Guidance for the Development of a Performance-Based Solution for Smoke Dampers

April 2024

BC HOUSING

Acknowledgements

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Contents

1.0 Introduction

This guide has been prepared at the request of BC Housing for the development of a performance-based solution relative to Sentence 3.1.8.7.(2) of the 2018 and 2024 British Columbia Building Code (2018 BCBC and 2024 BCBC). This Sentence (Sentence 3.1.8.7.(2)) requires a smoke damper, or a combination smoke/fire damper to be installed at various locations in residential building ventilation systems. This was a new requirement in the 2018[1] BCBC (then also in 2024 BCBC), adopted from the 2015 National Building Code of Canada (2015 NBCC), which previously only required a fire damper at certain locations within a ventilation system. The intent of this requirement is to limit the probability of smoke spreading from one side of a fire separation to another by way of ventilation ducts.

Application of the updated requirements of Sentence 3.1.8.7.(2) has created a significant challenge to the design, construction, and maintenance of new residential buildings by BC Housing; which utilize a centralized ventilation system for many multi-family residential buildings. As a directs result of this change in requirements, tens to hundreds of new combination smoke/fire dampers at small (5 to 6-inch diameter) duct penetrations between the residential suites and the adjacent corridors, would be required to comply[2]. This not only increases the complexity in design, ongoing maintenance, annual inspection, and replacement, but also significantly increases the capital and total Lifecycle Cost of the building. In addition, these dampers would preclude current designs that are intended to achieve BC Housing and provincial energy objectives while maintaining affordability for populations/residents in BC.

The information provided in this guide for the application of the development of Alternative Solutions to specific projects will require coordination with the Authority Having Jurisdiction (AHJ), and potentially require coordination with the coordinating registered professional, Architect, Mechanical Consultant and Code Consultant. Coordination with the AHJ will facilitate determining documentation or other information that may be required, in addition to the information contained in this guide, to support such an Alternative Solution.

The guide addresses the following:

- Describe the BC Housing centralized ERV/HRV system including the energy performance objectives and rationale versus in-suite self-contained ERVs.
- Describes the applicable building code requirements for combination smoke/fire dampers in ducts penetrating fire separations.
- Describes the approach to a performance-based solution that achieves the objectives of the building code to limit the probability smoke will spread from one fire compartment to another fire compartment through openings in a fire separation.
- Supplements with an appendix that standardizes the project-ready alternate solution based on the successful projects in various regions of BC.

1 The 2018 BCBC references area also reflected in the 2020 National Building Code of Canada (NBCC) and the 2024 BCBC.
2 For example, a typical 5-storey BC Housing building with 70 residential suites would require minimum 140 combination smoke/fire dampers (two per each suite).

1.1. Duty of the Responsible Professional(s)

It is incumbent upon the Responsible Professional(s) for the mechanical design and the approach to code compliance to utilize the content of this guide in a judicious manner. The information contained within this guide is to be used as supporting material in the development of a project-specific Alternative Solution.

1.2. Limitations of Guide

This guide is intended to apply to most BC Housing residential projects that incorporate a centralized ERV/HRV with 5 to 6-inch diameter branch ducts to and from residential suites and has been developed to be generically applicable to residential low- and mid-rise buildings not considered to be “high buildings” (Subsection 3.2.6. of the 2024 BCBC).

It is noted that this guide addresses buildings with monitored sprinkler systems only, per BC Housing policy.

2.0 BC Housing Typical Central Ventilation System

A central distribution ventilation system is preferred for BC Housing projects as it is much easier to maintain without the need of entering individual residential suites and the incremental cost increase associated with each additional system component. It can also provide partial cooling for residential suites by mechanically cooling ventilation air in summer and it has, typically, higher efficiency than individual in-suite ERVs. The central system is designed to provide 100% outdoor air to each housing unit through noncombustible ducts with no recirculation of air. The air supply system is physically separate from the return system and is intended to operate continuously.

2.1. Energy Objectives

The BC Housing *Design Guidelines and Construction Standards* [1] provide technical guidelines and requirements for the design and construction of buildings funded and financed by BC Housing. This document is intended to be a reference and baseline from which a full project design and specifications are to be developed by the design team.

One of the important goals of these guidelines is to "pursue sustainable designs and construction practices that balance environmental responsibility, the well-being of the users and efficient use of resources while considering economics of building construction and life cycle costs;" including capital, operational and renewal costs. The energy performance target of all BC Housing projects is aligned with 2024 BCBC achieving higher Step Code levels and BC Housing's Green House Gas (GHG) reduction target with the provincial Climate Change Accountability Act. GHG reduction targets for all new buildings are to be zero-carbon by 2030. Therefore, it is mandatory that all BC Housing projects require major ventilation systems in a building to include energy recovery to meet this higher performance target.

2.2. Central System

Energy or Heat Recovery Ventilation (ERV[3]/HRV[4]) can be provided on a residential unit basis, or by a centralized system. Central ERV/HRV units are being utilized in many of BC Housing's social housing buildings that are already built or in various stages of design as they offer a practical and cost effective method of providing partial mechanical cooling for residential suites as outdoor ventilation air can be easily mechanically cooled in summer, especially in milder climate zones. Considering changing climate and warmer summers, it is becoming more and more evident that at least conditioned cooling[5] should be considered for residential apartments in the climate zones where, traditionally, no mechanical cooling was provided in the past [2].

Where central or semi-central ERV/HRVs are provided with mechanical cooling, increasing minimum ventilation rates for the apartments facing south and west can be considered as a means of providing better partial cooling during the summer season [2]. The service life of the buildings equipped with central ERV/HRVs is 60-100 years. A form of cooling is therefore required to maintain thermal comfort for BC Housing's populations/residents and considering changing climates.

3 ERV: Energy Recovery Ventilator - transfers sensible & latent heat, does not require condensate drain
4 HRV: Heat Recovery Ventilator - transfers sensible heat only, requires condensate drain
5 Conditioned cooling is considered partial cooling of the entire suite. *BC Housing Design Guidelines and Construction Standards Technical Bulletin No. 3–2023* defines partial cooling as cooling of the living room only.

The advantages of utilizing central ERV/HRV units over in-suite ERVs (provided inside each residential suite) are as follows:

- Centralized method of providing conditioned mechanical cooling for an entire residential suite.
- Central ERV/HRV units are more energy efficient than the in-suite ERVs as they can utilize heat pump equipment for the supplementary heating and cooling.
- Central ERV/HRV units can provide “free-cooling” and “night-cooling” by simply stopping the enthalpy energy recovery wheel. In-suite ERVs don’t have this option and are “recovering” energy even when it is detrimental to the overheating of residential suites.
- Central ERV/HRV units are typically located on the high roof of a building and, sometimes, in the parkade or on a lower roof level. Where reasonable, this central system can also be considered in floor by floor level. They are much easier to service and maintain compared to a large number of in-suite ERVs, which can result in a significant reduction of the operating/maintenance costs by the societies operating the social housing buildings.
- Central ERV/HRV units located on the roof or in the parkade of a building are less prone to vandalism and general damage.
- Central ERV/HRV units eliminate the need for accessing individual residential suites for servicing and maintenance. In-suite ERVs require entering each residential suite at least a few times a year for cleaning/replacing filters.
- Reduced risk of false alarms by not having fire alarm detection devices located in close downstream proximity of residential suite kitchens and showers.
- Longer service life of central ERV/HRV units in comparison to the service life of in-suites ERVs; the number of replacements is more frequent considering the total life of the building. The in-suite replacement process is also a disruption to the tenants.
- As part of climate adaptation strategies, it is easier to mitigate effects of air pollution from wild forest fires by having a much smaller number of high-efficiency filters in central ERV/HRV units. Refer to *BC Housing Design Guidelines and Construction Standards, [1] Section 4* on wildfires and filtration.
- Avoids in-suite ERVs located in the ceiling space of each residential suite which can result in tenant noise complaints.
- Central ERV/HRV units are easier to maintain and replace in comparison to in-suite units which are more expensive and invasive, typically requiring demolition and re-instatement of ceiling finishes to gain access and may require temporary relocation of tenants during work. Utility costs are lower because of the respective building manager’s control over the system. No heating and cooling at the same time in residential units.

Based on the advantages outlined above, central ventilation systems can offer cost effective solution to meeting the energy efficiency, greenhouse gas emissions, indoor comfort quality targets and long term service life and lower maintenance in BC Housing buildings.

2.3. Typical Central ERV/HRV System Design

The typical central ERV/HRV unit in BC Housing projects is located on the roof of the building and includes supply & exhaust fans, enthalpy energy recovery wheel with variable speed controls, a variation of heating coil, combination heating/cooling coil and/or DX cooling coil, filters and protected outdoor air intake & exhaust hoods/louvres.

Exhaust air is ducted from all residential bathrooms in the building and is used to pre-heat (in winter) and pre-cool (in summer) outdoor air supplied for ventilation. A conceptual air flow diagram for a central ERV/HRV is included in **Figure 1** below. Outdoor air is further treated inside the central ERV/HRV by adding supplementary heating (at low outdoor temperatures) or by providing mechanical cooling (in summer) and it is ducted directly to all residential living rooms and bedrooms. Exhaust and supply air are typically ducted through central vertical duct risers to exhaust/supply horizontal ducts in the corridor’s ceiling space on each floor.

The supply & exhaust ducts entering each residential suite are typically 5"-6" in diameter. Most multi-family BC Housing projects have residential suites numbering from the tens to the hundreds.

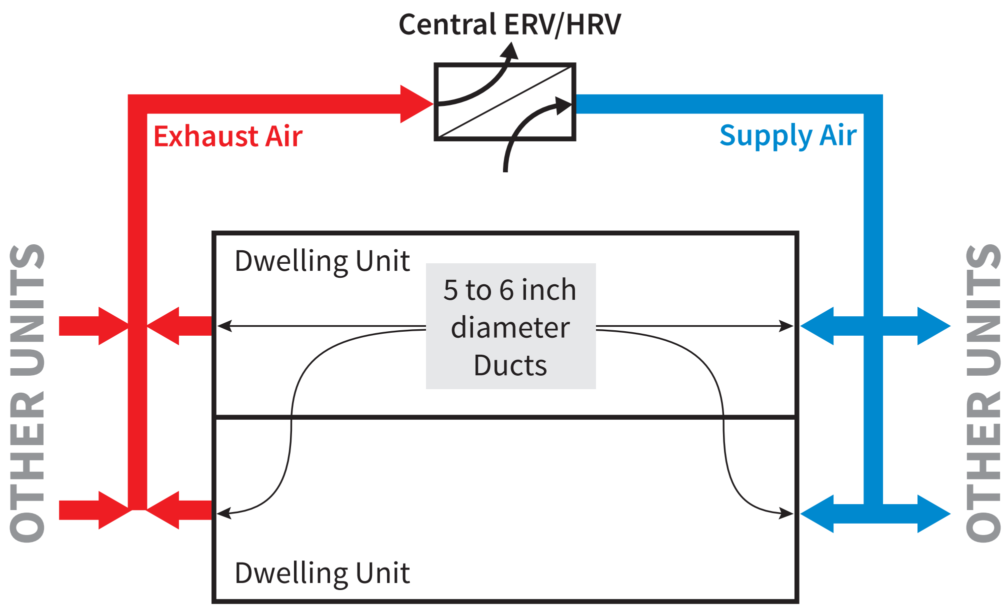

Figure 1: Conceptual ERV/HRV central system air flow.

3.0 Building Code Requirements

The following sections of this guide identify the applicable building code requirements; objectives, functional and intent statements attributed to those requirements; and the basis for development of the requirements to facilitate the identification of the acceptable level of performance required by an Alternative Solution.

3.1. Applicable Requirements

Sentence 3.1.8.7.(2) of the 2018 BCBC and 2024 BCBC require that a smoke damper or a combination smoke/fire dampers be installed in conformance with Article 3.1.8.11. in ducts or air-transfer openings that penetrate an assembly required to be a fire separation, where the fire separation:

a) separates a public corridor,

b) contains an egress door referred to in Sentence 3.4.2.4.(2),

c) serves an assembly, care, treatment, detention or residential occupancy, or

d) is installed to meet the requirements of Clause 3.3.1.7.(1)(b) or Sentence 3.3.3.5.(4).

The BC Housing projects to which Sentence 3.1.8.7.(2) applies will be residential occupancies. Therefore, Clause 3.1.8.7.(2)(c) will be applicable to all duct and air-transfer openings that penetrate an assembly required to be a fire separation in these projects. Previously only a fire damper was required.

Article 3.1.8.11. requires the following relative to the installation of smoke dampers:

3.1.1. Damper Location and Access:

- **Air-Transfer Opening:** where smoke dampers are used as a closure in an air-transfer opening, they are required to be installed in the plane of the fire separation [Sentence 3.1.8.11.(1)].
- **Combination smoke/fire dampers:** combination smoke/fire dampers are required to be installed within 610 mm of the plane of the fire separation, provided there is no inlet or outlet opening between the fire separation and the damper [Sentence 3.1.8.11.(2)].
- **Damper Position:** Smoke dampers or combination smoke/fire dampers are required to be installed in the vertical or horizontal position in which they were tested [Sentence 3.1.8.11.(4)].
- **Damper Access:** A tightly fitted access door shall be installed for each smoke damper and combination smoke/fire dampersto provide access for their inspection and the resetting of the release device [Sentence 3.1.8.11.(5)]. The access door is intended to be provided in the duct and, if the duct is enclosed with an architectural finish, that a second access door be provided through that finish [Note A-3.1.8.11.(5)].

3.1.2. Damper Activation:

- Except as required by a smoke control system, smoke dampers and combination smoke/fire dampers shall be configured so as to close automatically upon a signal from an adjacent smoke detector located as described in CAN/ULC-S524, “Installation of Fire Alarm Systems,” within 1.5 m horizontally of the duct or air-transfer opening in the fire separation [Sentence 3.1.8.11.(3)]:
  - on both sides of the air-transfer opening, or
  - in the duct downstream of the smoke damper or combination smoke/fire damper.

- There is no requirement for dampers to be provided with emergency power or to be designed to be normally closed in the event of a power failure.

3.2. Objectives, Functional and Intent Statements Attributed to Sentence 3.1.8.7.(2)

The Objective of Sentence 3.1.8.7.(2) is to limit the probability of injury and damage due to fire by [F03-OS/OP1.2] retarding the effects of fire on areas beyond its point of origin. This is specifically achieved by limiting the probability that smoke will spread from one fire compartment to another fire compartment through openings in a fire separation.

3.3. Level of Performance Required

The level of performance required by the Alternative Solution is based on the level of performance of a design that satisfies Sentence 3.1.8.7.(2). Specifically, the Notes to Clause 1.2.1.1.(1)(b) of Division A state that:

- Division B establishes the quantitative performance targets that Alternative Solutions must meet.
- An effort must be made to demonstrate that an Alternative Solution will perform **as well as** a design that would satisfy the applicable acceptable solutions in Division B.]

The Notes to Clause 1.2.1.1.(1)(b) of Division A further states that:

> *Where Division B offers a choice between several possible designs, it is likely that these designs may not all provide exactly the same level of performance. Among a number of possible designs satisfying acceptable solutions in Division B, the design providing the lowest level of performance should generally be considered to establish the minimum acceptable level of performance to be used in evaluating Alternative Solutions for compliance with the Code.*

A number of designs are possible in compliance with Clause 3.1.8.7.(2)(c) that will have differing levels of performance in limiting the spread of smoke from one fire compartment to another. The intent of Sentence 3.1.8.7.(2) is to limit the spread from one fire compartment to another fire compartment; therefore, the lowest level of performance of these designs is one in which smoke has the greatest probability of spread from one fire compartment to another as discussed further below.

Further, the performance of a system is established as a function of the direction of airflow, which is assumed to be of greater concern flowing from a compartment of fire origin to another compartment. This assumption is based on the location of the smoke detector (i.e., “downstream of the smoke damper or combination smoke/fire damper”) required to activate a smoke or combination smoke/fire damper.

The design features considered in establishing the minimum acceptable level of performance (“compliant system”) to which the proposed alternative design will be compared is included in **Table 1**.

Table 1: Design Features in Compliance with Sentence 3.1.8.7.(2).

Design Element	Feature	Code/Standard Reference	Requirement	Design Performance Considerations
Smoke Damper	Type	2018/2024 BCBC, Division B, Sentence 3.1.8.7.(2)	A smoke damper or a combination smoke/fire damper.	For purposes of simplicity, the compliant system will include separate smoke and fire dampers.
	Location	2018/2024 BCBC, Division B, Sentence 3.1.8.11.(1)	Where smoke dampers are used as a closure in an air-transfer opening, they shall be installed in the plane of the fire separation.	The smoke damper for the compliant system will be located in the plane of the fire separation between the public corridor and adjacent residential units.
	Activation Time	CAN/ULC-S112.1 Clause 15.2.6	The closing time shall not exceed 75 s.	This will allow the passage of smoke beyond the smoke damper and plane of the fire separation.
Smoke Detector	Type and Location	2018/2024 BCBC, Division B, Sentence 3.1.8.11.(3)	Located as described in CAN/ULC-S524, "Installation of Fire Alarm Systems," within 1.5 m horizontally of the duct opening in the fire separation in the duct downstream of the smoke damper or combination smoke/fire damper.	• The BCBC does not specify the type of detector required in conformance with Sentence 3.1.8.11.(3); however, the detector is required to be located in the duct. • Regardless of the type of detector, the location 1.5 m downstream of the damper will result in the spread of smoke beyond the damper prior to the smoke detector being exposed to smoke.
		Clause 8.3.12.1 of CAN/ULC-S524	The smoke detector (spot type) shall not be installed directly in the stream of the air supply.	This means that a spot type smoke detector is not permitted in the duct where it would be directly in the stream of the air supply. Therefore, a duct-type smoke detector would be required.
	Activation Considerations	Manufacturers technical data sheets	Varies.	Duct-type smoke detectors specify minimum and maximum air flows relative to operation. The 2018 BCBC does not require a continuous minimum airflow for ducts that penetrate a fire separation. Therefore, conditions may exist where smoke can move through a duct below the manufacturer's specified lower air flow limit and not be detected. This can result in the spread of smoke from one fire compartment to another at low velocities.

Design Element	Feature	Code/Standard Reference	Requirement	Design Performance Considerations
Emergency Electrical Power	Motor driven damper and/ or electrically operated smoke detector	N/A	• A smoke damper is not required by the 2018/2024 BCBC to be provided with emergency power. • The smoke detector is not required to be connected to a fire alarm system*. The 2018/2024 BCBC does not require that smoke detectors that are not connected to a fire alarm system be provided with emergency power.	No emergency power provided. This means that during a power outage, the smoke damper may not operate.

* The smoke detector is not required by the 2018/2024 BC Building Code to be connected to the fire alarm system, only "located as described in CAN/ULC-S524, 'Installation of Fire Alarm Systems'".

This is supported by a review conducted by the Standing Committee on Fire Protection relative to an enquiry as to whether the requirements of Sentence 3.1.8.11.(3) for a smoke detector invoke the requirement for a fire alarm system even in a building that would not otherwise be required to have a fire alarm system. The results of the review noted that:

there is no clear indication that the smoke detector used for this purpose is also required to:

- *be connected to a fire alarm system;*
- *activate the fire alarm system; or*
- *notify the occupants for timely evacuation.*

Given the performance considerations detailed in **Table 1**, smoke is expected to spread from one fire compartment to the other through the duct when designed in conformance with Sentence 3.1.8.7.(2) and Article 3.1.8.11. The quantity of smoke entering an adjacent fire compartment would be a function of the density of smoke and airflow in the duct. The magnitude of smoke spread considering these factors will be a function of the time for a smoke damper to operate and limit any further spread of smoke.

Therefore, it is proposed to compare the performance of a design in compliance with Sentence 3.1.8.7.(2) to the alternative design on the basis of timing. On this basis, the following sequence of events is expected to occur relative to the operation of the smoke damper when designed in compliance with Sentence 3.1.8.7.(2) and Article 3.1.8.11.:

1. **Detection:** The smoke is detected by the duct smoke detector. Detector activation is difficult to quantify as it is a function of smoke concentration, airflow and detector sensitivity. Therefore, it is assumed that the detector could take from several seconds to minutes to detect smoke.
2. **Response:** The duct smoke detector activates the smoke damper actuator. It is assumed that this is instantaneous but may be delayed by several seconds. This would be further exacerbated by Sentence 3.1.8.11.(3), permitting the detector to be as much as 1.5 m downstream of the damper. This is expected to further delay the activation of the damper relative to the amount of smoke that passes downstream of the damper (and therefore beyond the fire compartment boundary).

3. **Activation:** The smoke damper actuator closes the smoke damper and limits further spread of smoke in the duct. As noted in **Table 1**, this can take up to 75 seconds and during that time smoke is expected to continue to pass downstream of the damper.

The performance of a design in compliance with Sentence 3.1.8.7.(2) and Article 3.1.8.11. is expected to result in the continued spread of smoke from one fire compartment to another as a function of the events and timing detailed above. This performance and these events will be further considered later in this report relative to the comparative performance of the proposed alternative design.

3.4. Energy Objectives Attributed to the Use of ERV/HRVs

The use of ERV/HRVs are supported by the energy efficiency objective of the 2018 BCBC, which intends to limit the probability of inefficient energy performance of buildings or building components [OE1.1] caused by:

- unnecessary demand and/or consumption of energy for heating and cooling [F95],
- inefficiency of equipment [F98], and
- unnecessary rejection of reusable waste energy [F100].

3.5. Risk of False Alarms from Duct-Mounted Smoke Detectors

Having duct-mounted smoke dampers in individual air supply/exhaust duct connections to/from residential suites creates a risk of false alarms by setting off smoke detectors in exhaust ducts by steam from showers or cooking smoke where kitchens are located close to bathrooms. This problem has already been reported by some BC Housing buildings provided with smoke/fire dampers in duct connections from a central ventilation system.

3.6. Development and Basis of Sentence 3.1.8.7.(2)

The changes to Sentence 3.1.8.7.(2) were initiated by a proposed code change during the development of the 2010 National Building Code of Canada (2010 NBCC) and upon review several challenges were identified relative to interpretations of the intended performance of a fire separation relative to the passage of smoke. A Task Group was formed for the development of the 2015 NBCC to address the issue of smoke tightness of closures in fire separations. The following was noted relative to inconsistencies in the interpretation of the intent of a fire separation relative to limiting the passage of smoke [3]:

> *The National Building Code (NBC 2005) is unclear whether a fire separation is meant to act as a barrier to the passage of smoke. As currently provided for in the Code, it is highly possible that in a fire, a doorway opening would be required to close upon detection of smoke in the vicinity, yet a large air-transfer opening immediately above the door may remain open allowing large quantities of toxic combustion gases to pass through the fire separation until the ambient air gets hot enough to melt a fusible link that causes a fire damper to close. Some authorities having jurisdiction and designers, however, will base their design or enforcement on the perceived intent. For the situation described above, these jurisdictions and designers would require the air-transfer opening be closed at the same time as the adjacent door.*

The Task Group recommended changing the appendix note to the definition of “fire separation” to refer to all products of combustion including smoke relative to the performance of a fire separation in limiting the spread of fire and smoke. This change was seen as formalizing what was already the intent of the Code based on the industry term “smoke separation” attributed to a fire separation that does not require a fire-resistance rating.

In addition to the definition change, the Task Group recommended introducing provisions for smoke dampers in fire separations in areas of buildings considered critical to the life safety of occupants and to clarify the intent of the provision of a fire separation and facilitate appropriate application of the associated requirements. Fire separations serving residential buildings were considered critical to the life safety of the occupants given the "current high rate of deaths due to smoke inhalation".

The Proposed Change (PC) resulting in the requirement for smoke dampers in Sentence 3.1.8.7.(2) justified the change to the Code noting that [4]:

> *Statistically, approximately 80% of fire deaths are caused by smoke inhalation. Preventing the passage of smoke in specific areas should significantly reduce the likelihood of smoke propagation in the means of egress, which should contribute to safety to persons trying to escape a building on fire.*

The cost implications identified in the PC included several examples of typical installations in residential, care and office buildings ranging from small to large in size. The result of the cost implication analysis noted the following [4]:

> **1.** Five-Storey Office Building
>
> - Total mechanical cost: $1 100 000
> - Total smoke dampers required: 9
> - Total smoke damper cost ($2400/damper installation): $21 600
> - Total New Cost with smoke dampers included $1 121 600
> - Increase to mechanical cost: 1.96%
>
> …
>
> *Other than the 5-storey office building the cost increase for installing the additional smoke dampers was negligible. For the 5-storey building the increased cost although small represented a significant change in cost. This change, however, could have been mitigated through a different choice of duct routing. Had this happened then only five smoke dampers would have been required.*
>
> *Once designers become accustomed to the proposed changes, then design decisions can be made to route ducting in a way that will minimize the need for smoke dampers as is typically done to minimize the quantity of fire dampers required.*

The result of the cost implication analysis noted a significant cost increase for the 5-storey office building example with 9 smoke dampers and suggested that this cost could be mitigated through different duct routing.

In summary, the change to Sentence 3.1.8.7.(2) to require smoke dampers in fire separations was rationalized based on:

- A change to the definition of fire separation to clarify the intent of limiting the passage of products of combustion including smoke, which was considered a formalization of what was already the intent of the Code based on the industry term "smoke separation" which was attributed to a fire separation that does not require a fire-resistance rating.
- Air-transfer openings and ducts penetrating a fire separation could potentially allow large quantities of toxic combustion gases to pass through the fire separation prior to activation of the fusible link that causes a fire damper to close.
- Approximately 80% of fire deaths are caused by smoke inhalation and preventing the passage of smoke in specific areas should significantly reduce the likelihood of smoke propagation in the means of egress, which should contribute to safety of persons trying to escape a building on fire.
- The increased mechanical cost to a project of approximately 0.5% (for projects other than the 5 storey example shown above) was considered negligible and higher costs could be mitigated through a different choice of duct routing.

The Cost analysis does not appear to have taken in consideration the requirements of the National Energy Code or the BC Step Code, adopted at the same time, that effectively makes the default options in the Code for dwelling units impractical due to limitations in duct sizes.

Further it does not appear to have fully recognized that both the number of reported fires and number of fire deaths per reported fire are significantly less than in unsprinklered buildings. Similarly, in a sprinklered building, smoke propagation outside the room of fire origin is significantly reduced. Note that the solution to limit smoke spread developed by the Task Group is specific to provision of a physical barrier and does not consider other methods such as pressure differentials, which are permitted for the same purpose by other parts of the 2018/2024 BCBC. Smoke control by pressure differential will be discussed in more detail later in this guide.

3.7. Application of Sentence 3.1.8.7.(2) to BC Housing Projects

Central ERV/HRV units are considered as the practical and cost-effective method of providing energy recovery for ventilation and allowing for partial mechanical cooling of residential suites to achieve BC Housing and Provincial energy performance targets. As outlined earlier, a central ventilation system requires multiple small penetrations of the residential corridor's walls (two per each residential apartment), which in accordance with Sentence 3.1.8.7.(2) would require tens to hundreds of combination smoke/fire dampers be installed.

Requiring combination smoke/fire dampers will result in a significant initial cost of installing the dampers (powered/controlled from the fire alarm system), providing additional duct mounted smoke detectors (within 1.5 m downstream of each fire/smoke damper), and requiring ongoing annual inspection and maintenance requirements in conformance with CAN/ULC-S536, "Standard for Inspection and Testing of Fire Alarm Systems". This is further complicated where smoke dampers are required and installed in a building that is not equipped with a fire alarm system. The addition of so many devices as a part of the building's life safety system will also increase the probability of failure of one or more of the system components, limiting the intended operation of the system and daily functionality of the building. The provision of ERVs in each dwelling unit would reduce or eliminate the required combination smoke/fire dampers, but it should not be the only solution for BC Housing projects for all the reasons outlined in **Section 2.0** of this guide.

Therefore, it is proposed to permit the use of central ERV/HRVs for BC Housing multi-family residential unit projects without the provision of combination smoke/fire dampers on a performance-basis, which will be detailed in the following section of this guide. This will allow these projects to meet BC Housing and provincial energy reduction objectives, maintain the affordability of social housing projects and thermal comfort for BC Housing's populations, and address climate change, smoke mitigation and overheating.

4.0 COST ANALYSIS OF COMBINATION SMOKE/FIRE DAMPERS VERSUS FIRE DAMPERS

This section provides cost analysis of smoke/fire dampers in relates to capital cost with two sample BC Housing projects.

4.1. Itemized Costs

Table 2 provides an itemized installation cost for both smoke/fire dampers and fire dampers for typical 6" Ø branch ducts as well as larger rectangular ducts.

Table 2 smoke/fire dampers and Fire Damper Itemized Cost Comparison

Item	Wholesale Price	Contractor's Markup-15%	Mechanical Installation Cost	Electrical Installation Cost	Commissioning Cost	Total Cost
Combination Smoke/Fire Dampers						
6"Ø smoke/fire dampers[1]	$ 1,130	$ 170	$ 455	$ 260	$ 60	$ 2,075
Rect. smoke/fire dampers[1]	$ 1,260	$ 189	$ 507	$ 290	$ 70	$ 2,316
[1] 12GA sleeve, motorized actuator, integral smoke detector, test switch						
Fire Dampers Type C and A						
6"Ø fire dampers	$ 106	$ 16	$ 105	$ --	$ 25	$ 252
Rect. fire dampers	$ 119	$ 18	$ 110	$ --	$ 30	$ 277
The above costs are exclusive of taxes						

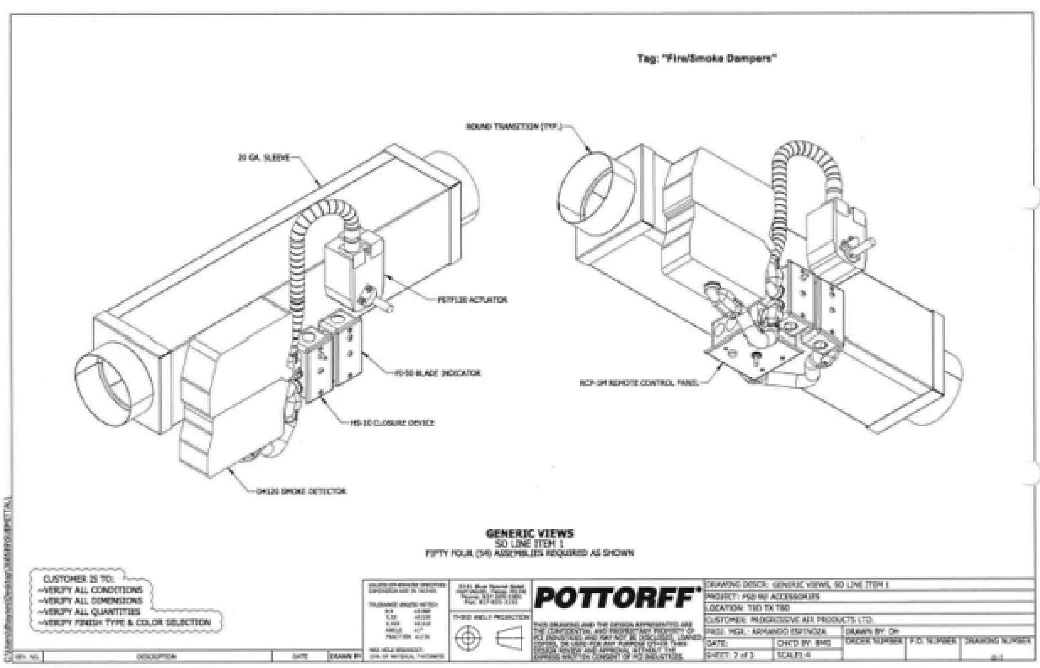

Figure 2: Typical smoke/fire dampers assembly for small round ducts c/w factory mounted smoke detector & test switch

4.2. Examples

4.2.1. New Vista Affordable Housing, 7898 18th Avenue, Burnaby, BC

This is a three-storey building with a concrete parkade. There are 25 residential suites, in a mix of studio, one-bedroom, two-bedroom, and three-bedroom suites. Total building floor area – 2,009 m^2 (21,625 ft^2), parkade area – 929 m^2 (10,000 ft^2).

The Issued for Construction Drawings were completed in March 2021. The alternative solution was not successful to eliminate the smoke/fire dampers as per the direction of AHJ; therefore, smoke/fire dampers were provided at all supply and exhaust connections from the roof mounted, central ventilation unit to all residential suites, the amenity area, and connections from duct risers to corridor ceiling spaces.

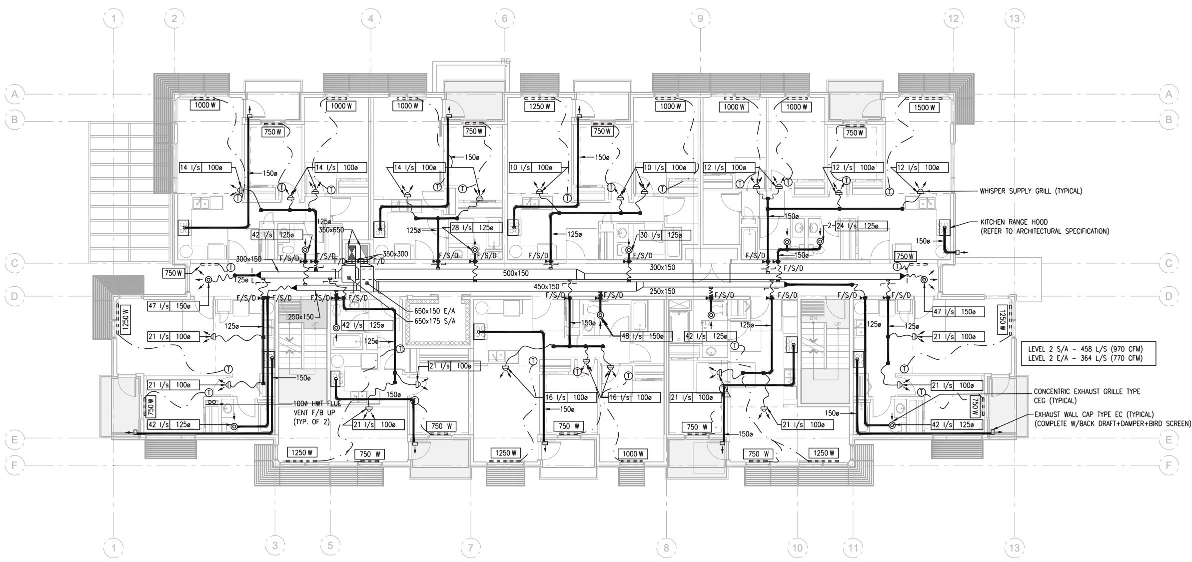

Figure 3: Typical floor plan

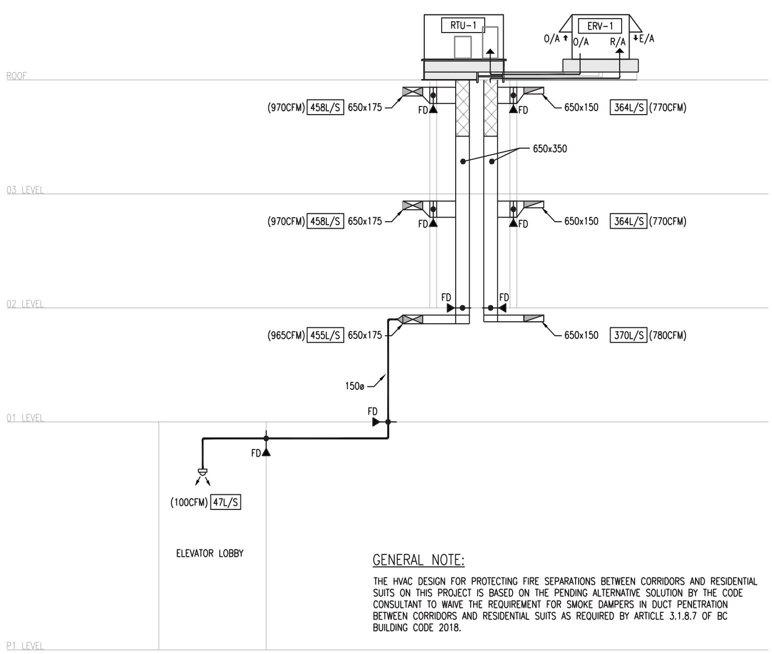

Figure 4: Air distribution schematic

There were 50 x 6"Ø smoke/fire dampers at penetrations between corridors and residential suites, 3 x 6"Ø at penetrations between the corridor and the amenity space on Level 1, and 6 larger rectangular smoke/fire dampers at penetrations between corridors and the main duct riser.

Table 3 provides a cost comparison between smoke/fire dampers and fire dampers.

Table 3: Example 1 Cost Comparison

Type \ Size	6"Ø		Larger Rectangular		Cost
	#	Cost	#	Cost	
Smoke/Fire Dampers	53	$2,075	6	$2,316	$123,871
Fire Dampers	53	$252	6	$277	$15,018
				Cost Difference	**$108,853**

The total construction cost of this project is $9,027,000 and the mechanical cost was $1,004,800. The extra cost of smoke/fire dampers amounted to 1.21% of the total cost and 10.8% of the mechanical cost. The cost excludes any replacement, annual inspection, or operational costs over the life of the building.

4.2.2. Sohkeya Phase 2 Affordable Housing, 7563-7565 140th Steet, Surrey, BC

This project includes 4-storey Building B **(Figure 5)** and three-storey Building C **(Figure 6)** located on top of the common, concrete parkade. There are 60 residential suites in Building B and 44 residential suites in Building C (104 in total), in a mix of studio, one-bedroom, two-bedroom, and three-bedroom suites. Total Building B floor area – 4,633 m^2 (49,864 ft^2), total Building C floor area – 3,127 m^2 (33,662 ft^2) (7,760 m^2-86,526 ft^2 in total), parkade area – 4,157 m^2 (44,750 ft^2).

The Issued for Tender Drawings were completed in September 2021. The Alternate Solution was not successful to eliminate the smoke/fire dampers as per the direction of AHJ; therefore, smoke/fire dampers were provided at all supply and exhaust connections from the two, roof mounted, central ventilation units to all residential suites, the amenity area, laundry rooms, and connections from duct risers to corridor ceiling spaces.

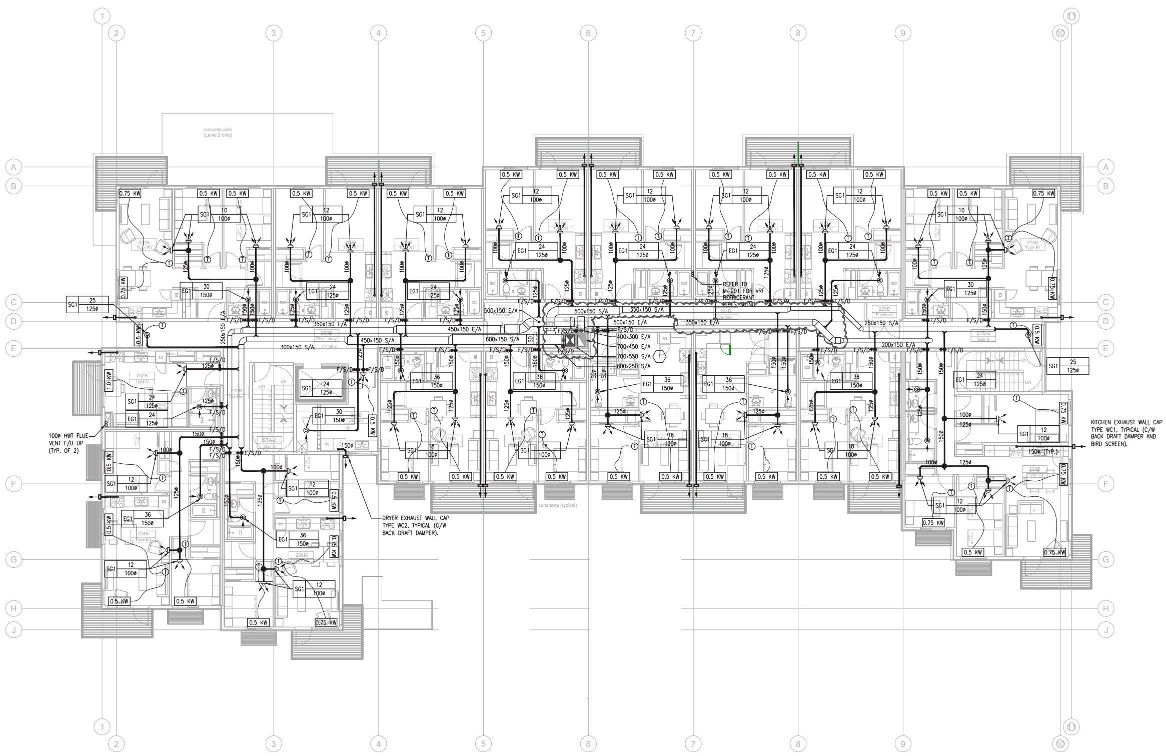

Figure 5: Building B typical floor plan

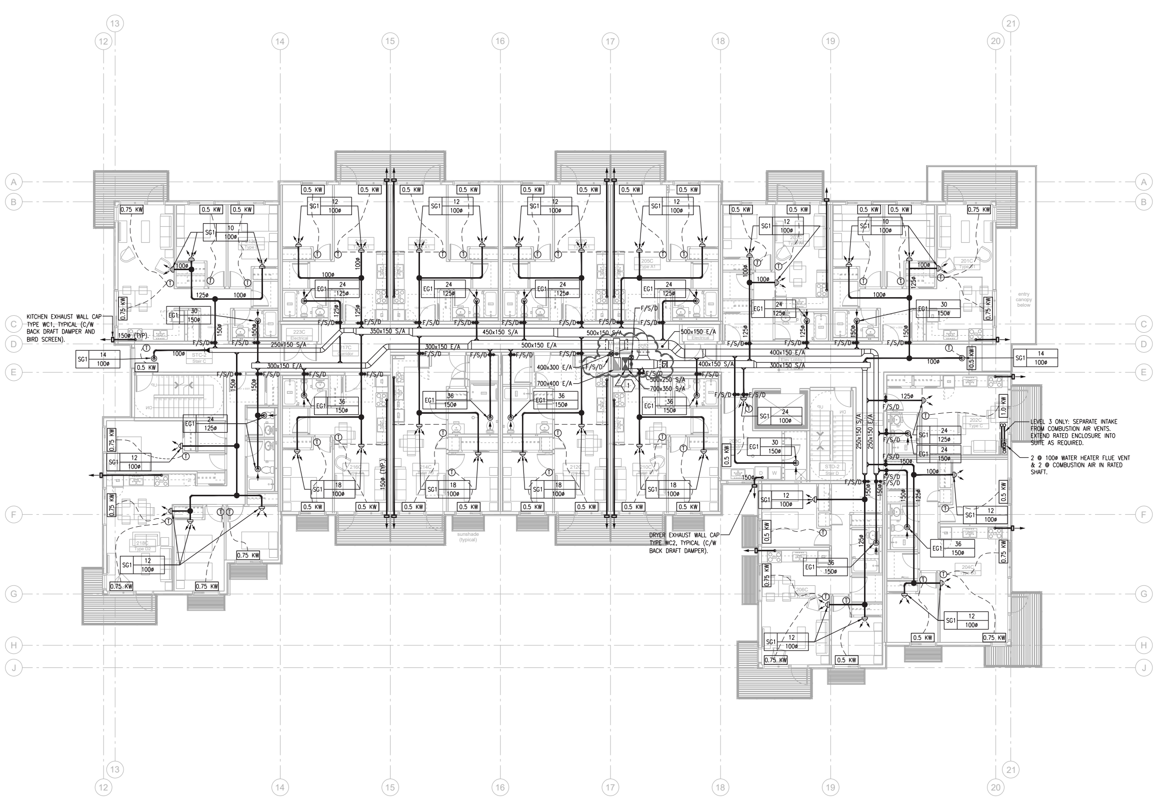

Figure 6: Building C typical floor plan

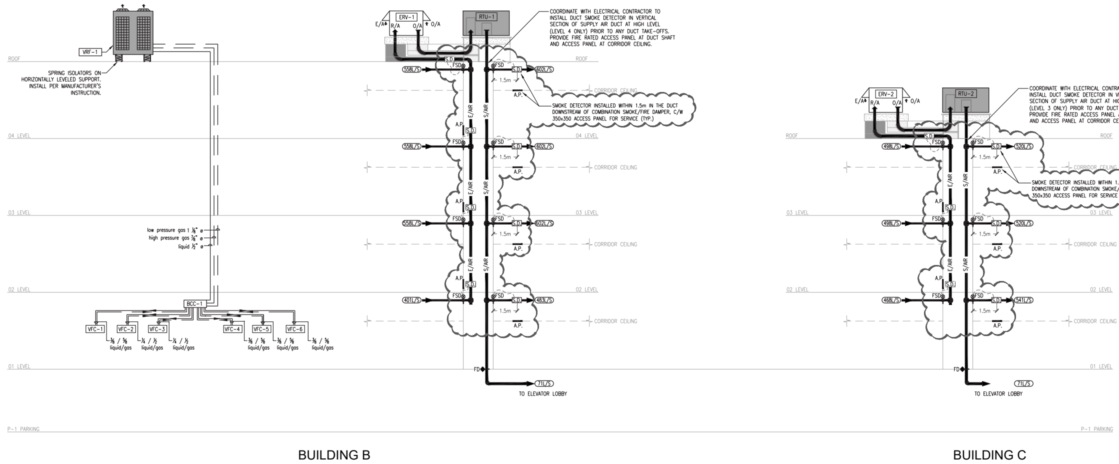

Figure 7: Air Distribution Schematic

There were 208 x 6”Ø smoke/fire dampers at penetrations between corridors and residential suites, 17 x 6”Ø at penetrations between the corridor and the amenity space & laundry rooms, and 14 larger, rectangular smoke/fire dampers at penetrations between corridors and the main duct riser.

Table 4 provides a cost comparison between smoke/fire dampers and fire dampers.

Table 4 Example 2 Cost Comparison

Size / Type	6”Ø		Larger Rectangular		Cost
	#	Cost	#	Cost	
Smoke/Fire Dampers	225	$2,075	14	$2,316	$499,299
Fire Dampers	225	$252	14	$277	$60,578
				Cost Difference	**$438,721**

The total construction cost of the project was $28,129,500 and the mechanical cost was $3,592,600. The extra cost of smoke/fire dampers amounted to 1.56% of the total cost and 12.2% of the mechanical cost. The cost excludes any replacement, annual inspection, or operational costs over the life of the building.

4.3. Cost Comparison Conclusion

The cost analysis of utilizing combination smoke/fire dampers versus regular fire dampers in ductwork distributions from central ventilation systems indicates the extra construction cost of between 1.2% to 1.6% of the total project cost and between 11% to 12% of the mechanical cost. These costs do not include the maintenance costs of annual testing of smoke/fire dampers as a part of testing the life safety systems. Typically, it is considered that the operation and maintenance costs for the lifecycle of a building can be up to 80% of the total project lifecycle cost whereas 20% is only capital costs.

If the requirement for utilizing smoke dampers in all fire separations required in residential occupancies cannot be avoided thorough alternative methods, the central ventilation systems shall be avoided on the BC Housing projects due to significant additional construction and maintenance costs.

5.0 Approach to Compliance

Compliance with the 2018/2024 BCBC is achieved by complying with the applicable acceptable solutions in Division B or using alternative solutions. Alternative Solutions are those that are accepted by the AHJ under Section 2.3 of Division C, which will achieve at least the minimum level of performance required by Division B in the areas defined by the objectives and functional statements attributed to the applicable acceptable solutions [Sentence 1.2.1.1.(1)].

The BCBC further notes that a proponent of an alternative solution must demonstrate that the alternative solution addresses the same issues as the applicable acceptable solutions in Division B and their attributed objectives and functional statements, and an effort is required to demonstrate that an alternative solution will perform as well as a design that would satisfy the applicable acceptable solutions in Division B.

The following sections of this guide detail a performance-based approach to achieving the objectives attributed to Sentence 3.1.8.7.(2) in requiring smoke dampers where ducts penetrate fire separations. This performance-based approach can be used to support the development of a project-specific alternative solution.

5.1. Sentence 3.1.8.7.(2) Performance Criteria and Development Considerations

As noted in **Section 3.2** of this guide, the objective of Sentence 3.1.8.7.(2) is to limit the probability that smoke will spread from one fire compartment to another fire compartment through openings in a fire separation. This is achieved by providing a physical barrier (smoke damper) that is activated by the fire alarm system upon activation of a proximal smoke detector. This solution was rationalized based on an analysis of the intent of a fire separation, the potential for smoke movement through air-transfer openings and life safety considerations. The development of the ultimate solution (smoke dampers) was based on a balance of the benefits smoke dampers provide to limit smoke movement, relative to the cost to provide smoke dampers. It is not clear from the available information whether other solutions to limiting smoke spread were considered and the cost analysis was limited in breadth and potentially not considering the substantial cost implications in residential applications including capital, maintenance, inspection and on-going operation.

The following sections of this guide examine the rationalization of Sentence 3.1.8.7.(2) and other available methods to limit the spread of smoke from one fire compartment to another.

5.1.1. Rationalization of Sentence 3.1.8.7.(2)

As outlined in **Section 3.5** of this guide, the change to Sentence 3.1.8.7.(2) to require smoke dampers in fire separations was rationalized, in part, based on an increased mechanical cost to a project of approximately 0.5%, which was considered negligible and that higher costs could be mitigated through a different choice of duct routing .

This cost increase of 0.5% was based on the requirement of less than 5 smoke dampers for a single building, whereas an increased mechanical cost associated with requiring 9 smoke dampers at an increase mechanical cost of 1.96% while not considered negligible, was considered acceptable given the option to reroute the ducting, thus reducing the number of smoke dampers to 5.

As noted in **Section 3.7** of this guide, as a result of the configuration of the ducting for an ERV/HRV in BC Housing projects, a significantly larger number of smoke dampers would be required than for the cases examined by the Task Group in the development of Sentence 3.1.8.7.(2). Three example BC Housing residential projects with central ERV/HRV systems were examined and the number of smoke dampers that would be required based on Sentence 3.1.8.7.(2) ranged from 50 to 250 for typical units ranged from 5 – 70 unit for low to mid-rise construction The cost increase associated with the provision of this number of dampers would be significant. Based on a cost analysis of recently complete BC Housing facilities, the requirement for smoke/fire dampers increased the mechanical costs by ~11-12% and the overall project costs by 1.2-1.6% [**Section 4.3**].Thus, installation of smoke dampers and associated smoke detectors in 5 to 6 inch diameter ducts is not practical.

Rerouting the ducting is not possible without utilizing in-suite ERVs or using more conventional de-centralized heating/cooling systems. However, as noted in **Section 1.1** of this guide, these design approaches would limit option of achieving BC Housing and provincial energy objectives while maintaining housing affordability.

Other methods of limiting smoke movement from one fire compartment to another fire compartment are available without the provision of smoke dampers at all fire separations. One such method is discussed in the following section of this guide.

5.1.2. Care and Treatment Occupancies

Clause 3.1.8.9.(1)(c) waives the requirement for smoke dampers in ducts that penetrate a vertical fire separation required by Sentence 3.3.3.5.(4) for dividing fire compartments for patients' or residents' sleeping rooms provided:

- the movement of air is continuous, and
- the configuration of the air-handling system prevents the recirculation of exhaust or return air under fire emergency conditions.

Care and treatment occupancies containing patients' or residents' sleeping rooms are considered by the Code to house a more vulnerable population than would be expected in the BC Housing residential buildings. Provision of a central ERV/HRV system as proposed in this guide, would not require smoke dampers where those ducts penetrate the fire separations of patients' or residents' sleeping room fire compartments. Note that these fire compartments are required by Sentences 3.3.3.5.(1) and (2) to separate groups of patients' or residents' sleeping rooms into areas not more than 1000 m^2.

5.1.3. Other Smoke Control Methods

As noted in **Section 3.5** of this guide the means by which Sentence 3.1.8.7.(2) intends to achieve the objective of limiting smoke movement from one fire compartment to another is through the provision of a physical barrier, and does not recognize other methods permitted to achieve the same objective by other parts of the 2018/2024 BCBC. One such method is provision of a pressure differential between a compartment involved in fire and an adjacent space creating an opposing air flow that impedes the movement of smoke into that space.

Sentence 3.2.6.2.(3)[6] of the 2018/2024 BCBC requires that for high buildings each stairway that serves storeys above the lowest exit level is vented to the outdoors, at or near the bottom of the stair shaft. The explanatory note to this requirement states that:

> *The purpose of providing open doors and vents at the bottom of a stair shaft is to create a positive pressure in the shaft relative to adjacent floor areas and thus keep it free of smoke.*

6 The proposed Alternative Solution is not being anticipated for use in a building considered by the 2018 to be a 'high building' [Subsection 3.2.6. of the 2018 BCBC], but to illustrate that the 2018 BCBC considers other means to limit the movement of smoke from one fire compartment to another, other than a physical barrier.

This requirement anticipates the movement of occupants and firefighters between floor areas and exit stairs, and the potential for smoke to spread from a floor area to an exit during such movement. Note that this requirement is not intended to completely limit the movement of smoke from a floor area (one fire compartment) to an exit stair (another fire compartment), which is impractical. The smoke movement requirements of the 2018/2024 BCBC allow an exit stair to contain up to 1% by volume of contaminated air from the fire floor [Sentence 3.2.6.2.(2)].

The explanatory note to the smoke movement requirements of the 2018/2024 BCBC for high buildings further note that:

> *If mechanical methods are used to develop a positive pressure in a stair shaft, a minimum pressure differential of 12 Pa is recommended to prevent smoke migration from floor areas in a sprinklered building where fire temperatures are controlled and smoke movement may be dominated by stack effect in a stair shaft.*
>
> …
>
> *The maximum pressure differential created by a mechanical system should not prevent doors to the stair shafts from being opened.*

This explanatory note identifies an important consideration relative to pressure differentials and the impact on exit/egress doors, which will be discussed later in this guide relative to challenges associated with the provision of barrier-type smoke dampers.

Similar to the high building requirements of the 2018/2024 BCBC, NFPA 92, "Standard for Smoke Control" considers the following design approaches relative to smoke containment:

- Stairwell pressurization,
- Zoned smoke control,
- Elevator pressurization,
- Vestibule pressurization, and
- Smoke refuge area pressurization

There are numerous other codes and standards that provide similar pressure differential methods to control smoke movement from one fire compartment to another.

5.2. ERV/HRV Operational Considerations Relative to Smoke Spread

The following sections of this guide examine central ERV/HRV operational considerations relative to two potential avenues for smoke to spread from one fire compartment to another.

5.2.1. Fires in Compartments

As noted earlier, the central ERV/HRV is intended to operate continuously and provide 100% outdoor air to each housing unit through noncombustible ducts with no recirculation of air. The supply and exhaust systems will be physically separate. This means that in the event of a fire in a dwelling unit, smoke will be impeded from entering the duct as a result of opposed airflow created by the supply duct. Smoke entering the exhaust duct would be impeded from spreading to other housing units due to the negative pressure created by the ERV/HRV exhaust duct system and would be exhausted to the exterior of the building.

Buildings are becoming more airtight as a function of the increasing energy performance targets[7]. Recent full scale testing [5, 6] to examine the impact of the increased airtightness on compartment fire conditions have shown that fire-induced overpressure peaks of 850 to 2035 Pa were measured without mechanical ventilation (ducts closed), and values from 420 to 750 Pa were measured with the mechanical ventilation operating. Pressures in the hundreds of pascals were observed within the first 23 seconds following ignition [5], which is expected to occur prior to sprinkler activation. The magnitude of the pressure increase in a compartment fire tends to correlate with the magnitude of the fire based on compartment temperatures. If the temperature is reduced, the pressure tends to drop. Accordingly, sprinkler controlled fires would generally have lower temperatures and correspondingly lower pressures than in unsprinklered buildings.

If the overpressure in the fire compartment is greater than the supply pressure of the ERV/HRV system, backflow of smoke into the duct system is possible. However, the extent of backflow is expected to be limited by the following:

1. **Sprinklered buildings:** In a sprinklered building, activation of the sprinkler system is expected to reduce the temperature of the fire compartment, which would reduce the pressure and subsequent backflow potential. Sprinklers are expected to operate within the first few minutes of fire growth; thus, the overpressure in a sprinklered compartment is expected to be short in duration, significantly limiting the potential for smoke spread in a duct system. Note that all new BC Housing buildings are being provided with automatic sprinkler systems utilizing quick response residential sprinkler heads.
2. **Activation of the fire damper by hot fire gases:** In the remote event that the sprinkler system does not operate, fire growth in the fire compartment is expected to increase compartment temperature and at approximately 75 °C to 140 °C cause the fire damper link to fuse, closing the damper and limiting backflow.

In addition to the potential for backflow in the central ERV/HRV duct system, fire compartment overpressures can also result in pressures on inward opening doors, limiting occupant's ability to open the door and escape. This is a growing concern relative to the shift toward more airtight structures. In associated testing, this was observed to occur in an unsprinklered fire compartment for up to 3 minutes [5] following the development of an overpressure condition. A system that includes combination smoke/fire dampers in conformance with Sentence 3.1.8.7.(2) would not provide any relief to the overpressure. However, an ERV/HRV system that continues to operate would provide some overpressure relief by way of the exhaust system. This was measured in the testing, summarized above, where the overpressure of a compartment with mechanical ventilation operating was approximately half to one-third of the overpressure with ducts closed.

5.2.2. ERV/HRV, Roof Fires, and Smoke Re-entrainment

In the event that fire originates in the central ERV/HRV, or the ERV/HRV is impacted by exterior smoke spread or roof fire, a smoke detector in the supply fan section will shut down the ERV/HRV. This will limit the probability of the spread of smoke to the interior corridors or individual housing units from a fire in the ERV/HRV, involving the roof, or through re-entrainment from the exterior.

5.3. Proposed Performance-Based Solution Design and Maintenance Requirements

Clause 3.1.8.9.(2)(a) exempts the requirement for smoke dampers where noncombustible branch ducts have a melting point above 760 °C that penetrate a fire separation for:

- **Supply Ducts:** where the ducts have a cross-sectional area not more than 0.013 m^2 and serve only air-conditioning units or combined air-conditioning and heating units discharging air not more than 1.2 m above the floor [Subclause 3.1.8.9.(2)(a)(i)].

7 BC Housing, Airtightness Guidelines, https://www.bchousing.org/research-centre/library/residential-design-construction-guides/illustrated-guide-achieving-airtight

- **Exhaust Ducts:** where the ducts extend not less than 500 mm inside exhaust duct risers that are under negative pressure and in which the airflow is upward as required by Article 3.6.3.4. [Subclause 3.1.8.9.(2)(a)(ii)].

Article 3.6.3.4. requires that if a vertical service space contains an exhaust duct that serves more than one fire compartment,

a) the duct is required to have a fan located at or near the exhaust outlet to ensure that the duct is under negative pressure, and

b) the individual fire compartments are not permitted to have individual fans that exhaust directly into the duct in the vertical service space.

The duct configurations permitted by the exemption in Clause 3.1.8.9.(2)(a) are not considered to "lead to a significant spread of smoke" [NBCC 2015 Intent Statements].

The ERV/HRV supply ducts will serve only air-conditioning/heating units, be constructed of noncombustible materials, and have a cross-sectional area at the supply port to each residential unit between 0.013 to 0.018 m^2 (5" to 6" diameter) in cross-sectional area. However, the supply duct port is intended to be located near ceiling level of the residential units (approx. 2.4 m). The ERV/HRV exhaust ducts will be constructed of noncombustible materials and will operate under negative pressure with an upward airflow consistent with that required by Article 3.6.3.4. Therefore, while the supply/exhaust duct system does not directly comply with all of the parameters identified in Clause 3.1.8.9.(2)(a), the system is expected to perform as intended by the exemptions and not lead to a significant spread of smoke.

5.3.1. Proposed Design

Based on the analysis outlined in this guide, the following design elements and parameters are proposed to provide a design that achieves the objectives, functional and intent statements attributed to Sentence 3.1.8.7.(2), and that is consistent with the intent of the exemptions permitted by Clause 3.1.8.9.(2)(a):

- Provision of a smoke detector in the ERV/HRV's supply fan section. This will limit the probability of smoke spread through the duct system by the ERV/HRV if there is an ERV/HRV/roof fire or smoke re-entrainment from outside of the building.
- Continued operation of the system following initiation of the fire alarm system[8]. The continuous operation of the system is intended to positively pressurize the supply air ductwork and negatively pressurize the exhaust air ductwork to limit smoke spread to other compartments. This will limit the probability of backflow into the duct system based on the same principles required by Subsection 3.2.6. of the 2018/2024 BCBC for high buildings.
- The provision of 100% outdoor air to each unit with no recirculation. This will limit the probability of recirculation of contaminated air.
- No isolation dampers will be installed on the supply and exhaust sides of the central ERV/HRV unit. This will facilitate the potential stack effect to direct smoke through the duct system to the outside even when the unit is shut down by the smoke detector in the ERV/HRV's fan supply or building power is disabled.
- Continuous noncombustible ducts and branch ducts up to the interface with the residential unit it serves (noncombustible flexible ducts are permitted on the suite side). This will maintain the continuity of the duct system if exposed to high temperatures, limiting the potential for smoke ingress due to failure of the duct system.
- Provision of smoke/fire dampers in conformance with Sentence 3.1.8.7.(1) and Article 3.1.8.10. In the remote event that backflow occurs, provision of a fire damper will limit the extent of smoke spread in the duct by closing the damper and limiting backflow.

8 Continued operation of the system may provide additional oxygen to an otherwise vitiated environment. However, the additional combustion that may occur as a result of the air supply will be limited, and the benefit will be provided by limiting smoke ingress into the ducts and a potential reduction in pressures on inward opening doors.

- Testing of the ERV/HRV and associated equipment in accordance with Sentence 3.2.9.1.(1), which requires that where fire protection and life safety systems and systems with fire protection and life safety functions are integrated with each other, they shall be tested as a whole in accordance with CAN/ULC-S1001, “Integrated Systems Testing of Fire Protection and Life Safety Systems,” to verify that they have been properly integrated. The testing of the mechanical system is required to be included in compliance with Sentence 3.2.9.1.(1).
- All BC Housing residential buildings are required by Section 1 of the BCH Design Guidelines [1] to be sprinklered whether required by the 2018/2024 BCBC or not. Additionally, this includes the provision of a fire alarm system.
- BC Housing residential buildings that have populations like at-risk homelessness, shelter, and transition homes and are provided with onsite support and supervision of 24 hours a day, 7 days a week [1].
- BC Housing residential buildings where there is potential risk of damage to in-suite smoke alarms, staffed on site 24/7, are provided with smoke detectors (in addition to the smoke alarms) inside the residential suites [1].

5.3.2. Proposed Maintenance Considerations

The following are recommended for maintenance of the central ERV/HRV system relative to this performance-based solution:

- Maintain the central ERV/HRV system in conformance with applicable codes and standards and BC Housing policies/guidelines for the provided components.
- Include this guide and associated Alternative Solution documentation with the maintenance documentation for the building and reference in the Fire Safety Plan. Any changes to the system would require re-examination of the associated Alternative Solution.

6.0 Conclusion

The performance-based approach outlined in this guide is to address Sentence 3.1.8.7.(2) of the 2018/2024 BCBC, which requires a smoke damper, or a combination smoke/fire damper, be installed at various locations in residential building ventilation systems. BC Housing projects have been utilizing central ERV/HRVs to achieve energy objectives and maintain thermal comfort for BC Housing's populations/residents through the provision of partial cooling. The nature of the ducting for the central ERV/HRVs would require that tens to hundreds of combination smoke/fire dampers be installed in new buildings, which far exceeds the number anticipated by the Task Group responsible for the development of the new Sentence 3.1.8.7.(2) requirements.

The proposed performance-based solution to Sentence 3.1.8.7.(2) is based on an existing smoke control principle permitted by the 2018/2024 BCBC for high buildings, by creating a pressure differential through continued operation of a central ERV/HRV during a fire condition. This eliminates the need for a smoke damper, which may exacerbate an overpressure condition in a fire compartment, limiting an occupant's ability to operate an inward-opening egress door. The provision of an unimpeded exhaust duct to a residential suite would tend to provide some relief to overpressure, easing the pressure on an inward-opening egress door.

In addition, the proposed system will achieve the objective of Subclauses 3.1.8.9.(2)(a)(i) and (ii), which will address the concern without the use of smoke dampers.

The following design and maintenance items are proposed to be included as part of an Alternative Solution for Sentence 3.1.8.7.(2):

- continued operation of the ERV/HRV upon initiation of the fire alarm;
- provision of 100% outdoor air with no recirculation;
- no isolation dampers in the ERV/HRV to keep the supply/exhaust duct system open to the outside;
- continuous noncombustible ducts and branch ducts;
- fire dampers in accordance with the 2018 BCBC;
- maintainenance of the central ERV/HRV system in conformance with applicable codes and standards and BC Housing policies/ guidelines; and
- inclusion of this guide and associated Alternative Solution documentation in maintenance documentation and reference to the Alternative Solution in the fire safety plan.

The design of the ERV/HRV system incorporating the items noted above will be at least as good as a system that complies with Sentence 3.1.8.7.(2) and will achieve the objective of limiting the probability that smoke will spread from one fire compartment to another fire compartment through openings in a fire separation.

7.0 Sources of Information

The following sources of information were referenced relative to the development of this guide:

1. BC Housing *Design Guidelines and Construction Standards 2019*.
2. HVAC Strategies for BC Housing projects
3. National Research Council of Canada, Canadian Commission on Building and Fire Codes, “Agenda for the 2010-02 Meeting of the Fire Protection Working Group on Smoke Tightness of Closures in Fire Separations”, December 10, 2010 Page B-3
4. National Research Council of Canada, Canadian Commission on Building and Fire Codes, “Public Review on Proposed Changes to the 2010 National Model Construction Codes — Fall 2012”, 2012.
5. Sylvain Brohez and Irene Caravita, ‘’ Overpressure induced by fires in airtight buildings”, *Journal of Physics: Conference Series*, Volume 1107, Issue 4.
6. Simo Hostikka, Rahul Kallada Janardhan, “Pressure management in compartment fires”, *Espoo*, November 28, 2016.

Appendix A

Standardized Alternative Solution Information

The following is supplemental information that can be used to support an alternative design solution by the respective Responsible Professional(s). **The information outlined below is required to be made Project specific and not used without due diligence on the part of the Responsible Professional(s).**

Items **highlighted** and **bolded** are known items that require updating based on each specific project.

Information in **RED TEXT**, are additional items for the Responsible Professional(s) to consider incorporating into their respective designs based on the specifics of the project and the requirements of the municipality.

Building Description and Scope of Project

1. Introduction

This Alternative Solution report has been prepared at the request of **CLIENT** relative to the application of Sentence 3.1.8.7.(2) of the **CODE** + **EDITION (20YY CODE)** to the BC Housing Project located at **PROJECT ADDRESS** (the "Project").

1.1. Building Description

The Project will be a **UPDATE TO SPECIFIC CLIENT (such as supportive, senior, family)** housing building containing a Group C major occupancy **with subsidiary assembly (Group A, Division 2) and business and personal service (Group D) spaces on the main floor**. The Project building will be **X** storeys in building height, approximately **XXX** m^2 in building area and fully sprinklered. The Project building will be constructed of combustible construction as permitted by Article 3.2.2.**XX**., "Group C, **UPDATE TO REFLECT ARTICLE OF CONSTRUCTION.**"

The Project building will include a centralized **energy/heat** recovery ventilator (**E/H**RV). The central **E/H**RV system requires two duct penetrations of the suite separation between the public corridor on each floor of the Project building and the residential suites units served by the **E/H**RV. These penetrations are shown in **Figure 8** with the supply duct highlighted in blue and the exhaust duct highlighted in green.

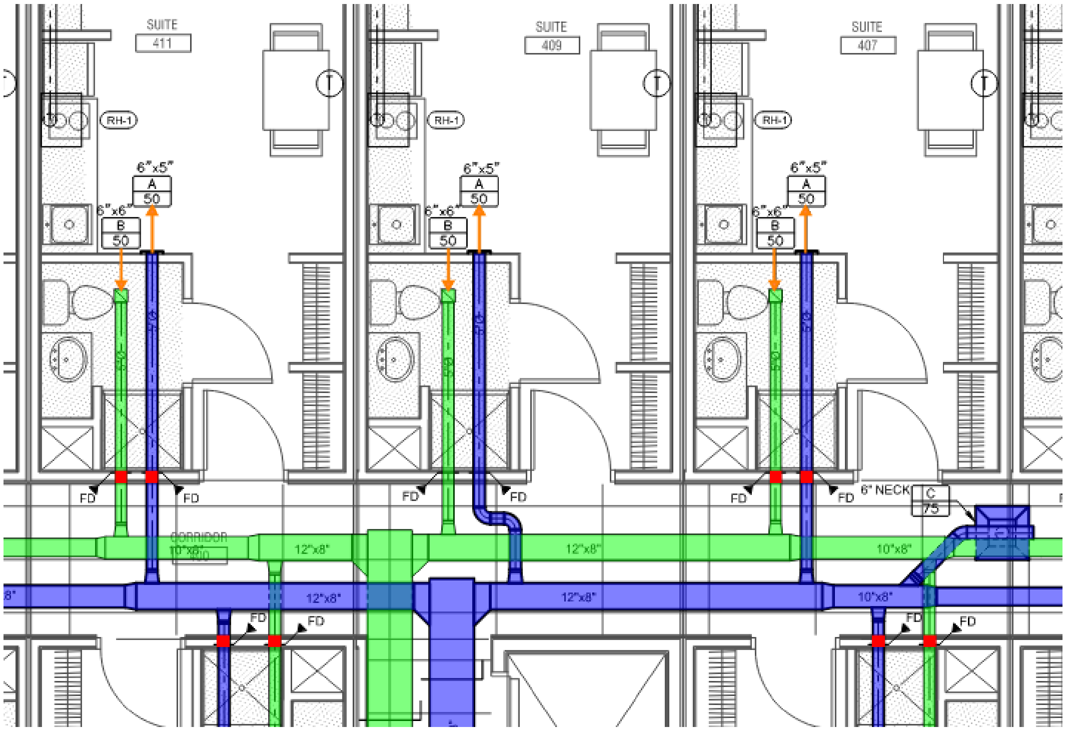

Figure 8: EXAMPLE Project building – typical HRV supply/exhaust duct configuration for residential suites.

The location of the duct penetration of the public corridor is shown highlighted **red**, and the flow of air is shown for each duct by the **orange** arrows in **Figure 8.** As discussed above, Sentence 3.1.8.7.(2) requires smoke dampers or combination smoke/fire dampers to be installed within 610 mm of the plane of the public corridor fire separation. FDS are shown in the plane of the fire separation between the units and the public corridor by **red** squares in **Figure 8**.

The Project building **E/H**RV system is intended to be operated continuously, with operating characteristics consistent with a smoke control system (i.e., pressure differentials and no recirculation).

Mechanical Drawings showing the **E/H**RV system and associated ducts are appended to the end of this Alternative Solution. **INCLUDE ALL MECHANICAL HVAC PLANS AND THE HVAC MECHANICAL SCHEMATIC.**

1.2. Scope of this Alternative Solution

Sentence 3.1.8.7.(2) requires smoke dampers or combination smoke/fire dampers for the duct penetrations of the public corridor fire separation for the Project building. The E/HRV is intended to operate continuously; therefore, it is proposed to permit the use of the centralized E/HRV for this Project without the provision of smoke dampers or combination smoke/fire dampers on an Alternative Solution basis.

The following sections of this report detail the applicable requirement for smoke dampers; the objective, functional and intent statements associated with the requirement; the level of performance associated with the requirement for smoke dampers; and the proposed approach to Alternative Solution compliance for this Project.

Building Code Edition, References, and Summary of Deviations

2. Applicable Requirements

The applicable building code for this Project is the **20XX CODE**. All building code references will be to the **20XX CODE** unless otherwise noted.

Sentence 3.1.8.7.(2) of the 2018/2024 BCBC requires that a smoke damper or a combination smoke/fire dampers be installed in conformance with Article 3.1.8.11. in ducts or air-transfer openings that penetrate an assembly required to be a fire separation, where the fire separation:

a) separates a public corridor,

b) contains an egress door referred to in Sentence 3.4.2.4.(2),

c) serves an assembly, care, treatment, detention or residential occupancy, or

d) is installed to meet the requirements of Clause 3.3.1.7.(1)(b) or Sentence 3.3.3.5.(4).

The Project building is a residential major occupancy; therefore, Clause 3.1.8.7.(2)(c) is applicable to all duct and air-transfer openings that penetrate an assembly required to be a fire separation in this Project. As noted, previously, an Alternative Solution is being proposed for the ducts that penetrate the fire separations between residential units and the public corridor serving these residential suites.

Article 3.1.8.11. requires the following relative to the installation of smoke dampers in ducts:

Damper Location and Access:

- **Air Transfer Opening:** where smoke dampers are used as a closure in an air-transfer opening, they are required to be installed in the plane of the fire separation [Sentence 3.1.8.11.(1)].
- **Combination smoke/fire dampers:** combination smoke/fire dampers are required to be installed within 610 mm of the plane of the fire separation, provided there is no inlet or outlet opening between the fire separation and the damper [Sentence 3.1.8.11.(2)].
- **Damper Position:** Smoke dampers or combination smoke/fire dampers are required to be installed in the vertical or horizontal position in which they were tested [Sentence 3.1.8.11.(4)].
- **Damper Access:** A tightly fitted access door shall be installed for each smoke damper and combination smoke/fire dampersto provide access for their inspection and the resetting of the release device [Sentence 3.1.8.11.(5)]. The access door is intended to be provided in the duct and, if the duct is enclosed with an architectural finish, that a second access door be provided through that finish [Note A-3.1.8.11.(5)].

Damper Activation:

- Except as required by a smoke control system, smoke dampers and combination smoke/fire dampers shall be configured so as to close automatically upon a signal from an adjacent smoke detector located as described in CAN/ULC-S524, “Installation of Fire Alarm Systems,” within 1.5 m horizontally of the duct or air-transfer opening in the fire separation [Sentence 3.1.8.11.(3)]:
  - on both sides of the air-transfer opening, or
  - in the duct downstream of the smoke damper or combination smoke/fire damper.
- There is no requirement for dampers to be provided with emergency power or to be designed to be normally closed in the event of a power failure.

2.1. Development and Basis of Sentence 3.1.8.7.(2)

Sentence 3.1.8.7.(2) was changed between the 2010 and 2015 editions of the National Building Code of Canada (2010 NBCC and 2015 NBCC) due to review of interpretations of the intended performance of a fire separation relative to the passage of smoke. A Task Group was formed for the development of the 2015 NBCC to address the issue of smoke tightness of closures in fire separations. The following was noted relative to inconsistencies in the interpretation of the intent of a fire separation relative to limiting the passage of smoke[9]:

The National Building Code (NBC 2005) is unclear whether a fire separation is meant to act as a barrier to the passage of smoke. As currently provided for in the Code, it is highly possible that in a fire, a doorway opening would be required to close upon detection of smoke in the vicinity, yet a large air-transfer opening immediately above the door may remain open allowing large quantities of toxic combustion gases to pass through the fire separation until the ambient air gets hot enough to melt a fusible link that causes a fire damper to close. Some authorities having jurisdiction and designers, however, will base their design or enforcement on the perceived intent. For the situation described above, these jurisdictions and designers would require the air-transfer opening be closed at the same time as the adjacent door.

The Task Group recommended changing the appendix note to the definition of "fire separation" to refer to all products of combustion including smoke relative to the performance of a fire separation in limiting the spread of fire and smoke. This change was seen as formalizing what was already the intent of the Code based on the industry term "smoke separation" attributed to a fire separation that does not require a fire-resistance rating.

In addition to the definition change, the Task Group recommended introducing provisions for smoke dampers in fire separations in areas of buildings considered critical to the life safety of occupants and to clarify the intent of the provision of a fire separation and facilitate appropriate application of the associated requirements. Fire separations serving residential buildings were considered critical to the life safety of the occupants given the "current high rate of deaths due to smoke inhalation".

The justification for the Proposed Change (PC) resulting in the requirement for smoke dampers in Sentence 3.1.8.7.(2) noted that[10]:

Statistically, approximately 80% of fire deaths are caused by smoke inhalation. Preventing the passage of smoke in specific areas should significantly reduce the likelihood of smoke propagation in the means of egress, which should contribute to safety to persons trying to escape a building on fire.

The cost implications identified in the PC included several examples of typical installations in residential, care and office buildings ranging from small to large in size. The result of the cost implication analysis noted the following[10]:

1. Five-Storey Office Building

- Total mechanical cost: $1 100 000
- Total smoke dampers required: 9
- Total smoke damper cost ($2400/damper installation): $21 600
- Total New Cost with smoke dampers included $1 121 600
- Increase to mechanical cost: 1.96%

. . .

9 National Research Council of Canada, Canadian Commission on Building and Fire Codes, "Agenda for the 2010-02 Meeting of the Fire Protection Working Group on Smoke Tightness of Closures in Fire Separations", December 10, 2010 Page B-3.

10 National Research Council of Canada, Canadian Commission on Building and Fire Codes, "PublicReview on Proposed Changes to the 2010 National Model Construction Codes — Fall 2012", 2012.

Other than the 5-story office building the cost increase for installing the additional smoke dampers was negligible. For the 5-story building the increased cost although small represented a significant change in cost. This change, however, could have been mitigated through a different choice of duct routing. Had this happened then only five smoke dampers would have been required.

Once designers become accustomed to the proposed changes, then design decisions can be made to route ducting in a way that will minimize the need for smoke dampers as is typically done to minimize the quantity of fire dampers required.

It was noted that the significant cost increase for the 5-storey office building example with 9 smoke dampers could be mitigated through different duct routing, which could work for a traditional ventilation system, but is impractical for an HRV-based system.

In summary, the change to Sentence 3.1.8.7.(2) to require smoke dampers in fire separations was rationalized based on:

- A change to the definition of fire separation to clarify the intent of limiting the passage of products of combustion including smoke, which was considered a formalization of what was already the intent of the Code based on the industry term "smoke separation", which was attributed to a fire separation that does not require a fire-resistance rating.
- Air-transfer openings and ducts penetrating a fire separation could potentially allow large quantities of toxic combustion gases to pass through the fire separation prior to activation of the fusible link that causes a fire damper to close.
- Approximately 80% of fire deaths are caused by smoke inhalation and preventing the passage of smoke in specific areas should significantly reduce the likelihood of smoke propagation in the means of egress, which should contribute to safety to persons trying to escape a building on fire.
- The increased mechanical cost to a project of approximately 0.5% was considered negligible, and higher costs could be mitigated through a different choice of duct routing.

Note that the solution to limit smoke spread developed by the Task Group is specific to provision of a physical barrier and does not consider other methods such as pressure differentials, which are permitted for the same purpose by other parts of the **20XX CODE**. Smoke control by pressure differential will be discussed in more detail later in this report.

2.2. Application of Sentence 3.1.8.7.(2) to BC Housing Projects

Central ERV/HRV units are considered as the practical and cost-effective method of providing energy recovery for ventilation and allowing for partial mechanical cooling of residential suites to achieve BC Housing and Provincial energy performance targets. As outlined earlier, a central ventilation system requires multiple small penetrations of the residential corridor's walls (two per each residential apartment), which in accordance with Sentence 3.1.8.7.(2) would require tens to hundreds of combination smoke/fire dampers be installed.

Requiring combination smoke/fire dampers will result in a significant initial cost of installing the dampers (powered/controlled from the fire alarm system), providing additional duct-mounted smoke detectors (within 1.5 m downstream of each smoke/fire damper), and requiring ongoing annual inspection and maintenance requirements in conformance with CAN/ULC-S536, "Standard for Inspection and Testing of Fire Alarm Systems". This is further complicated where smoke dampers are required and installed in a building that is not equipped with a fire alarm system. The addition of so many devices as a part of the building's life safety system will also increase the probability of failure of one or more of the system components, limiting the intended operation of the system. The provision of ERVs in each dwelling unit would reduce or eliminate the required combination smoke/fire dampers, but it should not be the only solution for BC Housing projects, for the following reasons:

- Centralized method of providing conditioned mechanical cooling for an entire residential suite.
- Central **E/H**RV units are more energy efficient than the in-suite ERVs as they can utilize heat pump equipment for the supplementary heating and cooling.
- Central **E/H**RV units can provide "free-cooling" and "night-cooling" by simply stopping the enthalpy energy recovery wheel. In-suite ERVs don't have this option and are "recovering" energy even when it is detrimental to the overheating of residential suites.
- Central **E/H**RV units are typically located on the high roof of a building and, sometimes, in the parkade or on a lower roof level. Where reasonable, this central system can also be considered in floor-by-floor level. They are much easier to service and maintain compared to a large number of in-suite ERVs, which can result in a significant reduction of the operating/maintenance costs by the societies operating the social housing buildings.
- Central **E/H**RV units located on the roof or in the parkade of a building are less prone to vandalism and general damage.
- Central **E/H**RV units eliminate the need for accessing individual residential suites for servicing and maintenance. In-suite ERVs require entering each residential suite at least a few times a year for cleaning/replacing filters.
- Central **E/H**RV units can mitigate the potential of false alarms associated with in-suite ERVs detectors due to tenant kitchen exhaust or showers.
- As part of climate adaptation strategies, it is easier to mitigate effects of air pollution from wild forest fires by having a much smaller number of high-efficiency filters in central **E/H**RV units. Refer to *BC Housing Design Guidelines and Construction Standards [1]* on wildfires and filtration.
- In-suite ERVs located in the ceiling space of each residential suite can result in tenant noise complaints.
- Service life of these in-suites ERVs is less than that of a central system, and the number of replacements is more frequent considering the total life of the building. The in-suite replacement process is also a disruption to the tenants.
- Replacement of in-suite units is more expensive and invasive, typically requiring demolition and re-instatement of ceiling finishes to gain access, and may require temporary relocation of tenants during work. Utility costs are lower because of the respective building manager's control over the system. No heating and cooling can occur at the same time in residential units.

Therefore, it is proposed to permit the use of a central **E/H**RV for this Project without the provision of combination smoke/fire dampers on an Alternative Solution basis, which will be detailed in the following sections of this report. This will allow this Project to meet BC Housing and Provincial energy reduction objectives, maintain the affordability of social housing projects and create thermal comfort for BC's populations.

2.3. Level of Performance Required

The level of performance required by the Alternative Solution is based on the level of performance of a design that satisfies Sentence 3.1.8.7.(2). Specifically, the Notes to Clause 1.2.1.1.(1)(b) of Division A state that:

- Division B establishes the quantitative performance targets that Alternative Solutions must meet.
- An effort must be made to demonstrate that an Alternative Solution will perform **as well as** a design that would satisfy the applicable acceptable solutions in Division B

The Notes to Clause 1.2.1.1.(1)(b) of Division A further state that:

> *Where Division B offers a choice between several possible designs, it is likely that these designs may not all provide exactly the same level of performance. Among a number of possible designs satisfying acceptable solutions in Division B, the design providing the lowest level of performance should generally be considered to establish the minimum acceptable level of performance to be used in evaluating Alternative Solutions for compliance with the Code.*

A number of designs are possible in compliance with Clause 3.1.8.7.(2)(c) that will have differing levels of performance in limiting the spread of smoke from one fire compartment to another. The intent of Sentence 3.1.8.7.(2) is to limit the spread from one fire compartment to another; therefore, the lowest level of performance of these designs is one in which smoke has the greatest probability of spread from one fire compartment to another.

Further, the performance of a system is established as a function of the direction of airflow, which is assumed to be of greater concern flowing from a compartment of fire origin to another compartment. This assumption is based on the location of the smoke detector (i.e., “downstream of the smoke damper or combination smoke/fire damper”) required to activate a smoke or combination smoke/fire damper.

The design features considered in establishing the minimum acceptable level of performance (“compliant system”) to which the proposed alternative design will be compared is included in **Table 5**.

Table 5: Design Features in Compliance with Sentence 3.1.8.7.(2).

Design Element	Feature	Code/Standard Reference	Requirement	Design Performance Considerations
Smoke Damper	Type	**20XX CODE**, Division B, Sentence 3.1.8.7.(2)	A smoke damper or a combination smoke/fire damper.	For purposes of simplicity, the compliant system will include separate smoke and fire dampers.
	Location	**20XX CODE**, Division B, Sentence 3.1.8.11.(1)	Where smoke dampers are used as a closure in an air-transfer opening, they shall be installed in the plane of the fire separation.	The smoke damper for the compliant system will be located in the plane of the fire separation between the public corridor and adjacent residential units.
	Activation Time	CAN/ULC-S112.1 Clause 15.2.6	The closing time shall not exceed 75 s.	This will allow the passage of smoke beyond the smoke damper and plane of the fire separation.

Smoke Detector	Type and Location	20XX CODE , Division B, Sentence 3.1.8.11.(3)	Located as described in CAN/ULC-S524, "Installation of Fire Alarm Systems," within 1.5 m horizontally of the duct opening in the fire separation in the duct downstream of the smoke damper or combination smoke/fire damper.	▸ The 20XX CODE does not specify the type of detector required in conformance with Sentence 3.1.8.11.(3); however, the detector is required to be located in the duct. ▸ Regardless of the type of detector, the location 1.5 m downstream of the damper will result in the spread of smoke beyond the damper prior to the smoke detector being exposed to smoke.
		Clause 8.3.12.1 of CAN/ULC-S524	The smoke detector (spot type) shall not be installed directly in the stream of the air supply.	This means that a spot-type smoke detector is not permitted in the duct where it would be directly in the stream of the air supply. Therefore, a duct-type smoke detector would be required.
	Activation Considerations	Manufacturers, technical data sheets	Varies.	Duct-type smoke detectors specify minimum and maximum air flows relative to operation. The 20XX CODE does not require a continuous minimum airflow for ducts that penetrate a fire separation. Therefore, conditions may exist where smoke can move through a duct below the manufacturer's specified lower air flow limit and not be detected. This can result in the spread of smoke from one fire compartment to another at low velocities.
Emergency Electrical Power	Motor-driven damper and/or electrically operated smoke detector	N/A	▸ A smoke damper is not required by the 2018/2024 BCBC to be provided with emergency power. ▸ The smoke detector is not required to be connected to a fire alarm system*. The 2018/2024 BCBC does not require that smoke detectors that are not connected to a fire alarm system be provided with emergency power.	No emergency power provided. This means that during a power outage, the smoke damper may not operate.

*The smoke detector is not required by the 20XX CODE to be connected to the fire alarm system, only "located as described in CAN/ULC-S524, 'Installation of Fire Alarm Systems'".

This is supported by a review conducted by the Standing Committee on Fire Protection relative to an enquiry as to whether the requirements of Sentence 3.1.8.11.(3) for a smoke detector invoke the requirement for a fire alarm system even in a building that would not otherwise be required to have a fire alarm system. The results of the review noted that:

there is no clear indication that the smoke detector used for this purpose is also required to:

- *be connected to a fire alarm system;*
- *activate the fire alarm system; or*
- *notify the occupants for timely evacuation*

Given the performance considerations detailed above, smoke is expected to spread from one fire compartment to another through a duct when designed in conformance with Sentence 3.1.8.7.(2) and Article 3.1.8.11. The quantity of smoke entering an adjacent fire compartment would be a function of the density of smoke and airflow in the duct. The magnitude of smoke spread considering these factors will be a function of the time for a smoke damper to operate and limit any further spread of smoke.

Therefore, it is proposed to compare the performance of a design in compliance with Sentence 3.1.8.7.(2) to the alternative design on the basis of timing. On this basis, the following sequence of events is expected to occur relative to the operation of the smoke damper when designed in compliance with Sentence 3.1.8.7.(2) and Article 3.1.8.11.:

1. **Detection:** The smoke is detected by the duct smoke detector. Detector activation is difficult to quantify as it is a function of smoke concentration, airflow and detector sensitivity. Therefore, it is assumed that the detector could take from several seconds to minutes to detect smoke.
2. **Response:** The duct smoke detector activates the smoke damper actuator. It is assumed that this is instantaneous but may be delayed by several seconds. This would be further exacerbated by Sentence 3.1.8.11.(3), permitting the detector to be as much as 1.5 m downstream of the damper. This is expected to further delay the activation of the damper relative to the amount of smoke that passes downstream of the damper (and therefore beyond the fire compartment boundary).
3. **Activation:** The smoke damper actuator closes the smoke damper and limits further spread of smoke in the duct. As noted in the table above, this can take up to 75 seconds, and during that time smoke is expected to continue to pass downstream of the damper.

The performance of a design in compliance with Sentence 3.1.8.7.(2) and Article 3.1.8.11. is expected to result in the continued spread of smoke from one fire compartment to another as a function of the events and timing detailed above. This performance and these events will be further considered later in this report relative to the comparative performance of the proposed alternative design.

List Objective(s) and Functional Statement(s)

The Objective of Sentence 3.1.8.7.(2) is to limit the probability of injury and damage due to fire by [F03-OS/OP1.2] retarding the effects of fire on areas beyond its point of origin. This is specifically achieved by limiting the probability that smoke will spread from one fire compartment to another through openings in a fire separation.

Therefore, the issue to be addressed by the Alternative Solution for this Project is the spread of smoke from one fire compartment to another through interconnected ducts.

Summary of Solutions/List Mitigating Features

The following design elements and parameters are proposed to provide a design that achieves the objectives, functional and intent statements attributed to Sentence 3.1.8.7.(2):

- Provision of a smoke detector in the **E/H**RV's supply fan section. This will limit the probability of smoke spread through the duct system by the HRV if there is an **E/H**RV/roof fire or smoke re-entrainment from outside of the building.
- Continuous operation of the system to positively pressurize the supply air ductwork and negatively pressurize the exhaust air ductwork to limit smoke spread to other compartments. This will limit the probability of backflow into the duct system based on the same principles required by Subsection 3.2.6. of the **20XX CODE** for high buildings, and NFPA 92.
- The provision of 100% outdoor air to each residential unit with no recirculation. This will limit the probability of recirculation of contaminated air.
- No isolation dampers will be installed on the supply and exhaust sides of the **E/H**RV unit. This will facilitate the potential stack effect to direct smoke through the duct system to the outside even when the unit is shut down by the smoke detector in the **E/H**RV's fan supply.
- Continuous noncombustible ducts and branch ducts up to the interface with the residential unit it serves. This will maintain the continuity of the duct system if exposed to high temperatures, limiting the potential for smoke migration outside the duct due to failure of the duct system.
- Provision of fire dampers in conformance with Sentence 3.1.8.7.(1) and Article 3.1.8.10. In the remote event that backflow occurs, provision of a fire damper will limit the extent of smoke spread in the duct.
- Testing of the **E/H**RV and associated equipment in accordance with Sentence 3.2.9.1.(1), which requires that where fire protection and life safety systems and systems with fire protection and life safety functions are integrated with each other, they shall be tested as a whole in accordance with CAN/ULC-S1001, "Integrated Systems Testing of Fire Protection and Life Safety Systems," to verify that they have been properly integrated. The testing of the mechanical system is required to be included in compliance with Sentence 3.2.9.1.(1).
- All BC Housing residential buildings are required by Section 1 of the BC Housing *Design Guidelines and Construction Standards* to be sprinklered whether required by the **20XX CODE** or not. Additionally, this includes the provision of a fire alarm system.
- BC Housing residential buildings that have populations like at-risk homelessness, shelter, and transition homes and are provided with onsite support and supervision of 24 hours a day, 7 days a week [1].
- BC Housing residential buildings where there is potential risk of damage to in-suite smoke alarms, staffed on site 24/7, are provided with smoke detectors (in addition to the smoke alarms) inside the residential suites.

The following are recommended for maintenance of the **E/H**RV system relative to this Alternative Solution:

- Maintain the **E/H**RV system in conformance with applicable codes and standards and BC Housing policies/guidelines for the provided components.
- Include this report and associated Alternative Solution documentation with the maintenance documentation for the building and reference in the Fire Safety Plan. Any changes to the system would require re-examination of the associated Alternative Solution.

As the guide has been utilized by BC Housing Consultants for implementation into the numerous BC Housing projects, there have been variations to the initial list of proposed mitigation design elements. Those variants are:

- Spring-operated backdraft dampers are included in each supply/exhaust duct serving each residential unit.
- Provision of gasketing and weatherstripping to all residential unit entrance doors, where the leakage rate of the doors are determined in accordance with the 2004 edition of ANSI/UL–1784, "Air Leakage Tests of Door Assemblies and Other Opening Protectives" [Sentence 3.1.8.4.(4) of the **20XX CODE**], and the doors are installed in accordance with the 2013 edition of NFPA 105, "Smoke Door Assemblies and Other Opening Protectives" [Sentence 3.1.8.5.(7) of the **20XX CODE**]. As well as the necessary maintenance for the residential unit entrance doors in accordance with NFPA 105 and reference to the applicable maintenance requirements in the Fire Safety Plan.
- Provision of dampers on the ducts serving the public corridors.
- The addition of a plenum to the exhaust louvre of the **E/H**RV to limit the proximity of the exhaust and supply and limit the probability of short-circuiting.
- Provision of a "fire mode" in the fire alarm system that will on any alarm:
  - Transmit a signal to building management system to implement fire mode on the ERV.
  - Operation of the duct dampers (see item below) to close.
  - Shut down of the enthalpy wheel in each residential unit.

Provide Analysis and Evaluation to Validate Acceptance

3. Approach

In accordance with Clause 1.2.1.1.(1)(b) of Division A of the **20XX CODE**, it is proposed to permit the use of a centralized HRV for this Project without the provision of smoke dampers or combination FDS on an Alternative Solution basis. The following sections of this report detail the proposed alternative approach to compliance.

3.1. Proposed System Operation

The Project's central **E/H**RV unit will be located on the roof of the building and will include supply and exhaust fans, enthalpy energy recovery wheel with variable speed controls, a variation of heating coil, combination heating/cooling coil and/or DX cooling coil, filters and protected outdoor air intake and exhaust hoods/louvres.

The Project's central **E/H**RV system will be designed to provide 100% outdoor air to each residential unit through noncombustible ducts with no recirculation of air. The air supply system will be physically separate from the return system and is intended to operate continuously.

Exhaust air is ducted from all residential bathrooms in the Project building and is used to pre-heat (in winter) and pre-cool (in summer) outdoor air supplied for ventilation. A conceptual air flow diagram for a centralized **E/H**RV is included in Figure 9 below. Outdoor air is further treated inside the central **E/H**RV by adding supplementary heating (at low outdoor temperatures) or by providing mechanical cooling (in summer) and it is ducted directly to all residential living rooms. Exhaust and supply air will be ducted through central vertical duct risers to exhaust/supply horizontal ducts in the corridor's ceiling space on each floor. The supply and exhaust ducts entering each residential suite will be **X**-inches in diameter.

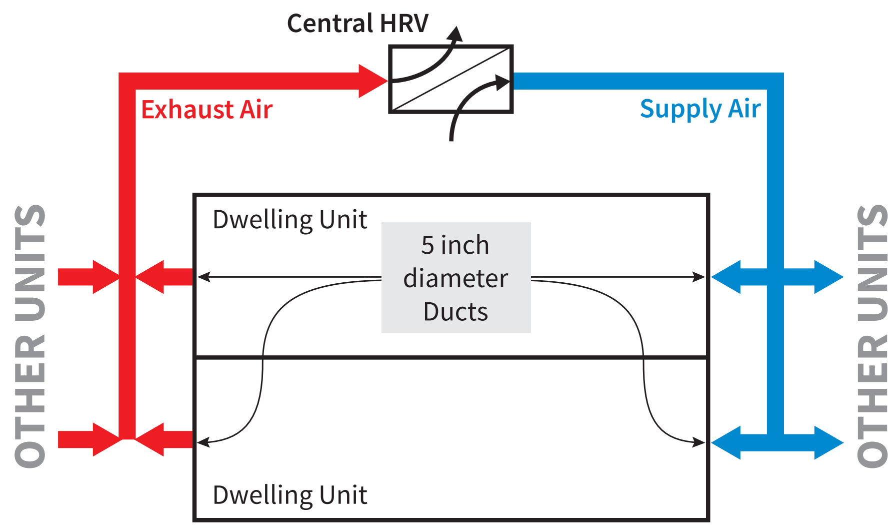

Figure 9: Conceptual HRV central system air flow.

The locations in which smoke dampers would be required by Sentence 3.1.8.7.(2) and are proposed to not be provided on an Alternative Solution basis are shown on the mechanical Drawings included as an appendix to this report.

3.2. Sentence 3.1.8.7.(2) Performance Criteria and Development Considerations

As noted previously, the objective of Sentence 3.1.8.7.(2) is to limit the probability that smoke will spread from one fire compartment to another fire compartment through openings in a fire separation. This is achieved by providing a physical barrier (smoke damper) that is activated by the fire alarm system upon activation of a proximal smoke detector. This solution was rationalized based on an analysis of the intent of a fire separation, the potential for smoke movement through air transfer openings and life safety considerations. The development of the ultimate solution (smoke dampers) was based on a balance of the benefits smoke dampers provide to limit smoke movement, relative to the cost to provide smoke dampers. It is not clear from the available information whether other solutions to limiting smoke spread were considered, and the cost analysis was limited in breadth and potentially not considering the substantial cost implications in residential applications including capital, maintenance, inspection and ongoing operation.

The following sections of this report examine the rationalization of Sentence 3.1.8.7.(2) and other available methods to limit the spread of smoke from one fire compartment to another.

3.2.1. Rationalization of Sentence 3.1.8.7.(2)

As outlined previously in this report, the change to Sentence 3.1.8.7.(2) to require smoke dampers in fire separations was rationalized, in part, based on an increased mechanical cost to a project of approximately 0.5%, which was considered negligible, and that higher costs could be mitigated through a different choice of duct routing .

This cost increase of 0.5% was based on the requirement of less than 5 smoke dampers for a single building, whereas an increased mechanical cost associated with requiring 9 smoke dampers at an increase mechanical cost of 1.96%, while not considered negligible, was considered acceptable given the option to reroute the ducting and reducing the number of smoke dampers to 5.

As noted previously in this report, as a result of the configuration of the ducting for an **E/H**RV in BC Housing Projects, a significantly larger number of smoke dampers would be required than for the cases examined by the Task Group in the development of Sentence 3.1.8.7.(2). Three sample BC Housing residential projects with central **E/H**RV systems were examined, and the number of smoke dampers that would be required based on Sentence 3.1.8.7.(2) ranged from 50 to 250 for typical units, and from 5 to 70 for low- to mid-rise construction The cost increase associated with the provision of this number of dampers would be significant. Based on a cost analysis of recently completed BC Housing facilities, the requirement for smoke/fire dampers increased the mechanical costs by approximately 11% to 12% and the overall project costs by 1.2% to 1.6%. Thus, installation of smoke dampers and associated smoke detectors in 5- to 6-inch diameter ducts is not practical.

Rerouting the ducting is not possible without utilizing in-suite ERVs or more conventional heating/cooling systems. However, these design approaches would not achieve BC Housing and Provincial energy objectives or allow greater comfort control while maintaining housing affordability.

Other methods of limiting smoke movement from one fire compartment to another are available without the provision of smoke dampers at all fire separations. One such method is discussed in the following section of this report.

3.2.2. Care and Treatment Occupancies

Clause 3.1.8.9.(1)(c) waives the requirement for smoke dampers in ducts that penetrate a vertical fire separation required by Sentence 3.3.3.5.(4) for dividing fire compartments for patients' or residents' sleeping rooms, provided that:

- the movement of air is continuous, and
- the configuration of the air-handling system prevents the recirculation of exhaust or return air under fire emergency conditions.

Care and treatment occupancies containing patients' or residents' sleeping rooms are considered by the Code to house a more vulnerable population than would be expected in the BC Housing residential buildings. Provision of a central **E/H**RV system as proposed in this report would not require smoke dampers where those ducts penetrate the fire separations of patients' or residents' sleeping room fire compartments. Note that these fire compartments are required by Sentences 3.3.3.5.(1) and (2) to separate groups of patients' or residents' sleeping rooms into areas not more than 1,000 m^2.

3.2.3. Other Smoke Control Methods

As noted previously in this report, the means by which Sentence 3.1.8.7.(2) intends to achieve the objective of limiting smoke movement from one fire compartment to another is through the provision of a physical barrier and does not recognize other methods permitted to achieve the same objective by other parts of the **20XX CODE**. One such method is provision of a pressure differential between a compartment involved in fire and an adjacent space, creating an opposing air flow that impedes the movement of smoke into that space.

Sentence 3.2.6.2.(3)[11] of the **20XX CODE** requires that for high buildings each stairway that serves storeys above the lowest exit level have a vent to the outdoors, at or near the bottom of the stair shaft. The explanatory note to this requirement states that:

> *The purpose of providing open doors and vents at the bottom of a stair shaft is to create a positive pressure in the shaft relative to adjacent floor areas and thus keep it free of smoke.*

11 The proposed Alternative Solution is not being anticipated for use in a building considered by the **20XX CODE** to be a "high building" [Subsection 3.2.6. of the **20XX CODE**], but to illustrate that the **20XX CODE** considers other means to limit the movement of smoke from one fire compartment to another that is other than a physical barrier.

This requirement anticipates the movement of occupants and firefighters between floor areas and exit stairs, and the potential for smoke to spread from a floor area to an exit during such movement. Note that this requirement is not intended to completely limit the movement of smoke from a floor area (one fire compartment) to an exit stair (another fire compartment), which is impractical. The smoke movement requirements of the **20XX CODE** allow an exit stair to contain up to 1% by volume of contaminated air from the fire floor [Sentence 3.2.6.2.(2)].

The explanatory note to the smoke movement requirements of the **20XX CODE** for high buildings further note that:

> *If mechanical methods are used to develop a positive pressure in a stair shaft, a minimum pressure differential of 12 Pa is recommended to prevent smoke migration from floor areas in a sprinklered building where fire temperatures are controlled and smoke movement may be dominated by stack effect in a stair shaft.*
>
> …
>
> *The maximum pressure differential created by a mechanical system should not prevent doors to the stair shafts from being opened.*

This explanatory note identifies an important consideration relative to pressure differentials and the impact on exit/egress doors, which will be discussed later in this report relative to challenges associated with the provision of barrier-type smoke dampers.

Similar to the high building requirements of the **20XX CODE**; NFPA 92, "Standard for Smoke Control", considers the following design approaches relative to smoke containment:

- Stairwell pressurization,
- Zoned smoke control,
- Elevator pressurization,
- Vestibule pressurization, and
- Smoke refuge area pressurization

There are numerous other codes and standards that provide similar pressure differential methods to control smoke movement from one fire compartment to another.

3.3. E/HRV Operational Considerations Relative to Smoke Spread

The following sections of this report examine the Project's central **E/H**RV operational considerations relative to two potential avenues for smoke to spread from one fire compartment to another, and discuss emergency power considerations.

3.3.1. Fires in Compartments

The Project's central **E/H**RV will be operated continuously and provide 100% outdoor air to each residential unit through noncombustible ducts with no recirculation of air. The supply and exhaust systems will be physically separate. This means that in the event of a fire in a dwelling unit, smoke will be impeded from entering the duct as a result of opposed airflow created by the supply duct. Smoke entering the exhaust duct would be impeded from spreading to other housing units due to the negative pressure created by the **E/H**RV exhaust duct system and would be exhausted to the exterior of the building.

Buildings are becoming more airtight as a function of the increasing energy performance targets. Recent full-scale testing[12,13] to examine the impact of the increased airtightness on compartment fire conditions have shown that fire-induced overpressure peaks of 850 Pa to 2035 Pa were measured without mechanical ventilation (ducts closed), and values from 420 Pa to 750 Pa were measured with the mechanical ventilation operating. Pressures in the hundreds of pascals were observed within the first 23 seconds following ignition11, which is expected to occur prior to sprinkler activation. The magnitude of the pressure increase in a compartment fire tends to correlate with the magnitude of the fire based on compartment temperatures. If the temperature is reduced, the pressure tends to drop. Accordingly, sprinkler controlled fires would generally have lower temperatures and correspondingly lower pressures than in unsprinklered buildings. Even in the event of a shielded fire, the sprinkler system is expected to control fire growth as a result of entrained water vapour and adequately cool the fire compartment and limit overpressure.

If the overpressure in the fire compartment is greater than the supply pressure of the **E/H**RV system, backflow of smoke into the supply duct system is possible. However, the extent of backflow is expected to be limited by the following:

1. **Sprinklered Buildings**: In a sprinklered building, activation of the sprinkler system is expected to reduce the temperature of the fire compartment, which would reduce the pressure and subsequent backflow potential. Sprinklers are expected to operate within the first few minutes of fire growth; thus, the overpressure in a sprinklered compartment is expected to be short in duration, significantly limiting the potential for smoke spread in a duct system. Note that all new BC Housing buildings are being provided with automatic sprinkler systems utilizing quick-response residential sprinkler heads.
2. **Activation of the fire damper by hot fire gases**. In the remote event that the sprinkler system does not operate, fire growth in the fire compartment is expected to increase compartment temperature and at approximately 75 °C to 140 °C cause the fire damper link to fuse, closing the damper and limiting backflow.

In addition to the potential for backflow in the central **E/H**RV duct system, fire compartment overpressures can also result in pressures on inward opening doors, limiting an occupant's ability to open the door and escape. This is a growing concern relative to the shift toward more airtight structures. In associated testing, this was observed to occur in an unsprinklered fire compartment for up to 3 minutes11 following the development of an overpressure condition. A system that includes combination fire/smoke dampers in conformance with Sentence 3.1.8.7.(2) would not provide any relief to the overpressure. However, an **E/H**RV system that continues to operate would provide some overpressure relief by way of the exhaust system. This was measured in the testing, summarized above, where the overpressure of a compartment with mechanical ventilation operating was approximately half to one-third of the overpressure with ducts closed.

Therefore, the combination of the continued operation of the **E/H**RV system and the opposed airflow results shown above are expected to limit smoke into the **E/H**RV supply system.

3.3.2. HRV, Roof Fires and Smoke Re-entrainment

In the event that fire originates in the Project's central **E/H**RV, or the **E/H**RV is impacted by exterior smoke spread or roof fire, a smoke detector in the supply fan section will shut down the HRV. This will limit the probability of the spread of smoke to the interior corridors or individual residential units from a fire in the HRV, involving the roof, or through re-entrainment from the exterior.

12 Sylvain Brohez and Irene Caravita, ‘’ Overpressure induced by fires in airtight buildings”, *Journal of Physics: Conference Series, Volume 1107, Issue 4*.
13 Simo Hostikka, Rahul Kallada Janardhan, “Pressure management in compartment fires”, *Espoo*, November 28, 2016.

3.3.3. Emergency Power

Article 3.2.7.9. requires emergency power for specific building services under certain conditions. For example, an emergency power supply capable of operating under a full load for not less than two hours is required for fans venting high buildings. However, emergency power is not required for fans that may penetrate the fire separation of a fire compartment containing patients' or residents' sleeping rooms, as outlined previously in this report, which are required to provide continuous movement of air.

Emergency power is generally required for ventilation fans utilized for life safety where there could be a significant delay in evacuation or firefighting activities, such as high buildings. However, for lower and smaller buildings (i.e., buildings of up to 6 storeys in building height), delays in evacuation or firefighting activities are expected to be less than those for a high building. Further, all BC Housing residential buildings will be sprinklered. The probability of occupants being exposed to smoke as a result of a failure of the ERV/HRV electrical supply prior to occupants evacuating the building is expected to be low, and therefore an emergency power supply is not proposed to be used for the central E/HRV system.

3.3.4. Proposed Design and Maintenance Provisions

The following design and maintenance provisions are proposed for the Project building and will perform as well as or better than a design that complies with Sentence 3.1.8.7.(2).

Clause 3.1.8.9.(2)(a) exempts the requirement for smoke dampers where noncombustible branch ducts having a melting point above 760°C that penetrate a fire separation for:

- **Supply Ducts:** where the ducts have a cross-sectional area not more than 0.013 m^2 and serve only air-conditioning units or combined air-conditioning and heating units discharging air not more than 1.2 m above the floor [Subclause 3.1.8.9.(2)(a)(i)].
- **Exhaust Ducts:** where the ducts extend not less than 500 mm inside exhaust duct risers that are under negative pressure and in which the airflow is upward as required by Article 3.6.3.4. [Subclause 3.1.8.9.(2)(a)(ii)].

Article 3.6.3.4. requires that if a vertical service space contains an exhaust duct that serves more than one fire compartment,

a) the duct is required to have a fan located at or near the exhaust outlet to ensure that the duct is under negative pressure, and

b) the individual fire compartments are not permitted to have individual fans that exhaust directly into the duct in the vertical service space.

The duct configurations permitted by the exemption in Clause 3.1.8.9.(2)(a) are not considered to "lead to a significant spread of smoke" [2015 NBCC Intent Statements].

The **E/H**RV supply ducts will serve only air-conditioning/heating units, be constructed of noncombustible materials and have a cross-sectional area at the supply port to each residential unit between 0.013 to 0.018 m^2 (5" to 6" diameter) in cross-sectional area. However, the supply duct port is intended to be located near ceiling level of the residential units (approx. 2.4 m). The **E/H**RV exhaust ducts will be constructed of noncombustible materials and will operate under negative pressure with an upward airflow consistent with that required by Article 3.6.3.4. Therefore, while the supply/exhaust duct system does not directly comply with all of the parameters identified in Clause 3.1.8.9.(2)(a), the system is expected to perform as intended by the exemptions and not lead to a significant spread of smoke.

In addition to the analysis contained with the body of the guide, some AHJs have requested additional information on the following sections:

Fires in Compartments

- System airflow velocities to mitigate smoke propagation from communicating spaces based on the methodology outlined with NFPA 92 (2018).

$$v_e = 0.64\left(gH\frac{T_f - T_o}{T_f}\right)^{1/2}$$

where:

v_e = limiting average air velocity (m/sec)
g = acceleration of gravity (9.81 m/sec^2)
H = height of the opening as measured from the bottom of the opening (m)
T_f = temperature of heated smoke (K)
T_o = temperature of ambient air (K)

Figure 10: NFPA 92 (2018) equation 5.10.3b.

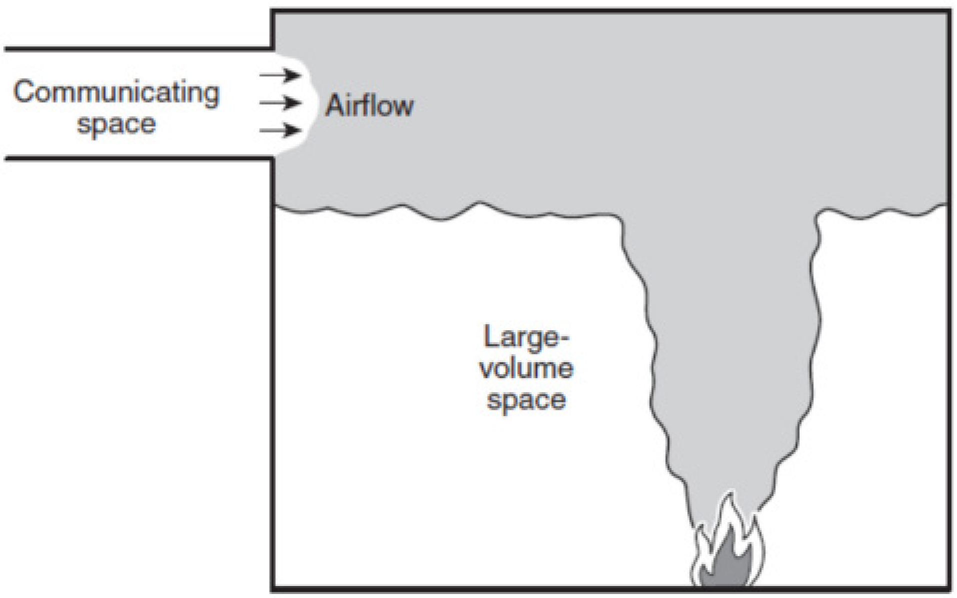

FIGURE 5.10.3 Use of Airflow to Prevent Smoke Propagation from a Large-Volume Space to a Communicating Space Located Above the Smoke Layer Interface.

Figure 11: NFPA 92 (2018) figure 5.10.3.

- Operation of the system in **summer** mode (**XX** cfm) following initiation of the fire alarm system: The continuous operation of the system is intended to positively pressurize the supply air ductwork and negatively pressurize the exhaust air ductwork to limit smoke spread to other compartments. This will limit the probability of backflow into the duct system based on the same principles required by Subsection 3.2.6. of the **2018/2024 BCBC** for high buildings, and NFPA 92.