Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Daylighting Controls

Effective design using gentle, diffuse daylight can provide building occupants with a natural quality of light that has been proven to improve productivity and reduce incidences of illness in workers, students, and teachers. Automatically reducing electric lighting in response to natural daylight can save significant energy. But using daylight without careful consideration of glare, heat gain, or integration with electric lighting can be counter productive.

The Oregon Energy Code only requires automatic daylighting controls in two kinds of nonresidential spaces—classrooms or atriums. An atrium is defined as follows:

> "An opening connecting two or more stories other than enclosed stairways, elevators, hoistways, escalators, plumbing, electrical, air-conditioning, or other equipment, which is closed at the top and not defined as a mall. Stories, as used in this definition, do not include balconies within assembly groups or mezzanines that comply with section 505."

In these spaces, two situations will trigger requirements for daylighting controls according to section 1313.3.1.3:

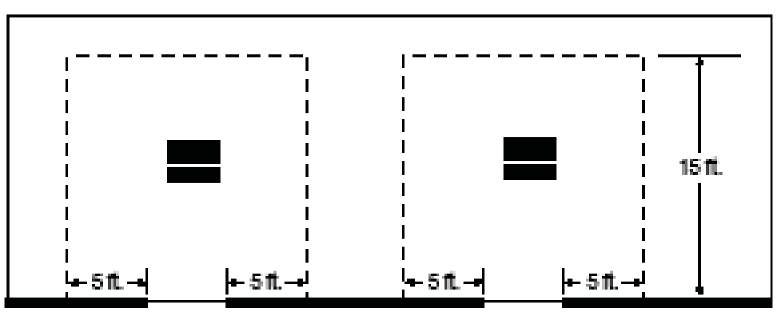
- If there are any skylights in the classroom or atrium

  or

- When the window-to-exterior wall ratio (measured on the *inside* of the exterior wall) in the classroom or atrium is greater than 50%.

Calculating the Daylit Zone

If your space meets the criteria above, daylight sensing controls are required for luminaires that fall within the daylit zones. The figures below show how to calculate daylit zones for both windows and skylights according to sections 1313.3.1.3.1 and 1313.3.1.3.2.



Daylit Zone – Windows

Continues on page 2

Code Language

Documentation: To document compliance with this section of code, fill out Compliance Form 5a.

1313.3.1.3 Daylighting controls. Daylighting controls meeting the requirements of this section shall be required for all classrooms and atriums.

1313.3.1.3.1 Daylighting requirements for windows. Classrooms and atriums with a window to exterior wall ratio of 50 percent or greater shall use automatic daylight sensing controls for all permanently installed luminaires 15 feet (4572 mm) inward and 5 feet (1524 mm) on each side of the windows. For the purpose of this section, window to wall ratio is measured on the inside room of the exterior walls.

1313.3.1.3.2 Daylighting requirements for skylights. In classrooms and atriums with skylights, monitors or other fenestration at or above ceiling level, all permanent luminaires within an area equal to the footprint of the ceiling opening plus the floor to ceiling height in each direction of the opening, shall be controlled by automatic daylight sensing controls.

1313.3.1.3.3 Automatic daylight sensing controls. When required by this section, automatic daylight sensing controls shall:

1. Be capable of reducing the light output of the controlled luminaires by at least one-half while maintaining a uniform level of illuminance,
2. Provide continuous dimming of the controlled luminaires,
3. Control only luminaires within the daylit area, and
4. Incorporate time-delay circuits to prevent cycling of light level changes of less than three minutes.

Exception:

Atriums may utilize step switching or other non-continuous dimming devices provided they have adjustable separation (deadband) of on and off points to prevent short cycling.

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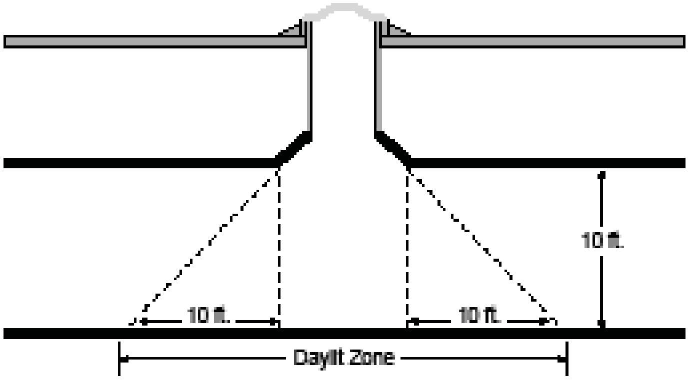

Daylit Zone – Skylight

Daylight Sensing Controls

For classrooms, the system must provide continuous dimming which requires dimming ballasts. Atriums are permitted to use stepped or on/off control provided they have adjustable separation (deadband) of on and off points to prevent short cycling.

Additions and Alterations [1313.6]

Any lighting systems installed in additions to or alterations of existing buildings must comply with the daylighting control requirements of Section 1313.3.1.3. However, if your alterations replace less than 50% of the luminaires/fixtures and do not increase the existing total connected lighting power, than your project is exempt and does not need to add lighting controls for that space.

Find Out More

Copies of Code:
Oregon Building Officials Association
phone: 503-873-1157 fax: 503-373-9389

Technical Support:
Oregon Department of Energy
625 Marion Street NE phone: 503-378-4040
Salem, OR 97301-3737 toll free: 800-221-8035
www.oregon.gov/energy fax: 503-373-7806

This fact sheet was developed with funding from
the Northwest Energy Efficiency Alliance
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Northwest Energy Efficiency Alliance
www.nwalliance.org

Photo on page 1 c/o Warren Gretz, DOE/NREL

65/05 ODOE CF-125/Fact Sheet 1

Non-residential code lighting Fact Sheets include:

- Exterior Lighting and Controls • Interior Lighting Controls
- Interior Connected Lighting Power • Daylighting Controls

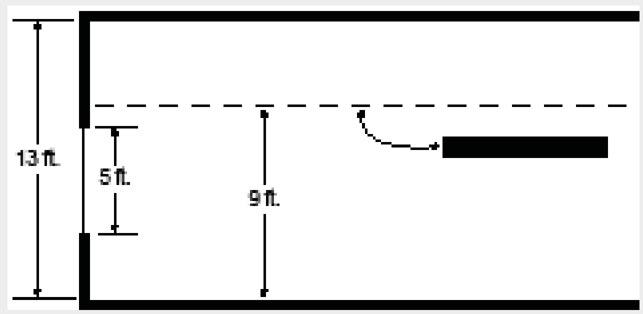
Examples

Q I want to use automatic daylighting controls in spaces other than a classroom or atrium. If I do, can I install more lighting power than would otherwise be permitted?

A No, you do not receive any “tradeoff credit” for installing automatic daylighting controls when not required by code. However, you may be eligible for incentives or tax credits from:

- The Energy Trust of Oregon (www.energytrust.org/business/index.html)
- The Oregon Department of Energy’s Business Energy Tax Program (http://egov.oregon.gov/ENERGY/CONS/BUS/BETC.shtml)
- Utility incentives (check with your local utility).

Q If I have a 5-ft-high continuous window in a space designed like the figure below, am I required to use daylighting controls or not?

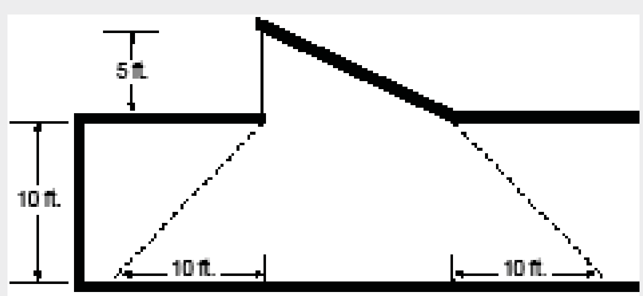


Measurements

A In this configuration, if the window were a continuous window across the entire space, the window-to-wall ratio WOULD be greater than 50% and daylighting controls would be necessary for luminaires in the daylit zone. This is because the ratio is calculated using the inside room measurements and *not* the exterior wall measurements.

Q My design incorporates a roof monitor. How do I calculate the daylit zone?

A With a roof monitor, the ceiling opening is the same as for a skylight (see figure below). Do not use the vertical opening where the glazing is installed for daylit zone measurements.



Daylit Zone – Roof Monitor

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Interior Lighting Controls

Indoor lighting is one of the single largest consumers of energy in a nonresidential building, representing about one-third of electricity use. Because of this fact, lighting controls are critical for minimizing lighting energy use while still ensuring that the space is functional and comfortable for occupants.

The Oregon Department of Energy requires lighting controls for interior lighted spaces according to section 1313.3.1 of the Oregon Energy Code.

Local Shutoff Control [1313.3.1.1]

The code requires that most spaces have some means for turning lights on and off. A wall toggle switch, an occupancy sensor, or a dimmer can meet this requirement. The control must be within the room and available to the room occupants, and it cannot control an area larger than 2,000 ft^2.

There are four exceptions to the code requirement for local shutoff controls. Low-lighting spaces such as warehouses and parking garages, areas that must be continuously lit, public areas such as concourses and corridors, and contiguous single-tenant retail spaces do not require local shutoff controls. Other lighting applications may be exempt from the code—see 1313.1.

Automatic Shutoff Control [1313.3.1.2]

This section of code requires that lights be automatically shut off during normally unoccupied periods. Occupancy sensors, which turn off lights in the area no more than 30 minutes after the area has been vacated, and automatic time switches, which turn off lights during nights, holidays, and other unoccupied times can fulfill these requirements (1313.3.1.2.1 and 1313.3.1.2.2 specify requirements for these controls).

The code requires that automatic time switches incorporate an override switching device for a person needing to use the space after regular hours. The override switch must be accessible, manually operated, and located so that a person using the device can see the effects of the control. If local shutoff controls are required, each override switch cannot control an area larger than 2,000 ft^2 (186 m^2). If an occupant overrides the automatic shutoff control (i.e., switches on the light during a normally unoccupied time), the shutoff control is also required to employ a device that automatically turns off the lights again in no more than 2 hours.

In addition, regardless of building size, all offices smaller than

Continues on page 2

Code Language

Documentation: To document compliance with this section of code, fill out Compliance Form 5a.

1313.3.1 Interior lighting controls. The following controls are required for interior lighted spaces:

1313.3.1.1 Local shutoff control. At least one local shutoff lighting control shall be provided for every 2,000 square feet (186 m^2) of lit floor area and for all spaces enclosed by walls or ceiling height partitions.

Exceptions:

1. Lighting for warehouses, parking garages or spaces using less than 0.5 watts per square feet (5.4 W/m^2).
2. Lighting systems serving areas that must be continuously lit.
3. Public areas, such as concourses, with switches that are accessible only to authorized personnel.
4. Lighting for contiguous, single-tenant retail spaces.

1313.3.1.2 Automatic shutoff control. Buildings greater than 5,000 square feet (465 m^2) and office occupancies over 2,000 square feet (186 m^2) of contiguous floor area shall be equipped with separate automatic controls to shut off the lighting during unoccupied periods. Automatic controls shall be an occupancy sensor, time switch or other device capable of automatically shutting off lighting that complies with Section 1313.3.1.2.1 or 1313.3.1.2.2

Offices less than 300 square feet (27.9 m^2), meeting and conference rooms, and school classrooms shall be equipped with occupancy sensors that comply with Section 1313.3.1.2.1.

Exceptions:

1. Emergency and pathway lights as required by code.
2. Where the system is serving an area that must be continuously lit.
3. Display and accent lighting, including plug-in, track and display case lighting, shall be separately controlled.
5. Hospitals and laboratory spaces.
6. Areas in which medical or dental tasks are performed.
7. Mechanical and electrical equipment rooms.

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1313.3.1.2.1 Occupancy sensors. Occupancy sensors shall be capable of automatically turning off all the lights in an area, no more than 30 minutes after the area has been vacated. Lighting fixtures controlled by occupancy sensors shall have a wall-mounted, manual switch capable of turning on and off lights when the space is occupied.

1313.3.1.2.2 Automatic time switches. Automatic time switches shall have a minimum 7-day clock and be capable of being set for 7 different day types per week and incorporate an automatic holiday "shut-off" feature, which turns off all loads for at least 24 hours and then resumes normally scheduled operations. Automatic time switches shall also have program back-up capabilities, which prevent the loss of program and time settings for at least 10 hours, if power is interrupted.

Automatic time switches shall incorporate an override switching device that:

1. Is readily accessible,
2. Is located so that a person using the device can see the effects of the control
3. Is manually operated,
4. Allows the lighting to remain on for no more than 2 hours when an override is initiated, and
5. Controls an area not exceeding 2,000 ft^2 (186 m^2).

Note: Refer to separate fact sheet for code regarding Daylighting [1313.3.1.3.]

Find Out More

Copies of Code:
Oregon Building Officials Association
phone: 503-873-1157 fax: 503-373-9389

Technical Support:
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Salem, OR 97301-3737 toll free: 800-221-8035
www.oregon.gov/energy fax: 503-373-7806

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Northwest Energy Efficiency Alliance
www.nwalliance.org

12/05 ODOE CF-125/Fact Sheet 2
Photo on page 1 c/o Warren Gretz, DOE/NREL

Non-residential code lighting Fact Sheets include:
- Exterior Lighting and Controls
- Interior Lighting Controls
- Interior Connected Lighting Power
- Daylighting Controls

Continued from page 1

300 ft^2, all meeting and conference rooms, and all school classrooms are required to be equipped with occupancy sensors (1313.3.1.2.1) that turn off lights automatically in no more than 30 minutes.

A few spaces, because of safety or functional concerns, need continuous lighting and are exempted from the automatic shutoff control requirement. These include emergency and pathway lights, display and accent lighting, switching for manufacturing processes, patient care areas in hospitals and any other areas where medical or dental tasks are performed, and mechanical and electrical equipment rooms.

Additions and Alterations [1313.6]

Any lighting systems installed in additions to or alterations of existing buildings must comply with the interior lighting control requirements of Section 1313.3.1. However, if your alterations replace less than 50% of the luminaires/fixtures and do not increase the existing total connected lighting power, then your project is exempt and does not need to add lighting controls for that space.

Examples

Q I'm a new tenant occupying 4,000 ft^2 of a 20,000 ft^2 building, and I want to replace most of the lighting fixtures in my space. Am I required to install controls according to Section 1313.3.1?

A Even though your 4,000 ft^2 space is not 50% of the building space, the space is 100% of your *permitted project*, so you would still be required to meet the requirements of Section 1313.3.1: adding local shutoff controls and automatic shutoff controls (either occupant sensors or automatic time switches).

Q I'm designing a bank and some of the interior lighting needs to remain on all night for security purposes. Am I exempt from the requirements of Section 1313.3.1?

A Yes, lighting systems that serve areas that must be continuously lit for security or emergency reasons, such as bank security lighting, police dispatch areas, and 24-hour convenience stores, are exempted.

Q The code says that hospital spaces are exempted from having automatic shutoff controls [1313.3.1.2]. Does that mean I don't need to install automatic shutoff controls in office spaces or meeting rooms in the hospital I'm designing?

A No. Patient care areas in hospitals, medical, and dental facilities, and areas of the facilities in use 24 hours a day (such as emergency rooms) are exempted, but any areas not used by patients still require automatic shutoff controls.

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Exterior Lighting and Controls

Requirements

Lighting used on the exterior of buildings is one of the more visible energy uses. The Oregon Energy Code requires that lighting used to illuminate building facades, canopies, parking lots, pedestrian walkways, gardens, and other landscaped areas associated with a building have controls that enable them to be automatically shut off when they are not needed. The use of incandescent or mercury vapor luminaires is also prohibited for many exterior lighting applications, since these light sources are less efficient.

In terms of control, all exterior lighting shall be automatically controlled with either a photosensor switch or clock switch which is capable of turning off the lights when daylight is present. If a clock switch is used, it shall automatically compensate for the length of the day and how it changes throughout the year. Such a clock switch is often referred to as an astronomical clock switch. The clock switch shall also have battery backup so that it does not need to be reprogrammed after a temporary power outage. The control requirements apply to all exterior lighting applications that receive their power through the building's utility meter.

Incandescent and mercury vapor luminaires are prohibited for exterior building lighting. Exterior building lighting is a subset of total exterior lighting and includes façade lighting, canopy lighting, and lighting for adjacent walkways and loading areas with and without canopies. The restriction does not apply to parking lot lighting, landscape lighting or other applications that are not considered exterior building lighting. The restriction applies to the luminaire, not the lighting source, e.g. a screw-in compact fluorescent lamp in an incandescent luminaire counts as an incandescent luminaire.

Exceptions

Some exterior lighting applications are exempt from both control and luminaire type restrictions. These include athletic facilities, tunnels, high-risk security areas such as the area around automatic teller machines (ATMs), and areas designed for visually disabled persons. Sign lighting and nonpermanent lighting is also exempt, but these lighting applications must be separately controlled, e.g. they shall have their own switch and not be grouped with other lighting applications.

Continues on **page 2**

Code Language

1302 Definitions EXTERIOR BUILDING LIGHTING. Lighting directed to illuminate the exterior of the building and adjacent walkways and loading areas with or without canopies.

1313.1 General. The provisions in this section apply to lighting equipment, related controls and electric circuits serving the interior spaces of other buildings, exterior building facades (including illuminated roofs and other architectural features), and exterior areas such as entrances, exits, loading docks, illuminated canopies, roads, open parking, exterior retail and landscaping. Alterations to existing buildings shall comply with Section 1313.6.

Exceptions:

1. Lighting for the following areas:
   - 1.1 Outdoor athletic facilities.
   - 1.2 Dwelling units, lodging houses, one or two family dwellings and guest rooms.
   - 1.3 Industrial plants—manufacturing spaces only.
   - 1.4 Paint shops and painting spray booths.
   - 1.5 High-risk security areas such as detention facilities, automatic teller machines (ATMs) and night drops.
   - 1.6 Areas specifically designed for visually disabled people.
   - 1.7 Tunnels.
2. Lighting equipment used for the following shall be exempt provided that it is in addition to general lighting and is controlled by an independent control device:
   - 2.1 Production lighting for theatrical, television, spectator sports and similar performance areas.
   - 2.2 Decorative, special effect and production lighting for those portions of entertainment facilities such as theme parks, nightclubs, discos and casinos where lighting is an essential technical element for the function performed.
   - 2.3 Lighting equipment for sale.
   - 2.4 Task lighting for medical and dental purposes.
   - 2.5 Bench lighting for research laboratories.

Code Language continued from page 1

2.6 Lighting to be used solely for indoor plant growth during the hours of 10:00 p.m. to 6:00 a.m.
2.7 Emergency lighting that is automatically off during normal building operation.
2.8 Art accent lighting required for art exhibits or displays in galleries, museums and monuments.
2.9 Sign lighting.
2.10 Nonpermanent lighting.

1313.3.2 Exterior and canopy lighting controls. All exterior lighting systems, including those attached to building exterior surfaces, mounted onto or in adjacent structures, attached to poles or mounted onto or in the ground, shall be controlled by photoelectric switches, clock switches or both, which shall be designed and programmed to extinguish lights when daylight is present. Clock switches shall be astronomic (seasonal correcting) type with separate programs for each day of the week and shall store energy to maintain timekeeping during power outages. A motion sensor, if used, shall employ a photoelectric switch to prevent operation during daytime.

1313.5 Exterior lighting. No incandescent or mercury vapor lighting sources shall be used for exterior building lighting.

Exception: Lighting used in or around swimming pools,water features, or other locations subject to the requirements of Article 680 of the National Electrical Code. Lighting power requirements for covered parking and storage garage areas shall be included in the interior lighting power of Section 1313.4.

Find Out More

Copies of Code:
Oregon Building Officials Association
phone: 503-873-1157 fax: 503-373-9389

Technical Support:
Oregon Department of Energy
625 Marion Street NE phone: 503-378-4040
Salem, OR 97301-3737 toll free: 800-221-8035
www.oregon.gov/energy fax: 503-373-7806

This fact sheet was developed with funding from the Northwest Energy Efficiency Alliance and the US Department of Energy under contract DE-FG51-02R021378.

Northwest Energy Efficiency Alliance
www.nwalliance.org

Photo on page 1 c/o Warren Gretz, DOE/NREL

12/05 ODOE CF-125/Fact Sheet 3

Other Non-residential Code LIGHTING Fact Sheets include:

- Daylighting Controls
- Interior Lighting Controls
- Exterior Lighting and Controls
- Interior Connected Lighting Power

Continued from page 1

Limits on Lighting Power

Apart from the restriction on incandescent and mercury vapor luminaires, there are no restrictions on the lighting power that is used for exterior lighting applications, with the exception of areas under roofs. Canopies, and covered parking areas are lumped together with interior lighting applications for the purpose of power restrictions. See the fact sheet on Interior Lighting Power for details.

Examples

Q The lighting system under an entrance canopy to a theatre is designed with incandescent cans. The building, including the canopy, complies with the interior lighting power allowances. Are the incandescent luminaries permitted?

A No. Even though the canopy is considered interior lighting for the purpose of the lighting power allowance, the luminaires are installed on the exterior of the building and section 1313.5 prohibits the use of incandescent or mercury vapor lamps for exterior building lighting.

Q Would the entrance canopy in the previous example comply with section 1313.5 if screw-in compact fluorescent lamps were used in the recessed cans?

A No. The restrictions of Section 1313.5 on the use of incandescent or mercury vapor applies to the luminaire, not the lamp. Incandescent luminaires that accept screw-in compact fluorescent luminaries do not qualify.

Q Incandescent marquis lighting is proposed for the entrance canopy in the previous example. Is this permitted?

A Yes. Marquis lighting is considered sign lighting and exception 2.9 to Section 1313.1 applies.

Q A designer would like to use incandescent path lighting next to a sidewalk that leads to the entrance of an office building. Is this permitted?

A No. Pathway lighting leading to the building is considered exterior building lighting and Section 1313.5 applies. Furthermore, this lighting must be controlled by an astronomical clock switch or a photosensor switch.

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Interior Connected Lighting Power

Requirements

The requirements for interior lighting power are one of the most important sections of the Oregon Energy Code. They set a maximum for the installed electrical power of interior building lighting. As with the other sections of the Standard, however, the lighting criteria are minimum requirements. Through improved technology and thoughtful design, quality lighting with even greater efficiency can be achieved.

There are two methods for determining the interior lighting power allowance. The tenant space method (1313.4.1) is the simplest and is appropriate for an entire building or an entire tenant space within a building. The space-by-space method (1313.1.2) accounts for specific lighting applications and can distinguish, for instance, between various types of seating areas in an auditorium. This method offers more flexibility and may result in a higher lighting power allowance for some applications. Both methods establish a budget for the entire building. The budget may be distributed throughout the building in any way seen fit by the designer (traded off), so long as total tenant space or building budget is not exceeded.

Note that these lighting allowances apply regardless of whether a space, such as a warehouse, is heated or unheated. Also, be aware that some outdoor spaces such as covered (but open) parking garages and canopies (including service station canopies) are included as interior lighting for the purposes of the requirements.

Non-Regulated Lighting

Most interior lighting must be included in the calculations of installed lighting power. However, certain specialized lighting is exempt as defined in exceptions 1 and 2 of 1313.1. The lighting identified in exception 1 is categorically exempt, such as athletic fields. However, the lighting applications identified in exception 2 are exempt only if they are not the only lighting source in the space and if they are controlled by an independent control device. Exempt lighting can be ignored when determining the installed lighting power for comparison against the lighting power allowance.

Tenant Space Method (1313.4.1)

The tenant space method assigns a single interior lighting power density in W/ft^2 based on the type of tenant space (see Table 13-G of the Code.) If a tenant space type is not listed in Table 13-G, the closest match should be chosen with the approval of the local building official. The lighting power density is multiplied by

Continues on **page 2**

Code Language

1313.1 General. The provisions in this section apply to lighting equipment, related controls and electric circuits serving the interior spaces of other buildings, exterior building facades (including illuminated roofs and other architectural features), and exterior areas such as entrances, exits, loading docks, illuminated canopies, roads, open parking, exterior retail and landscaping.

Alterations to existing buildings shall comply with Section 1313.6.

Exceptions:

1. Lighting for the following areas:
   - 1.1 Outdoor athletic facilities.
   - 1.2 Dwelling units, lodging houses, one or two family dwellings and guest rooms.
   - 1.3 Industrial plants—manufacturing spaces only.
   - 1.4 Paint shops and painting spray booths.
   - 1.5 High-risk security areas such as detention facilities, automatic teller machines (ATMs) and night drops.
   - 1.6 Areas specifically designed for visually disabled people.
   - 1.7 Tunnels.
2. Lighting equipment used for the following shall be exempt provided that it is in addition to general lighting and is controlled by an independent control device:
   - 2.1 Production lighting for theatrical, television, spectator sports and similar performance areas.
   - 2.2 Decorative, special effect and production lighting for those portions of entertainment facilities such as theme parks, nightclubs, discos and casinos where lighting is an essential technical element for the function performed.
   - 2.3 Lighting equipment for sale.
   - 2.4 Task lighting for medical and dental purposes.

Code Language continues on **page 2**

Documentation: The Non-Residential Energy Code Compliance Manual has compliance forms both in manual and electronic form that may be used to show compliance with these requirements. These forms are supported by instructions and data tables.

Code Language continued from **page 1**

2.5 Bench lighting for research laboratories.
2.6 Lighting to be used solely for indoor plant growth during the hours of 10:00 p.m. to 6:00 a.m.
2.7 Emergency lighting that is automatically off during normal building operation.
2.8 Art accent lighting required for art exhibits or displays in galleries, museums and monuments.
2.9 Sign lighting.
2.10 Nonpermanent lighting.

1313.2 Luminaire wattages. Lighting luminaire wattage shall be determined in the following manner:

1. Incandescent luminaires. The maximum rated lamp wattage permitted in the luminaire shall be the luminaire's wattage for the purpose of this standard.
2. Luminaire wattage shall be input wattages including lamp and ballast losses, determined from values approved by the Building Codes Administrator. If a nonstandard product or system is used, ANSI input wattages shall be from the manufacturer's literature.
3. For compliance with this chapter, track lighting shall be calculated at 37.5 watts per linear foot (123 W/m) of track or the maximum circuit load as determined by the overcurrent device protecting the track, whichever is less.

1313.4 Interior connected lighting power. The interior connected lighting power shall not exceed the interior power allowance established in either Section 1313.4.1 or 1313.4.2.

Where multiple, independently operating lighting systems serve the same space and are controlled to prevent simultaneous operation, the connected lighting power shall be based on the system with the highest connected lighting power.

1313.4.1 Tenant space power allowance method. The total interior connected lighting power shall not exceed the maximum power allowance calculated by multiplying the lighting power density(ies) from Table 13–G based on the predominant use by the floor area of the entire tenant space or building.

1313.4.2 Space-by-space method. The total interior connected lighting power shall not exceed the maximum power allowance calculated by multiplying the lighting power density from Table 13–H for each space by the floor area of that space.

1313.4.2.1 Additional lighting power for retail displays. For retail display lighting that is specifically directed to highlight retail merchandise and controlled separately from the space general light system, an additional lighting power allowance shall be calculated as follows:

Code Language continues on **page 3**

Continued from page 1

the gross lighted area of the building to determine the interior lighting power allowance. The gross lighted area is measured to the outside surface of exterior walls and to the center line of partitions that separate tenant spaces. The gross lighted area may also include garages and service station canopies.

The tenant space method is the easiest way of determining the lighting power allowance. In the case of an office, the tenant space allowance is 1.0 W/ft². This is an average for the typical mix of spaces included in an office, e.g. conference rooms, rest rooms, lobbies and corridors.

Space-by-Space Method (1313.4.2)

The space-by-space method is the second of the two methods for determining interior lighting power allowance. This approach offers greater flexibility and is applicable for all building types; however, it requires more time and effort. Rather than looking up the lighting power allowance for an entire building, the lighting power allowance is determined separately for each space within a building and then summed. The space-by-space allowances are included in Table 13-H of the Code.

The space-by-space method has two categories of allowances; common space types are applicable to any building while specific space types are particular to the building type. For instance, a courthouse has specific space types for the courtroom and judges' chambers. These space types are unique to a courthouse and may only be used for courthouses. The common space types are appropriate for any building. If a particular space type is not listed in Table 13-H, the closest match should be chosen with the approval of the local building official.

The compliance process is to divide the gross lighted area of the building into each of the space types. The lighting power allowance for each space type is determined by multiplying the gross lighted area of the space times the lighting power density (from Table 13-H). The gross lighted area is measured to the outside of exterior walls and to the centerline of partitions. The allowance for the whole building is the sum of the allowances for each of the applicable space types.

Under the space-by-space method, an additional lighting power of 1.75 W/ft² is allowed for retail display lighting (up to a maximum of 17,500 Watts per space). This allowance applies only to the sales area of the retail store and does not include storage rooms, offices or other support spaces. Additional power shall be allowed only if the specified lighting is installed, used only for the specified display lighting luminaires, and not used for any other purpose or in any other space. The term "use-it-or-lose-it" applies for this type of lighting allowance. The additional display lighting shall be separately circuited, switched and controlled.

Installed Interior Lighting Power (1313.2)

Once the interior lighting power allowance has been determined, it is then necessary to calculate the connected lighting power

Continues on **page 3**

Continued from page 2

and to show that this value is less than or equal to the allowance. Interior connected lighting power is simply the sum of the input wattage of all nonexempt luminaires in the building. Luminaire wattage must be determined in accordance with 1313.2.

The installed or connected lighting power – which is compared to the allowed lighting power – must include not only that of the lamp, but also the power used by the ballast or the transormer used to power lamps.

Table 5c of the Non-Residential Energy Code Compliance Manual has default data on lamp and ballast power for typical lamp/ballast combinations used in common luminaires. If the appropriate lamp ballast combination is not included in Table 5c, use the manufacturer's data for luminaire wattages and include a catalogue cut sheet with the compliance submittal.

Some lighting applications have multiple systems that are not intended for simultaneous operation. For example, a multi-function room in a hotel might have one lighting system with incandescent downlights suitable for ballroom activities and another lighting system to provide office-level illumination for meetings and conferences. If controls are implemented to prevent the simultaneous operation of multiple lighting systems, then it is only necessary to consider the lighting system with the greatest power when determining compliance with the Standard.

With many types of luminaires, designers may be uncertain about the wattage to use in compliance calculations. This is particularly true for luminaires capable of accepting multiple lamp sizes and for track lighting where additional luminaires can easily be added. These special cases are described below.

Incandescent and Tungsten-Halogen Luminaires without Permanently Installed Ballasts

This type of luminaire can accept lamps of many different sizes. For the purpose of determining installed interior lighting power, assume the maximum labeled wattage of the luminaire. This means that a luminaire rated for 150 W is calculated at 150 W for lighting power. This applies regardless of whether the lamp used is 75 W incandescent or 13 W screw-in compact fluorescent. To achieve credit for compact fluorescent lamps, the fixture must have a permanently installed ballast.

Luminaires with Permanently Installed Ballasts

Luminaires with permanently installed or remote ballasts shall use the input wattage of the lamp/ballast combination shown on the plans and specifications for the building. This information can be obtained from manufacturer's literature or from an independent testing laboratory. See Table 5c of the Compliance Manual

Continues on **page 4**

Code Language continued from **page 2**

Additional Lighting Power for Retail Displays = 1.75 Watts/sq. ft. multiplied by area of retail floor space (sq. ft.) up to a maximum of 17,500 Watts.

This additional lighting power shall only be used for retail display lighting in the applicable space, and shall not be used to increase lighting power allowance with other spaces or general lighting system within the space.

1313.6 Additions and alterations. Lighting systems in additions and alterations shall comply with the provisions of Section 1313. .

Exception:

Alterations to existing lighting systems that do not replace more than 50 percent of the luminairies in the permitted project and do not increase the existing total connected lighting power.

Examples

Q Do I need to consider portable desk lamps or furniture mounted lighting when I tally up the connected lighting of an office space?

A No, this lighting is considered nonpermanent (exception 2.10) and is exempt as long as it is not the only lighting and it is controlled by an independent control device.

Q I am designing an office space with no permanently mounted lighting fixtures. Ambient indirect lighting is provided by luminaires mounted on top of the furniture partitions and this is supplemented by furniture mounted task lighting. Do I need to include this lighting when I tally up the connected lighting power of the space?

A Yes. While this lighting can be considered nonpermanent since it is not hard wired, it is the only lighting in the space, and as such, does not qualify for exception 2.10.

Q The lighting system in an art gallery consists entirely of incandescent track mounted luminaires. Is this lighting exempt per exception 2.8?

A No. Since the lighting is the only lighting in the space, it is not exempt. If a secondary system were installed for use after hours, then the display lighting would be exempt.

Examples

Q The lighting system for an office building is constructed in phases. The lighting systems for the entrance lobby, rest rooms, and other common building are included with the plans and specifications for the base building. As tenants move into the building, the tenant improvement plans will include the lighting system for each tenant space. Can the tenant space method be used for the base building lighting system? What about the tenant lighting systems?

A The tenant space method may be used for either the tenant spaces or the base building when separately permitted. If the permit is for the base building only and does not include permanent lighting in the tenant spaces, the area of the tenant spaces should not be included when determining the base building budget.

Q An existing lighting system in an office is being re-lamped and re-ballasted with modern T-8 lamps and electronic ballasts. The existing luminaires are being used. Do the standards apply?

A No. Retrofits do not have to meet the lighting requirements unless more than 50% of the luminaires are being replaced or the overall connected lighting power is increased. In this case, none of the luminaries are being replaced and overall connected lighting power is being reduced.

Find Out More

Copies of code:

Oregon Building Officials Association
phone: 503-873-1157 fax: 503-373-9389

Technical Support:

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Salem, OR 97301-3737 toll free: 800-221-8035
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This fact sheet was developed with funding from the Northwest Energy Efficiency Alliance and the US Department of Energy under contract DE-FG51-02R021378.

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12/05 ODOE CF-125/Fact Sheet 4

Non-residential code LIGHTING Fact Sheets include:

- Daylighting Controls
- Interior Lighting Controls
- Exterior Lighting and Controls
- Interior Connected Lighting Power

Continued from page 3

regarding data for common lamp/ballast combinations.

Line-Voltage Track Lighting

Track lighting is a very common lighting technique for display lighting in retail stores and galleries. It consists of a line-voltage, plug-in busway that allows for the addition or relocation of luminaires without having to change the wiring system. This makes it very easy to add fixtures to the track after the final occupancy permit has been issued. When accounting for track lighting that operates at line voltage, the designer must assume at least 37.5 W per lineal foot of track. A track that is 10 feet long would have a minimum of 375 W, even if only one 100 W fixture was shown in the drawings. If a track lighting system is on a separate circuit that has an overcurrent device (circuit breaker) protecting the circuit, then the maximum power is the line voltage times the maximum current.

Low-Voltage Track Lighting

Some track lighting systems use a transformer to energize the busway at 12 or 24 volts. Examples include decorative fixtures with exposed conductors. When these systems are used for interior lighting, the wattage used for compliance calculations is the maximum wattage of the transformer that supplies power to the system.

Additions and Alterations (1313.6)

The interior lighting power requirements apply to additions in the same way as they apply to new construction. The application of the requirements to alterations depends on the extent of the improvements. The requirements do not apply to minor alterations when fewer than 50% of the luminaires are replaced and when the overall connected lighting power is not increased (see the exception to 1313.6).

Examples

Q A jewelry store has display cases for rings, necklaces and bracelets. The store has three cases measuring 2 ft by 6 ft. What is the display allowance for these cases?

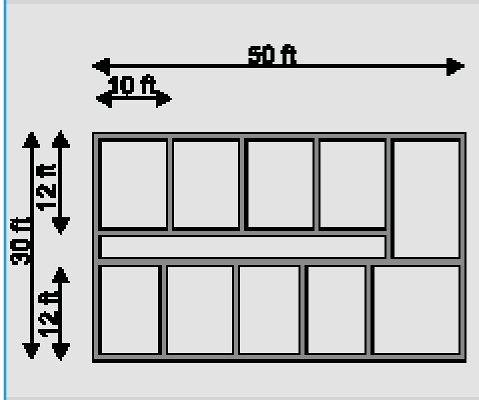
A The lighting in the display cases is considered nonpermanent lighting per exception 2.10 and does not need to be considered.

Q A 60 ft track lighting system in a gallery is on a separate circuit with a circuit breaker that trips when current exceeds 15 amps. What lighting power should be assumed for the lighting system?

A The power to be assumed is the lesser of 37.5 W/ft or the maximum power of the circuit. The maximum power of the circuit is 110 V times 15 amps or 1,650 W. The maximum power based on track length is 60 ft times 37.5 W/ft or 2,250 W. The power to be assumed is the lesser of these values or 1,650 W.

Examples

Q A building consists of 10 similar private offices ranging from 10 ft. by 12 ft. to 10 ft. by 14 ft. in size and totaling 1,350 sq. ft. (average size 135 sq. ft.) In addition, the building has 150 sq. ft. of corridors. The total floor area of the building is 1,500 sq. ft. What is the interior lighting power allowance for the building?



A Using the tenant space method, the interior lighting power allowance is 1,500 sq. ft. x 1.0 W/sq. ft. = 1,500 W. Using the space-by-space method, the allowance for the enclosed offices is 1,350 sq. ft. x 1.1.W/sq.ft. = 1,485 W. The allowance for the corridors is 150 sq. ft. x 0.5 W/sq. ft. = 75 W. The total allowed interior lighting power is 1,560 W.

Q A retail clothing store with a sales area of 1,000 sq. ft. has five display tables that are 3 ft. by 3 ft. each and a separate veritical display of dresses that measures 10 ft. wide and 6 ft. high. What additional lighting power is permitted for these displays?

A The allowance is 1.75 W/sq. ft. of retail floor space. In this case, the retail floor space is the 1,000 square feet of sales area. The additional allowance for display lighting is a maximum of 1,000 sq. ft. times 1.75 W/sq. ft. or 1,750 W. This allowance may only be used for display lighting, however, and the display lighting must highlight merchandise and be separately controlled from the general lighting area.

Q A conference room is being renovated. The existing four recessed troffers will be retained, and three new compact fluorescent recessed cans will be installed at the front of the room to illuminate displays. Do the interior lighting requirements apply?

A Yes. In this case, the interior lighting power is increased so the exception to 1313.6 does not apply. If the existing luminaires were re-lamped and re-ballasted so that the connected lighting power for the room does not increase, then the exception would apply.

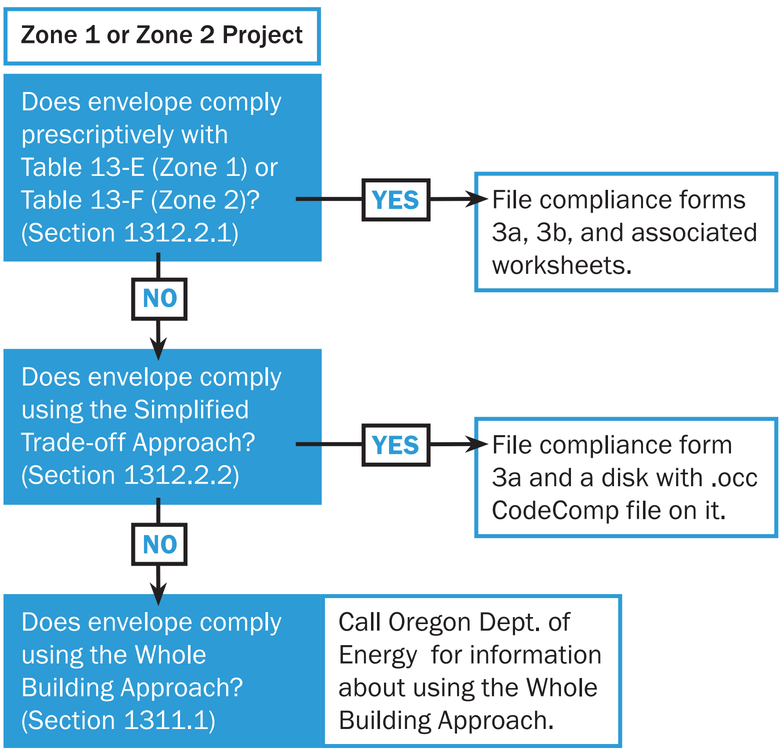
Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Envelope Compliance Approaches

Complying with Envelope Requirements

There are several methods of showing that building envelope components comply with the state's energy efficiency code as shown below.



Prescriptive Approach

The simplest is the prescriptive approach to compliance (1312.2.1), requiring buildings to meet minimum code requirements for walls, roofs, floors and windows/skylight insulation and efficiency.

This can be done by meeting R-value (for door, floors, roofs, and walls), or minimum assembly requirements for windows and skylights. If the envelope component does not meet these minimum requirements, calculate the U-factor by completing worksheets 3a through 3c, using values from tables 3a through 3d. Worksheets 3a through 3d are only necessary when using component U-factor to demonstrate compliance.

Simplified Trade-Off Approach

If your building does not meet these minimum code requirements,

Continues on **page 2**

Code Language

1312.2.1 Prescriptive path approach. Buildings in Zone 1 shall meet the Prescriptive Path Approach if they comply with the values in Table 13-E. Buildings in Zone 2 shall meet the Prescriptive Path Approach if they comply with the values in Table 13-F. Each component (walls, roofs, etc.) shall meet either the U-factor standard for the assembly or the R-value standard for the insulation in the table.

Glazing and skylight fractions shall be calculated separately for conditioned spaces, semi-conditioned spaces, mechancal penthouses, and parking garages.

Trade-offs between components or averaging of component U-factors is not allowed.

1312.2.2 Simplified trade-off approach. Buildings may demonstrate compliance with the thermal performance standards of this section by using the Simplified Trade-off Approach (STA). The STA is an analytical method to determine if a proposed building has no larger annual heating load through the exterior envelope and no larger annual cooling load through the exterior envelope than a similar building meeting the Prescriptive Path Approach.

1311.1 Alternate method of compliance using the whole building approach. Alternative building systems and equipment designs may be approved by the building official for other buildings. Applicants shall demonstrate that the whole building annual energy consumption will not exceed that used by a similar building using similar forms of energy designed in accordance with the prescriptive requirements of this chapter. Compliance under this section allows trade-offs between the performance requirements in all sections of this chapter using 8,760-hour annual building simulation. The building official may require review of the simulation results by an independent reviewer.

Documentation: To document compliance with this section of code, fill out Compliance Form 3a.

In addition:

- **Prescriptive Approach:** Form 3b with the appropriate associated worksheets.
- **Simplified Trade-Off Approach:** Submit a disk with the CodeComp file on it. This file can be found in the GDT\CodeComp\Project directory with an .occ file extension.
- **Whole Building Design Approach:** Call Oregon Dept. of Energy for information on complying via the Whole Building Design Approach.

Examples

Q My design doesn't meet prescriptively, so I want to use one of the tradeoff approaches. Can I use the data from LEED modeling to demonstrate compliance via the STA or the WBA?

A No, the Oregon Energy Code has strict requirements for both of those two approaches that are different from the requirements of LEED and utility programs. STA requires the use of CodeComp, which can not used for LEED or incentive programs. WBA requires the use of DOE2.1E, which may be used for LEED or utility programs, but extensive modifications would be needed.

Q My building has a window-wall-ratio of 45%. (a) Can I use the STA by reducing interior lighting usage and daylighting? (b) Can I achieve compliance by reducing plug loads (installing more energy efficient office equipment)?

A (a) No. The STA only considers the heat gain and loss through the building envelope. The WBA is the only approach that can be used to demonstrate compliance in this case. (b) No. While the WBA allows tradeoffs between building envelope and other building components, reducing plug loads is not a component that would be eligible for tradeoffs.

Find Out More

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12/05 ODOE CF-125/Fact Sheet 5

Non-residential code ENVELOPE fact sheets include:

- Envelope Compliance Approaches
- Fenestration Performance • Walls • Roofs

Continued from page 1

you can use the Simplified Tradeoff Approach (STA) (1312.2.2), which takes into consideration the entire building's annual heating and cooling loads through the exterior envelope. This approach is generally used when a building has higher glazing percentages (usually higher than 30%–40% in Climate Zone 1 and 25%–30% in Climate Zone 2) or when not insulating walls (want protected durable surface). The STA allows tradeoffs between different components of the building envelope—for example, an increase in wall and roof insulation beyond the code minimum may offset the high heat loss and heat gain through buildings with high window-wall ratios. The STA uses a program called CodeComp that can be downloaded at: www.oregon.gov/energy/cons/codes/cdpub.shtml. If using the STA, you must turn in a disk with the .occ file on it along with Form 3b to show compliance.

Whole Building Approach

Finally, the Whole Building Approach (WBA) (1311.1) can be used to demonstrate compliance with building energy codes as well. The WBA differs from the STA in that it allows tradeoffs between almost all energy code-related components, including building envelope, lighting, and HVAC systems. This approach would be required for a building with an energy-inefficient shell that meets neither the prescriptive nor the simplified tradeoff approaches of compliance. An example would be a library that uses large amounts of glazing for daylighting. Through the WBA, the poor thermal performance of the building envelope could be traded off with other efficiency measures, such as reduced electric lighting and efficient heating and cooling systems. The WBA uses an hourly building energy simulation program (DOE-2.1E) to predict annual energy use. The building must use no more energy than a "baseline" reference building that minimally complies with Oregon prescriptive requirements. However, this approach is complex and rarely used. Before going down the path of complying via the WBA, you must contact the Oregon Deptartment of Energy for more information.

Additions and Alterations [1313.6]

Building envelope components (walls, roof, floor, windows, etc.) in additions to or alterations of existing buildings must comply with the envelope requirements of Section 1312, with several exceptions outlined in Section 1312.3. Exceptions to requirements for additions and alterations can be documented using any of the three compliance approaches described.

Examples

Q My building meets the prescriptive code requirements. But, can I still use CodeComp and the STA method of compliance if I want to?

A No, CodeComp should only be used if one or more components of your building don't meet prescriptive requirements.

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Roofs

Roofs are one way that heat is gained or lost through the building envelope to the outdoors. The Oregon Energy Code's prescriptive standard requires that either the nominal R-value of the insulation or the U-factor of the roof assembly meets minimum requirements.

Prescriptive Approach

The simplest way to comply with the prescriptive approach is to use insulation with a minimum R-value of R-19. A 2x6 wood framed roof with batt insulation that fills the entire cavity will meet the prescriptive requirement. Continuous insulation with a minimum R-value of R-19 will also meet the prescriptive requirement (in fact, using continuous insulation will improve thermal performance).

U-factor Calculation

If the insulation R-value doesn't meet or exceed R-19, then calculate the U-factor of the assembly.

The U-factor calculation is performed on Worksheet 3b of the compliance documentation (this worksheet is not required to be completed if insulation R-value is used to demonstrate compliance).

The first step is to determine the effective R-value of the various components of the roof. Table 3a provides effective R-values for a variety of roof framing and insulation assemblies, including wood framing, metal framing, and metal trusses. Table 3b gives insulation R-values of other common components of the roof assembly (such as gypsum board ceiling.) Table 3d gives the R-values of air layers next to the interior and exterior surface of the roof. The inverse of the total R-value is the U-factor for the assembly. If the calculated U-factor exceeds 0.050, you will need additional insulation to meet the prescriptive requirement. The following figure is an example of a typical U-factor calculation for a roof taken from Worksheet 3b of the energy code compliance forms.

Roof Assembly 1 - ID Flat Roof Over Gym

(a) Layer	(b) Description	(c) Detail	(d) R-value
Exterior	Moving Air		0.17
A	Roofing	Roofing built-up	0.33
B	Rigid Insulation	Cellular polyisocyanurate 1" unfaced, 1.5 lb/ft3	5.56
C	Roof/Floor Framing/Insulati	Roof/Floor Engineered Wood Comp. I-Beam 48" o.c. R-13	12.70
D	Interior Finish	Hardwood Maple 1"	0.88
I			
J			
Interior	Still Air		0.61
1. Total column (d)			20.25

Continues on page 2

Code Language

1312.1.1 Air leakage. Penetrations or through openings in the building envelope that are potential sources of air leakage shall be caulked, gasketed, or weatherstripped, or otherwise sealed to limit infiltration and exfiltration.

Doors and operable glazing separating conditioned from unconditioned spaces shall be weatherstripped. Fixed windows and sash in operable windows shall be tightfitting with glass retained by stops with a continuous air seal.

Exception: Openings required to be fire resistant. Building assemblies used as ducts or plenums shall be sealed, caulked and gasketed to limit air leakage.

Exterior joints around windows and door frames, between wall cavities and window or door frames, between wall and foundation, between wall and roof, between wall panels, at penetrations or utility services through walls, floors and roofs and all other openings in the exterior envelope shall be sealed in a manner approved by the building official.

1312.1.2 Insulation materials and installation. All insulation materials shall be installed according to the manufacturer's instructions to achieve proper densities, maintain clearances and maintain uniform R-values. Access to equipment shall be provided which prevents damaging or compressing the insulation. Refer to section 1312.2 for performance requirements.

To the maximum extent possible, insulation of the required R-value shall extend over the full component area.

Exception: Access doors and hatches from conditioned spaces to unconditioned spaces.

Documentation: To document compliance with this section of code, fill out Compliance Form 3a.

In addition:

- **Prescriptive Approach:** Form 3b with the appropriate associated worksheets.
- **Simplified Trade-Off Approach:** Submit a disk with the Code-Comp file on it. This file can be found in the GDT\CodeComp\Project directory with an .occ file extension.
- **Whole Building Design Approach:** Call Oregon Dept. of Energy for information on complying via the Whole Building Design Approach.

Code Language continues on page 2

Code Language continued from page 1

1312.1.2.1 Suspended ceilings. Suspended ceilings shall not be used to separate conditioned spaces from unconditioned spaces.

1312.1.2.2 Recessed light fixtures. Recessed light fixtures shall not be installed in ceilings separating conditioned from unconditioned spaces.

Exception: Fixtures designed and labeled as suitable for being installed in direct contact with insulation (i.e., IC rated)

1312.1.4 Moisture control. A 1-perm vapor retarder shall be installed on the warm side (in winter) in all exterior floors, walls and ceilings of heated buildings.

Exceptions:

1. Masonry walls with exposed interior surfaces. Slab-on-grade floors need not have a warm-side vapor barrier.
2. The building official may require designed moisture control systems for refrigerated buildings, buildings convering swimming pools or similar buildings with unusual potential for moisture damage.
3. The building official may accept designed moisture control systems which may include vapor barriers, ventilation, dehumidification or combinations thereof.

A ground cover shall be installed in the crawl space for both new and existing buildings when insulation is installed. Ground cover shall be 6-mil black polyethylene or other approved material of equivalent perm rating. Ground cover shall be lapped 12 inches (305 mm) at all joints and over the entire surface area extending full width and length of the crawl space.

1312.2 Thermal performance. All heated or mechanically cooled buildings and structures, or portions thereof, shall be constructed so as to provide the required thermal performance of the various components as set forth in this subsection.

Exception: Glazing up to 1 percent of the exterior wall area is exempt from the U-factor and shading coefficient requirements of this code.

Buildings shall comply by using either Section 1312.2.1 or 1312.2.2.

1312.3.1 Additions. Additions shall meet all requirements that apply to new buildings.

Exceptions:

1. Additions of the same use and occupancy classification as the existing building which increase floor area up to 10 percent of the existing building area, not to exceed 1,000 square feet (93 m^2), if the component U-factors, including glazing, are equal to or less than corresponding U-factors in the existing building.

Code Language continues on **page 3**

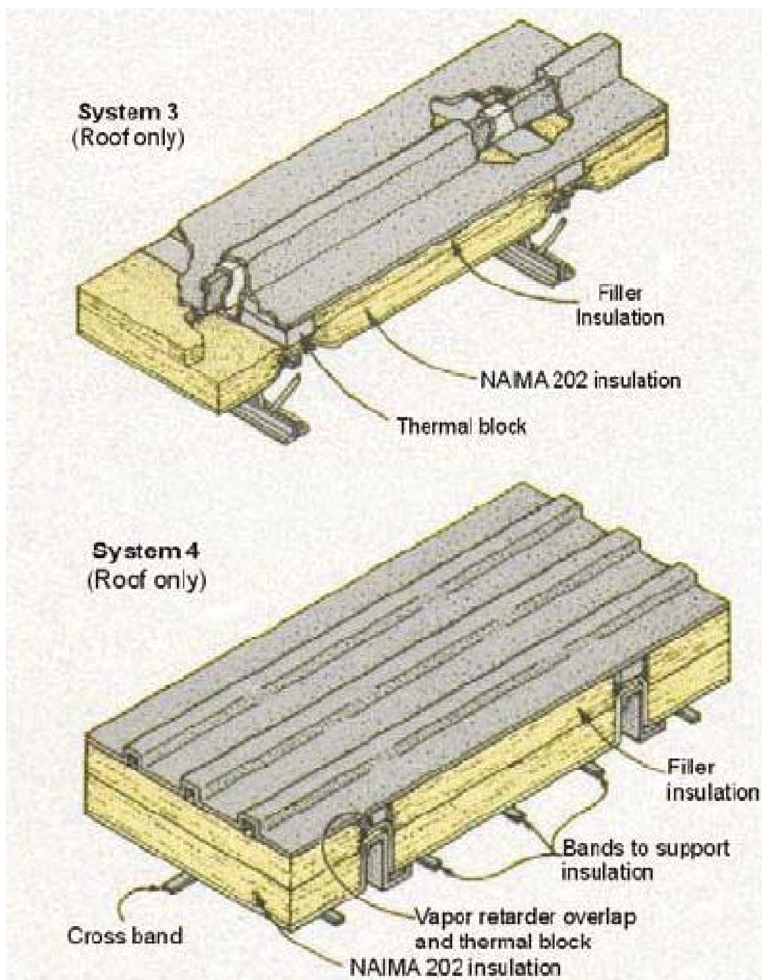
Continued from page 1

Providing continuous insulation is an effective way to improve thermal performance. It also can serve as an air barrier and vapor barrier. Common types of continuous insulation include expanded polystyrene foam (bead board) or polyisocyanurate foam. "Polyiso" foam has a higher R-value per inch of thickness than polystyrene foam, but its performance deteriorates over time more rapidly.

Metal Framed Roofs and Metal Buildings

While metal framed rafter or attic roofs may comply with prescriptive insulation R-value requirements, they would require additional insulation to meet the prescriptive U-factor requirement. In addition to batt insulation installed between the rafters, the assembly will typically include continuous rigid insulation at the ceiling or rigid foam thermal block material over the steel framing.

There are several insulation options for metal building roofs. The North American Insulation Manufacturers Association (NAIMA) provides information on insulation types and representative U-factors. Although the use of R-19 NAIMA-202 insulation will meet the prescriptive requirement, the installation method affects thermal performance. When possible, use a system that avoids compression of the insulation at the framing members and includes rigid foam thermal blocks at the framing members. The insulation can be installed either on top of and perpendicular to the framing



Continues on **page 3**

Continued from page 2

members, or between the metal purlins. The placement of rigid foam thermal blocks on top of the purlins will prevent thermal bridging across framing members. Default U-factors for metal building roof assembly are found in Table 3c of the Non-Residential Energy Code compliance manual.

Other Compliance Options

In most cases, the roof assembly should meet the prescriptive requirement. However, if neither the insulation R-value nor the U-factor meet the requirement, the simplified tradeoff method may be used to demonstrate compliance (see the Envelope Compliance Methods fact sheet for more information).

Moisture Control

Oregon code requires a vapor retarder to be installed on the "winter warm" side of the roof assembly. For all Oregon climates this is the interior of the assembly. Materials with a low permeance rating (generally lower than 1 perm) (57 ng/s-m^2-Pa), are considered vapor retarders. Vapor retarders can either be film materials such as asphalt coated kraft paper, aluminum foil or polyethylene sheet, or closed-cell insulation materials such as extruded polystyrene. Asphalt coated kraft paper, asphalt-impregnated felt, are both wood-based materials and perform very differently than foil and polyethylene. While the performance of polyethylene and foil in resisting vapor diffusion is independent of the relative humidity of the surrounding air, wood-based materials such as kraft paper, asphalt-impregnated felt, and oriented strand board increase their perm rating with an increase in the humidity of the adjacent air. This allows more water vapor to pass through the material, allowing increased drying when needed.

New synthetic materials, resistant to mold and rot, have been formulated to perform in a similar way and are called "smart" vapor retarders. These new materials are specially formulated to act as vapor retarders when the RH drops indoors in the winter, yet allow drying through them during warm, humid outdoor conditions.

Suspended Ceilings

As outlined in Section 1312.1.2.1, Oregon code does not allow suspended ceilings "to be used to separate conditioned spaces from unconditioned spaces." In other words, batt insulation on a suspended ceiling cannot be used to create the thermal envelope of the building. This is because air moves relatively freely from a room to a space above a suspended ceiling. Insulation above suspended ceiling tiles is often moved around and not replaced as tiles are moved for access to the space above the ceiling. Insulation can be placed on the tiles for sound attenuation purposes, but if it is, code minimum insulation must also be placed at the roof.

Demising Surfaces

In Oregon code, demising surfaces are defined as, "A building element consisting of walls, windows, doors, floors, or ceilings that

Continues on **page 4**

Code Language continued from **page 2**

2. Additions which have glazing areas and/or skylight areas exceeding the maximum allowed under the prescriptive path and meet all of the following requirements:
   - 2.1 The maximum height of the addition shall not exceed 20 feet (6.1 m^2) measured from the ground floor.
   - 2.2 The maximum floor area of the addition shall not exceed 3,000 square feet (279 m^2) or 15 percent of the existing building ground floor area, whichever is less.
   - 2.3 The center-of-glass U-factor shall not exceed 0.30, tested or calculated on the vertical plane,
   - 2.4 The shading coefficient for overhead glazing shall not exceed 0.40, the shading coefficient for vertical glazing shall not exceed 0.57,
   - 2.5 At least 25 percent of the gross area of the exterior wall of the addition shall have a U-factor not to exceed 0.13 in Zone 1 and 0.09 in Zone 2, and
   - 2.6 Any opaque roof/ceiling portions shall have a U-factor not to exceed 0.05 or an insulation value not less than R-19.

Examples

Q I have a wood-framed 2x4 rafter roof, with only R-13 batt insulation. Can I still use the prescriptive compliance method?

A Only if the U-factor does not exceed 0.050. From Table 3A of the compliance manual, a 2x4 wood-framed roof, with framing 24" o.c and R-13 insulation, the effective R-value of the framing with insulation is 9.36. A continuous insulation with an R-value of R-10 or greater will meet the prescriptive U-factor requirement:

$$R_{roof} = R_{(exterior\ air\ resistance)} + R_{(framing/insulation)} + R_{(continuous\ insulation)} + R_{(Interior\ air\ res)}$$
$$= 0.17 + 9.36 + 10 + 0.61 = 20.14$$
$$U_{roof} = 1/R_{roof} = 1 / 20.14 = 0.0497$$

Adding rigid insulation having an R-value of 6 or greater will comply with the prescriptive R-value requirement:

R-13 batt insulation + R-6 rigid insulation = Total R-19 insulation.

Q My building has a cool roof. Can I get credit for using this technology?

A No. While code does not provide any credit for a cool roof, it may still be beneficial to use this system.

Examples

Q I am replacing a leaky roof membrane. The rigid insulation will be exposed when I remove the leaky membrane, and is only R-10. Do I need to add insulation to bring it up to current code requirements (R-19)?

A Yes, alterations to existing roofs must meet current code requirements. An exception to this requirement is if the existing insulation is not exposed by the re-roofing project (for instance when insulation is below roof deck).

Q I am installing rigid insulation on my roof that will be sloped to allow proper drainage. The insulation at its thickest point is equivalent to R-25 and at its thinnest R-15. It averages out to R-20. Does this comply since the average is greater than the R-19 prescriptive minimum?

A No. Prescriptive R-values are minimum values. If the roof insulation is sloped it must be R-19 at its thinnest point.

Q My building has a metal building roof. R-19 insulation is installed between the purlins so as not to compress the insulation. According to Table 3C, the U-factor for this assembly is 0.079. Does this assembly still meet the prescriptive requirement?

A Yes. Even though the calculated U-factor is higher than 0.050, since R-19 insulation is installed, the assembly complies.

Find Out More

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12/05 ODOE CF-125/Fact Sheet 6

Non-residential code ENVELOPE fact sheets include:

- Envelope Compliance Approaches
- Fenestration Performance
- Walls
- Roofs

Continued from page 3

separates conditioned space from either unconditioned or semi-conditioned space(s).”

Oregon code requires that demising elements are treated the same as exterior walls, and must meet building envelope requirements according to Section 1312.1.

Additions

Additions must meet the same requirements as a new building with a few exceptions. Small additions are one exception to this rule. Specifically, your addition is exempt if it is:

- 10% or less the size of the existing building (no more than 1,000 ft^2),
- of the same use/occupancy, and
- with U-factors equal to or less than the existing building.

Alterations

Alterations must comply with the requirements of the code.

If you open up a roof, you must ventilate it according to Section 1203.2 and insulate it according to Tables 13-E and 13-F. If a roof alteration exposes the roof insulation, it must be brought up to current code requirements.

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Walls

The construction of exterior walls affects comfort, operating costs, acoustic separation, and the size of heating and cooling systems. Oregon Department of Energy Code includes a variety of requirements to ensure that walls are an efficient part of the building envelope.

Prescriptive Approach

The easiest way to comply is to use insulation that meets the minimum R-value requirements for walls in Table 13-E (if you are in Zone 1) or Table 13-F (if you are in Zone 2). Wall requirements from these tables are shown below.

There are different requirements depending on the class of wall (frame, masonry with interior, exterior, or integral insulation) and the glazing fraction of the building.

No averaging or tradeoffs are allowed. For example, if one portion of the wall is masonry and another framed, each portion must comply on its own.

Zone 1 Prescriptive Requirements for Walls
(From Table 13-E of the Oregon Energy Code)

Wall Construction	Maximum Glazing Fraction	Maximum Component U-Factor		Minimum R-Value
Masonry, with integral insulation*	15%	0.300		
Masonry, with integral insulation**	40%	0.210		
Masonry or concrete, with interior insulation	40%	0.130	or	11
Masonry or concrete, with continuous exterior insulation	15%	0.300	or	1.4
Masonry or concrete, with continuous exterior insulation	40%	0.210	or	2.8
Frame	40%	0.130	or	13
Other	40%	0.130	or	13
Below-grade walls		0.110	or	7.5

* All cores to be filled. At least 50% of cores must be filled with vermiculite or equivalent fill insulation.

** All cores except bond beams must contain rigid insulation inserts approved for use in reinforced masonry walls.

Continues on **page 2**

Code Language

1312.1.1 Air Leakage. Penetrations or through openings in the building envelope that are potential sources of air leakage shall be caulked, gasketed, or weatherstripped, or otherwise sealed to limit infiltration and exfiltration.

Exception: Openings required to be fire resistant.

Building assemblies used as ducts or plenums shall be sealed, caulked, and gasketed to limit air leakage.

Exterior joints around windows and door frames, between wall cavities and window or door frames, between wall and foundation, between wall and roof, between wall panels, at penetrations or utility services through walls, floors, and roofs, and all other openings in the exterior envelope shall be sealed in a manner approved by the building official.

1312.1.2 Insulation materials and installation. All insulation materials shall be installed according to the manufacturer's instructions to achieve proper densities, maintain clearances and maintain uniform R-values. Access to equipment shall be provided which prevents damaging or compressing the insulation. Refer to Section 1312.2 for performance requirements.

To the maximum extent possible, insulation of the required R-value shall extend over the full component area.

1312.1.2.3 Batt insulation. Wall batt insulation shall be installed flush with the heated side of the cavity.

1312.1.4 Moisture control. A 1-perm vapor retarder shall be installed on the warm side (in winter) in all exterior floors, walls and ceilings of heated buildings.

Code Language continues on **page 2**

Documentation: To document compliance with this section of code, fill out Compliance Form 3a.

In addition:

- **Prescriptive Approach:** Form 3b with the appropriate associated worksheets.
- **Simplified Trade-Off Approach:** Submit a disk with the CodeComp file on it. This file can be found in the GDT\CodeComp\Project directory with an .occ file extension.
- **Whole Building Design Approach:** Call Oregon Dept. of Energy or information on complying via the Whole Building Design Approach.

Code Language continued from **page 1**

Exceptions:

1. Masonry walls with exposed interior surfaces.
2. The building official may require designed moisture control systems for refrigerated buildings, buildings covering swimming pools or similar buildings with unusual potential for moisture damage.
3. The building official may accept designed moisture control systems which may include vapor barriers, ventilation, dehumidification or combinations thereof.

1312.2 Thermal performance. All heated or mechanically cooled buildings and structures, or portions thereof, shall be constructed so as to provide the required thermal performance of the various components as set forth in this subsection.

Exception: Glazing up to 1 percent of the exterior wall area is exempt from the U-factor and shading coefficient requirements of this code.

Buildings shall comply by using either Section 1312.2.1 or 1312.2.2.

1312.3 Additions and alterations.

1312.3.1 Additions. Additions shall meet all requirements that apply to new buildings.

Exceptions:

1. Addition of the same use and occupancy classification as the existing building which increase floor area up to 10 percent of the existing building area, not to exceed 1,000 square feet (93 m^2), if the component U-factors, including glazing, are equal to or less than corresponding U-factors in the existing building.
2. Additions which have glazing areas and/or skylight areas exceeding the maximum allowed under the prescriptive path and meet all of the following requirements:
   - 2.1 The maximum height of the addition shall not exceed 20 feet (6.1 m) measured from the ground floor area.
   - 2.2 The maximum floor area of the addition shall not exceed 3,000 square feet (279 m^2) or 15 percent of the existing building ground floor area, whichever is less.
   - 2.3 The center-of-glass U-factor shall not exceed 0.30, tested or calculated on the vertical plane,
   - 2.4 The shading coefficient for overhead glazing shall not exceed 0.40, the shading coefficient for vertical glazing shall not exceed 0.57,
   - 2.5 At least 25 percent of the gross area of the exterior wall of the addition shall have a U-factor not to exceed 0.13 in Zone 1 and 0.09 in Zone 2, and

Code Language continues on **page 3**

Continued from page 1

Zone 2 Prescriptive Requirements for Walls
(From Table 13-F of the Oregon Energy Code)

Wall Construction	Maximum Glazing Fraction	Maximum Component U-Factor		Minimum R-Value
Masonry, with integral insulation*	15%	0.300		
Masonry, with integral insulation**	33%	0.160		
Masonry or concrete, with interior insulation	33%	0.090	or	13
Masonry or concrete, with continuous exterior insulation	15%	0.270	or	1.8
Masonry or concrete, with continuous exterior insulation	33%	0.160	or	4.3
Frame	33%	0.090	or	19
Other	33%	0.090	or	19
Below-grade walls		0.110	or	7.5

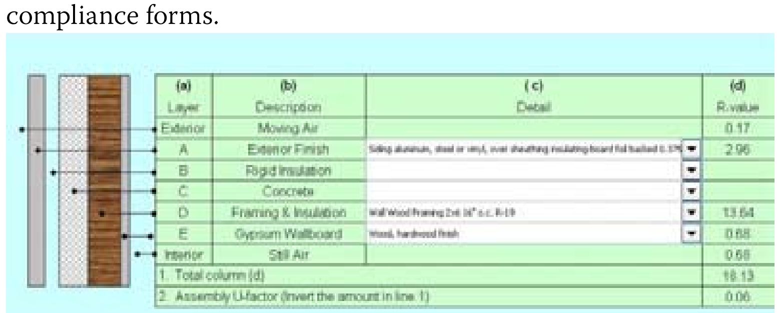
* All cores to be filled. At least 50% of cores must be filled with vermiculite or equivalent fill insulation.

** All cores except bond beams must contain rigid insulation inserts approved for use in reinforced masonry walls.

U-factor Calculation

If the wall insulation R-value doesn't meet the requirements in the tables above, then calculate the U-factor of the assembly on Worksheet 3b of the compliance documentation (this worksheet is not required to be completed if insulation R-value is used to demonstrate compliance).

The first step is to determine the effective R-value of the various components of the wall. Table 3a provides effective R-values for a variety of wall framing and insulation assemblies, including wood framing and metal framing. Table 3b gives insulation R-values of other common components of the wall assembly (such as gypsum wall board.) Table 3d gives the R-values of air layers next to the interior and exterior surfaces of the wall. The inverse of the total R-value is the U-factor for the assembly. If the calculated U-factor of the wall does not meet the requirements in the tables above, you will need additional insulation to meet the prescriptive requirement. The figure below is an example of a typical U-factor calculation for a wall taken from Worksheet 3b of the energy code compliance forms.



Continues on **page 3**

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Providing continuous insulation is an effective way to improve thermal performance. It also can serve as an air barrier and vapor barrier. Common types of continuous insulation include expanded polystyrene foam (bead board) or polyisocyanurate foam. “Polyiso” foam has a higher R-value per inch of thickness than polystyrene foam, but its performance deteriorates over time more rapidly.

Other Compliance Options

If you can not meet prescriptive requirements for walls as shown above, the Simplified Trade-Off may be used to demonstrate compliance (see the Envelope Compliance Methods fact sheet for more information).

Moisture Control

As with exterior floors and ceilings, exterior walls of heated buildings must have a 1-perm vapor retarder installed on the warm side (in winter) (Section 1312.1.4). For all Oregon climates this is the interior of the assembly. Vapor retarders can either be film materials such as asphalt coated kraft paper, aluminum foil or polyethylene sheet, or closed-cell insulation materials such as extruded polystyrene. Asphalt coated kraft paper, asphalt-impregnated felt, are both wood-based materials and perform very differently than foil and polyethylene. While the performance of polyethylene and foil in resisting vapor diffusion is independent of the relative humidity of the surrounding air, wood-based materials such as kraft paper, asphalt-impregnated felt, and oriented strand board increase their perm rating with an increase in the humidity of the adjacent air. This allows more water vapor to pass through the material, allowing increased drying when needed. New synthetic materials, resistant to mold and rot, have been formulated to perform in a similar way and are called “smart” vapor retarders. These new materials are specially formulated to act as vapor retarders when the RH drops indoors in the winter, yet allow drying through them during warm, humid outdoor conditions.

Demising Surfaces

In Oregon code, demising surfaces are defined as, “A building element consisting of walls, windows, doors, floors, or ceilings that separates conditioned space from either unconditioned or semi-conditioned space(s).”

Oregon code requires that demising walls must meet building envelope requirements:

General Exceptions to Insulation Requirements

1. Exterior wall insulation is not required in semi-conditioned spaces, which are defined as spaces that have a limited heating system output capacity that:
   - Does not exceed 15 Btu/hr ft^2 (47 W/m^2) or 4 W/ft^2 (47 W/m^2) of heated floor area (Climate Zone 1) or

Continues on **page 4**

Code Language continued from **page 2**

2.6 Any opaque roof/ceiling portions shall have a U-factor not to exceed 0.05 or an insulation value not less than R-9.

1312.3.2 Alterations. Alterations to the building envelope shall meet the prescriptive requirements of the code. Exterior wall, roof and floor cavities opened or created during alteration shall be ventilated as required by Section 1505.3 and insulated as required by Table 13-E and 13-F or to the full depth of the cavity, whichever is less.

Exceptions:

1. When up to 25 percent of the glazing in any one wall is being replaced, it may be replaced with glazing with a U-factor and shading coefficient equal or better than the existing glazing.
2. Walls and floors without framing cavities need not be insulated.

The addition of heating to an unconditioned space shall require that the entire roof and one-half the opaque wall area meet or exceed the prescriptive path standards described in Section 1312.2.1. The addition of cooling to a heated space does not initiate any requirements to improve the envelope.

Examples

Q **My space is only freeze-protected. Am I exempted from envelope requirements?**

A No, but it may be exempt from exterior wall insulation if your space, meets **requirements** for a semi-conditioned space as defined by Oregon Code: “Spaces that have a limited heating system output capacity that does not exceed the values listed below, and where each heating system is controlled by a thermostat with a maximum setpoint capacity of 45°F (7°C), mounted no lower than heating unit for convection systems or below the heating unit for radiation systems.

Climate Zone 1: 15 Btu/hr ft^2 (47 W/m^2) or 4 W/ft^2 (47 W/m^2) of heated floor area.

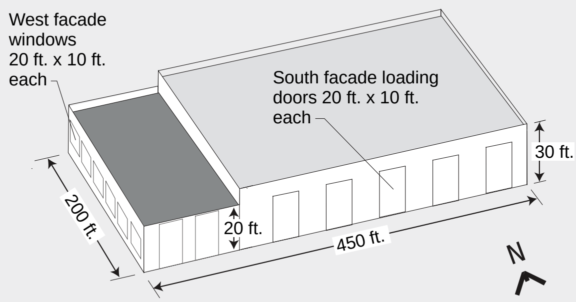
Climate Zone 2: 20 Btu/hr ft^2 (47 W/m^2) or 5.86 W/ft^2 (47 W/m^2) of heated floor area.”

Q **I have a wall that is partially below grade. What’s the insulation requirement?**

A You are allowed to install less insulation on a below-grade wall. The above grade wall requirements are more stringent. However, most people meet above grade requirements for ease of design and construction.

Examples

Q We have an office next to a n unconditioned warehouse.



Do we need to comply?

A Since the office is considered a conditioned space and the warehouse an unconditioned space, the wall separating the two is defined as a demising wall. Therefore, the office must comply with the code requirements.

Q Can I construct a CMU wall without insulation?

A No, but it will comply if at least 50% of the cells are un-grouted and filled with insulation. If the glazing fraction is 15% or less, the fill insulation may be loose-fill vermiculite. If the glazing fraction is greater than 15% (up to the maximum glazing fraction allowed), the fill insulation must be rigid insulation inserts approved for use in masonry walls.

Find Out More

Copies of Code:
Oregon Building Officials Association
phone: 503-873-1157 fax: 503-373-9389

Technical Support:
Oregon Department of Energy
625 Marion Street NE phone: 503-378-4040
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Northwest Energy Efficiency Alliance
www.nwalliance.org

Photo on page 1 c/o Warren Gretz, DOE/NREL

12/05 ODOE CF-125/Fact Sheet 7

Non-residential code ENVELOPE fact sheets include:

- Envelope Compliance Approaches
- Fenestration Performance
- Walls
- Roofs

Continued from page 3

20 Btu/hr ft² (63 W/m²) or 5.86 W/ft² (63 W/m²) of heated floor area (Climate Zone 2).

- Has each heating system controlled by a thermostat with a maximum setpoint capacity of 45°F (7°C)
- Is mounted no lower than heating unit for convection systems or below the heating unit for radiation systems.

2. Exterior wall insulation and doors in spaces enclosed in Group S, Division 3 Occupancies or Group H, Division 4 Occupancies, motor vehicle service station occupancies where each heating system is controlled by a thermostat with a maximum set point of 55°.
3. Windows installed in demising walls need not meet the shading coefficient requirements of this section.
4. Buildings whose sole source of space conditioning energy is from on-site solar or wind resources.
5. Greenhouses intended primarily for plant propagation.

Additions

Additions must meet the same requirements as a new building with a few exceptions. Small additions are one exception to this rule. Specifically, your addition must be:

- 10% or less the size of the existing building (no more than 1,000 ft²),
- of the same use/occupancy, and
- with U-factors equal to or less than the existing building.

Another exception is if you exceed the amount of glazing area allowed under the prescriptive requirements (more than 40% in Zone 1, and more than 33% in Zone 2). If the addition exceeds the maximum glazing area and a host of other criteria listed in the code language above are met, it is excepted.

Alterations

Alterations must comply with the requirements of the code.

Opening up a cavity or adding a new wall cavity to an existing un-insulated wall requires insulation as required by Tables 13-E and 13-F or to the full depth of the cavity, whichever is less.

Walls and floors without framing cavities are exempted from this requirement.

Examples

Q I am converting an old, heated warehouse to office space. I will be furring out the CMU exterior walls and adding interior finished wall board. Do I need to insulate the walls?

A Yes, since you are creating a wall cavity it must be filled with insulation to the prescriptive requirements of Table 13 E or F, or to the full depth of the cavity, whichever is greater.

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Fenestration Performance

This Factsheet provides information on how to comply with window and skylight requirements of the Oregon Energy Code. This Factsheet focuses on the Prescriptive Compliance Method.

Window Performance

An important facet of an energy-efficient building envelope is the performance of the windows and skylights. It is also an area of the Oregon Energy Code that is often misunderstood. The Code includes prescriptive requirements for thermal performance (maximum U-factor and Shading Coefficient (SC)) as well as limitations on the maximum glazing fraction. These requirements differ depending on the type of opaque wall assemblies in the building and the climate zone the project is located in (Zone 1 or Zone 2). Requirements apply to windows and skylights, including site-built fenestration, curtain walls and glazed portions of doors with leaf width greater than four feet (including sliding glass doors). It is important to understand that the U-factor requirements are for the entire window assembly including glazing and framing and not just for the glass itself. Using center-of-glass performance for U-value will significantly overestimate the window performance. Unlike the U-factor, the SC may be determined as a center-of-glass value. Prescriptive code requirements are summarized in Table 1 - Prescriptive Fenestration Requirements.

Climate Zone 1 The Code allows a glazing fraction of up to 40% if high thermal performance windows are matched with a well-insulated wall. For example, if the building uses a frame wall with R-13 insulation, windows with overall U-factor of 0.37 or better, and an SC of 0.35 or better, the maximum glazing fraction is 40%. If the building uses masonry walls with integral insulation (CMU with filled cores), and windows with a maximum U-factor of 0.54 and maximum SC of 0.57, the maximum allowable glazing fraction is only 15%. Regardless of the type of wall construction, the window thermal performance requirements vary with the glazing percentage. For any glazing percentage up to 30%, the windows must have a maximum U-factor of 0.54 and a maximum SC of 0.57. For a glazing percentage between 30% and 40% (when wall construction allows), the windows must have a maximum U-factor of 0.37 and a maximum SC of 0.35.

Climate Zone 2 The Code allows a glazing fraction of up to 33% if high thermal performance windows are matched with a well-insulated wall. For example, if the building uses a frame wall with R-19 insulation, window with overall U-value maximum of 0.37, and maximum SC of 0.43, the maximum glazing fraction is 33%. If the building uses masonry walls with integral insulation (CMU with filled cores) and windows with a maximum U-factor of 0.50 and

Continues on **page 2**

Code Language

1312.1.3 Windows and doors. All windows shall comply with this section. Refer to Section 1312.2 for performance requirements.

Exceptions:

1. Code-required fire doors and windows.
2. Windows in exterior walls up to 1 percent of the exterior wall area.

1312.1.3.1 U-factors. U-factors for exterior windows and doors shall include the effects of the window frame and shall be determined using the commercial size category values listed in Chapter 30, 2001 *ASHRAE Handbook of Fundamentals*, Table No. 4, or rated according to the National Fenestration Rating Council (NFRC) 100-2001 Version 2 *Procedure for Determining Fenestration Product Thermal Performance.* U-factors shall be certified through the NFRC Fenestration Thermal Performance Rating Certification and Labeling Program.

1312.1.3.2 Shading coefficient. For calculations, opaque portions of doors shall have a shading coefficient of zero. Shading coefficients for glazing shall be taken from Chapter 30, 2001 *ASHRAE Handbook of Fundamentals*; or manufacturers' test data; or certified according to NFRC 200-2001 Edition *Procedure for Determining Solar Heat Gain Coefficient* (SHGC) at normal incidence. The center of glass values for the shading coefficient at normal incidence may be converted from the SHGC by dividing the SHGC by a factor of 0.87. SHGC shall be certified through the NFRC Certification and Labeling Program.

1312.1.3.3 Certification and labeling. Windows shall be certified and labeled according to the procedures specified in Sections 1312.1.3.1 and 1312.1.3.2.

Continues on **page 2**

Documentation:

To document compliance with this section of code, fill out Compliance Form 3a. Window Schedule information is listed on Worksheet 3d; skylight schedule information is listed on Worksheet 3e.

- Prescriptive Method Form 3b with the appropriate associated worksheets.
- Simplified Trade-Off Approach—submit a disk with the . Code-Comp project file on it. This file can be found in the GDT\Code-Comp\Project directory with a .occ file extension name on it.
- Whole Building Design Approach—Call Oregon Dept. of Energy for information on complying via the Whole Building Design Method.

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Windows shall have a temporary label not to be removed before inspection.

Exception:

Site-built windows shall have a single certificate specifying glazing type, special coatings, spacers, gas fills, center-of-glass and overall U-factor, and center-of-glass shading coefficient for every type of site-built glass used. These certificates shall be maintained on the job site and made available to the inspector.

Examples

Q **A small waterfront restaurant along the coast has a west-facing curtain wall with a view of the ocean. The plan for clear glazing would not meet prescriptive window SHGC requirements. Can an overhang be used as a prescriptive alternative to reduce the effective solar heat gain through the window?**

A No. The prescriptive code requirement specifies the center-of-glass shading coefficient for the fenestration, and does not account for effects of exterior (or interior) shading. If the other facades have a low window area, the building may still comply using the Simplified Tradeoff Approach.

Q **My building uses roof monitors for daylighting. Is this treated as a skylight or window? Is this counted in the window glazing fraction?**

A The roof monitor features vertical glazing above the main roofline. The fenestration in a roof monitor should be entered as a window since it is oriented vertically. This should be counted towards the window glazing fraction.

Q **How is a sawtooth monitor classified – as a window or as a skylight?**

A These feature vertical glazing and a sloped roof surface. It should be entered as a window since it is oriented vertically.

Continued from page 1

maximum SC of 0.57, the maximum glazing fraction is only 15%. Regardless of the type of wall construction, the window thermal performance requirements differ based on the glazing percentage. For any glazing percentage up to 25%, the windows must have a maximum U-factor of 0.50 and a maximum SC of 0.57. For a glazing percentage between 25% and 33% (when wall construction allows), the windows must have a maximum U-factor of 0.37 and a maximum SC of 0.43.

Compliant Window Assemblies

There are three allowed sources of window and skylight performance data: tabulated default values in the ASHRAE Handbook of Fundamentals, National Fenestration Council (NFRC) ratings, or documentation of a compliant minimum assembly (MA). The source of information is listed on the Window Schedule (Worksheet 3d) and Skylight Schedule (Worksheet 3e).

ASHRAE Default. Most of the relevant information in the ASHRAE Handbook of Fundamentals is included in Tables 3e and 3f of the Oregon compliance documentation. Table 3e shows default window U-factors for operable windows, fixed windows and curtain wall windows. If this option is used, each specific window component – frame type and operator, glass type (airspace, low-e, argon gas filled, etc) – must be specified on the project plans or in its documented specifications. If the center-of-glass U-factor and shading coefficient is known and specified, it is acceptable to extrapolate the overall window U-factor from this table. Worksheet 3d of the envelope compliance form performs this calculation automatically (if the Excel version is used).

NFRC Rating. The NFRC provides certification for window thermal performance: U-factor and Solar Heat Gain Coefficient. The NFRC 100 test procedure yields a U-factor rating for the entire window assembly, including framing. The NFRC 200 test procedure produces a rating for solar heat gain coefficient (SHGC). The solar heat gain coefficient (SHGC) is a ratio of the solar energy admitted through the window to the amount that falls on the window surface. A low SHGC is important in reducing cooling energy and is especially important on south and west facing glazing. The solar heat gain coefficient can be converted to shading coefficient by dividing SHGC by 0.87. Visible transmittance (also referred to as visible light transmittance or VLT) is also provided for daylight assessment. Windows used for daylighting should have a high VLT and low solar heat gain coefficient (SHGC). Spectrally selective "low e" coatings are ideal for daylighting applications: they allow visible light to pass while reducing solar heat gain. While not explicitly required by code, a best practice for daylighting windows includes a "light to solar gain" ratio (the VLT divided by the SHGC) of 1.25 or greater. If the NFRC method of compliance is chosen, the project plans or specifications must indicate that the window is NFRC certified and meets the minimum required performance levels.

Minimum Assembly. The third method of documenting window performance is to indicate that the window meets the minimum assembly requirements listed in the code. For example, in Climate Zone 1, double-glazed windows with a ½" air space, low-e coating and aluminum frame will meet the minimum assembly require-

Continues on **page 3**

Continued from page 2

ment for fixed windows in buildings with a maximum glazing fraction of 30%. The same building using operable windows or curtain walls requires a frame with a thermal break. A thermal break is an insulating spacer in the frame that reduces the heat transfer across the frame. Aluminum frames in particular will have a thermal "bridging" effect: heat is transferred through the frame at a high rate. If the glazing fraction exceeds 30% (for buildings with wall types that allow this percentage), the minimum assembly becomes more stringent. An example of a compliant assembly is a double-glazed fixed window with a low-e coating and minimum 1/2" argon-filled space. Operable windows and curtain wall assemblies do not qualify for the minimum assembly path when the glazing fraction is above 30% (25% in Zone 2).

Metal curtain walls, commonly used in high-rise buildings, differ in performance from "fixed" metal-framed windows. The heat transfer is affected by the aluminum spacer between panels and the steel screws used to secure the panel to the frame. Consequently, curtain walls have a relatively poor thermal performance, compared to fixed windows with the same type of glazing.

Skylights

To comply with the Oregon Code prescriptive requirements, the skylight area must be no greater than 6% of the entire roof area over the conditioned space. If the skylight area exceeds this limit, the Simplified Tradeoff Approach must be used. The same limit applies separately to semi-conditioned spaces and mechanical penthouses. Skylight area covers the rough opening area including the skylight framing.

Each skylight must meet performance requirements for U-factor and Shading Coefficient (SC). These requirements can be documented by the same three different methods discussed above: through NFRC-certification, by using the ASHRAE default tables, or by meeting the Minimum Assembly requirement. For Minimum Assembly, any double-glazed skylight with a half-inch airspace will meet the U-factor requirement. There is no Minimum Assembly that meets the SC requirement for skylights. Tinting of one of the panes is typically required to meet the prescriptive SC requirement of 0.47. It is important to note that a window assembly will have a higher U-factor when oriented horizontally. If NFRC rating data is available for vertical fenestration assembly, a conversion can be made to determine an effective U-factor for the same assembly used as a skylight. U-factors for vertically oriented surfaces can be used when the glazing is mounted within 30° of the vertical plans.

Skylight U-Factor (horiz.) = 0.08 + 1.62 x U-Factor (vert.)

Other factors will influence the design and selection of skylights. The visible light transmittance of the skylight, its diffusing properties, and the design of the skylight well all affect how daylighting is distributed to the space.

Site-Built Fenestration

All site-built fenestration must include a certificate specifying the glazing type, type of coatings, spacers and fills, the center-of-glass U-factor, overall window U-factor and center-of-glass shading coefficient for every type of fenestration used. The National Fenestration Rating Council (NFRC) also has developed a rating procedure for site-built fenestration, NFRC 100-SB.

Alterations and Additions

Additions to buildings will comply if they meet the same prescriptive requirements as new buildings. There are two exceptions stated in section 1312.3.1 of the code. First, additions of the same use and occupancy type which increase floor area by no more than the lesser of 10% of the existing building area or 1000 ft^2, if the wall, window and skylight U-factors are equal to or less than the U-factors of the existing building. The second exception is for additions that have skylight or window glazing areas that exceed the prescriptive requirements. For the second exception, the addition will comply only if several requirements are met. The additional floor area cannot exceed the lesser of 15 percent of the existing building's floor area, or 3,000 ft^2. The ceiling height of the addition cannot exceed 20 feet from the ground floor. Also, requirements for center-of-glass U-factor, shading coefficient and exterior wall U-factor must be met, to claim this exception.

Other Compliance Options

If the U-factor or shading coefficient of any of the windows or skylights used in the building fails to meet the prescriptive requirements, the Simplified Tradeoff Approach may be used to demonstrate that the annual heating and cooling loads through the building envelope do not exceed code requirements. Also, buildings with glazing that exceeds the maximum glazing fraction may use the Simplified Tradeoff Approach for compliance. For example, a designer could compensate for using a large window area by specifying high performance windows with very low U-factor and solar heat gain, or by increasing envelope insulation. The CodeComp software is used to document compliance using this approach.

If the building still fails using the Simplified Tradeoff Approach, the Whole Building Approach must be used to demonstrate compliance. The Whole Building Approach requires the use of an approved hourly building energy simulation program – consult the Oregon Department of Energy for details.

Table 1 - Prescriptive Fenestration Requirements

Continues on **page 4**

Examples

Q My building includes mostly steel framed walls with R-13 batt insulation. However, there is a small area of the building constructed of CMU with vermiculite filled cores. There are no windows in the CMU walls, and 25% glazing fraction for framed walls only. The entire building glazing fraction is 22%. My building is in Zone 1. Does it comply prescriptively?

A No. The maximum glazing fraction allowed is determined by the "worst case" wall. In this building, the worst case wall is the CMU wall with integral insulation. Therefore, the maximum glazing fraction for the entire building is 15%, regardless of which wall contains the windows.

Additional Information

1. National Fenestration Rating Council, http://www.nfrc.org.
2. The Efficient Windows Collaborative provides information on the benefits and performance characteristics of high performance window assemblies, http://www.efficientwindows.org.
3. Skylight Design Guidelines, developed by Energy Design Resources is an excellent design resource for skylights, http://www.energydesignresources.com.

Find Out More

Copies of Code:

Oregon Building Officials Association
phone: 503-873-1157 fax: 503-373-9389

Technical Support:

Oregon Department of Energy
625 Marion Street NE phone: 503-378-4040
Salem, OR 97301-3737 toll free: 800-221-8035
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This fact sheet was developed with funding from the Northwest Energy Efficiency Alliance and the US Department of Energy under contract DE-FG51-02R021378.

Northwest Energy Efficiency Alliance
www.nwalliance.org

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12/05 ODOE CF-125/Fact Sheet 8

Non-residential code ENVELOPE fact sheets include:

- Envelope Compliance Approaches
- Fenestration Performance
- Walls
- Roofs

Continued from page 3

Wall / Insulation Type	Maximum Glazing Fraction	Window Max. U-Factor	Window Max. Shading Coefficient
Zone 1			
CMU Masonry, w/integral loose fill insulation	Up to 15%	0.540[1]	0.57[1]
Masonry or concrete, w/cont. exterior insulation			
CMU Masonry, w/integral rigid fill insulation	Up to 30%	0.540[1]	0.57[1]
Masonry or concrete, w/interior insulation			
Masonry or concrete, w/cont exterior insulation			
Frame (wood or metal framing)			
Other (provide short description)			
CMU Masonry, w/integral rigid fill insulation	Up to 40%	0.370[2]	0.35[2]
Masonry or concrete, w/interior insulation			
Masonry or concrete, w/cont exterior insulation			
Frame (wood or metal framing)			
Other (provide short description)			
Zone 2			
CMU Masonry, w/integral loose fill insulation	Up to 15%	0.500[3]	0.57[3]
Masonry or concrete, w/cont. exterior insulation			
CMU Masonry, w/integral rigid fill insulation	Up to 25%	0.500[3]	0.57[3]
Masonry or concrete, w/interior insulation			
Masonry or concrete, w/cont exterior insulation			
Frame (wood or metal framing)			
Other (provide short description)			
CMU Masonry, w/integral rigid fill insulation	Up to 33%	0.370[4]	0.43[4]
Masonry or concrete, w/interior insulation			
Masonry or concrete, w/cont exterior insulation			
Frame (wood or metal framing)			
Other (provide short description)			

1. Prescriptive MA (Minimum Assembly) - For Fixed Windows: double-glazed window with a 0.5 inch air space, low-e coating and aluminum frame. MA shading coefficient description is a tinted outboard pane of glass. For Operable Windows or Curtainwall: double-glazed window with a 0.5 inch air space, low-e coating and thermally broken frame. MA shading coefficient description is a tinted outboard pane of glass.
2. Prescriptive MA (Minimum Assembly) - For Fixed Windows: double-glazed window with a 0.5 inch argon filled space, low-e coating (e<= 0.05) and thermal break frame. For Operable Windows or Curtainwall: only use Max U-Factor. MA shading coefficient description is a 0.25-inch thick glass with low-e coating (e<= 0.05) with a tinted outboard pane.
3. Prescriptive MA (Minimum Assembly) - For Fixed Windows: double-glazed window with a 0.5 inch air space, low-e coating and aluminum frame. For Operable Windows or Curtainwall: double-glazed window with a 0.5 inch air space, low-e coating (e<= 0.1) and thermally broken frame. MA maximum shading coefficient description is a tinted outboard pane of glass.
4. Prescriptive MA (Minimum Assembly) - For Fixed Windows, a double-glazed window with a 0.5 inch argon filled space, low-e coating (e<= 0.05) and thermal break frame. For Operable Windows or Curtainwall, only use Max U-Factor. MA shading coefficient description is a 0.25-inch thick glass with low-e coating (e<= 0.05).

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Simple vs Complex HVAC Systems

This fact sheet distinguishes between simple and complex HVAC systems and describes major code requirements for each type of system.

Simple HVAC Systems

The Oregon Energy Code distinguishes between "simple" and "complex" HVAC systems. Simple HVAC systems include single-package constant volume unitary equipment, small split systems, packaged terminal air conditioners and heat pumps and ground-coupled heat pumps. Single-packaged systems include an evaporator coil and supply fan, compressor, condenser coil and condenser fan in a single package. The system may include gas heating, electric resistance heating or use a reverse refrigeration cycle in a heat pump configuration. Split systems consist of an outdoor unit that includes the compressor, condenser coil and fan, and an indoor section that contains the evaporator coil and indoor fan. A packaged terminal air conditioner or heat pump is specifically designed for a through-the-wall installation, and provides cooling for a single area.

Some larger constant-volume systems can be configured to serve multiple zones through a set of zone dampers and special controls. This type of control system is often referred to as a variable volume and temperature (VVT) control. When a VVT control system is installed on a constant-volume packaged unit, the HVAC unit is considered a complex system.

Control requirements for simple HVAC systems are documented in Section 1317.4 of the code. Requirements include deadband control and automatic setback or shutdown controls during unoccupied periods. Outdoor air shutoff dampers are required for unoccupied periods as well. Simple systems must meet minimum efficiency requirements, which are documented on applicable Worksheets 4a, 4c, 4e, 4f and 4j. The Worksheets specify minimum steady-state and seasonal efficiency requirements for a specific system type. Efficiency of certain equipment, such as electric resistance and radiant (gas and electric) heaters, is not regulated.

Complex HVAC Systems

Any systems that do not meet the requirements of simple HVAC systems under section 1317.9 of the code are considered complex systems. These include variable air volume systems, large split systems, any multizone systems, water-cooled systems and central cooling with chilled water systems. Code requirements for complex systems are found in Sections 1317 and 1318.

Continues on **page 2**

Code Language

1317.9 Simple HVAC Systems. To qualify as a simple system, systems shall be one of the following:

1. Air cooled, constant volume packaged unitary equipment, packaged terminal air conditioners and packaged terminal heat pumps which provide heating, cooling or both and which requires only external connection to ductwork and energy services.

2. Air cooled, constant volume split systems, which provide heating, cooling or both, with cooling capacity of 54,000 Btu/hr (15,827 W) or less.

3. Ground-coupled heat pumps with cooling capacity of 54,000 Btu/hr (15,827 W) or less.

4. Heating only systems which have a capacity of less than 5,000 cubic feet per minute (2,360 L/s) or which have a minimum outside air supply of less than 70 percent of the total air circulated.

1317.10 Complex HVAC systems. Complex HVAC systems shall be all field-fabricated systems and systems constructed of subsystem components and systems not qualifying under Section 1317.9 (Simple Systems).

1317.3.1 Controls. Complex systems shall provide controls as specified in Sections 1317.4 and 1318.2.

1317.3.2 Equipment performance. In addition to the requirements of Section 1317.5, equipment in complex systems shall also comply with Section 1318.3.

1317.10.3 Motor efficiency of electric motors serving built-up HVAC systems (fans, compressors, chillers and pumps). Electric motors, which are NEMA Design A & B squirrel-cage T-frame induction permanently wired poly-phase motors of 1 horsepower or more and which serve built-up HVAC systems, shall have a nominal full-load motor efficiency no less than corresponding values for energy

Documentation:

The type of system (simple or complex) is designated on line 2 of Form 4a. For simple systems, only form 4a and equipment efficiency Worksheets are required. Depending on the specific HVAC system(s), one or more of Worksheets 4a, 4c, 4e and 4f will need to be completed. For packaged units that include gas heating, Worksheet 4j must also be completed.

For complex systems, Forms 4a and 4b are required, along with relevant equipment efficiency Worksheets.

Code Language continued from page 1

efficient motors provided in Table 13-T.

Exceptions:

1. Motors used in systems designed to use more than one speed of a multispeed motor.
2. Factory-installed motors for HVAC equipment meeting the equipment efficiency requirements of Section 1317.1.4.

Examples

Q My building design specifies a 10 ton packaged rooftop air conditioner, with gas heating. It also will include a field-installed economizer and powered exhaust. Since this has a field-installed component, does it fall into the complex system category?

A No. The unit is a constant-volume packaged unitary system and meets all requirements for simple systems. The field installation of the powered exhaust does not make it a complex system.

Q Can a constant volume system serving four classrooms, each with its own thermostat controlling bypass dampers, qualify as a simple HVAC system?

A No. Even though the HVAC system has a constant speed fan, separate controls for each space requires adjustment of the air volume to each space by bypassing some of the supply air back to the unit. Any multizone system is considered a complex HVAC system.

Find Out More

Copies of code:

Oregon Building Officials Association
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Technical Support:

Oregon Department of Energy
625 Marion Street NE phone: 503-378-4040
Salem, OR 97301-3737 toll free: 800-221-8035
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12/05 ODOE CF-125/Fact Sheet 9

Non-residential code HVAC fact sheets include:

- Ventilation Controls System
- Economizers
- Exhaust Air Heat Recovery
- Airside Design Requirements
- Hydronic Design and Controls
- Airside Controls
- Large Volume Fan Systems
- Air Transport Energy
- Simple vs. Complex HVAC Systems

Continued from page 1

The table below summarizes compliance documentation requirements for common HVAC systems.

HVAC System Designation

HVAC System Type	Type	Worksheets
Small Unitary Equipment	Simple	4a, 4j
Large Unitary Equipment (constant volume)	Simple	4a, 4j
Unitary Heat Pump	Simple	4c
Unitary Equipment, Water-Cooled	Complex	4b 4l
Water-Source Heat Pump	Complex	4d 4l
Ground-Coupled Heat Pump	Simple (<54kBtu/h) Complex	4d
Packaged-Terminal Heat Pumps, PTACs	Simple	4f
Large Split System	Complex	4a, 4h, (*4k, 4l)
Air-Cooled Chiller	Complex	4g, 4h (*4k, 4l)
Water-Cooled Chiller	Complex	4g , 4h (*4k, 4l)
Central Boiler	Complex	4i
Small Furnace	Simple	4j
Large Furnace (>5000 cfm) *worksheet may be needed	Complex	4j

Efficiency of complex systems is documented on applicable Worksheet(s) 4a – 4j. Equipment must meet both steady-state and part-load efficiency requirements, as listed on the appropriate Worksheet. Efficiency information must be specified at ARI rating conditions. Ratings can be obtained either from the Air Conditioning and Refrigeration Institute (ARI) or from manufacturer's cut sheets. Multizone systems that use terminal units with reheat coils will require Worksheet 4k to demonstrate compliance. Large fan systems may require Worksheet 4l to demonstrate that fan power complies with Code – see Air Transport Energy fact sheet.

For More Information

Air Conditioning and Refrigeration Institute, 4100 N. Fairfax Drive, Suite 200, Arlington, VA 22203.

Consortium for Energy Efficiency, Inc., 98 North Washington St., Suite 101, Boston MA 02114-1918. See http://www.ceehvacdirectory.org/ for a listing of ARI-certified unitary equipment that exceed minimum federal efficiency requirements.

Simple Systems – see related fact sheets on Economizers, and Ventilation Controls for High Occupancy Areas.

Complex Systems – see related fact sheets on Airside Design, Airside Control, Hydronic Design and Control, Large Volume Fan Systems, and Air Transport Energy.

Q A small office building is served by two 15-ton variable air volume packaged units with gas heating. Which forms need to be filled out?

A The systems are classified as complex systems since they are not constant volume. Forms 4a and 4b are filled out, along with Equipment Efficiency Worksheets 4a and 4j, and Air Transport Energy (4l) and Simultaneous Heating & Cooling (4k).

Oregon Non-Residential Building Energy Code

Airside System Design Requirements

These sections fall under 1318.2 Complex Control Systems. They are grouped here as the topic Airside Design because they affect the fundamental system design, including system type selection and system layout.

Simultaneous Heating and Cooling

The intent of section 1318.2.1 is to minimize energy waste by limiting the amount of simultaneous heating and cooling that occurs in HVAC systems. Simultaneous heating or cooling occurs when supply air that has been previously cooled is reheated, supply air that has been previously heated is recooled, or supply air that has been cooled is mixed with supply air that has been heated. The most important consequence of this requirement is that certain HVAC system types are prohibited except under special circumstances. The following system types are generally not allowed:

- Constant-volume reheat system. A single air handler that provides a constant flow of cool air to multiple zones, with a hot water or electric resistance coil at each zone to reheat the air and control space temperature.
- Two-deck multizone system. A single air handler that serves multiple zones and delivers a mixture of heated and cooled air to each zone in a separate duct. The ratio of heated and cooled air is varied separately for each zone to control space temperatures.
- Constant-volume dual-duct system. Similar in principle to the multizone system, except that the mixing occurs at the zone level instead of within the air handler.

Those system types are allowed in only three special cases: 1) where constant airflow is necessary to maintain pressure relationships between spaces in order to prevent cross-contamination, 2) where reheat is necessary to maintain special humidity conditions, and 3) where reheat is provided by recovered waste heat or solar heat.

This code section generally requires the use of one of the following system types.

- Variable air volume (VAV) with or without reheat
- VAV dual-fan, dual-duct
- Single zone systems, such as fan coils, packaged rooftop units, or water-source heat pumps.

For VAV systems, section 1318.2.1 regulates the minimum air-

Continues on **page 2**

Code Language

1318.2.1 Simultaneous heating and cooling. Zone thermostatic and humidistatic controls shall be capable of operating in sequence the supply of heating and cooling energy to the zone. Such controls shall prevent reheating, recooling, and mixing or simultaneous supply of air that has been previously mechanically heated with air that has been previously mechanically cooled.

Exceptions:

1. Variable air volume (VAV) systems which, during periods of occupancy, are designed to reduce the air supply to each zone to a minimum before reheating, recooling or mixing takes place. This minimum volume shall be no greater than the larger of the following:
   - 1.1 Thirty percent of the peak supply volume;
   - 1.2 The minimum required to meet ventilation requirements, unless increasing the volume to critical zones (zones with the highest ratio of outside air to total supply air) beyond the minimum ventilation requirements results in a decrease in overall outside air required by the HVAC system. An increase beyond minimum ventilation rates shall not be applied to more than 20 percent of the zones with reheat, on any one system; or
   - 1.3 0.4 cfm/ft^2 (2 L/s per m^2) of zone conditioned floor area.
2. Zones where special pressurization relationships or cross–contamination requirements are such that variable air volume systems are impractical, such as some areas of hospitals and laboratories. Systems which use this exception and supply heated or cooled air to multiple zones shall include controls which automatically reset supply air temperatures by representative building loads or by outside air temperature unless it can be shown that supply air temperature reset increases overall building annual energy costs.

Code Language continues on **page 2**

Documentation:

The simultaneous heating and cooling requirements are documented on Form 4b, Line 4 as well as Worksheet 4k.

Zone isolation controls are documented on Form 4b, Line 11.

Compliance with separate air distribution requirements must be recorded on Form 4b, line 10.

Code Language continued from **page 1**

3. At least 75 percent of the energy for reheating or for providing warm air in mixing systems comes from a site–recovered or site–solar energy source.
4. Zones where specified humidity levels are required to satisfy process needs, such as computer rooms, museums and areas of hospitals.
5. Zones with a peak supply air quantity of 300 cfm (142 L/s) or less.

1318.2.6 Zone isolation controls. A system serving multiple occupancies or floors in the same building shall be independently zoned and equipped with isolation devices capable of automatically shutting off the supply of conditioned air and outside air to and from each isolated area. Each isolated area shall be controlled independently and satisfy temperature setback (Section 1317.4.2) and optimum start control requirements. The central fan system air volume shall be reduced through fan speed reduction.

Exceptions: A cooling system less than 240,000 Btu/hr (70 kW) or a heating system with less than 300,000 Btu/hr (88 kW) total capacity.

1318.2.7 Separate air distribution systems. Zones with special process temperature requirements and/or humidity requirements shall be served by separate air distribution systems from those serving zones requiring only comfort conditions; or shall include supplementary control provisions so that the primary systems may be specifically controlled for comfort purposes only.

Exceptions: Zones requiring only comfort heating or comfort cooling that are served by a system primarily used for process temperature and humidity control provided that:

1. The total supply air to those comfort zones is no more than 25 percent of the total system supply air, or
2. The total conditioned floor area of the zones is less than 1,000 square feet (90 m^2)

Continued from page 1

flow setpoint on VAV boxes. The code establishes an upper limit, and the intent is to reduce airflow as much as possible during low cooling-load periods before using reheat.

There are three options for calculating this limit, and the designer can apply the method that results in the highest airflow. There is also an exception for zones with peak airflow no greater than 300 cfm. The first calculation option, 30 percent of peak air flow, and the third method, 0.4 cfm per square foot, are fairly simple. The second calculation method is more complicated than the other two because it is based on overall system outdoor air ventilation rate calculations.

The second method typically applies to zones with high occupant density, and it allows system designers to optimally solve Equation 6-1 in ASHRAE Standard 62.1-2004. That equation shows that the amount of outdoor air required for a system is a function of how much air is supplied to the “critical zone” in the system. The higher the supply air rate to the critical zone, the less outdoor air is required at the air-handler. The designer would determine which is more energy efficient, increasing outdoor air intake and minimizing reheat at the critical zone, or increasing the supply air rate and reheat energy required at the critical zone and minimizing the outdoor air rate. This “upsizing” of the minimum flow may only be applied to a maximum of 20 percent of the zones with reheat on each system. The designer should submit calculations demonstrating that increasing the volume to critical zones reduces overall outdoor air fraction. A detailed discussion of ventilation rate calculations is beyond the scope of this fact sheet, and more details are available in ASHRAE Standard 62.1-2004 and its User’s Manual.

When specifying VAV box settings, the designer should consider the energy savings opportunities for minimum airflow set points that are significantly lower than upper limits set by the energy code. Reducing the minimum flow set point saves fan energy as well as cooling and heating energy. Studies of real buildings have shown that many zones operate at their minimum flow for a majority of the time because cooling loads are often lower than predicted by the designer. A good resource for recommendations is the Advanced VAV System Design Guide.

There are several potential design strategies that provide good comfort and ventilation performance in heating mode while allowing low minimum settings in VAV boxes. The potential problem with low air flow is that the velocity of the buoyant warm supply air will be too low to provide adequate mixing with room air. Thermal stratification (warm air at the ceiling, cool air at the floor) is more likely to occur as the supply air temperature gets warmer (more buoyant) and the velocity of air leaving the diffuser decreases.

There are some strategies to combat stratification in heating mode. Parallel fan-powered VAV boxes have fans that turn on to increase air flow in heating mode and draw the extra air from the return air plenum. In addition to improving comfort in heating mode, parallel fan-powered boxes will reduce or eliminate the need for reheat. Series fan-powered VAV boxes are another,

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though less desirable option, which maintain constant discharge air flow while allowing the primary (ventilation) airflow to decrease to a minimum setpoint. A series fan-powered box provides good comfort performance but is generally less energy efficient because it induces warm plenum air at all but peak cooling times, leading to increased cooling requirements as well as higher fan energy. Another alternative is to use separate perimeter heating systems such as radiant panels or baseboard heaters instead of reheat coils in VAV boxes. In this strategy, the VAV box air flow can be allowed to drop to a low minimum without concern of stratification occuring, and the separate heating system prevents overcooling.

Zone Isolation Controls

The intent of Section 1318.2.6 is to avoid conditioning the whole building at times when only portions are occupied. These zone isolation control requirements apply to systems that serve more than one occupancy or multiple floors. At a minimum, such systems must be able to serve each occupancy or each floor independently while shutting off air flow to and from the other areas served by the system. In addition, each isolation area must have independent time-of-day, setback, and optimal-start controls.

These requirements do not apply to small HVAC systems. Cooling systems smaller than 20 tons (240,000 Btu/hr) of cooling capacity are exempt. Heating systems with capacity of less than 300,000 Btu/hr are also exempt.

A straight-forward option for complying with these requirements is to include motorized dampers that shut off supply and return ducts to each isolation zone. In a multi-story building, this option might consist of dampers located at the connections to the supply and return air shafts to isolate each floor. The local fire official may allow the use of fire/smoke dampers to serve this purpose as long as they are wired so that life-safety controls take precedence over off-hour controls.

A VAV system might comply if it has the capability to set the operating schedule of each zone (or at least sets of zones) independently, so that the VAV box damper may be shut on some zones while others continue to operate. A direct digital control (DDC) system should be able to provide this level of control. However, the code also requires that return air flow from the isolation zone be shut off, and additional motorized dampers in the return air path will still be necessary.

The code also requires that central systems with zone isolation controls use fan speed control to throttle back flow when one or more zones is shut off. Most large central systems will already meet this requirement because variable speed fan control is now common for duct pressure control in new VAV systems.

Separate Air Distribution Systems

Many buildings include spaces that require special environmental conditions. Examples of such spaces include hospital operating rooms, laboratories, special material storage such as rare books,

Continues on **page 4**

Examples

Q A 1,000 square foot space is served by a VAV box sized for 1,500 cfm peak airflow. What is the upper limit on the minimum air flow setting for the VAV box?

A Section 1318.2.1 sets the limit at the largest of 30 percent of peak airflow, 0.4 cfm per square foot, or the amount required for ventilation. In this case, the 30 percent option yields 450 cfm (30 percent of 1,500 cfm) and the 0.4 cfm per square foot option yields 400 cfm. Using the larger of these two results allows the minimum VAV box flow to be set as high as 450 cfm. However, it is possible that the outdoor air ventilation rate required for this space would exceed 450 cfm for high density cases such as a meeting room or classroom. If that is the case, then the ventilation rate can be used as the upper limit. Finally, there is an exception in Section 1318.2.1 that allows the minimum flow to be set even higher if doing so will reduce the overall outdoor air ventilation rate for the central air handler.

Q Is a triple-deck multizone system, which has hot deck, cold deck, and neutral (no heating or cooling) deck, allowed under the simultaneous heating and cooling requirements of Section 1318.2.1?

A Yes, as long as the controls do not allow the mixing of air from the cold and hot decks. In other words, the controls must ensure that the air delivered to each zone is a mix of cold and neutral or hot and neutral.

Q The VAV system in a multi-story office building is being provided with motorized dampers on the supply and return ducts at each floor to provide zone isolation control. The toilet rooms are exhausted by central fan. Is it also necessary to provide isolation dampers for the toilet exhaust at each floor?

A Yes, Section 1318.2.6 requires that the air flow to and *from* each isolation zone, in this case each floor, is capable of being shut off. Therefore, motorized dampers in the exhaust duct will be required at the connection to each floor.

Examples

Q A two-story building is served by a water-loop heat pump system, consisting of 25 heat pumps that total 100 tons of cooling capacity. A central air handler delivers ventilation air to each heat pump. This air handler has a heating coil to temper outdoor air during the winter. How do the zone isolation controls apply?

A If the heating capacity of the central air handler is 300,000 Btu/hr or more, then isolation capability is required for delivery of outside air to each floor, and exhaust or return air paths from each floor would require isolation dampers.

Q A data center consists of computer rooms with special temperature and humidity requirements as well as supporting office and storage spaces. Can the support areas be served by the same air handler that serves the computer rooms?

A Section 1318.2.7 of the code allows the support areas to share the computer room air handler under two conditions: 1) the total floor area of the support rooms is less than 1,000 sq. ft. or 2) the air flow provided to the support areas is less than 25 percent of the total system air flow.

Find Out More

Copies of code:

Oregon Building Officials Association
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Technical Support:

Oregon Department of Energy
625 Marion Street NE phone: 503-378-4040
Salem, OR 97301-3737 toll free: 800-221-8035
www.oregon.gov/energy fax: 503-373-7806

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12/05 ODOE CF-125/Fact Sheet 10

Non-residential code HVAC fact sheets include:

- Ventilation Controls System
- Economizers
- Exhaust Air Heat Recovery
- Airside Design Requirements
- Hydronic Design, Controls
- Airside Controls
- Large Volume Fan Systems
- Air Transport Energy
- Simple vs. Complex HVAC Systems

Continued from page 3

clean rooms or other special manufacturing spaces, computer rooms, or other special electronic equipment.

The energy required to maintain conditions in these "process" spaces is typically greater than for spaces where human comfort is the only criterion.

The intent of section 1318.2.7 is that these spaces with process requirements be served by separate systems so that energy is not wasted by "overconditioning" the other portions of the building.

In some cases, it may not be practical to provide separate systems, and the code allows some exceptions. These exceptions permit a small amount of "comfort" conditioned space to be served by systems that primarily serve the process areas. The comfort areas must either receive no more than 25 percent of the air flow or must be less than 1,000 sq. ft.

For More Information

See also the fact sheets covering Airside Control Requirements, Air Transport Energy, Economizers, Ventilation Controls for High Occupancy Areas, and Exhaust Air Heat Recovery.

See the Advanced VAV System Design Guide for detailed recommendations on VAV box minimum airflow settings. Available at http://www.newbuildings.org/mechanical.htm.

See also ASHRAE Standard 62.1-2004 Ventilation for Acceptable Indoor Air Quality and the Standard 62.1-2004 User's Manual for guidance in determining ventilation rates and in performing "critical zone" calculations. Available at www.ashrae.org.

Examples

Q An office building includes a 200 square foot retail space adjacent to the lobby as well as a 2,000 square foot cafeteria. May these spaces be served by the central HVAC system?

A Yes, these zones can be served by the central system. The separate air distribution system requirements (1318.2.7) do not apply in this case because the primary system serving the office spaces is being controlled only for comfort purposes. However, the zone isolation requirements of Section 1318.2.6 require that the system be able to shut off air flow to and from these different occupancies separately from the office occupancies. In addition, if this is a multi-story building, then each floor must have isolation controls capability.

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Exhaust Air Heat Recovery

This fact sheet describes Oregon Energy Code requirements for heat recovery for large volume fan systems and indoor pool facilities.

Exhaust Air Heat Recovery

Heat recovery is an essential means of reducing both the heating and cooling energy required to condition outside air. Some types of heat recovery systems can also both add and remove moisture (latent heat) from the incoming air. Heat recovery is important for systems that bring in large percentages of outside air. The code requires heat recovery for systems with a design supply air capacity of 10,000 cfm or greater and a minimum outside air supply of 70 percent or greater.

The Code requires that the heat recovery system raise the outside air supply temperature by 20°F for Climate Zone 1 and by 30°F by Climate Zone 2. This corresponds to a heat recovery effectiveness of approximately 50 percent.

Heat recovery effectiveness, in terms of energy delivered to the supply air, is defined as:

$$\eta_{HR} = \frac{h_{OA,entering} - h_{OA,leaving}}{h_{OA,entering} - h_{RA}}$$

where the terms are the enthalpy of the entering and leaving outside air and enthalpy of the return air, respectively. For systems that provide only sensible heat recovery, the heat recovery effectiveness is given by:

$$\eta_{HR} = \frac{T_{OA,entering} - T_{OA,leaving}}{T_{OA,entering} - T_{RA}}$$

The Code expresses heat recovery requirement in terms of temperature gain at design heating conditions. For example, for a building in Climate Zone 1 with a 30°F winter design dry-bulb temperature, and a return air temperature of 70°F, the required heat recovery effectiveness is $\eta_{HR} = (30 - 50) / (30 - 70) = 0.50$ Note that the effectiveness of many types of heat recovery devices decreases as the entering air temperature decreases. The device must meet the effectiveness requirement at design heating conditions.

Types of heat recovery systems that may meet this requirement include run-around coils, fixed plate heat exchangers, heat pipes or enthalpy wheels. A run-around coil is a common method of heat

Continues on **page 2**

Code Language

Documentation: Exhaust air heat recovery is documented on Form 4a, line 14. Heat recovery for swimming pools is documented on Form 4a, line 18.

1318.3 Exhaust air-heat recovery. An exhaust air heat recovery system shall be installed for each HVAC fan system that has all of the following:

1. A design supply air capacity of 10,000 cfm (4,720 L/s) or greater,
2. A minimum outside air supply of 70% or greater,
3. At least one exhaust fan rated at 75% of the minimum outside air supply.

The heat recovery system shall be capable of increasing the outside air supply temperature at design heating conditions by 20°F in Climate Zone 1 and 30°F in Climate Zone 2. A provision shall be made to bypass or control the heat recovery system to permit air economizer operation as required by Section 1317.3.

Exceptions:

1. HVAC systems with ventilation controls for high occupancy areas per Section 1317.2.2.
2. Laboratory systems meeting Section 1317.2.1.
3. Systems serving spaces which are not cooled and which are heated to less than 55°F.
4. Systems exhausting toxic, flammable, paint exhaust, corrosive fumes, or dust.
5. Type 1 kitchen hoods.
6. Where more than 60% of the heating energy is provided from site-recovered or solar energy.
7. Systems that provide only cooling.

1315.5.3 Heat recovery. Heated indoor swimming pools and Spas or Hot tubs over 200 square feet in size shall provide for energy conservation by at least one of the following methods:

1. The ventilating system shall provide a heat recovery of 70% at winter design conditions;
2. Heat recovered through dehumidification shall be used to heat pool, spa or hot tub room supply air.

Exception: Pools heated by renewable energy or waste heat recovery sources capable of providing at least 70% of the heating energy required over an operating season.

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1317.2.1 Fume Hoods. Buildings with fume hood systems having a total exhaust rate greater than 15,000 cfm (7 m^3/s) shall include at least one of the following features:

1. Variable air volume hood exhaust and room supply systems capable of reducing exhaust and makeup air volume to 50 percent or less of design values; or
2. Direct makeup (auxiliary) air supply equal to at least 75 percent of the exhaust rate, heated no warmer than 2°F below room setpoint, cooled to no cooler than 3°F above room setpoint, no humidification added, and no simultaneous heating and cooling used for dehumidification control; or
3. Heat recovery systems to precondition makeup air from fume hood exhaust in accordance with Section 1318.3.

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recovery, where heat rejected from the exhaust air stream is recovered and sent to the supply airstream using a heat transferring fluid such as a water and glycol solution. A distinct advantage of this type of system is that the supply and exhaust air streams can be separated. Glycol, added to the water for freeze protection, can significantly lower the heat recovery effectiveness. Other methods of heat recovery require the supply and exhaust air streams to be adjacent. The recovery effectiveness of these other devices are generally better than run-around coils. Fixed plate heat exchangers have low pressure drops and a typical sensible recovery effectiveness of 50-80%. Heat pipes provide energy transfer through evaporation and condensation of a working fluid (refrigerant). They are compact in design and typically have an effectiveness of 45-65%. Rotary enthalpy wheels (heat wheels) use a desiccant to transfer both heat and moisture. Enthalpy wheels are compact and have relatively low pressure drops.

The heat recovery effectiveness of all of these devices is largely driven by the heat transfer surface area. Larger devices can have higher efficiencies, but cost more to purchase and require more space dedicated to mechanical equipment.

When selecting the heat transfer device it is also important to consider the air pressure drop across the heat exchanger. A lower pressure drop reduces the fan energy penalty needed to move air through the heat exchanger. Heat recovery in cold climates, Climate Zone 2, should also incorporate some form of frost control so the warm moist air stream doesn't ice up on the heat recovery device, restricting coil area and limiting airflow capacity.

Heat recovery will reduce heating and cooling requirements, so HVAC equipment should be selected based on the reduced design loads that account for the effect of heat recovery. The heat recovery design must also allow for a means to bypass heat recovery during economizer operation, to avoid unneeded heat gain and the pressure drop across the heat exchanger.

Exceptions

- Densely occupied spaces, with an average occupant load factor of 20ft²/person or less (50 or more occupants/1,000ft²) with 1,500 cfm (or more) of outdoor ventilation air, may allow either ventilation controls or a heat recovery system with an energy recovery effectiveness of 50% or greater. These requirements are mutually exclusive – either a heat recovery system or demand controlled ventilation system must be installed. Refer to the Ventilation Controls fact sheet for more information. Ventilation controls are more commonly used for spaces with variable occupancy, such as a lecture hall, gymnasium, restaurant, or theater.

- Buildings such as laboratories that use fume hood systems with a total exhaust air flow rate exceeding 15,000 cfm require heat recovery to precondition makeup air. Exceptions are provided for systems that use variable air volume control that is capable of reducing the airflow to 50% of the

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peak design airflow. A VAV system will reduce fan energy and also reduce the energy required to precondition makeup air. The code also allows an exception for direct makeup systems that heat the air to no warmer than 2°F below room setpoint and cool the air to no cooler than 3°F above the setpoint. The auxiliary system must not add humidity to the incoming air. Direct makeup systems have difficulty in maintaining tight humidity control, and are less effective than variable air volume systems.

- A building, such as storage facility, that is not cooled and only heated to less than 55°F qualifies as an exception.
- Type 1 kitchen exhaust hoods are also exempted from the heat recovery requirement.
- Another exception is provided when more than 60% of the heating energy requirement is met by site-recovered energy or solar energy. Site-recovered energy could be in the form of cogeneration, where the exhaust heat is recovered for hot water heating. Cogeneration is especially effective in applications that have a large and continuous heating load, such as pool heating. Solar water heating is commonly used in low-temperature applications such as pool heating and service water heating.

Heat Recovery for Indoor Swimming Pools

The Code requires heat recovery for indoor swimming pools, spas and hot tubs over 200 ft² in size. The Code requires either heat recovery from the ventilation system, with a recovery effectiveness of 70% at winter design conditions, or heat recovery from dehumidification. Indoor pool facilities require dehumidification to offset evaporation from the pool to the indoor air. Indoor temperature is typically controlled to 2 degrees above the pool water temperature. Lowering the air temperature below the pool water temperature raises the pool evaporation rate significantly and increases the energy required to heat the pool water. Indoor humidity is typically controlled between 50% and 60% RH. Higher humidity levels can create conditions where the interior building walls, structural columns and roof surface temperature reach the dew-point, causing condensation that allows mold growth and can lead to problems with the structure of the building. Lower humidity levels increases both dehumidification energy and pool heating energy, through an increase in evaporation rate. Evaporation, the major source of indoor pool heat loss, can be greatly reduced by the use of a pool cover.

There are two means of controlling the building humidity level: either by using large amounts of outside air to flush out the humid air or by using a refrigerant based dehumidification system that mechanically pulls moisture from the humid air. Heat recovery is required for either system. Pool dehumidification systems allow

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Examples

Q A theatre whose HVAC system has a design air capacity of 20,000 cfm and requires 15,000 cfm of outside air plans to use a run-around coil for heat recovery. The coil requires glycol for freeze and burst protection. The resulting recovery efficiency is only 40 percent (less than the 50 percent code minimum requirement). How can this building comply with code?

A The run-around coil can be redesigned to add coil rows or reduce the concentration of glycol to increase effectiveness. For example, in Climate Zone 1, a 25 percent concentration level might be more appropriate than a 40 percent concentration level. The heat transfer effectiveness is increased by 15 percent with the 25 percent glycol solution. Selecting the coils based on burst temperature allows for lower glycol levels and greater heat transfer effectiveness. The table below demonstrates the difference in freeze point, burst point temperatures, and heat transfer rate for 25 percent and 40 percent glycol solutions.

Additional alternatives to increase efficiency include the use of other heat recovery methods such as air-to-air heat exchange, or, if the space has a high occupant density, the use of demand controlled ventilation can override the requirement for heat recovery.

Propylene Glycol % vol	Freeze Temperature	Burst Temperature	Heat Transfer Rate
40 percent	-10°F	-40°F	0.904 Btu / h- °F
25 percent	10°F	-5°F	0.957 Btu / h-°F

Q An indoor pool facility uses a packaged cogeneration system to provide electricity for the pool circulation pumps and other loads, and uses the waste heat to pre-heat pool water. Does this qualify as an acceptable method of heat recovery?

A Yes, if the system supplies 70% of the heating energy requirement over an operating season. The system should be designed to follow the thermal load. (In some cases this may result in excess electricity generation, which may be sold back to the local electric utility.)

Examples

Q An indoor pool facility uses a dehumidification system to maintain the indoor temperature and humidity levels. Heat rejected from the refrigeration cycle is recovered and used to pre-heat the pool water. Does this system qualify as heat recovery under Section 1315.5.3 of the Code?

A No. Although the system uses heat recovery, the Code requires that the heat recovery system be able to first heat the supply air during the heating season. After the air heating load is met, excess heat can be used to pre-heat pool water.

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exhaust air heat to be captured and be used for air heating and/or water heating as a standard option. The Code requires that heat recovered from the dehumidification system be used for heating the indoor air first and pool water secondly.

An exception to the heat recovery requirement is given for pools heated by renewable energy sources, such as solar collectors, or waste heat recovery sources (i.e., cogeneration). The renewable or site-generated source must be able to provide 70% of the annual pool heating requirement. If this exception is taken, calculations showing annual pool heating requirements must be provided to, and approved by, the building official.

Find Out More

Copies of Code:
Oregon Building Officials Association
phone: 503-873-1157 fax: 503-373-9389

Technical Support:
Oregon Department of Energy
625 Marion Street NE phone: 503-378-4040
Salem, OR 97301-3737 toll free: 800-221-8035
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Northwest Energy Efficiency Alliance
www.nwalliance.org

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12/05 ODOE CF-125/Fact Sheet 11

Non-residential code HVAC fact sheets include:

- Ventilation Controls System
- Economizers
- Exhaust Air Heat Recovery
- Airside Design Requirements
- Hydronic Design and Controls
- Airside Controls
- Large Volume Fan Systems
- Air Transport Energy
- Simple vs. Complex HVAC Systems

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Airside Controls

This fact sheet highlights three important control requirements that apply to variable air volume (VAV) HVAC systems: 1) "deadband" control, 2) static pressure reset, and 3) supply air temperature reset. When implemented properly, these measures provide significant savings in fan, cooling, and reheat energy.

Space Temperature Control Deadband

Section 1317.4.2.1 includes an important requirement that must be considered during selection of the control system vendor and communicated to the control system contractor. This section requires a "deadband" of at least 5°F for space temperature control. As stated in the code, "Variable air volume (VAV) terminal units shall be programmed to operate at the minimum airflow setting without addition of reheat when the zone temperature is within the set deadband."

To meet this requirement, the control system must allow separate heating and cooling setpoints that are at least 5°F apart. If, for example, the cooling setpoint is 75°F, then the control system cannot enable the reheat coil until the space temperature drops to 70°F or below.

There are a few cases where this requirement does not apply. First, of course, is cooling-only terminal units (VAV boxes), which do not have reheat and are typically serving interior zones. Second, there is an exception in the code for special occupancies that require tight temperature control.

Dual-duct VAV boxes are a special case. These terminal units do not have reheat coils, instead they have two inlets – cool duct and warm duct – each with its own volume damper. In order to meet the deadband control of section 1317.4.2.1, the warm duct damper must remain closed when space temperature is within the 5°F deadband.

Another special case is parallel fan-powered VAV boxes, which have a small fan that activates in heating mode and draws air from another space such as a return air plenum. To meet the requirements of section 1317.4.2.1, these fans must be programmed to remain off when space temperature is within the deadband.

The minimum airflow setting for VAV boxes is discussed in the fact sheet titled Airside Design.

A good discussion of VAV box control strategies can be found in the Advanced VAV System Design Guide (see page 4).

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Code Language

1317.4.2.1 Control capabilities. Where used to control comfort heating, zone thermostatic controls shall be capable of being set locally or remotely down to 55°F (13°C).

Where used to control comfort cooling, zone thermostatic controls shall be capable of being set locally or remotely up to 85°F (29°C).

Where used to control both comfort heating and cooling, zone thermostatic controls shall be capable of providing a temperature range or dead band of at least 5°F (3°C) within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum.
Variable air volume (VAV) terminal units shall be programmed to operate at the minimum airflow setting without addition of reheat when the zone temperature is within the set deadband.

Exceptions:

1. Special occupancy, special usage or code requirements where deadband controls are not appropriate (such as process applications and areas of hospitals normally used by patients).
2. Thermostats that require manual changeover between heating and cooling modes.

1318.2.3 Variable air volume system static pressure reset controls. The system static pressure set point shall be reset to the lowest point possible while still providing the required air flow to the zones with the greatest demand.

Exceptions:

1. Systems that are not controlled by a static pressure sensor.

Code Language continues on **page 2**

Documentation:
Each of the requirements described in this fact sheet must be included in the sequence of operations for the control system. The location of this information in the plans and/or specifications must be indicated on the compliance form.

The deadband control requirements are documented on compliance form 4a, line 6.3.

Variable Air Volume System Static Pressure Reset Controls requirement is documented on compliance Form 4b, line 6.

Supply-air Temperature Reset Controls are to be documented on Form 4b, line 8.

Code Language continued from **page 1**

2. Systems without direct digital control of individual zone boxes.

1318.2.5 Supply-air temperature reset controls. Multiple zone HVAC systems must include controls that automatically reset the supply-air temperature in response to representative building loads, or to outdoor air temperature. The controls must be capable of resetting the supply air temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

Exceptions:

1. Systems that prevent re-heating, re-cooling, or mixing of heated and cooled supply air.
2. 75 percent of the energy for reheating is from site recovered or site solar energy sources.
3. Zones with peak supply air quantities of 300 cfm or less.

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Static Pressure Reset

In a typical VAV system, the fan speed is controlled to maintain static pressure at a specific setpoint, often somewhere between 1 in. and 2 in. w.c. of pressure. The code requires that this set point be adjusted automatically to minimize fan energy. The required controls will maintain the pressure in the duct only as high as necessary to meet the airflow requirements for all zones. These static pressure reset controls can provide very significant fan energy savings, because buildings operate at partial-load conditions most of the time. Another common benefit is reduced fan noise.

There are several methods for implementing static pressure reset control. Options will vary based on the capabilities of the control system hardware and software (it is, therefore, important to clearly specify the required capabilities for new control systems). The desired control method is to monitor VAV box damper position for all zones and adjust the static pressure setpoint so that the damper in the most demanding zone is close to 100 percent open. If zone damper position information is not available in the control system, then another control option is to make periodic adjustments to the static pressure setpoint while comparing actual space temperatures to the desired space temperature setpoint. The DDC system can monitor zone temperatures and slowly lower the supply air pressure setpoint as long as all zones are meeting their temperature setpoint. As the duct pressure setpoint is lowered, and one or more zones begins to exceed its temperature setpoint, then it is time to slightly increase the pressure setpoint again. The Advanced VAV System Design Guide listed at the end of this fact sheet is a good source for more information on control methods, and it includes a sample sequence of operations.

The intent of the pressure reset requirements is to avoid situations where the dampers in all VAV boxes are partially closed, which means that the air pressure in the supply duct is greater than necessary at that point and fan energy is being wasted.

The code allows for a few exceptions to the static pressure reset requirement. The most significant exception is for systems without direct digital control of individual zone VAV boxes. The reason for this exception is that the central control system requires information from each zone – such as the space temperature, VAV box air flow, or VAV box damper position – in order to know whether or not the zone loads are being satisfied. Without that information, the central system cannot know whether it is ok at any point in time to reduce the pressure setpoint or whether additional pressure is needed.

In order for the system to take full advantage of the energy savings potential of pressure reset controls, pay special attention during design and construction to avoid creating “rogue” zones. These are zones that require higher duct pressure than all the others and force the whole system to operate at higher static pressure even though all the other zones would receive adequate airflow at a lower duct pressure setpoint. Rogue zones can occur if either the loads in a zone turn out to be greater than expected (i.e. the VAV

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box is undersized for the loads) or if there are airflow constraints in the ductwork that result in greater than expected pressure loss. One measure to help avoid rogue zones is to be extra generous in sizing duct and VAV boxes for zones with uncertain loads.

Supply-air Temperature Reset

To prevent unnecessary cooling and reheat energy consumption, the code requires automatic controls that adjust, or “reset”, the supply air temperature (Section 1381.2.5). The intent is that the supply air temperature be no cooler than necessary to satisfy space temperature requirements at any point in time. This requirement is especially important in most parts of Oregon, where outdoor temperatures often fall in the range of about 55°F to 65°F. In these areas, a supply air temperature reset scheme significantly increases the number of hours when “free cooling” from an economizer cycle can be used instead of mechanical cooling.

There are several acceptable supply air temperature control methods. The code requires that the controls act in “response to representative building loads, or to outdoor air temperature.” Control vendors can typically provide a function in DDC systems that monitors space thermostat cooling demand to determine whether the supply air temperature needs to be adjusted downwards because one or more zones is getting too warm or whether the zone thermostat can be adjusted upwards because all zones are satisfied with less than 100 percent airflow. This type of control is generally preferred over a reset scheme based on outdoor air temperature because it reduces the odds of a zone going unsatisfied.

The code also specifies a minimum range of adjustment capability, stating that “the controls must be capable of resetting the supply air temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.” For a typical system designed for 55°F supply air and 75°F space temperature, the code requires an adjustment capability of at least 5°F – equal to (75-55)*0.25. Therefore, in that case the control system must be able to reset the supply air temperature up to at least 60°F.

The code offers a few exemptions from the reset requirement. The first is for “systems that prevent re-heating, re-cooling, or mixing of heated and cooled supply air.” This exemption will apply to cooling-only VAV systems or generally to any single-zone system. The second exemption applies to systems where, “75 percent of the energy for reheating is from site-recovered or site solar energy sources.” Sources that would qualify as “site-recovered” include condenser heat (which would otherwise be rejected to outdoors via a cooling tower or air-cooled condenser), heat recovered from an electric generator (i.e. cogeneration), or heat from a process that would otherwise be rejected to outdoors.

There are several important considerations to keep in mind when specifying supply air temperature reset controls. There is usually

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Examples

Q My system has pneumatic actuators on VAV box dampers and reheat coil valves. Which of these requirements apply?

A The only exception for pneumatic controls is for the supply air pressure reset requirements (1318.2.3). VAV systems with pneumatic controls must comply with the deadband requirements in 1317.4.2.1 and the supply air temperature reset requirements of 1318.2.5, unless the system falls under one of the other specific exceptions to those sections.

Q My project is a tenant improvement on one floor of a five story building with a central air handler. All ductwork and VAV boxes on this floor are to be replaced. No changes to the central air handler or other floors are planned. Which of these requirements apply?

A The deadband controls of1317.4.2.1 apply to all new zone controllers, therefore, they are required for the new VAV boxes and their controls on this project. The static pressure reset controls will be required only if the central control system is being replaced and all other existing zones in the building have direct digital control. Similarly, supply air temperature reset control is required only in the case that the central control system is being replaced.

Q How do these requirements apply to a DDC control system retrofit project on an existing building with a VAV system?

A All three requirements will apply: deadband controls, static pressure reset, and supply air temperature reset.

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a tradeoff between fan energy, cooling energy, and reheat energy. Lower supply air temperatures lead to less fan energy but usually higher cooling and reheat energy. For any point in time there will be an optimal supply air temperature that balances these tradeoffs to minimize energy cost. A good discussion of optimal supply air temperature control can be found in the Advanced VAV System Design Guide (see For More Information below).

Another important design consideration is that for supply air temperature reset to be successful, the air flow to interior zones must be sized based on the fully reset supply air temperature (e.g. 60°F to 65°F) rather than the normal design air temperature (typically around 55°F). Otherwise, those interior zones may require a constant supply of 55°F air and never allow the control system to reset the supply air temperature upwards. As an alternative design strategy, zones with constant or unique loads could be served by a separate system.

Coordination between supply air temperature reset control and static pressure reset control requires some attention. However, in the recommended control method there should not be a problem. In that method (which requires zone-level DDC control), supply air temperature is controlled based on the zone with the highest "thermostat cooling demand" value (typically available from the VAV box controller) and static pressure is controlled based on the zone with the "most open" damper. Therefore, these control loops are based on different inputs, and as long as the temperature reset control loop responds relatively slowly compared to the static pressure reset control loop, then operation should be stable. Where problems might occur is in control schemes where temperature and pressure are being reset based on the same input.

For More Information

See also the fact sheets covering Airside System Design Requirements, Air Transport Energy, Economizers, Ventilation Controls for High Occupancy Areas, and Exhaust Air Heat Recovery.

See the Advanced VAV System Design Guide for detailed recommendations on VAV box minimum airflow settings. Available at http://www.newbuildings.org/mechanical.htm.

See also ASHRAE Standard 62.1-2004 Ventilation for Acceptable Indoor Air Quality and the Standard 62.1-2004 User's Manual for guidance in determining ventilation rates and in performing "critical zone" calculations. Available at www.ashrae.org.

Find Out More

Copies of Code:

Oregon Building Officials Association
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Northwest Energy Efficiency Alliance
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12/05 ODOE CF-125/Fact Sheet 12

Non-residential code HVAC fact sheets include:

- Simple vs. Complex HVAC Systems
- Ventilation Controls
- Airside System Design Req.
- Exhaust Air Heat Recovery
- Airside Controls
- Hydronic Design and Controls
- Economizers
- Large Volume Fan Systems
- Air Transport Energy

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Hydronic Design and Controls

This fact sheet covers design and control code requirements of hydronic systems that serve space-conditioning systems.

Hydronic System Controls

Two-Pipe Systems. The Oregon Energy Code places restrictions on two-pipe systems that use a common distribution system to deliver both heated and chilled water. The system must include an outside air temperature deadband of at least 15°F for changeover between heating and cooling. For instance, if hot water is supplied at an outside air temperature of 60°F, chilled water can only be supplied when the outside air temperature exceeds 75°F. Two-pipe delivery systems require a significant amount of energy to heat or cool the mass of water in the system when the control changes between heating and cooling. To limit the wasted energy required for changeover, the Code requires that the systems operate in one mode for a minimum of 4 hours. Also, the change in water temperature setpoint when the system changes from cooling to heating, or vice versa, cannot exceed 30°F.

Water Loop Heat Pump Systems. Water-loop heat pumps are typically served by a common condenser water loop and connected to central heat rejection sources (e.g., a cooling tower) and central heating sources, such as a boiler, if the temperature falls too low. To restrict heating and cooling energy use from this equipment, the Code requires that the controls ensure a 20°F deadband between heat rejection from the cooling tower and heat addition from the boiler. However, the deadband between actual setpoints can be set through the use of controls that can determine the most efficient operating temperature based on demand and operating conditions.

For water loop systems with a pumping power of 10 hp or greater, a two-position isolation valve must be installed at each heat pump. The valve is interlocked to shut off water flow when the compressor is off. Since this effectively creates a variable flow system, the Code requires variable-speed drive controls.

Closed-circuit cooling towers (fluid coolers) must have either an automatic bypass valve to bypass the tower or low-leakage dampers to limit heat loss across the heat exchanger. A bypass valve is a much more effective means of isolation. If a bypass valve is used, a minimal amount of water may be circulated through the heat exchanger to prevent freezing.

An open-circuit tower that is directly in the heat pump water loop must have an automatic bypass valve for isolation. If a separate heat exchanger is used to isolate the cooling tower from the water

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Code Language

Documentation: Compliance with hydronic system controls is documented on Form 4b, lines 9 and 13. Compliance with variable-speed drive requirements for variable flow pumping is documented on Form 4a, line 16.

1318.2.8 Hydronic system controls. The heating of fluids in hydronic systems that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with the following:

1318.2.8.1 Three-pipe system. Hydronic systems that use a common return system for both hot water and chilled water shall be prohibited.

1318.2.8.2 Two-pipe changeover system. Systems that use a common distribution system to supply both heated and chilled water shall meet the following:

1. The system is designed to allow a deadband between changeover from one mode to the other of at least 15 °F outside air temperature.
2. The system is designed to operate and is provided with controls that will allow operation in one mode for at least four hours before changing over to the other mode.
3. Reset controls are provided that allow heating and cooling supply temperatures at the changeover point to be no more than 30°F apart.

1318.2.8.3 Hydronic (water loop) heat pump systems. Hydronic heat pumps connected to a common heat pump water loop with central devices for heat rejection (e.g., cooling tower) and heat addition (e.g., boiler) shall meet the following requirements:

1. Controls shall be installed that are capable of providing heat pump water supply temperature dead band of at least 20°F between initiation of heat rejection and heat addition by the central devices (e.g., tower and boiler).
2. Closed-circuit tower (fluid cooler) shall have either an automatic valve installed to bypass all but a minimal flow of water around the tower (for freeze protection) or low-leakage positive closure dampers.

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3. Open-circuit tower installed directly in the heat pump loop shall have an automatic valve installed to bypass all heat pump water flow around the tower. Open-circuit towers used in conjunction with a separate heat exchanger to isolate the tower from the heat pump loop shall be controlled by shutting down the circulation pump on the cooling tower loop.
4. A two-position valve at each hydronic heat pump for hydronic systems having a total pump system power exceeding 10 hp.

1318.2.8.4 Variable flow controls. Controls capable of varying pump flow shall be installed on hydronic pumping systems with motors of 10 hp and greater.

1318.2.4 Chilled and hot water temperature reset controls. Chilled and hot water systems with a design capacity exceeding 300,000 Btu/hr (88 kW) supplying chilled or heated water (or both) to comfort conditioning systems shall include controls that automatically reset supply water temperatures by representative building loads (including return water temperature) or by outside air temperature.

Exceptions:

1. Where the supply temperature reset controls cannot be implemented without causing improper operation of dehumidifying systems.
2. Hydronic systems that use variable flow to reduce pumping energy.

1317.5.4.2 Variable flow controls. Cooling tower fans shall have control devices that vary flow by controlling leaving fluid temperature or condenser temperature/pressure of the heat rejection device.

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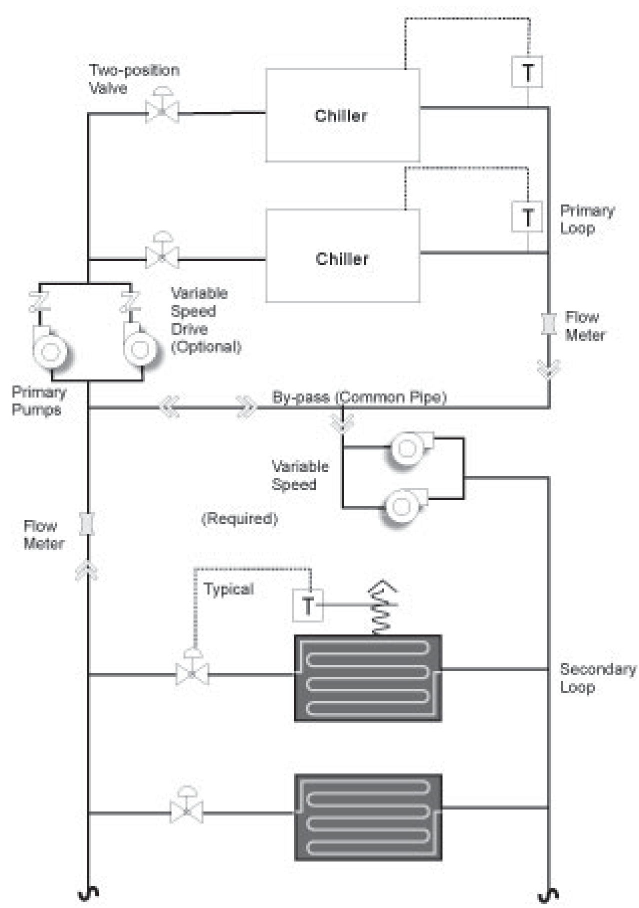
loop, shutting down the circulation pump on the water loop is an acceptable means of controlling heat loss.

Variable Flow Controls. The Code requires variable flow controls on pumps with motors of 10 hp (nameplate) or greater. Section 1317.10.3.1 describes a requirement that such motors serving variable flow systems must be controlled by a variable-speed drive. Exceptions are given to dedicated pumps that serve equipment and are required to maintain a minimum flow rate. An example is a multiple-chiller system with a primary-secondary pumping arrangement.

Primary-Secondary Systems. The primary loop pumps serving the equipment, which maintain the equipment minimum flow rate requirements, can be constant flow. Although not required by code, variable-speed controls can also be used to vary the primary pump water flow through the evaporator since the minimum flow rate is often less than 50 percent of the system design flow rate. The secondary loop that serves the cooling coils must utilize two-way valves and variable-speed drives to save pump energy at part-load conditions.

Primary-Secondary Pumping Arrangement



Continued from page 2

Variable-speed drives save a considerable amount of energy, as pumping power varies with the cube of rotational speed. The variable speed drive should be controlled to maintain a minimum system pressure which is generally sensed at the end of the distribution piping. Variable-speed drives will provide the greatest energy savings when coupled with demand-based reset of hydronic control valves. A DDC system can reset system pressure with demand to maintain at least one valve nearly 100 percent open.

Primary-only Systems. A system with primary-only pumping needs to be variable flow. Primary-only, variable flow pumping systems are becoming more popular since they have lower installation and operating costs than a primary-secondary pumping system. However, the control must prevent rapid changes in flow, as a sudden drop in flow would result in a rapid drop in leaving chilled water temperature, and could trigger a low-temperature safety alarm. It is also important to maintain a minimum flow rate through the evaporator to ensure proper heat transfer. Chiller manufacturer Chiller Management System controllers are capable of managing these critical flow and temperature limitations to assure safe chiller operation.

Variable flow controls in chilled water and hot water delivery systems with pumps less than 10 hp and no variable speed drives can also save energy. The use of two-way control valves saves pump energy by allowing the pump to ride its system curve, using less energy at reduced flows. For chilled water systems, however, variable speed drives will be most energy efficient and will normally be cost-effective to install.

Chilled and Hot Water Temperature Reset Controls

The Code requires that chilled and hot water systems with a design capacity exceeding 300,000 Btu/hr include controls to reset supply water temperature by "representative building loads" or by outside air temperature. The Code does not specify how the chilled or hot water temperature is controlled, nor does it require a specific reset amount. There are several methods of controlling water temperature. An efficient method is to control the temperature to just meet the requirement of the zone with the highest demand. The water temperature can be adjusted so that the control valve serving the zone with the greatest demand is nearly 100 percent open. Alternatively, with a central control system, space temperature (and humidity) can be compared to temperature and humidity setpoints, to verify that sensible and latent cooling loads are met. Other control methods include chilled water reset based on return air temperature or on return water temperature. Return water temperature is only indicative of average zone demand and should be used with caution. Reset based on outside air temperature can be an effective method with central heating systems, since there is a strong correlation of heating requirements to outside air temperature. It is less effective for cooling systems.

Reset controls are exempted when systems use variable flow to reduce pumping energy. Since variable flow is required on all systems with pumps of 10 hp or more, this effectively limits the reset

Examples

Q **A chiller plant has two chillers piped in parallel in a primary-only piping arrangement. The chillers are is sized in a 1/3 and 2/3 capacity arrangement and each chiller has a minimum flow rate of 50 percent of the chiller design flow rate. The smaller chiller is served by a 7.5 hp pump and the larger chiller a 15 hp pump. Can this system be designed for constant flow and are variable speed drives required on the chilled water pumps?**

A Flow Control: The Code requires variable flow controls for systems with motors of 10 hp or greater. The design flow is the total flow through the system, not through each chiller. Since this system has a total flow of 22.5 hp the system must have variable flow controls, i.e. 2-way control valves.

A Pump Control: The Code also requires variable speed drives on pumps of 10 hp or greater. Therefore, only the larger 15 hp chiller pump would be required to have variable speed control. The smaller chiller pump could operate as constant speed with a bypass line (control valve between the chiller supply and return lines), allowing variable flow out into the system. Even though a constant speed pump arrangement is allowed by code, it is unlikely this would function satisfactory in a primary-only arrangement because the bypass flow could cause the dreaded "low chilled return water temperature" syndrome and constrain the chiller's effective cooling capacity

Q **A water loop on a heat pump system uses a 15 hp pump for the condenser loop. What flow controls are required for the pump?**

A Variable flow controls are required for the system. Specifically, the pump must use a variable-speed drive and two-position valves must be installed at each heat pump.

Q **A chiller plant uses a primary-secondary pumping arrangement. The primary circulation pumps are two 10 hp circulation pumps serving two chillers. The secondary pump is a 30 hp circulation pump serving fan coil units. What are the control requirements for this system?**

A The Code requires variable-speed drives on the pump serving the fan coil units. The two primary pumps serving the chillers may be constant flow. Since variable flow is used, chilled water reset is optional for this system.

Continued from page 3

requirement to smaller systems. Chilled and hot water temperature reset can be still used with variable flow pumping, and is often added to heating loops to enhance heat coil temperature control during low load and to increase the operating efficiency of condensing boilers. An exception is also allowed for cooling loops supplying dehumidification systems that would not operate correctly at reset temperatures. Resetting the chilled water setpoint higher would raise the supply air temperature and reduce the latent heat removal capacity of the system.

Condenser Temperature Control

The code requires controls for cooling tower fans that vary flow to control the leaving fluid temperature or condenser temperature of the heat rejection device. The Code does not require specific flow controls on the condenser pump; rather, it is an airside control. A variable-speed drive on the cooling tower fan will produce the most energy savings, but a two-speed fan can also save energy. Another option for belt-driven fan applications is a dual primary/auxiliary fan motor arrangement, with the two motors installed on the same shaft. The smaller "pony" motor operates during part-load conditions. This dual motor arrangement also allows for some redundancy in the event of motor failure.

With a variable-speed fan, control of condenser water temperature involves a tradeoff between cooling tower energy and chiller energy. Reducing the condenser water setpoint will increase cooling tower energy but reduce chiller energy. The optimum setpoint depends on tower efficiency and the effect that the condenser temperature reset has on chiller efficiency. Commercial control packages are available that dynamically determine the optimum setpoint based on ambient conditions and the relative power consumption of the different system components. Another method is to reset the condenser temperature lower based on outdoor wet-bulb temperature. While this method can be effective, it requires careful design of the control and accurate sensor calibration to work properly.

For More Information:

CoolTools – Chilled Water Plant Design and Specification Guide, PG&E, 2000, http://www.hvacexchange.com/cooltools/.

Find Out More

Copies of Code:
Oregon Building Officials Association
phone: 503-873-1157 fax: 503-373-9389

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12/05 ODOE CF-125/Fact Sheet 13

Non-residential code HVAC fact sheets include:
- Ventilation Controls
- Exhaust Air Heat Recovery
- Hydronic Design and Controls
- Large Volume Fan Systems
- Simple vs. Complex HVAC Systems
- Economizers
- Airside System Design Req
- Airside Controls
- Air Transport Energy

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Air Transport Energy

The energy code places an upper limit on fan power for HVAC systems, with the intent of encouraging energy efficient air distribution design.

The fan power limit in Section 1318.4.2 applies to systems with a total motor nameplate horsepower of 7.5 hp or greater. This total horsepower threshold applies to the sum of all fan motors in the system, including the supply, return, and exhaust fans as well as motors in fan-powered terminal units (with a few exceptions as noted later).

For the purpose of this requirement, a "fan system" is essentially a central air handler and all other fans that serve the same zones. A single building often has more than one fan system, and it is possible that some of those systems fall under the scope of the fan power limit, meaning they total more than 7.5 hp, while others do not.

Fan Power Savings Opportunities

Fan energy is a significant component of energy use in commercial buildings. Designers are encouraged to consider the many opportunities for reducing fan power far below the limits in the energy code.

- Efficient fan selection.
- Selection of "housed" fans rather than "plenum" or "plug" type fans where practical.
- Increased coil and filter face area for reduced pressure loss.
- Generous duct sizing.
- Selection of low-loss duct transitions.
- Minimizing the number of duct turns.
- Use of a return air plenum rather than ducted return air where practical.
- Selection of VAV boxes for low pressure loss.
- Generous return air shaft sizing.
- Use of low pressure drop air filters.
- Minimal use of sound traps.

Calculating the Fan Power Allowance

The code specifies a formula for calculating the maximum

Continues on **page 2**

Code Language

Documentation:

Air transport energy for complex systems is documented in line 2 of Form 4B. Worksheet 4L must be completed for each fan system where total motor nameplate horsepower is 7.5 hp or greater.

1318.4.2 Air transport energy. The energy demand of each HVAC fan system shall be limited as specified in Section 1318.4.1 and 1318.4.2. For the purposes of determining allowable fan motor horsepower, maximum combined fan motor horsepower is the sum of the motor brake horsepower of all fans operating at design conditions, including supply fans, return/exhaust fan and fan-powered terminal units.

Exceptions:

1. Individual HVAC fan systems with total nameplate fan system motor horsepower of 7.5 or less.
2. Individual exhaust fans with nameplate fan horsepower of 1 hp or less.
3. Induction/dilution exhaust fans used in hospitals and laboratories.
4. Fan-powered, parallel airflow terminal units where the fan does not operate in cooling mode.

1318.4.2.1 Constant volume fan systems. For fan systems which provide a constant air volume whenever the fans are operating, the power required by the motors for combined fan system at design conditions shall not exceed Formula CV-1 shown below. This requirement includes 2-speed motors.

Formula CV-1 $$\text{BHP} = \frac{\text{Design Airflow (CFM)} * 4.3}{4131}$$

Fan systems with filtration systems that have a pressure drop at design air flow in excess of 1" w.c. when the filters are clean, heat recovery or direct evaporative humidifier/cooler may use Formula CV-2:

Formula CV-2 $$\text{BHP} = \frac{\text{Design Airflow (CFM)} * (PD + 4.3)}{4131}$$

1318.4.2.2 Variable air volume (VAV) fan systems. For fan systems which are able to vary air volume automatically as a function of load, the power required by the motors for the combined fan system shall not exceed Formula VAV-1 shown below.

Formula VAV-1 $$\text{BHP} = \frac{\text{Design Airflow (CFM)} * 6.0}{4131}$$

Code Language continued from **page 1**

Fan systems with filtration systems that have a pressure drop at design air flow in excess of 1" w.c. when the filters are clean, heat recovery or direct evaporative humidifier/cooler may use Formula CV-2:

Formula VAV-2

$$\text{BHP} = \frac{\text{Design Airflow (CFM)} * (PD + 6.0)}{4131}$$

(Refer to the Oregon code for variable definitions and additional information.)

1318.4.2.3 Selecting and sizing nameplate motor horsepower: Selected fan motor shall be no larger than the first available motor size greater than the brake horsepower.

EXCEPTIONS:

1. Constant Volume Fans: Where the first available motor larger than the brake horsepower has a nameplate rating within 22% of the brake horsepower, the next larger nameplate motor size may be selected.
2. Fans with Variable Speed: Where the motor is controlled by a variable speed drive and where the first available motor larger than the brake horsepower has a nameplate rating within 50% of the brake horsepower, the next larger nameplate motor size may be selected.

Examples

Q My building includes a rooftop air conditioner with a 7.5 hp supply fan and 2 hp powered exhaust. The exhaust fan is controlled to maintain building static pressure at a fixed setpoint by cycling on and off. It mainly comes on when the system is in economizer mode. Does the air transport energy section of the code apply to this system?

A Yes, the code applies in this case. The exhaust fan must be included in the total fan horsepower calculation because the fan may come on even when the system is not in economizer mode. Therefore, the total fan system nameplate horsepower is 9.5 hp, which exceeds the 7.5 hp threshold. If the exhaust fan was not controlled based on building pressure, but instead was interlocked with the economizer operation, then the exhaust fan could be excluded, and Section 1318.4.2 of the code would not apply.

Continued from page 1

allowed brake horsepower (BHP) as a function of design airflow in cubic feet per minute (cfm). For constant volume systems and for systems with two-speed fans, the following formula applies:

$$\text{Constant Volume BHP} = \frac{\text{Design Airflow (CFM)} * 4.3}{4131}$$

For variable air volume (VAV) systems, the fan power allowance is somewhat higher due to extra air pressure loss through the VAV boxes. This formula also applies to fan systems in hospitals and laboratories that are nominally constant volume systems yet have flow control devices within the air distribution system to maintain precise space pressure control and avoid cross contamination.

$$\text{Variable Air Volume BHP} = \frac{\text{Design Airflow (CFM)} * 6.0}{4131}$$

Additional Fan Power Allowances

There are several cases where an additional fan power allowance applies. In these cases, an excess pressure drop (PD) term is added to the brake horsepower formula. The formulas to be used when one or more of these special allowances apply are the following:

$$\text{Constant Volume BHP} = \frac{\text{Design Airflow (CFM)} * (PD + 4.3)}{4131}$$

$$\text{Variable Air Volume BHP} = \frac{\text{Design Airflow (CFM)} * (PD + 6.0)}{4131}$$

The PD values are determined as follows:

- If air filter pressure drop is greater than 1 in. w.c., then PD is equal to the excess beyond 1 in. For example, if filter pressure drop is 1.6 in. w.c., then PD is equal to 0.6. The pressure drop value used for the calculation must be for clean filters selected at the design airflow. It is important to note that the calculated pressure drop is for all the filters in the system.
- Heat recovery component pressure drop may be added to the PD value. Examples include the pressure drop due to run-around coils, air-to-air heat exchangers, enthalpy wheels, or heat pipes.
- The pressure drop due to direct evaporative sections used for humidification and/or cooling may also be added to PD.

For hospitals and laboratories only, the following extra pressure drop allowances may apply:

- Systems with fully ducted return and/or exhaust air systems are allowed an additional 0.5 in. w.c. PD.
- Systems with return and/or exhaust air flow control devices are allowed an additional 0.5 in. w.c. PD.
- Filter systems of individual filter efficiency greater than 85 percent are also allowed an additional 0.5 in. w.c. PD. For example a lab or hospital HEPA filter would qualify for this pressure drop credit in addition to the previous credit for filtration with

Continues on **page 3**

Continued from page 2

PDs greater than one inch. This additional credit is allowed to account for the fact that the system must be designed to overcome the pressure drop of filters as they become loaded.

Determining Compliance

The fan system complies with the requirements of Section 1318.4.2 if the total fan motor brake horsepower is no greater than the allowance described above. Note that the limit is expressed in terms of brake horsepower, not motor nameplate horsepower.

For each fan system, sum the total brake horsepower of all fan motors that operate at design conditions. This includes supply, return, and exhaust fans as well as fans in series fan-powered VAV boxes.

There are a few fans that may be left out of the calculations:

- Individual exhaust fans that have motors with nameplate horsepower of 1 hp or less.
- Induction/dilution fans used in hospitals and laboratories. These specialized fans are used to increase discharge velocity or dilute toxic exhaust air using additional outside air.
- Fans in parallel fan-powered boxes where the fan does not operate in cooling mode.

Sizing Fan Motors

Section 1318.4.2.3 of the energy code sets an upper limit on the nameplate horsepower rating of individual fan motors. In general, the motor shall be no larger than the first available motor size greater than the brake horsepower required by the fan. However, the code allows the next larger fan motor size to be selected under the following circumstances:

- For constant volume fans, if a nameplate rating is within 22 percent of the calculated brake horsepower, the next larger fan size may be selected.
- For variable air volume fans, if a nameplate rating is within 50 percent of the calculated brake horsepower, the next larger fan size may be selected.

For More Information

See the Advanced VAV System Design Guide for recommendations on duct design, fan selection, and coil selection for low pressure loss, available at www.newbuildings.org/mechanical.htm or www.energydesignresources.com.

Another good resource is the Design Brief titled Design Details, available at www.energydesignresources.com.

Examples

Q A contant-volume air handler serving a hospital wing has a design supply airflow of 10,000 cfm, a 20 hp supply fan motor with brake horsepower of 15.5 hp and a 5 hp return fan motor with brake horsepower of 3.5. The filter pressure drop is 1.9 in. w.c., and return air is fully ducted. The system uses 100 percent outside air and has a run-around heat recovery system with a coils in the supply and exhaust air streams, each with 0.4 in. w.c. pressure drop at design airflow. Does the fan system comply?

A The maximum allowable fan brake horsepower is calculated by formula VAV-2. The pressure drop in excess of 1 in. w.c. is 0.9 in. w.c. An additional 0.5 in. w.c. credit is allowed due to the fully ducted return air path. The pressure drop due to the heat recovery system coils can also be added to the equation. The allowed brake horsepower is:

BHP = 10000 * [(0.9+0.5+0.4) + 6.0] / 4131 = **19.8 hp**

The total installed fan brake horsepower is 19.0 hp, which is lower than the allowed power. Therefore, this system complies with Section 1318.4.2.2 of the code.
Both the supply and return fan motors are the next available size greater than the calculated fan brake horsepower, therefore, they comply with the sizing criteria of Section 1318.4.2.3.

Find Out More

Copies of Code:
Oregon Building Officials Association
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12/05 ODOE CF-125/Fact Sheet 14

Non-residential code HVAC fact sheets include:

- Ventilation Controls
- Exhaust Air Heat Recovery
- Hydronic Design/Controls
- Large Volume Fan Systems
- Simple vs. Complex HVAC Systems
- Airside System Design Req.
- Airside Controls
- Air Transport Energy
- Economizers

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Ventilation Controls

Ventilation Controls for High Occupancy Areas

Ventilation controls both ensure that required ventilation air is delivered to the space and that excess air isn't delivered to the space when the space is partially occupied. The strategy of reducing ventilation air when the space is partially occupied is commonly referred to as Demand Controlled Ventilation. Ventilation requirements are included under Section 403.3 of the 2004 edition of the Oregon Mechanical Specialty Code (OMSC).

A special requirement pertains to HVAC systems that serve spaces with high occupant densities. If the system provides at least 1,500 cfm of outside ventilation air, and has an average occupant load factor of 20 ft^2 per person or less, code Section 1317.2.2 applies. The occupant density is determined by Table 1004.1.2 of the Oregon Structural Specialty Code (OSSC). Typically, this will only apply to spaces such as conference rooms, auditoriums, gymnasiums, and school classrooms. It is important to note that this requirement is based on the **average** occupant load of spaces served by a system. If a large HVAC system serves multiple space types, some of which have occupant load factors greater than 20 ft^2 per person and others with occupant load factors less than 20 ft^2 per person, the requirement may not apply.

Code Language

1317.2 Mechanical Ventilation. Ventilation shall be provided as specified in the Oregon Mechanical Specialty Code and this section.

1317.2.2 Ventilation Controls for high occupancy areas. HVAC systems with ventilation air capacities of at least 1,500 cfm and serving areas having an average occupant load factor of 20 or less (as established in Table 1004.1.2) shall include a means to automatically reduce outside air intake below design rates when spaces are partially occupied. Large rooms served by multiple systems with a combined air capacity of 1,500 cfm and an occupant load factor of 20 or less must also meet this requirement.

Exception: System equipped with an energy recovery device with at least 50 percent recovery effectiveness.

Documentation: To document compliance with this section of code, fill out Compliance Form 4a, line 14.

In addition:

- If the ventilation control requirement applies, specify the location of control sensors and indicate the control sequence used to control ventilation levels.

The code provides an exception for systems that include energy recovery devices. Energy recovery is used to recover either sensible heat, or in the case of an enthalpy wheel, both sensible and latent heat from the exhaust stream. The recovered heat is used to pre-cool outside ventilation air in the summer and pre-heat ventilation air in the winter. The energy recovery device should be able to recover at least 50 percent of the energy from the exhaust air stream.

How Ventilation Air Is Controlled

The code requires that the amount of ventilation air is automatically controlled by the HVAC system, but is not specific about how that should be accomplished. A common means of controlling ventilation air for variable-occupancy spaces is to use carbon dioxide as an indicator of the amount of outside air delivered to the space. Chapter 4 of the OMSC and ASHRAE 62.1-2004, Ventilation Requirements for Indoor Air Quality, define ventilation requirements for various spaces. The recommended minimum outside air ventilation rate corresponds to the amount required to maintain an indoor CO_2 level that is no greater than 700 ppm above the ambient concentration. For typical outdoor conditions, this amounts to an indoor maximum of about 1,100 ppm. The demand-controlled ventilation system includes a sensor to monitor CO_2 levels, and a control to adjust the outside air intake. If the CO_2 level is well below the limit, the outside air dampers modulate to close towards the minimum position to save energy. If the CO_2 level is above the limit, the outside air dampers modulate open to increase the rate that outside ventilation air is introduced to the space. The sensor signal is fed back to the building energy management system or to the economizer of a packaged HVAC unit. CO_2 sensors used to control ventilation should have accuracy to at least +/- 30 to 50 ppm. Sensors typically cost $300 each. Sensors should be verified as part of commissioning and may require periodic calibration.

The sensor should be located in an occupied zone of the space, at a height of 3 to 6 ft. A good sensor location is 6 to 10 ft

Continues on **page 2**

Examples

Q My building includes a large air handler serving twelve offices, with 300 ft² of floor area each, and six 400-ft² conference rooms Does my space require ventilation controls?

A No. The occupant load factor of the offices (from Table 1004.1.2) is 100 ft² per person or 36 people (12 x 300 ft² / 100 ft² per person). The load factor for the conference rooms is 15 ft² per person or 160 people (6 x 400 ft² / 15 ft² per person). The total floor area served by the system is 6,000 ft². The total occupancy for the system is 196 people (36 +160). Therefore the average load factor is 31 ft² /person (6,000ft² / 196 people). Even though the conference room has a high occupant load, for the entire space, the load factor is greater than 20 ft² /person. Therefore, ventilation controls aren't needed.

Q I have a packaged rooftop unit serving a small cafeteria with a floor area of 1,200 ft² and average peak occupancy of 80. The ventilation requirement is 15 cfm/person. Does the unit require ventilation controls?

A No. Even though the occupant load factor is only 15 ft² /person, the system is designed to bring in a minimum of 1,200 cfm of outside ventilation air. Thus, ventilation controls are not required.

Find Out More

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12/05 ODOE CF-125/Fact Sheet 15

Non-residential code HVAC fact sheets include:

- Ventilation Controls
- Exhaust Air Heat Recovery
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- Simple vs. Complex HVAC Systems
- Economizers
- Airside System Design Req.
- Airside Controls
- Air Transport Energy

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from the occupants. Avoid placing sensors in close proximity to operable windows or supply air outlets. If a single HVAC system serves multiple spaces, a separate CO_2 sensor may be required for each space. For a system that serves several spaces, locating a single sensor in a common return is not a good practice—this will lead to overventilation of some spaces and underventilation of others. If using a single sensor, it should be placed in the space that requires the highest percentage of outdoor air.

An important distinction of this control is that CO_2 measurements are an indication of occupancy levels, so that ventilation rates may be adjusted accordingly. CO_2 is a related factor but not a direct indication of indoor air quality. Outside air ventilation is just one means of treating indoor pollutants, by diluting their concentration with outside air.

Other methods may be used to control ventilation automatically, but any method must be able to reduce ventilation levels for partial occupancy. For instance, an alternate method of ventilation control for a theater could be an occupant counter that tracks entry and exiting of occupants.

Benefits

Automatic control of ventilation levels provides several benefits. It ensures that the correct amount of ventilation air is delivered to the space, which will ensure that indoor air quality meets requirements and the space doesn't "get stuffy." In some cases, it may also save considerable energy, particularly for large spaces with highly variable occupancies such as gymnasiums and theaters. Control of ventilation is recognized by the U.S. Green Building Council in its Leadership in Energy and Environmental Design (LEED) voluntary certification program. Ventilation controls are an effective component of a high-performance HVAC design.

Examples

Q Can occupancy sensors be used for ventilation control?

A No. The control method must be able to automatically vary ventilation for partial occupancy.

Q I have a large conference room that is being served by two packaged rooftop air handling units. Each air handler has 1,000 cfm of ventilation air. Am I required to use demand controlled ventilation in this space?

A Yes. The requirement is for spaces with a minimum of 1,500 cfm. Even though each air handler is sized for 1,000 cfm of ventilation air, the total is greater than 1,500 cfm.

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Economizers

Economizers are control systems that save cooling energy by using outside air as a first stage of cooling. The Oregon Energy Code requires that economizers be installed on systems that use mechanical cooling (such as packaged rooftop units and outdoor air handlers). The economizer must be capable of adjusting outside air and return air dampers to provide up to 100 percent outside air. Economizers are especially effective in temperate climates, when outdoor conditions often allow for "free cooling."

There are several exceptions to this requirement. Exceptions are given to small direct-expansion (DX) units that have a total cooling capacity of 54,000 Btu/hr (4.5 tons) or less each. However the total cooling capacity of units per building that can qualify for this exception is limited to 240,000 Btu/hr (20 tons) or 10 percent of the building total cooling capacity, whichever is greater. An exception is provided for systems with water side economizers (which use evaporative cooling), and ground-coupled heat pumps. Systems that use heat recovery between interior and exterior zones also qualify as an exception. For instance, a heat recovery chiller for a large office building can recover rejected condenser heat for use in heating perimeter offices. An economizer would reduce the amount of time when the compressor would operate in cooling mode during cool outdoor conditions. This would reduce the effectiveness of heat recovery.

Building Pressurization

The introduction of high amounts of outside air through a mechanical system can lead to building overpressurization unless there is some means to relieve that air. Overpressurization of the interior space can make it difficult to open or close doors and cause non-compliance with the American Disabilities Association's accessibility requirements. For that reason, the code requires some method of pressure relief.

The pressure can be relieved mechanically using a return or exhaust fan. Passive relief using a barometric relief damper may be sufficient for some applications.

Integrated Economizers

Integrated economizers allow outside air to be used as a partial source of cooling, even if mechanical cooling is required. An example of when this is most useful is a mild sunny day (65°F). The space may require air-conditioning during such conditions, but the return air (75°F) will likely be warmer than the outside air (65°F). Therefore, even though mechanical cooling is required, it

Continues on **page 2**

Code Language

Documentation: Economizer cooling is documented on compliance Form 4a, line 7. Check the "Complies" box if fan systems have economizers.

Building pressure relief controls and integration of economizers is documented by checking the appropriate boxes on line 8 of Form 4a.

1317.3 Economizer Cooling. Each fan system with mechanical cooling shall have an air economizer system capable of modulating outside air and return dampers to provide up to 100 percent of the design supply air quantity as outdoor air.

Exceptions:

1. Systems at locations where the air quality is so poor as to require extensive treatment of the air.
2. Systems serving only residential spaces and hotel or motel guest rooms.
3. Cooling equipment with direct expansion coils rated at less than 54,000 Btu/hr (15,827 W) total cooling capacity. The total capacity of all such units without economizers shall not exceed 240,000 Btu/hr (70,342 W) per building area served by one utility meter or service, or 10 percent of its total installed cooling capacity, whichever is greater. That portion of the equipment dwelling units and guest rooms is not included in determining the total capacity of units without economizers.
4. Systems having a water economizer system capable of cooling air by direct and/or indirect evaporation and providing 100 percent of the expected systems cooling load at outside temperatures of 50°F (10°C) dry bulb and 45°F (7°C) wet bulb and below.
5. Ground-coupled heat pumps with cooling capacity of 54,000 Btu/hr or less.
6. Internal/external zone heat recovery is used.

1317.3.1 Pressure Relief. The fan or building envelope shall provide a means of preventing overpressuring the building envelope during air economizer operation. Drawings shall specifically identify the pressure relief mechanism for each fan system.

1317.3.2 Integration. Economizer systems shall be capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load.

Code Language continued from page 1

Exceptions:

1. Direct-expansion systems may include controls to reduce the quantity of outdoor air as required to prevent coil frosting, but not less than required by this code, at the lowest step of compressor unloading.
2. Individual direct-expansion units that have a cooling capacity of 15 tons (53 kW) (nominal) or less may use economizer controls that preclude economizer operation whenever mechanical cooling is required simultaneously.

Examples

Q My building includes a large computer server room in the basement with a 15 ton cooling load and precise temperature and humidity requirements. I would like to use a split system air conditioning unit that only recirculates air, Is this allowed?

A No, an economizer is required by code. Cooling energy savings will normally outweigh any additional energy requirements for humidification or dehumidification. Your choices are to either provide enough outside air for 100 percent of the design supply capacity, or as an alternative you could use recirculated air only combined with a waterside economizer.

Find Out More

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12/05 ODOE CF-125/Fact Sheet 16

Non-residential code HVAC fact sheets include:

- Ventilation Controls
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- Airside Controls
- Air Transport Energy

Continued from page 1

will be more energy-efficient to cool outside air (65°F) vs return air (75°F). For an integrated economizer, the controller for the HVAC unit would use economizer cooling first. If the space cannot be maintained at the setpoint with outside air, mechanical cooling would be used in conjunction with economizer cooling. Integrated economizers are required on units with a cooling capacity of 15 tons or greater.

With integrated economizers, special attention should be given to operation under low load conditions. A packaged HVAC unit with a single compressor could encounter problems with coil frosting during cool outdoor conditions. For this reason, integrated economizers are more common for systems with multiple compressors or other means of capacity control. Dual-compressor systems are widely available for systems with a cooling capacity of 8 tons or greater and integrated economizers are encouraged for any systems with multiple compressors.

Economizer Control Options

Economizers can be controlled in one of several ways: outside air dry-bulb temperature, differential dry-bulb temperature, or differential enthalpy. An outside air dry-bulb controller is the simplest form of control: economizer cooling is used whenever the outside air is below a set limit. Differential dry-bulb control uses economizer cooling whenever the outside air is cooler than the return air. This is a more energy-efficient (though more complicated) strategy. Differential enthalpy controllers restrict the use of economizer cooling to times when the enthalpy (heat content) of the outside air is less than the enthalpy of the return air. This helps to maintain indoor humidity levels at design levels during cool to mild, humid outdoor conditions. The Oregon climate rarely has high humidity at the economizer changeover temperature, so differential dry-bulb is the recommended option. Enthalpy-based sensors are also more prone to false readings and failure.

Economizers have controls and components (dampers, linkages, actuators, temperature sensors, and logic controllers) that are prone to failure and require continued maintenance. Successful economizer installation means careful selection of quality components and functional testing to ensure that economizer controls are set correctly. Over time, dirt and corrosion can cause dampers to become stuck in a fixed position. If the outside air damper is stuck closed, poor air quality will result. If the damper is stuck open, the building will require excess energy for heating and cooling. To prevent corrosion of dampers, particularly in coastal areas, stainless steel dampers can be specified. Damper operations can also be improved by selecting ball bearing or nylon bushings. Direct-drive actuators are less prone to failure than dampers connected using linkage arms. Sensors may need periodic testing and recalibration to ensure that accurate temperature readings are obtained. Functional testing and commissioning of economizer controls is important to ensure proper operation. As a minimum, economizers should be tested to verify that low lockout and high-limit temperatures are adjusted properly. These temperatures disable the economizer when the outdoor temperature gets too low (50°F) or too high (75°F) and resets the damper to the minimum ventilation air setting.

Oregon Non-Residential Building Energy Code

OREGON DEPARTMENT OF ENERGY

Large Volume Fan Systems

The Oregon Energy Code has special fan speed control requirements for large-volume fan systems. The requirement applies to single-zone systems with a supply airflow of 15,000 cfm or greater. These are common in large interior spaces such as gymnasiums and cafeterias.

The Code requires that these systems include either a two-speed fan or a variable-speed drive for reducing airflow to a maximum of 60 percent of peak airflow or to the minimum ventilation requirement. The minimum ventilation requirement, defined in Chapter 4 of the Oregon Mechanical Specialty Code, specifies minimum outside air requirements for a given space type. In most cases, the code minimum requirement for ventilation will be less than 60 percent of design airflow. Variable-speed drives offer an excellent opportunity for energy savings. Fan power varies with the cube of airflow; the greater the turndown ability for the fan system, the greater the energy savings will be. VAV control will also allow for improved humidity control at part-load conditions, by maintaining the desired supply air temperature.

Exceptions

Exceptions are provided for systems that provide specific humidity control or that supply air required for an exhaust system. A dehumidification heat pump system serving a natatorium would be an example of the humidty control exemption. This system needs to dehumidify large quantities of natatorium air to control humidity levels. A kitchen make-up unit would be an example of a system fitting the exception of supplying an exhaust system. For these applications, a constant volume system is allowed.

Typical direct-expansion (DX) systems provide dehumidification only indirectly. The systems primarily address sensible loads by controlling the space temperature to the thermostat setting. By cooling the supply air to below its dewpoint temperature, dehumidification also occurs. Some systems provide an additional humidity control option, with a RH sensor and a control algorithm to turn on compressor cooling under low load conditions if the relative humidity exceeds the setpoint. These type of systems, that treat occupant and ventilation air latent loads, do not qualify for the exception.

Controlling Cooling Supply Air Temperature

The Code requirement for large volume fan systems applies to units with either direct-expansion (DX) air handlers or with chilled water coils, as well as heating only systems. An HVAC unit with a design airflow capacity of 15,000 cfm or greater corresponds to a design cooling capacity of 35 to 40 tons or greater. To

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Code Language

1318.4.2.4 Large volume fan systems. Fan systems over 15,000 (7 m^3/s) cfm that serve single zone areas including but not limited to gymnasiums, cafeterias, auditoriums or warehouses, are required to reduce airflow based on space thermostat heating and cooling demand. A two-speed motor or variable frequency drive shall reduce airflow to a maximum 60 percent of peak airflow or minimum ventilation air requirement as required by Chapter 4 of the Oregon Mechanical Specialty Code, whichever is greater.

Exception: Systems where the function of the supply air is for purposes other than temperature control, such as maintaining specific humidity levels or supplying an exhaust system.

Documentation: Large Volume Fan System fan speed control is documented on Form 4A, line 15. Note that single-zone packaged DX units that would otherwise be classified as simple systems by the Oregon Code become complex if an automatic fan speed control is required.

Examples

Q A 10,000 ft² cafeteria at a high school is conditioned by a heating/ventilation unit. The unit includes two stages of heating and specifies a 20,000 cfm design airflow. What controls are required for this system?

A Since the design airflow is greater than 15,000 cfm, the system requires fan speed controls. The minimum ventilation requirement is determined from Chapter 4 of the Oregon Mechanical Specialty Code. If the peak occupancy is 500 persons, the outdoor air requirement is 500 person x 20 cfm/person = 10,000 cfm of outdoor air. This is less than 60% of the design airflow, so the airflow must be reduced to a minimum of 12,000 cfm (60% of 20,000 cfm) or lower. The occupant load factor from Table 1004.12 of the Oregon Structural Specialty Code is 15 ft²/person. Since the occupant load factor is less than 20, Ventilation Controls for High Occupancy Areas (Section 1317.2.2) must also be provided. (A heat recovery system with an effectiveness of 50% or greater may be specified, as an alternative to ventilation controls, as specified in Section 1317.2.2.)

Examples

Q **A large open exhibit hall in a museum uses a 35-ton packaged DX unit to provide heating and cooling, and to provide close humidity control to 50% or lower, to maintain the integrity of the historic documents and artifacts. Is a fan speed control required for this system?**

A No. Since the process entails specific dehumidification requirements, a constant volume system is acceptable.

Q **A 40-ton packaged DX unit that provides 16,000 cfm of supply air at design conditions is specified with a two-speed fan. The high fan speed is used in cooling mode only. The low fan speed setting is used in ventilation mode and in heating mode. Does this unit comply with the fan speed control requirement?**

A Yes, this is an acceptable design. This system should be designed with the first stage of cooling using the economizer at low fan speed (if outside air conditions allow economizer operation). If load is not met with this operation, the fan should be increased to full speed.

Find Out More

Copies of Code:
Oregon Building Officials Association
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Technical Support:
Oregon Department of Energy
625 Marion Street NE phone: 503-378-4040
Salem, OR 97301-3737 toll free: 800-221-8035
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Northwest Energy Efficiency Alliance
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Non-residential code HVAC fact sheets include:
- Ventilation Controls
- Exhaust Air Heat Recovery
- Hydronic Design and Controls
- Large Volume Fan Systems
- Simple vs. Complex HVAC Systems
- Economizers
- Airside System Design Req.
- Airside Controls
- Air Transport Energy

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maintain a steady supply air temperature (SAT) as supply air flow is reduced, the cooling capacity will need to be staged. DX systems of this size typically have multiple compressors to reduce capacity at part-load conditions. The cooling capacity can typically be reduced to as low as 25 percent of peak capacity. To maintain a steady supply air temperature (SAT), the air volume can be staged in discrete steps with the cooling capacity.

Chilled water systems consist of a water coil and control valve to provide space cooling. With a chilled water system, air volume can be varied continuously while still maintaining tight control of the supply air temperature. This is achieved by modulating the flow through a chilled water coil. A PID control sequence will allow for the closest control of supply air temperature and minimize temperature fluctuations. It is important to verify control operation and tune the loops as necessary.

Controlling Heating Suppy Air Temperature

Some large volume fan systems will provide heating or ventilation only, to spaces such as gymnasiums. These systems also require fan speed control. Units with gas-fired heaters are typically capable of reducing airflow by 50 percent or greater when operating in a heating mode. A reduction in airflow will lead to an increased temperature rise of the supply air. Multiple heating stages or modulating burner controls with up to 10:1 turndown are recommended with such systems, to maintain acceptable supply air temperature control. These systems often provide very warm supply air (90-105°F) from outlets high in the space. High supply air temperatures, combined with a ceiling supply and return, can lead to poor ventilation effectiveness. Some of the supply air can short-circuit to the return before it has a chance to condition the space under these conditions. To help achieve a more fully mixed air-space, it is preferable to design the system with low return grilles to counterbalance the natural buoyancy of warm air. If supply and returns must be located high in the space, moderating the supply air temperature in heating can increase ventilation effectiveness.

Maintaining Minimum Ventilation Air

When specifying VAV control, it is important to verify that the outside air damper minimum position varies as the fan speed setting moves between the maximum and minimum flow. When CO_2 based control of outside air (see Ventilation Controls fact sheet) is combined with a variable air volume single zone system, supply airflow can be greatly reduced during periods of low occupancy and reduced thermal load.

Related Code Sections
Variable air volume (VAV) systems must also meet maximum fan power limitations of Section 1318.4.2.2. Systems that are used with high occupancy spaces, such as theaters or cafeterias, may require ventilation controls as specified in Section 1317.2.2. A heating-only system may have a relatively low design airflow per occupant. Such a system may require exhaust air heat recovery, as specified in Section 1318.3. Large volume fan systems must also include optimum start controls (1317.4.3.2) and shutoff damper controls (1317.4.3.3.1), which close outdoor air supply and exhaust dampers when the systems are providing conditioning during unoccupied periods.