# User's Guide – National Energy Code of Canada for Buildings 2017

**Issued by the**

**Canadian Commission on Building and Fire Codes**

**National Research Council of Canada**

This publication was made possible with the technical and financial support of:

Natural Resources Canada | Ressources naturelles Canada

First Edition 2014
Second Edition 2019
Third Edition 2019

ISBN 0-660-25778-5

NR24-24/1-2017E-PDF

NRCC-CONST-56247E



Printed in Canada

First Printing

2 4 6 8 10 9 7 5 3 1

Aussi disponible en français :

Guide de l'utilisateur du Code national de l'énergie pour les bâtiments – Canada 2017
NRCC-CONST-56247F
ISBN 0-660-25780-8
NR24-24/1-2017F-PDF

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# Introduction

This is the third edition of the User's Guide – National Energy Code of Canada for Buildings (NECB). It is intended to complement the NECB 2017 and increase users' understanding of the Code's intent and application in the field; as such, it is not to be used as a standalone document. The User's Guide contains background information, explanatory material and, in some cases, suggested approaches to certain design or compliance matters, but does not contain mandatory requirements and is neither a textbook nor a design guide. The figures it contains are schematic only and the examples are illustrative only: they do not represent design recommendations.

The User's Guide comprises commentaries on NECB Parts 3 to 8 but does not address each and every Article of the NECB: content was developed for subject areas that were deemed to require further explanation or detailed examples and calculations.

## Development

This edition of the User's Guide is based on the 2015 edition of the User's Guide. New content was developed for the 2017 edition to address new and updated requirements in the NECB 2017.


The User's Guide was prepared by the Working Group on User's Guide of the Standing Committee on Energy Efficiency in Buildings. Members of the Working Group include:

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Codes Canada owes a special thanks to E. Richman and N. Smirnov for contributing their technical expertise to the development of this User's Guide.


## Overview of the NECB

### Objectives

As with the other National Model Construction Codes, the NECB is an objective-based code. Its primary objective is to limit the negative impact of building design and construction on the environment (objective "OE Environment"). Specifically, its provisions aim to limit the probability that buildings will use an excessive amount of energy (sub-objective "OE1.1 excessive use of energy"). Whereas the other Codes address different objectives of safety, health, protection of buildings and accessibility, the NECB's sole objective is energy efficiency. For example, while the NECB contains requirements related to the power demand of ventilation fan systems, it does not have ventilation flow requirements as these primarily address the health objective and are found in the National Building Code of Canada.

## NECB Parts Covered in this Guide

The User's Guide deals with the technical provisions of the NECB, which are contained in NECB Parts 3 to 8 of Division B:

- Part 3: Building Envelope
- Part 4: Lighting
- Part 5: Heating, Ventilating and Air-conditioning Systems
- Part 6: Service Water Systems
- Part 7: Electrical Power Systems and Motors
- Part 8: Building Energy Performance Compliance Path

## Compliance

There are three compliance paths in the NECB: the prescriptive path, the trade-off path and the performance path (see the flow chart in NECB Figure A-1.1.2.1. of Division B).

The prescriptive path is a formulaic approach to achieving building design compliance whereby the provisions in NECB Sections 3.2., 4.2., 5.2., 6.2., and 7.2. are applied as stated. For example, to achieve a Code-compliant building envelope using the prescriptive path method, a designer would follow the provisions presented in NECB Section 3.2., Prescriptive Path.

If a builder, designer or building owner wants to use a particular building system or parameter that does not meet the minimum performance level required in the prescriptive path, it may still be possible to demonstrate compliance using the trade-off path provisions in NECB Sections 3.3., 4.3., 5.3., and 6.3. (there are no trade-off options in NECB Part 7). The trade-off path affords some degree of flexibility in the application of the prescriptive requirements, with limitations. One overriding limitation is that each trade-off path is Part-specific: component performance cannot be traded between different building systems or parameters. For example, the HVAC trade-off path cannot be used to trade efficiencies between the HVAC system and the building envelope. But it could be used to trade-off a boiler that does not meet the prescriptive path requirements against air handler units with high-efficiency motors driven by variable frequency drives, as these exceed the minimum performance level of the applicable prescriptive requirements. Other limitations are specific to individual trade-off paths: for example, the lighting trade-off path applies only to interior lighting and not to exterior lighting.

The overriding principle behind the trade-off paths is that the total energy used by the proposed building system or parameter must be less than or equal to that of the reference building system or parameter, which is based on the prescriptive path. The main advantage of the trade-off-path is the flexibility it allows designers over the prescriptive path.

A designer can use any of the simple prescriptive or trade-off options presented in each Part or a combination of simple prescriptive for some building parameters and trade-off for others.

The building energy performance compliance path in NECB Part 8 is a whole building approach. The path compares the performance of a proposed building to that of a reference building, i.e., one that follows the prescriptive path. The performance path allows performance losses in one building system or parameter to be offset by performance gains in another. For example, a proposed building with a boiler that is less efficient than required in the prescriptive path could have a building envelope with better thermal performance than required in the prescriptive path. If the total energy consumption of the proposed building is less than or equal to that of the reference building, the design is considered NECB-compliant. The performance path cannot be used to test the compliance of individual building systems or parameters; if chosen, it must be used for the compliance of all building systems and parameters.

Due to the complexity of the calculations involved (e.g., hourly calculations) in applying the performance path provisions, computer simulations are typically used to demonstrate compliance.

## Referenced Standards

Unless otherwise specified, the applicable editions of the standards referenced in this User's Guide are the editions referenced in the NECB 2017, including any updates to those standards published by Codes Canada.

## Additional Information

Readers are encouraged to familiarize themselves with the preface of the NECB to gain important insight into the Code development process, the structure of the NECB, and the relationship between its Divisions, as well as a deeper understanding of the objective-based approach and how it opens the door to innovation.

# Commentary on Part 3

# Building Envelope

## Scope (Article 3.1.1.1.)

**1.** NECB Part 3 addresses the transfer of heat and air through the building envelope and establishes the minimum acceptable measures for the adequate thermal performance of the building envelope materials, components and assemblies. The NECB defines the building envelope as the collection of components that separate conditioned space (including semi-heated space) from unconditioned space, the exterior air or the ground, or that separate interior spaces intended to be conditioned to temperatures differing by more than 10°C at design conditions. The building envelope, which includes the walls, roofs, floors, fenestration and doors of a building, plays an important role in determining the amount of energy required to accommodate the occupancy of a building. The transfer of heat and air through the building envelope is an important consideration for energy efficiency.

## Application (Article 3.1.1.2.)

**2.** The requirements in NECB Part 3 apply to all new buildings and additions that are equipped with space-conditioning systems or have provisions for the future installation of such systems and that have a heating and/or cooling system output capacity that is equal to or greater than 10 W/m² of floor surface area. The requirements do not apply to unconditioned spaces or to farm buildings.

## Compliance (Article 3.1.1.3.)

**3.** Compliance with NECB Part 3 can be achieved by following one of three paths: the prescriptive path, the trade-off path, or the performance path. The three paths allow designers the flexibility to either strictly apply the NECB prescriptive requirements, use trade-offs to meet the requirements, or apply a more detailed whole building energy performance approach to their design. The flow chart in NECB Figure A-3.1.1.3.(1) shows the available options for building envelope compliance. The three compliance paths are explained in Paragraphs 42 to 68.

## Thermal Characteristics of Building Assemblies (Article 3.1.1.5.)

**4.** The thermal characteristics of building envelope materials are typically determined through testing in accordance with relevant material standards, many of which are referenced in the National Building Code of Canada 2015 (NBC). Where no standard exists for a particular material, or where a particular standard does not address the thermal characteristics of a material, this data can be obtained through testing in accordance with ASTM C 177, "Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus," or ASTM C 518, "Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus." Manufacturers often reference these standards in their material literature along with the thermal properties of their materials.

**5.** An understanding of heat transfer fundamentals, including the concepts of thermal conductivity and thermal resistance, is essential to the design, selection and evaluation of building envelope assemblies that comply with the NECB Part 3 requirements.

**6.** Heat spontaneously travels from an area of high temperature to an area of low temperature in an attempt to reach thermal equilibrium. Heat flow in building envelope assemblies occurs through a combination of convection, radiation and conduction. The NECB requirements address conduction. Heat transfer in building envelope assemblies can be minimized by using a combination of building components that resist heat flow and by controlling air leakage.

**7.** The overall thermal transmittance (U-value) is a measure of the rate, in W/(m²·K), at which heat is transferred through a building assembly whose two faces are simultaneously exposed to different temperatures. The U-value represents the amount of heat transferred through a unit area, in a unit of time, induced under steady-state conditions by a unit temperature difference between the environments on its two faces. The U-value reflects the capacity of all elements to transfer heat through the thickness of the assembly, including through air films. The effective thermal resistance (RSI value, in metric units) is the reciprocal of the overall thermal transmittance, as shown in the following equation, and is measured in (m²·K)/W:

$$\mathrm{RSI} = \frac{1}{\mathrm{U}}$$

where
RSI = effective thermal resistance, in (m²·K)/W, and
U = overall thermal transmittance, in W/(m²·K).

**8.** Ideally, building envelope assemblies are selected or designed based on the building type, use, and location since they must be appropriate for both internal and external loads. They can drastically improve a building's overall performance and energy efficiency. Building envelope assemblies do not require the direct use of energy and have a significant impact on thermal comfort and building heating and cooling loads. The consideration of outdoor conditions to which a building envelope assembly will be subjected is one of the first steps in the design and selection process.

**9.** A reasonable estimate of annual heating energy consumption can be obtained from the demand and the heating degree-days (HDD) of the building location. The NECB Part 3 requirements for the maximum U-value of building envelope assemblies are related to the applicable HDD category for the building location. An HDD value is the sum of the differences between the mean temperature for the day and 18°C for every day in the year when the mean temperature is below 18°C. Values for selected locations in Canada are listed in NECB Table C-1. For locations not listed, HDD values may be obtained from Environment and Climate Change Canada (www.ec.gc.ca).

**10.** The NECB uses the following six HDD categories, known as Zones:

**Table 3-1**
**Heating Degree-Day Zones**

| Zone | Heating Degree-Days of Building Location, Celsius Degree-Days |
|---|---|
| 4 | < 3000 |
| 5 | 3000 to 3999 |
| 6 | 4000 to 4999 |
| 7A | 5000 to 5999 |
| 7B | 6000 to 6999 |
| 8 | ≥ 7000 |

**11.** In general, the ascending numbered Zones designate southern to northern areas of Canada. The Zones are based on the climate zones found in ANSI/ASHRAE/IES 90.1, "Energy Standard for Buildings Except Low-Rise Residential Buildings." Canada has no locations falling under Zones 1 to 3; Zone 4 is the mildest zone in Canada (Victoria, British Columbia, is an example of a Zone 4 location), while Zone 8 is the coldest (Yellowknife, Northwest Territories, is an example of a Zone 8 location). In the NECB Part 3 requirements, the maximum overall thermal transmittance of building assemblies decreases (i.e., becomes more stringent) as the HDD value increases. For example, the maximum overall thermal transmittance for roofs in Zone 4 is 0.193 W/(m²·K) compared to 0.121 W/(m²·K) for roofs in Zone 8.

## Accounting for Thermal Bridging Elements (Sentence 3.1.1.5.(5) and Article 3.1.1.7.)

**12.** In the 2011 and 2015 editions of the NECB, thermal bridging of only a few building elements was factored into the calculation of the overall thermal transmittance of building envelope assemblies. The surface areas of these elements were considered as heat transfer paths. This approach disregarded other heat transfer paths, such as window-to-wall transitions, which have no definable area but are a source of significant heat transfer. Not accounting for all occurrences of thermal bridging across the building envelope meant that opaque building assemblies could have greater actual overall thermal transmittance values than those required by the NECB—possibly two or more times higher than the values determined from calculation methods that ignore the cumulative effect of thermal bridging.

**13.** The consequences of not appropriately accounting for the impact of all thermal bridges include higher energy use than expected based on the results of energy use analyses carried out with inaccurate input values, missed opportunities to achieve lower energy costs, and wasted resources (e.g., when a high level of thermal insulation is called for in a design and the assumed benefit is not achieved due to thermal bridging).

**14.** The 2017 edition of the NECB requires that thermal bridging of many more elements be accounted for, which should motivate designers to mitigate its effects through improved construction details. Current methods of determining overall thermal transmittance produce more accurate values by using linear and point transmittance data to account for thermal bridging.

**15.** See the 2016 edition of the "Building Envelope Thermal Bridging Guide" for an example on how to determine the thermal characteristics of a building envelope assembly using the ISO 14683 standard for a generic building interface or using both a clear field assembly and the Guide's linear and point transmittance catalogue.

## Calculation of Overall Thermal Transmittance (Article 3.1.1.7.)

**16.** A thorough understanding of the methods used in determining or calculating the U-value of opaque building envelope assemblies is important for demonstrating compliance with NECB Part 3.

**17.** NECB Sentence 3.1.1.7.(4) provides a credit for any unconditioned space protecting a component of the building envelope. The enclosure's assumed overall thermal transmittance (U-value) of 6.25 W/($m^2$·K) allows the effective thermal resistance (RSI value) for the protected areas of above-ground opaque building envelope assemblies to be reduced by 0.16 ($m^2$·K)/W, as demonstrated in Example 3-1. The credit provided in NECB Sentence 3.1.1.7.(4) does not apply to vented spaces because such spaces are considered to be part of the exterior space (see NECB Note A-3.1.1.7.(5)).

**Example 3-1 – Maximum Overall Thermal Transmittance of an Exterior Above-Ground Opaque Wall Protected by an Enclosed Unconditioned Space**

In Regina, Saskatchewan, an exterior above-ground opaque wall is protected by an enclosed unconditioned space. According to NECB Table C-1, Regina has an HDD of 5600, which corresponds to Zone 7A (see Table 3-1 in Paragraph 10). The maximum overall thermal transmittance (U-value) for above-ground opaque walls in Zone 7A is 0.21 W/(m²·K) according to NECB Table 3.2.2.2. To apply the credit of 6.25 W/(m²·K) provided in NECB Sentence 3.1.1.7.(4), both the credit and the maximum overall thermal transmittance must be converted to RSI values as follows:

$$\mathrm{RSI_{wall}} = \frac{1}{\mathrm{U_{wall}}} = \frac{1}{0.21\ \mathrm{W}/\left(\mathrm{m}^2 \cdot \mathrm{K}\right)} = 4.76\ \left(\mathrm{m}^2 \cdot \mathrm{K}\right)/\mathrm{W}$$

$$\mathrm{RSI_{credit}} = \frac{1}{\mathrm{U_{credit}}} = \frac{1}{6.25\ \mathrm{W}/\left(\mathrm{m}^2 \cdot \mathrm{K}\right)} = 0.16\ \left(\mathrm{m}^2 \cdot \mathrm{K}\right)/\mathrm{W}$$

The adjusted RSI value for the protected wall is then calculated as follows:

$$\mathrm{RSI_{net}} = \mathrm{RSI_{wall}} - \mathrm{RSI_{credit}}$$
$$\mathrm{RSI_{net}} = 4.76\ \left(\mathrm{m}^2 \cdot \mathrm{K}\right)/\mathrm{W} - 0.16\ \left(\mathrm{m}^2 \cdot \mathrm{K}\right)/\mathrm{W} = 4.60\ \left(\mathrm{m}^2 \cdot \mathrm{K}\right)/\mathrm{W}$$

To obtain the adjusted maximum overall thermal transmittance (U-value) for the protected wall, the adjusted RSI value is converted to a U-value as follows:

$$\mathrm{U_{net}} = \frac{1}{\mathrm{RSI_{net}}} = \frac{1}{4.60\ \left(\mathrm{m}^2 \cdot \mathrm{K}\right)/\mathrm{W}} = 0.217\ \mathrm{W}/\left(\mathrm{m}^2 \cdot \mathrm{K}\right)$$

Therefore, the adjusted maximum overall thermal transmittance for the protected wall is 0.217 W/(m²·K).

**18.** Building envelope assemblies are typically composed of several components, which may include building materials, thermal insulation, and air spaces (or air cavities). Each component has its own ability to resist heat flow. Since heat transfer occurs across the entire assembly, the thermal resistance (RSI value) of each component, including any air space, is used to calculate the U-value of the assembly. Air films on the interior and exterior surfaces of the assembly also have an impact on heat transfer and must be considered in the calculation of the U-value. The thermal resistance of these air films is affected by their position in the assembly, the direction of heat transfer, the temperature of the surface and the air, the difference between the temperature of the surface and that of the surroundings, and the surface's long-wave emittance.

**19.** In cases where the U-value of a building envelope assembly has not already been determined through computer analysis and/or laboratory tests, it can be calculated using the simplified calculation procedures described in the "ASHRAE Handbook – Fundamentals." The method of calculation used depends on the type of assembly in question. Three methods of calculating the U-value of a building envelope assembly are described below:

- Isothermal Planes Method: method for assemblies with continuous components and no thermal bridging effects. Refer to Figure 3-1 in Paragraph 27.
- Isothermal Planes and Parallel Path Method: method that applies to wood-frame assemblies where heat flow through the thermal bridge is parallel to heat flow through the insulation and the temperature at each plane in the assembly is constant. This method differs from the Isothermal Planes Method, which applies only to assemblies with continuous components. Refer to Figure 3-2 in Paragraph 32.
- Metal-frame Assembly Method: method that applies to metal-frame assemblies where an effective value for the insulation/framing portion is used and the Isothermal Planes Method is used for continuous material layers. Refer to Figure 3-3 in Paragraph 35.

**20.** To calculate the U-value of a building assembly using the three methods described in Paragraph 19, the following information is required:

- the RSI value and thickness of each component that makes up the assembly (see Paragraph 21),

- the RSI values of air spaces that form part of the assembly (see Paragraph 22),
- the RSI values of indoor and outdoor air film resistances, as applicable (see Paragraph 23), and
- the type, size and spacing of repetitive framing members that form part of the assembly and have a thermal bridging effect on the assembly (see Paragraph 24).

**21.** Typical RSI values for some common insulation and building envelope materials are listed in Tables 3-4 to 3-8 (see Paragraph 70). RSI values can also be obtained from material manufacturers and the "ASHRAE Handbook – Fundamentals."

**22.** The RSI value of air spaces varies with heat flow direction. Typical RSI values for air spaces are listed in Table 3-8 (see Paragraph 70) according to the type of assembly (i.e., ceiling, floor or wall) and the thickness of the air space. For air space geometries not shown, data can be sourced from the "ASHRAE Handbook – Fundamentals."

**23.** The RSI value of air films also varies with heat flow direction. For exterior air films, the RSI values depend on wind speed. Typical RSI values for air films are listed in Table 3-8 (see Paragraph 70) according to type (interior or exterior) and location (ceiling, floor or wall). For air film types not shown, data can be sourced from the "ASHRAE Handbook – Fundamentals."

**24.** Values for framing percentages for typical wood-frame assemblies are listed in Table 3-9 (see Paragraph 70) according to assembly type and frame spacing. Values for framing percentages can also be calculated based on actual construction. These values are needed to calculate U-values in the Isothermal Planes and Parallel Path Calculation Method for wood-frame assemblies.

**25.** For all of the methods described above, the effects of fasteners, brick ties and connectors through the building envelope components are typically ignored in assemblies with continuous insulation since these components have little effect on U-value. In an uninsulated cavity, the effect of metal wall ties is negligible. In any cavity, the effect of plastic ties is negligible. In some cases, the RSI value of certain building components, such as polyethylene vapour barriers, metal decks, fabric or paper sheeting products, is so low as to be considered negligible, and as such they are assigned an RSI value of zero in the U-value calculations.

### U-value Calculation for Building Assemblies with Continuous Insulation – Isothermal Planes Calculation Method

**26.** Where a building assembly contains only continuous materials, the simplest method of calculating the U-value can be used, which is the one-dimensional Isothermal Planes Calculation Method. It applies, for example, to building assemblies that do not use framing within the insulating portion of the assembly, such as flat roofs or a fully insulated floor slab. The method involves adding together the thermal resistances of each component of the assembly. The reciprocal of this sum is the U-value of the assembly, $U_T$, which is calculated as follows:

$$U_T = \frac{1}{RSI_T}$$

where

$RSI_T$ = sum of the thermal resistances of the components of the assembly, including interior and exterior air films, in $(m^2 \cdot K)/W$.

**27.** Figure 3-1 shows a graphical representation of the Isothermal Planes Method heat flow calculation through a flat roof assembly.

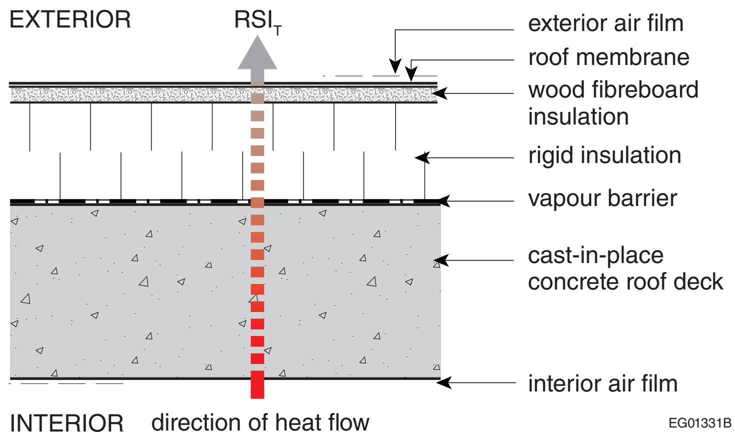



**Figure 3-1**
**Graphical representation of U-value calculation using the Isothermal Planes Calculation Method**

**28.** Examples of U-value calculations using the Isothermal Planes Calculation Method are presented in Examples 3-2 to 3-5.

**Example 3-2 – Floor: Insulated Concrete Slab-on-Grade**

Figure A shows an insulated concrete slab-on-grade with radiant heating.

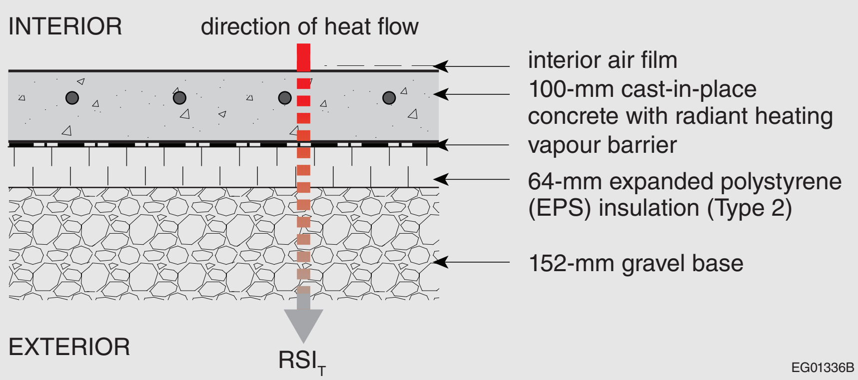



**Figure A**
**Insulated concrete slab-on-grade (section view)**

Since the assembly contains only continuous materials, the Isothermal Planes Calculation Method is used to calculate the overall thermal transmittance. The RSI values of all the assembly's components can be obtained from Tables 3-4 to 3-8 (see Paragraph 70), taking into account the thickness of the materials and the RSI value of the interior air film. The overall thermal transmittance, $U_T$, can be calculated as follows:

| Assembly Components | RSI, $(m^2 \cdot K)/W$ |
|---|---|
| Interior air film | 0.16 |
| 100-mm cast-in-place concrete slab (normal density aggregate) | 0.04 |
| Vapour barrier | 0.00 |
| 64-mm EPS insulation (Type 2) | 1.79 |
| $RSI_T$ | 1.99 |
| $U_T = 1/RSI_T$ | 0.503 |

**Example 3-3 – Roof: Flat Roof (4-ply built-up roofing (BUR) and steel deck)**

Figure A shows a roofing assembly with 4-ply BUR and a steel deck.

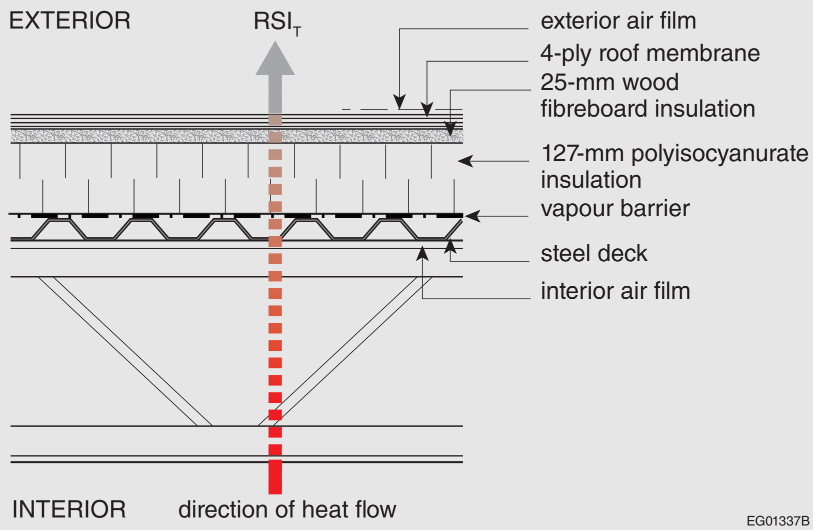



**Figure A**
**Flat roof – 4-ply BUR and steel deck (section view)**

Since the assembly contains only continuous materials and the metal decking does not penetrate the thermal insulation, the Isothermal Planes Calculation Method is used to calculate the overall thermal transmittance. The RSI values of all the assembly's components can be obtained from Tables 3-4 to 3-8 (see Paragraph 70), taking into account the thickness of the materials and the RSI values of the interior and exterior air films. If the roof insulation is tapered to allow roof drainage, the average insulation thickness would be taken into account in the calculations. The overall thermal transmittance, $U_T$, can be calculated as follows:

| Assembly Components | RSI, $(m^2 \cdot K)/W$ |
|---|---|
| Exterior air film | 0.03 |
| 4-ply roof membrane (built-up roofing, 10 mm) | 0.06 |
| 25-mm wood fibreboard insulation (insulating fibreboard) | 0.40 |
| 127-mm polyisocyanurate insulation | 4.85 |
| Vapour barrier | 0.00 |
| Steel deck | 0.00 |
| Interior air film | 0.11 |
| $RSI_T$ | 5.45 |
| $U_T = 1/RSI_T$ | 0.183 |

**Example 3-4 – Roof: Flat Roof (4-ply BUR and cast-in-place concrete deck)**

Figure A shows a roofing assembly with 4-ply BUR and a cast-in-place concrete deck.

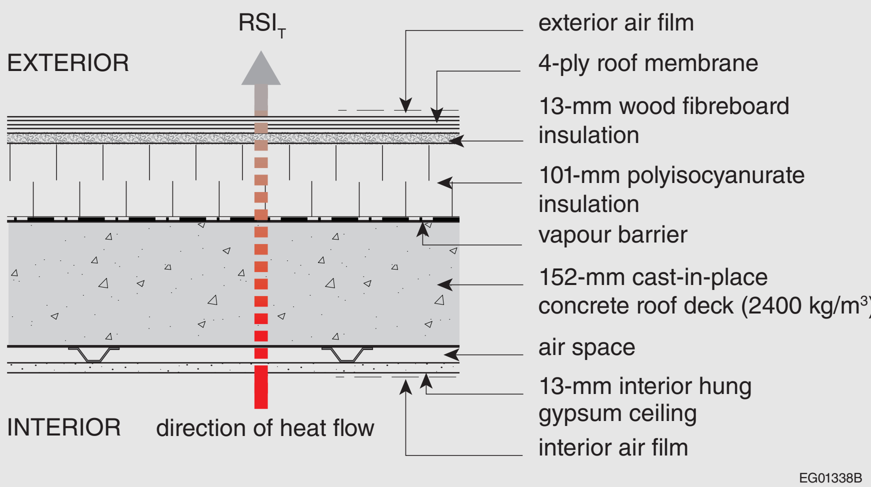



**Figure A**
**Flat roof – 4-ply BUR and concrete deck (section view)**

Since the assembly contains only continuous materials, the Isothermal Planes Calculation Method is used to calculate the overall thermal transmittance. The RSI values of all the assembly's components can be obtained from Tables 3-4 to 3-8 (see Paragraph 70), taking into account the thickness of the materials and the RSI values of the interior and exterior air films. The overall thermal transmittance, $U_T$, can be calculated as follows:

| Assembly Components | RSI, (m²·K)/W |
|---|---|
| Exterior air film | 0.03 |
| 4-ply roof membrane (built-up roofing, 10 mm) | 0.06 |
| 13-mm wood fibreboard insulation (insulating fibreboard) | 0.21 |
| 101-mm polyisocyanurate insulation (permeably faced) | 3.86 |
| Vapour barrier | 0.00 |
| 152-mm cast-in-place concrete roof deck | 0.06 |
| 38-mm air space | 0.16 |
| 13-mm gypsum board | 0.08 |
| Interior air film | 0.11 |
| $RSI_T$ | 4.57 |
| $U_T = 1/RSI_T$ | 0.219 |

**Example 3-5 – Roof: Flat Roof (protected membrane and pre-cast concrete deck)**

Figure A shows a roofing assembly with a protected membrane and pre-cast concrete deck.

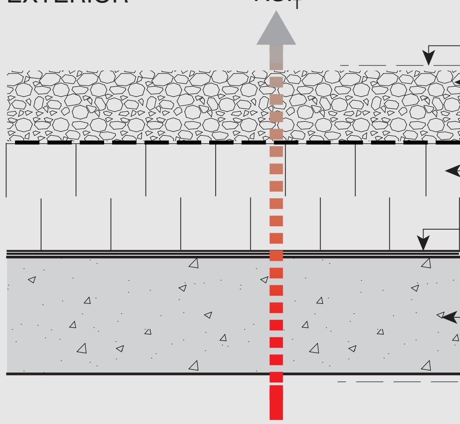



**Figure A**
**Flat roof – single-ply membrane and concrete deck (section view)**

Since the assembly contains only continuous materials, the Isothermal Planes Calculation Method is used to calculate the overall thermal transmittance. The RSI values of all the assembly's components can be obtained from Tables 3-4 to 3-8 (see Paragraph 70), taking into account the thickness of the materials and the RSI values of the interior and exterior air films. The overall thermal transmittance, $U_T$, can be calculated as follows:

| Assembly Components | RSI, (m²·K)/W |
|---|---|
| Exterior air film | 0.03 |
| 60-mm crushed stone (ballast) | 0.04 |
| Filter fabric | 0.00 |
| 152-mm extruded polystyrene insulation | 5.32 |
| Single-ply roofing membrane | 0.00 |
| Protection sheet | 0.00 |
| 152-mm pre-cast concrete roof deck | 0.06 |
| Interior air film | 0.11 |
| $RSI_T$ | 5.56 |
| $U_T = 1/RSI_T$ | 0.180 |

### U-value Calculation for Wood-frame Construction – Isothermal Planes and Parallel Path Calculation Method

**29.** For building assemblies that use wood-frame construction, the U-value can be calculated using the Isothermal Planes Method for the continuous material layers and the parallel path method for the framing portion of the assembly. The method involves adding the thermal resistances of each component of the assembly together for the continuous material layers and using the parallel path method to calculate the thermal resistance of the assembly along the line that goes through the framing portion of the assembly, and along the line that goes through the cavity portion of the assembly. For the parallel path method, the values are combined in proportion to the relative areas of the framing and insulation to calculate the effective RSI value.

**30.** The effective (i.e., overall) thermal resistance, $RSI_T$, using the parallel path method is calculated as follows:

$$RSI_T = \frac{100}{(\%\,\text{area of framing} \div RSI_F) + (\%\,\text{area of cavity} \div RSI_C)}$$

where
$RSI_F$ = thermal resistance of the framing portion of the assembly, and
$RSI_C$ = thermal resistance of the cavity portion of the assembly.

**31.** The values for the framing and cavity percentages can be obtained from Table 3-9 (see Paragraph 70) or can be calculated based on the actual construction. The reciprocal of $RSI_T$ is the overall U-value of the assembly, $U_T$

**32.** Figure 3-2 shows a graphical representation of the Isothermal Planes and Parallel Path Method heat flow calculation through a wood-frame wall assembly.

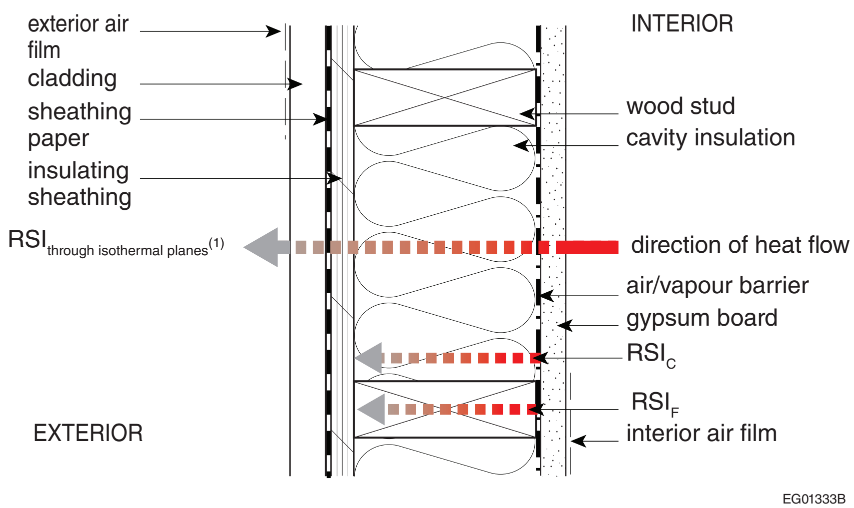



**Figure 3-2**
**Graphical representation of U-value calculation using the Isothermal Planes and Parallel Path Calculation Method**
**Note to Figure 3-2:**
(1) All materials are continuous on either side of framed portion.

**33.** Examples of U-value calculations using the Isothermal Planes and Parallel Path Method are presented in Examples 3-6 to 3-9.

**Example 3-6 – Roof: Attic-Type Wood Truss**

Figure A shows an attic-type wood truss assembly.

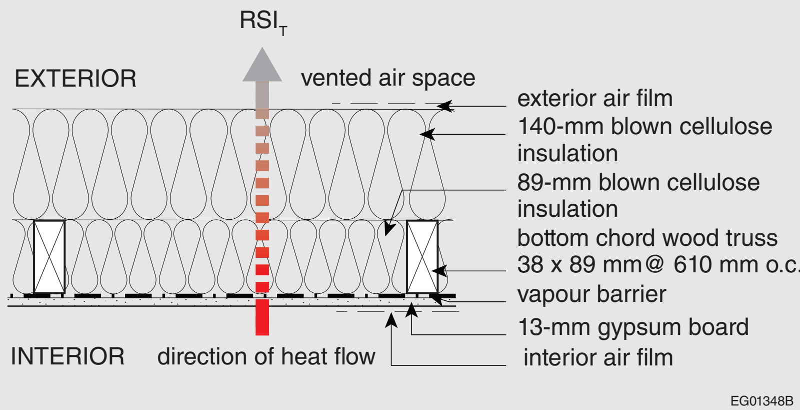



**Figure A**
**Attic-type wood truss (section view)**

Since the assembly contains wood framing, the Isothermal Planes and Parallel Path Method is used to calculate the overall thermal transmittance. The RSI values of all the assembly's components can be obtained from Tables 3-4 to 3-8 (see Paragraph 70), taking into account the thickness of the materials and the RSI values for the interior and exterior air films. The framing percentages can be obtained from Table 3-9 (see Paragraph 70). The overall thermal transmittance, $U_T$, can be calculated as follows:

| Assembly Components | | | RSI, (m²·K)/W |
|---|---|---|---|
| Roof air space (exterior air film) | | | 0.03 |
| Blown cellulose insulation | | | 3.50 |
| | % Area Framing | % Area Cavity | |
| Framing percentages (wood trusses @ 610 mm o.c.) | 11 | 89 | |
| | RSI$_F$ through bottom chord, (m²·K)/W | RSI$_C$ through cavity, (m²·K)/W | |
| Bottom chord (89 mm x 0.0085 RSI/mm) | 0.757 | – | 1.78 |
| Blown cellulose insulation | – | 2.14 | |
| Vapour barrier | | | 0.00 |
| 13-mm gypsum board | | | 0.08 |
| Interior air film | | | 0.11 |
| RSI$_T$ | | | 5.50 |
| $U_T$ = 1/RSI$_T$ | | | 0.182 |

**Example 3-7 – Wall: Wood-Frame Wall (brick masonry veneer)**

Figure A shows a wood-frame wall with brick masonry veneer.

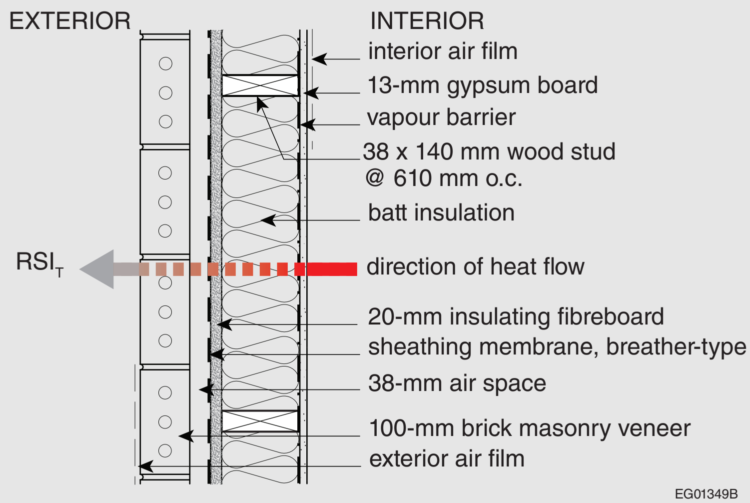



**Figure A**
**Wood frame wall – brick masonry veneer (plan view)**

Since the assembly contains wood framing, the Isothermal Planes and Parallel Path Method is used to calculate the overall thermal transmittance. The RSI values of all the assembly's components can be obtained from Tables 3-4 to 3-8 (see Paragraph 70), taking into account the thickness of the materials and the RSI values of the interior and exterior air films. The framing percentages can be obtained from Table 3-9 (see Paragraph 70). The overall thermal transmittance, $U_T$, can be calculated as follows:

| Assembly Components | | | RSI, $(m^2 \cdot K)/W$ |
|---|---|---|---|
| Exterior air film | | | 0.03 |
| 100-mm brick masonry veneer | | | 0.07 |
| 38-mm air space(1) | | | 0.18 |
| Sheathing membrane, breather-type | | | 0.00 |
| 20-mm insulating fibreboard | | | 0.32 |
| | % Area Framing | % Area Cavity | |
| Framing percentages (wood studs @ 610 mm o.c.) | 20 | 80 | |
| | $RSI_F$ through stud, $(m^2 \cdot K)/W$ | $RSI_C$ through cavity, $(m^2 \cdot K)/W$) | |
| Wood studs (140 mm x 0.0085 RSI/mm) | 1.19 | – | 2.80 |
| Batt insulation | – | 4.23 | |
| 13-mm gypsum board | | | 0.08 |
| Interior air film | | | 0.12 |
| $RSI_T$ | | | 3.60 |
| $U_T = 1/RSI_T$ | | | 0.278 |

(1) The air space in this Example's masonry cladding system with weep holes at its base is considered, in this illustrative calculation only, to be an enclosed air space as described in the "ASHRAE Handbook – Fundamentals." The most appropriate means of determining the overall thermal values, whether by calculation or by laboratory testing per NECB Sentence 3.1.1.5.(5), must be carefully considered for each situation.

**Example 3-8 – Wall: Wood-frame Wall (exterior insulation and finish system)**

Figure A shows a wood-frame wall with an exterior insulation and finish system (EIFS).

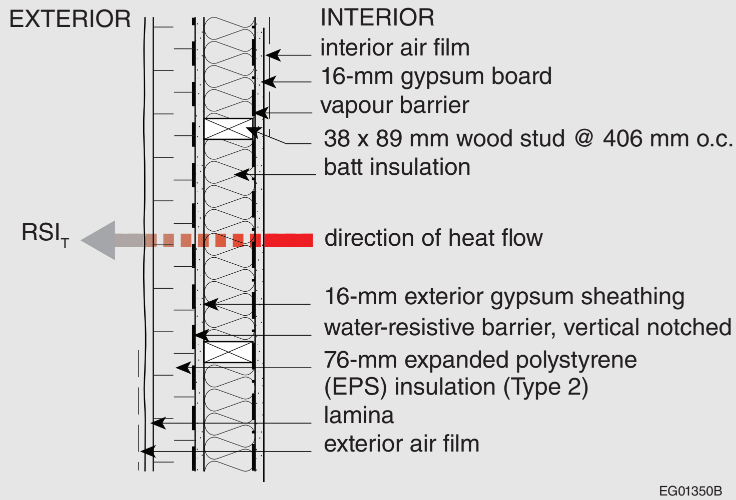



**Figure A**
**Wood-frame wall with EIFS (plan view)**

Since the assembly contains wood framing, the Isothermal Planes and Parallel Path Method is used to calculate the overall thermal transmittance. The RSI values of all the assembly's components can be obtained from Tables 3-4 to 3-8 (see Paragraph 70), taking into account the thickness of the materials and the RSI values of the interior and exterior air films. The framing percentages can be obtained from Table 3-9 (see Paragraph 70). The overall thermal transmittance, $U_T$, can be calculated as follows:

| Assembly Components | | | RSI, $(m^2 \cdot K)/W$ |
|---|---|---|---|
| Exterior air film | | | 0.03 |
| Lamina | | | – |
| 76-mm EPS insulation (Type 2) | | | 2.13 |
| Water-resistive barrier (vertical notched) | | | 0.00 |
| 16-mm exterior gypsum sheathing | | | 0.101 |
| | % Area Framing | % Area Cavity | |
| Framing percentages (wood studs @ 406 mm o.c.) | 23 | 77 | |
| | $RSI_F$ through stud, $(m^2 \cdot K)/W$ | $RSI_C$ through cavity, $(m^2 \cdot K)/W$ | |
| Wood studs (89 mm x 0.0085 RSI/mm) | 0.757 | – | 1.62 |
| Batt insulation | – | 2.47 | |
| Vapour barrier | | | – |
| 16-mm gypsum board | | | 0.098 |
| Interior air film | | | 0.12 |
| $RSI_T$ | | | 4.10 |
| $U_T = 1/RSI_T$ | | | 0.244 |

**Example 3-9 – Wall: Wall in Contact with Ground (concrete wall with wood framing)**

Figure A shows a concrete wall with wood framing in contact with the ground.

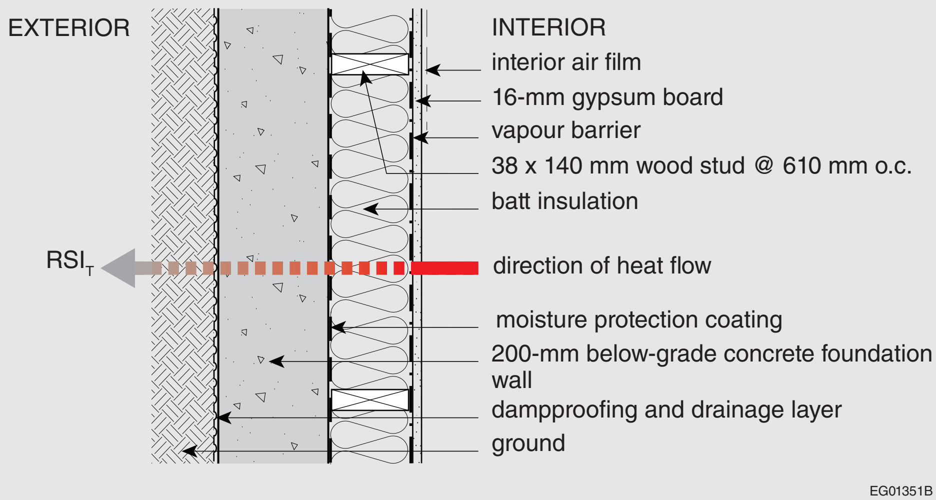



**Figure A**
**Wall in contact with ground – interior wood framing (plan view)**

Since the assembly contains wood framing, the Isothermal Planes and Parallel Path Method is used to calculate the overall thermal transmittance. The RSI values of all the assembly's components can be obtained from Tables 3-4 to 3-8 (see Paragraph 70), taking into account the thickness of the materials and the RSI values of the interior and exterior air films. The framing percentages can be obtained from Table 3-9 (see Paragraph 70). The overall thermal transmittance, $U_T$, can be calculated as follows:

| Assembly Components | | | RSI, (m²·K)/W |
|---|---|---|---|
| Dampproofing and drainage layer | | | 0.00 |
| 200-mm concrete | | | 0.08 |
| Moisture protection coating | | | 0.00 |
| | % Area Framing | % Area Cavity | |
| Framing percentages (wood studs @ 610 mm o.c.) | 13 | 87 | |
| | $RSI_F$ through stud, (m²·K)/W | $RSI_C$ through cavity, (m²·K)/W | |
| Wood studs (140 mm x 0.0085 RSI/mm) | 1.19 | – | 3.18 |
| Batt insulation | – | 4.23 | |
| Vapour barrier | | | 0.00 |
| 16-mm gypsum board | | | 0.098 |
| Interior air film | | | 0.12 |
| $RSI_T$ | | | 3.48 |
| $U_T = 1/RSI_T$ | | | 0.287 |

### U-value Calculation for Metal-frame Construction – Variation on the Isothermal Planes Method

**34.** For building assemblies that use metal-frame construction, a variation on the Isothermal Planes Method can be used in which the framed portion is treated as a continuous layer since its effective thermal resistance is known. The effective thermal resistance of the insulation/framing is obtained from Tables 3-2 and 3-3 for the framed portion of the assembly and added to the sum of the thermal resistance value of each component of the assembly to obtain the overall thermal resistance of the assembly. The use of Tables 3-2 and 3-3 should be limited to the rated RSI value of insulation shown in the Table and interpolation within those Table values. The Table values should not be extrapolated as an accurate result will not be obtained.

**Table 3-2**
**Effective RSI Values of the Insulation/Framing Layer in Metal-frame Roof and Floor Assemblies (1.2 m on centre)(1)**

| Rated RSI Value of Insulation | Correction Factor | Effective Framing/Cavity RSI Value |
|---|---|---|
| 0.00 | 1.00 | 0.00 |
| 0.70 | 0.97 | 0.68 |
| 0.88 | 0.96 | 0.85 |
| 1.41 | 0.94 | 1.32 |
| 1.76 | 0.92 | 1.62 |
| 1.94 | 0.91 | 1.76 |
| 2.11 | 0.90 | 1.90 |
| 2.29 | 0.90 | 2.06 |
| 2.64 | 0.88 | 2.32 |
| 2.82 | 0.87 | 2.45 |
| 3.35 | 0.86 | 2.88 |
| 3.52 | 0.85 | 2.99 |
| 3.70 | 0.84 | 3.11 |
| 4.23 | 0.82 | 3.46 |
| 4.40 | 0.81 | 3.57 |
| 5.28 | 0.79 | 4.17 |
| 6.16 | 0.76 | 4.68 |
| 6.69 | 0.74 | 4.95 |
| 7.04 | 0.73 | 5.14 |
| 7.92 | 0.71 | 5.63 |
| 8.80 | 0.69 | 6.07 |
| 9.68 | 0.67 | 6.49 |

(1) This Table is reproduced from Table A9.2A of ANSI/ASHRAE/IES 90.1-2010 with permission (©ASHRAE).

Table 3-3
**Effective RSI Values of the Insulation/Framing Layer in Metal-frame Wall Assemblies(1)**

| Nominal Depth of Cavity, mm | Actual Depth of Cavity, mm | Rated RSI Value of Air Space or Insulation | Effective Framing/Cavity RSI Value at 406 mm o.c. | Effective Framing/Cavity RSI Value at 610 mm o.c. |
|---|---|---|---|---|
| Empty Cavity, No Insulation | | | | |
| 100 | 89 | 0.16 | 0.14 | 0.16 |
| Insulated Cavity | | | | |
| 100 | 89 | 1.94 | 0.97 | 1.16 |
| 100 | 89 | 2.29 | 1.06 | 1.27 |
| 100 | 89 | 2.64 | 1.13 | 1.37 |
| 150 | 152 | 3.35 | 1.25 | 1.51 |
| 150 | 152 | 3.70 | 1.30 | 1.58 |
| 200 | 203 | 4.40 | 1.37 | 1.69 |

(1) This Table is reproduced from Table A9.2B of ANSI/ASHRAE/IES 90.1-2010 with permission (©ASHRAE).

**35.** Figure 3-3 shows a graphical representation of the U-value calculation for metal-frame construction.

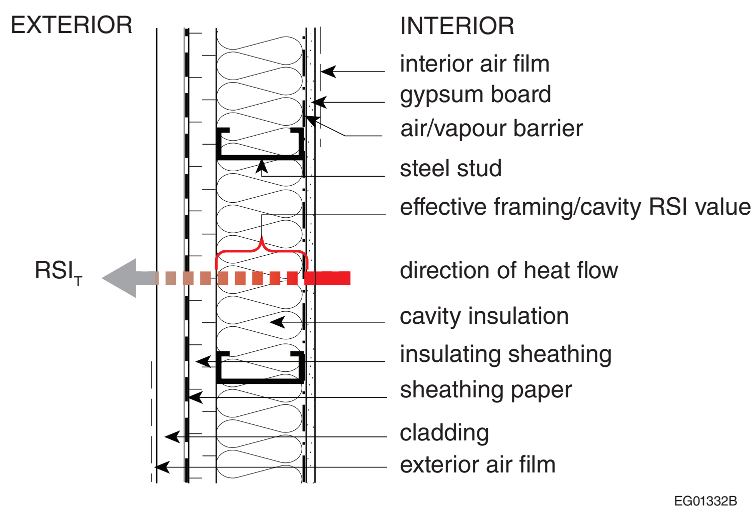



**Figure 3-3**
**Graphical representation of U-value calculation for metal-frame construction**

**36.** An example of a U-value calculation for metal-frame construction assemblies is presented in Example 3-10.

**Example 3-10 – Wall: Metal-frame Wall (insulated pre-cast concrete panels)**

Figure A shows a metal-frame wall with insulated pre-cast concrete panels.

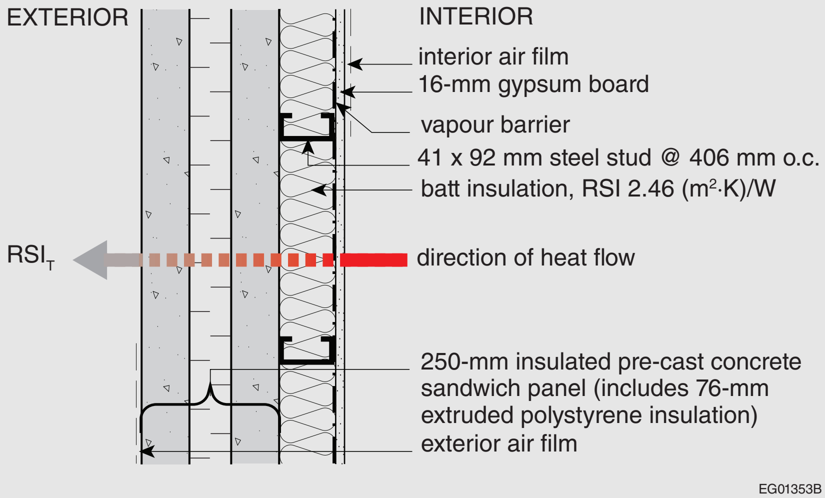



**Figure A**
**Metal-frame wall – insulated pre-cast concrete panels (plan view)**

Since the assembly contains metal framing, the Isothermal Planes Method for calculating the overall thermal transmittance is used with the effective insulation/framing layer U-values from Tables 3-2 and 3-3 (see Paragraph 32) for the framed portion of the assembly. The RSI value of the assembly's other components can be obtained from Tables 3-4 to 3-8 (see Paragraph 70), taking into account the thickness of the materials and the RSI values of the interior and exterior air films. The overall thermal transmittance, $U_T$, can be calculated as follows:

| Assembly Components | RSI, $(m^2 \cdot K)/W$ |
|---|---|
| Exterior air film | 0.03 |
| 250-mm precast concrete sandwich panel (includes 76-mm extruded polystyrene) | 2.73 |
| Effective RSI value steel studs/batt insulation interpolated from Table 3-3, batt = 2.46 $(m^2 \cdot K)/W$ | 1.094 |
| Vapour barrier | 0.00 |
| 16-mm gypsum board | 0.098 |
| Interior air film | 0.12 |
| $RSI_T$ | 4.072 |
| $U_T = 1/RSI_T$ | 0.246 |

**37.** Where building assemblies are more complex, such as in metal and glass curtain wall systems, the thermal bridging that occurs due to mullions and other components must be considered in the determination of the U-value. For complex assemblies, computer analysis and/or laboratory testing will provide greater accuracy in the determination of the U-value.

**38.** In wood- or metal-frame assemblies, heat transfer across the portion of the assembly that includes the framing members is greater than through the portion that is insulated (cavity). These framing members reduce the overall thermal efficiency of the assembly and the impact can be substantial since framing materials can account for 20% or more of the surface area of an assembly. This thermal bridging effect depends on the type of assembly, the type of framing material used, and the spacing of the framing member. These factors are considered in the U-value calculations. Values for framing percentages for typical wood assemblies are listed in Table 3-9. Effective insulation/framing RSI values for metal framing are listed in Tables 3-2 and 3-3.

**39.** Advanced framing is a technique used to reduce the quantity of materials used in wood-frame construction by engineering each framing element, as opposed to using standard framing details. Not only does it result in lower construction costs, since fewer materials and less labour are required, it also improves the energy efficiency of assemblies. Since fewer framing members are required, the effects of thermal bridging are reduced and therefore the effective thermal resistance of the assembly improves. Advanced framing is an energy-efficient alternative to standard wood-framing methods. Framing percentages associated with advanced wood framing are also listed in Table 3-9.

## U-value Calculation for Masonry Block Wall Construction

**40.** For building assemblies that use concrete masonry units with insulation inserts, hollow or filled cores, with or without wood- or metal-framing, the U-value of the assembly is calculated using the method that best suits the construction type. If the assembly uses wood framing on the interior, the Isothermal Planes and Parallel Path Method can be used; if the assembly uses metal framing or does not use any framing, the Isothermal Planes Method can be used.

**41.** An example of a U-value calculation for masonry block wall construction is presented in Example 3-11.

**Example 3-11 – Wall: Concrete Masonry Wall (no interior framing)**

Figure A shows a concrete masonry wall with no interior framing.

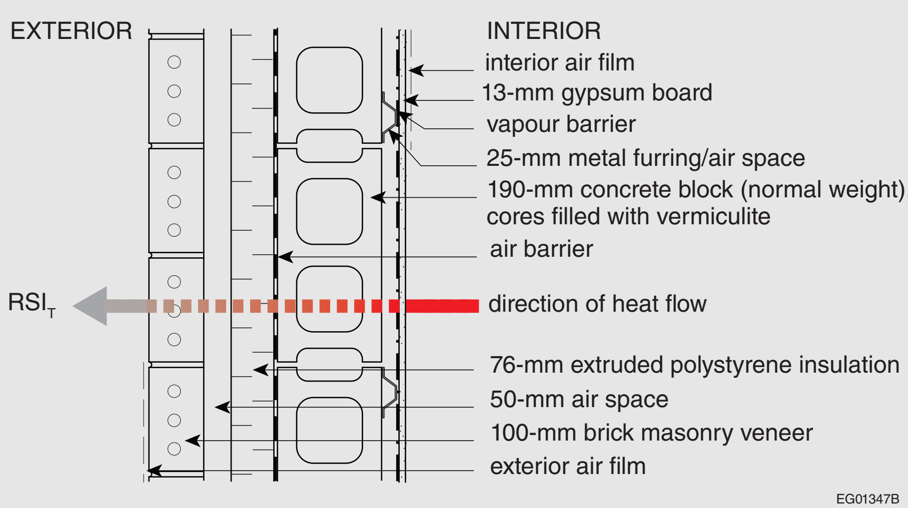



**Figure A**
**Concrete masonry wall – no interior framing (plan view)**

**Example 3-11 – Wall: Concrete Masonry Wall (no interior framing) (Continued)**

Since the wall assembly does not use framing, the Isothermal Planes Method is used to calculate the overall thermal transmittance of the wall. The RSI values of all the assembly's components can be obtained from Tables 3-4 to 3-8 (see Paragraph 70), taking into account the thickness of the materials and the RSI values of the interior and exterior air films. The overall thermal transmittance, $U_T$, can be calculated as follows:

| Assembly Components | RSI, $(m^2 \cdot K)/W$) |
|---|---|
| Exterior air film | 0.03 |
| 100-mm brick masonry veneer | 0.07 |
| 50-mm air space(1) | 0.18 |
| 76-mm extruded polystyrene insulation | 2.66 |
| Liquid-applied air barrier | 0.00 |
| 190-mm concrete block (normal weight), cores filled with vermiculite | 0.51 |
| 25-mm air space | 0.18 |
| Vapour barrier | 0.00 |
| 13-mm gypsum board | 0.08 |
| Interior air film | 0.12 |
| $RSI_T$ | 3.83 |
| $U_T = 1/RSI_T$ | 0.261 |

(1) The air space in this Example's masonry cladding system with weep holes at its base is considered, in this illustrative calculation only, to be an enclosed air space as described in the "ASHRAE Handbook – Fundamentals." The most appropriate means of determining the overall thermal values, whether by calculation or by laboratory testing per NECB Sentence 3.1.1.5.(5), must be carefully considered for each situation.

## Prescriptive Path Method of Compliance (Section 3.2.)

**42.** The prescriptive path method of compliance establishes the minimum acceptable thermal performance requirements for the building envelope and includes specific requirements for energy efficiency. It includes general requirements related to the protection of insulation materials, the continuity of insulation and the maximum allowable total vertical fenestration and door area to gross wall area ratio (FDWR). The prescriptive path also includes specific requirements related to the thermal characteristics of above-ground components of the building envelope, building assemblies in contact with the ground and the control of air leakage. With the prescriptive path method, building envelope compliance is achieved when all of the requirements in NECB Section 3.2. are met.

**43.** The requirements for above-ground components of the building envelope include specific criteria for vestibules, thermal design criteria for above-ground opaque building assemblies (exterior walls, roofs and exposed floors), and thermal design criteria for fenestration, doors and access hatches. The thermal design criteria are expressed in terms of a maximum overall thermal transmittance value (U-value), based on the HDD for the building location.

**44.** NECB Sentence 3.2.1.1.(1) requires that the building envelope be designed to limit the key factors affecting the field performance of thermal insulation. Conditions from both the interior and exterior building envelope environments, including air leakage and convection, wetting and moisture bypassing the plane of thermal resistance, affect the performance of the materials that make up the building envelope. Proper detailing for the management of water, vapour and thermal transfer in building assemblies is necessary for overall performance and durability.

**45.** Heat, air and moisture transfer through the building envelope are distinct issues but must be dealt with simultaneously. The various components that make up a building envelope assembly perform different but interrelated functions. Although thermal insulation, for example, is used to control heat transfer, it can also reduce the likelihood of condensation within a wall cavity. The proper control of heat, air and moisture through building envelope assemblies directly impacts the thermal performance of such assemblies.

**46.** Insulation materials are most effective when installed in accordance with the manufacturer's recommendations and in a manner that will achieve the expected thermal resistance of the insulation. For example, compressing insulation reduces its effective thermal resistance and consequently increases the U-value of the building envelope assembly.

## Spaces Heated to Different Temperatures (Article 3.2.1.3.)

**47.** NECB Sentence 3.2.1.3.(1) provides the equation to calculate the maximum allowable U-value for situations where a building assembly separates interior conditioned spaces that will be simultaneously heated to temperatures that differ by more than 10°C, for example, walls separating an office space from a refrigerated warehouse as presented in Example 3-12.

**48.** For heat flow calculations and heating system sizing, the most severe outdoor conditions that are likely to occur are used. For $t_0$ in the equation in NECB Sentence 3.2.1.3.(1), the 2.5% January design temperature is used as the outdoor design temperature, which represents a design condition that occurs all but 2.5% of the time. For 2.5% of the time, the building envelope will likely be subject to colder temperatures. If heating systems are closely sized to the calculated heat loss results, and actual outdoor temperatures fall below the winter design value, the system will not maintain the required indoor temperatures. In practice this is rather unlikely, since boilers and other heating equipment only come in certain size ranges, and so may be slightly oversized. NECB Table C-1 provides January winter design temperature values for 1% and 2.5%. The 2.5% winter design temperature is normally used. However, if there is a critical need to maintain indoor temperatures, the 1% (or an even more stringent design temperature) could be used.

**Example 3-12 – Maximum Overall Thermal Transmittance of Assemblies Separating Spaces Heated to Different Temperatures (Δ > 10°C)**

A food distribution company in Winnipeg, Manitoba is building a warehouse with office space. The warehouse will be maintained at 10˚C to prevent food spoilage and the swelling of canned goods; the office space will be maintained at 22˚C. The warehouse and office share a common wall.

According to NECB Table C-1, Winnipeg has a 2.5% January design temperature of −33°C and an HDD below 18˚C of 5670, which corresponds to Zone 7A (see Table 3-1 in Paragraph 10). According to NECB Table 3.2.2.2., the maximum overall thermal transmittance (U-value) of above-ground walls in Zone 7A is 0.21 W/(m²·K).

The maximum U-value of the wall separating the warehouse and office spaces is calculated using the equation in NECB Sentence 3.2.1.3.(1) as follows:

$$U_1 = \left[\frac{(t_2 - t_0)}{(t_2 - 0.5 \cdot t_1 - 0.5 \cdot t_0)}\right] \cdot U$$

$$U_1 = \left[\frac{(22 - (-33))}{(22 - (0.5 \cdot 10) - (0.5 \cdot (-33)))}\right] \cdot 0.21$$

$$U_1 = 0.345\ \mathrm{W}/\left(\mathrm{m}^2 \cdot \mathrm{K}\right)$$

Therefore, the maximum overall thermal transmittance value of the wall separating the warehouse and office spaces is 0.345 W/(m²·K).

## Allowable Fenestration and Door Area (Article 3.2.1.4.)

**49.** Since fenestration and door components can have a significant impact on the overall thermal performance of the building envelope, a maximum allowable total vertical fenestration and door area to gross wall area ratio (FDWR) is prescribed in the prescriptive path based on HDD values for the building location. For locations that have between 4000 and 7000 HDD, the FDWR is determined based on a linear equation found in NECB Sentence 3.2.1.4.(1). The maximum allowable FDWR decreases with an increased HDD. The FDWR is a fixed value for locations below 4000 HDD and above 7000 HDD.

**50.** Figure 3-4 shows a graphical representation of the FDWR equations.

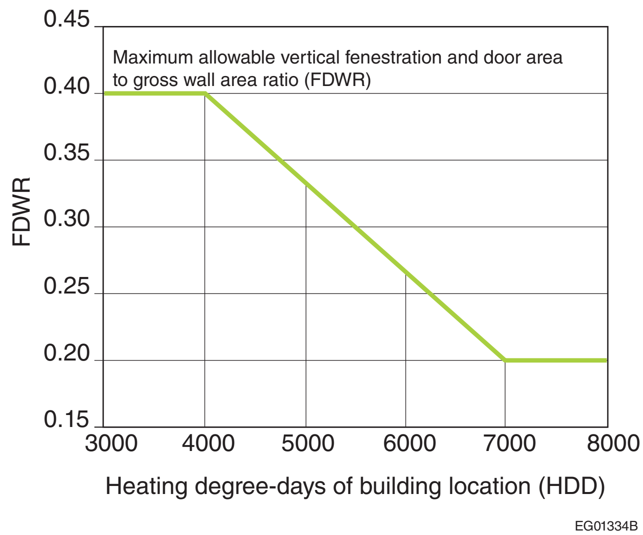



**Figure 3-4**
**Graph showing FDWR equations**

**Example 3-13 – Calculating Maximum Allowable FDWR**

The HDD value for a particular location can be found in NECB Table C-1. The HDD for Flin Flon, Manitoba is 6440. The FDWR can then be calculated using the following equation from NECB Sentence 3.2.1.4.(1):

$$\mathrm{FDWR} = (2000 - 0.2 \cdot \mathrm{HDD}) \div 3000$$
$$\mathrm{FDWR} = (2000 - 0.2 \cdot 6440) \div 3000$$
$$\mathrm{FDWR} = 0.24$$

The maximum allowable FDWR for a building located in Flin Flon, Manitoba is 0.24.

**Example 3-14 – Determining FDWR Compliance with the Prescriptive Requirements**

A five-storey condominium building is proposed for Richmond, British Columbia. The building measures 12 m wide × 16 m long × 16 m high. There are four units on each floor. The designer proposes that each unit have two windows on each of its two exterior walls. Each window measures 1.5 m wide × 1.5 m high. On the ground floor, each facade includes two doors, each measuring 2.1 m high × 0.9 m wide. The floor-to-floor height is 3.2 m. Figure A shows a sketch of the building.

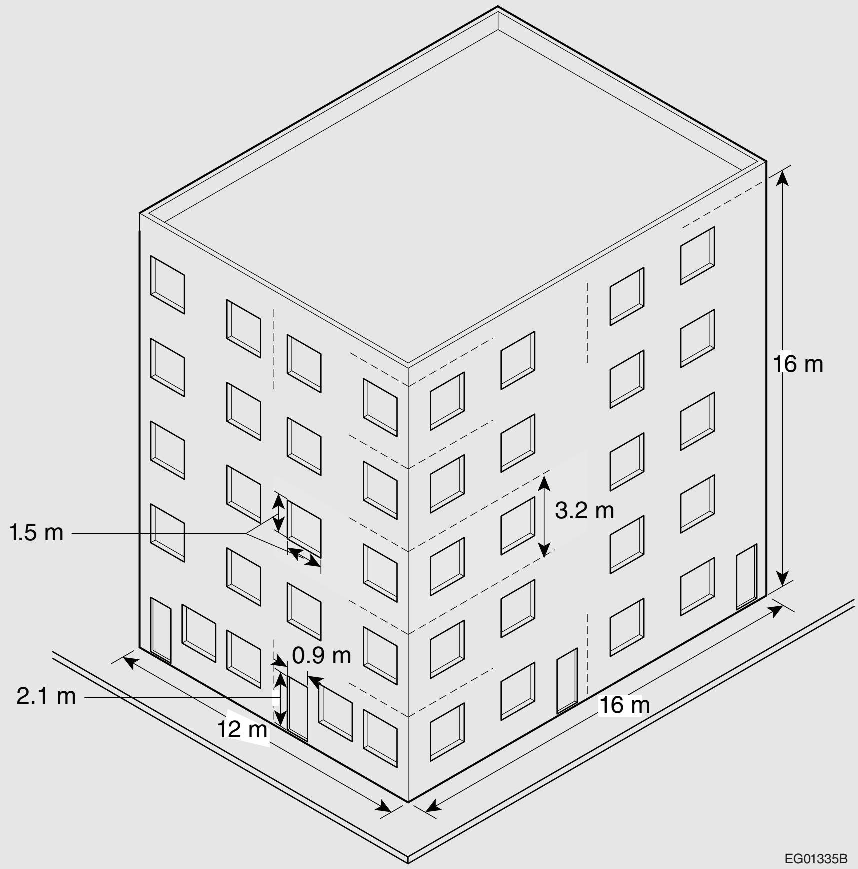



**Figure A**
**Sketch of building**

According to NECB Table C-1, Richmond has an HDD below 18°C of 2800. As per the prescriptive requirements in NECB Sentence 3.2.1.4.(1), the maximum allowable FDWR is 0.40.

To determine whether the proposed building satisfies the prescriptive FDWR requirements, the gross wall area of the building is calculated as described in NECB Sentence 3.1.1.6.(3).

The gross wall area is calculated to be 896 $m^2$. The maximum allowable FDWR is 0.40 in the prescriptive path, which is multiplied by the gross wall area for a maximum allowable fenestration and door area of 358 $m^2$. The gross area of the proposed windows and doors is calculated to be 195 $m^2$.

The FDWR for this Example is 0.22 (195 $m^2$/896 $m^2$). Since the FDWR is less than the prescriptive FDWR, the building satisfies the prescriptive requirements.

## Thermal Characteristics of Fenestration and Doors (Articles 3.2.2.3. and 3.2.2.4.)

**51.** The energy performance of fenestration and doors has a significant impact on the energy efficiency of a building. Due to their nature and function, these components of the building envelope are typically less energy-efficient than other above-grade assemblies, and as such, their proper selection is an important opportunity to improve the energy performance of the entire building envelope.

**52.** The NECB Part 3 requirements for the maximum U-value of fenestration and doors vary based on the applicable HDD category for the building, as is the case with opaque building assemblies. Fenestration assemblies include windows, skylights, clerestories, translucent wall panels, glass blocks, transoms, sidelights, glass doors (sliding, overhead or swinging), inserts in doors and other assemblies (including their frames) that transfer visible light. Doors include access hatches. There are no thermal requirements for storm doors, automatic sliding doors, glass doors, revolving doors and fire shutters since these types of doors typically cannot achieve the performance levels of other doors due to their function and properties.

**53.** The numerous design options for fenestration and doors—such as type of framing material, frame colour, number of glazing layers, glass type, spacer systems, tints, coatings, films, and gas filling—are variables that have an impact on energy performance.

**54.** Two properties that are used to describe the thermal performance of fenestration and doors are U-value and Solar Heat Gain Coefficient (SHGC). The U-value is a measure of the overall heat transfer through the entire fenestration or door product, including the frame, the glass edge and the centre of the glass. It represents the overall rate of heat transfer through all of these components and is measured in W/($m^2$·K). Although the NECB does not include any specific requirements for SHGC, selecting fenestration and door products with SHGC values that are appropriate for a particular building has an impact on building heating and cooling loads. The SHGC represents the amount of incident solar radiation transferred through a product, expressed as a decimal fraction between 0.0 and 1.0. The lower the SHGC value, the lower the amount of solar heat gain. Fenestration with a high SHGC value can help reduce heating costs, while products with low SHGC values can help reduce cooling costs. The proper selection of fenestration and door products requires consideration of the entire building design, including location, orientation, exterior shading, thermal properties, and areas of fenestration and doors.

**55.** The prescriptive requirements for the U-value of fenestration and doors range from 2.1 W/($m^2$·K) for Zone 4 building locations to 1.4 W/($m^2$·K) for Zone 8 building locations. The range of fenestration and door products that meet the NECB prescriptive requirements is broad. A U-value of 2.1 W/($m^2$·K) can typically be achieved using, for example, a thermally broken aluminum frame, double-glazed units with a low-emissivity coating, a non-metallic spacer and argon gas fill. A U-value of 1.4 W/($m^2$·K) can typically be achieved using, for example, a thermally broken aluminum frame, triple-glazed units with a low-emissivity coating, a non-metallic spacer and argon gas fill.

**56.** The directional orientation of building assemblies can affect their heat transfer characteristics. For example, the same type of glazing could have a greater heat loss when used in a horizontal or low-sloped application (e.g., skylight) compared to a vertical application, due to increased convection between the panes of glass.

## Thermal Requirements for Semi-Heated Buildings (Subsections 3.2.2. and 3.2.3.)

**57.** A semi-heated building with a set-point temperature of less than 15°C is permitted to meet less stringent building envelope requirements than those for a standard building, provided its annual energy consumption is less than or equal to the building energy target of the reference building, which uses a set-point temperature of 18°C. Examples of semi-heated buildings include, but are not limited to, warehouses, ice rinks, and self-service storage facilities.

**58.** When the prescriptive path is used to determine the thermal characteristics of building envelope assemblies for semi-heated buildings, the design data from NECB Table C-1 for heating degree-days (HDD) below 15°C apply. The lower number of heating degree-days listed for semi-heated buildings compared to standard buildings means that, for many locations in Canada, less stringent overall thermal transmittance values (U-values) can be used.

**59.** Example 3-15 compares the maximum U-values for a semi-heated building and a standard building in the same location.

**Example 3-15 – Determination of the Overall Thermal Transmittance of Building Envelope Assemblies in a Semi-Heated Building**

A semi-heated building is proposed for Nelson, British Columbia. According to NECB Table C-1, Nelson has an HDD below 15°C of 2600 and an HDD below 18°C of 3500, which correspond to Zones 4 and 5, respectively (see Table 3-1 in Paragraph 10). According to NECB Tables 3.2.2.2., 3.2.2.3., 3.2.2.4. and 3.2.3.1., the following overall thermal transmittance values apply to building envelope assemblies in these climate zones:

| Building Envelope Assemblies/Components | Heating Degree-Days of Building Location, in Celsius Degree-Days | |
|---|---|---|
| | Zone 4: < 3000 (Semi-Heated Building) | Zone 5: 3000 to 3999 (Standard Building) |
| | Maximum Overall Thermal Transmittance, in W/(m²·K) | |
| Above-ground assemblies | | |
| walls | 0.315 | 0.278 |
| roofs | 0.193 | 0.156 |
| floors | 0.227 | 0.183 |
| Fenestration | 2.1 | 1.9 |
| Doors | 2.1 | 1.9 |
| Assemblies in contact with the ground | | |
| walls | 0.568 | 0.379 |
| roofs | 0.568 | 0.379 |
| floors (for 1.2 m) | 0.757 | 0.757 |

Therefore, a semi-heated building in Nelson, B.C. is permitted to use the maximum U-values for building envelope assemblies in Zone 4 instead of the more stringent ones for its counterpart in Zone 5 (standard building).

In some locations, the climate zone that applies to standard buildings and semi-heated buildings is the same. For example, in Abbotsford, B.C., the values for HDD below 15°C and below 18°C (2000 and 2860, respectively) both correspond to climate zone 4. Similarly, in Kuujjuaq, Que., the values for HDD below 15°C and below 18°C (7520 and 8550, respectively) both correspond to climate zone 8. In such cases, the maximum overall thermal transmittance values for building envelope assemblies, fenestration and doors are the same for both standard and semi-heated buildings.

In other locations, the climate zone that applies to semi-heated buildings is removed by more than one zone from the climate zone that applies to standard buildings. For example, in Smith River, B.C., the values for HDD below 15°C (5980) and below 18°C (7100) correspond to Zones 7A and 8, respectively, which represents a reduction of two climate zones when determining the maximum overall thermal transmittance values for building envelope assemblies of semi-heated buildings.

## Air Leakage (Subsection 3.2.4.)

**60.** Many functions of the building envelope rely on adequate air leakage control. NECB Sentence 3.2.4.1.(1) requires that the building envelope be designed and constructed with a continuous air barrier system to control air leakage into and out of the conditioned space. The uncontrolled infiltration and exfiltration of air through the building envelope can lead to increased heating and cooling loads. An effective air barrier system is continuous and minimizes air leakage, and can reduce the energy needed for heating and cooling.

**61.** Air barriers consist of materials that are combined to form assemblies that are ultimately connected over the entire building envelope to provide an effective barrier to air leakage. As stated in NBC Article 5.4.1.2., air barrier materials must have leakage rates no greater than 0.02 L/(s·m²) measured at a pressure differential of 75 Pa in accordance with ASTM E 2178, “Air Permeance of Building Materials,” or CAN/ULC-S741, “Air Barrier Materials – Specification.” As stated in NECB Sentences

3.2.4.2.(2) and (3), air barrier assemblies for opaque elements must have a leakage rate no greater than 0.2 L/(s·m$^2$) measured at a pressure differential of 75 Pa in accordance with CAN/ULC-S742, “Air Barrier Assemblies – Specification,” or ASTM E 2357, “Determining Air Leakage of Air Barrier Assemblies.” While the NECB does not require entire buildings to undergo airtightness testing, attention should be paid to the airtightness of joints between assemblies.

**62.** NECB Articles 3.2.4.3. and 3.2.4.4. specify the maximum allowable air leakage rates for fenestration products, including metal and glass curtain walls, fixed windows and skylights, and operable windows and skylights, as well as doors, including revolving and automatic commercial sliding doors, overhead doors and main entry exterior doors.

## Simple Trade-off Path Method (Subsection 3.3.1.)

**63.** The simple trade-off path method of compliance offers designers flexibility in satisfying the NECB requirements for the building envelope. In this method, the reference building is defined as a building whose building envelope complies with the prescriptive requirements of the NECB. However, there are some restrictions on the types of trade-offs permitted.

**64.** Compliance with the simple trade-off path is determined using the equation in NECB Sentence 3.3.1.2.(2) to demonstrate that the sum of the areas of all above-ground assemblies of the building envelope multiplied by their respective U-values for the proposed building is not more than that for the reference building (based on the prescriptive limits).

**65.** The simple trade-off path method only addresses deviations from the maximum overall thermal transmittance of above-ground assemblies and the allowable fenestration and door areas (per the FDWR). The sum of the assembly UAs (U-values multiplied by assembly areas) of the proposed building is consistent with the prescriptive limits. The two input parameters are the U-values of the assemblies and the areas, and either or both of these can vary within the simple trade-off rules. The simple trade-off path can be used in several ways. For example, a building may be allowed to have an FDWR that exceeds the maximum allowable value, provided that above-ground assemblies have more stringent U-values. Alternatively, a building with an FDWR that is lower than the maximum allowable value may be allowed to use assemblies with U-values that exceed the maximum allowable values. The U-values of above-ground assemblies can also be traded-off against each other. For example, an above-ground exterior wall assembly that has a U-value that exceeds the maximum allowable value may be permitted if a fenestration system with a lower U-value (i.e., more stringent) is used.

**66.** This method of compliance includes restrictions regarding the type of trade-offs that are permitted: vertical above-ground building assemblies can only be traded-off against other vertical above-ground assemblies; horizontal above-ground assemblies can only be traded-off against other horizontal above-ground portions; and trade-offs with assemblies in contact with the ground are not permitted. For example, an above-ground exposed floor assembly can be permitted to have an overall thermal transmittance that is higher than what the prescriptive path allows, if it can be shown, through the trade-off calculation, that this deviation can be compensated by selecting a roof assembly that has a lower overall thermal transmittance than what the prescriptive path allows. Trade-offs between FDWR and U-values can only be done on vertical elements (i.e., FDWR vs. U-value of walls, windows or doors). Additions and semi-heated buildings are not permitted to use the simple trade-off path.

**67.** Within the limitations prescribed in the NECB, the simple trade-off path equation requires that the sum of the product of the overall thermal transmittances of all of the building envelope assemblies multiplied by their respective areas for the proposed building be equal to or less than that same sum calculated using the prescriptive path values for the reference building. Examples of simple trade-off path calculations are presented in Examples 3-16 and 3-17.

**Example 3-16 – Simple Trade-off Path Calculation for Commercial Building**

A one-storey community centre is proposed for Winnipeg, Manitoba. The building has a gross wall area of 560 m². According to NECB Table C-1, Winnipeg has an HDD below 18°C of 5670, which corresponds to Zone 7A (see Table 3-1 in Paragraph 10). Using the prescriptive path, the maximum allowable FDWR for a building located in Winnipeg is 0.289 (FDWR = 2000 – 0.2 × HDD ÷ 3000); however, based on the owner's requirements, the proposed design has an FDWR of 0.32.

According to the prescriptive requirements for Zone 7A, above-ground walls are required to have an overall thermal transmittance (U-value) of not more than 0.21 W/(m²·K) and both fenestration and doors are required to have a U-value of not more than 1.90 W/(m²·K). Using the maximum allowable FDWR of 0.289, the UA of the prescriptive building is calculated as follows:

**Prescriptive Path (Reference Building)**

| Building Envelope Assembly | Prescriptive Path U-Value ($U_{ir}$), W/(m²·K) | Area ($A_{ir}$), m² | Area Ratio due to Maximum FDWR | UA ($U_{ir}$ x $A_{ir}$), W/K |
|---|---|---|---|---|
| Walls | 0.21 | 398.16 | 0.711 | 83.61 |
| Fenestration and doors | 1.90 | 161.84 | 0.289 | 307.50 |
| | Totals: | 560 | 1 | 391.11 (391) |

Following the method of the simple trade-off path, the owner's requirement for a higher FDWR can be traded-off against the U-values for the fenestration and doors and/or walls, since these assemblies are vertical above-ground portions of the building envelope, provided that the sum of the UAs (ΣUA) of the proposed building does not exceed the ΣUA of the reference building (391 W/K in this Example).

In order to show compliance using the proposed FDWR of 0.32, the designer applies the simple trade-off calculations using fenestration and doors with lower U-values (i.e., better performing than prescriptive). As shown in Option 1, by using fenestration and doors with U-values of 1.70 W/(m²·K), the ΣUA of the proposed building (385 W/K) remains below that of the reference building (391 W/K) and the design is compliant with the trade-off path.

**Option 1 – Simple Trade-off Path (Proposed Building)**

| Building Envelope Assembly | Required U-Value ($U_{ip}$), W/(m²·K) | Area ($A_{ip}$), m² | Area Ratio due to Design Requirements | UA ($U_{ir}$ x $A_{ir}$), W/K |
|---|---|---|---|---|
| Walls | 0.21 | 380.80 | 0.68 | 79.97 |
| Fenestration and doors | 1.70 | 179.20 | 0.32 | 304.64 |
| | Totals: | 560 | 1 | 384.61 (385) |

The designer could also use a combination of measures to lower the U-value of the proposed building, for example, by modifying the U-values of both the walls and the fenestration and doors. In the calculation in Option 2, the U-value of the fenestration and doors is again decreased, but this permits an increased wall U-value.

**Option 2 – Simple Trade-off Path (Proposed Building)**

| Building Envelope Assembly | Required U-Value ($U_{ip}$), W/(m²·K) | Area ($A_{ip}$), m² | Area Ratio due to Design Requirements | UA ($U_{ir}$ x $A_{ir}$), W/K |
|---|---|---|---|---|
| Walls | 0.27 | 380.80 | 0.68 | 102.82 |
| Fenestration and doors | 1.60 | 179.20 | 0.32 | 286.72 |
| | Totals: | 560 | 1 | 389.54 (390) |

**Example 3-17 – Simple Trade-off Path Calculation for Warehouse**

A warehouse with a total gross wall area of 2 310 m² and an FDWR of 0.082 (8.2%) is proposed for Winnipeg, Manitoba. According to NECB Table C-1, Winnipeg has an HDD of 5670, which corresponds to Zone 7A (see Table 3-1 in Paragraph 10). Since the FDWR is less than the maximum allowable for Winnipeg (0.289), the designer wishes to trade-off a better performing element against the U-value of the fenestration and doors and/or above-ground walls.

The prescriptive building's UA is calculated as follows using the maximum allowable FDWR of 0.289:

**Prescriptive Path (Reference Building)**

| Building Envelope Assembly | Prescriptive Path U-Value ($U_{ir}$), W/(m²·K) | Area ($A_{ir}$), m² | Area Ratio due to Maximum FDWR | UA ($U_{ir}$ x $A_{ir}$), W/K |
|---|---|---|---|---|
| Walls | 0.21 | 1642.41 | 0.711 | 344.91 |
| Fenestration and doors | 1.90 | 667.59 | 0.289 | 1268.42 |
| | Totals: | 2310 | 1 | 1613.33 (1613) |

Following the simple trade-off path method, the proposed FDWR, that is less than the maximum allowable, can be traded-off against the U-values of the fenestration and doors and/or walls, since these assemblies are vertical above-ground portions of the building envelope, provided that the ΣUA of the proposed building does not exceed the ΣUA of the reference building (1613 W/K in this Example).

The designer applies the simple trade-off calculations using only wall U-values that are increased from the NECB prescriptive (less performing than prescriptive). As shown in Option 1, by using walls with a maximum U-value of 0.59 W/(m²·K), the ΣUA of the proposed building (1611 W/K) remains below that of the reference building (1613 W/K) and the design is compliant with the trade-off path.

**Option 1 – Simple Trade-off Path (Proposed Building)**

| Building Envelope Assembly | Required U-Value ($U_{ip}$), W/(m²·K) | Area ($A_{ip}$), m² | Area Ratio due to Design Requirements | UA ($U_{ir}$ x $A_{ir}$), W/K |
|---|---|---|---|---|
| Walls | 0.59 | 2120.58 | 0.918 | 1251.14 |
| Fenestration and doors | 1.90 | 189.42 | 0.082 | 359.90 |
| | Totals: | 2310 | 1 | 1611.04 (1611) |

The designer could also use a combination of measures to lower the U-value of the proposed building, for example, by modifying the U-values of the walls, fenestration and doors. The calculation in Option 2 shows the trade-off of FDWR for lesser performing walls, fenestration and doors.

**Option 2 – Simple Trade-off Path (Proposed Building)**

| Building Envelope Assembly | Required U-Value ($U_{ip}$), W/(m²·K) | Area ($A_{ip}$), m² | Area Ratio due to Design Requirements | UA ($U_{ir}$ x $A_{ir}$), W/K |
|---|---|---|---|---|
| Walls | 0.504 | 2120.58 | 0.918 | 1068.77 |
| Fenestration and doors | 2.85 | 189.42 | 0.082 | 539.85 |
| | Totals: | 2310 | 1 | 1608.62 (1609) |

### Performance Path Method of Compliance (Section 3.4.)

**68.** The performance path option is described in NECB Part 8. This method uses a whole building engineering approach to demonstrate building envelope compliance. Both the proposed and reference buildings are modeled identically using an overall building air leakage value of 0.25 L/(s·m²), as stated in Sentence 8.4.3.3.(3), which may not reflect the actual value encountered under real-time operating conditions. With this option, trade-offs can be made between not only building envelope assemblies, but all parameters of the building, including HVAC, lighting and other building systems. For example, a less stringent building envelope could be permitted with increased HVAC efficiencies. Building envelope limitations when using the performance path are described in NECB Article 3.4.1.2.

### Tables to be used with Examples 3-1 to 3-10

**69.** The thermal resistance values given in Tables 3-4 to 3-7 are generic and approximate values for the materials listed. The values were obtained by multiplying the thermal resistance (RSI) values per millimetre of thickness found in Table 3-8 by the thickness of the material. As such, values published by manufacturers for their proprietary materials may differ. Whenever possible, RSI values should be obtained from product manufacturers, where the values have been determined in accordance with applicable material standards. Data can also be obtained from the Canadian Construction Materials Centre's product listings, or from the "ASHRAE Handbook – Fundamentals."

**70.** All data in Tables 3-4 to 3-8 is reported at 24±1°C (75±2°F).

**Table 3-4**
**Thermal Resistance Values of Common Insulation Materials: Insulation Boards, Slabs and Sheathing**

| Insulation Materials | RSI/mm | RSI Values for Thickness of Insulation Board, Slab and Sheathing Materials | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Material Thickness, mm | | | | | | | | | | | |
| | | 13 | 16 | 19 | 25 | 38 | 51 | 64 | 76 | 89 | 101 | 127 | 152 |
| Expanded polystyrene (EPS) | | | | | | | | | | | | | |
| Type 1 | 0.026 | 0.34 | 0.42 | 0.49 | 0.65 | 0.99 | 1.33 | 1.66 | 1.98 | 2.31 | 2.63 | 3.30 | 3.95 |
| Type 2 | 0.028 | 0.36 | 0.45 | 0.53 | 0.71 | 1.06 | 1.43 | 1.79 | 2.13 | 2.49 | 2.83 | 3.56 | 4.26 |
| Type 3 | 0.030 | 0.39 | 0.48 | 0.57 | 0.76 | 1.14 | 1.53 | 1.92 | 2.28 | 2.67 | 3.03 | 3.81 | 4.56 |
| Extruded polystyrene (XPS), Types 2, 3, 4 | 0.035 | 0.46 | 0.56 | 0.67 | 0.88 | 1.33 | 1.79 | 2.24 | 2.66 | 3.12 | 3.54 | 4.45 | 5.32 |
| Semi-rigid mineral fibre(1) | 0.0298 | 0.39 | 0.48 | 0.57 | 0.75 | 1.13 | 1.52 | 1.91 | 2.26 | 2.65 | 3.01 | 3.78 | 4.53 |
| Insulating fibreboard | 0.016 | 0.21 | 0.26 | 0.30 | 0.40 | 0.61 | 0.82 | 1.02 | 1.22 | 1.42 | 1.62 | 2.03 | 2.43 |
| Polyisocyanurate/polyurethane – permeably faced, Types 1, 2, 3 | 0.03818 | 0.50 | 0.61 | 0.73 | 0.97 | 1.45 | 1.90 | 2.44 | 2.90 | 3.40 | 3.86 | 4.85 | 5.80 |
| Polyisocyanurate/polyurethane – impermeably faced, Types 1, 2, 3 | 0.03937 | 0.51 | 0.63 | 0.75 | 0.98 | 1.50 | 2.00 | 2.52 | 2.99 | 3.50 | 3.98 | 5.00 | 5.98 |
| Gypsum sheathing | 0.0063 | 0.082 | 0.101 | 0.120 | 0.158 | 0.239 | 0.321 | 0.403 | 0.479 | 0.561 | 0.636 | 0.800 | 0.958 |
| Particleboard – low density (593 kg/m³ = 37 lbs/ft.³) | 0.0098 | 0.127 | 0.157 | 0.186 | – | – | – | – | – | – | – | – | – |
| Particleboard – medium density (800 kg/m³ = 50 lbs/ft.³) | 0.0077 | 0.100 | 0.123 | 0.146 | – | – | – | – | – | – | – | – | – |
| Particleboard – high density (993 kg/m³ = 62 lbs/ft.³) | 0.0059 | 0.077 | 0.094 | 0.112 | – | – | – | – | – | – | – | – | – |
| Plywood – generic softwood | 0.0087 | 0.109 | 0.135 | 0.161 | – | – | – | – | – | – | – | – | – |
| Plywood – Douglas fir | 0.0111 | 0.139 | 0.172 | 0.205 | – | – | – | – | – | – | – | – | – |
| Waferboard – 705 kg/m³ | 0.0095 | 0.124 | 0.152 | 0.181 | – | – | – | – | – | – | – | – | – |
| Oriented strandboard (OSB) | 0.0098 | 0.127 | 0.157 | 0.186 | – | – | – | – | – | – | – | – | – |

(1) Semi-rigid mineral fibre includes both glass and rock wool fibre.

**Table 3-5**
**Thermal Resistance Values of Common Insulation Materials: Blanket and Batt Insulation**

| Insulation Materials | RSI Values for Thickness of Blanket and Batt Insulation Materials | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Material Thickness, mm | | | | | | | | | | |
| | 89/92 | 89/92 | 140 | 152 | 140/152 | 152 | 140/152 | 178/216 | 241 | 267 | 279/300 |
| | Material R-Value | | | | | | | | | | |
| | R12 | R14 | R19 | R20 | R22 | R22.5 | R24 | R28 | R31 | R35 | R40 |
| Blanket and batt mineral fibre (rock or glass) | 2.11 | 2.46 | 3.34 | 3.52 | 3.87 | 3.96 | 4.23 | 4.93 | 5.46 | 6.16 | 7.04 |

**Table 3-6**
**Thermal Resistance Values of Common Insulation Materials: Spray-Applied Insulation**

| Insulation Materials | RSI/mm | RSI Values for Thickness of Spray-Applied Insulation Materials | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Material Thickness, mm | | | | | | | | | |
| | | 51 | 76 | 89 | 101 | 127 | 140 | 152 | 202 | 254 | 305 |
| Sprayed cellulosic fibre – settled thickness | 0.024 | – | – | 2.14 | – | – | 3.36 | – | – | – | – |
| Sprayed glass fibre – density 16 kg/m$^3$ | 0.025 | – | – | 2.23 | – | – | 3.50 | – | – | – | – |
| Sprayed glass fibre – density 28.8 kg/m$^3$ | 0.029 | – | – | 2.58 | – | – | 4.06 | – | – | – | – |
| Sprayed polyurethane foam – medium density | 0.036 | 1.84 | 2.74 | 3.20 | 3.64 | 4.57 | 5.04 | 5.47 | 7.27 | 9.14 | 10.98 |
| Sprayed polyurethane foam – light density | 0.0255 | 1.30 | 1.94 | 2.27 | 2.58 | 3.24 | 3.57 | 3.88 | 5.15 | 6.48 | 7.78 |

**Table 3-7**
**Thermal Resistance Values of Common Insulation Materials: Loose-Fill Insulation**

| Insulation Materials | RSI/mm | RSI Values for Thickness of Loose-Fill Insulation Materials | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Material Thickness, mm | | | | | | | | | |
| | | 89 | 140 | 152 | 202 | 254 | 305 | 356 | 406 | 457 | 508 |
| Loose-fill cellulose | 0.025 | 2.23 | 3.50 | 3.80 | 5.05 | 6.35 | 7.63 | 8.90 | 10.15 | 11.43 | 12.70 |
| Loose-fill glass fibre for attics | 0.01875 | 1.67 | 2.63 | 2.85 | 3.79 | 4.76 | 5.72 | 6.68 | 7.61 | 8.57 | 9.53 |
| Loose-fill glass fibre for walls | 0.02865 | 2.55 | – | – | – | – | – | – | – | – | – |
| Loose-fill glass fibre for walls | 0.0289 | – | 4.05 | – | – | – | – | – | – | – | – |
| Loose-fill pouring wool for attics | 0.0200 | 1.78 | 2.80 | 3.04 | 4.04 | 5.08 | 6.10 | 7.12 | 8.12 | 9.14 | 10.16 |
| Perlite | 0.019 | 1.69 | 2.66 | 2.89 | 3.84 | 4.83 | 5.80 | 6.76 | 7.71 | 8.68 | 9.65 |
| Vermiculite | 0.015 | 1.34 | 2.10 | 2.28 | 3.03 | 3.81 | 4.58 | 5.34 | 6.09 | 6.86 | 7.62 |

**Table 3-8**
**Typical Thermal Characteristics of Common Building Materials(1)**

| **Air Films** | Thickness of Material | Thermal Resistance (RSI), (m$^2$·K)/W per mm | Thermal Resistance (RSI), (m$^2$·K)/W for thickness listed |
|---|---|---|---|
| Exterior: | | | |
| ceiling, floors and walls: wind 6.7 m/s (winter) | — | — | 0.03 |
| Interior: | | | |
| ceiling (heat flow up) | — | — | 0.11 |

Table 3-8 (Continued)

| Air Films | Thickness of Material | Thermal Resistance (RSI), $(m^2·K)/W$ per mm | Thermal Resistance (RSI), $(m^2·K)/W$ for thickness listed |
|---|---|---|---|
| floor (heat flow down) | — | — | 0.16 |
| walls (heat flow horizontal) | — | — | 0.12 |
| **Air Cavities**(2)(3) | Thickness of Air Space | Thermal Resistance (RSI), $(m^2·K)/W$ per mm | Thermal Resistance (RSI), $(m^2·K)/W$ for thickness listed |
| Ceiling (heat flow up) faced with non-reflective material(4) | 13 mm | — | 0.15 |
| | 20 mm | — | 0.15 |
| | 40 mm | — | 0.16 |
| | 90 mm | — | 0.16 |
| Floors (heat flow down) faced with non-reflective material(4) | 13 mm | — | 0.16 |
| | 20 mm | — | 0.18 |
| | 40 mm | — | 0.20 |
| | 90 mm | — | 0.22 |
| Walls (heat flow horizontal) faced with non-reflective material(4) | 13 mm | — | 0.16 |
| | 20 mm | — | 0.18 |
| | 40 mm | — | 0.18 |
| | 90 mm | — | 0.18 |
| **Cladding Materials** | Thickness of Material | Thermal Resistance (RSI), $(m^2·K)/W$ per mm | Thermal Resistance (RSI), $(m^2·K)/W$ for thickness listed |
| Brick: | | | |
| fired clay (2400 $kg/m^2$) | 100 mm | 0.0007 | 0.07 |
| concrete: sand and gravel, or stone (2400 $kg/m^2$) | 100 mm | 0.0004 | 0.04 |
| Cement/lime, mortar, and stucco | — | 0.0009 | — |
| Wood shingles: | | | |
| 400 mm, 190 mm exposure | — | — | 0.15 |
| 400 mm, 300 mm exposure (double exposure) | — | — | 0.21 |
| insulating backer board | 8 mm | — | 0.25 |
| Siding: | | | |
| Metal or vinyl siding over sheathing: | | | |
| hollow-backed | — | — | 0.11 |
| insulating-board-backed | 9.5 mm nominal | — | 0.32 |
| foiled-backed | 9.5 mm nominal | — | 0.52 |
| Wood: | | | |
| bevel, 200 mm, lapped | 13 mm | — | 0.14 |
| bevel, 250 mm, lapped | 20 mm | — | 0.18 |
| drop, 200 mm | 20 mm | — | 0.14 |
| hardboard | 11 mm | — | 0.12 |
| plywood, lapped | 9.5 mm | — | 0.10 |
| Stone: | | | |
| quartzitic and sandstone (2240 $kg/m^3$) | — | 0.0003 | — |
| calcitic, dolomitic, limestone, marble, and granite (2240 $kg/m^3$) | — | 0.0004 | — |

**Table 3-8 (Continued)**

| **Cladding Materials** | Thickness of Material | Thermal Resistance (RSI), (m²·K)/W per mm | Thermal Resistance (RSI), (m²·K)/W for thickness listed |
|---|---|---|---|
| Fibre-cement: single-faced, cellulose fibre-reinforced cement | 6.35 mm | 0.003 | 0.023 |
| | 8 mm | 0.003 | 0.026 |
| **Roofing Materials**(5) | Thickness of Material | Thermal Resistance (RSI), (m²·K)/W per mm | Thermal Resistance (RSI), (m²·K)/W for thickness listed |
| Asphalt roll roofing | — | — | 0.03 |
| Asphalt/tar | — | 0.0014 | — |
| Built-up roofing | 10 mm | — | 0.06 |
| Crushed stone | — | 0.0006 | — |
| Metal deck | — | — | negligible |
| Shingle: | | | |
| asphalt | — | — | 0.08 |
| wood | — | — | 0.17 |
| Slate | 13 mm | — | 0.01 |
| **Sheathing Materials** | Thickness of Material | Thermal Resistance (RSI), (m²·K)/W per mm | Thermal Resistance (RSI), (m²·K)/W for thickness listed |
| Gypsum sheathing | 12.7 mm | 0.0063 | 0.08 |
| Insulating fibreboard | — | 0.016 | — |
| Particleboard: | | | |
| low density (593 kg/m³) | — | 0.0098 | — |
| medium density (800 kg/m³) | — | 0.0077 | — |
| high density (993 kg/m³) | — | 0.0059 | — |
| Plywood – generic softwood | 9.5 mm | 0.0087 | 0.083 |
| | 11 mm | | 0.096 |
| | 12.5 mm | | 0.109 |
| | 15.5 mm | | 0.135 |
| | 18.5 mm | | 0.161 |
| Plywood – Douglas fir | 9.5 mm | 0.0111 | 0.105 |
| | 11 mm | | 0.122 |
| | 12.5 mm | | 0.139 |
| | 15.5 mm | | 0.172 |
| | 18.5 mm | | 0.205 |
| Sheet materials: | | | |
| permeable felt | — | — | 0.011 |
| seal, 2 layers of mopped (0.73 kg/m³) | — | — | 0.210 |
| seal, plastic film | — | — | negligible |
| Waferboard (705 kg/m³) | — | 0.0095 | — |

**Table 3-8 (Continued)**

| **Sheathing Materials** | Thickness of Material | Thermal Resistance (RSI), ($m^2 \cdot K$)/W per mm | Thermal Resistance (RSI), ($m^2 \cdot K$)/W for thickness listed |
|---|---|---|---|
| Oriented strandboard (OSB) | 9.5 mm | 0.0098 | 0.093 |
| | 11 mm | | 0.108 |
| **Insulation Materials**(6) | Thickness of Material | Thermal Resistance (RSI), ($m^2 \cdot K$)/W per mm | Thermal Resistance (RSI), ($m^2 \cdot K$)/W for thickness listed |
| Blanket and batt: rock or glass mineral fibre | | | |
| R12 | 89/92 mm | — | 2.11 |
| R14 | 89/92 mm | — | 2.46 |
| R19(7) (R20 compressed) | 140 mm | — | 3.34 |
| R20 | 152 mm | — | 3.52 |
| R22 | 140/152 mm | — | 3.87 |
| R22.5 | 152 mm | — | 3.96 |
| R24 | 140/152 mm | — | 4.23 |
| R28 | 178/216 mm | — | 4.93 |
| R31 | 241 mm | — | 5.46 |
| R35 | 267 mm | — | 6.16 |
| R40 | 279/300 mm | — | 7.04 |
| Boards and slabs: | | | |
| Roof board | — | 0.018 | — |
| Building board or ceiling tile, lay-in panel | — | 0.016 | — |
| Polyisocyanurate/polyurethane-faced sheathing: Types 1, 2 and 3 | | | |
| permeably faced | 25 mm | 0.03818 | 0.97 |
| | 50 mm | 0.0360 | 1.80 |
| impermeably faced | 25 mm | 0.03937 | 1.00 |
| | 50 mm | 0.0374 | 1.87 |
| Expanded polystyrene (EPS)(8) | | | |
| Type 1 | 25 mm | 0.026 | 0.65 |
| Type 2 | 25 mm | 0.028 | 0.71 |
| Type 3 | 25 mm | 0.030 | 0.76 |
| Extruded polystyrene (XPS): Types 2, 3 and 4 | 25 mm | 0.035 | 0.88 |
| | 50 mm | 0.0336 | 1.68 |
| Semi-rigid mineral fibre(9) | 25 mm | 0.0298 | 0.757 |
| Loose-fill insulation | | | |
| Cellulose | — | 0.025 | — |
| Glass fibre loose fill insulation for attics | 112 to 565 mm | 0.01875 | — |
| Glass fibre loose fill insulation for walls | 89 mm | 0.02865 | 2.55 |
| | 140 mm | 0.0289 | 4.05 |
| Pouring wool for attics | — | 0.0200 | — |
| Perlite | — | 0.019 | — |
| Vermiculite | — | 0.015 | — |
| Spray-applied insulation | | | |
| Sprayed polyurethane foam | | | |
| medium density | 25 mm | 0.036 | 0.90 |

**Table 3-8 (Continued)**

| **Insulation Materials**(6) | Thickness of Material | Thermal Resistance (RSI), ($m^2 \cdot K$)/W per mm | Thermal Resistance (RSI), ($m^2 \cdot K$)/W for thickness listed |
|---|---|---|---|
| | 50 mm | 0.036 | 1.80 |
| light density | 25 mm | 0.0255 | 0.60 |
| Sprayed cellulosic fibre | settled thickness | 0.024 | — |
| Spray-applied glass-fibre insulation | | | |
| density: 16 kg/$m^3$ | 89 mm | 0.025 | 2.30 |
| | 140 mm | 0.025 | 3.53 |
| density: 28.8 kg/$m^3$ | 89 mm | 0.029 | 2.64 |
| | 140 mm | 0.029 | 4.06 |
| **Structural Materials** | Thickness of Material | Thermal Resistance (RSI), ($m^2 \cdot K$)/W per mm | Thermal Resistance (RSI), ($m^2 \cdot K$)/W for thickness listed |
| Concrete | | | |
| Low-density aggregate | | | |
| expanded shale, clay, slate or slags, cinders (1 600 kg/$m^3$) | — | 0.0013 | — |
| perlite, vermiculite, and polystyrene bead (480 kg/$m^3$) | — | 0.0063 | — |
| Normal-density aggregate | | | |
| sand and gravel or stone aggregate (2 400 kg/$m^3$) | — | 0.0004 | — |
| Hardwood(10)(11) | | | |
| Ash | — | 0.0063 | — |
| Birch | — | 0.0055 | — |
| Maple | — | 0.0063 | — |
| Oak | — | 0.0056 | — |
| Softwood(10)(11) | | | |
| Amabilis fir | — | 0.0080 | — |
| California redwood | — | 0.0089 | — |
| Douglas fir-larch | — | 0.0069 | — |
| Eastern white cedar | — | 0.0099 | — |
| Eastern white pine | — | 0.0092 | — |
| Hemlock-fir | — | 0.0084 | — |
| Lodgepole pine | — | 0.0082 | — |
| Red pine | — | 0.0077 | — |
| Western hemlock | — | 0.0074 | — |
| Western red cedar | — | 0.0102 | — |
| White spruce | — | 0.0097 | — |
| Yellow cyprus-cedar | — | 0.0077 | — |
| Wood, structural framing, spruce-pine-fir(12) | — | 0.0085 | — |
| Steel, galvanized sheet, 0.14% carbon content | — | 0.0000161 | — |
| **Concrete Blocks** | Thickness of Material | Thermal Resistance (RSI), ($m^2 \cdot K$)/W per mm | Thermal Resistance (RSI), ($m^2 \cdot K$)/W for thickness listed |
| Limestone aggregate with 2 cores | | | |
| cores filled with perlite | 190 mm | — | 0.37 |
| | 290 mm | — | 0.65 |

**Table 3-8 (Continued)**

| Concrete Blocks | Thickness of Material | Thermal Resistance (RSI), ($m^2$·K)/W per mm | Thermal Resistance (RSI), ($m^2$·K)/W for thickness listed |
|---|---|---|---|
| Light-weight units (expanded shale, clay, slate or slag aggregate) with 2 or 3 cores | | | |
| no insulation in cores | 90 mm | — | 0.24 |
| | 140 mm | — | 0.30 |
| | 190 mm | — | 0.32 |
| | 240 mm | — | 0.33 |
| | 290 mm | — | 0.41 |
| cores filled with perlite | 140 mm | — | 0.74 |
| | 190 mm | — | 0.99 |
| | 290 mm | — | 1.35 |
| cores filled with vermiculite | 140 mm | — | 0.58 |
| | 190 mm | — | 0.81 |
| | 240 mm | — | 0.98 |
| | 290 mm | — | 1.06 |
| cores filled with molded EPS beads | 190 mm | — | 0.85 |
| molded EPS inserts in cores | 190 mm | — | 0.62 |
| Medium-weight units (combination of normal- and low-mass aggregate) with 2 or 3 cores | | | |
| no insulation in cores | 190 mm | — | 0.26 |
| cores filled with molded EPS beads | 190 mm | — | 0.56 |
| molded EPS inserts in cores | 190 mm | — | 0.47 |
| cores filled with perlite | 190 mm | — | 0.53 |
| cores filled with vermiculite | 190 mm | — | 0.58 |
| Normal-weight units (sand and gravel aggregate) with 2 or 3 cores | | | |
| no insulation in cores | 90 mm | — | 0.17 |
| | 140 mm | — | 0.19 |
| | 190 mm | — | 0.21 |
| | 240 mm | — | 0.24 |
| | 290 mm | — | 0.26 |
| cores filled with perlite | 190 mm | — | 0.35 |
| cores filled with vermiculite | 140 mm | — | 0.40 |
| | 190 mm | — | 0.51 |
| | 240 mm | — | 0.61 |
| | 290 mm | — | 0.69 |
| **Hollow Clay Bricks** | Thickness of Material | Thermal Resistance (RSI), ($m^2$·K)/W per mm | Thermal Resistance (RSI), ($m^2$·K)/W for thickness listed |
| Multi-cored without insulation in cores | 90 mm | — | 0.27 |
| Rectangular 2-core | | | |
| no insulation in cores | 140 mm | — | 0.39 |
| | 190 mm | — | 0.41 |
| | 290 mm | — | 0.47 |
| cores filled with vermiculite | 140 mm | — | 0.65 |
| | 190 mm | — | 0.86 |

**Table 3-8 (Continued)**

| **Hollow Clay Bricks** | Thickness of Material | Thermal Resistance (RSI), (m²·K)/W per mm | Thermal Resistance (RSI), (m²·K)/W for thickness listed |
|---|---|---|---|
| | 290 mm | — | 1.29 |
| Rectangular 3-core | | | |
| no insulation in cores | 90 mm | — | 0.35 |
| | 140 mm | — | 0.38 |
| | 190 mm | — | 0.41 |
| | 240 mm | — | 0.43 |
| | 290 mm | — | 0.45 |
| cores filled with vermiculite | 140 mm | — | 0.68 |
| | 190 mm | — | 0.86 |
| | 240 mm | — | 1.06 |
| | 290 mm | — | 1.19 |
| **Interior Finish Materials**(13) | Thickness of Material | Thermal Resistance (RSI), (m²·K)/W per mm | Thermal Resistance (RSI), (m²·K)/W for thickness listed |
| Gypsum board | — | 0.0061 | — |
| Hardboard – medium-density (800 kg/m³) | — | 0.0095 | — |
| Interior finish (plank, tile) board | — | 0.0198 | — |
| Particleboard | | | |
| low-density (590 kg/m³) | — | 0.0098 | — |
| medium-density (800 kg/m³) | — | 0.0074 | — |
| high-density (1 000 kg/m³) | — | 0.0059 | — |
| underlay | 15.9 mm | — | 0.140 |
| Plywood | — | 0.0087 | — |
| Flooring material | | | |
| Carpet and fibrous pad | — | — | 0.370 |
| Carpet and rubber pad | — | — | 0.220 |
| Cork tile | 3.2 mm | — | 0.049 |
| Hardwood flooring | 19 mm | — | 0.120 |
| Terrazzo | 25 mm | — | 0.014 |
| Tile (linoleum, vinyl, rubber) | — | — | 0.009 |
| Tile (ceramic) | 9.5 mm | — | 0.005 |
| Wood subfloor | 19 mm | — | 0.170 |
| Plastering | | | |
| Cement plaster: sand aggregate | — | 0.0014 | — |
| Gypsum plaster | | | |
| low-density aggregate | — | 0.0044 | — |
| sand aggregate | — | 0.0012 | — |

(1) The thermal resistance values given in Table 3-8 are generic values for the materials listed or minimum acceptable values taken from product standards. Values published by manufacturers for their proprietary materials may differ slightly but are permitted to be used, provided the values were obtained in accordance with applicable material standards. For materials not listed in this Table, or where the listed value does not reflect the thickness of the product, the thermal resistance value must be calculated by dividing the material's thickness, in metres, by its conductivity, in W/(m·K), which can be found in the manufacturer's literature.

(2) RSI values can be interpolated for air cavity sizes that fall between 13 mm and 90 mm, and they can be moderately extrapolated for air cavities measuring more than 90 mm. However, air cavities measuring less than 13 mm cannot be included in the calculation of effective thermal resistance of the assembly.

(3) Where strapping is installed, use the RSI value for an air layer of equivalent thickness.

**Table 3-8 (Continued)**

(4) Reflective insulation material may contribute a thermal property value depending on its location and installation within an assembly. Where a value is obtained through evaluation, it may be included in the calculation of the thermal resistance or transmittance of the specific assembly.
(5) Materials installed towards the exterior of a vented air space cannot be included in the calculation of overall thermal transmittance of the assembly.
(6) All types of cellular foam plastic insulation manufactured to be able to retain a blowing agent, other than air, for a period longer than 180 days should be tested for long-term thermal resistance (LTTR) in accordance with CAN/ULC-S770, "Determination of Long-Term Thermal Resistance of Closed-Cell Thermal Insulating Foams." This thermal resistance value must be input as the design thermal resistance value for the purpose of energy calculations. Product standards contain a baseline LTTR for a thickness of 50 mm, from which the LTTR for other thicknesses can be calculated.
(7) An RSI 3.52 (R20) batt compressed into a 140–mm cavity has a thermal resistance value of 3.34 (R19); if installed uncompressed in a 152-mm cavity (e.g., in a metal stud assembly), it will retain its full thermal resistance value of 3.52 ($m^2 \cdot K$)/W.
(8) Expanded polystyrene insulation is not manufactured to be able to retain a blowing agent; therefore LTTR requirements do not apply.
(9) Semi-rigid mineral fibre includes both glass and rock wool fibre.
(10) The thermal resistance values for wood species are based on a moisture content (MC) of 12%. In Canada, equilibrium moisture content for wood in buildings ranges from 8–14%. Thermal resistance values for wood species with 12% MC are readily available. The difference between the thermal properties of wood species with 12% MC and those with 14% MC is negligible.
(11) For wood species not listed in this Table, the RSI value of a wood species of equal or greater density (or specific gravity (relative density)) can be used since the thermal resistance of wood is directly related to its density (higher density wood has a lower thermal resistance).
(12) 0.0085 is considered a common value for structural softwood (SPF).
(13) Materials installed towards the interior of a conditioned air space cannot be included in the calculation of effective thermal resistance of the assembly.

**Table 3-9**
**Framing and Cavity Percentages for Typical Wood-frame Assemblies**

| Wood-frame Assemblies | | Frame Spacing, mm o.c. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 304 | | 406 | | 488 | | 610 | | 1220 | |
| | | % Area Framing | % Area Cavity | % Area Framing | % Area Cavity | % Area Fram-ing | % Area Cavity | % Area Framing | % Area Cavity | % Area Framing | % Area Cavity |
| Floors | lumber joists | – | – | 13 | 87 | 11.5 | 88.5 | 10 | 90 | – | – |
| | I-joists and truss | – | – | 9 | 91 | 7.5 | 92.5 | 6 | 94 | – | – |
| Roofs/ Ceilings | ceilings with typical trusses | – | – | 14 | 86 | 12.5 | 87.5 | 11 | 89 | – | – |
| | ceilings with raised heel trusses | – | – | 10 | 90 | 8.5 | 91.5 | 7 | 93 | – | – |
| | roofs with lumber rafters and ceilings with lumber joists | – | – | 13 | 87 | 11.5 | 88.5 | 10 | 90 | – | – |
| | roofs with I-joist rafters and ceilings with I-joists | – | – | 9 | 91 | 7.5 | 92.5 | 6 | 94 | – | – |
| | roofs with structural insulated panels (SIPs) | – | – | – | – | – | – | – | – | 9 | 91 |
| Walls | typical wood-frame | 24.5 | 75.5 | 23 | 77 | 21.5 | 78.5 | 20 | 80 | – | – |
| | advanced wood-frame with double top plate | – | – | 19 | 81 | 17.5 | 82.5 | 16 | 84 | – | – |
| | SIPs | – | – | – | – | – | – | – | – | 14 | 86 |
| | basement wood-frame inside concrete foundation wall | – | – | 16 | 84 | 14.5 | 85.5 | 13 | 87 | – | – |

# Commentary on Part 4

# Lighting

## Scope (Article 4.1.1.1.)

1. NECB Part 4 applies to interior and exterior lighting components and systems that are connected to the building's electrical service. The requirements address four subject areas: interior lighting power, interior lighting controls, exterior lighting power and exterior lighting controls.

2. The following lighting systems are exempt from these requirements:
   - emergency lighting that is automatically off during normal building operation; and
   - lighting in dwelling units.

   Also, if it can be shown to the authority having jurisdiction that the nature of the occupancy makes it impractical to apply the NECB Part 4 requirements, the lighting design may be exempt from having to comply with Part 4 (for example, lighting systems that are designed to meet health or safety regulatory requirements, such as those used in hospitals or extended health care facilities that have requirements for higher illuminance levels prescribed by the local jurisdiction or health authority).

## Compliance (Article 4.1.1.3.)

3. Compliance with NECB Part 4 can be achieved by applying one of the following paths:
   - the prescriptive path in Section 4.2., which is a simple approach whereby the designer applies the requirements as stated to achieve compliance for interior and exterior lighting;
   - the trade-off path in Section 4.3., which provides additional flexibility in meeting the interior lighting power and interior lighting control requirements (it cannot be used to show compliance with the exterior lighting requirements); and
   - the performance path in Part 8, which is an approach that entails the modeling of the entire building (if this path is chosen, it must be followed for all building parameters covered by the NECB, i.e., building envelope, lighting, HVAC, service water heating and electrical power systems/motors).

   The flow charts in NECB Figures A-4.1.1.3.(1)-A and B show the compliance paths for interior lighting and exterior lighting, respectively.

## Prescriptive Path (Section 4.2.)

4. The requirements in the prescriptive path were adapted from the lighting requirements contained in ANSI/ASHRAE/IES 90.1, "Energy Standard for Buildings Except Low-Rise Residential Buildings."

5. The lighting power densities (LPDs) listed in the 2011 and 2015 editions of the NECB were based on the use of a combination of lighting technologies ranging from LEDs (most efficient) to fluorescents (somewhat efficient) to halogens (least efficient). However, lighting technology has advanced rapidly in recent years; as such, the LPDs listed in the 2017 edition of the NECB reflect the new reality that the majority of lighting installations will now be equipped with LEDs.

6. LED (light-emitting diode) bulbs provide high-quality, energy-efficient lighting at a minimal cost. What's more, they have a much longer service life compared to fluorescent bulbs, which means reduced maintenance costs, and they are available in almost any colour temperature, are free of mercury, and emit very little heat.

7. Designers should be mindful of the situations and locations where proper lighting is required for safety or security reasons, and refer to the appropriate NBC requirements as well as the NECB when developing a lighting design: energy conservation must not be at the expense of safety.

### Interior Lighting Power (Subsection 4.2.1.)

8. A lighting design for a building complies with the NECB prescriptive interior lighting power requirements if the installed interior lighting power does not exceed the interior lighting power allowance. The interior lighting power allowance can be determined by using the building area method or the space-by-space method. The building area method provides a typical building lighting average whereas the space-by-space method is a more detailed approach to calculating the interior lighting power allowance.

9. Example 4-1 demonstrates how to calculate the interior lighting power using both the space-by-space and building area methods, and illustrates how to comply with the lighting control requirements.

**Example 4-1 – Interior Lighting Power**

This Example uses a space containing four space types: a meeting room, a lobby, a washroom and an open office space (see Figure A). With the exception of the washroom, all spaces have access to daylight through double-glazed windows.

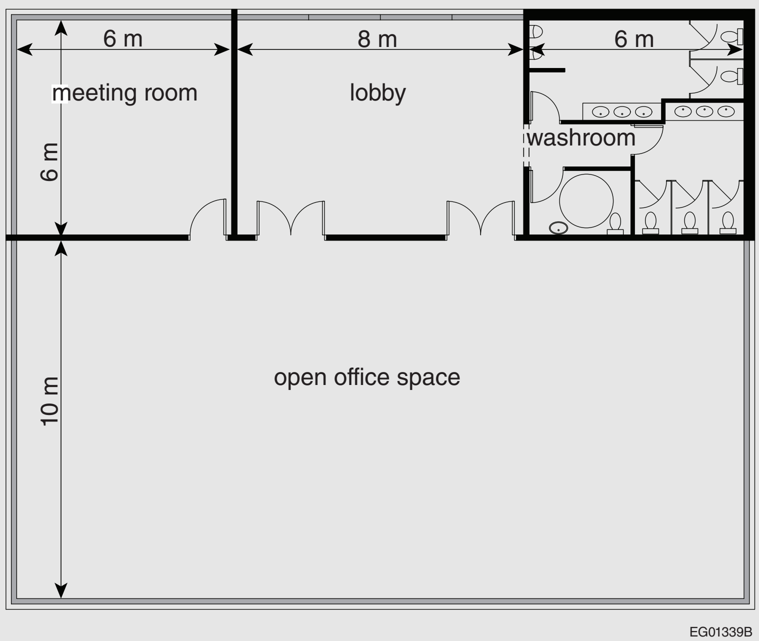



**Figure A**
**Floor plan of space**

All measurements represent the interior wall-to-wall dimensions, i.e., the wall thickness is discounted. The gross lighted area of each space can thus be determined by the given dimensions.

The designer chooses to illuminate each space with two-lamp F32T8 luminaires using electronic ballasts conforming to the requirements of CSA C654, "Fluorescent Lamp Ballast Efficacy Measurements," with a normal ballast factor. The design operating wattage of this lamp/ballast combination is 59 W, which is the connected lighting power per luminaire. The lighting design also includes exit signs but these do not have to be included in the calculation as per NECB Clause 4.2.1.4.(4)(j).

**Example 4-1 – Interior Lighting Power (Continued)**

The following table provides information on the lighting design that allows for the calculation of the installed interior lighting power.

**Lighting Power Design**

| Space Type | Number of Luminaires | Connected Lighting Power per Luminaire, W | Installed Interior Lighting Power, W |
|---|---|---|---|
| Meeting room | 8 | 59 | 472 |
| Lobby | 8 | 59 | 472 |
| Washroom | 5 | 59 | 295 |
| Open office | 28 | 59 | 1652 |
| | | | Total: 2891 |

***Building Area Method (4.2.1.5.)***

The entire space in Example 4-1 can be identified as being for office use, therefore the building area method can be used to determine the interior lighting power allowance. Note that the building area method could still be used even if up to 10% of the gross lighted area could be classified as "other than office" (see NECB Sentence 4.2.1.5.(3)). The lighting power density (LPD) listed in NECB Table 4.2.1.5. for building type "office" is 8.5 W/m$^2$. The gross lighted area of the space—which is equal to the actual area of the space in this case—is 320 m$^2$ (20 m × 16 m).

The interior lighting power allowance can now be calculated as follows:

$$\begin{aligned} \text{Interior lighting power allowance}_{\text{building area method}} &= \text{LPD} \cdot \text{gross lighted area} \\ &= 8.5\,\frac{\text{W}}{\text{m}^2} \cdot 320\,\text{m}^2 \\ &= 2720\ \text{W} \end{aligned}$$

***Space-By-Space Method (4.2.1.6.)***

Although the space meets the criteria to apply the building area method, the space-by-space method can also be used, whereby the lighting power allowance for each of the four spaces is added together. The following table provides the results of the calculations.

**Lighting Power Allowance Using the Space-by-Space Method**

| Space Type | Gross Lighted Area, m$^2$ | LPD from NECB Table 4.2.1.6., W/m$^2$ | Interior Lighting Power Allowance, W |
|---|---|---|---|
| Meeting room | 36 | 11.5(1) | 414.0 |
| Lobby | 48 | 10.8(2) | 518.4 |
| Washroom | 36 | 9.1(3) | 327.6 |
| Open office | 200 | 8.7(4) | 1740 |
| | | | Total: 3000 |

(1) LPD using space type "Conference/Meeting/Multi-purpose room"
(2) LPD using space type "Lobby – other"
(3) LPD using space type "Washroom – other"
(4) LPD using space type "Office – open plan"

The interior lighting power allowance using the space-by-space method is 3000 W.

**Example 4-1 – Interior Lighting Power (Continued)**

***Conclusion***

The installed interior lighting power and the interior lighting power allowances compare as follows:

$$\text{Installed interior lighting power} = 2891\ \text{W}$$
$$\text{Interior lighting power allowance}_{\text{building area method}} = 2720\ \text{W}$$
$$\text{Interior lighting power allowance}_{\text{space by space method}} = 3000\ \text{W}$$

The lighting design in this Example would not be deemed to comply with the prescriptive lighting path using the building area method, which results in the installed interior lighting power (2891 W) being greater than the interior lighting power allowance (2720 W). However, the design does comply using the space-by-space method, which results in an allowance of 3000 W.

Note that, although the installed interior lighting power for the meeting room (472 W) exceeds the interior lighting power allowance for the meeting room space type (414 W), this does not mean that the overall lighting design fails. For the purpose of showing compliance, the lighting power can be distributed in any way, in any of the spaces, provided the total installed interior lighting power does not exceed the total interior lighting power allowance (see NECB Sentence 4.2.1.3.(2)).

While the building area method requires a simpler calculation, it typically results in a lower power allowance. The space-by-space method can present advantages over the building area method because it accounts for the distribution of space types weighted by their individual areas, whereas the building area method assumes a standard distribution of space types in order to set one average LPD level, which may not be as representative of the building design in some cases.

***Interior Lighting Design using LED Luminaires***

If the designer chooses to illuminate each space in Figure A using two-lamp LED T8 luminaires with a design operating wattage of 35 W, which is the connected lighting power per luminaire, then the installed interior lighting power changes as follows:

**Lighting Power Design Using LED Luminaires**

| Space Type | Number of Luminaires | Connected Lighting Power per Luminaire, W | Installed Interior Lighting Power, W |
|---|---|---|---|
| Meeting room | 8 | 35 | 280 |
| Lobby | 8 | 35 | 280 |
| Washroom | 5 | 35 | 175 |
| Open office | 28 | 35 | 980 |
| | | | Total: 1715 |

The lighting design now complies with both the building area and the space-by-space methods, since the installed lighting power of 1715 W is less than the interior lighting power allowances of 2720 W and 3000 W.

## Interior Lighting Controls (Subsection 4.2.2.)

**10.** The prescriptive lighting path of NECB Section 4.2. also defines requirements for interior lighting controls. These requirements reflect the direction of current technologies and practices as outlined in ANSI/ASHRAE/IES 90.1. NECB Table 4.2.1.6. lists the types of lighting controls that are required and optional for each space type.

**11.** Example 4-2 compares the lighting design for an open office space with the NECB requirements for interior lighting controls.

### Example 4-2 – Interior Lighting Controls

In this example, a designer is developing the lighting design for a 120 m² open office space with workstations that is occupied during regular weekly hours. See Figure A.


**Figure A**
**Open office space with workstations**

The proposed lighting design for the office space shown in Figure A is as follows:

- installed interior lighting power of 890 W
- one manual lighting control device located next to the entrance door
- occupant sensors that turn on all the lights when occupants are detected
- photocontrols (daylight sensors) installed next to each of the three windows
- a scheduled shut-off control that operates based on the time of day and day of the week (the lights are programmed to turn off at 8 p.m. until 7 a.m. when the office space is unoccupied)

**Example 4-2 – Interior Lighting Controls (Continued)**

***Compliance of Lighting Power***

According to NECB Table 4.2.1.6., the lighting power density for the space type “Office – open plan” is limited to 8.7 W/m². The maximum lighting power allowance calculated in accordance with NECB Clause 4.2.1.6.(1)(c) is therefore 1044 W (10 m × 12 m × 8.7 W/m²), which is greater than the design interior lighting power of 890 W. As such, the proposed interior lighting power complies with the NECB.

***Compliance of Lighting Controls***

The following table compares the interior lighting control requirements stated in NECB Table 4.2.1.6. and Article 4.2.2.1. with the proposed lighting design for the open office space shown in Figure A.

| Lighting Control Requirements from NECB Table 4.2.1.6. | | Description of Proposed Lighting Design and Lighting Controls | Compliance of Proposed Lighting Design with NECB Table 4.2.1.6. and Article 4.2.2.1. |
|---|---|---|---|
| Type of Lighting Control | Requirement for Space Type “Office – open plan” | | |
| Manual | Required | Office is 120 m² in area and a manual light switch will be installed at the entrance. | Design complies as it meets Table 4.2.1.6. and 4.2.2.1.(3)(a) and (4). |
| Restricted to Manual ON<br>Restricted to Partial Automatic ON | At least one of these two types of lighting controls must be implemented | Occupant sensors turn on all the lights when occupants are detected. | Design does not comply as it does not meet Table 4.2.1.6. or 4.2.2.1.(6) or (8). Compliance could be achieved by requiring that the lights be turned on manually or by programming the occupant sensors to turn on 50% of the lights instead of all of them. |
| Bi-Level | Required | Not included in design. | Design does not comply as it does not meet Table 4.2.1.6. or 4.2.2.1.(9). Compliance could also be achieved by installing lighting controls of the type “Restricted to Partial Automatic ON.” |
| Automatic Daylight Responsive Controls for Sidelighting | Required | Location of sensors and controlled luminaires is not included in design. | Design partially complies as it meets Table 4.2.1.6. but does not meet 4.2.2.1.(10) and (11). |
| Automatic Daylight Responsive Controls for Toplighting | Required | No skylights or roof monitors are included in design. | Compliance with Table 4.2.1.6. and 4.2.2.1.(13) does not apply. |
| Automatic Partial OFF | Not required | Not included in design. | Compliance with Table 4.2.1.6. and 4.2.2.1.(16) is optional. |
| Automatic Full OFF<br>Scheduled Shut-off | At least one of these two types of lighting controls must be implemented | Scheduled shut-off control is included in design. | Design complies as it meets Table 4.2.1.6. and 4.2.2.1.(20). Compliance could also be achieved by providing vacancy sensors for “Automatic Full OFF” as per 4.2.2.1.(18). |

The proposed design for the interior lighting controls for the open office space does not fully comply with NECB Table 4.2.1.6. or Article 4.2.2.1.

## Lighting Controls in Storage Garages (Article 4.2.2.2.)

**12.** The NECB lighting control requirements for storage garages are aligned with the corresponding requirements stated in ANSI/ASHRAE/IES 90.1, which facilitates design and enforcement in jurisdictions that reference both documents.

**13.** Example 4-3 illustrates how the requirements for lighting controls in storage garages stated in NECB Article 4.2.2.2. are applied to the storage garage in Figure A.

**Example 4-3 – Lighting Controls in Storage Garages**

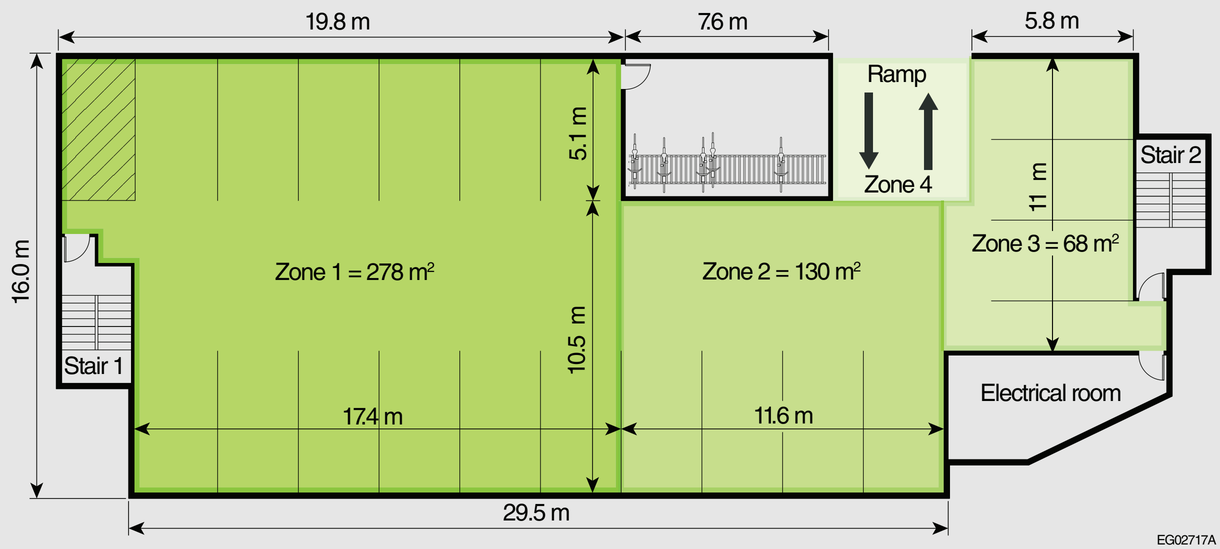



**Figure A**
**Storage garage divided into four lighting zones**

As required by NECB Sentence 4.2.2.2.(1), lighting in the storage garage is divided into zones no larger than 360 $m^2$.

As required by NECB Sentence 4.2.2.2.(2), three motion sensors—one in each of Zones 1, 2 and 3—will operate independently of each other to reduce the lighting power per zone by 30% when no activity is detected for 20 minutes.

As required by NECB Sentence 4.2.2.2.(3), a separate lighting control will be provided for Zone 4 to reduce the lighting by 50% from sunset to sunrise using a daylight sensor.

## Determination of Primary and Secondary Sidelighted Areas (4.2.2.3.)

**14.** Implementing daylighting strategies reduces energy use for interior lighting. The daylighting control provisions presented in NECB Article 4.2.2.1. allow both primary and secondary sidelighted areas to be taken into account using the calculation methods in NECB Article 4.2.2.3.

**15.** When calculating the primary and secondary sidelighted areas of a room, areas that are illuminated by light from more than one window must not be double-counted. Figure A of Example 4-4 shows the primary, secondary and corresponding overlapping sidelighted areas for the spaces from Example 4-1.

**16.** Example 4-4 illustrates the calculation of primary and secondary sidelighted areas.

**Example 4-4 – Calculation of primary and secondary sidelighted areas**

In this Example, the windows span the full width of the meeting room, lobby and office space, and extend from the sill height of 1 m to the ceiling height of 3 m. There are no vertical obstructions (e.g., partition walls) higher than 1.5 m.

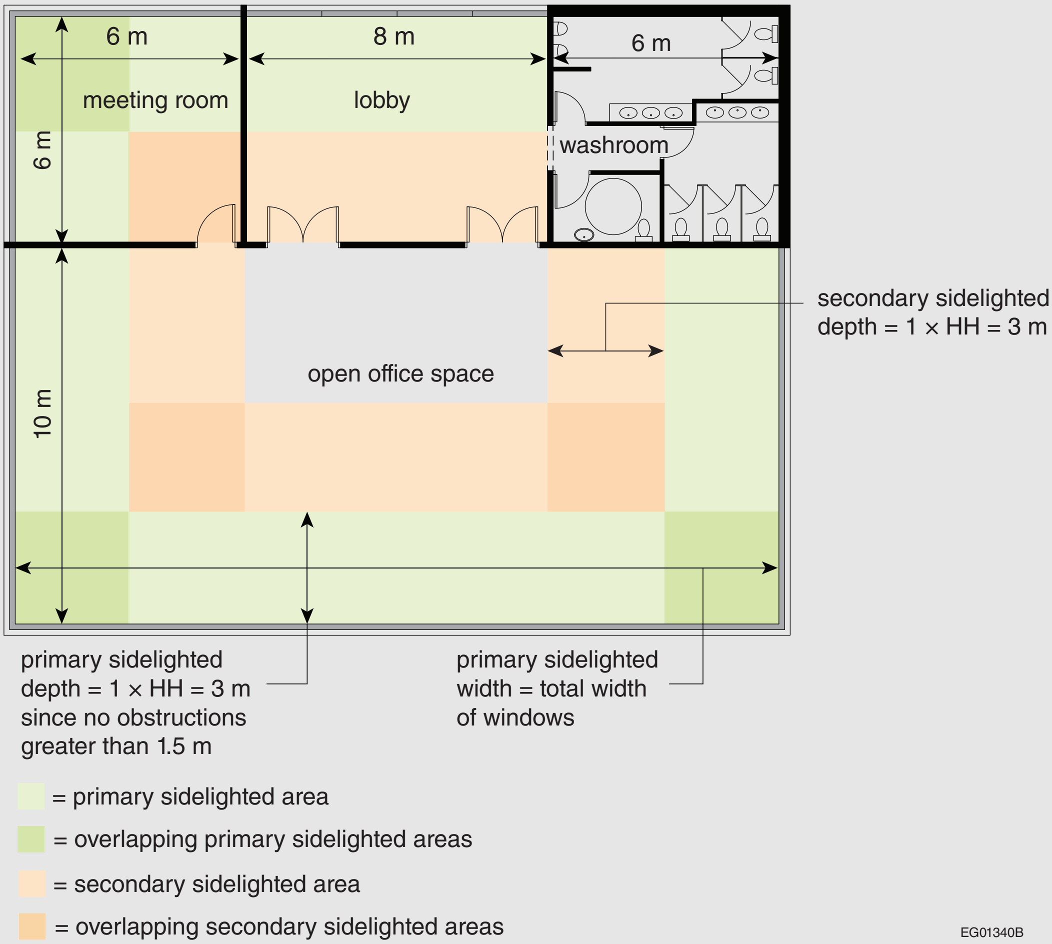



**Figure A**
**Primary, secondary and overlapping sidelighted areas**

All windows in Figure A span across the entire length of a wall so that the sidelighted width is the same as the length of the corresponding wall. The window head height (HH), which is the distance from the floor to the top of the glazing, is 3 m since the windows extend all the way to the ceiling. This defines the sidelighted depth (1 x HH) since there are no obstructions higher than 1.5 m in the spaces.

**Example 4-4 – Calculation of primary and secondary sidelighted areas (Continued)**

In the open office space, the primary sidelighted areas, $A_{DL,OOS}$, overlap by 3 m in two of the corners. $A_{DL,OOS}$ is calculated as follows:

$$\begin{aligned} A_{DL,OOS} &= \text{primary sidelighted areas} - \text{overlapping primary sidelighted areas} \\ &= A + B + C - \text{overlapping primary sidelighted areas} \\ &= (10\,m \times 3\,m) + (20\,m \times 3\,m) + (10\,m \times 3\,m) - [(3\,m \times 3\,m) + (3\,m \times 3\,m)] \\ &= 120\,m^2 - 18\,m^2 \\ &= 102\,m^2 \end{aligned}$$

The calculation of primary and secondary sidelighted area for the space types in Figure A are calculated as follows:

| Space Type | Primary Sidelighted Area, $m^2$ | Secondary Sidelighted Area, $m^2$ |
|---|---|---|
| Meeting room | 27 | 9 |
| Lobby | 24 | 24 |
| Washroom | 0(1) | 0(1) |
| Open office | 102 | 66 |

(1) The washroom has no windows, therefore no sidelighting.

**17.** None of the three exemption conditions stated in NECB Sentence 4.2.2.1.(12) apply to Example 4-4 since:
- there are no adjacent structures,
- the glazing is not less than 2 $m^2$, and
- none of the spaces are retail spaces.

## Determination of Daylighted Area Under Roof Monitors (Article 4.2.2.4.)

**18.** The NECB criteria on how to calculate the daylighted area under roof monitors are aligned with the corresponding criteria in ANSI/ASHRAE/IES 90.1, which facilitates design and enforcement in jurisdictions that reference both documents.

The method for the determination of the daylighted area under roof monitors is similar to the one for skylights. See Example 4-5.

## Determination of Daylighted Area Under Skylights (Article 4.2.2.5.)

**Example 4-5 – Determination of Daylighted Area Under Skylights**

Daylight is supplied to the engine room of a fire station through 15 double-glazed skylights, which are evenly spaced 6 m apart in both directions across the roof (see Figure A). Each skylight measures 1 m × 1 m and has a light well depth of 0.5 m. The engine room's ceiling height is 10 m and there will not be any permanent vertical obstructions within the space.

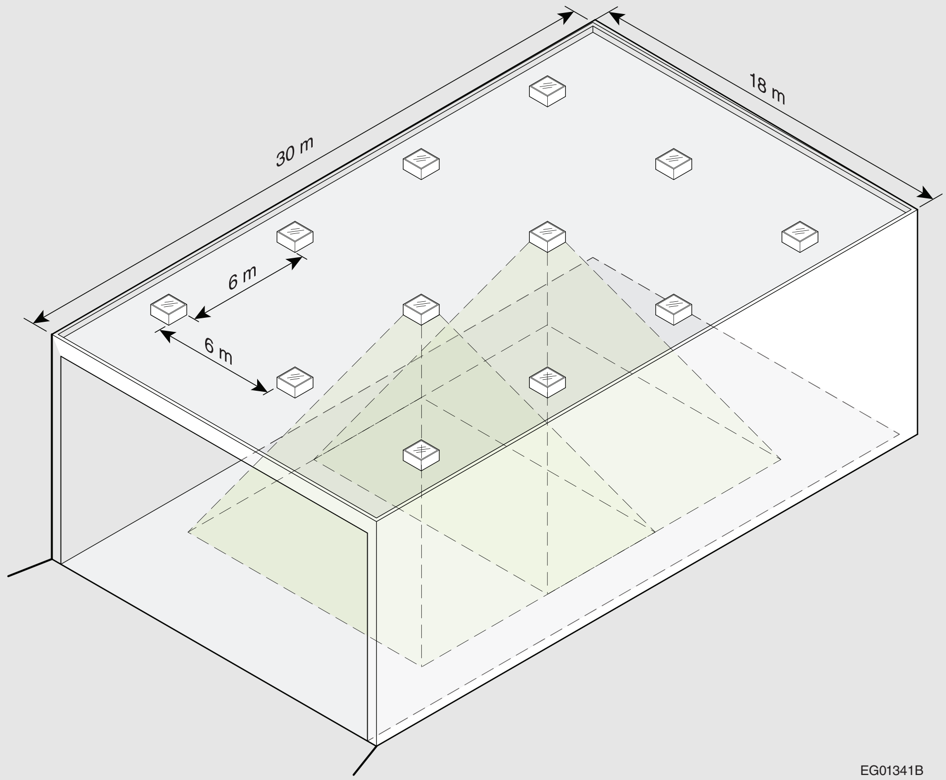



**Figure A**
**Distribution of skylights in fire station engine room (plan view)**

NECB Figure A-4.2.2.5.(2) illustrates how to calculate the daylighted area under skylights, which needs to be assessed for each skylight from the projection. The extent of the daylighted area in each direction beyond the simple projection on the area directly beneath the skylight is defined by the smallest of the following distances (see NECB Clauses 4.2.2.5.(2)(a) to (c)):
(a) 70% of the ceiling height;
(b) the distance to any other daylighted area; and
(c) the distance to the nearest face of any vertical obstruction that is further away than 70% of the distance between the top of the vertical obstruction and the ceiling.

**Example 4-5 – Determination of Daylighted Area Under Skylights (Continued)**

In this Example, the daylighted area of each skylight overlaps the daylighted area of adjacent skylights (the skylights are 6 m apart and distance (a) is equal to 7 m) and the daylighted areas of the perimeter skylights are bound by the exterior walls (vertical obstruction). Thus, it can be concluded that the whole engine room is the total daylighted area:

$$\begin{aligned} A_{DL,skylight} &= A_{engine\ room} \\ &= 30\,\mathrm{m} \times 18\,\mathrm{m} \\ &= 540\,\mathrm{m}^2 \end{aligned}$$

## Special Lighting Applications (Article 4.2.2.6.)

**19.** The NECB requires certain special lighting applications to be controlled separately from the general lighting and lighting in guest rooms and suites in commercial temporary lodgings to be automatically controlled. These requirements are aligned with the corresponding requirements in ANSI/ASHRAE/IES 90.1, which facilitates design and enforcement in jurisdictions that reference both documents.

## Exterior Lighting Power and Exterior Lighting Controls (Subsections 4.2.3. and 4.2.4.)

**20.** The NECB requirements that limit the amount of energy allowed to be used by exterior lighting are aligned with the corresponding requirements in ANSI/ASHRAE/IES 90.1, which facilitates design and enforcement in jurisdictions that reference both documents.

**21.** The exterior lighting power allowances listed in the 2011 and 2015 editions of the NECB were based on the use of a combination of less efficient lighting technologies such as high-intensity discharge (HID), metal halide and high-pressure sodium luminaires. However, lighting technology has advanced rapidly in recent years; as such, the lighting power allowances listed in the 2017 edition of the NECB are based on the use of LED luminaires, which are now widely available. LED bulbs provide high-quality, energy-efficient lighting at a minimal cost. What's more, they have a much longer service life compared to fluorescent bulbs, which means reduced maintenance costs, and they are available in almost any colour temperature, are free of mercury, and emit very little heat.

**22.** Building facade and landscape lighting can be programmed to shut off automatically based on building operating hours to reduce energy use when exterior lighting is not required.

**23.** Example 4-6 works through the requirements for exterior lighting systems with respect to lighting power (NECB Subsection 4.2.3.) and lighting controls (NECB Subsection 4.2.4.).

**Example 4-6 – Exterior Lighting Power**

In this Example, a designer is developing the exterior lighting design for a supermarket building with an adjacent open parking lot. The supermarket building is 10 m high and has a 3-m-wide walkway along two of its facades. The main entrance is 4 m wide and faces the parking lot. The building site is located in a commercial district with moderate activity. See Figure A.

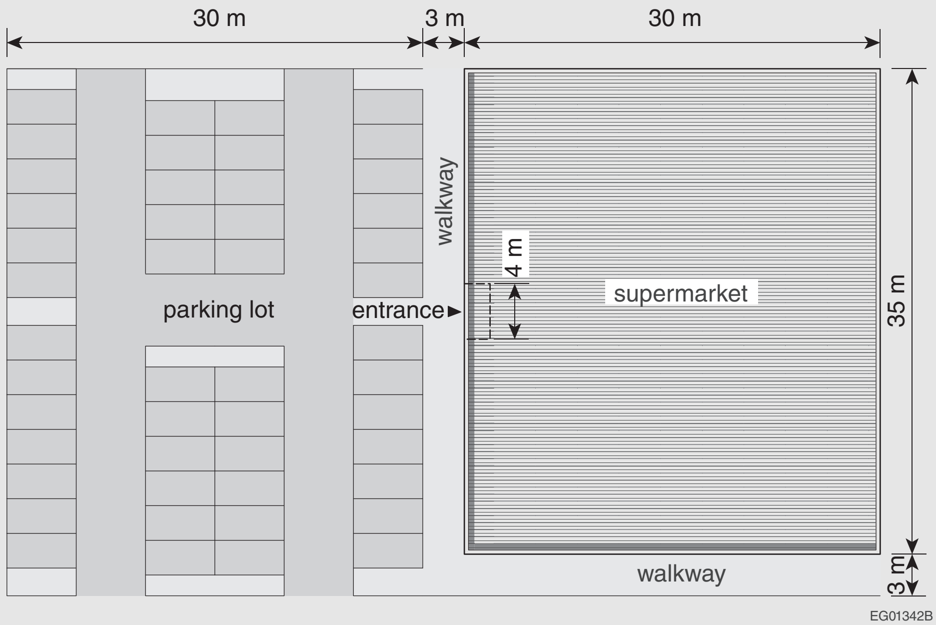



**Figure A**
**Layout of supermarket building and parking lot**

The designer wants to install luminaires in the following four exterior applications:
(1) facades: six luminaires illuminating the wall with the main entrance
(2) main entrance: two luminaires
(3) walkways: seven luminaires
(4) parking lot: eight luminaires

***Exterior Lighting Power (4.2.3.)***

The exterior lighting power allowance varies depending on the lighting zone in which the building will be located (note that this is different from the climate zones used in NECB Part 3). The supermarket building in this Example will be located in a commercial district that is not a high-activity area; so, according to NECB Table 4.2.3.1.-A, the Zone 3 exterior lighting power allowances will apply.

The exterior lighting power allowance is a combination of three allowances: the basic site allowance, the lighting power allowances for specific building exterior applications, and the lighting power allowances for general building applications. The basic site allowance in NECB Table 4.2.3.1.-B can be used towards any lighting application—specific or general. The specific lighting power allowances in NECB Table 4.2.3.1.-C can only be used for the application to which they apply, so any remaining allowance is lost. The general lighting power allowances in NECB Table 4.2.3.1.-D can be used towards any of the general lighting applications, so any remaining allowance can be applied to other general exterior applications.

**Example 4-6 – Exterior Lighting Power (Continued)**

***Basic Site Allowance for Exterior Lighting***

The basic site allowance for exterior lighting in Zone 3 is 500 W.

***Lighting Power Allowances for Specific Building Exterior Applications***

The facade under consideration in this Example qualifies as a specific building exterior application. The lighting design consists of six luminaires each equipped with a 50 W metal halide (MH) lamp. The lamp and ballast combination draws 70 W of electrical power. The connected exterior lighting power for the facade is calculated as follows:

$$\text{Connected exterior lighting power}_{\text{facade}} = 6\,\text{luminaires} \times 70\,\frac{\text{W}}{\text{luminaire}} = 420\,\text{W}$$

As per NECB Table 4.2.3.1.-C, the exterior lighting power allowance for facades is 1.6 W/m² for each illuminated wall or surface area or 12.3 W/m for each illuminated wall or surface length. The results for each of these calculations are as follows:

$$\text{Exterior lighting power allowance}_{\text{facade,area}} = 1.6\,\frac{\text{W}}{\text{m}^2}\,(35\,\text{m} \times 10\,\text{m}) = 560\,\text{W}$$

$$\text{Exterior lighting power allowance}_{\text{facade,linear}} = 12.3\,\frac{\text{W}}{\text{m}} \times 35\,\text{m} = 430.5\,\text{W}$$

The following table compares the specific exterior lighting power allowance with the connected exterior lighting power. The lighting design for the facade draws less wattage than the allowance and therefore complies with the NECB. Because the facade is a specific building exterior application, the difference between the connected power and the power allowance cannot be used towards any other exterior lighting application.

| Exterior Lighting Application | Connected Exterior Lighting Power, W | Specific Exterior Lighting Power Allowance, W |
|---|---|---|
| Facade | 420 W | 560 W |

Had the connected exterior lighting power been greater than the specific exterior lighting power allowance for one or more of the exterior applications, the designer could have applied some or all of the basic site allowance for exterior lighting in lighting Zone 3 (500 W) towards any of those applications in order to achieve a compliant exterior lighting design. If any of the basic site allowance is applied towards the specific building application, the basic site allowance is reduced accordingly. In this case, the entire basic site allowance for exterior lighting is still available for the remaining exterior lighting applications.

**Example 4-6 – Exterior Lighting Power (Continued)**

***Lighting Power Allowances for General Building Exterior Applications***

The calculation of the general building exterior lighting allowances is similar to the one for the specific exterior lighting power allowances. The parameter required is either the surface area or the length of the exterior application to be illuminated. The following table summarizes the connected exterior lighting power and the general exterior lighting power allowances applicable to Example 4-6 based on NECB Table 4.2.3.1.-D.

| Exterior Lighting Application | Number of Luminaires | Lamp and Ballast Combined Total Watts per Luminaire (lamp watts), W | Connected Exterior Lighting Power | Size of Illuminated Wall or Surface | Lighting Power Allowance for General Exterior Applications | General Exterior Lighting Power Allowance |
|---|---|---|---|---|---|---|
| Main entrance | 2 | 90 W (70 W MH) | 180 W | 4 m | 69 W/m | 276 W |
| Walkways | 5 | 90 W (70 W MH) | 450 W | 204 $m^2$ ((35 m + 3 m + 30 m) × 3 m) | 1.2 $W/m^2$ | 245 W |
| Parking lot | 6 | 180 W (150 W MH) | 1080 W | 1140 $m^2$ (38 m × 30 m) | 0.65 $W/m^2$ | 741 W |
| | | | Total: 1710 W | | | Total: 1262 W |

In this Example, the total connected exterior lighting power of 1710 W is greater than the total general exterior lighting power allowance of 1262 W. The basic site allowance of 500 W for exterior lighting has not yet been used so it can be added to the general exterior lighting power allowance for a total allowance of 1762 W, which is now greater than the total connected exterior lighting power, making the exterior lighting design compliant with the NECB Subsection 4.2.3. requirements.

Note that the walkways and parking lot have higher connected lighting power values than their applicable exterior lighting power allowance. But since all applications in this Example are general exterior lighting applications, the power allowances, including the basic site allowance, for each application can be applied to other applications, which is an approach that is similar to the space-by-space method for interior lighting power.

***Exterior Lighting Controls (Subsection 4.2.4.)***

The exterior lighting applications require lighting controls as stated in NECB Sentence 4.2.4.1.(1) since they do not meet the exemption conditions specified in NECB Sentences 4.2.4.1.(2) and (3):

- the exterior lighting is not designed for dusk-to-dawn operation; and
- the exterior lighting applications do not consist of covered vehicle exterior entrances or exits.

The designer decides to use a combination of photosensors and timer shut-off switches. In addition, a backup power supply is integrated into the design to meet the requirements of NECB Sentence 4.2.4.1.(6).

The exterior lighting design in this Example now complies with NECB Subsection 4.2.4.

## Trade-off Path (Section 4.3.)

**24.** The lighting trade-off path is an alternative NECB Part 4 compliance path that applies only to interior lighting power and interior lighting controls (see NECB Article 4.3.1.2. for the limitations on the application of this path) (see also NECB Figure A-4.1.1.3.(1)-A). In the trade-off path, the estimated energy consumption for the interior lighting systems of a given design is compared to the estimated baseline energy consumption of a lighting design that follows the prescriptive path: these two values are referred to as the installed interior lighting energy (IILE) and the interior lighting energy allowance (ILEA). The IILE must be less than or equal to the ILEA for the interior lighting design to be deemed compliant.

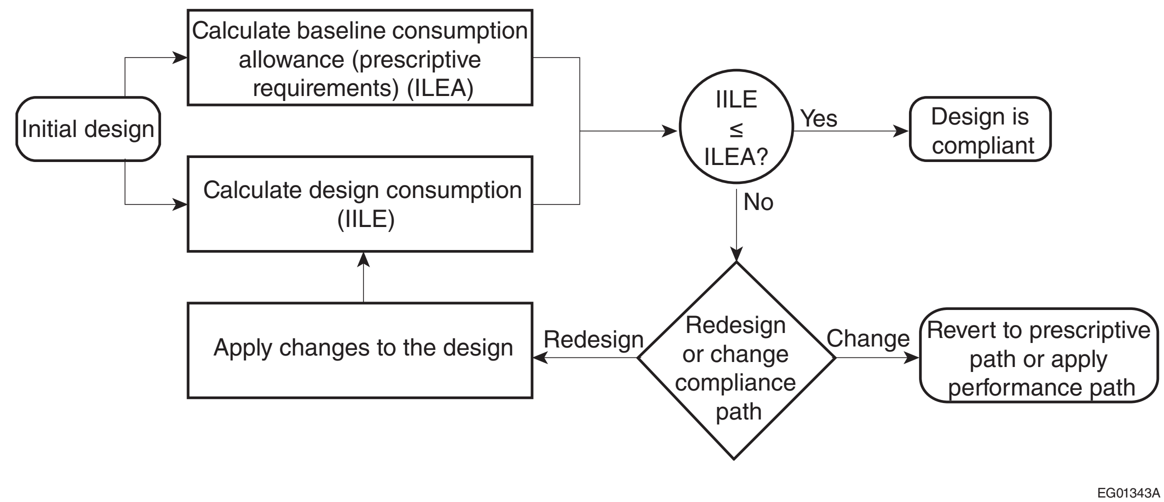



**Figure 4-1**
**Compliance flow chart for the interior lighting trade-off path**

**25.** The lighting trade-off path consists of two compliance options: compliance with NECB Subsections 4.3.2. and 4.3.3. or with a combination of selected NECB provisions and CSA C873.4, “Building Energy Estimation Methodology – Part 4 – Energy Consumption for Lighting” (commonly referred to as “BEEM”).

**26.** The combined NECB/BEEM option presents a simplified approach to the calculation of lighting energy consumption by using monthly averages instead of the dynamic equations used in hourly time-interval-based software. It allows three daylighting control systems—standard and light-directing systems, and permanent shading—as well as three latitude ranges (30° to 45°, 45° to 60°, and 60° to 75°).

**27.** Although it is common to find some differences between the results of daylighting calculations using NECB Subsections 4.3.2. and 4.3.3. and those using NECB/BEEM, they should nevertheless be comparable.

**28.** The installed lighting power density (LPD) and the influence of the lighting controls in both the daylighted and non-daylighted areas of a space must be considered when estimating the energy consumption of a lighting system design. The overall estimated consumption is the sum of the estimates for each of the spaces in a building. Figure 4-2 is a graphical representation of the calculation of the estimated lighting energy use for one space (see equations in NECB Sentences 4.3.2.1.(2) and 4.3.3.1.(2)).

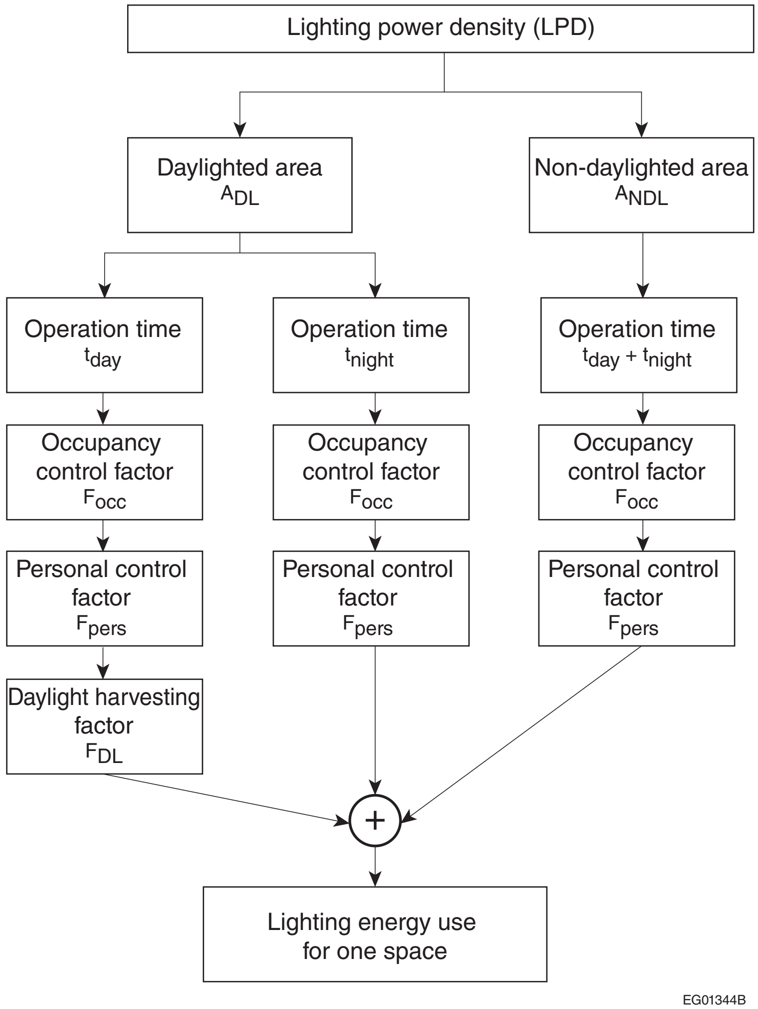



**Figure 4-2**
**Graphical representation(1) of the calculation of estimated lighting energy use**
**Note to Figure 4-2:**
(1) Adapted from Rosemann and Suvagau: Model To Determine Lighting Energy Savings In Commercial Buildings. Ingineria Iluminatului 2010; 12, 1: 33-42

**29.** Example 4-7 presents the calculations in the lighting trade-off path through a scenario in which the building owner's demands make it difficult for the designer to comply with the NECB prescriptive interior lighting requirements. The Example shows that the trade-off path affords the designer a way of meeting the owner's expectations while still complying with the objectives of the prescriptive requirements.

**Example 4-7 – Trade-off Path Calculations**

This Example deals with the lighting design for a seminar room and an open office space. The seminar room has no windows (so no daylighted areas). The open office space has a double-glazed window facing west, which spans across the width of the office and extends all the way up to the 3 m high ceiling. The spaces will be used from 8 a.m. to 5 p.m., Monday to Friday, for 250 days per year (the spaces shut down two weeks per year). The building containing these spaces is not obstructed on the outside from a daylighting perspective.

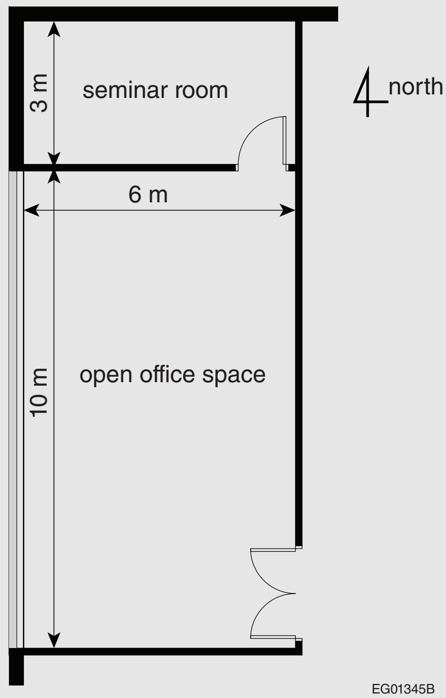



**Figure A**
**Layout of spaces**

The owner of the building requires an LPD of 12.5 W/m² in the seminar room because of the higher colour rendering and illuminance requirements of the activities carried out therein. The owner also insists on an LPD of 9.2 W/m² in the open office space to achieve 500 lux on the work surface. The design includes occupancy controls in both spaces but does not include daylight-dependent controls or personal dimming controls.

The owner's LPD requirements exceed the LPD allowances using either the building area method (8.5 W/m² for building type "Office" in NECB Table 4.2.1.5.) or the space-by-space method (10.3 W/m² for space type "Classroom/Lecture hall/Training room" and 8.7 W/m² for space type "Office – open plan" in NECB Table 4.2.1.6.). The design therefore does not comply with the prescriptive requirements, however, the designer can resolve the situation using the trade-off path. In doing so, the focus is shifted from the installed power for lighting to energy consumption, i.e., on the operation of the lighting system.

If the LPDs cannot be changed due to lighting requirements for activities carried out in the spaces, controls can be added to reduce the energy consumption to a level that is equal to or less than the energy consumption defined by the prescriptive approach. Example 4-7 shows that compliance with the objectives of NECB Section 4.2. and meeting the owner's needs can be achieved by applying the trade-off path.

Compliance using the trade-off path is achieved when the installed interior lighting energy (IILE) is less than or equal to the interior lighting energy allowance (ILEA).

**Example 4-7 – Trade-off Path Calculations (Continued)**

***Calculation of the Annual Energy Consumption and Annual Energy Consumption Allowance of Interior Lighting for the Seminar Room***

The IILE is the sum of the annual energy consumption of the proposed interior lighting in the spaces under consideration and is calculated as per NECB Subsection 4.3.2. The steps involved in the calculation of the annual energy consumption of the proposed interior lighting in the seminar room, $E_{1,proposed}$, are presented below.

**Installed Interior Lighting Energy (4.3.2.)**

*$E_{1,proposed}$: Determination of Lighting Power Density (4.3.2.2.)*

The proposed design uses a lighting power density, $p_{1,proposed}$, of 12.5 W/m².

*$E_{1,proposed}$: Determination of Daylighted and Non-Daylighted Areas (4.3.2.3. and 4.3.2.4.)*

Since there are no windows in the seminar room, the daylighted area, $A_{DL,1}$, is 0 m². The entire area of the seminar room is therefore the non-daylighted area, $A_{NDL,1}$, calculated as follows:

$$\begin{aligned} A_{NDL,1} &= A_1 - A_{DL,1} \\ &= (3\,\text{m} \times 6\,\text{m}) - 0\,\text{m}^2 \\ &= 18\,\text{m}^2 \end{aligned}$$

*$E_{1,proposed}$: Determination of Operational Times (4.3.2.6.)*

Based on the start and end times during which the space is in use (8 a.m. to 5 p.m., Monday to Friday, minus two weeks per year), the operational times during daytime, $t_{day}$, and nighttime, $t_{night}$, can been determined from NECB Tables 4.3.2.6.-A and 4.3.2.6.-B:

$$\begin{aligned} t_{day,1} &= 2217\,\text{h/a} \\ t_{night,1} &= 33\,\text{h/a} \end{aligned}$$

Since the space is used 250 days per year, $t_{day,1}$ and $t_{night,1}$ do not have to be adjusted in accordance with NECB Sentence 4.3.2.6.(3).

*$E_{1,proposed}$: Determination of Factor for Daylight Harvesting (4.3.2.7.)*

Since the seminar room does not have a window, the factor for daylight harvesting, $F_{DL,1}$, is set to 0 in accordance with NECB Article 4.3.2.7.

*$E_{1,proposed}$: Determination of the Factors for Occupancy Control and Personal Control (4.3.2.10.)*

The factor for occupancy control, $F_{occ,1}$, is determined by first looking up the relative absence of occupants, $C_{A,1}$, in NECB Table 4.3.2.10.-A for space type "Classroom/Lecture hall/Training room," the space type that most closely resembles a seminar room: the applicable factor is 0.5. The factor for the occupancy-sensing mechanism, $C_{occ,ctrl,1}$, which is "automatic full off (full on)" in this case, is then determined from NECB Table 4.3.2.10.-B: the applicable factor is 0.67. $F_{occ,1}$ can now be calculated as follows:

$$\begin{aligned} F_{occ,1} &= 1 - (C_{A,1} \times C_{occ,ctrl,1}) \\ &= 1 - (0.5 \times 0.67) \\ &= 0.665 \end{aligned}$$

The design does not include personal dimming controls, so the factor for personal control, $F_{pers,1}$, is set to 1. Note that, even if personal dimming controls were installed in the seminar room, $F_{pers,1}$ would still be 1 because $C_{pers,ctrl,1}$ is equal to 0 for space type "Classroom/Lecture hall/Training room" according to NECB Table 4.3.2.10.-A ($F_{pers,1} = 1 – C_{pers,ctrl,1} = 1 – 0 = 1$).

**Example 4-7 – Trade-off Path Calculations (Continued)**

***Calculation of the Annual Energy Consumption and Annual Energy Consumption Allowance of Interior Lighting for the Seminar Room (cont.)***

**Installed Interior Lighting Energy (4.3.2.) (cont.)**

*$E_{1,proposed}$: Determination of Effective Annual Operational Times (4.3.2.5.)*

The annual operational times and the factors to account for the impact of the control systems are combined as follows to determine the effective annual operational times:

$$
\begin{aligned}
t_{eff,day,DL,1} &= t_{day,1} \times F_{DL,1} \times F_{occ,1} \times F_{pers,1} = 2217\,h/a \times 0 \times 0.665 \times 1 = 0\,h/a \\
t_{eff,day,NDL,1} &= t_{day,1} \times F_{occ,1} \times F_{pers,1} = 2217\,h/a \times 0.665 \times 1 = 1474\,h/a \\
t_{eff,night,1} &= t_{night,1} \times F_{occ,1} \times F_{pers,1} = 33\,h/a \times 0.665 \times 1 = 22\,h/a
\end{aligned}
$$

*$E_{1,proposed}$: Determination of $E_{1,proposed}$*

With all the variables either calculated or determined by reference to the relevant NECB tables, $E_{1,proposed}$ can now be determined as follows:

$$
\begin{aligned}
E_{1,proposed} &= p_{1,proposed} \times [A_{DL,1} \times (t_{eff,day,DL,1} + t_{eff,night,1}) + A_{NDL,1} \times (t_{eff,day,NDL,1} + t_{eff,night,1})] \\
&= 12.5\frac{W}{m^2} \times \left[0\,m^2 \times (0\,h/a + 22\,h/a) + 18\,m^2 \times (1474\,h/a + 22\,h/a)\right] \times \frac{1\,kW}{1000\,W} \\
&= 337\,kWh/a
\end{aligned}
$$

**Interior Lighting Energy Allowance (4.3.3.)**

The ILEA is the sum of the annual energy consumption allowances for interior lighting in the spaces under consideration using the prescriptive path and is calculated as per NECB Subsection 4.3.3. The steps involved in the calculation of the annual energy consumption allowance for interior lighting in the seminar room, $E_{1,prescriptive}$, are presented below.

*$E_{1,prescriptive}$: Determination of Lighting Power Density ($LPD_i$) (4.3.3.2.)*

The $LPD_1$ for the space type “Classroom/Lecture hall/Training room” is 10.3 W/m² as per NECB Table 4.2.1.6.

*$E_{1,prescriptive}$: Determination of Daylighted and Non-Daylighted Areas (4.3.3.3. and 4.3.3.4.)*

The values of $A_{DL,1}$ and $A_{NDL,1}$ are the same as for the proposed design, i.e., 0 m² and 18 m², respectively.

*$E_{1,prescriptive}$: Determination of Operational Times (4.3.3.6)*

The values of $t_{day,1}$ and $t_{night,1}$ are the same as for the proposed design, i.e., 2217 h/a and 33 h/a, respectively.

*$E_{1,prescriptive}$: Determination of Factor for Daylight Harvesting (4.3.3.7)*

The value of $F_{DL,1}$ is the same as for the proposed design, i.e., 0.

**Example 4-7 – Trade-off Path Calculations (Continued)**

***Calculation of the Annual Energy Consumption and Annual Energy Consumption Allowance of Interior Lighting for the Seminar Room (cont.)***

**Interior Lighting Energy Allowance (4.3.3.) (cont.)**

*$E_{1,prescriptive}$: Determination of the Factors for Occupancy Control and Personal Control (4.3.3.10.)*

The occupancy controls for the proposed lighting design match the type required in the prescriptive path, i.e., "automatic full off (full on)". Therefore, $F_{occ,1}$ is the same as calculated for the proposed design, i.e., 0.665.

$F_{pers,1}$ is set to 1 as per NECB Sentence 4.3.3.10.(2).

*$E_{1,prescriptive}$: Determination of Effective Annual Operational Times (4.3.3.5.)*

The values of $t_{eff,day,DL,1}$, $t_{eff,day,NDL,1}$ and $t_{eff,night,1}$ are the same as for the proposed design, i.e., 0 h/a, 1474 h/a, and 22 h/a, respectively.

*$E_{1,prescriptive}$: Determination of $E_{1,prescriptive}$*

With all the variables either calculated or determined by reference to the relevant NECB tables, $E_{1,prescriptive}$, can now be determined as follows:

$$\begin{aligned}
E_{1,\text{prescriptive}} &= \text{LPD}_1 \times [A_{\text{DL},1} \times (t_{\text{eff},\text{day},\text{DL},1} + t_{\text{eff},\text{night},1}) + A_{\text{NDL},1} \times (t_{\text{eff},\text{day},\text{NDL},1} + t_{\text{eff},\text{night},1})] \\
&= 10.3\frac{\text{W}}{\text{m}^2} \times \left[0\,\text{m}^2 \times (0\,\text{h/a} + 22\,\text{h/a}) + 18\,\text{m}^2 \times (1474\,\text{h/a} + 22\,\text{h/a})\right] \times \frac{1\,\text{kW}}{1000\,\text{W}} \\
&= 277.40\ \text{kWh/a}
\end{aligned}$$

***Calculating the Annual Energy Consumption and Annual Energy Consumption Allowance of Interior Lighting for the Open Office Space***

The calculation of the annual energy consumption and annual energy consumption allowance of interior lighting for the open office space, $E_{2,proposed}$ and $E_{2,prescriptive}$, follows the same steps as for the seminar room. Since this space has a west-facing window, daylight harvesting will be taken into consideration (see NECB Article 4.3.2.7.).

**Installed Interior Lighting Energy (4.3.2.)**

*$E_{2,proposed}$: Determination of Lighting Power Density (4.3.2.2.)*

The owner insists on a lighting power density, $p_{2,proposed}$, of 9.2 W/m².

*$E_{2,proposed}$: Determination of Daylighted Area (4.3.2.3)*

The window spans across the entire western wall and extends to the ceiling. The daylighted area for sidelighting is determined in accordance with NECB Article 4.2.2.3. The width of the daylighted area is 10 m and the depth is 3 m, resulting in a total daylighted area of:

$$A_{\text{DL},2} = 10\,\text{m} \times 3\,\text{m} = 30\,\text{m}^2$$

**Example 4-7 – Trade-off Path Calculations (Continued)**

***Calculating the Annual Energy Consumption and Annual Energy Consumption Allowance of Interior Lighting for the Open Office Space (cont.)***

**Installed Interior Lighting Energy (4.3.2.) (cont.)**

*$E_{2,proposed}$: Determination of Non-Daylighted Area (4.3.2.4.)*

The remainder of the open office space is the non-daylighted area calculated as follows:

$$\begin{aligned} A_{NDL,2} &= A_2 - A_{DL,2} \\ &= (10\,m \times 6\,m) - 30\,m^2 \\ &= 30\,m^2 \end{aligned}$$

*$E_{2,proposed}$: Determination of Operational Times (4.3.2.6.)*

The open office space and the seminar room have the same operational times, so the values of $t_{day}$ and $t_{night}$ are the same, i.e., 2217 h/a and 33 h/a, respectively.

*$E_{2,proposed}$: Determination of Factor for Daylight Harvesting (4.3.2.7.)*

To calculate the factor for daylight harvesting, $F_{DL,2}$, for the office, the daylight supply factor, $C_{DL,sup,2}$, the daylight system control factor, $C_{DL,ctrl,2}$, and the daylight-dependent control factor for electric lighting, $C_{EL,ctrl,2}$, have to be determined.

*$E_{2,proposed}$: Determination of the Daylight Supply Factor for Sidelighting (4.3.2.8.)*

The daylight supply factor, $C_{DL,sup,2}$, depends on the effective luminous transmittance of the fenestration, $\tau_{eff,2}$, the raw daylight supply factor for the rough opening, $C_{DL,sup,raw,2}$, and the obstruction factor, $f_{obst,2}$.

Calculation of $\tau_{eff,2}$ for the fenestration providing sidelighting: the double-glazed windows have a luminous transmittance, $\tau_{D65,2}$, of 81%; approximately 10% of the window area is taken up by framing, so the factor to account for framing, $k_{1,2}$, is 0.9; the default values for factors $k_{2,2}$, 0.8, and $k_{3,2}$, 0.85, apply in this case (see NECB Sentence 4.3.2.8.(2)):

$$\begin{aligned} \tau_{eff,2} &= \tau_{D65,2} \times k_{1,2} \times k_{2,2} \times k_{3,2} \\ &= 0.81 \times 0.9 \times 0.8 \times 0.85 \\ &= 0.496 \end{aligned}$$

Determination of $C_{DL,sup,raw,2}$ for the rough opening: the applicable value for a design illuminance of 500 lux and sidelighting on the west side of the room is 0.64 according to NECB Table 4.3.2.8.

Calculation of $f_{obst,2}$: since the building is unobstructed, $f_{obst,2} = 1$.

The daylight supply factor, $C_{DL,sup,2}$, can now be calculated as follows:

$$\begin{aligned} C_{DL,sup,2} &= \tau_{eff,2} \times C_{DL,sup,raw,2} \times f_{obst,2} \\ &= 0.496 \times 0.64 \times 1 \\ &= 0.317 \end{aligned}$$

**Example 4-7 – Trade-off Path Calculations (Continued)**

***Calculating the Annual Energy Consumption and Annual Energy Consumption Allowance of Interior Lighting for the Open Office Space (cont.)***

**Installed Interior Lighting Energy (4.3.2.) (cont.)**

*$E_{2,proposed}$: Determination of $C_{DL,ctrl,2}$ and $C_{EL,ctrl,2}$ (4.3.2.7.)*

Determination of daylight system control factor, $C_{DL,ctrl,2}$: the initial proposed design does not incorporate daylight controls, so the daylight system must be controlled **manually**; the applicable factor for manual daylight system control according to NECB Table 4.3.2.7.-A is 0.5.

Determination of daylight-dependent control factor for electric lighting, $C_{EL,ctrl,2}$: the electric lighting will only be controlled **manually** in response to daylighting (it will not use daylight-dependent controls); the applicable factor according to NECB Table 4.3.2.7.-B is 0.1.

The factor for daylight harvesting, $F_{DL,2}$, can now be calculated as follows:

$$\begin{aligned} F_{DL,2} &= 1 - C_{DL,sup,2} \times C_{DL,ctrl,2} \times C_{EL,ctrl,2} \\ &= 1 - (0.317 \times 0.5 \times 0.1) \\ &= 0.98 \end{aligned}$$

*$E_{2,proposed}$: Determination of Factors for Occupancy Control and Personal Control (4.3.2.10.)*

The factor for occupancy control, $F_{occ,2}$, is determined using the same equation as for the seminar room. The value of the factor for the relative absence of occupants, $C_{A,2}$, for space type "Office – open plan" from NECB Table 4.3.2.10.-A is 0.2 and the factor for the occupancy-sensing mechanism, $C_{occ,ctrl,2}$, "automatic full off (full on)" from NECB Table 4.3.2.10-B is the same as for the seminar room, i.e., 0.67.

$$\begin{aligned} F_{occ,2} &= 1 - C_{A,2} \times C_{occ,ctrl,2} \\ &= 1 - (0.2 \times 0.67) \\ &= 0.866 \end{aligned}$$

The lighting design for the office does not include personal dimming controls, so $F_{pers,2}$ is set to 1. Note that, if dimming controls were installed, $F_{pers,2}$ would be equal to 0.9 because $C_{pers,ctrl,2}$ is equal to 0.1 for space type "Office – open plan" according to NECB Table 4.3.2.10.-A ($F_{pers,2} = 1 - C_{pers,ctrl,2} = 1 - 0.1 = 0.9$).

*$E_{2,proposed}$: Determination of Effective Annual Operational Times (4.3.2.5.)*

The annual operational times and the factors to account for the impact of the control systems are combined as follows to determine the effective annual operational times:

$$\begin{aligned} t_{eff,day,DL,2} &= t_{day} \times F_{DL,2} \times F_{occ,2} \times F_{pers,2} = 2217\,h/a \times 0.98 \times 0.866 \times 1889\,h/a \\ t_{eff,day,NDL,2} &= t_{day} \times F_{occ,2} \times F_{pers,2} = 2217\,h/a \times 0.866 \times 1 = 1920\,h/a \\ t_{eff,night,2} &= t_{night} \times F_{occ,2} \times F_{pers,2} = 33\,h/a \times 0.866 \times 1 = 29\,h/a \end{aligned}$$

**Example 4-7 – Trade-off Path Calculations (Continued)**

***Calculating the Annual Energy Consumption and Annual Energy Consumption Allowance of Interior Lighting for the Open Office Space (cont.)***

**Installed Interior Lighting Energy (4.3.2.) (cont.)**

*$E_{2,proposed}$: Determination of $E_{2,proposed}$*

With all the variables calculated or determined by reference to the relevant NECB tables, $E_{2,proposed}$ can now be determined as follows:

$$\begin{aligned} E_{2,proposed} &= p_{2,proposed} \times [A_{DL,2} \times (t_{eff,day,DL,2} + t_{eff,night,2}) + A_{NDL,2} \times (t_{eff,day,NDL,2} + t_{eff,night,2})] \\ &= 9.2\frac{W}{m^2} \times \left[30\,m^2 \times (1889\,h/a + 29\,h/a) + 30\,m^2 \times (1920\,h/a + 29\,h/a)\right] \times \frac{1\,kW}{1000\,W} \\ &= 1067\,kWh/a \end{aligned}$$

**Interior Lighting Energy Allowance (4.3.3.)**

The steps involved in the calculation of the annual energy consumption allowance for interior lighting in the open office space, $E_{2,prescriptive}$, are presented below.

*$E_{2,prescriptive}$: Determination of Lighting Power Density ($LPD_2$) (4.3.3.2.)*

The $LPD_2$ for the space type "Office – open plan" is 8.7 W/m² as per NECB Table 4.2.1.6.

*$E_{2,prescriptive}$: Determination of Daylighted and Non-Daylighted Areas (4.3.3.3. and 4.3.3.4.)*

The values of $A_{DL,2}$ and $A_{NDL,2}$ are the same as for the proposed design, i.e., 30 m² and 30 m², respectively.

*$E_{2,prescriptive}$: Determination of Operational Times (4.3.3.6)*

The values of $t_{day}$ and $t_{night}$ are the same as for the proposed design, i.e., 2217 h/a and 33 h/a, respectively.

*$E_{2,prescriptive}$: Determination of Factor for Daylight Harvesting (4.3.3.7)*

The value of $F_{DL,2}$ is the same as for the proposed design, i.e., 0.98.

*$E_{2,prescriptive}$: Determination of the Factors for Occupancy Control and Personal Control (4.3.3.10.)*

The occupancy controls for the proposed lighting design match the type required in the prescriptive path, i.e., "automatic full off (full on)". Therefore, $F_{occ,2}$ is the same as calculated for the proposed design, i.e., 0.866.

$F_{pers,2}$ is set to 1 since there are no personal dimming controls.

*$E_{2,prescriptive}$: Determination of Effective Annual Operational Times (4.3.3.5.)*

The values of $t_{eff,day,DL,2}$, $t_{eff,day,NDL,2}$ and $t_{eff,night,2}$ are the same as for the proposed design, i.e., 1889 h/a, 1920 h/a, and 29 h/a, respectively.

**Example 4-7 – Trade-off Path Calculations (Continued)**

***Calculating the Annual Energy Consumption and Annual Energy Consumption Allowance of Interior Lighting for the Open Office Space (cont.)***

**Interior Lighting Energy Allowance (4.3.3.) (cont.)**

*$E_{2,prescriptive}$: Determination of $E_{2,prescriptive}$*

With all the variables either calculated or determined by reference to the relevant NECB tables, $E_{2,prescriptive}$, can now be determined as follows:

$$\begin{aligned}
\mathrm{E}_{2,\mathrm{prescriptive}} &= \mathrm{p}_{2,\mathrm{prescriptive}} \times [\mathrm{A}_{\mathrm{DL},2} \times (\mathrm{t}_{\mathrm{eff,day,DL},2} + \mathrm{t}_{\mathrm{eff,night},2}) + \mathrm{A}_{\mathrm{NDL},2} \times (\mathrm{t}_{\mathrm{eff,day,NDL},2} + \mathrm{t}_{\mathrm{eff,night},2})] \\
&= 8.7\frac{\mathrm{W}}{\mathrm{m}^2} \times \left[30\,\mathrm{m}^2 \times (1889\,\mathrm{h/a} + 29\,\mathrm{h/a}) + 30\,\mathrm{m}^2 \times (1920\,\mathrm{h/a} + 29\,\mathrm{h/a})\right] \times \frac{1\,\mathrm{kW}}{1000\,\mathrm{W}} \\
&= 1009\,\mathrm{kWh/a}
\end{aligned}$$

***Comparing the Results***

To check whether the entire space complies with the objectives of the prescriptive lighting requirements, the results of $E_{proposed}$ and $E_{prescriptive}$ for the seminar room and the office need to be combined in accordance with NECB Sentence 4.3.2.1.(1) to determine the IILE and NECB Sentence 4.3.3.1.(1) to determine the ILEA:

$$\begin{aligned}
\mathrm{IILE} &= \mathrm{E}_{1,\mathrm{proposed}} + \mathrm{E}_{2,\mathrm{proposed}} = 337\,\mathrm{kWh/a} + 1067\,\mathrm{kWh/a} = 1404\,\mathrm{kWh/a} \\
\mathrm{ILEA} &= \mathrm{E}_{1,\mathrm{prescriptive}} + \mathrm{E}_{2,\mathrm{prescriptive}} = 277.40\,\mathrm{kWh/a} + 1009\,\mathrm{kWh/a} = 1287\,\mathrm{kWh/a}\ \text{(rounded)} \\
&\mathrm{IILE} > \mathrm{ILEA}
\end{aligned}$$

Because the IILE is greater than the ILEA, the lighting design as currently proposed does not comply with the trade-off path. In an effort to both preserve the owner's lighting power requirements and comply with NECB Part 4, the designer decides to add automatic daylight system controls and automatic daylight-dependent dimming controls to the lighting within the daylighted zone of the open office space, which means the value of $C_{DL,ctrl,2}$ is now 0.86 (instead of the initial 0.5 for manual control) and $C_{EL,ctrl,2}$ is now 1 (instead of the initial 0.51 for manual control), which, in turn, means the value of $F_{DL,2}$ becomes 0.73 (instead of the initial 0.92):

$$\begin{aligned}
\mathrm{F}_{\mathrm{DL},2} &= 1 - (\mathrm{C}_{\mathrm{DL,sup},2} \times \mathrm{C}_{\mathrm{DL,ctrl},2} \times \mathrm{C}_{\mathrm{EL,ctrl},2}) \\
&= 1 - (0.317 \times 0.86 \times 1) \\
&= 0.73
\end{aligned}$$

Consequently, the effective operational times in the daylighted area are now 1396 h/a (instead of 1889 h/a):

$$\begin{aligned}
\mathrm{t}_{\mathrm{eff,day,DL}} &= \mathrm{t}_{\mathrm{day}} \times \mathrm{F}_{\mathrm{DL}} \times \mathrm{F}_{\mathrm{occ}} \times \mathrm{F}_{\mathrm{pers}} \\
&= 2217\,\mathrm{h/a} \times 0.73 \times 0.866 \times 1 \\
&= 1396\,\mathrm{h/a}
\end{aligned}$$

**Example 4-7 – Trade-off Path Calculations (Continued)**

***Comparing the Results (cont.)***

The value of $E_{2,proposed}$ for the open office space with the automatic daylight system controls and the automatic daylight-dependent dimming controls is now 1115 kWh/a (instead of 1236 kWh/a):

$$\begin{aligned} E_{2,\text{proposed}} &= p \times [A_{DL} \times (t_{\text{eff,day,DL}} + t_{\text{eff,night}}) + A_{NDL} \times (t_{\text{eff,day,NDL}} + t_{\text{eff,night}})] \\ &= 9.2\,\frac{W}{m^2} \times \left[30\,m^2 \times (1396\,h/a + 29\,h/a) + 30\,m^2 \times (1920\,h/a + 29\,h/a)\right] \times \frac{1\,kW}{1000\,W} \\ &= 931\,kWh/a \end{aligned}$$

This new value of $E_{2,proposed}$ is added to $E_{1,proposed}$, resulting in an IILE of 1519 kWh/a (instead of the initial 1640 kWh/a):

$$\begin{aligned} \text{IILE} = E_{1,\text{proposed}} + E_{2,\text{proposed}} &= 337\,kWh/a + 931\,kWh/a = 1268\,kWh/a \\ \therefore \text{IILE} = 1268\,kWh/a &< \text{ILEA} = 1287\,kWh/a \end{aligned}$$

***Conclusion***

By adding automatic daylight system controls and automatic daylight-dependent dimming controls in the open office space, the overall energy consumption for lighting in the two spaces in Example 4-7 is reduced and meets the requirement of being less than or equal to the ILEA: the lighting design now complies with NECB Part 4.

# Commentary on Part 5

# Heating, Ventilating and Air-conditioning Systems

**1.** Except where otherwise noted in the NECB, all equipment, systems and controls installed to meet a new building's heating, ventilating, and/or air-conditioning requirements must comply with the requirements of NECB Part 5. This Commentary provides additional information on the means of achieving compliance. See the flow charts in NECB Figure A-5.1.1.3.(1) for the three compliance paths applicable to HVAC systems.

## Air Distribution Systems (Subsection 5.2.2.)

**2.** NECB Subsection 5.2.2. contains requirements for the design and installation of ducts, including the following:

- provisions for balancing air distribution systems to allow the adjustment and limitation of the volume of air delivered throughout the system;
- duct sealing and leakage testing requirements to limit loss of conditioned air and reduce energy use;
- insulation requirements to limit heat loss from air distribution systems;
- requirements on the use of outdoor air to reduce the amount of energy needed for mechanical cooling.

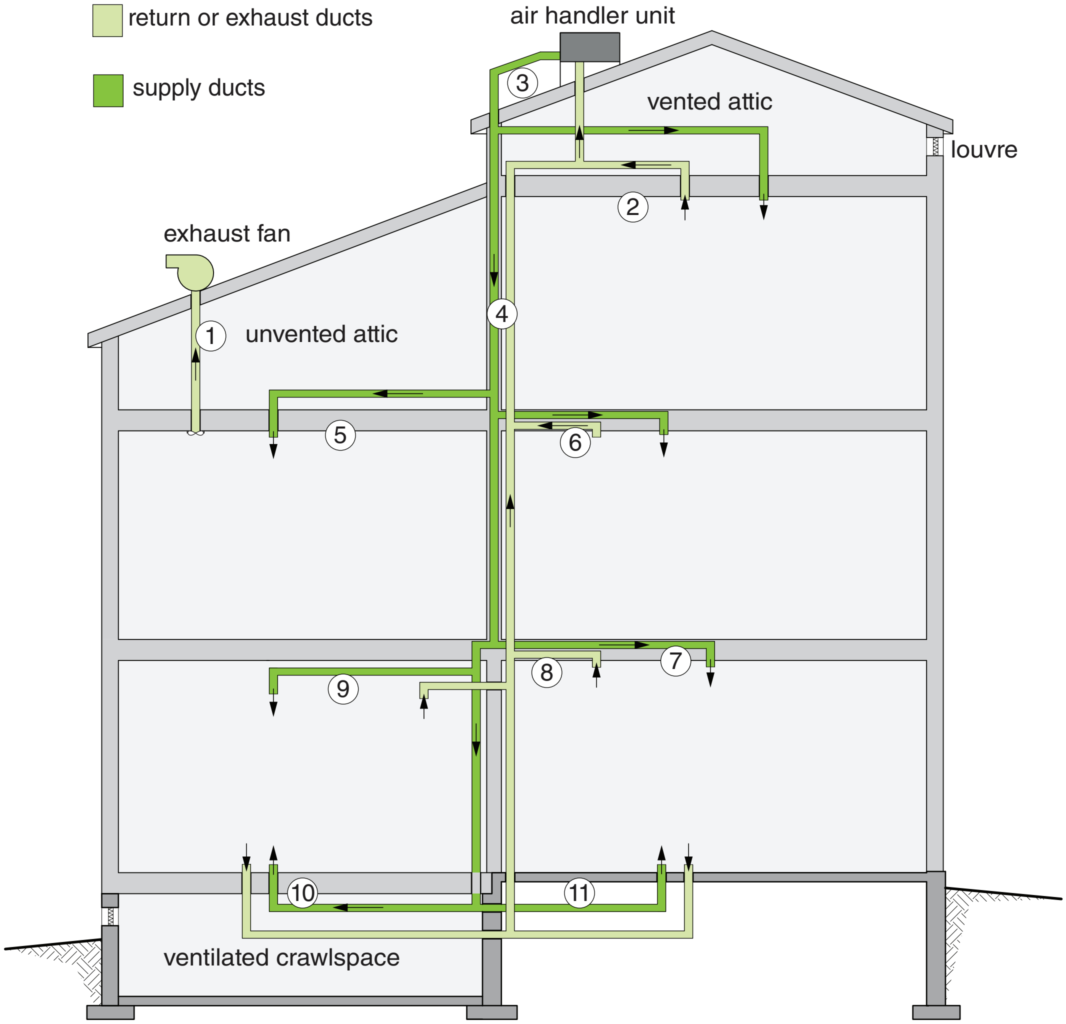
### Duct and Plenum Insulation (Article 5.2.2.5.)

**3.** Required insulation should be installed in accordance with industry good practice, such as that defined in the TIAC Best Practices Guide, the SMACNA HVAC Duct Construction Standards – Metal and Flexible, and Chapter 23 of the "ASHRAE Handbook – Fundamentals."

The requirement for duct insulation is influenced by
(a) duct location (conditioned versus unconditioned spaces), and
(b) the effect of heat loss or gain on energy use.

**4.** Ducts that pass through semi-conditioned or unconditioned spaces should be insulated depending on their location and ambient air conditions. See Figure 5-1 for examples of locations where ducts are required to be insulated. In summary, ducts must be insulated unless they serve a supply duct in an unvented attic or an exhaust duct in a conditioned space.

**5.** Duct work that is located outside the building envelope may require additional insulation above the levels listed in NECB Table 5.2.2.5. Furthermore, the insulation and its protective jacket should be rated for outdoor use.




| Key | Location | Duct Insulation Requirement |
|---|---|---|
| 1 | Exhaust ductwork in unvented attic | Required |
| 2 | Supply and return air in vented attic | Required |
| 3 | Supply and return air on exterior of building | Required |
| 4 | Supply and return air in unconditioned space | Required |
| 5 | Supply and return air in unvented attic space with insulated roof | See NECB Table 5.2.2.5. |
| 6 | Supply and return air in indirectly conditioned space | See NECB Table 5.2.2.5. |
| 7 | Supply run-out in return plenum | See NECB Table 5.2.2.5. |
| 8 | Supply duct in return plenum | See NECB Table 5.2.2.5. |
| 9 | Supply and return ducts in conditioned space | See NECB Table 5.2.2.5. |
| 10 | Supply and return ducts in crawl space vented to outdoors | Required |
| 11 | Supply and return ducts below grade | Required |

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**Figure 5-1**
**Examples of ducts required to be insulated**

### Protection of Duct Insulation (Article 5.2.2.6.)

6. Duct insulation that may be subject to mechanical or weather-related damage must be protected by a wrap or covering, typically made of plastic or metal. Condensation must be prevented from forming within the insulation as the thermal resistance of many insulation products decreases with exposure to moisture. As a secondary effect of exposure to moisture, microbial growth can occur, resulting in the deterioration of the protective jacket. A vapour barrier is required on cold-air supply ducts to prevent the formation of condensation within the insulation or on the duct.

### Cooling by Direct Use of Outdoor Air – Air Economizer System (Article 5.2.2.8.)

7. Air economizers within the air-handling system are equipped with motorized dampers that adjust the amount of outdoor air that is drawn into the system when the building requires cooling. Figure 5-2 provides a schematic of an air economizer system.

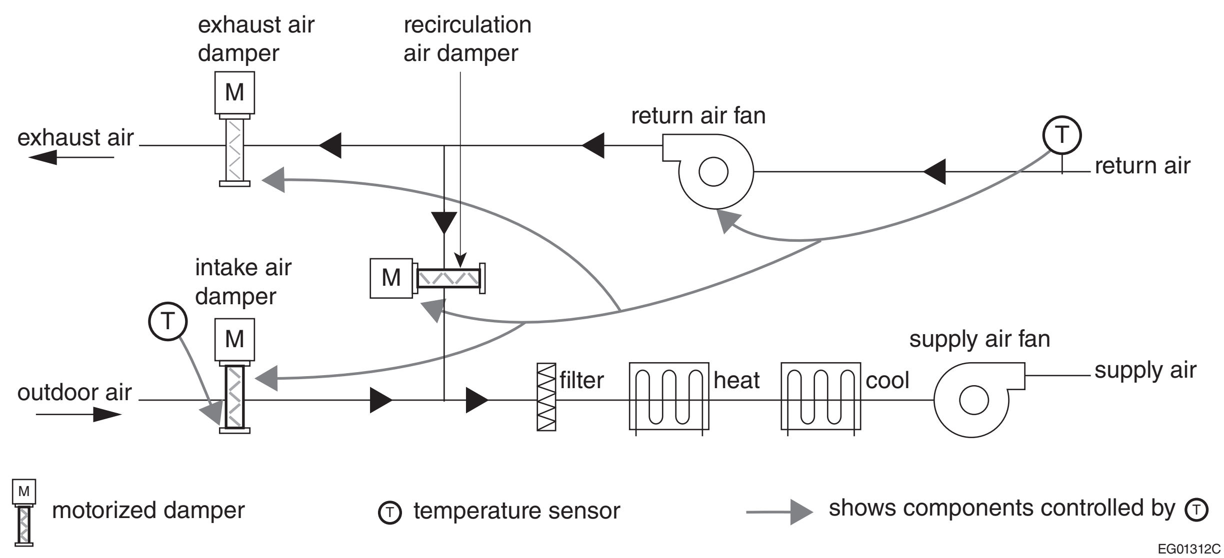


**Figure 5-2**
**Example of air economizer configuration**

8. The NECB requirements on air economizer systems aim to maximize the potential for passive cooling by:
   - prioritizing the use of outdoor air in conjunction with mechanical cooling to reduce the energy needed to condition the space,
   - using controls that activate the air economizer only when outdoor air conditions are favourable to a reduction in energy use, and
   - modulating/staging cooling equipment for trim cooling.

### Cooling by Indirect Use of Outdoor Air – Water Economizer System (Article 5.2.2.9.)

9. Water economizers reduce mechanical cooling requirements by using outdoor air to chill cooling distribution fluid, which is then used to cool supply air through a cooling coil. Typically, water is circulated through a cooling tower or fluid cooler where it is cooled, then circulated through the supply air cooling coils. Energy savings are achieved by reducing compressor operation. There are two typical configurations for a water economizer cycle:
   (a) evaporative cooling, an example of which is shown in Figure 5-3, and
   (b) sensible cooling, an example of which is shown in Figure 5-4.

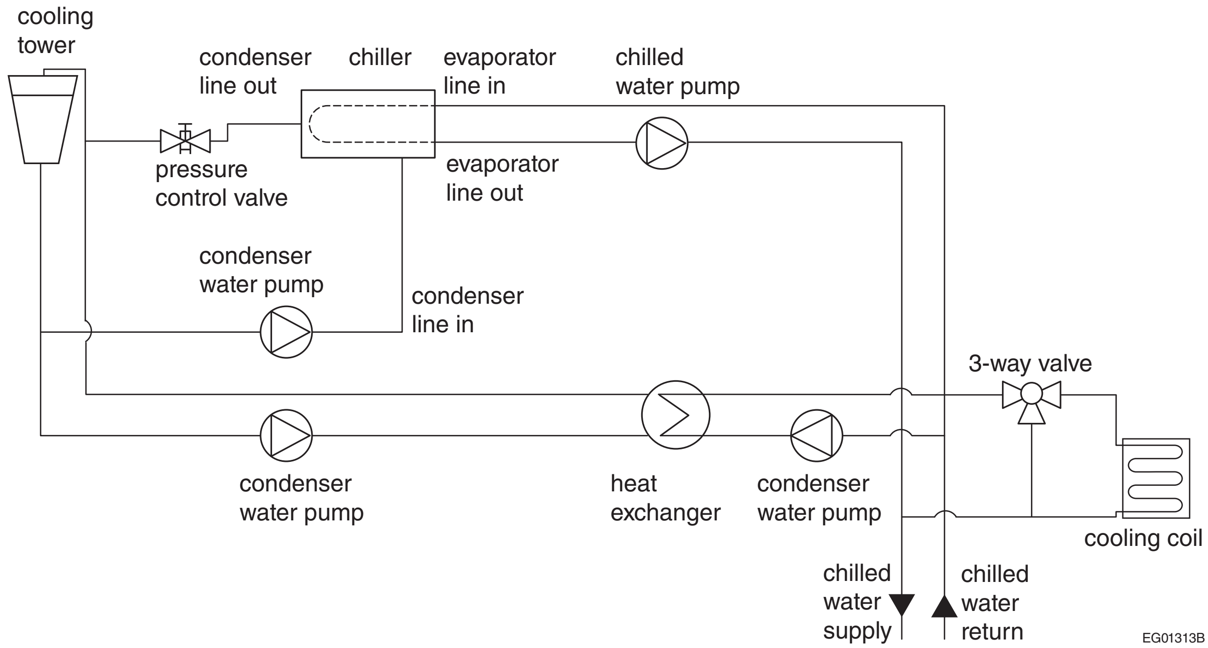


**Figure 5-3**
**Example of an evaporative cooling configuration for a water economizer system**

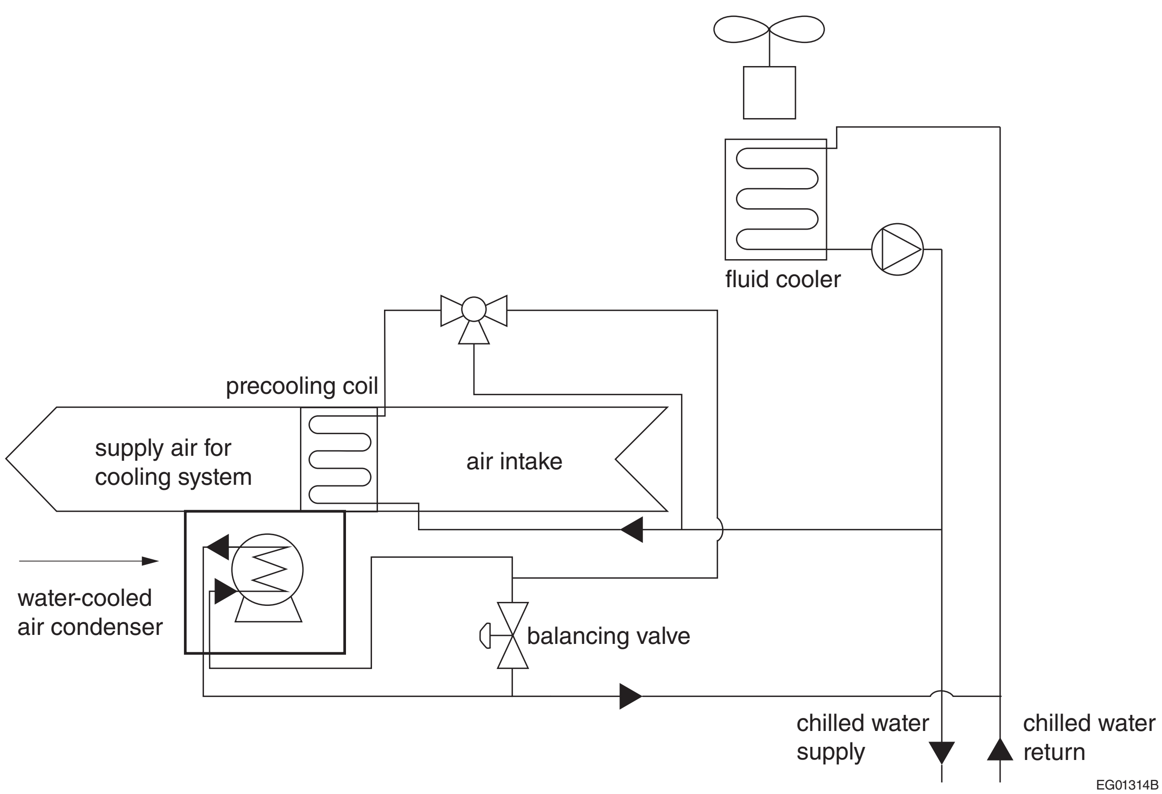


**Figure 5-4**
**Example of a sensible cooling configuration for a water economizer system**

## Demand Control Ventilation Systems (Article 5.2.3.4.)

**10.** It is common practice to employ demand control ventilation (DCV) to control contaminant levels (especially carbon monoxide and nitrous oxides) in enclosed semi-heated and conditioned spaces where fuel-powered equipment is used.

**11.** The NECB requirements on DCV are aligned with the corresponding requirements for DCV in heated and unheated indoor parking garages stated in ANSI/ASHRAE/IES 90.1, which facilitates design and enforcement in jurisdictions that reference both documents.

**Example 5-1 – Control Sequence for Staging Ventilation Fans**

A warehouse where gas-powered forklifts are used has implemented fan staging as a means to control carbon monoxide (CO) levels in two adjacent ventilation zones (A and B). Each zone is equipped with a make-up air unit (MAU) and an exhaust fan (EF), whose activation is triggered sequentially based on the limit set-point of CO detected: low (25 ppm), high (50 ppm), or critical (65 ppm).

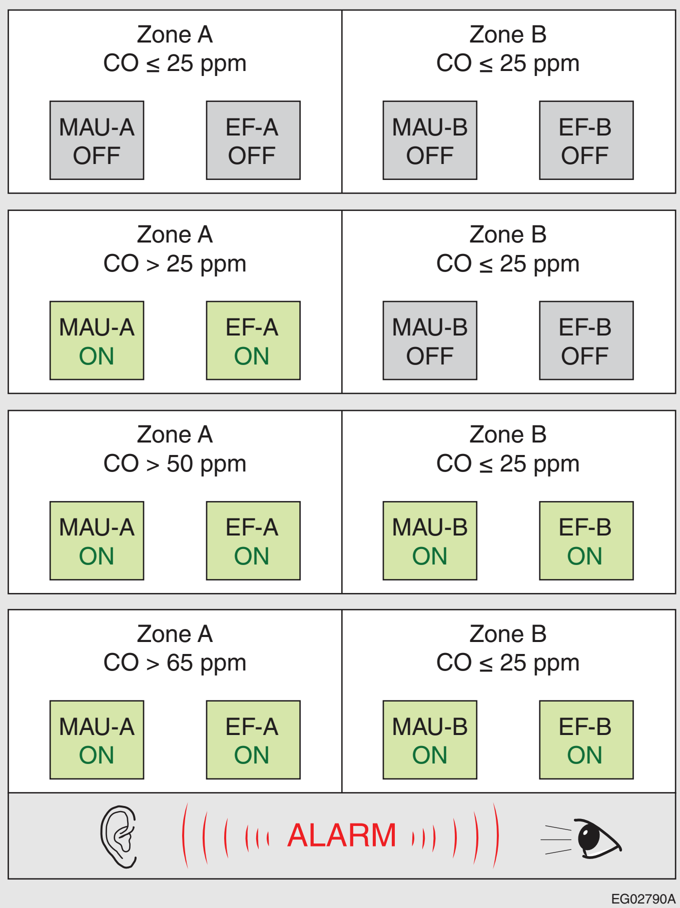


**Figure A**
**Control sequence for staging ventilation fans upon detection of CO levels above 25 ppm in Zone A**

If CO levels above 25 ppm are detected in Zone B, the control sequence is reversed, i.e., starts in Zone B.

The controls system returns to normal operation, i.e., turns off the MAUs and the EFs, once the CO level is below the low-limit set-point.

**12.** NECB Article 5.2.3.4. allows two demand control ventilation methods:
  (a) staging the ventilation fans, e.g., by cycling system fans on/off, and
  (b) modulating the outdoor airflow rates, e.g., by operating the ventilation fans at the lowest speed that effectively controls contaminants through variable-speed or multi-speed motors.

**13.** Examples 5-1 and 5-2 illustrate the control sequences for the two NECB DCV methods.

**Example 5-2 – Control Sequence for Modulating the Outdoor Airflow Rates**

An indoor parking garage uses outdoor air to control the CO levels in a single ventilation zone, which is equipped with a make-up air unit (MAU) and an exhaust fan (EF) with variable-speed motors.

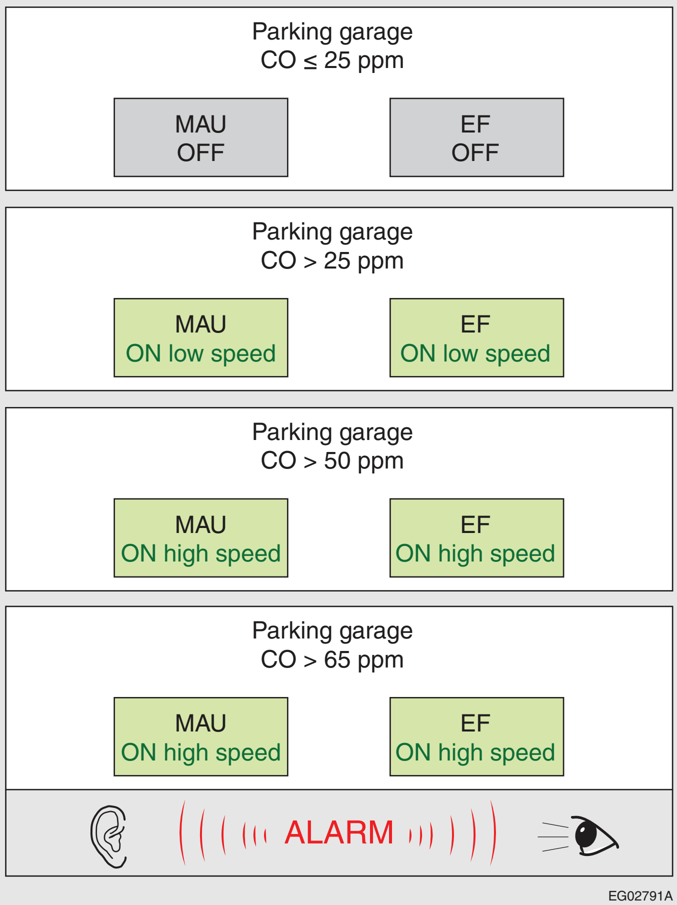


**Figure A**
**Control sequence for modulating outdoor airflow rates upon detection of CO levels above 25 ppm in a single ventilation zone**

The controls system returns to normal operation, i.e., turns off the MAU and the EF, once the CO level is below the low-limit set-point.

**14.** Demand control ventilation systems can significantly reduce the amount of energy used by HVAC systems in kitchen facilities. DCV systems adjust the amount of exhaust air required to maintain acceptable conditions for kitchen staff by monitoring cooking activity via duct temperature sensors, smoke detectors, and infrared sensors.

**Example 5-3 – DCV for a Commercial Kitchen Facility**

A building located in Edmonton, Alberta contains a kitchen with three kitchen hoods—KH-1, KH-2 and KH-3—that are exhausted by two fans—EF-1 and EF-2: EF-1 exhausts KH-1 with a capacity of 708 L/s and EF-2 exhausts both KH-2 and KH-3 with a total capacity of 1415 L/s.

The HDD below 18°C for the building location is 5120, which corresponds to climate zone 7A. According to NECB Table 5.2.3.4., the threshold design exhaust fan airflow rate for buildings in this zone is 1410 L/s.

The KH-1/EF-1 system's exhaust airflow rate of 708 L/s is well under the threshold value of 1410 L/s. However, the KH-2,KH-3/EF-2 system's exhaust airflow rate of 1415 L/s exceeds the threshold: a demand control ventilation system capable of reducing the design exhaust and make-up airflow rates by at least 50% in response to appliance operation is therefore required to be installed on this second system as per NECB Article 5.2.3.4.

## Required Dampers (Article 5.2.4.1.)

**15.** Motorized dampers can help mitigate heat loss or gain due to unintended air exfiltration or infiltration as they are maintained in the closed position by an actuation force when the ventilation system is not operational. They can be interlocked with the fan operation either directly or indirectly through a controls system.

## Design and Installation of Piping (Article 5.2.5.1.)

**16.** HVAC piping should be designed to minimize pressure losses in an effort to minimize pumping energy.

## Piping Insulation (Article 5.2.5.3.)

**Example 5-4 – Pipe Insulation**

A chilled water system is designed for a supply temperature of 6°C with an 8°C rise. The designer must determine whether insulation is required on the return piping.

As the chilled water return temperature is 14°C, the piping is exempt from the NECB requirement to be insulated. However, return water temperature is often lower than the design return temperature during part-load operation. Therefore, insulation may in fact be required according to the NBC in order to prevent the formation of condensation at part-load conditions.

## Variable-Flow Pumping Systems (Article 5.2.6.2.)

**17.** Figures 5-5 and 5-6 illustrate two types of pumping system.

**18.** In the primary-secondary pumping configuration shown in Figure 5-5, a secondary pump is selected to provide the design flow in the load from the common pipe between the supply and return lines. A two-way valve permits a variable primary flow in the supply by reducing the primary flow; a secondary pump provides a constant flow in the load coil. The primary pump at the chiller or boiler is selected to circulate the primary and mains, and the secondary pump is sized for the load coil.

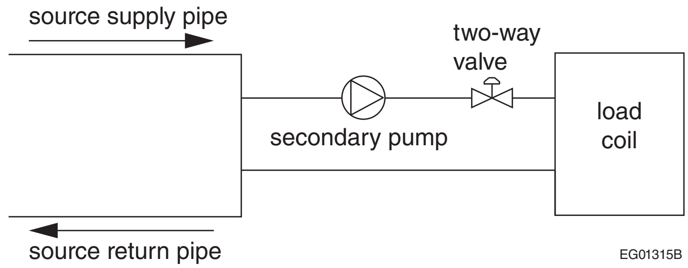


**Figure 5-5**
**Example of a primary-secondary pumping configuration**

**19.** Figure 5-6 illustrates a primary-secondary pump configuration for a chiller (or boiler) plant that requires constant-flow operation. The primary pumps provide a constant flow within the plant (primary loop) and the secondary pumps deliver flow from the plant to terminal and equipment loads (zones), which are equipped with two-way valves. The secondary pumps vary the flow within the secondary loop based on the load demand.

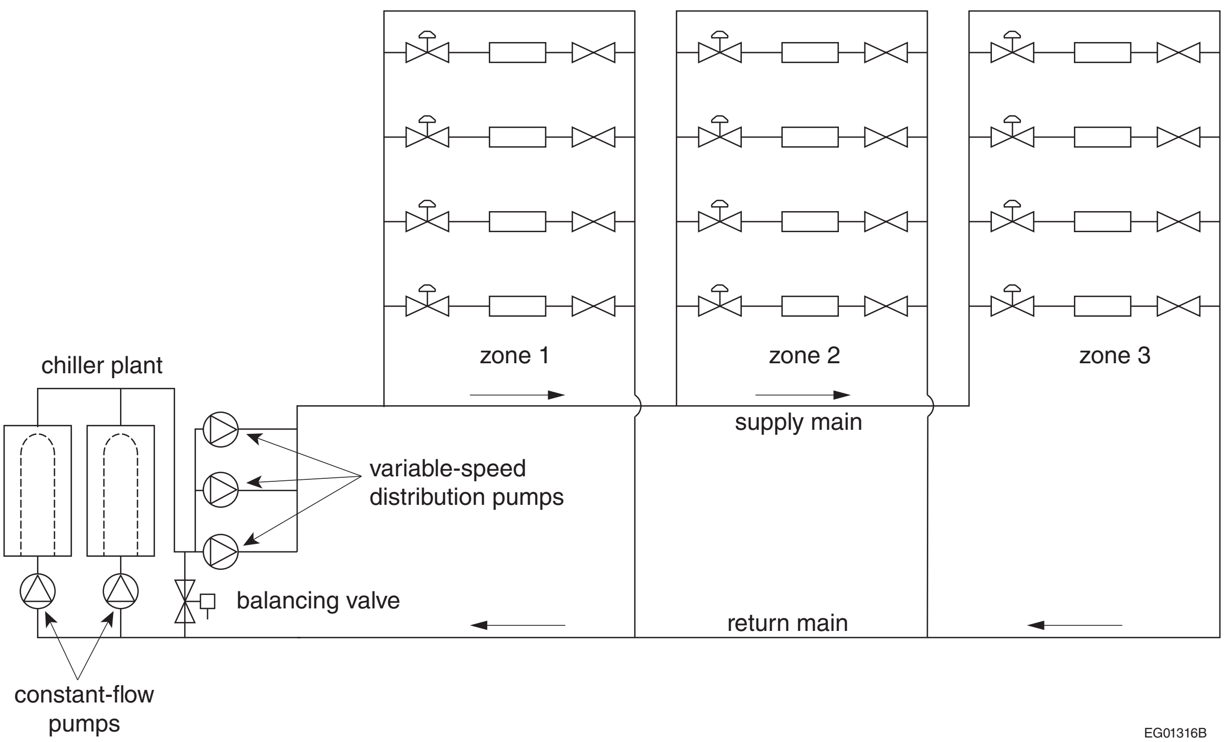


**Figure 5-6**
**Example of a primary-secondary pumping configuration for a chiller plant**

## Pumping Power Demand (Article 5.2.6.3.)

**20.** The allowable pumping power is a function of the thermal energy demand. It is common practice to install larger pumps than actually required. More efficient distribution layouts and sizing of pipes and loads allow for reduced pumping power.

**21.** Example 5-5 works through the calculation of the pumping power demand of the pumps in a heating plant to determine compliance with NECB Table 5.2.6.3.

**Example 5-5 – Hydronic Pump Sizing**

The pumping power demand is calculated by adding up the power of all pump motors required to operate during peak design conditions.

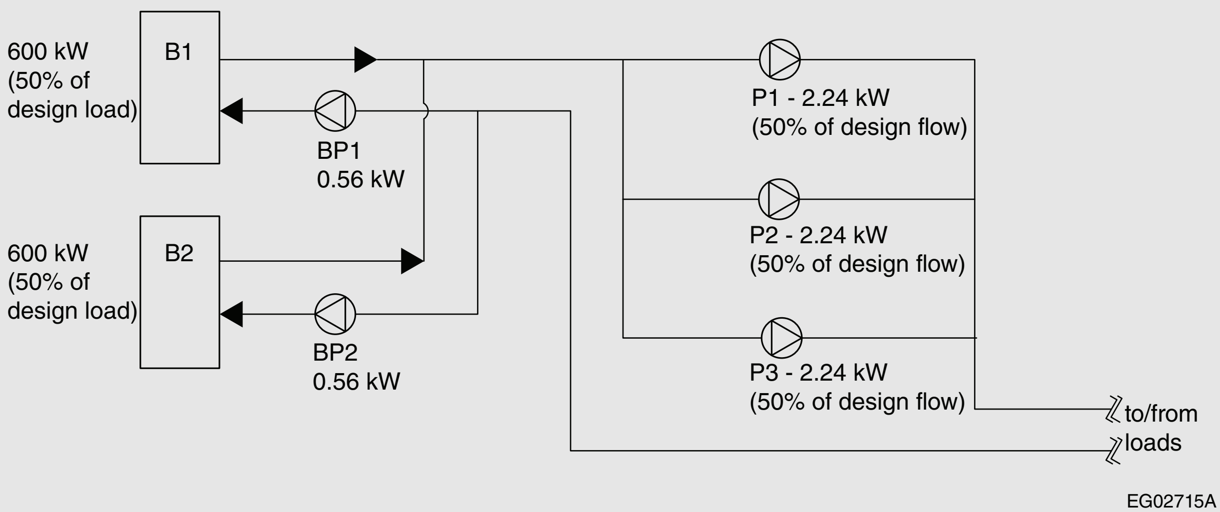


**Figure A**
**Schematic layout of pumping power demand for a heating plant for the purpose of pump sizing**

In the heating plant shown in Figure A, both boilers (B1 and B2) are needed to supply design capacity, therefore, both boiler pumps (BP1 and BP2) must be considered in the calculation of pumping power demand. Furthermore, since the distribution pumps (P1, P2 and P3) are sized for 50% of the design flow, P3 is considered redundant, so only the power demands on P1 and P2 are used in the calculation.

$$W_{\text{motorpower}} = W_{\text{BP1}} + W_{\text{BP2}} + W_{\text{P1}} + W_{\text{P2}} = 5600\ \text{W}$$
$$\text{kW}_{\text{thermalpeak}} = \text{kW}_{\text{B1}} + \text{kW}_{\text{B2}} = 1200\ \text{kW}$$
$$W_{\text{motorpower}}/\text{kW}_{\text{thermalpeak}} = 4.67\ \text{W/kW}$$

The pumping power demand in this Example exceeds the maximum value of 4.5 $W_{\text{motorpower}}/kW_{\text{thermalpeak}}$ permitted by NECB Table 5.2.6.3. for hydronic heating loops. Therefore, the pumping power demand as designed does not comply with the NECB.

## Temperature Controls (Subsection 5.2.8.)

**22.** To apply NECB Article 5.2.8.1., spaces can be grouped into control zones based on the similarity of their operating characteristics so that required space conditions can be maintained in all spaces. In general, exterior zones cannot be grouped with interior spaces. Similarly, spaces with windows facing one direction should not be grouped with spaces having windows that face another direction. Although radiant heating and cooling systems are normally controlled by thermostats, the mean radiant temperature effects should also be taken into account to avoid overheating or comfort issues within the space. For example, in a space with a radiant floor providing most or all of the heat, the space (air) temperature may be able to be set lower than in a system without radiant heating, with no compromise in occupant comfort.

## Energy Recovery Systems (Article 5.2.10.1.)

**23.** Typical energy recovery technologies are shown in Figures 5-7 to 5-10.

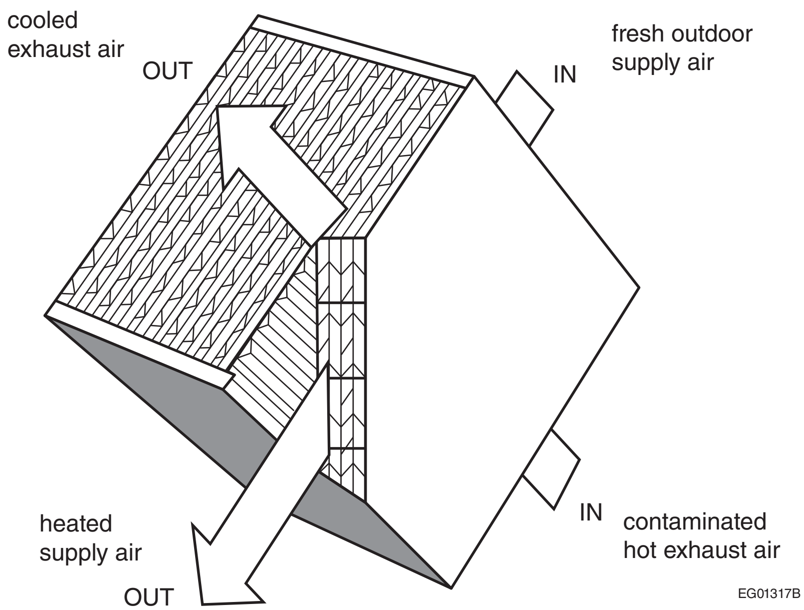


**Figure 5-7**
**Fixed-plate cross-flow heat exchanger**

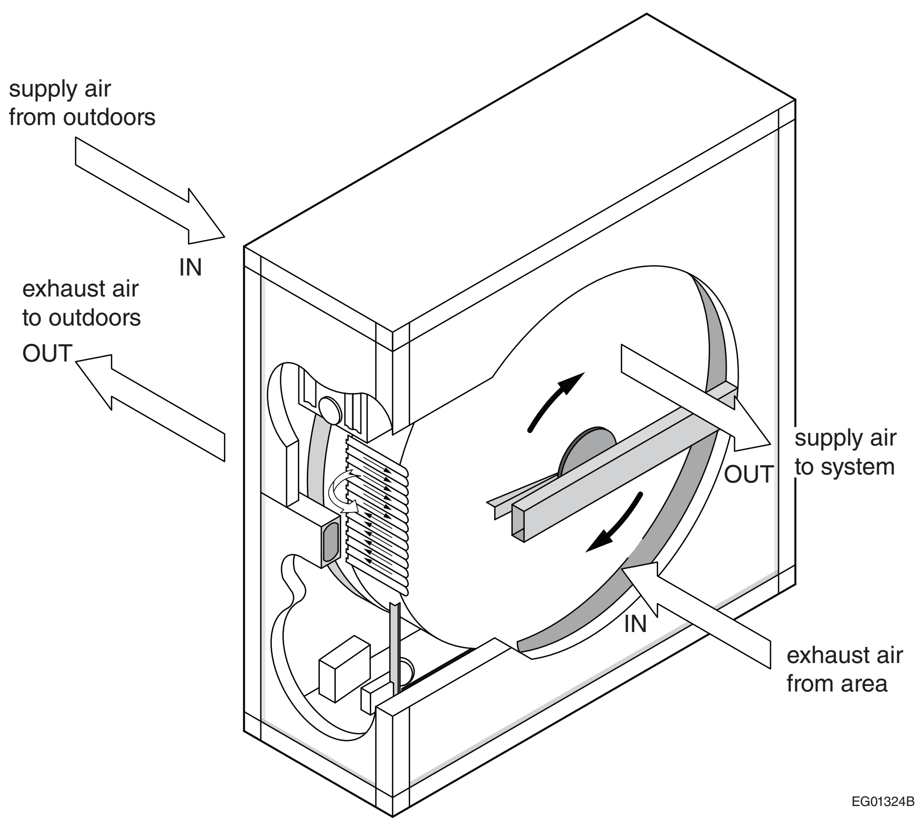


**Figure 5-8**
**Rotary heat wheel**

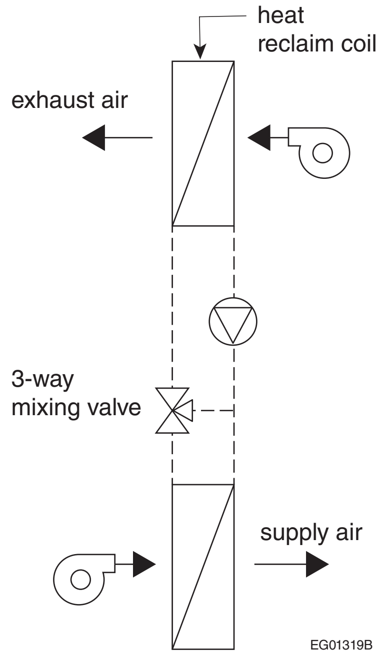


**Figure 5-9**
**Heat pipe**

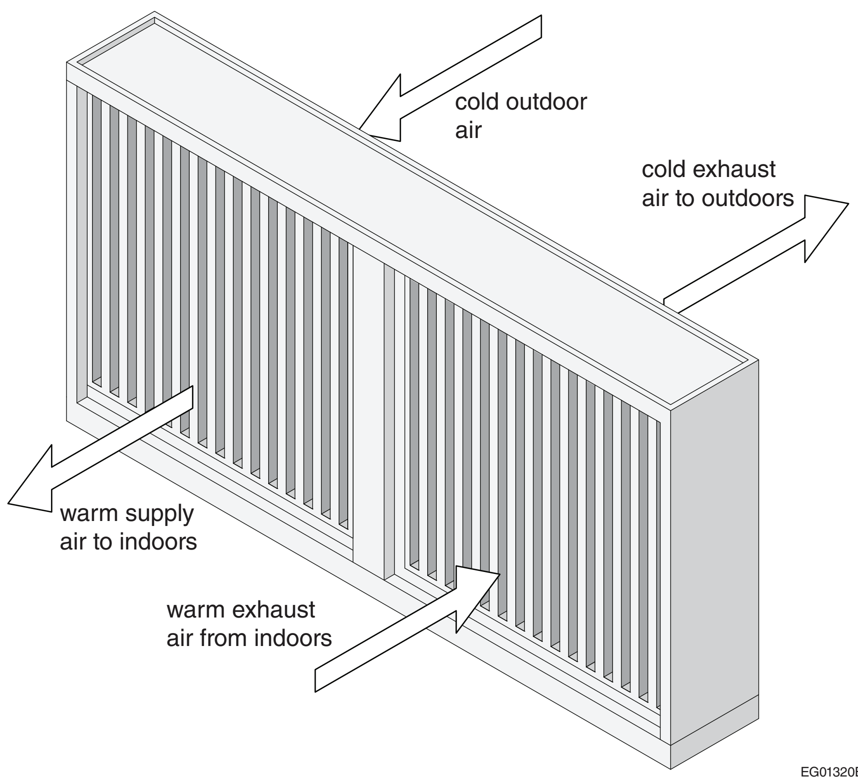


**Figure 5-10**
**Heat pipe assembly**

Example 5-6 demonstrates how to determine whether energy recovery is required using NECB Sentence 5.2.10.1.(4).

**Example 5-6 – Exhaust Air System in Edmonton, Alberta**

The owner of a building located in Edmonton, Alberta wants to determine if an energy recovery system is required to be installed on the building's exhaust air system, which operates less than 8000 hours per year and uses 35% outdoor air at a design supply fan airflow rate of 3200 L/s.

Because the exhaust air system operates less than 8000 hours per year, the applicable table to consult is NECB Table 5.2.10.1.-A. Given that the HDD below 18°C for the building location is 5120, which corresponds to climate zone 7A, the threshold supply fan airflow rate for this zone is 1180 L/s for an outdoor air usage rate between 30% and 40%. The building's exhaust air system's design supply fan airflow rate exceeds this threshold, therefore, an energy recovery system is required.

## Heat Recovery from Dehumidification in Swimming Pools (Article 5.2.10.2.)

**24.** Desiccant and mechanical dehumidification are two common methods of pool dehumidification. A typical desiccant dehumidification unit is shown in Figure 5-11.

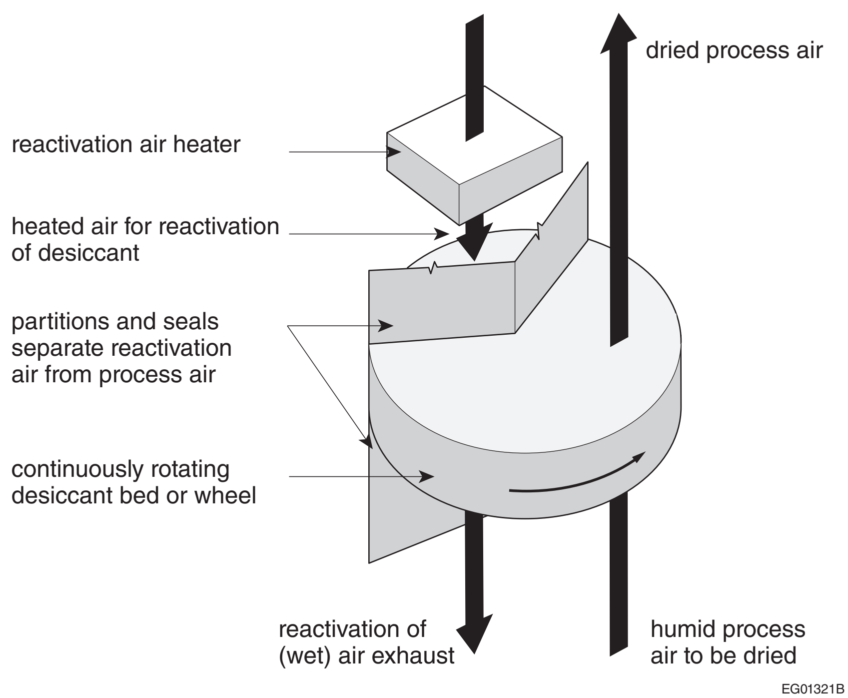


**Figure 5-11**
**Example of a typical rotary desiccant dehumidification wheel**

## Heat Recovery from Ice-making Machines in Arenas and Curling Rinks (Article 5.2.10.3.)

**25.** Ice-making systems in ice arenas generate a significant amount of heat that is often sufficient to meet a building's space- and water-heating requirements.

**26.** Condenser heat rejection is typically reclaimed through a designated condenser that is connected in parallel with the main condenser. Figure 5-12 shows an example of a heat-recovery system set-up and presents potential applications for the use of the recovered heat.

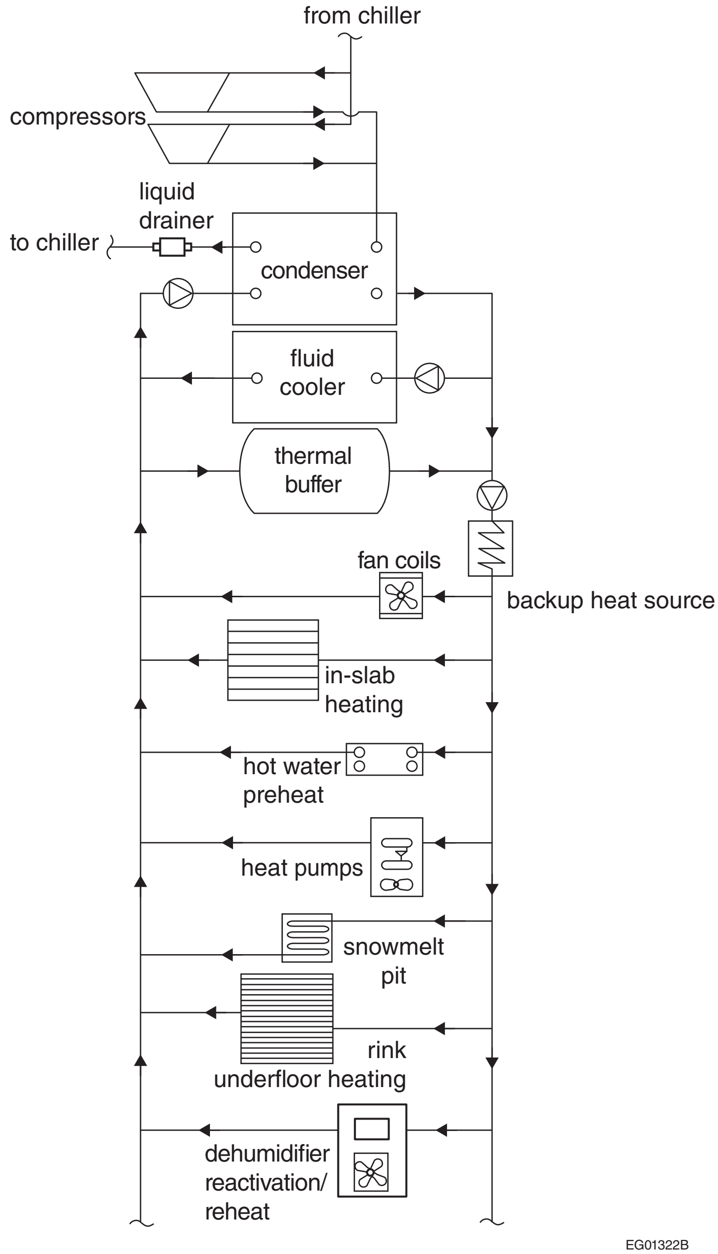


**Figure 5-12**
**Schematic of ice arena heat-recovery system and applications of recovered heat**

## Airflow Control Areas (Article 5.2.11.2.)

**27.** Airflow control areas are required in order to compartmentalize air distribution systems that serve multiple temperature-control zones so as to reduce energy use in unoccupied spaces. Figure 5-13 presents an example of an airflow control strategy using a variable-air-volume (VAV) system.

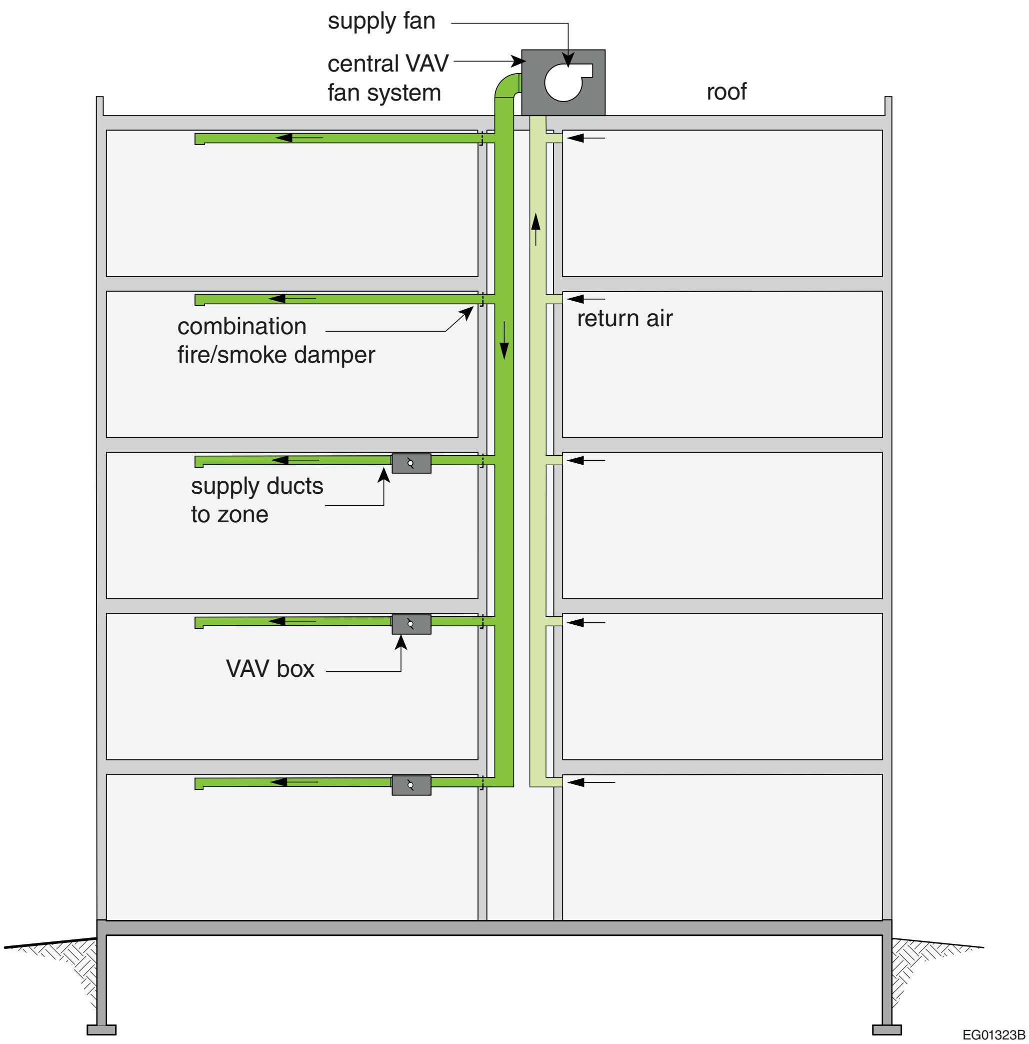


**Figure 5-13**
**Example of airflow control**

## Equipment Efficiency (Subsection 5.2.12.)

28. It is important to note that federal, provincial or territorial regulations may supersede the minimum efficiency requirements stated in NECB Subsection 5.2.12. for unitary and packaged HVAC equipment, including air conditioners, heat pumps, condensers, chillers, boilers and furnaces.

## Heat Rejection Equipment (Article 5.2.12.2.)

29. The NECB performance requirements for heat rejection equipment are aligned with the corresponding requirements stated in ANSI/ASHRAE/IES 90.1, which facilitates design and enforcement in jurisdictions that reference both documents.

30. Example 5-7 illustrates how to determine compliance of a cooling tower with NECB Table 5.2.12.2.

**Example 5-7 – Calculating Cooling Tower Performance**

A direct-contact cooling tower is equipped with two 15 kW centrifugal fans and has a design flow of 112 L/s at rated conditions. The water is 35°C when it enters the cooling tower and 29.4°C when it leaves the cooling tower.

$$\text{Total electrical load } = 2 \times 15\,\text{kW} = 30\,\text{kW}$$

$$\text{Total thermal load} = \mathrm{q} \cdot \mathrm{C_p} \cdot \rho \cdot \Delta_\mathrm{T}$$

where
- $q$ = fluid flow, in L/s,
- $C_p$ = specific heat, in kJ/(kg · °C),
- $\varrho$ = density of fluid, in kg/m³, and
- $\Delta_T$ = temperature difference of water entering versus leaving.

$$\text{Total thermal load} = 112\,\text{L/s} \cdot 4.186\,\text{kJ}/\,(\text{kg} \cdot {}^\circ\text{C}) \cdot 1000\,\text{kg/m}^3 \cdot (35^\circ\text{C} - 29.4^\circ\text{C}) = 2578\,\text{kW}$$

$$\text{Total electrical load/Total thermal load} = 30\,\text{kW}/2578\,\text{kW} = 0.0116$$

The electrical kW/thermal kW of 0.0116 is less than the maximum permitted value of 0.026 listed in NECB Table 5.2.12.2. Therefore, the performance of the cooling tower as designed complies with the NECB.

## Trade-off Path (Section 5.3.)

**31.** NECB Section 5.3. provides the benefit of design flexibility by allowing trade-offs between HVAC components based on the overall efficiency of the entire HVAC system determined from the tables in that Section. The idea behind the trade-off path is that, by taking into account all the losses in a system, it may be possible to reduce the amount of energy that is wasted. Systems with a trade-off index—$\mathrm{HVAC_{TOI}}$ calculated in accordance with NECB Sentence 5.3.2.1.(1)—greater than or equal to zero are deemed to comply with the objectives and functional statements attributed to the requirements in NECB Section 5.2. The trade-off factors by system type listed in NECB Table 5.3.2.2. were developed through the extensive modeling of different building types across Canada. These factors are combined in the trade-off method to develop an overall system efficiency.

**32.** The equations and coefficients given in NECB Section 5.3. were obtained from computer modeling, using sensitivity analysis and quadratic curve fitting. Due to the level of effort that modeling requires, only 27 of the most common HVAC systems were simulated and studied, and subsequently defined (see NECB Table 5.3.1.1.). The trade-off path cannot be used for systems other than these.

**33.** The following equation, reproduced from NECB Article 5.3.2.1., is used to determine HVAC system compliance.

$$\mathrm{HVAC_{TOI}} = \sum_{\mathrm{i}=1}^{32} \left(\alpha_\mathrm{i} \cdot \mathrm{ToV_i} + \beta_\mathrm{i} \cdot \mathrm{ToV_i}^2\right) \cdot \gamma_\mathrm{i} - \sum_{\mathrm{i}=1}^{32} \left(\alpha_\mathrm{i} \cdot \mathrm{BaV_i} + \beta_\mathrm{i} \cdot \mathrm{BaV_i}^2\right) \cdot \gamma_\mathrm{i}$$

**34.** The first summation represents the HVAC system efficiency of the proposed design while the second one represents the system efficiency of the reference design. Factors $\alpha_i$ and $\beta_i$ are weighting factors for component efficiencies within each system, and are calculated as shown in NECB Article 5.3.2.5. $\mathrm{ToV_i}$ and $\mathrm{BaV_i}$ refer to trade-off values for components of the proposed and reference buildings respectively.

**35.** The number of trade-off values is dependent on the complexity of the system. For example, only a few values need to be considered in the calculation for a system including a unit heater—System HVAC-25 of the 27 types. Only the $\gamma_i$ factors that are applicable to the system as indicated in NECB Table 5.3.2.2. are used.

36. A maximum of 32 trade-off values (see NECB Table 5.3.2.3.) are to be considered in the calculation of $HVAC_{TOI}$. These values refer to parameters such as fan efficiencies, coil temperature drop, piping insulation, and fluid flow controls.

37. It should be noted that the trade-off path does take into account climatic considerations by way of the climatic parameter "XDD" (used in the calculation of $\alpha$ and $\beta$). Climatic parameters for system components can be found in NECB Tables 5.3.2.8.-A to 5.3.2.8.-AA.

38. To achieve compliance using the trade-off path, the proposed HVAC system must have all the same components as those listed in NECB Table 5.3.2.2., and all its relevant parameters must be known. The performance of the individual components can vary from that of the reference system as long as the overall performance of the proposed system is equal to or better than that of the reference system.

39. Example 5-8 works through the trade-off calculations for an HVAC system and the implementation of equipment substitutions to render the system compliant with the NECB.

**Example 5-8 – Compliance Trade-off Calculation**

A school in West Vancouver plans to build a small standalone office and would like to reuse some existing HVAC equipment left over from previous HVAC renovations elsewhere on campus. The equipment to be reused is an 88,000 Btu/h gas-fired warm-air furnace with an annual fuel utilization efficiency (AFUE) of 90% (performance requirement as per NECB Table 5.2.12.1. is AFUE ≥ 92.4%) and a 5-ton split DX coil and condenser with a seasonal energy-efficiency ratio (SEER) of 10 (performance requirement as per NECB Table 5.2.12.1. is SEER = 15). Since neither the furnace nor the air conditioner meet the minimum efficiency requirements stated in NECB Table 5.2.12.1., the trade-off path is used to design the office's HVAC system.

The proposed system is a built-up single duct – single zone system (HVAC-4 in NECB Table 5.3.1.1.-A). Using NECB Tables 5.3.2.2. and 5.3.2.3., the designer determines that the following component factors, $\gamma_i$, and component trade-off values, $ToV_i$, are to be considered:

| Component Factor, $\gamma_i$ | Trade-off Value, $ToV_i$ | Description |
|---|---|---|
| 1 | $ToV_1$ | Supply fan mechanical efficiency |
| 1 | $ToV_2$ | Supply motor efficiency |
| 1 | $ToV_3$ | Return fan mechanical efficiency |
| 1 | $ToV_4$ | Return fan motor efficiency |
| 0 | $ToV_5$ | Supply temperature control |
| 0 | $ToV_6$ | Airflow control efficiency |
| 1 | $ToV_7$ | Supply fan total static pressure |
| 1 | $ToV_8$ | Supply duct insulation |
| 1 | $ToV_9$ | Return fan total static pressure |
| 1 | $ToV_{10}$ | Heating coil design temperature drop |
| 1 | $ToV_{12}$ | Boiler/furnace/heat pump heating efficiency |
| 1 | $ToV_{13}$ | Chillers/direct expansion system/heat pump cooling efficiency |
| 1 | $ToV_{14}$ | Rejection fan input power ratio |
| 1 | $ToV_{15}$ | Cooling by direct use of outdoor air (air economizer) |
| 1 | $ToV_{16}$ | Outdoor airflow control |
| 1 | $ToV_{17}$ | Exhaust air heat-recovery efficiency |

**Example 5-8 – Compliance Trade-off Calculation (Continued)**

The coefficient and base values and climatic parameters for these component trade-off values are then mapped out for the initial and final designs as shown in Tables 5-1 and 5-2, where

- $ToV_i$ is the trade-off value of component “i” for the proposed building based on design data and NECB Table 5.3.2.7.,
- $BaV_i$ is the base value of component “i” for the reference building taken from NECB Table 5.3.2.4.,
- $XDD_i$ is the climatic parameter determined in accordance with NECB Article 5.3.2.6., Tables 5.3.2.8.-A to 5.3.2.8.-AA (Table 5.3.2.8.-D applies in this Example), and Note A-8.4.2.3. for the determination of cooling degree-days (CDD),
- $\alpha1_i$, $\alpha2_i$ and $\alpha3_i$ are taken from NECB Table 5.3.2.8.-D,
- $\alpha_i$ is calculated in accordance with NECB Sentence 5.3.2.5.(1),
- $\beta1_i$, $\beta2_i$ and $\beta3_i$ are taken from NECB Table 5.3.2.8.-D, and
- $\beta_i$ is calculated in accordance with NECB Sentence 5.3.2.5.(2).

See Table 5-1 for the initial design iteration calculations.

Given that the system is designed with the minimum base values from NECB Tables 5.3.2.4. and 5.3.2.7., the furnace AFUE is 90% and the AC COP is 2.70, which result in an HVAC trade-off index ($HVAC_{TOI}$) of −0.0473. Since the trade-off index is less than 0, the system as designed is non-compliant.

By careful design of the supply ducting, $ToV_7$, supply fan total static pressure, can be reduced from the base value of 500 Pa to 348.4 Pa. The HVAC trade-off value is calculated to be −0.0102, which is still not enough to make the system compliant. The design of the return ducting can also be slightly improved so that $ToV_9$, return fan total static pressure, is reduced from its base value of 150 Pa to 135 Pa. This still only changes the HVAC trade-off value to −0.003 so another improvement is still required. The designer decides to install an HRV with an effectiveness of 0.50 and to increase the RSI of the supply duct insulation to 0.881.

See Table 5-2 for the revised design iteration calculations.

The resulting HVAC trade-off index is now calculated to be 0.032. The final HVAC system with the more efficient supply fan, return duct, HRV and supply duct is now compliant via the trade-off method.

**Table 5-1**
**Initial Design Iteration Calculations**

| Trade-off Value, $ToV_i$ | Units | $ToV_i$ | $BaV_i$ | $XDD_i$ | $\alpha 1_i$ | $\alpha 2_i$ | $\alpha 3_i$ | $\alpha_i$ | $\beta 1_i$ | $\beta 2_i$ | $\beta 3_i$ | $\beta_i$ | Proposed | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $ToV_1$ | % | 0.5455 | 0.5455 | 2950 | 1.96E+00 | −4.26E−04 | 2.47E−08 | 9.1825E−01 | −1.22E+00 | 2.62E−04 | −1.51E−08 | −5.7851E−01 | 3.2876E−01 | 3.2876E−01 |
| $ToV_2$ | % | 0.9167 | 0.9167 | 2950 | 1.22E+00 | −2.65E−04 | 1.52E−08 | 5.7053E−01 | −4.94E−01 | 1.06E−04 | −6.01E−09 | −2.3360E−01 | 3.2670E−01 | 3.2670E−01 |
| $ToV_3$ | % | 0.3125 | 0.3125 | 3170 | 9.52E−01 | −1.50E−04 | 6.63E−09 | 5.4312E−01 | −6.44E−01 | 1.01E−04 | −4.49E−09 | −3.6895E−01 | 1.3370E−01 | 1.3370E−01 |
| $ToV_4$ | % | 0.8 | 0.8 | 3170 | 5.93E−01 | −9.20E−05 | 3.92E−09 | 3.4075E−01 | −2.64E−01 | 4.03E−05 | −1.66E−09 | −1.5293E−01 | 1.7473E−01 | 1.7473E−01 |
| $ToV_5$ | ratio | 0 | 0 | 3170 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| $ToV_6$ | ratio | 0.6045 | 0.6045 | 3170 | 1.45E−01 | −2.80E−05 | 1.47E−09 | 7.1012E−02 | −1.89E−01 | 3.66E−05 | −1.93E−09 | −9.2372E−02 | 0.0000E+00 | 0.0000E+00 |
| $ToV_7$ | Pa | 500 | 500 | 2950 | −5.20E−04 | 1.23E−07 | −7.55E−12 | −2.2285E−04 | −3.22E−08 | 1.37E−12 | 1.90E−16 | −2.6505E−08 | −1.1805E−01 | −1.1805E−01 |
| $ToV_8$ | RSI-value | 0.58 | 0.58 | 2950 | 1.25E−01 | −1.43E−05 | −2.88E−12 | 8.2790E−02 | −2.47E−02 | −7.71E−07 | 4.40E−10 | −2.3145E−02 | 4.0230E−02 | 4.0230E−02 |
| $ToV_9$ | Pa | 150 | 150 | 3170 | −8.08E−04 | 1.30E−07 | −5.76E−12 | −4.5378E−04 | −1.65E−07 | −3.84E−11 | −2.66E−15 | −7.0002E−08 | −6.9642E−02 | −6.9642E−02 |
| $ToV_{10}$ | °C | 11.11 | 11.11 | 2950 | 4.17E−03 | −1.21E−06 | 1.11E−10 | 1.5665E−03 | −1.07E−04 | 3.11E−08 | −2.86E−12 | −4.0144E−05 | 1.2448E−02 | 1.2448E−02 |
| $ToV_{11}$ | °C | 11.11 | 11.11 | 2950 | 2.50E−02 | −4.81E−06 | 3.64E−10 | 1.3978E−02 | −5.86E−04 | 1.13E−07 | −8.55E−12 | −3.2706E−04 | 1.1493E−01 | 1.1493E−01 |
| $ToV_{12}$ | % | 0.9 | 0.924 | 2950 | 2.03E−01 | 1.44E−04 | −6.33E−09 | 5.7271E−01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 5.1544E−01 | 5.2919E−01 |
| $ToV_{13}$ | COP | 2.7 | 3.61 | 220 | −3.72E−04 | 3.65E−04 | −3.79E−07 | 6.1584E−02 | 7.62E−05 | −2.35E−05 | 2.45E−08 | −3.9080E−03 | 1.3779E−01 | 1.7139E−01 |
| $ToV_{14}$ | W/W | 0.015 | 0.015 | 220 | −1.75E−02 | −4.68E−04 | 1.38E−07 | −1.1378E−01 | 3.57E−01 | −3.46E−03 | 3.24E−06 | −2.4738E−01 | −1.7624E−03 | −1.7624E−03 |
| $ToV_{15}$ | ratio | 0.8 | 0.8 | 220 | 5.37E−01 | 9.57E−03 | −1.46E−05 | 1.9358E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 1.5486E+00 | 1.5486E+00 |
| $ToV_{16}$ | ratio | 0.8 | 0.8 | 2950 | −8.07E−01 | 7.24E−04 | −4.42E−08 | 9.4415E−01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 7.5532E−01 | 7.5532E−01 |
| $ToV_{17}$ | % | 0 | 0 | 3170 | 6.64E−02 | −1.34E−05 | 1.66E−09 | 4.0603E−02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{18}$ | % | 0 | 0 | 3170 | 9.92E−03 | −1.91E−06 | 9.13E−11 | 4.7828E−03 | −6.57E−03 | 1.26E−06 | −6.04E−11 | −3.1828E−03 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{19}$ | RSI-value | 0.8806 | 0.8806 | 2950 | 6.99E−01 | −1.96E−04 | 1.44E−08 | 2.4612E−01 | −3.26E−01 | 1.04E−04 | −7.90E−09 | −8.7950E−02 | 1.4853E−01 | 1.4853E−01 |
| $ToV_{20}$ | RSI-value | 0.8806 | 0.8806 | 220 | −2.14E−04 | 1.36E−04 | −1.72E−07 | 2.1381E−02 | 6.40E−04 | −4.28E−05 | 4.91E−08 | −6.3996E−03 | 1.3866E−02 | 1.3866E−02 |
| $ToV_{21}$ | kPa | 179.344 | 179.344 | 2950 | −2.76E−04 | 3.66E−08 | −3.06E−12 | −1.9466E−04 | −1.23E−07 | 5.29E−11 | −4.17E−15 | −3.2344E−09 | −3.5015E−02 | −3.5015E−02 |
| $ToV_{22}$ | kPa | 119.5627 | 119.5627 | 220 | −8.96E−05 | −2.17E−06 | 2.63E−09 | −4.3971E−04 | 2.27E−07 | 1.14E−11 | 2.19E−13 | 2.4011E−07 | −4.9140E−02 | −4.9140E−02 |
| $ToV_{23}$ | % | 0.6 | 0.6 | 2950 | 2.54E−01 | −3.65E−05 | 3.03E−09 | 1.7269E−01 | −1.31E−01 | 1.69E−05 | −1.41E−09 | −9.3416E−02 | 6.9987E−02 | 6.9987E−02 |
| $ToV_{24}$ | % | 0.6 | 0.6 | 220 | −7.24E−02 | 3.93E−03 | −4.96E−06 | 5.5214E−01 | 6.84E−02 | −2.81E−03 | 3.51E−06 | −3.7992E−01 | 1.9451E−01 | 1.9451E−01 |
| $ToV_{25}$ | % | 0.9 | 0.9 | 2950 | 2.29E−01 | −4.23E−05 | 3.50E−09 | 1.3467E−01 | −9.04E−02 | 1.73E−05 | −1.44E−09 | −5.1897E−02 | 7.9170E−02 | 7.9170E−02 |
| $ToV_{26}$ | % | 0.9 | 0.9 | 220 | 1.13E−02 | 4.38E−04 | −5.40E−07 | 8.1524E−02 | −4.72E−03 | −1.63E−04 | 2.02E−07 | −3.0803E−02 | 4.8421E−02 | 4.8421E−02 |
| $ToV_{27}$ | ratio | 0 | 0 | 2950 | 2.48E+00 | −3.87E−04 | 1.81E−08 | 1.4959E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{28}$ | ratio | 0 | 0 | 220 | 1.26E+00 | −9.94E−04 | 3.00E−07 | 1.0558E+00 | 5.61E+00 | −3.48E−02 | 3.95E−05 | −1.3420E−01 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{29}$ | ratio | 0 | 0 | 2950 | 3.37E+00 | −7.24E−04 | 4.69E−08 | 1.6423E+00 | −5.72E−01 | −6.24E−05 | 2.91E−08 | −5.0284E−01 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{30}$ | ratio | 0 | 0 | 220 | 1.62E−01 | 5.56E−03 | −6.80E−06 | 1.0561E+00 | 1.28E+00 | −4.47E−02 | 9.89E−05 | −3.7672E+00 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{31}$ | ratio | 0 | 0 | 2950 | 2.11E+00 | −3.94E−04 | 3.11E−08 | 1.2183E+00 | −5.81E+00 | 1.86E−03 | −1.29E−07 | −1.4456E+00 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{32}$ | ratio | 0 | 0 | 220 | 2.56E−01 | 4.23E−03 | −4.31E−06 | 9.7800E−01 | −1.81E+00 | 1.98E−02 | −3.36E−05 | 9.1976E−01 | 0.0000E+00 | 0.0000E+00 |

**Table 5-2**
**Revised Design Iteration Calculations**

| Trade-off Value, $ToV_i$ | Units | $ToV_i$ | $BaV_i$ | $XDD_i$ | $\alpha1_i$ | $\alpha2_i$ | $\alpha3_i$ | $\alpha_i$ | $\beta1_i$ | $\beta2_i$ | $\beta3_i$ | $\beta_i$ | Proposed | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $ToV_1$ | % | 0.5455 | 0.5455 | 2950 | 1.96E+00 | −4.26E−04 | 2.47E−08 | 9.1825E−01 | −1.22E+00 | 2.62E−04 | −1.51E−08 | −5.7851E−01 | 3.2876E−01 | 3.2876E−01 |
| $ToV_2$ | % | 0.9167 | 0.9167 | 2950 | 1.22E+00 | −2.65E−04 | 1.52E−08 | 5.7053E−01 | −4.94E−01 | 1.06E−04 | −6.01E−09 | −2.3360E−01 | 3.2670E−01 | 3.2670E−01 |
| $ToV_3$ | % | 0.3125 | 0.3125 | 3170 | 9.52E−01 | −1.50E−04 | 6.63E−09 | 5.4312E−01 | −6.44E−01 | 1.01E−04 | −4.49E−09 | −3.6895E−01 | 1.3370E−01 | 1.3370E−01 |
| $ToV_4$ | % | 0.8 | 0.8 | 3170 | 5.93E−01 | −9.20E−05 | 3.92E−09 | 3.4075E−01 | −2.64E−01 | 4.03E−05 | −1.66E−09 | −1.5293E−01 | 1.7473E−01 | 1.7473E−01 |
| $ToV_5$ | ratio | 0 | 0 | 3170 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| $ToV_6$ | ratio | 0.6045 | 0.6045 | 3170 | 1.45E−01 | −2.80E−05 | 1.47E−09 | 7.1012E−02 | −1.89E−01 | 3.66E−05 | −1.93E−09 | −9.2372E−02 | 0.0000E+00 | 0.0000E+00 |
| $ToV_7$ | Pa | 348.4 | 500 | 2950 | −5.20E−04 | 1.23E−07 | −7.55E−12 | −2.2285E−04 | −3.22E−08 | 1.37E−12 | 1.90E−16 | −2.6505E−08 | −8.0860E−02 | −1.1805E−01 |
| $ToV_8$ | RSI-value | 0.88 | 0.58 | 2950 | 1.25E−01 | −1.43E−05 | −2.88E−12 | 8.2790E−02 | −2.47E−02 | −7.71E−07 | 4.40E−10 | −2.3145E−02 | 5.4973E−02 | 4.0230E−02 |
| $ToV_9$ | Pa | 135 | 150 | 3170 | −8.08E−04 | 1.30E−07 | −5.76E−12 | −4.5378E−04 | −1.65E−07 | 3.84E−11 | −2.66E−15 | −7.0002E−08 | −6.2536E−02 | −6.9642E−02 |
| $ToV_{10}$ | °C | 11.11 | 11.11 | 2950 | 4.17E−03 | −1.21E−06 | 1.11E−10 | 1.5665E−03 | −1.07E−04 | 3.11E−08 | −2.86E−12 | −4.0144E−05 | 1.2448E−02 | 1.2448E−02 |
| $ToV_{11}$ | °C | 11.11 | 11.11 | 2950 | 2.50E−02 | −4.81E−06 | 3.64E−10 | 1.3978E−02 | −5.86E−04 | 1.13E−07 | −8.55E−12 | −3.2706E−04 | 1.1493E−01 | 1.1493E−01 |
| $ToV_{12}$ | % | 0.9 | 0.924 | 2950 | 2.03E−01 | 1.44E−04 | −6.33E−09 | 5.7271E−01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 5.1544E−01 | 5.2919E−01 |
| $ToV_{13}$ | COP | 2.7 | 3.61 | 220 | −3.72E−04 | 3.65E−04 | −3.79E−07 | 6.1584E−02 | 7.62E−05 | −2.35E−05 | 2.45E−08 | −3.9080E−03 | 1.3779E−01 | 1.7139E−01 |
| $ToV_{14}$ | W/W | 0.015 | 0.015 | 220 | −1.75E−02 | −4.68E−04 | 1.38E−07 | −1.1378E−01 | 3.57E−01 | −3.46E−03 | 3.24E−06 | −2.4738E−01 | −1.7624E−03 | −1.7624E−03 |
| $ToV_{15}$ | ratio | 0.8 | 0.8 | 220 | 5.37E−01 | 9.57E−03 | −1.46E−05 | 1.9358E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 1.5486E+00 | 1.5486E+00 |
| $ToV_{16}$ | ratio | 0.8 | 0.8 | 2950 | −8.07E−01 | 7.24E−04 | −4.42E−08 | 9.4415E−01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 7.5532E−01 | 7.5532E−01 |
| $ToV_{17}$ | % | 0.5 | 0 | 3170 | 6.64E−02 | −1.34E−05 | 1.66E−09 | 4.0603E−02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 2.0302E−02 | 0.0000E+00 |
| $ToV_{18}$ | % | 0 | 0 | 3170 | 9.92E−03 | −1.91E−06 | 9.13E−11 | 4.7828E−03 | −6.57E−03 | 1.26E−06 | −6.04E−11 | −3.1828E−03 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{19}$ | RSI-value | 0.8806 | 0.8806 | 2950 | 6.99E−01 | −1.96E−04 | 1.44E−08 | 2.4612E−01 | −3.26E−01 | 1.04E−04 | −7.90E−09 | −8.7950E−02 | 1.4853E−01 | 1.4853E−01 |
| $ToV_{20}$ | RSI-value | 0.8806 | 0.8806 | 220 | −2.14E−04 | 1.36E−04 | −1.72E−07 | 2.1381E−02 | 6.40E−04 | −4.28E−05 | 4.91E−08 | −6.3996E−03 | 1.3866E−02 | 1.3866E−02 |
| $ToV_{21}$ | kPa | 179.344 | 179.344 | 2950 | −2.76E−04 | 3.66E−08 | −3.06E−12 | −1.9466E−04 | −1.23E−07 | 5.29E−11 | −4.17E−15 | −3.2344E−09 | −3.5015E−02 | −3.5015E−02 |
| $ToV_{22}$ | kPa | 119.5627 | 119.5627 | 220 | −8.96E−05 | −2.17E−06 | 2.63E−09 | −4.3971E−04 | 2.27E−07 | 1.14E−11 | 2.19E−13 | 2.4011E−07 | −4.9140E−02 | −4.9140E−02 |
| $ToV_{23}$ | % | 0.6 | 0.6 | 2950 | 2.54E−01 | −3.65E−05 | 3.03E−09 | 1.7269E−01 | −1.31E−01 | 1.69E−05 | −1.41E−09 | −9.3416E−02 | 6.9987E−02 | 6.9987E−02 |
| $ToV_{24}$ | % | 0.6 | 0.6 | 220 | −7.24E−02 | 3.93E−03 | −4.96E−06 | 5.5214E−01 | 6.84E−02 | −2.81E−03 | 3.51E−06 | −3.7992E−01 | 1.9451E−01 | 1.9451E−01 |
| $ToV_{25}$ | % | 0.9 | 0.9 | 2950 | 2.29E−01 | −4.23E−05 | 3.50E−09 | 1.3467E−01 | −9.04E−02 | 1.73E−05 | −1.44E−09 | −5.1897E−02 | 7.9170E−02 | 7.9170E−02 |
| $ToV_{26}$ | % | 0.9 | 0.9 | 220 | 1.13E−02 | 4.38E−04 | −5.40E−07 | 8.1524E−02 | −4.72E−03 | −1.63E−04 | 2.02E−07 | −3.0803E−02 | 4.8421E−02 | 4.8421E−02 |
| $ToV_{27}$ | ratio | 0 | 0 | 2950 | 2.48E+00 | −3.87E−04 | 1.81E−08 | 1.4959E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{28}$ | ratio | 0 | 0 | 220 | 1.26E+00 | −9.94E−04 | 3.00E−07 | 1.0558E+00 | 5.61E+00 | −3.48E−02 | 3.95E−05 | −1.3420E−01 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{29}$ | ratio | 0 | 0 | 2950 | 3.37E+00 | −7.24E−04 | 4.69E−08 | 1.6423E+00 | −5.72E−01 | −6.24E−05 | 2.91E−08 | −5.0284E−01 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{30}$ | ratio | 0 | 0 | 220 | 1.62E−01 | 5.56E−03 | −6.80E−06 | 1.0561E+00 | 1.28E+00 | −4.47E−02 | 9.89E−05 | −3.7672E+00 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{31}$ | ratio | 0 | 0 | 2950 | 2.11E+00 | −3.94E−04 | 3.11E−08 | 1.2183E+00 | −5.81E+00 | 1.86E−03 | −1.29E−07 | −1.4456E+00 | 0.0000E+00 | 0.0000E+00 |
| $ToV_{32}$ | ratio | 0 | 0 | 220 | 2.56E−01 | 4.23E−03 | −4.31E−06 | 9.7800E−01 | −1.81E+00 | 1.98E−02 | −3.36E−05 | 9.1976E−01 | 0.0000E+00 | 0.0000E+00 |

# Commentary on Part 6

# Service Water Systems

1. Except where noted otherwise in the NECB, mechanical equipment, systems and controls installed to meet a new building's service water requirements must comply with the requirements of NECB Part 6. This Commentary provides additional information on the means of achieving these requirements.

2. See the flow chart in NECB Figure A-6.1.1.3.(1), which shows the three compliance paths applicable to service water systems.

## Combination Service Water Heating and Space-Heating Equipment (Article 6.2.2.4.)

3. Figure 6-1 shows an example of a typical configuration of a boiler system that provides both service water heating and space heating.

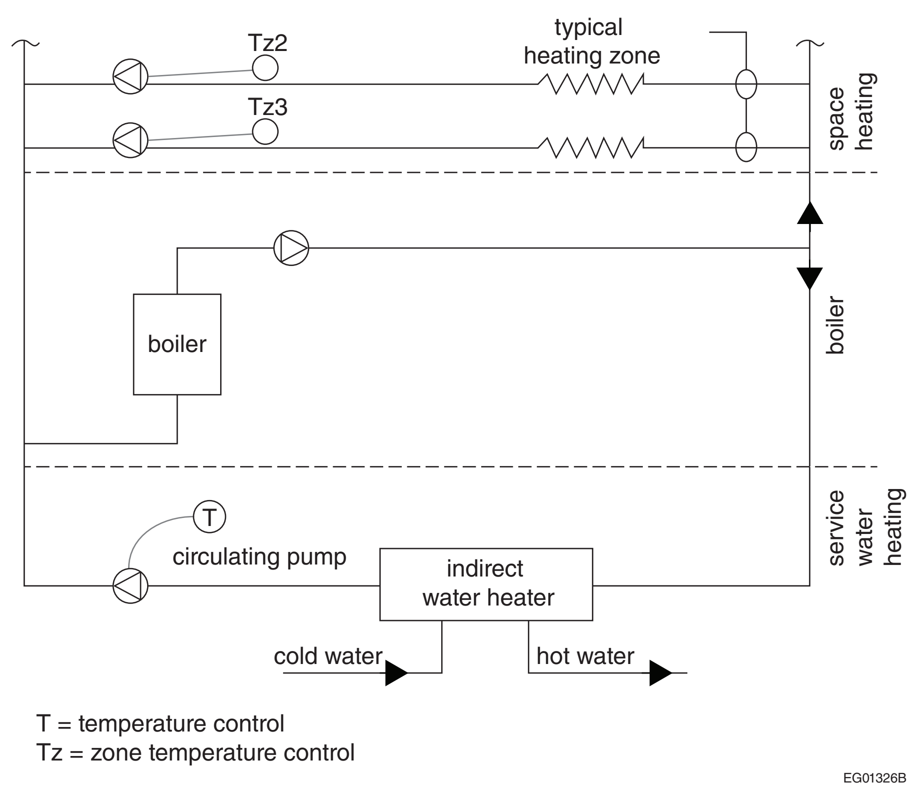


**Figure 6-1**
**Example of typical configuration of combination space- and water-heating system**

## Piping Insulation (Article 6.2.3.1.)

**4.** Figure 6-2 shows an example of service hot water piping that is required to be insulated in conformance with the requirements of NECB Article 6.2.3.1.

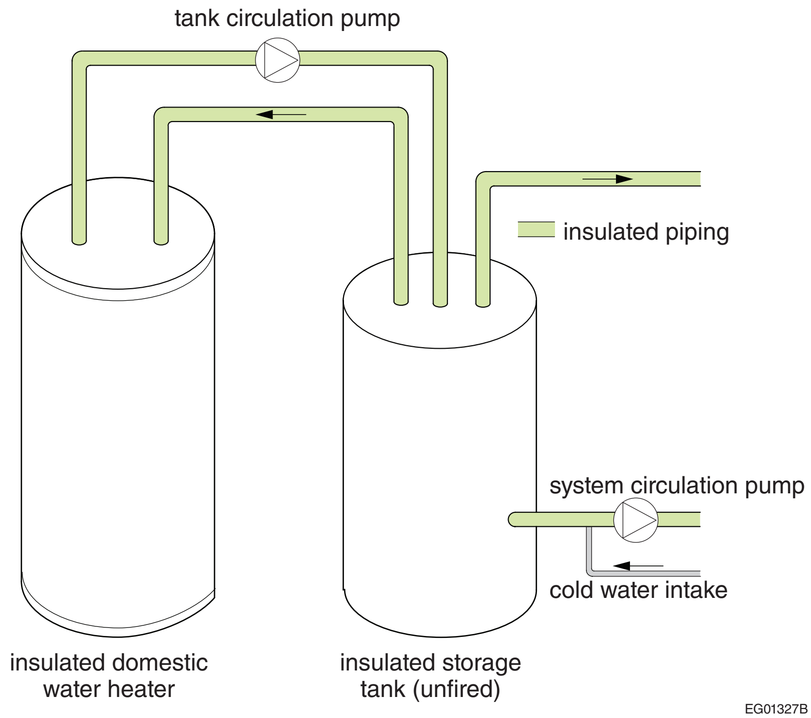


**Figure 6-2**
**Example of service water heating piping sections required to be insulated**

## Remote or Booster Heaters (Article 6.2.5.1.)

**5.** To reduce heat loss in applications where service water must be delivered at 60°C or higher—such as in dishwashers and other process cycles—separate local booster heaters must be installed to accommodate these high-temperature loads. Figure 6-3 shows a schematic of a dual-temperature service water heater with a booster heater.

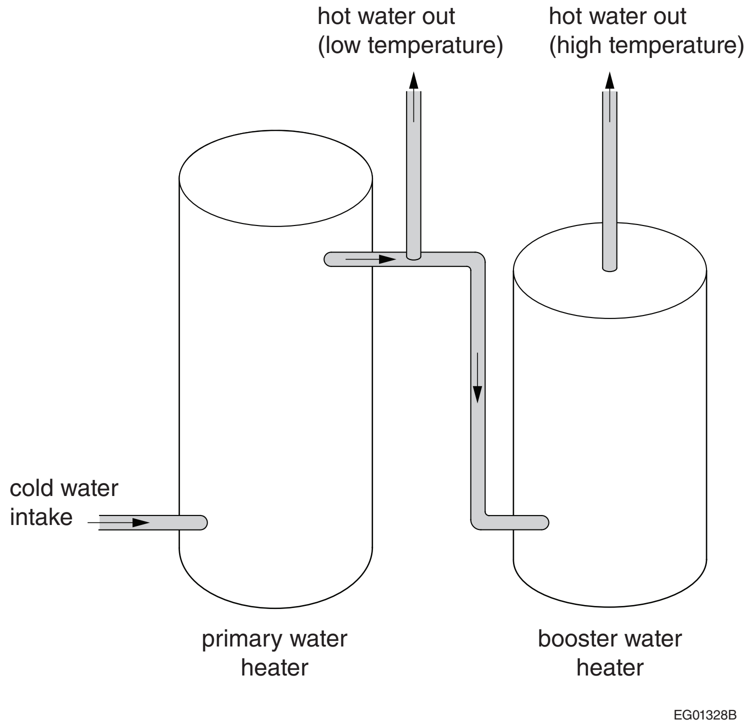


**Figure 6-3**
**Example of primary heater and booster heater configuration**

## Maximum Water Flow Rates for Showers and Lavatories (Articles 6.2.6.1. and 6.2.6.2.)

**6.** Installing water fixtures with low flow rates is an easy and inexpensive measure for reducing energy consumption in a building. It is particularly effective in buildings with high water usage such as residential and recreational buildings.

**7.** The maximum flow rates stated in the NECB are in line with guidelines and standards used across Canada (e.g., ASME A112.18.1/CSA B125.1, "Plumbing Supply Fittings") and can be met by many readily available products that do not affect the experience or effectiveness of handwashing and showering.

**8.** Note that the National Plumbing Code of Canada also includes requirements on maximum flow rates.

## Pressure Booster System (Subsection 6.2.8.)

**9.** The NECB requirements on pressure booster systems are aligned with the corresponding requirements stated in ANSI/ASHRAE/IES 90.1, which facilitates design and enforcement in jurisdictions that reference both documents.

**10.** Variable-speed pressure booster systems deliver the pumping power required at any given time. As demand decreases, a pressure sensor registers an increase in line pressure and the pump output is reduced accordingly. The expansion tank helps minimize potential pressure damage to the plumbing system. See Figure 6-4.

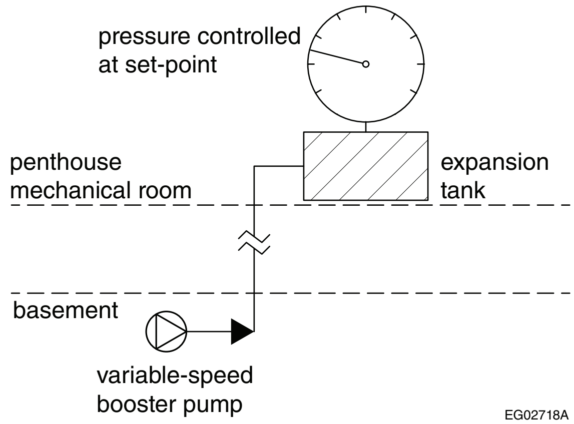


**Figure 6-4**
**Schematic layout of a variable-speed pressure booster system**

**11.** In contrast to variable-speed pressure booster systems, constant-speed pressure booster systems cycle as required to meet demand. A pressure switch in the expansion tank activates the pumps when the pressure drops below a certain set level (referred to as “cut-in pressure”) until the system pressure reaches a certain set level (referred to as “high cut-out pressure”), which means that the pumps are always providing higher-than-design pressure. The expansion tank provides draw-down volume so it must be sized generously to prevent frequent pump cycling. See Figure 6-5.

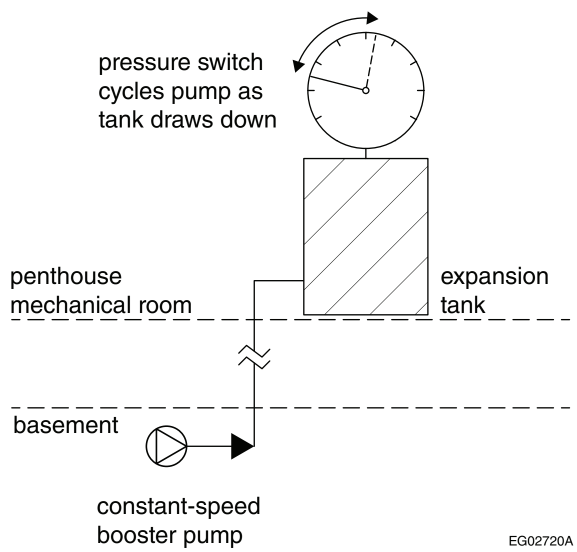


**Figure 6-5**
**Schematic layout of constant speed booster pump system**

## Trade-off Path (Section 6.3.)

**12.** Similar to the NECB Part 5 trade off path, the NECB Part 6 trade off path is based on the overall efficiency of the entire service water heating (SWH) system. The trade off path covers three types of SWH system: a service water heater with a tank, an instantaneous or tankless service water heater, and a system fed from a space-heating boiler through a heat exchanger. A trade-off index (TOI) is calculated for each type of SWH system in accordance with NECB Sentence 6.3.2.1.(1), (2) or (3), respectively. All three TOI equations are similar with the right side representing the reference design and the left side representing the proposed design. A proposed system design with a TOI greater than or equal to 0 is considered NECB compliant.

**Example 6-1 – Compliance Trade-off Calculation**

Developers plan to build a small multi-purpose assembly hall in a slightly remote area. The proposed service water heating design includes a natural-gas-fired storage-type service water heater with an input capacity of 125 kW, a volumetric capacity of 35 L, and no heat recovery. The designer decides not to install any form of automatic shut-off for the lavatories, which means that the proposed SWH tank system (SWH-1) does not meet the prescriptive requirements in NECB Section 6.2. The designer therefore opts to use the trade-off path to achieve compliance.

The trade-off parameters of the proposed design have the following values:

| Trade-off Parameters | Description | Units | $ToV_i$ |
|---|---|---|---|
| $ToV_1$ | Service water heating equipment efficiency | % | 75 |
| $ToV_2$ | Tank insulation value | RSI-value | 3.52 |
| $ToV_3$ | Piping insulation value | RSI-value | 1.76 |
| $ToV_4$ | Pump motor efficiency | % | 80 |
| $ToV_5$ | Pump efficiency | % | 60 |
| $ToV_6$ | Heat recovery ratio | kW/kW | 0 |
| $ToV_7$ | Average flow of all faucets | L/min | 9.8 |
| $ToV_8$ | Average flow of all showers | L/min | 9.8 |
| $ToV_9$ | Faucet flow ratio | fraction | 0.7 |
| $ToV_{10}$ | Shower flow ratio | fraction | 0.3 |

The other variables in the equation to calculate SWH-TOI for SWH-1 have the following values:

PDR = 1.56, as calculated in accordance with NECB Article 6.3.2.2. using an AFOU value of 18.9 L/min:

$$\text{PDR} = \frac{(9.8 \cdot 0.7) + (9.8 \cdot 0.3) + [18.9 \cdot (1 - 0.7 - 0.3)]}{(5.7 \cdot 0.7) + (7.6 \cdot 0.3) + [18.9 \cdot (1 - 0.7 - 0.3)]} = 1.56$$

$A_{norm}$ = 0.76, as calculated in accordance with NECB Article 6.3.2.3. using a $D_{norm}$ value of 0.21 calculated in accordance with NECB Article 6.3.2.4.:

$$D_{norm} = 0.63384 \cdot \left(35\ \text{L} \cdot \frac{1\ \text{m}^3}{1000\ \text{L}}\right)^{1/3} = 0.21$$

$$A_{norm} = 5.5 \cdot \pi \cdot (0.21)^2 = 0.76$$

$\eta_{ref}$ = 0.80, as determined in accordance with NECB Article 6.3.2.6.

**Example 6-1 – Compliance Trade-off Calculation (Continued)**

SWH-TOI is then calculated using the equation in NECB Sentence 6.3.2.1.(1) as follows:

$$\text{SWH-TOI} = 2.813 \cdot \left\{ \frac{2.813 \cdot 1.56}{0.75} \cdot \left\{1 - 0.6514 \cdot 0 \cdot e^{-0.312 \cdot 0}\right\} + 0.11667 \cdot \left( \frac{0.76}{3.52} + \frac{2.4322}{1.76} \right) + \frac{0.00677}{0.80 \cdot 0.60} \right\}^{-1} - 2.813 \cdot \left\{ \frac{2.813}{0.80} + 0.11667 \cdot \left( \frac{0.76}{2.222} + 3.3515 \right) + 0.0141 \right\}^{-1}$$

As designed, the service water heating system's SWH-TOI is −0.245, which is less than 0, so the system is therefore deemed to be non-compliant.

The designer replaces the service water heater with one that has a thermal efficiency of 82% and the faucets and showers with low-flow fixtures. The trade-off parameters of the revised proposed design have the following values:

| Trade-off Parameters | Description | Units | $ToV_i$ |
|---|---|---|---|
| $ToV_1$ | Service water heating equipment efficiency | % | 82 |
| $ToV_2$ | Tank insulation value | RSI-value | 3.52 |
| $ToV_3$ | Piping insulation value | RSI-value | 1.76 |
| $ToV_4$ | Pump motor efficiency | % | 80 |
| $ToV_5$ | Pump efficiency | % | 60 |
| $ToV_6$ | Heat recovery ratio | kW/kW | 0 |
| $ToV_7$ | Average flow of all faucets | L/min | 5.7 |
| $ToV_8$ | Average flow of all showers | L/min | 7 |
| $ToV_9$ | Faucet flow ratio | fraction | 0.7 |
| $ToV_{10}$ | Shower flow ratio | fraction | 0.3 |

With the low-flow fixtures, the PDR is now 0.97:

$$\text{PDR} = \frac{(5.7 \cdot 0.7) + (7 \cdot 0.3) + [18.9 \cdot (1 - 0.7 - 0.3)]}{(5.7 \cdot 0.7) + (7.6 \cdot 0.3) + [18.9 \cdot (1 - 0.7 - 0.3)]} = 0.97$$

SWH-TOI is then calculated using the revised PDR and $ToV_1$ value:

$$\text{SWH-TOI} = 2.813 \cdot \left\{ \frac{2.813 \cdot 0.97}{0.82} \cdot \left\{1 - 0.6514 \cdot 0 \cdot e^{-0.312 \cdot 0}\right\} + 0.11667 \cdot \left( \frac{0.76}{3.52} + \frac{2.4322}{1.76} \right) + \frac{0.00677}{0.80 \cdot 0.60} \right\}^{-1} - 2.813 \cdot \left\{ \frac{2.813}{0.8} + 0.11667 \cdot \left( \frac{0.76}{2.222} + 3.3515 \right) + 0.0141 \right\}^{-1}$$

With the three improvements, the SWH-TOI is now 0.088, which is greater than 0. The SWH system is therefore now compliant via the trade-off method.

# Commentary on Part 7

# Electrical Power Systems and Motors

## Scope (Article 7.1.1.1.)

**1.** NECB Part 7 applies to electrical power systems, transformers and motors connected to the building's electrical service and addresses the means for monitoring electrical distribution systems larger than 250 kVA, voltage drops in feeders and branch circuits.

## Compliance (Article 7.1.1.3.)

**2.** See the flow chart in NECB Figure A-7.1.1.3.(1) for the two compliance paths applicable to electrical power systems and motors.

## Monitoring (Article 7.2.1.1.)

**3.** The monitoring of electrical energy consumption is considered essential to energy management. The NECB requires that a means for monitoring electrical distribution systems larger than 250 kVA be installed. Typical compliance approaches are to design the distribution layout to include enough space to install equipment, such as meter sockets or clamp-on current transformers. Figure 7-1 shows the location of future meter sockets to monitor the interior lighting and HVAC panels.

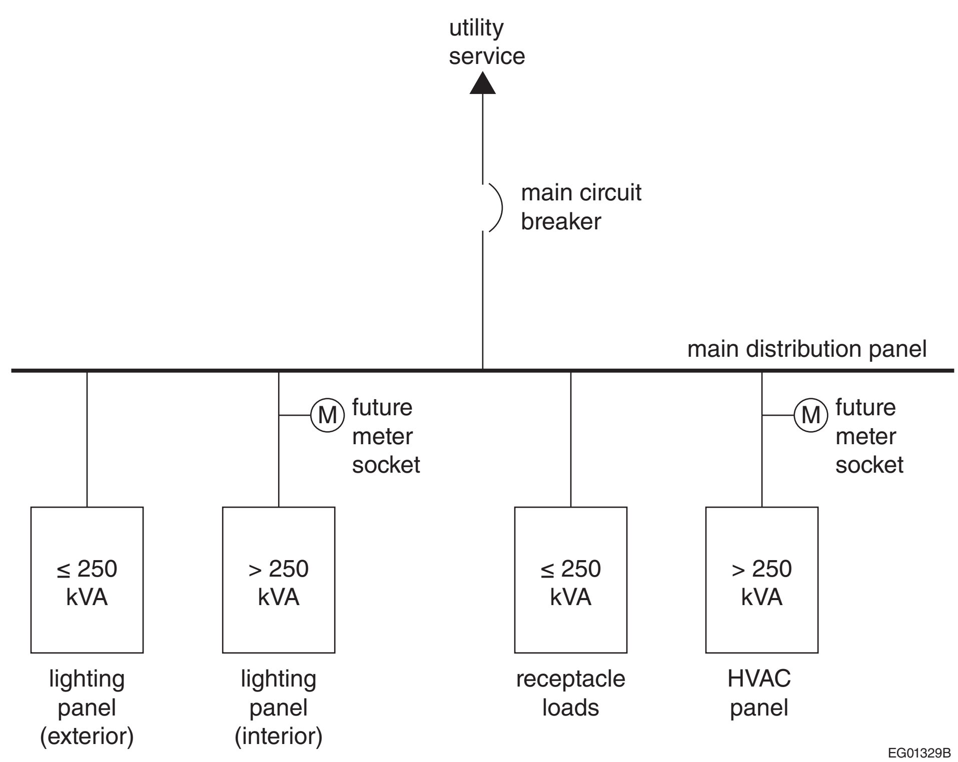


**Figure 7-1**
**Example of electrical distribution system**

## Voltage Drop (Subsection 7.2.2.)

4. Feeder conductors run between the service entrance equipment (where the power enters the building) and the branch circuit distribution equipment (e.g., circuit breaker). A maximum voltage drop of 2% is allowed in the feeder conductor.

5. Branch circuit conductors run from the final circuit breaker to the outlet or load. A maximum voltage drop of 3% is allowed in the branch circuit conductor.

6. Figure 7-2 shows the permissible voltage drops in feeder and branch circuit conductors.

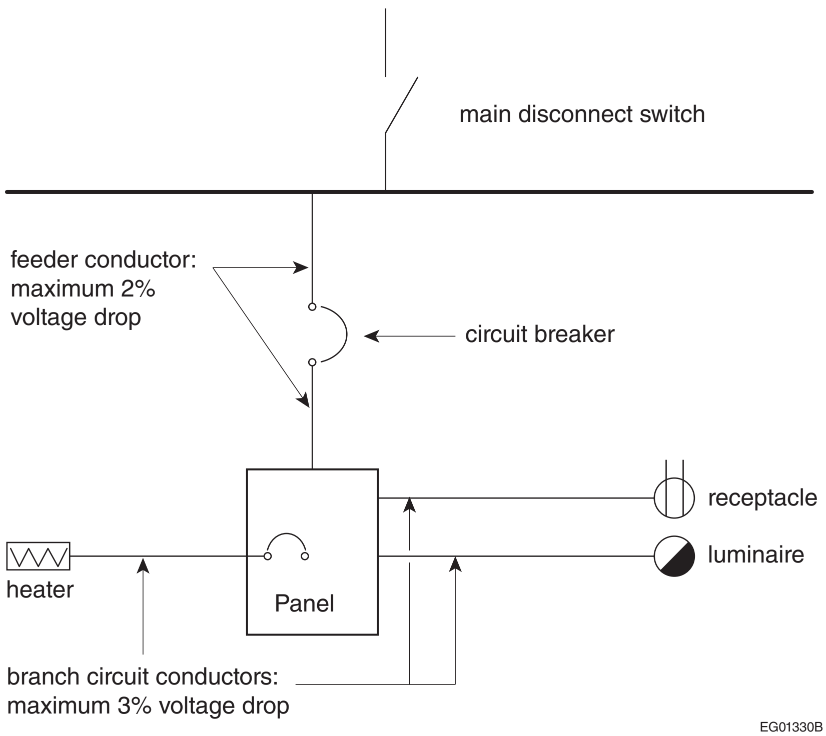


**Figure 7-2**
**Permissible voltage drops in feeder and branch circuit conductors**

**Example 7-1 – Example of Voltage Drop Calculation**

A designer wants to calculate the voltage drop in a 208 V, 2-wire, single-phase heating circuit with a load of 50 A and a one-way length of 30.5 m. The circuit consists of R90, #6 AWG copper conductors. The impedance of conductors depends on whether the conduit is made of PVC, aluminum or steel, on the power factor of the load, and on the temperature of the conductor; for the purposes of this example, the impedance is assumed to be 1.48 Ω/km.

The voltage drop, VD, in volts, for a single-phase circuit is calculated as follows:

$$\mathrm{VD} = \frac{2 \cdot \mathrm{L} \cdot \mathrm{Z} \cdot \mathrm{I}}{1000}$$

where
- L = one-way circuit length, in m,
- Z = effective impedance of conductor, in Ω (ohms)/km, and
- I = load current accounting for power factor, in amps.

Therefore, the voltage drop in this example is determined to be:

$$\mathrm{VD} = \frac{2 \cdot 30.5\ \mathrm{m} \cdot 1.48\ \Omega/\mathrm{km} \cdot 50\ \mathrm{A}}{1000\ \mathrm{m/km}} = 4.50\ \mathrm{V}$$

The approximate voltage drop is expressed as a percent of the circuit voltage calculated as follows:

$$\text{Percent VD} = \frac{4.5\ \mathrm{V}}{208\ \mathrm{V}} \cdot 100\% = 2.16\%$$

Since the voltage drop is less than 3%, the circuit meets the requirement of NECB Article 7.2.2.2.

The voltage drop for a three-phase circuit would be calculated as follows:

$$\mathrm{VD} = \frac{\sqrt{3} \cdot \mathrm{L} \cdot \mathrm{Z} \cdot \mathrm{I}}{1000}$$

# Commentary on Part 8

# Building Energy Performance Compliance Path

## Scope (Article 8.1.1.1.)

1. NECB Part 8 provides an alternative to using the prescriptive and trade-off path requirements stated in NECB Parts 3 to 7. This Commentary clarifies the scope, applications, calculation methods and modeling rules addressed in NECB Part 8 and presents examples of how the performance path could be applied using three types of buildings.

2. The purpose of the NECB Part 8 performance compliance procedure is not to develop an accurate prediction of the annual energy use of a proposed building but, rather, to evaluate the effects of deviations from the prescriptive building component requirements using fair and consistent calculation methods. The performance compliance path is intended to compare the energy performance of a proposed building to that of a building designed in accordance with the prescriptive requirements of the NECB, and is not intended to be predictive of actual (not building model) building energy consumption. As such, to complete the modelling exercise, the input data for certain building parameters must be determined based on reasonable assumptions. Simulation doesn't take into account any savings that would be achieved through manual operation of building components (e.g., the adjustment of curtains by occupants). Variations from the assumed occupancy default loads, variations in control and maintenance, variations from standard weather data and precision of the simulation program will also affect the actual energy usage.

3. The performance path is a whole building approach in which two buildings are simulated (i.e., modeled): a proposed building whose calculated energy usage is representative of the actual design plans and specifications and a reference building which is a full replica building modeled as complying with the prescriptive requirements stated in NECB Sections 3.2., 4.2., 5.2., 6.2. and 7.2. The yearly energy usage of the reference building is referred to as the "building energy target" and the yearly energy usage of the proposed building is referred to as the "annual energy consumption." Both simulations account for the effect of the building envelope, lighting, HVAC and service water heating systems, and electrical power and motors on energy consumption. Where construction techniques or building components are used that are more energy-efficient than those required in the prescriptive requirements, the extra performance over the prescriptive requirements can be credited, provided it can be quantified and is not dependent on occupant interaction; conversely, if construction techniques are used that are less efficient, a penalty on performance is modeled. A proposed building design is compliant if it uses equal or less energy than the reference building. Part 8 contains the rules for calculating the energy use of the proposed and reference buildings.

4. NECB Part 8 applies to buildings whose occupancy and location are known. Precise information about the occupancy allows the appropriate internal loads and associated schedules to be specified, and the location defines environmental loads and reference building component design.

## Performance Path (Section 8.4.)

### Compliance Overview

5. The basic steps in the determination of compliance are:

   (a) Gather the input data for the energy model calculations from the proposed building design, its occupancy, associated schedules, and climatic data for the location;

   (b) Check the input data for consistency and ensure any application limitations are satisfied;

   (c) Calculate the annual energy consumption of the proposed building through building energy simulation (using building energy analysis software, for example);

(d) If software is used but is not programmed to automatically generate a reference building, then create reference building data based on data from the proposed building design, such as identical floor space, building orientation, occupancy, schedules, and climatic data, and the NECB prescriptive path requirements;

(e) Calculate the annual energy consumption of the reference building (i.e., the building energy target);

(f) Compare load non-compliance hours of the two modeled buildings. There are several reasons for this comparison:

- One reason is to avoid generating an artificially low annual energy consumption by not fully heating the proposed building (i.e., not heating it to the set-point), while fully heating the reference building. Heating a building to a lower set-point than what is considered "normal" for the building type is acceptable under the NECB as long as the reference building is modelled using the same set-point (see NECB Article 8.4.4.2.);
- Another reason is that some simulation software programs (e.g., DOE-2.1E) have limitations, which means they cannot properly take into account insufficient heating and/or cooling from one time step to the other, and/or from one system level (e.g., an air-handling unit) to a higher system level (e.g., the plant), which leads to incorrect energy consumption calculations;
- Lastly, the number of unmet cooling hours is checked to verify that the amount of undersizing, if any, is similar in both the proposed and reference buildings. If the proposed building's thermal block is without any cooling capacity, then the reference building must also be modeled without cooling capacity;

(g) Compare the energy used by the proposed building to that used by the reference building. If the proposed building uses more energy than the reference building, its design parameters must be revised and the results recalculated, or a different compliance path can be adopted; if the proposed building uses an equal or lesser amount of energy than the reference building, generate compliance reports for submission to the building official.

## Compliance Calculations (Subsection 8.4.2.)

**6.** Many energy analysis software programs can perform the detailed energy simulations for both the proposed and reference building designs: DOE-2.1E and DOE-2.2 calculation engines; CanQUEST and eQUEST, which combine a graphical pre-/post-processor to a DOE calculation engine; EnergyPlus, IES-VE, TRNSYS; and others, such as those shown on the Building Energy Software Tools Directory of the US Department of Energy Web site (apps1.eere.energy.gov/buildings/tools_directory/subjects_sub.cfm). However, as of the 2015 edition of this User's Guide, only CanQuest and IES-VE can automatically generate a reference building that is compliant with the prescriptive requirements in NECB Parts 3 to 7 based on the specifications for the proposed building.

**7.** Where acceptable to the authority having jurisdiction (AHJ), all calculations need not be performed using the same method. For example, simple manual calculations may be combined with other means to take into account all pertinent characteristics of the proposed building leading to an energy credit and/or penalty. It is important to take into account any cross-effects between building characteristics or components where they apply, or to conservatively consider the results of those calculations.

## Air Leakage (Article 8.4.2.9.) (See also Sentences 8.4.3.3.(3) and 8.4.4.3.(6).)

Air leakage rates in real buildings are often difficult to predict as they vary depending on wind, stack effect, building construction quality, HVAC operation, and other factors. Therefore, both the reference and proposed buildings must have the same air leakage rate: the air leakage rate through the building envelope of both the reference and proposed building models must be set to a constant value of 0.25 $L/(s \cdot m^2)$ so as to ensure an even basis of comparison for the two models.

## HVAC Systems Calculations (Article 8.4.2.10.)

8. HVAC equipment efficiencies used as input in the proposed building energy model calculations must correspond to the rating conditions indicated in the relevant rating standard listed in NECB Table 5.2.12.1., and not to the actual design conditions shown in the specifications and drawings to ensure a fair comparison with the reference building's equipment, which will also be modeled with the efficiency listed in the Table. For example, for a proposed building located in Whistler, British Columbia, the combustion efficiency of a boiler would be entered in the model calculations without any adjustment to account for altitude, that is to say, as if the boiler were located at sea level.

9. It is important to note that the modeling of packaged system ventilation fans (supply and condenser) must be done separately from that of the compressors, since, at times, these fans may operate independently from the compressors—e.g., to distribute ventilation air during occupied hours without cooling or heating demand—or may operate at part-load conditions (for VAV applications), etc. Depending on the energy analysis software used, the equipment efficiencies may need to be manually adjusted to exclude the fan power demand, which would be entered separately in the energy model.

## Annual Energy Consumption of the Proposed Building (Subsection 8.4.3.)

10. The proposed building model must be consistent with the proposed building's specifications and design parameters and with the HVAC system rating conditions indicated in the relevant rating standard listed in NECB Table 5.2.12.1., and must take into account energy use resulting from the building envelope, lighting, HVAC systems, service water heating systems, and electrical power systems and motors that will be installed.

## Building Energy Target of the Reference Building (Subsection 8.4.4.)

11. The reference building model is a replica of the proposed building except that the design parameters entered into the calculations correspond to the prescriptive path requirements for each of the building parameters that affect energy consumption (i.e., building envelope (3.2.), lighting (4.2.), HVAC systems (5.2.), service water heating systems (6.2.) and electrical power systems and motors (7.2.)) for the building location's applicable heating degree-day zone (see NECB Sentence 1.1.4.1.(1)).

## General (Article 8.4.4.1.)

12. In the process of defining the reference building, one basic assumption is that the input data must be the same for the reference building as for the proposed building:
    - floor area and shape,
    - thermal blocks,
    - building type or space functions,
    - building location and orientation,
    - location of fenestration elements (windows, skylights, glazed doors) (these elements may have to be adjusted in cases where they differ from the ratio allowed in the NECB),
    - occupant density, service water heating, and internal loads and schedules, and
    - supply, return and exhaust fan schedules.

## Operating Schedules (Sentences 8.4.3.2.(1) and 8.4.4.2.(1))

13. The intent of NECB Sentences 8.4.3.2.(1) and 8.4.4.2.(1) is to ensure that an equal basis of comparison is used for the two models, since internal loads, schedules and building occupancy can greatly affect the energy consumption of a building.

14. Load values and schedules other than those provided in the NECB are permitted to be used, provided they are reasonable in the context of the proposed building design and its expected operation and that the same values and schedules are used in the reference building energy model.

15. See Examples 8-1 to 8-3, which give insight into the modeling of an NECB reference building if the software used does not automatically generate one.

# Commentary on Part 8

## Building Envelope Components (Sentence 8.4.4.3.(3))

**16.** Where the proposed building's total vertical fenestration and door area to gross above-ground wall area ratio (FDWR) is greater than the maximum FDWR permitted by NECB Article 3.2.1.4., its total vertical fenestration and door areas must be adjusted proportionally along each orientation until the FDWR of the proposed building design complies with NECB Article 3.2.1.4.

**17.** See Example 8-2, which illustrates building envelope design inputs for a semi-heated warehouse.

## Interior Partitions (Sentence 8.4.4.3.(7))

**18.** The U-value of interior partitions in the reference building model must be determined in accordance with NECB Article 3.2.1.3., where applicable, i.e., where the temperature set-points on each side of the partitions differ by more than 10°C. Otherwise, their U-value should be identical to that of the interior partitions in the proposed building.

## HVAC System Selection (Article 8.4.4.7.)

**19.** Table Note (3) of NECB Table 8.4.4.7.-B requires that thermal blocks be grouped together, which aligns with typical market practice. This approach ensures that the reference building does not have many small multi-zone systems, which would make it difficult to meet the energy recovery requirements of NECB Subsection 5.2.10.

## Equipment Oversizing (Article 8.4.4.8.)

**20.** The design heating/cooling load calculations can either be performed using the energy analysis software or dedicated load calculation software, as long as the same means—including equipment oversizing—are applied to both the proposed and reference building systems.

**21.** Equipment oversizing applies to the cooling and heating capacities of plants and systems, as well as to the airflow capacity of air-handling systems and terminal units. The value assigned for oversizing can be smaller than 1, meaning that the equipment or system is actually undersized. Undersizing is an acceptable practice as long as the requirements of NECB Sentences 8.4.1.2.(3) and (4) are met.

## Outdoor Air (Article 8.4.4.15.)

**22.** The NECB requires that the total outdoor airflow rates supplied by the reference building's air-handling units (AHUs) be identical to those supplied by the proposed building's AHUs. This requirement applies regardless of the number of systems or their configuration, factors that could theoretically lead to a change in outdoor airflow rate based on the requirements of the applicable ventilation standard.

## Energy-Recovery System (8.4.4.19.)

**23.** Regardless of where or how air is exhausted in the proposed building, energy recovery must be applied to all exhaust air defined in the reference building model, while keeping in mind the exception stated in NECB Sentence 5.2.10.1.(3).

**24.** Even if air is exhausted close to a thermal block in the proposed building—which means that recovering heat from this exhaust air may not be possible—it must not be accounted for in the reference building model.

**Example 8-1 – Component Design for Shell-and-Core Office Building**

A 33-storey office building to be located in Toronto, Ontario is being designed as a shell and core. The tenant office spaces will be left unfinished until they are leased, at which time they will be built to suit the tenants' needs. For the purposes of this example, the tenant fit-up assumptions are identical in the proposed and reference buildings and are treated as being minimally compliant, i.e., as meeting the prescriptive requirements. To determine the annual energy consumption of the proposed building, HVAC, envelope, lighting, and service water heating assumptions are needed as input data for the model to show compliance. See the following table.

**Building Component Assumptions Used to Model the Shell-and-Core Office Building**

| Component | Proposed Building Assumptions | Reference Building Assumptions |
|---|---|---|
| Building Envelope | Use design of proposed building. Building envelope assemblies that cover less than 5% of total assembly type may be combined with assemblies having same orientation and similar thermal performance (NECB Sentence 8.4.3.1.(6)). | Use prescriptive performance levels in NECB Section 3.2. |
| | Determine solar heat gain coefficient, solar absorptance and air leakage in accordance with NECB Article 8.4.3.3. | Use same solar absorptance values as for proposed building assemblies except use 0.7 for roof assemblies (see NECB Sentences 8.4.4.3.(1) and (2)). |
| | | If total vertical fenestration and door area to gross above-ground wall area ratio (FDWR) and skylight area differ from prescriptive maximums in NECB Article 3.2.1.4., adjust the FDWR and skylight area proportionally along each orientation until they comply with that Article (see NECB Sentence 8.4.4.3.(3)). |
| Lighting | Use building area method in NECB Article 4.2.1.5. to determine lighting power density (LPD) (8.5 W/m² for tenant spaces in this example) (see NECB Note A-4.2.1.3.). | Use same LPD as proposed building for tenant areas. |
| | Since the same LPD value is used for tenant spaces in both the proposed and reference building designs, no energy credit is available for lighting power reductions in tenant spaces. | The building area method does not take into account task lighting and room configurations within an office building. |
| HVAC | If HVAC zones in tenant areas have not yet been designed, multiple HVAC zones may be combined to create a single thermal block (see NECB Article 1.4.1.2. of Division A for definition). However, thermal blocks in interior and perimeter spaces cannot be combined ("perimeter space" refers to the space from the exterior wall extending about 4.6 m inward towards the core). | Use same types of heating and cooling systems as those used for proposed design. Loads are different due to differences in the building envelope. HVAC zoning must be identical to the proposed design in terms of floor areas, total envelope area per orientation, and internal assembly areas. However, the fenestration, door and skylight areas per orientation will be different from those of the proposed building as they must comply with NECB Article 3.2.1.4. |
| | Every thermal block is deemed to be heated and cooled, even if only rough-ins are provided (NECB Sentence 8.4.3.1.(4)). | Select appropriate HVAC system using NECB Table 8.4.4.7.-A (in this example, it is a multi-zone built-up system with baseboard heating). The baseboard heating must use the same energy source as the proposed design. |
| | Use applicable default loads for occupant density, peak receptacle load, and service water heating from NECB Table A-8.4.3.2.(2)-A and applicable default operating schedule from NECB Note A-8.4.3.2.(1) (in this example, NECB Table A-8.4.3.2.(1)-A best represents the building type). | Use same default operating schedule and loads as for proposed design. |

**Example 8-1 – Component Design for Shell-and-Core Office Building (Continued)**

**Building Component Assumptions Used to Model the Shell-and-Core Office Building (cont.)**

| Component | Proposed Building Assumptions | Reference Building Assumptions |
|---|---|---|
| HVAC (cont.) | | Minimum outdoor air requirements are based on minimum requirements dictated by applicable standards.<br><br>Apply same oversizing factors to the heating and cooling equipment as the ones applied to equipment in proposed building (see NECB Article 8.4.4.8.). However, if the oversizing factor of the heating equipment in the proposed building exceeds 30%, oversize the heating equipment in the reference building by 30%, and if the oversizing factor of the cooling equipment in the proposed building exceeds 10%, oversize the cooling equipment in the reference building by 10%. Calculate air handler load in each thermal block for heating, reheating, cooling and recooling systems, capacities of space-heating and space-cooling systems, air handler airflow rates for supply and return systems, and outdoor air requirements for cooling with outdoor air. |
| Service Hot Water | Since tenant loads and operating schedules are unknown, use applicable default office loads from NECB Table A-8.4.3.2.(2)-A and applicable default operating schedule from NECB Note A-8.4.3.2.(1). | Use applicable default office loads from NECB Table A-8.4.3.2.(2)-A and applicable default operating schedule from NECB Note A-8.4.3.2.(1) to calculate number of occupants and service water heating load.<br><br>The service water heater uses the same energy source(s) and equipment type as the proposed design and conforms to applicable performance standards identified in NECB Table 6.2.2.1., assuming none of the exceptions in NECB Sentences 8.4.4.20.(2) to (4) apply. |

**Example 8-2 – Component Design for a Semi-Heated Warehouse**

A 4 600 m² x 7.3 m high warehouse that is semi-heated to 7°C is being designed for construction in Edmonton, Alberta. The owner has requested that the bottom 3 m of the warehouse walls be constructed with concrete masonry units (CMU) to resist forklift damage and that the upper walls be made of sheet-steel-clad steel frame construction. The proposed design consists of 6% vertical fenestration and 6% doors. The flat roof is constructed as a steel deck insulated with isocyanurate rigid foam insulation and covered with a fastened single-ply roofing membrane. A 72 m² one-storey heated office is located at one end of the building. Since the CMU areas of the wall assemblies don't meet the prescriptive performance requirements and the steel building wall areas could not accommodate trade-off performance adjustments, the designer has decided to show compliance using the building energy performance compliance path. This proposed semi-heated building is permitted to meet less stringent building envelope requirements if its annual energy consumption is less than or equal to the building energy target of the reference building, which uses a set-point temperature of 18°C. To determine the annual energy consumption of the proposed building, HVAC, envelope, lighting, and service water heating assumptions are needed as input data for the model to show compliance. See the following table.

**Building Component Assumptions Used to Model the Semi-Heated Warehouse**

| Component | Proposed Building Assumptions | Reference Building Assumptions |
|---|---|---|
| Building Envelope | Use design of proposed building. Building envelope assemblies that cover less than 5% of total assembly type may be combined with assemblies having same orientation and similar thermal performance (NECB Sentence 8.4.3.1.(6)). | Use prescriptive performance levels in NECB Section 3.2. for all wall and roof areas. |
| | Determine solar heat gain coefficient, solar absorptance and air leakage in accordance with NECB Article 8.4.3.3. | Use same solar absorptance values as for proposed building assemblies except use 0.7 for roof assemblies (NECB Sentences 8.4.4.3.(1) and (2)). |
| | | Adjust window and door areas and skylight area proportionally along each orientation until they comply with the FDWR in NECB Article 3.2.1.4. (see NECB Sentence 8.4.4.3.(3)). |
| Lighting | Use actual operating schedule of proposed building or default operating schedule for warehouse lighting determined from NECB Table A-8.4.3.2.(1)-A (in this example, NECB Table A-8.4.3.2.(1)-A best represents the building type). | Use same operating schedule as for proposed building. |
| | Use lighting power density (LPD) of proposed design or use default LPD value for warehouse spaces listed in NECB Table 4.2.1.5. (5.2 W/m²) in both the proposed and reference building models (see NECB Note A-4.2.1.3.). | Use default LPD value for warehouse spaces listed in NECB Table 4.2.1.5. (5.2 W/m²). |
| HVAC | Use actual proposed operating schedule and loads and a heating system set-point operating temperature of 7°C. HVAC system is specified as a unit heater. | The set-point temperature of the heating system of the reference semi-heated warehouse is 18°C (see NECB Sentence 8.4.4.2.(3)). Use the same operating schedule as for the proposed building. |
| | If actual loads and schedule are not known, use applicable default loads for warehouses from NECB Table A-8.4.3.2.(2)-A (1 500 m² per occupant) and applicable default operating schedule from NECB Note A-8.4.3.2.(1) (in this example, Table A-8.4.3.2.(1)-A is the most applicable). | Use same default operating schedule and loads as for proposed design. Determine appropriate HVAC system using NECB Table 8.4.4.7.-A (in this example, the appropriate one is a single-zone make-up air unit with baseboard heating). The performance of the HVAC system must meet the prescriptive requirements of NECB Table 5.2.12.1. |

**Example 8-2 – Component Design for a Semi-Heated Warehouse (Continued)**

**Building Component Assumptions Used to Model the Semi-Heated Warehouse (cont.)**

| Component | Proposed Building Assumptions | Reference Building Assumptions |
|---|---|---|
| HVAC (cont.) | | Apply same oversizing factors to the heating and cooling equipment as the ones applied to equipment in proposed building (see NECB Article 8.4.4.8.). However, if the oversizing factor of the heating equipment in the proposed building exceeds 30%, oversize the heating equipment in the reference building by 30%, and if the oversizing factor of the cooling equipment in the proposed building exceeds 10%, oversize the cooling equipment in the reference building by 10%. |
| | Unit heaters complying with ANSI Z83.8/CSA 2.6 have separate combustion air and venting vertically through the roof or horizontally through a wall. Unit heaters do not supply outdoor air to meet outdoor air ventilation requirements. In ANSI/ASHRAE 62.1, the minimum outdoor air ventilation rate for warehouses is 0.3 L/(s·m$^2$) (0.06 cfm/ft.$^2$). An air handler or a make-up air unit (MUA) with 100% outside air may be used to meet zone ventilation requirements. | The HVAC zoning must be identical to the proposed design in terms of floor areas and internal assembly areas. |
| | | Minimum outdoor air rates for ventilation for each zone will be the same as the proposed building model. |
| | | Calculate air handler load in each thermal block for heating and reheating systems, capacities of space-heating systems, and air handler airflow rates for supply and return systems. |
| | | Fan power is that of the proposed design or as calculated according to NECB Article 8.4.4.17., whichever is less. |
| Service Hot Water | Use actual proposed operating schedule, loads and service water heating equipment. If actual loads and schedule are not known, use applicable default loads for warehouses from NECB Table A-8.4.3.2.(2)-A (1 500 m$^2$ per occupant and 300 W service water heating load per person) and applicable default operating schedule from NECB Note A-8.4.3.2.(1) (in this example, Table A-8.4.3.2.(1)-A is the most applicable). | Use proposed operating schedule and loads, and service water heating equipment that meets the performance requirements in NECB Table 6.2.2.1. |

**Example 8-2 – Component Design for a Semi-Heated Warehouse (Continued)**

As stated above, the total vertical fenestration and door area to gross wall area ratio (FDWR) for the proposed building is 6% windows + 6% doors resulting in a decimal ratio of 0.12. Given that the area of the building envelope is 2 000 $m^2$, the resulting window and door areas of the proposed building are as follows:

| Orientation | Proposed Building (FDWR = 0.12 or 240 $m^2$) | |
|---|---|---|
| | Windows (6%) | Doors (6%) |
| South | 80 $m^2$ | 20 $m^2$ (swinging) |
| West | 40 $m^2$ | 20 $m^2$ (swinging) |
| North | – | 80 $m^2$ (overhead) |
| East | – | – |

Given that the heating degree-days (HDD) below 18°C for the location of the building (Edmonton, Alberta) is 5120 (see NECB Table C-1), the maximum allowable FDWR for the reference building is 0.325 ((2000 – 0.2 · 5120)/3000) (see NECB Sentence 3.2.1.4.(1)). As stated in NECB Sentence 8.4.4.3.(3), the FDWR of the reference building must be adjusted proportionally along each orientation. The individual fenestration and door areas along each orientation of the reference building are obtained by multiplying the fenestration and door areas of the proposed building by an adjustment factor calculated as follows:

$$\text{Adjustment Factor} = \frac{\text{FDWR}_{\text{maximumallowable}}}{\text{FDWR}_{\text{proposeddesign}}} = \frac{0.325}{0.12} = 2.7$$

The resulting window and door areas of the reference building are as follows:

| Orientation | Reference Building (FDWR = 0.325 or 648 $m^2$) | |
|---|---|---|
| | Windows (16.2%) | Doors (16.2%) |
| South | 216 $m^2$ (10.8%) | 54 $m^2$ (swinging) (2.7%) |
| West | 108 $m^2$ (5.4%) | 54 $m^2$ (swinging) (2.7%) |
| North | – | 216 $m^2$ (overhead) (10.8%) |
| East | – | – |

The FWDR of the reference building can be adjusted using the same approach when the FDWR of the proposed building is greater than that permitted by NECB Sentence 3.2.1.4.(1).

In this example, since the FDWR of the proposed building is less than that permitted by NECB Sentence 3.2.1.4.(1), the proposed building design is given an energy consumption credit that can be applied to the design of other building components or systems.

**Example 8-3 – HVAC Design for Hospital Addition**

Five storeys above grade and a penthouse control room plus two storeys above grade are being added to a hospital. Both additions have one storey below grade. The table below lists the proposed space types in the addition as well as the HVAC systems to be installed to serve those spaces. The reference HVAC systems to be used in the energy model calculations are provided in the last column; they are based on HVAC systems recommended in NECB Table 8.4.4.7.-A for space types that are identical or similar to the space types for the proposed addition.

**HVAC System Design Assumptions for Hospital Addition**

| Space Type | Proposed Building HVAC Design(1) | Reference Building HVAC Design Based on NECB Table 8.4.4.7.-A(1) |
|---|---|---|
| Penthouse control room/office (intermittent occupancy) | Served by baseboard heater with thermostatically controlled exhaust fan for removal of excess heat, if necessary. Zero mechanical cooling required. | If considered a mechanical/electrical control room, select System 1 (AC with baseboard heating) and set cooling capacity at 0 kW. If considered an office, select System 3 (SZ RTU) and set cooling capacity at 0 kW (non-mechanically cooled). |
| Top 4 floors of 5-storey addition plus top floor of 2-storey addition: cancer ward rooms, long-term care rooms, some surgery recovery rooms | Both additions are served by same multi-zone HVAC system: dual duct, dual fan with occupant-sensor-controlled fan-powered VAV boxes with space fan coil units for perimeter heating and cooling. | Just like the proposed case, the reference system selection is based on space type, not number of storeys. If considered patient/recovery rooms, select System 3 (SZ RTU). Multiple spaces can be combined to form zones as is the case with proposed design. |
| Ground floors of 5- and 2-storey additions: offices, lobby, dining area, gym, recreation area, and dialysis, and physiotherapy rooms | Space-heating is provided by a hydronic system and space-cooling is provided by a VAV air handler with a water-cooled chiller. | Designate the gym, office, recreation and lobby areas as a General Area and select System 3 for maximum 2 storeys (SZ RTU). Designate dialysis, dining and physiotherapy areas as Assembly, Multipurpose Area and select System 6 for greater than 4 storeys (multi-zone built-up VAV system). In this example, space-heating and -cooling system selections are the same as for the proposed design. |
| Ground floor of 5-storey addition: | | |
| Space type A: steam/spa/sauna/water pool therapy rooms and adjoining change rooms and washrooms | A is served by a dedicated heating unit (mini-boiler with some solar preheat for the pool); pool area is not air-conditioned. | Designate A as a General Area and select System 3 (SZ RTU); pool area is not air-conditioned. |
| Space type B: food/meal preparation (not a main kitchen) area and a garbage recycling room | B is served by a dedicated dry cooler for food storage and space cooling; both zones are served by one dedicated MUA unit. | Designate B as a Food Service Area and select System 4 (SZ MUA) (group the two zones into a single zone so as to be able to use System 4). |
| Space type C: 2 sets of bathrooms | C (both sets) is served by one MUA serving two non-adjacent zones. | Designate C as a General Area and select System 3 (SZ RTU) (group the two zones into a single zone so as to be able to use System 3). |

**Example 8-3 – HVAC Design for Hospital Addition (Continued)**

**HVAC System Design Assumptions for Hospital Addition (cont.)**

| Space Type | Proposed Building HVAC Design[(1)] | Reference Building HVAC Design Based on NECB Table 8.4.4.7.-A[(1)] |
|---|---|---|
| Basement of 5-storey addition: | Each of the 4 areas has dedicated AHU. MRI and X-ray areas are not heated but are cooled with dedicated chilled water units. Waste heat from equipment is collected through a glycol heat exchanger and piped to adjacent mechanical room to supplement heating of fan coil water. | |
| Space type A: MRI area | Cooling for A > 20 kW. | Designate A as a Data Centre and, based on cooling load of proposed, select System 2 (four-pipe fan coil with MUA). |
| Space type B: X-ray diagnostic area | Cooling for B < 20 kW. | Designate B as a Data Centre and, based on cooling load of proposed, select System 1 (AC with constant-volume MUA) |
| Space type C: four surgical preparation rooms | C is served by a single MUA. | Designate C as a Hospital Area and select System 3 (SZ RTU). |
| Space type D: maintenance areas (mechanical/electrical/storage/janitorial) | D is served by a single MUA. | Designate D as a Warehouse Area and select system 4 (SZ MUA). |
| Basement and ground floor of 2-storey addition: 4 ICU (intensive care unit) rooms, 10 surgical recovery rooms, 6 surgery rooms | Design uses multi-zone MUA unit with air delivery controls dedicated to each room. When room is not in use, MUA airflow is reduced. The multi-zone system behaves like a single-zone system controlling heating and cooling to each room. | Designate as Hospital Area and select System 3 (SZ RTU). If the proposed design is modeled as a single zone for each room, then each room zone in the reference design is modeled with a separate SZ RTU. If the proposed design is modeled as one large zone, then the reference design is modeled as one large zone using System 3 (SZ RTU). |

(1) The abbreviations used in the Table have the following meanings:
AC = air conditioner
AHU = air-handling unit
MUA = make-up air unit
RTU = rooftop unit
SZ = single zone
VAV = variable air volume

## Conversions

| SI Units | Imperial Units | To convert SI units to imperial units, multiply by | To convert imperial units to SI units, multiply by |
|---|---|---|---|
| **Temperature** | | | |
| °C | °F | 1.8 and add 32 | subtract 32 divide by 1.8 |
| **Length** | | | |
| mm | in. | 0.03937 | 25.4 |
| cm | in. | 0.3937 | 2.54 |
| m | ft. | 3.281 | 0.3048 |
| **Area** | | | |
| $mm^2$ | $in.^2$ | 0.00155 | 645.16 |
| $cm^2$ | $in.^2$ | 0.155 | 6.4516 |
| $m^2$ | $ft.^2$ | 10.76 | 0.092903 |
| **Volume** | | | |
| $cm^3$ | $in.^3$ | 0.061 | 16.3871 |
| $m^3$ | $ft.^3$ | 35.31 | 0.02832 |
| L | gal. (Imp) | 0.22 | 4.55 |
| L | gal. (US) | 0.2642 | 3.785 |
| **Flow** | | | |
| L/s | $ft.^3$/min. (cfm) | 2.11889 | 0.471947 |
| L/min. | $ft.^3$/min. (cfm) | 0.0353 | 28.329 |
| $m^3$/h | $ft.^3$/min. (cfm) | 0.5886 | 1.699 |
| **Power** | | | |
| W | Btu/h | 3.413 | 0.2930711 |
| **Heat Flux** | | | |
| $W/m^2$ | Btu/h · $ft.^2$ | 0.317 | 3.154591 |
| **Overall Heat Transfer Coefficient (U-value)** | | | |
| $W/m^2$ · K | Btu/h · $ft.^2$ · °F | 0.17612 | 5.678263 |
| $W/m^2$ · °C | Btu/h · $ft.^2$ · °F | 0.17612 | 5.678263 |
| **Thermal Resistance** | | | |
| $m^2$ · °C/W (RSI) | $ft.^2$ · h · °F/Btu (R) | 5.678 | 0.17611 |
| **Thermal Conductivity, k** | | | |
| W/m · K | Btu · in./h · $ft.^2$ · °F | 6.93347 | 0.1442279 |
| $W/m^2$ · °C (per m thickness) | Btu · ft./h · $ft.^2$ · °F | 0.5777 | 1.731 |
| $W/m^2$ · °C (per m thickness) | Btu · in./h · $ft.^2$ · °F | 6.9444 | 0.144 |
| **Pressure** | | | |
| Pa | in. of water | 0.004014 | 249 |
| kPa | psi | 0.145 | 6.895 |
| kPa | psf | 20.88 | 0.04788 |
| **Energy** | | | |
| MJ | kWh | 0.278 | 3.6 |
| J | Btu | 0.0009478 | 1055.056 |