single package, air source heat pump: HSPF ≥ 6.6 , COP ≥ 3.0
☐ Water source heat pump: COP ≥ 3.8
☐ Ground source heat pump: COP ≥ 3.0
- ☐ ☐ **31** Central heating system AFUE rating, as listed in the GAMA Directory, shall be $\geq .78$.
- ☐ ☐ **32** Non-central combustion heating systems shall have Intermittent Ignition.
- ☐ ☐ **33** Maximum heating system output (150% of design heat load, S. 503.2.2) is _____ Kw or BTU/Hr.
- ☐ ☐ **34** High-efficiency, forced-air furnace ($\leq 56,000$ BTU/Hr. output) may exceed 150% of the DHL because: ☐ GAMA listed AFUE is $\geq .78 + 1$ per each 5000 BTU/Hr. of output that it exceeds the DHL.
Heating system requirements will be met with following system (S.503.4.1.1):
Mfr. _____ Model # _____ Max. output _____ KW or BTU/Hr.
Type _____

WSEC Insulation phase requirements:

Inspected by: _____ Date: _____

FINAL PHASE

- ☐ ☐ **35** Crawl space floors shall be insulated without compression, and with support $\leq 24"$ O.C. to: R- _____
- ☐ ☐ **36** Non-vaulted, attic ceilings shall be insulated without compression to: R- _____ (See Calculations)
- ☐ ☐ **37** Door systems shall meet: U- _____
Door types are (1) _____ (2) _____ (3) _____

COMPLIANCE
REQUIRED

1991 WSEC, CHAPTER 5, RESIDENTIAL COMPLIANCE FORM

INSPECTION
APPROVED IMPORTANT: **DO NOT** place checks in the two left columns.**FINAL PHASE (Continued)****Sample**

- ☐ ☐ **38** Exposed foam insulation shall comply as follows (S. 502.1.4.7):
- 1) Protected with metal or plastic flashing, or other suitable material that extends below grade.
 - 2) Insulation is approved for sub-grade, exterior use and properly installed.
- ☐ ☐ **39** Airflow between fresh air ports and whole house fan ensured by undercut doors/grills (VIAQ, S. 302.6.4).
- ☐ ☐ **40** Loosefill insulation OK if (S.502.1.4.5):
- 1) Maximum ceiling slope not > 3 in 12
 - 2) $\geq 30"$ of clear distance from top of bottom chord to underside of roof sheathing at the roof ridge.
- ☐ ☐ **41** 6 mil black polyethylene ground cover, shall be lapped 12" at joints and extend to foundation wall.
- ☐ ☐ **42** Clearances shall meet listed minimums between insulation and (S.502.1.4.3):
- 1) Chimney
 - 2) Non-IC rated recessed lights: 1/2" to combustibles, 3" to insulation.
- ☐ ☐ **43** Attic hatch shall be insulated to required ceiling R-value and is weatherstripped (S.502.1.4.4).
- ☐ ☐ **44** Attic access shall have wood dam or equivalent to retain loose fill insulation in attic (S. 502.1.4.4).
- ☐ ☐ **45** All exterior doors (except 20 minute doors) shall be weatherstripped (S. 502.4.3).
- ☐ ☐ **46** Service hot & cold water piping in unconditioned spaces shall be insulated to R-3 (S. 503.11).
- ☐ ☐ **47** Service recirculation hot water piping in unconditioned spaces shall be insulated (Table 5-12).
- ☐ ☐ **48** Heat pump thermostat shall have programable capability (S. 503.8.3.5).
- ☐ ☐ **49** Thermostat provided for each HVAC system with range of 55-75° F (heating) (S.503.8.1.1).
- ☐ ☐ **50** Readily accessible, automatic or manual means provided to restrict or shut-off heating input to each zone or floor during periods not requiring heat (S. 503.8.3.1).
- ☐ ☐ **51** Controls for backup heat prohibit simultaneous operation of the primary system (S. 503.2.2(3)).
- ☐ ☐ **52** Mechanical ventilation system shall have proper timers, and/or switches (VIAQ, S. 302.3).
- ☐ ☐ **53** Mechanical ventilation exhaust ducts in unconditioned spaces shall have R-4 ins. (VIAQ, S. 302.5).
- ☐ ☐ **54** Mechanical ventilation supply ducts in conditioned spaces shall have R-4 ins. (VIAQ, 302.5).
- ☐ ☐ **55** Supply ducts shall have volume dampers, or the equivalent, to balance flows (S. 503.6).
- ☐ ☐ **56** Supply and return air ducts shall have sealed duct joints in unconditioned spaces (S. 503.10.2).
- ☐ ☐ **57** HVAC plenums, supply, and return air ducts shall have R-8 insulation (Table 5-11, All options).
- ☐ ☐ **58** Water heater(s) shall have (S. 504.2.1, 504.3, 504.4):
- 1) Separate power, or gas shut-off
 - 2) 1987 NAECA label on tank
 - 3) Elect only: non-compressible R-10 pad (unheated spaces, slabs)
 - 4) Temperature setting ≤ 120 F.
- ☐ ☐ **59** Showers and lavatories shall limit flow to ≤ 3.0 gallons/minute (S. 504.8.1).
- ☐ ☐ **60** Swimming pools (S. 504.5) shall have:
- 1) Readily accessible ON/OFF switch (pump, heater)
 - 1) Pool cover
 - 3) Piping insulated to S. 503.11
- ☐ ☐ **61** All fireplaces (VIAQ, S. 402.3) shall have:
- 1) 6 square inch combustion air supply duct w/ accessible damper directly connected to the fire box
 - 2) Tight-fitting glass or metal doors.
 - 3) Tight-fitting flue damper
- ☐ ☐ **62** Solid fuel burning appliance(s) (VIAQ, S. 402.2) shall have:
- 1) Tight-fitting glass or metal doors
 - 2) Outside combustion air source directly connected to the fire box
- Exception:** Non-direct, 4" diameter, dampered, combustion air source: allowed only for (1) New stove installations in existing homes where obstructions preclude direct combustion air, or (2) Central heating systems located in unheated spaces.
- ☐ ☐ **63** Three-month, etched-track radon monitor, printed instructions, and information sheets shall be supplied to the single-family dwelling or first-floor units of multi-family dwellings by the general contractor (VIAQ, S. 502.2.1).

WSEC Final phase requirements:

Inspected by: _____

Date: _____

Jurisdiction Logo here

Tip: Reproduce each form type in a different color.

Sample**1991 WSEC Residential Compliance Form Instructions:**

About this form: The main purpose of this form is to provide enforcement consistency between inspectors and building jurisdictions. Instead of spending time searching through the WSEC and VIAQ Code, this form will help organize and condense requirements that apply to your project. It is also an excellent tool for learning the residential WSEC requirements.

Page 1. Includes a Table of options, one of which you will select for your particular design. Choose a compliance option that best suits the economics and design of your project.

Pages 2 through 6. Requirements are grouped under **Foundation, Framing, Insulation, and Final Phases**. Each phase lets you know what, and when requirements will be checked by the inspector. **In the shaded areas only**, provide information and check circles that apply to your specific project. Because the form is intended to cover most design variations, many of the listed requirements won't apply to a given project. **Do not** place marks in the two left side columns labeled "COMPLIANCE REQUIRED" and "INSPECTION APPROVED" or in boxes located in non-shaded areas (These are for Department use).

Responsibility for Information: Although designated Department staff members will help you with general questions about completing this form, it is ultimately your responsibility to provide detailed information about heating systems, glazing, insulation, and other requested building specifications. Since this form will be evaluated for completeness and accuracy, you can avoid unnecessary permit delays by carefully providing all required information. Disregard items that don't address your particular building or equipment.

Design changes: Be sure to get prior approval from the Department if you wish to make changes in your project during construction.

How the form will be used: This form will ultimately be used for all WSEC field inspections. When it is returned with your permit, relevant boxes under the "COMPLIANCE REQUIRED" column will have been checked by the Building Department. This denotes which WSEC requirements apply to your project. The inspector will inspect your dwelling against these checked items and, when deemed acceptable, place a second check in the "INSPECTION APPROVED" column.

Code Books: For more requirement detail, refer to the 1991 Washington State Energy Code, First Edition and the 1991 Ventilation and Indoor Air Quality Code, First Edition. Both may be purchased for \$11 from the Washington Association of Building Officials (WABO), P.O. Box 7310, Olympia, Washington 98507

WEES/BOWMAN/JANUARY 92

***All Residential Occupancies, Zone 2
Prescriptive (Chapter 6)
OTHER heat source (Gas, oil, propane, wood, heat pumps)***

Permit # _____

91 WSEC Residential Compliance FormPrescriptive (Chapter 6) Options for all R and U-values, 2000
Heat Source: _____ Oil (provide your heat pump)**Sample****Instructions:**

1) Carefully review the requirements of each of the options below. Choose an option that best suits your dwelling design. Glazing percentage typically determines which option to choose. Your building must match the selected option requirements without exceptions or substitutions.

2) In the shaded areas on the pages that follow, make checks in the circles next to the requirements of your option (the option numbers are listed next to the requirements). Disregard components or equipment that don't apply to your project. Your permit will be processed more efficiently if you provide all of the requested information. Department staff can help you with general questions about this form.

Can't comply? If none of the Prescriptive (Chapter 6) Options are acceptable, consider the Component Performance (Chapter 5) Approach. The main advantage is flexibility to juggle individual R and U-values as long as an overall maximum value isn't exceeded. Note that the overall Component Performance requirements are no less stringent than the Prescriptive requirements. Calculations may be performed with a **Component Performance (Chapter 5) Form**, or by using an acceptable computer program such as **WATTSUN 5.2**.

Plan Review*(For official use only)*

The selected Option is appropriate for this dwelling design.

YES ☐
NO ☐

Option ____ may be a better choice.

Notes: _____

Approved by: _____

Date: _____

	OPT I ○	OPT II ○	OPT III ○	OPT IV ○	OPT V ○	OPT VI ○	OPT VII (≤ 2 Stories) ○	OPT VIII (≤ 2 Stories) ○
Furnace AFUE	.78	.78	.88	.78	.74	.78	.78	.78
H. Pump HSPF	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Glazing max:								
% of floor	10%	12%	17%	17%	17%	21%	25%	30%
U-value	0.70	0.65	0.65	0.60	0.50	0.50	0.45	0.40
Door U-value¹ (or R-value)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)	0.40 (R-2.5)
Cellings:								
with attics	R-38	R-38	R-38	R-38	R-38	R-38	R-38	R-38
vaulted	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30
Walls:								
or above grade	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
below grade								
interior	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
exterior	R-12	R-12	R-12	R-12	R-12	R-12	R-12	R-12
Floor	R-25	R-25	R-25	R-30	R-30	R-30	R-30	R-30
Slab on grade	R-10	R-10	R-10	R-10	R-10	R-10	R-10	R-10

Footnote:

1) Glazing and door U-values may be weighted to meet the option U-value requirement.

COMPLIANCE
REQUIRED ☒**1991 WSEC RESIDENTIAL COMPLIANCE FORM**

Model Form for Use in New York State

INSPECTION
APPROVED ☒

IMPORTANT: Supply information in the shaded area by checking the appropriate circles. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

FOUNDATION PHASE**Sample**

- ☐ ☐ **1** Slab Insulation (Table 6-4) shall be R-10 and located on the:
☐ A. Exterior (See INSULATION INSPECTION).
OR
☐ B. Interior extending downward from the top slab surface to its undersurface and horizontally under the slab for a total distance of 24", or vertically 24".
- ☐ ☐ **2** Radiant slab Insulation shall have R-10 and extend under the entire slab (S. 502.1.4.9).
- ☐ ☐ **3** Below-grade masonry wall insulation (S. 502.1.4.10) shall be full-depth and located on the:
☐ A. Exterior and rated R-12 (See INSULATION PHASE).
OR
☐ B. Interior (See INSULATION PHASE)
- ☐ ☐ **4** Thermal break(s) shall be placed in the slab (S. 502.1.4.8, 201.1: BUILDING ENVELOPE) between the conditioned and unconditioned spaces checked below, and extend from the top of the slab to the bottom, then underneath toward the conditioned space for a 24" total developed dimension.
☐ Dwelling/garage ☐ Dwelling/connected space ☐ Slab edge and foundation wall.
- ☐ ☐ **5** Radon mitigation system (VIAQ, S. 502.1) shall be installed if one of the following is checked:
☐ A. Net foundation ventilation area is less than 1 Ft² per 300 Ft² of crawl space.
☐ B. Foundation vents are closable.
☐ C. Under floor plenum acts as supply or return air duct

WSEC Foundation phase requirements:

Inspected by: _____ Date: _____

FRAMING PHASE

- ☐ ☐ **6** All structural panels such as plywood, particle board, wafer board, and oriented strand board shall be labeled "EXPOSURE I" "EXTERIOR" or "HUD-APPROVED" (VIAQ, S. 401.1).
- ☐ ☐ **7** Insulation baffles shall be placed in attics/ceilings to maintain at least 1" ventilation space and extend at least 6" vertically above batts or 12" vertically above loosefill insulation (S. 502.1.4.5).
- ☐ ☐ **8** Glazing efficiency required under the selected option shall be (S. 502.1.5, 602.7.2):
☐ ≤ U.70 (Option I) ☐ ≤ U.65 (Options II, III) ☐ ≤ U.60 (Option IV)
☐ ≤ U.50 (Option V, VI) ☐ ≤ U.45 (Option VII) ☐ ≤ U.40 (Option VIII)

Symbols used: = equals > greater than < less than ≥ greater than or equal ≤ less than or equal

WEES/BOWMAN/JANUARY 92

COMPLIANCE
REQUIRED ☒**1991 WSEC RESIDENTIAL COMPLIANCE FORM**INSPECTION
APPROVED ☒

IMPORTANT: Supply information and check appropriate circles in the shaded boxes. Disregard topics that don't describe your building or equipment. DO NOT place checks in the two left columns.

FRAMING PHASE (Continued)**Sample**

- ☐ ☐ **17** Exhaust ventilation shall be provided for each dwelling unit (VIAQ, S. 303):

Location	Minimum at .25 w.g.	Mfr./model	Fan label (CFM)
Kitchen fan	100 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Laundry fan	50 CFM		
18 Whole house fan (choose one)	☐ 50 CFM (1-2 bedrms)		
	☐ 80 CFM (3 bedrms)		
	☐ 100 CFM (4 bedrms)		

Whole house fan: Location _____ Sone rating _____ (≤ 1.5 if attic fan closer than 4' to ceiling)

☐ Whole house fan is intended for Continuous use.

☐ Whole house fan wiring for control routed to central location (dehumidistat only).

- ☐ ☐ **19** Whole house fan also serves as a kitchen or bath spot fan. ☐ Yes ☐ No
(If a spot fan is designated as a whole house fan, the capacity shall be the larger CFM requirement.)

- ☐ ☐ **20** Whole house fan shall run continuously: Kitchen rate 25CFM; Bath & laundry rate 20CFM.

- ☐ ☐ **21** Integrated forced-air furnace ventilation (VIAQ Code, S. 303.1.2(b)) shall be synchronized with a whole house fan to supply fresh air to the dwelling: ☐ Yes ☐ No

☐ If yes, a 6" diameter outside air inlet duct w/ motorized damper shall run from the building exterior to the furnace return plenum and limit the ventilation rate to between .35 - .5 ACH.

☐ Modifications to the above integrated forced air system may require performance testing, in a manner acceptable to the building official, to demonstrate .35 - .5 Air Changes/Hour.

- ☐ ☐ **22** Mechanical ventilation fan ducts shall be $\geq 4"$ and properly sized (VIAQ, Table 3-3).

- ☐ ☐ **23** Fresh air shall be provided for each dwelling unit as follows (VIAQ, S. 302.6.1):

☐ Each bedroom: Tested, screened, controllable, through-wall port (≥ 4 Sq. in.) to the exterior.

☐ Each recreation room: One wall port as specified for bedrooms.

☐ Other enclosed "habitable" rooms: One wall port as specified for bedrooms.

☐ Overall living area: One wall port as specified for bedrooms.

- ☐ ☐ **24** OR ☐ Central forced air furnace which delivers outside makeup air through the ducting system.

- ☐ ☐ **25** Recessed lighting fixtures (S. 502.4.4) shall comply w/ one or more of the following:

☐ IC rated, no slots or holes in cans, caulked or sealed between can and ceiling.

☐ IC rated with label certifying an ASTM E283 tested airleakage ≤ 2.0 CFM.

☐ Any UL listed fixture enclosed by a 1/2" gypboard box or other manufactured box w/ 1/2" clearance to combustibles, and 3" clearance to insulation.

WSEC Framing phase requirements:

Inspected by _____ Date _____

COMPLIANCE
REQUIRED **1991 WSEC RESIDENTIAL COMPLIANCE FORM**

Heat source: OTHER Zone 2

INSPECTION
APPROVED

IMPORTANT: Please supply information in the shaded boxes and check the appropriate circles. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

INSULATION PHASE**Sample**

- ☐ ☐ **26** Walls, including rim joists, shall be insulated without compression to R-19 (All Options, Table 6-4).
- ☐ ☐ **27** Skylight wall insulation is installed and equivalent to the required wall R-values above.
- ☐ ☐ **28** Interior below grade wall insulation shall be R-19 (All Options, Table 6-4).
- ☐ ☐ **29** Exterior below grade wall insulation, if not insulated on the interior, shall be R-12 (Table 6-4).
- ☐ ☐ **30** Exterior slab on grade insulation, if not located on the interior, shall be R-10 (Table 6-4).
- ☐ ☐ **31** Exterior Slab or wall insulation shall be approved for below grade use.
- ☐ ☐ **32** Vaulted ceilings shall be insulated without compression to R-30 (All Options, Table 6-4).
- ☐ ☐ **33** Vapor retarders shall be installed toward the warm surface as represented below (502.1.6):
Select one option for floors, walls, and appropriate ceilings:
Floors: ☐ Plywood w/ exterior glue ☐ Poly (≥ 4 Mil) ☐ Backed batts
Walls: ☐ Poly plastic (≥ 4 Mil) ☐ Face-stapled, backed batts ☐ Low-perm paint
Ceilings: ☐ Not required where ventilation space averages $> 12"$ above insulation.
☐ Face-stapled backed batts ☐ Poly plastic (≥ 4 mil) ☐ Low-perm paint
- ☐ ☐ **34** Heating system efficiency and sizing requirements shall be met as represented below (S. 503):
- ☐ ☐ **35** Heat pump efficiency, as listed in the ARI directory, shall be met as follows:
☐ Split system, air source heat pump: HSPF ≥ 6.8 , COP ≥ 3.0 .
☐ Single package, air source heat pump: HSPF ≥ 6.6 , COP ≥ 3.0 .
☐ Water source heat pump: COP ≥ 3.8 .
☐ Ground source heat pump COP ≥ 3.0 .
- ☐ ☐ **36** Central heating system AFUE rating, as listed in the GAMA Directory, shall be:
☐ $\geq .78$ (Options I, II, IV, VI, VII, VIII) ☐ $\geq .88$ (Option III) ☐ $\geq .74$ (Option V)
- ☐ ☐ **37** Non-central, combustion heating systems shall have intermittent ignition.
- ☐ ☐ **38** Maximum heating system output (150% of design heat load) is _____ KW or BTU/hr.
- ☐ ☐ **39** High efficiency forced-air furnace ($\leq 56,000$ BTU/hr. output) may exceed 150% of DHL because: ☐ GAMA listed AFUE is $\geq 78 + 1$ per each 5000 BTU/hr output that it exceeds the DHL.
Heating system requirements will be met with following system (S.503.4.1.1):
Mfr. _____ Model # _____ Max. output _____ KW or BTU/Hr.
Type _____ HSPF _____ and/or COP _____

WSEC Insulation phase requirements:

Inspected by: _____

Date: _____

FINAL PHASE

- ☐ ☐ **40** Envelope Floors shall be insulated without compression, and with support $\leq 24"$ O.C. to (Table 6-4):
☐ R-25 (Options I, II, III) ☐ R-30 (Options IV, V, VI, VII, VIII)
- ☐ ☐ **41** Door systems shall meet U.40 (All Options, Table 6-4).
Door types are (1) _____ (2) _____ (3) _____
- ☐ ☐ **42** Non-vaulted, attic ceilings shall be insulated without compression to R-38 (All Options, Table 6-4)
- ☐ ☐ **43** Exposed foam insulation shall be protected with metal or plastic flashing or equivalent material that extends below grade (S. 502.1.4.8).

COMPLIANCE
REQUIRED **1991 WSEC RESIDENTIAL COMPLIANCE FORM**

Heat Source: OTHER Zone 2

INSPECTION
APPROVED **IMPORTANT: Disregard topics that don't describe your building or equipment.
DO NOT place checks in the two left columns.****Sample****FINAL PHASE (Continued)**

☐	☐	☐	44 Airflow from habitable rooms to whole-house fan ensured by undercut doors or grilles (VIAQ, S. 302.6.4).
☐	☐	☐	45 Loosefill Insulation OK if (S.502.1.4.5):
1) Maximum ceiling slope $\leq$ 3 in 12
2) $\geq$ 30" of clear distance from top of bottom chord to underside of roof sheathing at the roof ridge.
☐	☐	☐	46 6 mil black polyethylene ground cover, lapped 12" at joints and to foundation wall.
☐	☐	☐	47 Clearances shall meet listed minimums between insulation and (S.502.1.4.3):
1) Chimney 2) Non-IC rated recessed lights: 1/2" to combustibles, 3" to insulation.
☐	☐	☐	48 Attic hatch shall be insulated to required ceiling R-value and is weatherstripped (S.502.1.4.4).
☐	☐	☐	49 Attic access shall have wood dam or equivalent to retain loose fill insulation in attic (S. 502.1.4.4).
☐	☐	☐	50 All exterior doors (except 20 minute doors) shall be weatherstripped (S. 502.4.3).
☐	☐	☐	51 Service hot & cold water piping shall be insulated to R-3 (S. 503.11).
☐	☐	☐	52 Service recirculation hot water piping shall be insulated to Table 5-12 levels.
☐	☐	☐	53 Thermostat provided for each HVAC system with range of 55-75° F (heating) (S.503.8.1.1).
☐	☐	☐	54 Readily accessible, automatic or manual means provided to restrict or shut-off Heating input to each zone or floor during periods not requiring heat (S. 503.8.3.1).
☐	☐	☐	55 Controls for backup heat prohibit simultaneous operation of the primary system (S. 503.2.2(3)).
☐	☐	☐	56 Mechanical ventilation system shall have proper timers, and/or switches (S. 302.3).
☐	☐	☐	57 Mechanical ventilation ducts shall have insulation $\geq$ R-4 in unconditioned spaces (VIAQ, S. 302.5).
☐	☐	☐	58 Mechanical supply ducts in conditioned spaces shall have $\geq$ R-4 insulation (VIAQ, S. 302.5).
☐	☐	☐	59 Supply ducts shall have volume dampers, or the equivalent, to balance system (S. 503.6).
☐	☐	☐	60 Supply and return air ducts shall have sealed duct joints in unconditioned spaces (S. 503.10.2).
☐	☐	☐	61 HVAC plenums, supply, and return air ducts shall have R-8 insulation (Table 5-11, All options).
☐	☐	☐	62 Electric water heater(s) shall have (S. 504.2.1, 504.3, 504.4) :
1) Separate power shut-off 3) 1987 NAECA Label on tank
2) Non-compressible R-10 pad (unheated spaces only) 4) Temperature setting $\leq$ 120 F.
☐	☐	☐	63 Showers and lavatories shall limit flow to $\leq$ 3.0 gallons/minute (S. 504.8.1).
☐	☐	☐	64 Swimming pool(s) (S. 504.5) shall have:
1) Readily accessible ON/OFF switch (pump, heater) 2) Pool cover 3) Piping insulated to S. 503.11
☐	☐	☐	65 Fireplace(s) (VIAQ, S. 402.3) shall have:
1) 6 square inch combustion air supply duct w/ operable damper, directly connected to the fire box
2) Tight-fitting glass or metal doors; or flue draft induction fan. 3) Tight-fitting flue damper.
☐	☐	☐	66 Solid fuel burning appliance(s) (VIAQ, S. 402.2) shall have:
1) Tight-fitting glass/metal doors
2) Outside combustion air source directly connected to the fire box
Exception: Non-direct, 4" diameter, dampered, combustion air source: allowed only for (1) New stove installations in existing homes where obstructions preclude direct combustion air, or (2) Central heating systems located in unheated spaces.
☐	☐	☐	67 Three month, etched track, radon monitor, printed instructions, and an information sheet shall be supplied by the builder to each single family dwelling and to each ground floor unit of multi-family dwellings (VIAQ, S. 502.2.1).

WSEC Final phase requirements:

Inspected by: _____

Date: _____

Jurisdiction Logo here

Tip: Reproduce each form type in a different color.

Sample

1991 WSEC Log Dwelling Compliance Form Instructions:

About this form: The main purpose of this form is to provide enforcement consistency between inspectors and building jurisdictions. Instead of spending time searching through the WSEC and VIAQ Code, this form will help organize and condense requirements that apply to your project. It is also an excellent tool for learning the residential code requirements.

Page 1. Includes a Table of options, one of which you will select for your particular design. Choose a compliance option that matches the *average* log thickness of the walls in your project. For round log walls, this must be determined by calculations or by consulting the attached **Average Log Thickness Graph**.

Pages 2 through 6. Requirements are grouped under **Foundation, Framing, Insulation, and Final Phases**. Each phase lets you know what, and when requirements will be checked by the inspector. ***In the shaded areas only***, provide information and check circles that apply to your specific project. Because the form is intended to cover most design variations, many of the listed requirements won't apply to a given project. ***Do not*** place marks in the two left side columns labeled "COMPLIANCE REQUIRED" and "INSPECTION APPROVED" or in boxes located in non-shaded areas (These are for Department use).

Responsibility for information: Although designated Department staff members will help you with general questions about completing this form, it is ultimately your responsibility to provide detailed information about heating systems, glazing, insulation, and other requested building specifications. Since this form will be evaluated for completeness and accuracy, you can avoid unnecessary permit delays by carefully providing all required information. Disregard items that don't address your particular building or equipment.

Design changes: Be sure to get prior approval from the Department if you wish to make changes in your project during construction.

How the form will be used: This form will ultimately be used for all WSEC field inspections. When it is returned with your permit, relevant boxes under the "COMPLIANCE REQUIRED" column will have been checked by the Building Department. This denotes which WSEC requirements apply to your project. The inspector will inspect your dwelling against these checked items and, when deemed acceptable, place a second check in the "INSPECTION APPROVED" column.

Code Books: For more requirement detail, refer to the 1991 Washington State Energy Code, First Edition and the 1991 Ventilation and Indoor Air Quality Code, First Edition. Both may be purchased for \$11 from the Washington Association of Building Officials (WABO), P.O. Box 7310, Olympia, Washington 98507

WEE S/BOWMAN/FEBRUARY 92

All Residential Log Dwellings, Zone 2 Prescriptive (Chapter 6)

Electric Heat source (excluding heat pumps)

Permit # _____

'91 WSEC Log Home Residential Compliance FormPrescriptive (Chapter 6) Options: All R Occupancies, Zone 2
ELECTRIC heat source (All except heat pumps)**Sample****Instructions:**

1) Carefully review the requirements of each of the options below. Choose an option that best suits your dwelling design. Average log thickness typically determines which option to choose and can be determined by using the attached graph. Your building must match the selected option requirements without exceptions or substitutions.

2) In the shaded areas on the pages that follow, make checks in the circles next to the requirements of your option (the option numbers are listed next to each requirement). Disregard components or equipment that don't apply to your project. Your permit will be processed more efficiently if you provide all of the requested information. Department staff can help you with general questions about this form.

Can't comply? If none of the Prescriptive (Chapter 6) Options are acceptable, consider the Component Performance (Chapter 5) Approach. The main advantage is flexibility to juggle individual R and U-values as long as an overall maximum value isn't exceeded. The overall Component Performance requirements are no less stringent than the Prescriptive requirements. Calculations may be performed with a **Component Performance (Chapter 5) Form**, or by using an acceptable computer program such as **WATTSUN 5**.

Plan Review

(For official use only)

Selected Option is appropriate for this dwelling design.

YES ☐No ☐

Option _____ may be a better choice.

Notes: _____

Approved by: _____

Date: _____

WEES/BOWMAN/JANUARY 92

	OPT IV (≤2 stories) ☐	OPT V (≤2 stories) ☐	OPT VI (≤2 stories) ☐	OPT VII (≤2 stories) ☐	OPT VIII ☐
Average Log Thickness	6.7"	8.7"	9.8"	10.5"	13.5"
Glazing max:					
% of floor	15%	15%	15%	15%	15%
U-value ³	0.31	0.40	0.40	0.40	0.40
Door U-value³					
(R-value)	0.14 (R-7)	0.14 (R-7)	0.20 (R-5)	0.20 (R-5)	0.20 (R-5)
Ceilings:					
with attics ⁴	R-60(Adv)	R-60(Adv)	R-60(Adv)	R49(Adv)	R-38
vaulted	R-38	R-38	R-38	R-38	R-30
Floor	R-38	R-38	R-30	R-30	R-30
Slab on grade	R-10	R-10	R-10	R-10	R-10

Footnotes:

- 1) Thickness denotes average wall thickness. See average wall thickness chart.
- 2) The "≥" symbol means "more than or equal to"; "≤" means "less than or equal to".
- 3) Glazing & door U-values may be weighted if they don't exceed the Option U-value.
- 4) "Adv." refers to advanced framing techniques.

COMPLIANCE
REQUIRED **1991 WSEC RESIDENTIAL COMPLIANCE FORM**

Heat Source: ELECTRIC (All electric except heat pumps) - Zone 2

INSPECTION
APPROVED **IMPORTANT:** Supply information in the shaded area by checking the appropriate circles. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.**FOUNDATION PHASE**

☐	☐	1 Slab Insulation (Table 6-5) shall be R-10 and located on the:
☐ A. Exterior (See INSULATION INSPECTION).
OR
☐ B. Interior extending downward from the top slab surface to its undersurface and horizontally under the slab for a total distance of 24", or vertically 24".
☐	☐	2 Radiant Slab Insulation (Table 6-5, Footnote #1) shall be R-10 and extend under the entire slab.
☐	☐	3 Below grade wall insulation (Table 6-5, Footnote #1) shall be full-depth and located on the:
☐ A. Exterior and rated R-12 (See INSULATION PHASE).
OR
☐ B. Interior (See INSULATION PHASE)
☐	☐	4 Thermal break(s) shall be placed in the slab (S. 502.1.4.8, 201.1: BUILDING ENVELOPE) between the conditioned and unconditioned spaces checked below, and extend from the top of the slab to the bottom, then underneath toward the conditioned space for a 24".
☐ Dwelling/garage ☐ dwelling/connected space ☐ slab edge and foundation wall
☐	☐	5 Radon Requirements (VIAQ, S. 502.1) shall be met if <i>one</i> of the following is checked:
☐ A. Net foundation ventilation area is less than 1 Ft ² per 300 Ft ² of crawl space.
☐ B. Foundation vents are closable.
☐ C. Crawl space acts as a supply, or return air plenum.

WSEC Foundation phase requirements:

Inspected by: _____

Date: _____

FRAMING PHASE

☐	☐	6 All structural panels such as plywood, oriented strand board, particle board, and wafer board shall be labelled "EXPOSURE I", "EXTERIOR", or "HUD-APPROVED" (VIAQ, S. 401.1).
☐	☐	7 Insulation baffles shall be placed in attics/ceilings to maintain at least 1" ventilation space and extend at least 6" vertically above batts or 12" vertically above loosefill insulation (S. 502.1.4.5).
☐	☐	8 Glazing efficiency required under the selected option shall be (Table 6-5):
☐ $\leq$ U.31 (Option IV) ☐ $\leq$ U.40 (Options V, VI, VII, VIII)

Symbols used: = equals > greater than < less than $\geq$ greater than or equal $\leq$ less than or equal

WEES/BOWMAN/JANUARY 92

IMPORTANT: Please supply information in the shaded boxes and check the appropriate circles. Disregard topics that don't describe your building or equipment. DO NOT place checks in the two left columns.

FRAMING PHASE (Continued)

No.	Manufacturer	Frame material	# Layers	Model #	Area (Ft ²)	Uo value	Tested?
						U. ____	Yes ☐
						U. ____	Yes ☐
						U. ____	Yes ☐
						U. ____	Yes ☐
						U. ____	Yes ☐
						U. ____	Yes ☐
						U. ____	Yes ☐
						U. ____	Yes ☐
						U. ____	Yes ☐
						U. ____	Yes ☐
						U. ____	Yes ☐
10 Single Glazing (No more than 1% of heated floor area before doubling, S. 602.7.2)						U. ____	Yes ☐
Type: _____		No: _____		Area: _____ X 2		U. ____	Yes ☐
Type: _____		No: _____		Area: _____ X 2		U. ____	Yes ☐
11 Untested Glazing (Use only default U-values in Chapter 10, S. 1006.1)							
Type: _____		No: _____		Area: _____		U. ____	
Type: _____		No: _____		Area: _____		U. ____	
TOTAL GLAZING AREA (Add entire column) →							

12 Maximum allowed glazing area(Table 6-5) is derived by taking the the total glazing area (measure rough framed openings) of _____ Ft² and dividing by the total area of all conditioned floors _____ Ft². Multiply this number by 100. This value equals _____ Ft² and doesn't exceed the 21% maximum for all Options.

13 Documentation Insufficient, U-values shall be justified by Mfr. testing report.

14 Glazing air leakage(S. 502.4.3 (c)) measures shall be met as follows :

- 1) Fixed-site built: stops with sealant.
- 2) Operating site-built: weatherstripped with closer

15 Concealed Insulation shall be placed: 1) Behind shower/tub 2) Behind partition studs/corner

16 Standard air leakage (S. 502.4.3) caulking is complete and installed in the following locations :

- 1) Between Sole plate/subfloors
- 2) Wiring/plumbing/duct register penetrations
- 3) Rim joists/mud sills (heated lower floors)
- 4) Partition stud penetrations
- 5) Light fixture/ flue penetrations
- 6) Around window and door frames

COMPLIANCE
REQUIRED ☒**1991 WSEC RESIDENTIAL COMPLIANCE FORM**INSPECTION
APPROVED ☒

IMPORTANT: Supply information and check appropriate circles in the shaded boxes. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

FRAMING PHASE (Continued)

☐ **17** Exhaust ventilation shall be provided for each dwelling unit as follows (VIAQ S. 303):

Spot fans	Minimum at .25 w.g.	Mfr./model	Fan label CFM(.1W.G.)
Kitchen fan	100 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Laundry fan	50 CFM		
18 Whole house fan* (choose one)	☐ 50 CFM (1-2 bedrms)		
	☐ 80 CFM (3 bedrms)		
	☐ 100 CFM (4 bedrms)		

Whole house fan: Location _____ Sone rating _____ (≤ 1.5 if attic fan closer than 4' to ceiling)

☐ Whole house fan is intended for Continuous use.

☐ Whole house fan wiring for control routed to central location if a dehumidistat is used.

☐ **19** *Whole house fan also serves as a kitchen or bath spot fan. ☐ Yes ☐ No

If a spot fan is designated as a whole house fan, the capacity shall be the larger CFM requirement.

☐ **20** Whole house fan shall run continuously: Kitchen (25CFM); Bath & laund. (20CFM) ☐ Yes ☐ No

☐ **21** Integrated forced-air furnace ventilation (IAQ Code, S. 303.1.2(b)) shall be synchronized with a whole house fan to supply fresh air to the dwelling: ☐ Yes ☐ No

☐ If yes, a 6" outside air inlet duct w/ motorized damper shall run from the building exterior to the furnace return plenum and limit the ventilation rate to between .35 - .50 Air Changes/Hour.

☐ Modifications to the above integrated forced air system may require performance testing, in a manner acceptable to the Building Official, to demonstrate .35 - .5 Air Changes/Hour.

☐ **22** Mechanical ventilation fan ducts shall be $\geq 4"$ and properly sized (VIAQ, Table 3-3).

☐ **23** Fresh air shall be provided for each dwelling unit as follows (VIAQ, S. 302.6.1):

☐ Each bedroom: Tested, screened, controllable, through-wall port (≥ 4 Sq. in.) to the exterior.

☐ Each Recreation room: One wall port as specified for bedrooms.

☐ Other enclosed "habitable" rooms: One wall port as specified for bedrooms.

☐ Overall living area: One wall port as specified for bedrooms.

☐ **24** OR ☐ Central forced air furnace which delivers outside makeup air through the ducting system.

☐ **25** Recessed lighting fixtures (S. 502.4.4) shall comply w/ one or more of the following:

☐ IC rated, with no slots or holes in cans, caulked or sealed between can and ceiling.

☐ IC rated with label certifying an ASTM E283 tested air leakage ≤ 2.0 CFM.

☐ Any UL listed fixture enclosed by a 1/2" gypboard box or other manufactured box w/ 1/2" clearance to combustibles, and 3" clearance to insulation.

WSEC Framing phase requirements:

Inspected by _____ Date _____

INSPECTION
APPROVED

INSULATION PHASE

Sample

- ☐ ☒ 26 Interior below-grade wall insulation shall be R-21 (Table 6-3).
- ☐ ☒ 27 Exterior below-grade wall insulation, if not insulated on the interior, shall be R-12 (Table 6-3).
- ☐ ☒ 28 Exterior slab on grade insulation, if not insulated on the interior, shall be R-10 (Table 6-5).
- ☐ ☒ 29 Exterior slab or below-grade wall insulation shall be approved for below grade use.

- ☐ ☒ **30 Walls** shall have logs with the following dimensions (Table 6-5 & Average Log Thickness Graph):
Diameter = _____ Thickness between logs = _____ Average thickness = _____
- ☐ ☒ **31 Vaulted ceilings** shall be insulated without compression to (Table 6-5)
☐ R-38 (Options IV, V, VI, VII) ☐ R-30 (Option VIII)

- ☐ ☒ **32** Skylight wall Insulation shall be equivalent to the wall R-value (#30) above.

- ☐ **33 Vapor retarders** shall be installed toward the warm surface as represented below (502.1.6):
Select one option for floors, walls, and appropriate ceilings:
- Floors: ☐ Plywood w/ exterior glue ☐ Poly (≥ 4 Mil) ☐ Backed batts
- Walls: ☐ Poly plastic (≥ 4 Mil) ☐ Face-stapled, backed batts ☐ Low-perm paint
- Ceilings: ☐ Not required where ventilation space averages $>12"$ above insulation,
☐ Face-stapled backed batts ☐ Poly plastic (≥ 4 mil) ☐ Low-perm paint

- ☐ ☒ **34** Heating system sizing requirements shall be met as represented below:
- ☐ ☒ **35** Maximum heating system output (150% of design heat load) is _____ KW (S. 503.2.2).
- ☐ ☒ **36** Heating system requirements will be met with following system (S.503.4.1.1):
Mfr. _____ Model # _____ Max. output _____ KW
Type _____

Inspected by: _____ Date: _____

FINAL PHASE

- ☐ ☐ **37 Envelope floors** shall be insulated without compression, and with support $\leq 24"$ O.C. to:
☐ R-38 (Options IV, V) ☐ R-30 (Options VI, VII, VIII) See Table 6-5

☐ ☐ **38 Non-vaulted, attic ceilings** shall be insulated without compression:
☐ R-60 w/Advanced framing (Option IV, V, VII) ☐ R-49 w/ Adv. framing (Option VII) ☐ R-38 (Option VIII)

☐ ☐ **39 Door systems shall meet:** ☐ U.14 (Options IV, V) ☐ U.20 (Options VI, VII, VIII)
 Door types are (1) _____ (2) _____ (3) _____

☐ ☐ **40 Exposed foam insulation** shall be protected with metal or plastic flashing or equivalent material that extends below grade (S. 502.1 4.7).

1991 WSEC RESIDENTIAL COMPLIANCE FORMCOMPLIANCE
REQUIRED INSPECTION
APPROVED **IMPORTANT: Disregard topics that don't describe your building or equipment.
DO NOT place checks in the two left columns.****Sample****FINAL PHASE (Continued)**

☐	☐	41 Airflow between fresh air ports and whole-house fan ensured by undercut doors/grilles (VIAQ, S.302.6.4).
☐	☐	42 Loosefill Insulation OK if (S.502.1.4.5):
1) Maximum ceiling slope not > 3 in 12
2) ≥30" of clear distance from top of bottom chord to underside of roof sheathing at the roof ridge.
☐	☐	43 6 mil black polyethylene ground cover, lapped 12" at joints and to foundation wall.
☐	☐	44 Clearances shall meet listed minimums between insulation and (S.502.1.4.3):
1) Chimney 2) Non-IC rated recessed lights: 1/2" to combustibles, 3" to insulation.
☐	☐	45 Attic hatch shall be insulated to required ceiling R-value and is weatherstripped (S.502.1.4.4).
☐	☐	46 Attic access shall have wood dam or equivalent to retain loose fill insulation in attic (S. 502.1.4.4).
☐	☐	47 All exterior doors (except 20 minute doors) shall be weatherstripped (S. 502.4.3).
☐	☐	48 Service hot & cold water piping shall be insulated to R-3 (S. 503.11).
☐	☐	49 Service recirculation hot water piping shall be insulated to Table 5-12 levels.
☐	☐	50 Thermostat provided for each HVAC system with range of 55-75° F (heating) (S.503.8.1.1).
☐	☐	51 Readily accessible, automatic or manual means provided to restrict or shut-off Heating input to each zone or floor during periods not requiring heat (S. 503.8.3.1).
☐	☐	52 Controls for backup heat prohibit simultaneous operation of the primary system (S. 503.2.2(3)).
☐	☐	53 Mechanical ventilation system shall have proper timers, and/or switches (VIAQ, S. 302.3).
☐	☐	54 Mechanical ventilation ducts shall have insulation ≥ R-4 in unconditioned spaces (VIAQ, S. 302.5).
☐	☐	55 Mechanical supply ducts in conditioned spaces shall have ≥ R-4 insulation (VIAQ, S. 302.5).
☐	☐	56 Supply ducts shall have volume dampers, or the equivalent, to balance system (S. 503.6).
☐	☐	57 Supply and return air ducts shall have sealed duct joints in unconditioned spaces (S. 503.10.2).
☐	☐	58 HVAC plenums, supply, and return air ducts shall have R-8 insulation (Table 5-11, All options).
☐	☐	59 Electric water heater(s) shall have (S. 504.2.1, 504.3, 504.4) :
1) Separate power shut-off 3) 1987 NAECA Label on tank
2) Non-compressible R-10 pad (slab or unheated spaces) 4) Temperature setting ≤ 120 F.
☐	☐	60 Showers and lavatories shall limit flow to ≤ 3.0 gallons/minute (S. 504.8.1).
☐	☐	61 Swimming pools (S. 504.5) shall have:
1) Readily accessible ON/OFF switch (pump, heater) 2) Pool cover 3) Piping insulated to S. 503.11
☐	☐	62 All fireplaces (VIAQ, S. 402.3) shall have:
1) 6 square inch combustion air supply duct w/ damper, directly connected to the fire box
2) Tight-fitting glass or metal doors 3) Tight-fitting, readily accessible, flue damper.
☐	☐	63 Solid fuel burning appliance(s) (VIAQ, S. 402.2) shall have:
1) Tight-fitting glass or metal doors
2) Outside combustion air source directly connected to the fire box
Exception: Non-direct, 4" diameter, dampered, combustion air source: allowed only for (1) new stove installations in existing homes where obstructions preclude direct combustion air, or (2) Central heating systems located in unheated spaces, or tested/listed under HUF (VIAQ, S. 402.1(b)).
☐	☐	64 Radon Monitor, printed instructions, and information sheets shall be supplied by the builder to each single-family dwelling and to each ground-floor unit of multi-family dwellings (VIAQ, S. 502.2.1).

WSEC Final phase requirements:

Inspected by: _____

Date: _____

Average Thickness for Round Log Walls

EXAMPLE: 12" Diameter logs with a 10" depth at the log joints. Average depth is 10 - 3/4".

Permit No. _____

1991 WSEC, Chapter 5, Residential Additions Form**Use only for additions, under 750 ft², that don't comply****Sample**

PURPOSE: This worksheet demonstrates compliance for a proposed addition where heat loss improvements in the existing home receive credit toward compliance. Perform a Chapter 5 calculation *only on the addition* before using this form.

MAIN WORKSHEET

1	PROPOSED CASE UA VALUE (pg. 2)	
2	STANDARD CASE UA VALUE (pg. 2)	
3	Addition heat loss deficit (box 1 minus box 2)	
4	Existing dwelling improvement credit. See 4A & 4B	

ADDITION COMPLIES IF BOX 4 IS GREATER THAN BOX 3**4 A**

Existing Dwelling Improvement credit calculations (List separate improvements)

Change (location)	Area (Ft ²)	U-Value	UA	INSPECTED
Existing glazing (_____)		x U_____	(a)	
Replacement glazing (_____)		x U_____	(b)	
Existing home improvement credit	SUBTRACT (b) from (a)		(c)	
Existing glazing (_____)		x U_____	(d)	
Replacement glazing (_____)		x U_____	(e)	
Existing home improvement credit	SUBTRACT (e) from (d)		(f)	
Existing insulation (_____)		x U_____	(g)	
New insulation (_____)		x U_____	(h)	
Existing home improvement credit	SUBTRACT (h) from (g)		(i)	
Existing insulation (_____)		x U_____	(j)	
New insulation (_____)		x U_____	(k)	
Existing home improvement credit	SUBTRACT (k) from (j)		(l)	
TOTAL CREDITS (Add c, f, i, & l. Insert into 4 on MAIN WORKSHEET)				WEES/BOWMAN/JANUARY Page _____

4 B**Existing dwelling and improvement U-values:**

Refer to the 1991 WSEC, Chapter 10, for all U-values not listed below.

Existing (untested) glazing default values:

Single pane	U 1.20
Double pane	U .90
Double pane w/vinyl or wood sash	U .75

Existing building envelope values:

Ceilings w/no insulation	U .30
Floors w/no insulation	U .13
Walls w/no insulation	U .31
Glass block	U .60

WEEKS/BOWMAN/JANUARY 92

Page 2a

COMPLIANCE
REQUIRED ☒

1991 WSEC Residential Check List

VENTILATION REQUIREMENTS FOR ADDITIONS

INSPECTION
APPROVED ☒

IMPORTANT: Supply information and check appropriate circles in the shaded boxes. Disregard topics that don't describe your building or equipment. **DO NOT** place checks in the two left columns.

FRAMING PHASE (Continued)

Sample

1 Prescriptive exhaust ventilation requirements for residential additions (VIAQ, S. 101.3.1.1)

Spot Fans	Minimum (.25 w.g.)	Mfr./model	Fan label (.1WG)
Kitchen fan	100 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Bathroom fan(_____)	50 CFM		
Laundry fan	50 CFM		
2 Whole house fan ☐ 50 CFM (1-2 bedrms)			
(If addition > 500Ft ²) ☐ 80 CFM (3 bedrms)			
(choose one) ☐ 100 CFM (4 bedrms)			

Whole house fan: Location _____ Sone rating _____ (< 1.5 if attic fan closer than 4' to ceiling)

☐ Whole house fan is intended for continuous use.

☐ Whole house fan wiring for control routed to central location (dehumidistat only).

3 Whole house fan also serves as a kitchen or bath spot fan. ☐ Yes ☐ No
(spot fan designated as a whole house fan shall meet whole house fan requirements.)

4 Spot fan isn't suitable for whole house fan and must be separate ☐ Yes ☐ No

5 Whole house fan shall run continuously: Kitchen(25CFM), Bath & laundry(20CFM) ☐ Yes ☐ No

6 Integrated forced-air furnace ventilation (see footnote)(VIAQ Code, S. 303.1.2(b)) shall be synchronized with a whole house fan to supply fresh air to the dwelling: ☐ Yes ☐ No

☐ If yes, a 6" diameter outside air inlet duct w/ motorized damper shall run from the building exterior to the furnace return plenum and limit the ventilation rate to between .35 - .5 ACH,

☐ Modifications to the above integrated forced air system may require performance testing, in a manner acceptable to the building official, to demonstrate .35 - .5 Air Changes/Hour.

*Five bedrooms or larger requires a designed whole house fan system (Rate is .35 - .5 ACH)

7 Mechanical ventilation fan ducts shall be $\geq 4"$ and properly sized (VIAQ, Table 3-3).

Fresh air supply required for all habitable rooms if overall addition is over 500 Ft².

8 Fresh air shall be provided for each dwelling unit as follows (VIAQ, S. 302.6.1):

☐ Each bedroom: Tested, screened, controllable, through-wall port (≥ 4 Sq. in.) to the exterior.

☐ Each recreation room: One wall port as specified for bedrooms.

☐ Other enclosed "habitable" rooms: One wall port as specified for bedrooms.

☐ Overall living area: One wall port as specified for bedrooms.

9 OR ☐ Integrated forced-air furnace that delivers outside makeup air through the ducting system

10 Airflow between fresh air ports and wholehouse fan ensured by undercut doors/grills (VIAQ, S. 302.6.4)

WEE S/BOWMAN/OCTOBER 91

WSEC Ventilation phase requirements:

Inspected by _____ Date _____

COMPLIANCE
REQUIRED **1991 WSEC RESIDENTIAL RADON PRESCRIPTIVE REQUIREMENTS**

Only for designated jurisdictions requiring special radon measures

INSPECTION
APPROVED

Additional Radon Prescriptive Requirements (VIAQ, S. 503) shall be met in the following Counties: Ferry, Grant, Okanogan, Pend Oreille, Skamania, Spokane, Stevens, and Wahkiakum. (See Radon Control for Higher Risk Counties Factsheet).

FOUNDATION PHASE**Sample**

☐	☐	1 Concrete slabs in direct contact with the ground shall have a minimum of 4" of aggregate placed beneath the slab. This requirement applies to slabs on grade and slabs in basements in residential construction. Slabs in garages and in other non-residential occupancies are exempted from this requirement.
☐	☐	2 A Soil-gas Retarder Membrane consisting of at least one layer of 6 mil polyethylene or equivalent shall be placed directly under the slab. The membrane shall extend to the foundation wall or to the outside edge of a monolithic slab. Any seams must overlap at least 12".
☐	☐	3 The 4" layer of aggregate used under the slab shall meet <i>one</i> of the following gradation standards: 1. Comply with Uniform Building Standard 26-2, Table 26-2-A, and be 3/4" - No. 4 aggregate or larger. 2. Meet the Washington State Dept. of Transportation specification 9-03.1 (3) "Course Aggregate for Portland Cement Concrete." Aggregate size shall be Grade 5 or larger. 3. Screened and washed consistent with UBC Standard 26-2 with 100% of the gravel passing a 1" sieve and less than 2% passing a Number 4 sieve.
☐	☐	4 All penetrations and joints in concrete slabs, other floor systems, masonry walls, and below-grade walls that are not visible at the final inspection phase, shall be sealed to create an air barrier to limit the movement of soil-gas into the indoor air.

FRAMING PHASE

☐	☐	5 One continuous sealed radon vent pipe shall run from a point within the aggregate under each concrete slab to a point outside the building. Joints and connections shall be gas tight. The radon vent pipe shall meet <i>all</i> of the following requirements: 1. Minimum 3" diameter or as approved. 2. PVC schedule 40 or ABS or approved equivalent smooth walled pipe. 3. Shall terminate no less than 12" above the eave. 4. Termination shall be more than 10' (horizontal) from chimneys or operable windows. 5. Visibly labelled "RADON VENT". 6. Exterior pipe opening shall be protected from blockage by snow. 7. Pipe shall be located within the thermal envelope to the extent practical (see S. 503.2.6, exception).
☐	☐	6 Installation of a fan is not required but provision must be made for the possible location of an in-line fan. This location should be near the exit point of the pipe from the building. The location for the fan and all downstream piping should be isolated from the indoor air. A 110 volt power supply must be provided to a junction box near this location.
☐	☐	7 If the 4" aggregate layer underneath the slab is separated into distinct isolated areas by footings or other barriers, a separate radon vent must be installed into each distinct area. Separate areas may be considered a single area if a minimum 3" diameter connection joining areas is provided for every 30' of barrier.
☐	☐	8 For other requirements that may apply, see the factsheet, "Radon Vents for Crawlspace", The Washington State Ventilation and Indoor Air Quality Code, or contact your local building jurisdiction.

UPDATED JANUARY 91

Sample Take-off Worksheet

WATTSUN 5 Worksheet

This worksheet will help you organize your house data for input into the WATTSUN 5 energy code compliance program. For Component Performance qualification it is necessary to know the areas and construction types of all components of the house. Energy Budget qualification requires additional details about the heating system and ducts. Information can be gathered from house plans and heating system specifications. Only the basic qualification portions of the program are covered here.

WATTSUN 5 supports the following energy codes and standards:

- 1986 Washington State Energy Code, 3rd Edition
- 1985 Oregon UBC/Chapter 53
- HUD Energy Efficient Housing Guidelines
- 1991 Washington State Energy Code
- 1990 Oregon Residential Energy Code
- 1991 Super Good Cents Standards
- 1991 Idaho Residential Energy Standards
- 1987 Northwest Energy Code
- 1987 Tacoma Energy Code

Energy Code Information

House type	Notes
☒ Single family/duplex ☐ Multi-family ☐ Manufactured Housing	■ Selection affects Energy Budget calculation and checklist.
# of bedrooms: <u>3</u> # of living units: _____	
Total heated floor area: <u>2143</u> ft ²	■ All habitable floor area within the conditioned space.
Reference Code for <i>electric</i> fuel: <u>1991 WASH CODE</u>	■ Selection determines which Energy Code will be used as the Reference case if the Proposed house uses electric heat.
Reference Code for <i>other</i> fuel types: <u>1991 WASH CODE</u>	■ Selection determines which Energy Code will be used as the Reference case if the Proposed house uses a fuel type other than electric.
Solar access characteristics: <ul style="list-style-type: none"> ☐ Shaded ☒ Partially shaded ☐ Unshaded 	■ Describe the amount of sunlight striking the windows between the hours of 10 a.m. and 3 p.m. in mid-winter. Shaded = less than 75% of available sunlight; Partially shaded = 75%; Unshaded = more than 75%.
Wood burning appliance: <u>(Y/N)</u>	■ Selection affects checklist only.

Sample Take-off Worksheet

Heating System Information

Heating system/fuel type

Notes

☐ Zoned electric resistance	_____ % Efficiency	■ Defaults to 100% nominal efficiency.
☐ Central electric furnace	_____ % Efficiency	■ Defaults to 100% nominal efficiency.
☐ Air source heat pump	_____ HSPF	■ Use values listed in ARI Directory.
	_____ kBtu Capacity at 47°F	
☐ Packaged terminal heat pump	_____ kBtu Capacity at 47°F	■ Use values listed in ARI Directory.
	_____ COP at 47°F	
	_____ °F Cut out temp.	■ Defaults to 0°F.
☐ Ground/water source heat pump	_____ kBtu Capacity at 70°F	■ Use values listed in ARI Directory.
	_____ COP at 70°F	
	_____ kBtu Capacity at 50°F	
	_____ COP at 50°F	
☒ Gas furnace	<u>78</u> AFUE	■ Use value listed in GAMA Directory.
☐ Oil furnace	_____ AFUE	■ Use value listed in GAMA Directory.
☐ Propane furnace	_____ AFUE	■ Use value listed in GAMA Directory.
☐ Woodstove	_____ % Efficiency rating	
☐ Other	_____ % Efficiency rating	

Duct Information

Location of majority of *supply* ducts

☐ Attic or garage	☐ All in unheated space	■ If there are any supply ducts in unheated spaces, select the space in which the majority of the ducts are located.
☒ Vented crawlspace	☐ Unducted	
☐ Unvented crawlspace		

Supply duct surface area ~~DEFAULT~~ ft²

- Surface area of all supply ducts.

Average supply duct R-value 11

- Average nominal supply duct R-value.

Location of majority of *return* ducts

☒ Attic or garage	☐ All in unheated space	■ If there are any return ducts in unheated spaces, select the space in which the majority of the ducts are located.
☐ Vented crawlspace	☐ Unducted	
☐ Unvented crawlspace		

Return duct surface area ~~DEFAULT~~ ft²

- Surface area of all supply ducts.

Average return duct R-value 11

- Average nominal return duct R-value.

Duct Detail Option

Descriptions

Length ft

Type

- Optional way to describe ductwork.
- Determine average nominal duct R-value.
- Describe duct diameter or size in inches.
- Duct type: Supply or Return.
- Measure length of each type.

Sample Take-off Worksheet

Component Performance Qualification

Below Grade Walls and Slabs

Descriptions

Wall ft²

Slab ft

Notes

2' Depth

3.5' Depth R-11 INTERIOR 192 SQ. FT. 24 FT.
WITH THERMALLY BROKEN SLAB
7' Depth R-11 INTERIOR 560 SQ. FT. 70 FT.
W/TB

- Break out walls by depth below grade.
- Determine wall insulation R-value.
- Describe insulation type: batt or foam.
- Is there an R5 thermal break at the slab edge?
- Measure square footage of below grade wall area.
- Measure linear footage of below grade slab length.
- Measure to outside edge of wall/slab.

Slab On Grade

Descriptions

Length ft

R-10 WITH THERMAL BREAK 40 FT.
HORIZONTAL 2 FT

- Determine slab insulation R-value.
- Describe insulation width and position (vertical/horizontal).
- Is there an R5 thermal break at the slab edge?
- Measure linear footage of slab perimeter length.
- Include perimeter between heated and unheated spaces.

Floors Over Unheated Spaces

Descriptions

Area ft²

R-19 VENTED JOISTED 440 SQ. FT.

- Determine floor insulation R-value.
- Determine foundation wall perimeter insulation R-value.
- Is the crawlspace vented or unvented (i.e., <1:300).
- Describe framing type and spacing.

Windows

Descriptions

Area ft²

DOUBLE GLAZED 236 SQ. FT.
1/2" AIR SPACE VINYL & ARGON
DOUBLE GLAZED 125 SQ. FT.
1/2" VINYL LO E
2 GL 1/2" VINYL 75 SQ. FT.
TESTED U=0.45

- Use tested U-values and descriptions whenever possible.
- When using default values, determine # glazings, frame type, gas filling, and low-e coating.
- Measure rough opening.

Doors

Descriptions

Area ft²

WOOD PANEL 1 3/4" 40 SQ. FT.
FIBERGLASS
TESTED U=0.10 17 SQ. FT.

- Use tested U-values and description whenever possible.
- When using default values, determine type of door, thickness, whether it is a panel or flush, and whether or not there is a storm door.
- Doors with more than 50% glazing are windows.
- Measure rough opening.

Above Grade Walls

Descriptions

Area ft²

R-19 STANDARD FRAME 1593 SQ. FT.
LAPPED WOOD SIDING

- Determine wall insulation R-value(s).
- Describe wall type (single, double stud; strap wall).
- Describe framing type (standard, intermediate, advanced).
- Show siding type.
- Measure to outside of walls. Include rim joists, vault and attic knee walls, skylight wells and any wall separating heated/unheated spaces. Subtract window and door area.

Sample Take-off Worksheet

Component Performance Qualification (continued)

Skylights

Descriptions

Area ft²

NONE

Notes

- Use tested U values and descriptions whenever possible.
- When using default values, determine # glazings, frame type, gas filling, and low-e coating.
- Include any glazing tilted less than 60 from horizontal.
- Measure rough opening.

Ceilings

Descriptions

Area ft²

R-38 ATTIC BLOWN INSULATION

1069 SQ. FT.

R-30 VAULTED 2x12 RAFTERS

550 SQ. FT.

- Determine ceiling insulation R-value.
- Determine type of ceiling: flat attic, scissor truss attic, vented and unvented vault, or roof deck.
- Describe framing type and insulation type.
- Measure to outside of walls. Subtract skylight and chimney area.

Air Leakage

Description

Volume ft³STANDARD AIR SEALING 22000 FT³

- Determine whether air tightening package is Standard, Advanced with Heat Recovery Ventilation, or Advanced with Non-Heat Recovery Ventilation.
- Compute volume of heated space above grade.

Energy Budget Qualification

Structural Mass

Descriptions

Floor Area ft²

SLAB W/NO CARPET

1520 SQ. FT.

LIGHT FRAMED FLOORING 1173 SQ. FT.

- Describe and measure floor types (light frame or slab).
- Note wall type and floor covering for each floor type.
- Total mass area must equal the total heated floor area.

Additional Mass

Descriptions

Surface Area ft²

- Describe additional mass elements such as masonry fireplaces, solar mass walls, and extra layers of sheetrock.
- Measure surface area of mass.
- Do not include anything having > R1 covering.

Glazing Orientation

Direction

Glazing Area ft²

- Determine total window area facing each direction.
- Do not count skylights.
- Total orientation area must match total window component area.

South	50 SQ. FT.
South East	
East	119 SQ. FT.
North East	
North	150 SQ. FT.
North West	
West	117 SQ. FT.
South West	

Appendix E: Sample Checklists & Worksheets

```
=====
WATTSUN 5.2          1991 WA STATE ENERGY CODE COMPLIANCE REPORT          03/24/92
FILE: C:WATTSUN5SAMPLE2.WS          HOUSE ID: Sample2
=====
```

```

Site:      Bellingham, WA
Analyst:   Joe Storage
Jurisdiction: Whatcom County
Utility:   Big City PUD

Homeowner:      House Type: Single Family/Duplex
                  Floor Area:  2693 ft2

Builder:        Weather Data: Bellingham, WA
                  Climate Zone: 1
                (    )

```

```
=====
The PROPOSED design *COMPLIES* with 1991 WA State Energy Code.

```

	REFERENCE	PROPOSED
COMPONENT PERFORMANCE	565	496 Btu/hr-F
ENERGY BUDGET	10.09	8.41 kWh/ft2-yr

REFERENCE DESIGN

Component	Reference Value	X	Area =	UA
BG Wall 3.5'	U-0.041		192	7.9
BG Slab 3.5'	F-0.640		24ft	15.4
BG Wall 7'	U-0.036		560	20.2
BG Slab 7'	F-0.554		70ft	38.8
On Grade Slab	F-0.540		40ft	21.6
Floor	U-0.041		440	18.0
Glazing @15%	U-0.650		404.0	262.6
Doors	U-0.400		57.0	22.8
AG Wall	U-0.062		1625	100.8
Ceiling, Attic	U-0.036		1069	38.5
Ceiling, Vault	U-0.034		550	18.7
Infiltration	ACH-0.350		22000ft3	(140.9)
Reference UA				565

PROPOSED DESIGN COMPONENTS

Component	Description	Value	X	Area =	UA
BG Wall	R11 Batt 3.5' depth w/TB	U-0.061		192	11.7
BG Slab		F-0.546		24ft	13.1

```
=====
Items in parentheses not included in COMPONENT PERFORMANCE totals.
** Denotes non-standard values - check calculation of thermal value.
=====
```

Appendix E: Sample Checklists & Worksheets

1991 WA STATE ENERGY CODE COMPLIANCE REPORT

03/24/92

HOUSE ID: Sample2

BG Wall	R11 Batt 7' depth w/TB	U-0.053	560	29.7
BG Slab		F-0.489	70ft	34.2
On Grade Slab	R10 2' horizontal w/TB	F-0.540	40ft	21.6
Floor	R19 vented Joist 16oc	U-0.041	440	18.0
Glazing @16%	2G1 Vinyl 1/2" w/Ar	U-0.490	236.0	115.6
	2G1 Vinyl 1/2" w/low-E	U-0.410	125.0	51.3
	**2 GL VINYL 1/2" tested	U-0.450	75.0	33.8
Doors	Wood 1-3/4" solid panel	U-0.390	40.0	15.6
	**FIBERGLASS tested	U-0.100	17.0	1.7
AG Wall	R19 STD Lap Wood	U-0.062	1593	98.8
Ceiling	R38 blown Attic STD baffled	U-0.031	1069	33.1
	R30 batt Vault vented 2x12 24oc	U-0.033	550	18.1
Infiltration	Standard Air Sealing	ACH-0.350	22000ft3	(140.9)

Proposed UA				496
Struc Mass	Slab w/No cover, Sheetrock walls	M-10.000	1520	15200
	Light Frame, Sheetrock walls	M- 3.000	1173	3519

HEATING/COOLING/VENTILATING SYSTEMS

Heating System Type: Gas Furnace
Make: Standard Furnace
Model: N/A/

```

System Efficiency:      78 %
Modified Efficiency:    64 %

```

Design ACH:	0.60
Heating Load(at 55F dt):	41914 Btu/hr
System Size:	41.9 kBtu/hr
Maximum Size @150%:	62.9 kBtu/hr

Average Annual Heat:	112 MBtu
Annual Cost:	\$ 628

Ventilation System: Integrated Spot
& Whole House

Cooling Load(at -1F dt): 30801 Btu/hr
Recommended Size @125%: 3.6 tons

Solar Access: Partially Shaded

=====

WATTSUN 5.2	1991 WA STATE ENERGY CODE COMPLIANCE REPORT	03/24/92
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=====

FILE: C:WATTSUN5SAMPLE2.WS

=====

HOUSE ID: Sample2

=====

PROPOSED DUCT SYSTEM

	Location	Avg Rvalue	Surface Area
SUPPLY	Vented crawlspace	R-11.0	538.6 ft2
RETURN	Attic or garage	R-11.0	107.7 ft2

GLAZING ORIENTATION

	PROPOSED		PROPOSED
South:	50.0 ft2	North:	150.0 ft2
Southeast:		Northwest:	
East:	119.0	West:	117.0
Northeast:		Southwest:	

=====

Economic and energy consumption estimates are designed for comparative purposes only. Actual cost for heating will vary depending on weather conditions, occupant lifestyle and other factors.

=====

Plans Examiner and Inspector Checklist

Permit No. _____ Address _____

Plans Examiner: Check, write in N/A, or fill in value on shaded boxes.

Inspector: Check off boxes at left as items are found to comply.

Compliance approach: (check one) ☐ Systems analysis ☐ Component performance ☐ Prescriptive path

Note: Some specifics on this form may not apply if

A) compliance approach is systems analysis or component performance;

B) compliance to minimum ventilation criteria is demonstrated through engineering calculations or performance testing.

FOUNDATION PHASE

- ☐ Slab: R-_____ Exterior down to frostline/slab bottom; or Interior 24" horizontal or vertical; or, if radiant, under entire slab
- ☐ Below grade exterior wall insulation: R-_____ (if interior — see Insulation Phase)
- ☐ Radon mitigation: _____ If locally required, or crawlspace venting <1ft/300ft² of crawl, or vents include an operable damper

FRAMING PHASE

- ☐ Framing: ☐ Standard ☐ Intermediate ☐ Advanced
- ☐ Std air seal: solep/subflr; rim jst/mud sill; window & door frms; penetration-wire, plumb, duct, partition studs, flue, light fixtures
- ☐ Source specific exhaust fans: Size requirement — bath, laundry (50cfm); kitchen (100cfm)
- ☐ Whole house exhaust fan _____ cfm Intermittent system has manual & auto controls; Outdoor air supply req. for habitable rms.
- ☐ Integrated forced-air system _____ outside air duct (with damper) allowing between .35 and .5 ACH

INSULATION PHASE

- ☐ R-_____ Wall insulation (above grade)
- ☐ R-_____ Wall insulation (below grade): interior wall insulation
- ☐ R-_____ Floor insulation
- ☐ R-_____ Ceiling insulation: including attic hatch
- ☐ R-_____ Vaulted ceiling insulation
- ☐ Vapor retarders: walls, floors, ceiling
- ☐ Heating system type: _____ For heatpumps, list size, HSPF, and COP _____

FINAL PHASE

- ☐ Radon monitor on site: with instructions and general information
- ☐ Thermostat: heat range, 55-75; AC range, 70-85; both, 55-85. Backup heat controls prevent simultaneous operation of primary sys.
- ☐ Solid fuel appliances: glass or metal doors; direct comb. air source, or 4" dia., dampened, indirect source for uncond. areas
- ☐ Fireplaces: 6" combustion air supply duct w/damper direct to firebox; tight fitting glass or metal doors.
- ☐ DHW heaters: NAECA label; separate power or gas shut-off; on R-10 pad if electric and in uncond. area or if on concrete
- ☐ Mechanical ventilation ducts insulated to R-4; exhaust ducts in unconditioned areas/supply ducts in conditioned areas
- ☐ R-_____ HVAC ducts/plenum insulation: ducts in unconditioned areas are insulated and joints are sealed
- ☐ Pipe insulation: R-3 for hot and cold water piping in unconditioned areas (if service or recirculating, see Table 5-12)
- ☐ Ground cover: 6 mil black polyethylene/approved equal lapped 12" at joints and extending to foundation wall

GLAZING

Plans Examiner — fill out this glazing section or attach a window schedule to this checklist. Inspector — verify window information during field inspections. Include skylights, glass doors and all other glazing on this form. Use rough opening area for calculations.

Size	Quantity	Area	U-Value/Manufacturer	Verified

Total glazing area: _____

Total conditioned area: _____

Percentage glazing: _____ Verified _____

DOORS

Plans Examiner — list opaque doors by type (solid core, insulated, etc.), quantity, U-value, and manufacturer. Inspector — verify door information during field inspection.

Type/Quantity	U-Value/Manufacturer	Verified

Signature of Building Official: _____

Date of Final Inspection: _____

E-01

Appendix F: Radon Information

Department of Health Radon Fact Sheet

F2

Radon Requirements Matrix

F5

Appendix F: Radon Information

KRISTINE GIBBE
Secretary

STATE OF WASHINGTON

DEPARTMENT OF HEALTH

Airustrial Center, Bldg 5 • Mail Stop 1E-13 • Olympia, Washington 98504

December 11, 1991

RADON and Your New Home

Starting July 1, 1991, all new homes in Washington must meet the state's new construction standards on radon. These new standards, adopted by the State Building Code Council, are a response to concerns about radon and how it affects us in our homes. This brochure answers some questions about radon, tells you how to check your house, and offers some things you can do to lower the level of radon in your home.

What is radon?

Radon is a natural radioactive gas in the ground. It comes from the decay or breakdown of uranium, a radioactive element in rocks and soil. Radon has no odor, color, or taste.

Why all the fuss about radon?

If you can't see, smell, or taste radon, you might wonder why you should be concerned. The reason is that radon can hurt your lungs and may slowly lead to lung cancer.

Outdoors, radon is diluted to such low levels that it is not a risk. But if radon gets inside your home, it can build up to levels that increase your chances of getting lung cancer.

While it is hard to estimate the risk, studies show that the more you are exposed to radon, the greater your chances of getting lung cancer.

Radon exposure means both the level of radon and the length of time you are exposed. So, for example, your risk may be greater from the amount of time you are exposed than from the level of radon in your home.

Which houses are affected?

The level of radon in your house depends on how it is built and on how much radon is in the soil underneath. Some areas of Washington have higher amounts of radon in the soil. Eight counties test higher than other Washington counties for radon levels: Ferry, Grant, Okanogan, Pend Oreille, Skamania, Spokane, Stevens, and Wahkiakum. The new state building codes require builders to take additional actions in these counties to protect against radon.

Just because you live in one of these counties, however, does not mean that you have higher levels of radon in your house. And if you live in another county, you may still have a radon problem. Radon levels vary from house to house, even in the same area. Most houses are not likely to have a problem, even in areas with higher levels of radon, but the only way to know for sure is to test your house.

How can I test my house?

There are two kinds of monitors you can use to test your house for radon--charcoal canisters and alpha track detectors. You can buy them at most hardware stores, or the Department of Health can send you a list of providers. Both of these radon monitors work by exposing them to the air in your house, then sending them to a laboratory for testing. It is very important that you follow the directions carefully to get the best results.

Builders are now required to provide alpha track detectors for most new houses and additions built under a permit dated July 1, 1991, or later. This requirement does not cover electrically-heated houses built under the Northwest Energy Code.

The testing laboratory will give you the results of your test in units called picoCuries per liter of air (pCi/l). This is a standard measure of radon.

What should I do when I get my test results?

Your next step depends on the result of your test. The U.S. Environmental Protection Agency (EPA) tells you what steps to take if your results are:

4 pCi/l or lower

This level is average or slightly above average. Although exposures in this range mean there is some risk of lung cancer, reducing the level may be difficult, sometimes impossible.

4 to 20 pCi/l

This level is above average. Take action within a few years to reduce the level of radon, sooner if the levels are at the upper end of this range.

Appendix F: Radon Information

20 to 200 pCi/l

This level is greatly above average. Take action within several months to reduce the radon level.

200 pCi/l or higher

This is the highest level. Take action within several weeks to reduce the level of radon. If this is not possible, you should decide, after talking to the Department of Health, if you need to leave temporarily until the levels can be reduced. A longer test may be needed.

What actions can I take to reduce my risk from radon?

If your basic test shows that your home has above average levels of radon, there are some steps you can take.

Increase the air flow

Whenever you can, open windows and turn on fans to move more air through your house. This is especially important in the basement.

Spend less time in the basement

Basements usually have higher levels of radon, but other parts of the house may have high levels, too. You increase your risk with the amount of time you spend in parts of the house that have higher levels of radon.

Keep crawl space vents open

If there is a crawl space under your house, make sure all vents on all sides of the house are fully open all year.

Stop smoking

Smoking may increase your risk from exposure to radon. If you stop smoking and discourage smoking in your house, you can reduce your family's overall chances of getting lung cancer.

Where can I get more information?

These actions help reduce your risk, but they are not a long-term solution. You can get more information from the Department of Health.

Write to:

Washington State Department of Health
Office of Radiation Protection
Mail Stop LE-13
Olympia, Washington 98504

Or call toll-free:

Radon Information Line
1-800-323-9727

Washington State Radon Requirements

Building Condition	Location	Monitor In Residence	Radon Vent Pipe	Activated ¹ System	Aggregate	Soil Gas Retarder Membrane
Crawlspace with Ventilation 1/300 or more	Statewide	YES	----	----	----	----
Crawlspace with Ventilation < 1/300 or Operable Vents	Statewide	YES	YES	----	----	NO ²
Crawlspace used as Return or Supply Plenum	Statewide	YES	YES	YES	YES	YES ³ (sealed)
Basement Slabs/ Slabs-on-Grade	High Risk ⁴ Counties	YES	YES	----	YES	YES (seal not req. ⁵)
Basement Slabs/ Slabs-on-Grade	Other Counties	YES	----	----	----	----
¹ Sealed membrane, sealed joints, continuously operating fan ² No soil gas retarder is required per se, but a ground moisture cover of 6 mil black polyethylene, or equivalent material, is required by the WSEC. ³ Unless there is a concrete slab which has been properly sealed. ⁴ Ferry, Grant, Okanogan, Pend Oreille, Skamania, Spokane, Stevens, Wahkiakum. ⁵ Assumes sealing is done on the slab.						

Appendix G: Directory of Acronyms

AAMA	American Architectural Manufacturers Association
ACCA	Air Conditioning Contractors of America
ACH	Air changes per hour
AFUE	Annual Fuel Utilization Efficiency
AMCA	Air Movement Control Association
ANSI	American National Standards Institute, Inc.
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.
ARI	Air-Conditioning and Refrigeration Institute
ASTM	American Society for Testing and Materials
AWC	Association of Washington Cities and Counties
Btu(s)	British Thermal Unit(s)
BTUH	British thermal units per hour
DCD	Department of Community Development (state)
DCLU	Department of Construction and Land Use (City of Seattle)
DCL	Design cooling load
DHL	Design heating load
DOE	Department of Energy (federal)
DOH	Department of Health (state)
EER	Energy Efficiency Ratio
EES	Energy Extension Service, division of WSEO
GAMA	Gas Appliance Manufacturer's Association
HSPF	Heating Season Performance Factor
HUD	Department of Housing and Urban Development (federal)
HVAC	Heating, ventilating and air-conditioning
HVI	Home Ventilating Institute, division of AMCA
ICBO	International Congress of Building Officials
IES	Illuminating Engineering Society of North America
kWh	kilowatt hours
L&I	Department of Labor and Industry (state)
MCS	Model Conservation Standards
NAECA	National Appliance Energy Conservation Act
NEC	National Electrical Code
NESCA	National Environmental System Contractors Association
NWEC	Northwest Energy Code
NWWDA	National Wood Window and Door Association
SBCC	State Building Code Council
SMACNA	Sheet Metal and Air-Conditioning Contractors National Association, Inc.
TYM	Typical meteorological year
UBC	Uniform Building Code
UMC	Uniform Mechanical Code
UPC	Uniform Plumbing Code
VAV	Variable air volume
VIAQ	Ventilation and Indoor Air Quality Code
WABO	Washington Association of Building Officials
w.g.	inches of water gauge
WSEC	Washington State Energy Code
WSEO	Washington State Energy Office

Introduction

This manual is designed to provide building department personnel with specific inspection and plan review skills and information on provisions of the 1991 edition of the Washington State Energy Code (WSEC). It also provides information on provisions of the new stand-alone Ventilation and Indoor Air Quality (VIAQ) Code.

WHY AN ENERGY CODE?

Nearly a third of all the energy used in the U.S. is consumed through some form of tempering our indoor climate -- through space heating or cooling, water heating, and lighting. Of the energy used in buildings, nearly 75% is dedicated to heating and air conditioning systems. Furthermore, many studies indicate that much more energy is consumed than is necessary to do the job.

The intent of the WSEC is to reduce the amount of energy used by requiring energy-efficient construction. Such conservation reduces energy requirements, and, as a result, reduces the use of finite resources, such as gas or oil. Lowering energy demand helps everyone by keeping electricity costs down. (It is less expensive to use existing electrical capacity efficiently than it is to develop new and additional capacity needed to heat or cool inefficient buildings.)

The measures required or recommended in the WSEC are not intended to require unnecessary or unreasonable expense. Lengthy cost-analysis has been conducted on the paths and options presented in the Code and explained in this manual. Every attempt has been made to develop a practical and effective approach to energy-efficient construction.

THE VIAQ CODE

The new VIAQ Code (effective July, 1991) is a natural companion to the energy code. Whether energy-efficient or not, all homes have potential indoor air quality problems. Studies have shown that indoor air is often more polluted than outdoor air! The VIAQ Code provides a means of exchanging stale air for fresh, without compromising energy savings, by setting standards for a controlled ventilation system. It also offers requirements meant to prevent indoor air pollution from building products or radon.

HOW TO USE THE MANUAL

This manual is intended to act as a day-to-day reference for code enforcers, but is meant to supplement, not supplant, other sources of information and training currently available to Washington's code enforcement personnel (see below). As much as possible, the manual reflects the most recent information and clarifications arising from interaction with code officials and inspectors in the field.

The WSEC is presented first, including a general information section, a residential compliance section, and a "commercial" (or non-residential) compliance section. The VIAQ Code is presented next, again beginning with general information, followed by a unit on administrative requirements, a unit on residential

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