



# Air Leakage Control for Multi-Unit Residential Buildings

## CMHC helps Canadians meet their housing needs.

Canada Mortgage and Housing Corporation (CMHC) has been helping Canadians meet their housing needs for more than 70 years. As Canada's authority on housing, we contribute to the stability of the housing market and financial system, provide support for Canadians in housing need, and offer unbiased housing research and advice to Canadian governments, consumers and the housing industry. Prudent risk management, strong corporate governance and transparency are cornerstones of our operations.

For more information, visit our website at [www.cmhc.ca](http://www.cmhc.ca) or follow us on [Twitter](#), [LinkedIn](#), [Facebook](#) and [YouTube](#).

You can also reach us by phone at 1-800-668-2642 or by fax at 1-800-245-9274. Outside Canada call 613-748-2003 or fax to 613-748-2016.

Canada Mortgage and Housing Corporation supports the Government of Canada policy on access to information for people with disabilities. If you wish to obtain this publication in alternative formats, call 1-800-668-2642.

# Air Leakage Control for Multi-Unit Residential Buildings

CANADA MORTGAGE AND HOUSING CORPORATION

MARCH 2017

CMHC offers a wide range of housing-related information. For details, call 1-800-668-2642 or visit our website at [www.cmhc.ca](http://www.cmhc.ca)

Cette publication est aussi disponible en français sous le titre : Réduction des fuites d'air dans les tours d'habitation, mars 2017, 65848

Library and Archives Canada Cataloguing in Publication

Air Leakage Control for Multi-Unit Residential Buildings.

Issued also in French under title: Réduction des fuites d'air dans les tours d'habitation.

ISBN 978-0-662-47493-7

Cat. no.: NH15-434/2007E

1. Dwellings--Insulation--Handbooks, manuals, etc.
  2. Dwellings--Energy conservation--Handbooks, manuals, etc.
  3. High-rise apartment buildings--Maintenance and repair--Handbooks, manuals, etc.
- I. Canada Mortgage and Housing Corporation.

TH1715.A57 2007

693.8'32

C2007-980280-X

© 2007 Canada Mortgage and Housing Corporation.

This document, or any discrete portion of this document (such as a chapter or section) may be reproduced for redistribution, without obtaining the permission of the copyright owner, provided that no changes whatsoever (including translation) are made to the text; that the entire document or discrete part is reproduced; that this copyright notice is included in its entirety in any and all copies of the document or any discrete part of the document; and that no use is made of any part of the document, or the name or logo of the owner of the copyright to endorse or promote any product or service. For any use of this document other than reproduction or for the general reference purposes as set out above, please contact: the Canadian Housing Information Centre (CHIC) at [chic@cmhc.ca](mailto:chic@cmhc.ca); 613-748-2367 or 1-800-668-2642. For permission, please provide CHIC with the following information: Publication's name, year and date of issue.

Revised: 2010, 2017  
Printed in Canada  
Produced by CMHC

## Acknowledgments

Canada Mortgage and Housing Corporation acknowledges the learned contributions of the following individuals to this manual:

Innes Hood, The Sheltair Group

Gracia Zunino Architects Inc.

Dr. Robert Dumont, Saskatchewan Research Council

Bert Philips, UNIES Limited

Tony Woods, CAN AM Building Envelope Specialists

The information contained in this publication represents current research results available to CMHC. Readers are advised to evaluate the information, materials and techniques cautiously for themselves and to consult appropriate professional resources to determine whether information, materials and techniques are suitable in their case. The text is intended as general information only and project- and site-specific factors of climate, cost, esthetics, practicality, utility and compliance with applicable building codes and standards must be taken into consideration. Any reliance or action taken based on the information, materials and techniques described are the responsibility of the user. CMHC accepts no responsibility for consequences arising from the reader's use of the information, materials and techniques herein.

# Table of contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Practical guidance for building owners and property managers	2
<b>2</b>	<b>Benefits of air leakage control (ALC)</b>	<b>3</b>
2.1	Building energy consumption	4
2.2	Building envelope durability	4
2.3	Occupant health, comfort and safety	5
2.4	HVAC system performance	6
<b>3</b>	<b>Air leakage principles</b>	<b>7</b>
	Air leakage: Why it happens	7
3.1	The “forces”	7
3.2	Typical leakage paths—the “holes”	8
<b>4</b>	<b>Developing an air leakage control plan</b>	<b>11</b>
4.1	Step 1: Assess and define air leakage control opportunities	12
4.2	Step 2: Prioritize air leakage work	20
4.3	Step 3: Assess potential obstacles to air sealing	21
4.4	Step 4: Select materials	23
4.5	Step 5: Perform the air sealing work	30
4.5.1	Air sealing at the bottom of the building	30
4.5.2	Air sealing at the top of the building	33
4.5.3	Air sealing of the exterior walls of the building	37
4.5.4	Air sealing of interior walls and floors	41
<b>5</b>	<b>Appendix A – Air leakage control resources</b>	<b>44</b>
<b>6</b>	<b>Appendix B – References</b>	<b>45</b>
<b>7</b>	<b>Appendix C – Air leakage control checklist form</b>	<b>47</b>



# Figures

Figure 1-1	Air leakage in MURBs	3
Figure 2-1	Component heat loss in MURBs	4
Figure 2-2	Wall with discontinuous air barrier	4
Figure 3-1	Wind pressure, stack effect and mechanical pressure	8
Figure 4-1	Exterior air leakage control system	13
Figure 4-2	Interior air leakage control system	13
Figure 4-3	Inaccessible air leakage control system	14
Figure 4-4	Fire stopping and air sealing of penetrations	16
Figure 4-5	Blower door installation with two blowers; this would be suitable for most small to medium-sized MURBs	16
Figure 4-6	Infrared and visible images of an exterior wall	18
Figure 4-7	Wood-frame wall with a steel lintel	19
Figure 4-8	Spray-applied foam products	23
Figure 4-9	Caulking joint design	25
Figure 4-10	Typical installation sequence for caulking	25
Figure 4-11	Weatherstripping profiles	26
Figure 4-12	Typical door sweep and threshold seal on outward opening door	26
Figure 4-13	Weatherstripping options	26
Figure 4-14	Plumbing penetrations	30
Figure 4-15	Plumbing penetrations of parking garage walls	31
Figure 4-16	Sealing service pipes	31
Figure 4-17	Sealing ducts	32
Figure 4-18	Sealing around elevator cables	33
Figure 4-19	Air sealing at wiring	33
Figure 4-20	Air sealing roof-to-wall interface	34
Figure 4-21	Air seal of roof penetration	35
Figure 4-22	Curb-mounted equipment	36
Figure 4-23	Air sealing metal door jamb	36
Figure 4-24	Air sealing windows	37
Figure 4-25	Air sealing a hot soffit	38
Figure 4-26	Air sealing awning windows	39
Figure 4-27	Air sealing electrical penetrations	40
Figure 4-28	Air sealing of louvres	40
Figure 4-29	Air sealing pipes and ducts within shafts	41
Figure 4-30	Typical conduit penetration	42
Figure 4-31	Air sealing plumbing penetration	42

# 1 Introduction



This manual provides guidance to air leakage control (ALC) contractors on how to reduce air leakage in existing high-rise, multi-unit residential buildings (MURBs). The objective of the manual is to assist ALC contractors to understand where, how and why MURBs leak so that they can prepare ALC plans that will reduce air leakage.

The manual also provides practical guidance for property managers and owners to help them identify when a building is experiencing air leakage-related problems and to provide some guidance in selecting and using the services of an ALC contractor.

MURBs are unique in terms of their design, construction and operation in comparison with other types of large buildings. For example:

- Ease of accessing the building envelope to undertake air sealing can be complicated by the ownership structure of the building. For instance, some owners may refuse access for ALC work in condominiums.
- In MURBs, it is important to understand who pays the heating bills as this will have a significant impact on whether or not the ALC work gets done and the size (and budget) of the project.
- Typical MURB mechanical design strategies utilize relatively simple central corridor ventilation and kitchen/bathroom exhaust systems. Uncontrolled infiltration can significantly impact the performance of these systems.

## What is a “building envelope?”

The building envelope is the indoor-outdoor environmental separation that is made up of the roof, walls, windows, doors and foundation of buildings. In some cases the bottom floor also forms part of the building envelope when it is located over parking garages or breezeways.





- MURBs can experience high moisture loads and widely varying occupant expectations for comfort.
- Most MURBs have operable windows that are controlled by tenants. Opening a window in a multi-storey MURB can radically alter the pressure regimes that the building envelope experiences and thus affect how much air leakage occurs. This applies to the building envelope of the entire structure, not just the unit in which the window is located.

The manual provides general guidance only and is not intended to replace professional site-specific advice. When information from this guide is used to air seal buildings, it must be reviewed by experienced tradespeople and reflect the unique conditions found in each building.

While the air leakage control strategies and measures presented in this manual are directed at high-rise, multi-unit residential buildings, some of the measures are appropriate for application in low-rise, wood-frame apartment buildings.

## 1.1 PRACTICAL GUIDANCE FOR BUILDING OWNERS AND PROPERTY MANAGERS

Although this manual is primarily designed for ALC contractors, some practical advice is offered here specifically for building owners and property managers.

If you know or suspect that there is an air leakage problem throughout your building, then the information in this manual should generally apply. If the problem is confined to one or a few, specific areas of the building (such as wetting patterns or mould growth appearing in just a handful of locations), then it may be necessary to consult with an engineering or architectural firm that specializes in building envelope work before beginning any remedial actions.

This manual describes how to identify and properly seal most of the types of air leaks found in MURBs. However, no building will experience leakage at all these locations so this manual discusses diagnostic techniques to aid in their identification and prioritization. Sealing “holes” that are not leaking is a waste of time and money.

Some government agencies and energy utilities have programs to assist property owners with air leakage control retrofits for commercial buildings, such as MURBs, as part of their energy conservation programs. These may provide direct financial assistance for the retrofit and/or airtightness testing and diagnostics.

When selecting an ALC contractor, find out the following:

- How much relevant ALC training and experience does he/she have with buildings similar to yours?
- Does he/she have experience with the types of construction found on your building (for example, wood frame vs. masonry vs. steel studs)?
- What diagnostic methods does he/she use to find air leaks (visual inspections, blower door tests to pressure/depressurize the building, infrared thermography, etc.)?
- Does he/she have experience working on occupied buildings?



## 2 Benefits of air leakage control (ALC)



Most MURBs are very leaky. Air tends to move with relative ease into, through and out of the building. Figure 1-1 shows typical air flow movement in high-rise residential buildings. Reducing the amount of uncontrolled air leakage has several benefits for the building and its occupant:

- Reduced energy costs, primarily the space heating and cooling costs
- Improved building durability and reduced, long-term maintenance costs
- Enhanced occupant comfort
- Better HVAC system performance

Each of these issues is further discussed below.

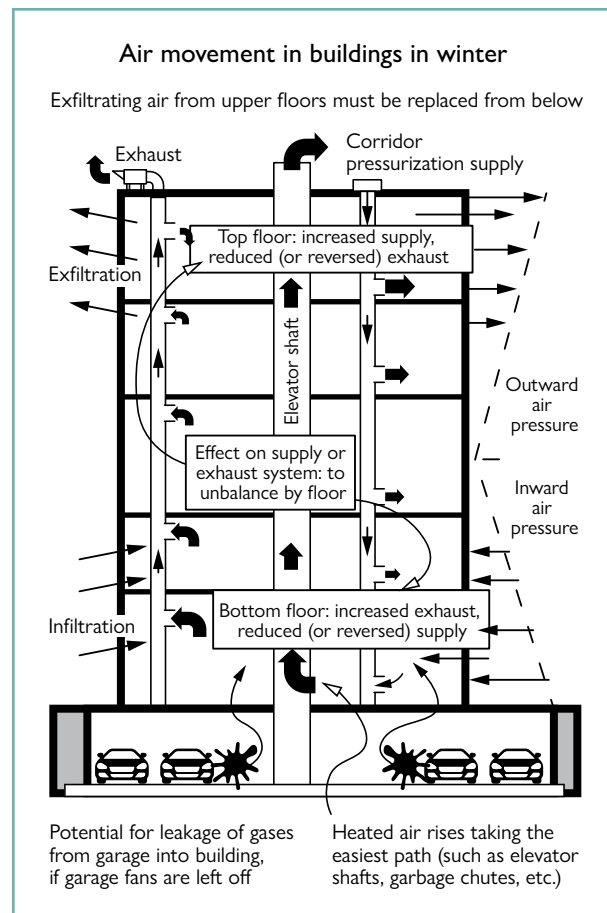


Figure 1-1 Air leakage in MURBs



## 2.1 BUILDING ENERGY CONSUMPTION

Air leakage has a significant impact on annual space heating and cooling costs as well as peak energy demand. A breakdown of heat loss in MURBs is presented in figure 2-1, which shows that air leakage represents up to 25 per cent of space heating energy use.

During design winter conditions, air leakage can be as much as 40 per cent of the peak space heating load. Air leakage contributes significantly to electric demand charges in electrically heated buildings as the greatest air leakage occurs during the coldest periods of the year. In air-conditioned buildings, air leakage contributes significantly to cooling costs, electricity peak demand charges and makes it difficult to maintain comfortable indoor conditions.

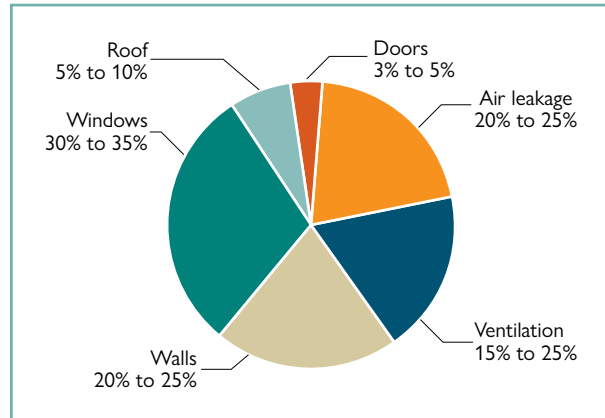


Figure 2-1 Component heat loss in MURBs

## 2.2 BUILDING ENVELOPE DURABILITY

Air leakage allows moisture migration into, through and out of the building envelope (that is, roof, walls, windows, doors and foundations of a building). In winter, indoor air carrying moisture will tend to leak out of the upper storeys of buildings. As the moisture carried in the air comes into contact with cold surfaces on or within the building envelope, it can condense and wet the materials it comes in contact with (figure 2-2).

Moisture carried by air leakage can corrode fasteners, steel studs and other structural assemblies, deteriorate exterior cladding (bricks, stucco, concrete), wet thermal insulation (reducing R-value) and damage interior drywall or exterior sheathing materials and finishes.

These types of air leakage-induced moisture problems can become so severe that a complete recladding of the building envelope may be necessary, which, for a typical multi-storey MURB, can cost several million dollars and cause disruption to the normal operation of the building.

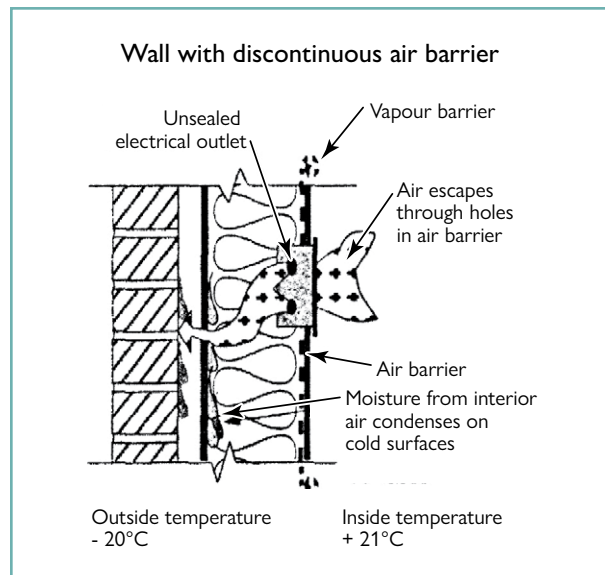


Figure 2-2 Wall with discontinuous air barrier

## 2.3 OCCUPANT HEALTH, COMFORT AND SAFETY

Moisture deposited in, or on, the building envelope as a result of air leakage can produce conditions necessary for mould growth, which may be a health concern.

Moisture-related problems are strongly affected by the relative humidity (RH) at which the building is maintained. Buildings with high RH levels tend to experience more problems than those with lower moisture levels. Since the RH is influenced by the number of people in the building, and MURBs have a relatively high occupant density, they can be particularly vulnerable to these types of problems.

Air leakage also causes drafts that can result in occupant discomfort. During the winter, air tends to leak into buildings on the lower floors and on the windward side of the building (the side facing the prevailing wind direction). Occupants perceive air leaking into buildings during the winter as cold drafts or a failure of the space heating system.

While sealing a building to improve indoor air quality may seem counterintuitive, most buildings leak so badly that reducing the amount of uncontrolled, random air movement can actually improve conditions. Theoretically, a building could be sealed to a point where there is inadequate indoor-outdoor air exchange and the incidence of indoor air quality problems could increase—however, there are two features of MURBs that exist that generally prevent such problems from occurring:

1. MURBs have operable windows. Sealing unintentional holes in the building envelope will not affect the ventilation capabilities of the operable windows in an apartment. ALC work will give the occupants *more* control over the ventilation of their space by eliminating random air exchange.
2. MURBs tend to have continuously operating corridor air systems, and the apartments are usually equipped with bathroom and kitchen exhaust fans. ALC work actually helps these systems to work better while reducing random and uncontrolled ventilation.

Air leakage can also cause a significant amount of air transfer between apartments and common areas in apartment buildings. This can result in the transfer of odours (for example, cooking odours and tobacco smoke) between apartments. It can draw car exhaust fumes from underground parking garages, or permit the movement of smoke during fire emergencies.

Holes that exist in the exterior building envelope and interior partition walls, ceilings and floors can also allow for the entry and proliferation of houseflies, cockroaches, mice and other pests. Air leakage pathways also allow for the transfer of noise from outdoors to indoors and between apartments. During the years when energy costs were relatively affordable, ALC contractors found that the bulk of their business was driven by occupant complaints of drafts, flies, odours and noise control.



## 2.4 HVAC SYSTEM PERFORMANCE

### Space heating and cooling systems

ALC projects will reduce air leakage-related heating and cooling loads and will allow the space conditioning systems to work more effectively to meet occupant needs. Excessive air leakage can undermine the performance of space heating and cooling systems if the systems were not designed to deal with the loads imposed by the continuous and uncontrolled movement of outdoor air into the building. Air leakage during the winter months can freeze pipes serving space heating and domestic water systems causing significant damage to adjacent apartments.

### Ventilation systems

ALC work can help ventilation systems to operate properly and achieve their design goals. Air leakage can undermine the performance of corridor air ventilation systems by establishing air flow and pressure regimes across the interior partitions of buildings that can reduce the amount of air delivered to each floor and in some cases cause flow reversal. Air leakage can also prevent bathroom and range hood exhaust fans from operating properly, particularly in the windward apartments on lower floors of buildings. Air leakage can adversely affect the performance of parking garage ventilation systems and allow parking garage odours and pollutants, including car exhaust, into the building.

A major source of air leakage in some large buildings occurs as the result of damper leakage in the ventilation system. Mechanical dampers, when closed, are supposed to limit leakage, however they often don't seal properly as a result of years of use and exposure to the elements (they are often located directly behind the exterior grilles of the ductwork). Damper leakage can be identified during the building examination conducted as part of an airtightness test (described in section 4.1). Although damper repairs are outside the scope of most ALC contractors, and may require the services of a mechanical contractor, damper leakage should be considered in the development of the air leakage control strategy.

In summary, it is important to remember that while air leakage control is primarily about sealing buildings to reduce heat loss, the work can also have an impact on occupant comfort, the prevention of odour problems, pest control and building durability. ALC contractors can use this to their advantage when proposing ALC projects to building owners.



# 3 Air leakage principles



## AIR LEAKAGE: WHY IT HAPPENS

For air leakage to occur there must be a **force** (that is, a *pressure differential between the indoors and the outdoors*) and a **hole** (that is, an *air leakage path*). High-rise residential buildings are subjected to a variety of forces imposed by wind, stack effect and mechanical systems. It is important to understand the nature of the driving forces behind air leakage as it will help to identify where buildings leak and where the air sealing opportunities are.

### 3.1 THE “FORCES”

**Wind:** Figure 3-1 illustrates how wind forces act upon a building creating positive pressure differentials on the windward side and negative pressure differentials on the leeward side. As a result (and in the absence of other forces), the windward side experiences air infiltration while the leeward side is subjected to air exfiltration. This can create a horizontal air flow through the building from the windward to the leeward side. Wind action is the most powerful of the three forces that control air leakage, but also the most intermittent. The magnitude of the wind forces are affected by the wind speed, the height of the building (since winds tend to increase with altitude) and the local shielding provided by adjacent buildings and vegetation.

**Stack effect:** As shown in figure 3-1, during the heating season a MURB operates in a fashion analogous to a chimney—cold air leaks in through the lower portion of the building and leaks out through the upper portion. As the infiltrating air leaks into the building, it is heated and humidified, and then travels up through the structure until it finds holes to leak outwards (exfiltration). The stack effect is determined by the height of the building (the higher the structure, the greater the stack effect) and the temperature differential between the indoors and outdoors.



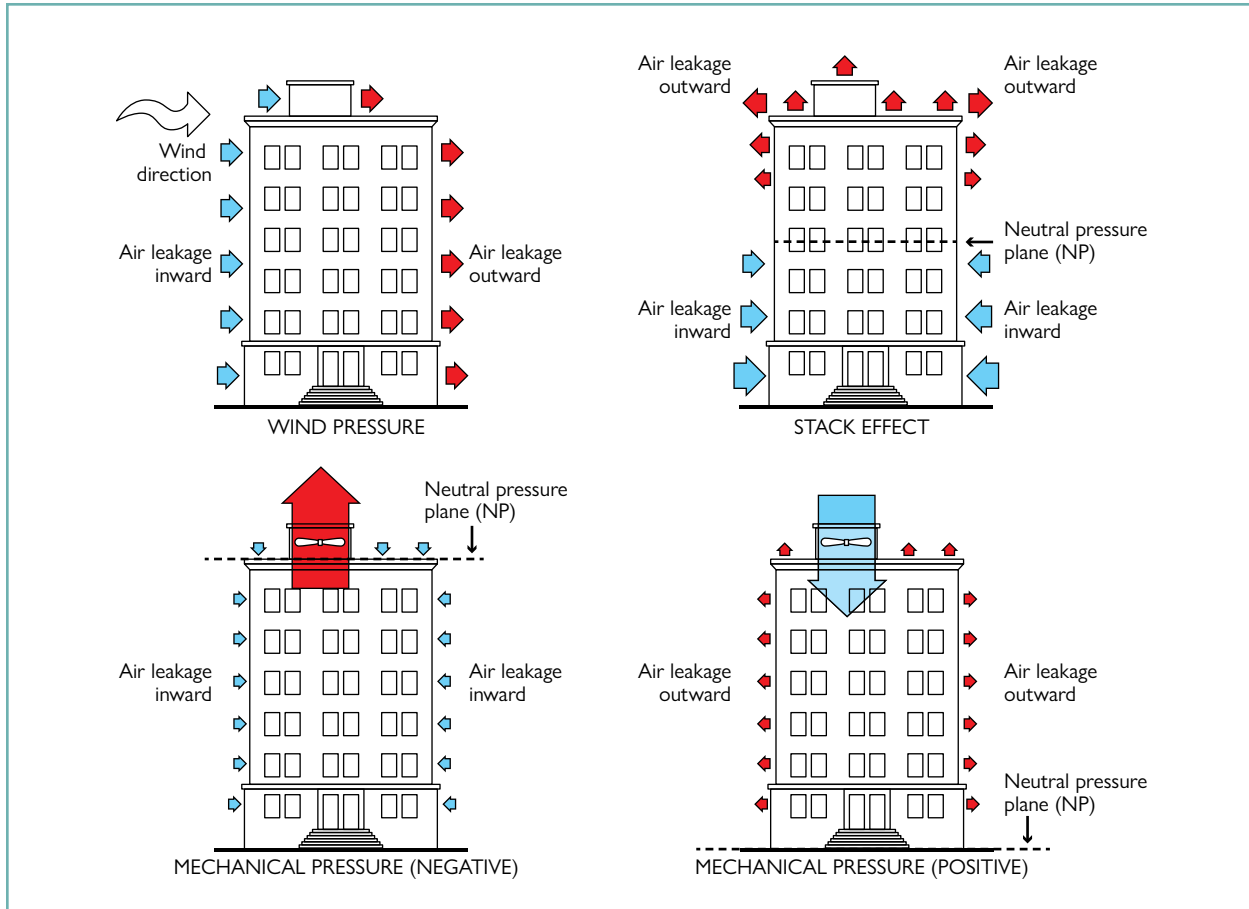


Figure 3-1 Wind pressure, stack effect and mechanical pressure

**Mechanical forces:** The building’s mechanical system can also impose pressure differentials on the building envelope. Exhaust fans, such as bathroom fans, range hoods, clothes dryers, utility room fans, venting systems for combustion devices, etc. all tend to depressurize the building. Fans that supply air to the building, such as corridor pressurization systems, will positively pressurize the structure. In general, the mechanically induced pressure differentials, which the envelope experiences, will be determined by the net, mechanical airflow rate—that is, the difference between the exhaust and supply flow rates.

### 3.2 TYPICAL LEAKAGE PATHS—THE “HOLES”

While there are many potential leakage locations in the building envelope, they all basically fall into one of three categories:

- **Joints** – locations where assemblies, typically in the same geometric plane, meet; such as joints between wall panels or window-wall installations.
- **Intersections** – locations where assemblies meet, typically in different geometric planes; such as wall-roof or wall-floor intersections.
- **Penetrations** – locations where components, such as ductwork, electrical lines or other services, penetrate through the building envelope.

Table 3-1 below highlights some of the most common air leakage locations in MURBs. A more comprehensive list is included in appendix C. However, never forget that all buildings are different and to develop a comprehensive air leakage control strategy, a careful examination of each building is required. While some leaks can be identified with a careful visual examination, others can only be found by depressurizing (or pressurizing) the building.

Most air leakage control strategies concentrate on sealing the building envelope. However, there may also be benefits in sealing portions of the building interior to limit air movement between different zones. Improving the airtightness of interior partitions and other surfaces reduces the overall leakage rate of the building since air that leaks into the building has to traverse through the structure before it leaks out. A tighter interior impedes the air's movement. This also improves smoke and fire safety.

If the building has an underground parking garage, then any holes in the floor separating the ground floor from the garage should be found and sealed. In addition, the walls that separate the core of the building (usually containing the elevator, stairwells, storage rooms and vestibules) from the garage must be checked for leakage. If the building contains an indoor swimming pool, all surfaces that separate it from the rest of the building should be carefully checked since the pool room is normally maintained at a much higher relative humidity than the rest of the building.

**Table 3-1** Air leakage locations in MURBs

At the bottom of the building	Exterior walls
<ul style="list-style-type: none"> <li>• Parkade to building interface (walls, ceilings, floors, doors)</li> <li>• Overhanging soffits</li> <li>• Service penetrations of core walls and floor between garage and ground floor—wiring, plumbing, ducts, garage doors, garage exit doors</li> <li>• Underground service penetrations from adjacent buildings</li> </ul>	<ul style="list-style-type: none"> <li>• Windows (both through the window and the rough opening)</li> <li>• Doors</li> <li>• Joints between different materials and envelope elements</li> <li>• Overhead doors and service bays</li> <li>• Backdraft dampers and louvres</li> <li>• Sleeves for through-wall HVAC units</li> <li>• Electrical penetrations (electric baseboard heaters, switches, outlets, exterior wall mount lights, outlets, etc.)</li> <li>• Plumbing penetrations—hose bibs</li> <li>• Duct penetrations</li> </ul>
At the top of the building	Interior partitions
<ul style="list-style-type: none"> <li>• Mechanical penthouses</li> <li>• Rooftop penetrations—wiring, plumbing, ducts</li> <li>• Parapets</li> <li>• Rooftop HVAC equipment and plumbing penetrations, garbage chute stack</li> <li>• Stairwell and roof access doors</li> <li>• Roof hatches (in stairwells and penthouses)</li> <li>• Roof-to-wall joint</li> <li>• Elevator cables, wiring</li> </ul>	<ul style="list-style-type: none"> <li>• Stairway-corridor doors</li> <li>• Plumbing risers and stack penetrations through floor levels</li> <li>• HVAC duct risers through partition walls and floors</li> <li>• Garbage chute door and access hatches</li> <li>• Wiring raceways through walls and floors</li> <li>• Wall-floor and wall-ceiling joint in service areas such as garbage room, mechanical room, electrical room and common areas and suites</li> <li>• Elevator doors</li> </ul>





## 4 Developing an air leakage control plan



Implementing an air leakage control project in MURBs can be a challenge. In the absence of a plan, efforts to seal leaks may be ineffective at best, and at worst, it may result in the development of other problems, such as trapping moisture in the walls with subsequent damage to the building envelope or projected energy savings not being achieved. The plan also must consider whether or not access to suites in a condominium or rental building is necessary or practical.

Therefore, the development of an air leakage control plan is the first step in any successful project. The plan involves the following:

**Step 1:** Assess and define air leakage control opportunities.

**Step 2:** Prioritize air leakage control opportunities.

**Step 3:** Assess obstacles to air leakage control.

**Step 4:** Select the materials.

**Step 5:** Perform the air sealing work.



## 4.1 STEP 1: ASSESS AND DEFINE AIR LEAKAGE CONTROL OPPORTUNITIES

The first step in developing an effective air leakage control plan is to familiarize yourself with the building, its maintenance history, occupancy characteristics, etc. Most owners will be able to provide copies of the original construction drawings plus those of any renovations. Talking to the building's maintenance personnel can often provide significant insights into how the building operates. Likewise, tenants can offer observations that may prove useful, particularly with regard to identifying locations of air leaks.

Identifying the size, location and distribution of air leaks in a building provides a starting point for any project. Assessing the potential for air leakage control provides owners with information on the impact of air leaks in terms of energy bills, comfort and safety. It can also provide contractors with an estimate of the scope of work for budgeting purposes. In addition to defining the existing air leakage characteristics of a project, an initial assessment may be used to:

- identify building envelope elements that form the air leakage control system;
- identify methods for sealing the various elements of the air leakage control system together;
- assess potential obstacles to air sealing;
- review potential problems with the building components or systems that may require attention prior to proceeding with air leakage sealing (such as indoor air quality or building envelope issues); and
- prioritize the order in which the work should be done.

### Identify the air leakage control system

An air leakage control system is made up of the various materials and assemblies that are put in place to stop air from leaking into and out of a building. An air leakage control system is sometimes referred to as an air barrier system or the plane of airtightness. The important thing for a contractor to remember is that the materials and assemblies making up an air leakage control system are all impermeable to air and they are all sealed together with impermeable materials.

While an air leakage control system should be designed and built into the building envelope during construction, in many older buildings, little consideration was given to such issues. For example, in the walls of some high-rise MURBs, the air leakage control system may use sheet polyethylene (poly) installed over the wall framing. However, the poly may or may not be sealed to the window and door frames, and the ceiling and floor slabs. Further, poly is best suited to wood-frame construction where its edges and overlaps can be sealed with a non-hardening sealant and then mechanically fastened using staples. Attempting to seal poly to steel studs or concrete floor slabs is not likely to be successful.

It is important to remember that the air barrier on the walls must be sealed to the air barrier on the roof as well as the system that encloses the foundations and separates the parking garage from the core of the building. In this way, a complete air leakage control system is provided that is continuous around the building envelope.

Developing an air leakage control plan for existing apartment buildings requires an understanding of how to best take advantage of accessible building envelope elements that can be sealed together to form as continuous an air leakage control system as possible. There is no point in randomly sealing holes in materials or between components if holes elsewhere cannot be sealed. For example, sealing cracks in brick veneer systems or the gaps between the brick veneer and windows will have little impact on the airtightness of the building as it is next to impossible to make an air leakage control system from brick veneer.



MURBs typically have one of the following three types of air leakage control systems:

1. **Exterior air leakage control systems**

(figure 4-1) have the air barrier located on the exterior surface of a building envelope system. This is typical of cast-in-place concrete walls and some watertight roofing systems. If an exterior air barrier was originally used, the air sealing work can be done from the outside of the building. Caution must be taken to ensure that openings deliberately installed for water drainage or pressure equalization are not sealed. A building envelope specialist should be consulted in such cases.

2. **Interior air leakage control systems**

(figure 4-2) use the inside surface of the building envelope to provide the air barrier. An example of this type of system is the airtight drywall approach (ADA). If the original air barrier utilizes an accessible system, then the air sealing work will utilize interior components, materials and finishes.

Unlike exterior air leakage control systems, interior systems are vulnerable to air leakage where interior partition or demising walls intersect with the exterior wall systems. In most older buildings, little or no effort was made to seal this location. Since partition walls are constructed of steel studs (which contain holes) or wood studs (which usually have holes drilled in them for electrical lines), air can flow relatively unimpeded from the building interior into the partition walls and then laterally to the exterior wall.

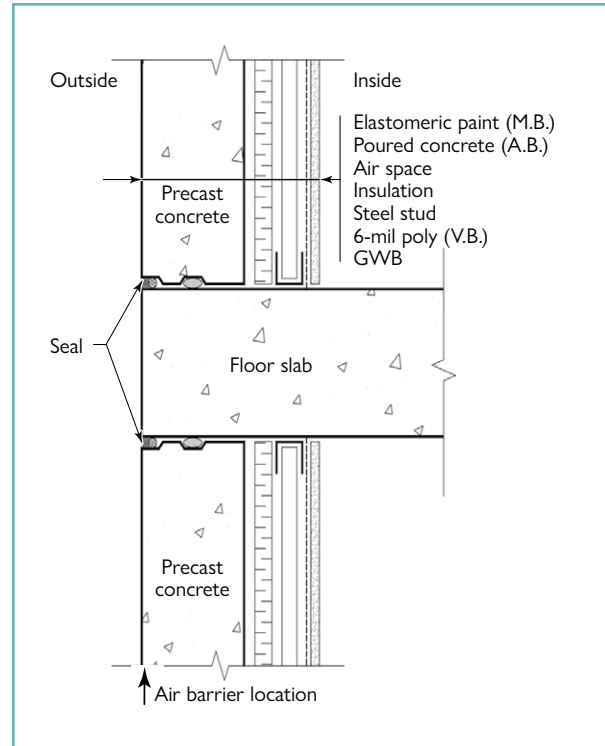


Figure 4-1 Exterior air leakage control system

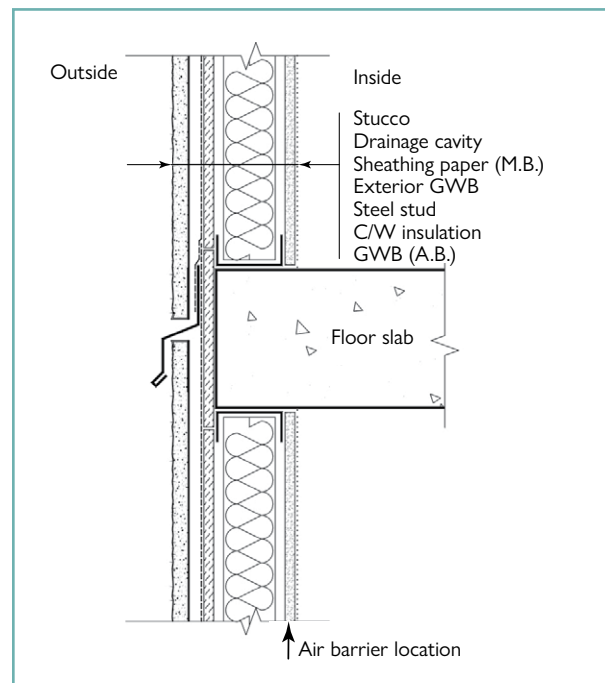


Figure 4-2 Interior air leakage control system



### 3. An inaccessible air leakage control system

(figure 4-3) has the air leakage control system located within an assembly. Examples of this include the peel-and-stick membrane on exterior gypsum wallboard or the waterproof membrane used in an inverted roof. Sheet polyethylene installed over wall framing and rigid foam insulation applied over masonry and concrete walls are other common examples of inaccessible air barrier systems.

Air sealing an inaccessible system may require that elements of the assembly be dismantled or that an alternative air barrier approach be utilized. This is usually expensive, disruptive and beyond the scope of most air sealing projects. For this reason, ALC projects in existing buildings do not often deal with inaccessible systems unless major renovation work is being considered.

In such cases, it is necessary to develop an alternate approach to define a new plane of airtightness (usually the interior) as a basis for proceeding with air sealing work. This requires an understanding of how various airtight materials and systems of a building envelope can be sealed together to form a new air leakage control system. For instance, the drywall finish may be selected as the dedicated air barrier. Consideration must then be given to sealing the drywall at all penetrations, including windows, doors, floors and ceiling slabs. If the floor or ceiling is constructed with joists or trusses, ensuring that the air barrier is continuous through the ceiling and floors is frequently a challenge that should be considered. Otherwise, a significant location of air leakage will be present at each floor level and will undermine the effectiveness of the air leakage control work.

It is often useful to obtain a cross-sectional drawing of the building to start the process of identifying how the ALC project will seal together the walls, windows, doors, penetrations as well as the intersections between walls and roof and walls and foundation (parking garage). One should be able to move a pencil around the perimeter of the building envelope (without lifting it), from material to material, assembly to assembly, identifying the air leakage control system. This exercise will allow the contractor to become aware of the ALC systems and to target the plan at specific air leakage locations.

### Requirements of an air leakage control system

An effective air leakage control systems should have:

1. *continuity* from material to material and component to component forming the air leakage control system;
2. *impermeability to air flow*—fibreglass makes a fine filter but is not acceptable as an air barrier material;

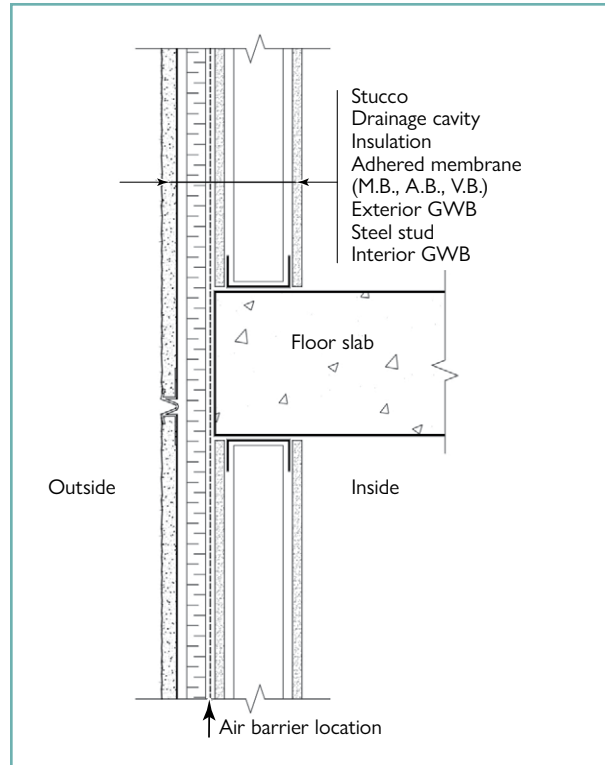


Figure 4-3 Inaccessible air leakage control system



3. *structural support*—the air barrier should not be dislodged or stressed by wind, stack and mechanical forces discussed earlier. It either needs to be strong enough to support itself (for example, drywall) or it has to be supported (for example, peel-and-stick membrane supported by drywall on one side and framing on the other);
4. *structural movement*—the air barrier should be able to accommodate any reasonable or expected movement in the substrate to which it is applied. Such movement can be caused by thermal expansion and contraction of materials; and
5. *durability*—it has to last under normal operating conditions.

While continuity and impermeability to air are self-evident, ensuring the air leakage control system is fully supported and durable is essential to the long-term performance of air leakage control strategies. To be effective over the long term, the material selected for an air leakage control project must have sufficient:

- elasticity to accommodate movement between the materials it is sealing together;
- adhesive strength to bond to the materials being sealed; and
- cohesive strength to avoid tearing or creep from differential motion and imposed forces.

## Fire stopping and air leakage control

In many situations, air sealing work will also require fire stopping. If a fire stopping product is already installed (but does not seem to provide the level of airtightness desired), it may need to be removed, prior to the installation of an air sealing product and then reapplied once air sealing has been completed.

Often, air leakage points will be found in the fire-rated assemblies that may exist between parking garages and the building, at each floor level or through partition walls. Specific materials must be used as a part of fire-rated assemblies.

## Caution

### Compatibility of materials

An emerging issue related to durability of air barriers is the compatibility of materials. There is growing recognition in the industry that materials used for sealing assemblies can be incompatible as the application of one material adjacent to another may cause one, or both, to deteriorate and fail.

Examples of incompatible materials include the following:

- Bituminous membranes in contact with polyisocyanurate foam insulation
- Bitumens in contact with polystyrene foam insulation
- EPDM membranes in contact with bituminous-based air barrier membranes and flashings
- Some sealants in contact with rigid insulation and plastic vent pipes
- Silicone caulking in contact with rubber and urethane
- Polyurethane caulking in contact with polyethylene sheet
- Polyurethane caulking in contact with asphaltic materials

In some cases, solvents from one material will cause the adjacent surface to become brittle and fail earlier. In the case of caulking in contact with rigid insulation, the solvents contained in some caulking products may erode polystyrene foam products. Adhesion between air sealing products is also a concern. For example, adhesion between urethane foam and polyethylene sheet products is poor.



ALC measures should only use approved materials in such cases and the local building code officials must review and approve the work being done in these locations. A typical air seal and fire stopping detail that uses fire-rated grout is shown in figure 4-4. Information regarding fire stopping and smoke sealing materials may be found in the *National Building Code of Canada*, the various provincial building codes and the Underwriters' Laboratories of Canada (ULC) publications.

### Locating leaks: Inspection and testing methods

The most important, and perhaps the most difficult, task in developing an effective air leakage control strategy is to identify and prioritize the leaks. While some locations on the building envelope are known to be common sources of leakage, no two buildings are exactly alike so a careful investigation should be made in every case. Knowing where the leaks are and developing a sense of their relative magnitudes will reduce the cost of the sealing program since the greatest emphasis (and effort) can be directed at the most important leaks. Fortunately, a number of techniques have been developed to aid in this task.

#### *Whole building airtightness testing (qualitative and quantitative)*

A common method of leak detection is to use calibrated blower doors to pressurize or depressurize the entire building so that air leaks are accentuated, thereby making it easier to identify their locations and relative strengths. Smaller MURBs, such as three-storey walk-up buildings, can often be tested using one or more calibrated blower doors designed for residential applications. Larger, multi-storey MURBs may require several, more powerful blower doors that are designed for commercial applications, see figure 4.5.

Blower doors are also used to quantify the building's overall airtightness if a test is performed according to an established testing standard (see below). This permits the building's airtightness to be compared to other, similar structures and also provides a means to evaluate the effectiveness of the air leakage control measures, if before and after tests are performed. Quantified tests may also be required by some building owners (such as government agencies responsible for public housing) or mandated if the retrofit project is being performed as part of a government- or utility-sponsored air leakage sealing program.

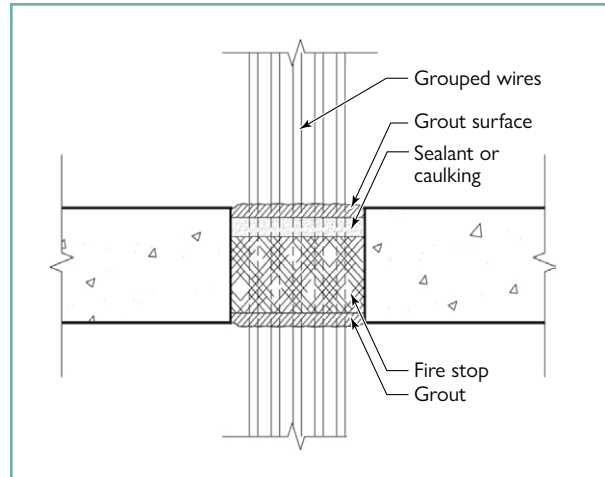


Figure 4-4 Fire stopping and air sealing of penetrations



Figure 4-5 Blower door installation with two blowers; this would be suitable for most small to medium-sized MURBs

Airtightness tests are normally conducted with all the building's interior doors open, thereby creating a single large zone. In an occupied MURB, this can be very difficult, if not impossible, to achieve since it requires the co-operation of all the residents. However, recent research sponsored by CMHC has indicated that accurate results can still be obtained with the MURB's interior doors closed.

The protocol most commonly used to perform quantitative airtightness tests on larger buildings such as MURBs (AABA/USACE. "Standard Method for Building Enclosure Airtightness Compliance Testing," draft) has two sealing schedules for treatment of the building's "intentional openings" (these are holes deliberately made in the envelope, such as exhaust and supply openings for the ventilation system). If the primary purpose of the air leakage sealing work is to reduce energy costs, then the so-called "energy" sealing schedule should be used in which the dampers in the intentional openings are closed, but not sealed (as is done when the "envelope" sealing protocol is used). Using the energy sealing schedule allows the integrity of the ductwork dampers to be evaluated (since they are not sealed) but requires additional air moving capacity since the blower doors have to accommodate the damper leakage.

**Cost of whole building airtightness testing** – high

**Availability of testing services** – low

**What the test provides** – quantitative airtightness results and qualitative identification of leakage locations and their relative magnitude for the entire building

### *Floor, zone or unit airtightness testing (qualitative)*

In many cases, it may not be possible, or necessary, to conduct a whole building test due to cost, availability of a testing agency or other reasons. Instead, qualitative tests can be performed on an individual floor, zone or unit within a MURB to identify and prioritize typical leakage locations. Since multi-storey buildings generally use the same floor plan (usually on all but the top and bottom floors) and employ similar construction techniques throughout, problems identified on one floor, or in one zone or suite are likely to be replicated in other, similar areas. Since only a portion of the building is being tested, the required flow capacity of the test equipment is reduced and, in many instances, can be performed using residential blower doors.

In MURBs, a very useful application of this type of qualitative testing is as part of a quality control program for window replacements. A residential blower door can easily depressurize an individual suite within a MURB allowing a qualitative examination of the new window installation to be performed—particularly the rough opening seal between the window frame and the rough opening. Testing the first few installations will help to identify any problems with the contractor's sealing techniques and could prevent major problems down the road.

In some cases, it may be possible to conduct a qualitative examination without the use of a blower door to depressurize the space, but rather using the natural pressure differential created by the building's stack effect. Since the magnitude of the stack effect increases with building height and the indoor-to-outdoor pressure differential, in taller MURBs under winter conditions, the pressure differential at the top and bottom of the building can exceed the pressure differential used to conduct airtightness tests. A digital micromanometer, of the type used to performed airtightness tests, can be used to measure the natural pressure differential using an operable window or door across which a pressure tap can be installed.

These types of targeted airtightness tests are also very effective at identifying specific air leakage problems that may be affecting a single part of the building—such as an air leakage pathway that is transporting moisture into just one portion of the building envelope. The ability to identify these types of pathways



can be further enhanced if the airtightness test is combined with pressure diagnostics. This is a technique in which the pressure differential between the test zone and a second space (such as a suspected pathway or another zone) is measured while the test zone is depressurized to determine if there is communication between the two spaces.

**Cost of floor, zone or unit airtightness testing** – low

**Availability of testing services** – high

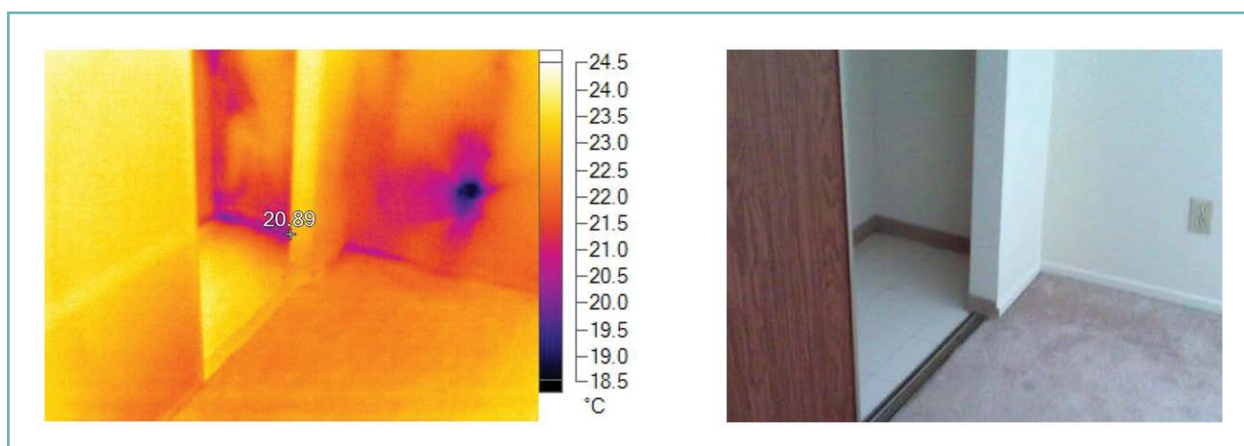
**What the test provides** – qualitative identification of leakage locations and their relative magnitude for the zones tested

Procedures have also been developed for testing of building components—such as windows. However, these are generally used in new construction to insure compliance with the construction specifications and are fairly costly.

### *Flow visualization and leak identification*

Various qualitative techniques can be used to identify air leaks. The most effective and widely used methods are the following:

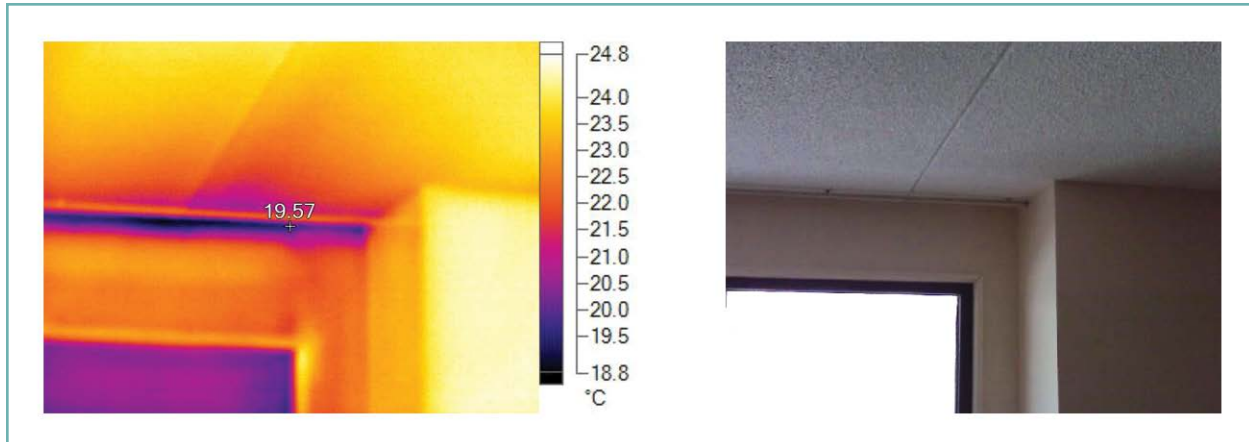
- Visual inspections – Look for cracks and gaps in the building envelope as well as evidence of long-standing air leaks—such as dust streaking or dust accumulations at baseboards, cracks, etc., as shown in figure 4-6. Sometimes the dust streaking patterns can also provide clues as to the direction of the air flow.
- Hand inspections – If the building or zone is pressurized or depressurized by a blower door, most medium- to large-sized leaks can be easily detected by hand.
- Smoke puffers – These produce a small quantity of smoke that can be directed at suspected leak locations, particularly small ones that may not be detectable by hand inspection. They are most effective when the building (or zone) is mechanically pressurized or depressurized using a blower door.
- Thermography – Infrared cameras are a valuable tool for identifying thermal anomalies on the building envelope such as those caused by air leaks. The examinations are normally performed while the building (or zone) is depressurized, thereby permitting large areas of the building envelope to be quickly and efficiently scanned. However, thermal anomalies can also be due to other causes, such as thermal bridging or insulation wetting, so possible leakage sites should be verified by hand or with smoke puffers. Modern infrared cameras require an indoor-to-outdoor temperature differential of at least 10°C to give useful results, so they cannot be used during certain temperature conditions. See figures 4-6 and 4-7.



**Figure 4-6** Infrared and visible images of an exterior wall. Note air leakage at the wall's bottom plate and the electrical outlet.







**Figure 4-7** Wood-frame wall with a steel lintel. Note air leakage at the intersection between the wall and the floor slab above.

As the leaks are identified, their locations should be documented along with an assessment of their relative strength. Assuming that the examination is performed while the building is pressurized or depressurized (to between 50 and 75 pascals, typical values used during airtightness tests and examinations), the ranking system shown below can be used to assess their strength. Once all of this information has been assembled for the building, it can be used to help design the air leakage control strategy by focusing on the most significant leaks.

**Table 4-1** Guide for assessing the strength of air leaks

Leakage Class	Indicators	Potential Impact on the Building Envelope, Energy Costs or Indoor Environment
Trivial	Barely detectable using a smoke puffer	Of no practical significance
Minor	Easily detectable using smoke puffer, or barely detectable by hand	May have an impact, particularly if leak is exposed to sustained pressure differentials
Major	Easily detectable by hand	Good possibility that it could lead to problems
Massive	Detectable by hand, 0.3 m (1 ft.) from the leak	Very good possibility of problems

### Testing organizations

Finding organizations that conduct airtightness testing can sometimes be a challenge since they are not that common. Engineering firms that specialize in building science and building envelope engineering may provide these services. Firms, or individuals, who conduct residential and commercial building energy evaluations, such as those for the ecoENERGY for Houses program, may also have the equipment and skills to conduct building airtightness tests.



### Testing standards

- CGSB 149.10 “Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method.”  
**Application** – Airtightness tests on houses and small buildings, mainly used in Canada.
- ASTM E779 “Standard Test Method for Determining Air Leakage Rate by Fan Pressurization.”  
**Application** – Airtightness tests on houses and small buildings. Similar to CGSB 149.10, but mainly used in the U.S.
- AABA/USACE. “Standard Method for Building Enclosure Airtightness Compliance Testing” (draft).  
**Application** – Airtightness tests on larger, commercial buildings (such as MURBs).
- ASTM E1186 “Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems.”  
**Application** – Standardized techniques for locating air leakage sites in building envelopes and air barrier systems; applicable to all types of buildings.

### Air leakage location checklist

Appendix C contains a checklist to assist ALC contractors in locating and documenting air leakage locations. It includes the most common air leakage locations found in MURBs and includes space to identify their relative magnitude.

## 4.2 STEP 2: PRIORITIZE AIR LEAKAGE WORK

Once the air leakage locations have been identified, they should be prioritized in an order that reflects the ease of doing the work and the potential impact on air leakage. Generally, air leakage projects have been conducted in the following order:

### Seal the bottom of the building

Sealing the bottom of the building will deal with air leakage into the building where it causes drafts and comfort problems. This usually involves sealing leakage between the lower floors and outdoors and the lower subgrade core of the building and the parking garage. The bottom of the building represents a relatively easy and accessible place to implement air leakage control measures.

Sealing the bottom of the building can also help prevent parking garage pollutants from entering the building.

### Seal leakage at the top of the building

This is done to “cap” the top of the building to prevent heated air leaking out. Generally, dealing with leakage at the top of the building is relatively easy as most leakage locations are in service areas or rooftop mechanical rooms.

### Seal the exterior walls of the building

Sealing exterior walls is often difficult to do because access into individual apartments can be a problem. If access to the individual suites is possible, consideration should be given to sealing the exterior walls. This often involves sealing electrical, plumbing and duct penetrations, providing new weatherstripping and seals on windows and balcony doors. Sometime exterior hoods for exhaust fans can be accessed from the balcony.



## Seal the interior of the building

Sealing the interior partitions and shafts will help prevent air movement into, through and eventually out of the building. The interior partitions that should be sealed are those that separate service rooms from common areas (foyers, corridors) and common areas from the apartments. Also of concern is the penetration of building services through floors and walls. Although these penetrations should have been sealed to ensure the integrity of fire separations, the seals can be poorly done or missing altogether. Repair and retrofit work, such as the installation of new services through interior floors and walls, often leaves gaps in affected walls and floors. Stairwell and vestibule doors should be equipped with weatherstripping to prevent air movement around them.

The checklist provided in appendix C has been structured to reflect the order that ALC measures should be performed. However, sometimes, building managers will have different priorities that will have to be reflected in the ALC plan. For instance, the manager may want occupant comfort complaints dealt with first, therefore ALC work in the individual apartments may be the first place to start. There may be obvious holes in the building envelope made during repairs or renovations that can be easily and inexpensively sealed. Noise and odour control problems in the building may mean that interior sealing is of higher priority than work on the exterior envelope. The ALC contractor should work closely with the property manager to ensure that the project addresses as many issues as possible.

### 4.3 STEP 3: ASSESS POTENTIAL OBSTACLES TO AIR SEALING

While the holes in the building envelope may be readily found, sealing them may not be as straightforward. The following sections describe some of the more common problems and issues an ALC contractor will face.

#### Ownership issues

The ownership structure in the building may impact what air sealing gets done. For instance, in condominiums, individual owners may not agree to have air sealing measures being done within their units. In rental units where the owner of the building does not pay the heat in the individual apartments, air sealing measures within the apartments may not be approved. Physical access to air leakage locations may be difficult given occupant furnishings and other possessions. An ALC plan must anticipate such obstacles and plan accordingly.

#### Ongoing building performance problems

Other problems may exist in MURBs that should be corrected before air leakage control work begins. This is necessary to prevent the ALC work from making the problems worse and to prevent the ALC work from being associated with a problem that existed before the work was started. Problems that may exist in MURBs that should be corrected prior to air sealing include:

- complaints about poor indoor air quality, including stuffiness, mould and condensation that indicate inadequate ventilation;
- poorly operating corridor ventilation and in-suite exhaust systems;
- high humidity and condensation problems within the suites;
- rain penetration or water leakage problems that wet the building envelope and interior surfaces; and
- combustion venting problems from fuel-fired appliances such as boilers, furnaces and hot water tanks.



## Indoor air quality problems

If apartments show signs of high humidity, lingering odours, stuffiness, mould growth or condensation on windows during the winter months, the building is:

- underventilated;
- over-occupied;
- experiencing moisture source control problems; or
- displaying a combination of some, or all, of the above. Implementing an air leakage control program under such circumstances could make problems worse. If such conditions exist at the time the ALC assessment is under way, recommend that the problem be solved before any air sealing measures are installed.

## Rain penetration problems

If the building is experiencing rain penetration or water leakage problems, air leakage control projects should not be implemented until the problems are dealt with. Rain penetration may wet interior surfaces and contribute to mould growth. It can also cause the building envelope to deteriorate. There is little point in sealing building envelope components that are in poor state of repair as the sealing will not last.

The air leakage control plan should not interfere with the moisture management strategy of a building. For example, in a drained cavity wall, intentional exterior openings are provided to permit drainage of moisture that may get into the wall system. Drain holes should not be sealed as part of an air leakage control project.

An air leakage control plan should form part of any building envelope remedial work undertaken to correct rain penetration or other problems.

## Combustion

### *Venting problems*

Air sealing projects can reduce the amount of air available to ensure the proper venting of fuel-fired appliances, such as furnaces, domestic hot water heaters, fireplaces and kitchen stoves. This is particularly true in the case where the equipment does not use sealed combustion systems and indoor air is drawn into the appliance to support combustion and venting.

Combustion venting can be undermined if there is a lack of combustion air supplied to the space or exhaust appliances, such as bathroom fans, clothes dryers, range hoods, and service room exhausts are located in the space. The operation of these fans in well-sealed buildings can cause the venting systems of combustion appliances to fail. If unsealed combustion appliances are present in a service room or apartment where air leakage control measures are to be implemented, conversion of the equipment to sealed combustion appliances should be considered. If this is not practical, the combustion air needs of the appliances will have to be assessed and an appropriate amount of combustion air will have to be provided to the space.

When combustion equipment is located within an individual dwelling unit undergoing air sealing, it is recommended that a test be completed to assess the potential for combustion spillage in accordance with CGSB 51.71 “Depressurization Test.” If the building uses a central heating system, and there are concerns about spillage, a mechanical contractor should be consulted.



## 4.4 STEP 4: SELECT MATERIALS

Once the air leakage locations to be sealed have been determined and prioritized, and any building problems or other issues have been addressed, the actual air sealing work can begin. First, the materials and sealing methods for each location should be identified. A variety of materials are available for sealing air leaks:

- Spray-applied foam sealants, including one- and two-part polyurethane foam systems
- Caulking, available with a range of joint movement and durability options
- Weatherstripping and gasket material
- Membranes

### Spray foam

Spray foam is one of the most widely used products for air leakage control work. A range of foam sealant products are available for air sealing. These typically are formulated using one-part or two-part urethane, or polyisocyanate (figure 4-8). Benefits of the material include:

- good adhesion to a range of materials;
- high insulation value of material;
- ability to be used as an air barrier and insulation material; and
- economic to install.

Insulating foam is available in a range of densities and expansion characteristics. For air barrier applications, densities of  $16 \text{ kg/m}^3$  (1  $\text{lbm/ft}^3$ ) to  $50 \text{ kg/m}^3$  (3  $\text{lbm/ft}^3$ ) are recommended. While lower density foams are less expensive, they have an open cell structure, which reduces their cohesive and adhesive strengths.

Foam expansion can range from 10 per cent to over 100 per cent after application. Care should be exercised in the application of high expansion foam as these products can cause buckling and displacement of adjacent materials. This is particularly true when foam is used to air seal around windows, as high expansion foams may result in distortion of the window frame.

Be aware of the manufacturer's recommendations for the range of temperature under which foam products can be applied.

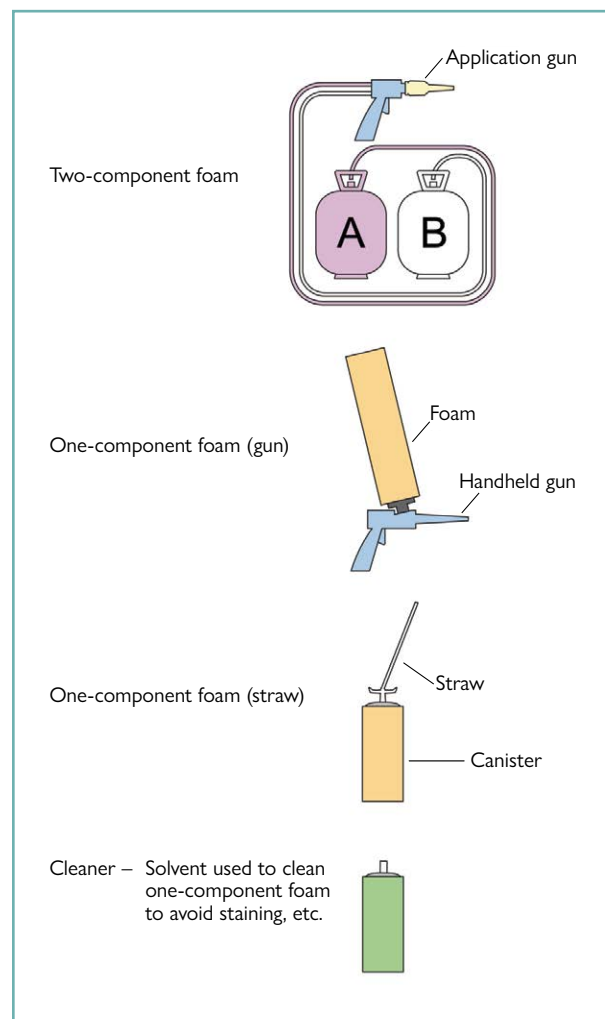


Figure 4-8 Spray-applied foam products

## Caulking

A range of caulking products exists and may be classified into the following types:

- High-performance neutral cure silicone caulking
- Polyurethanes
- Polysulphide caulking
- Thermoplastic elastomeric caulking
- Mildew-resistant silicones
- Acetoxy silicones
- Acrylics
- Acrylic latex one part
- Acoustical
- Butyl
- Oil-based

Choosing the correct caulking product requires an understanding of its characteristics and limitations. Movement capacity is one of the most important factors when selecting a caulking, especially if the joint is expected to move in response to solar heating, changes in moisture or structural movement. Other factors that must be considered when selecting a caulking are ultraviolet light resistance, compatibility with the substrates (that is, materials it will seal together), expected life, proper joint design and, if used indoors, the potential impact on indoor air quality as the material cures.

## Low-movement caulking

Low-movement or plastic caulking products will withstand only slight and infrequent joint movement as they are not very flexible once set. Their durability is reduced by exposure to sunlight and extremes of heat and cold. Low-movement caulking products include bituminous rubber, oleoresinous and butyl rubber. Applications of this type of caulking product should be restricted to joints that are not subjected to constant movement cycles or large deflections and are relatively protected from weather. Recommended maximum movements are usually below 5 per cent of the joint width. The service life of this group of caulking products will vary with the type of material and the exposure condition. Caulking products in this category may be suited for sealing interior non-moving joints such as interior ceiling-wall and wall-floor joints. However, the service life generally ranges from two to five years when used in exposed exterior applications.

## Medium-movement caulking

Medium-movement caulking products can be grouped into two categories: plasto-elastic and elasto-plastic. Plasto-elastic caulking products include acrylic latex, acrylic solvent and butyl and thermoplastic elastomers (kreytons). These products perform adequately in slow moving joints such as masonry control joints. Recommended maximum movements are usually below 25 per cent of the joint width. When installed properly the service life may range from 5 to 15 years for plasto-elastic material and 10 to 20 years for elasto-plastic material.

## Caution

### Fire rating of foam sealants

Foam sealants can be fire and smoke hazards as they generate significant amounts of toxic smoke if they catch on fire. Most building codes require foam sealants be covered by a fire-resistant material, such as drywall or grout, consult with the local building code authority having jurisdiction prior to installation to ensure conformance with local regulations.



## High-movement caulking

High-movement or elastic caulking products include materials such as one- and two-part polyurethanes as well as acetoxy and neutral cure silicones. These types of products recover completely after most deformations and are suitable for large or fast-moving joints such as those between metals and other materials (such as at window frames). Adhesion is good for a wide range of materials. These caulking products typically have life expectancies ranging from 10 to 25 years.

## Caulking joint design

While the air leakage contractor must work with existing joints, it is worthwhile knowing how caulking joints should be designed and installed. Caulking installed into a joint must allow the adjacent material to expand and contract without cracking (cohesive failure) or pulling away from the substrate (adhesive failure). To reduce the probability of these two failure mechanisms, the following guidelines are recommended:

- The maximum extension of a caulking joint is generally required on a cold day when the materials have contracted away from one another. Many caulking materials behave differently at different temperatures. Ensure that the caulking is able to undergo its maximum extension at the coldest temperature to which it will be exposed.
- The width of the caulking joint should be designed based on the expected relative movement of the two adjacent surfaces to be sealed and the movement capability of the caulking. Generally, a caulking joint should be greater than 6 mm, regardless of expected movement, to allow for proper application.
- The depth of caulking at the centre of the joint should generally be half of the width. A round foam backer rod should be used to provide the proper joint profile. Caulking joints should be bonded only to two surfaces on opposite sides of the joint. If a backer rod is used this is not usually a problem. If a fillet joint is used, a bond breaker tape should be used to allow joint movement to occur. Figure 4-9 shows three caulking joint profiles commonly used in construction. Typical backer rod material includes polyethylene foam rope. The sequencing of the installation of caulking around penetrations is shown in figure 4-10.

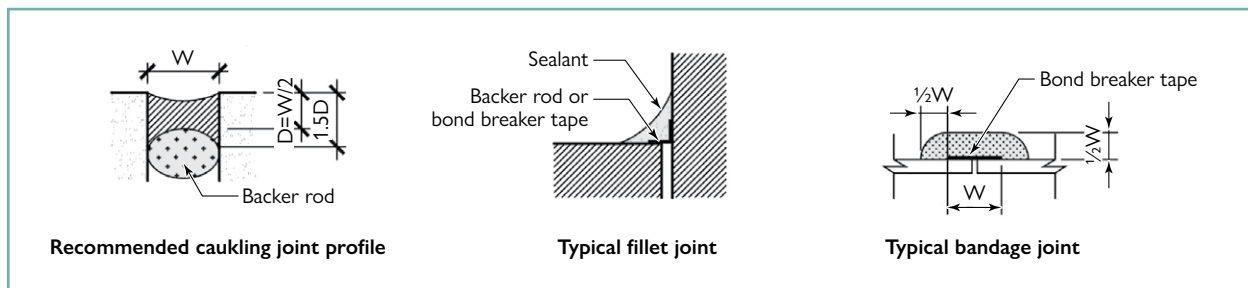


Figure 4-9 Caulking joint design

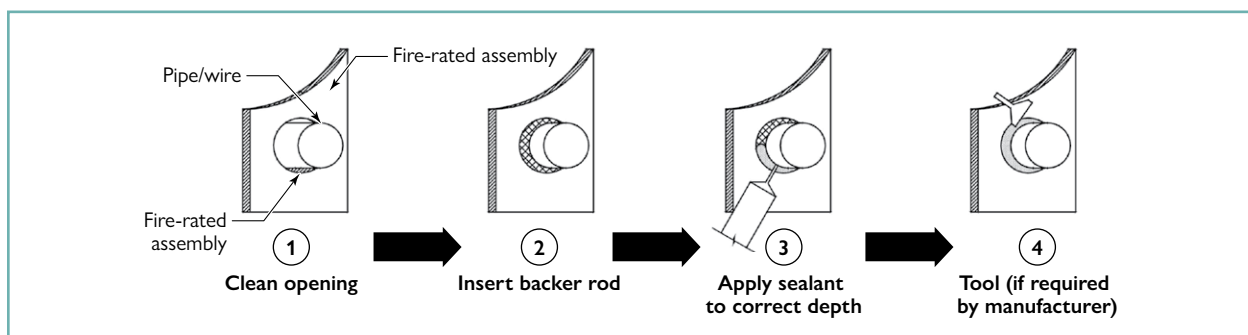


Figure 4-10 Typical installation sequence for caulking

## Weatherstripping

A range of weatherstripping products exists for windows and doors. For example:

- replacement bulb seal and pile seals are available for completing window retrofits, as shown in figure 4-11;
- heavy duty V-seal products and foam compression materials for air sealing doors into their frames; and
- doorway sweeps (figure 4-12).

The selection of the proper type of weatherstripping is critical to improving air leakage performance of windows and doors. In particular, door weatherstripping must be durable and flexible, but at the same time, it must not impede the use of the door or prevent it from closing properly.

The width of the gap between a door and its frame varies from point to point and season to season. Therefore, when selecting new weatherstripping, preference should be given to those types that can accommodate changes in gap width of as much as 5 mm (0.2 in.) over a period of years.

Door weatherstripping works by compression (for example, hollow tubular seals) or by bending (for example, plastic V-seals). The type of seal should be selected so that excessive closing force is not required. Options for positioning weatherstripping include edge seals, stop seals and side-mounted seals as shown in figure 4-13. The jamb seal is a tubular type of weatherstripping. The edge seal is a V-type weatherstripping. The stop seal is hollow tubular.

Depending on the direction in which the door swings, stop seals are more exposed to exterior temperatures and may not last as long.

Side-mounted stop seals must also be able to accommodate a wide gap variation. In some designs, this is achieved with spring loading, which allows the seal to move up to about 6 mm (¼ in.). Side-mounted seals are also completely exposed to exterior temperatures. Finally, spring-loaded seals may allow air to pass around the spring when it is compressed.

The requirements at the head jamb are the same as for the strike jamb, though the range of the gap width may be less severe. Where possible, the same seals should be used on the head jamb and hinge jamb as on the strike jamb.

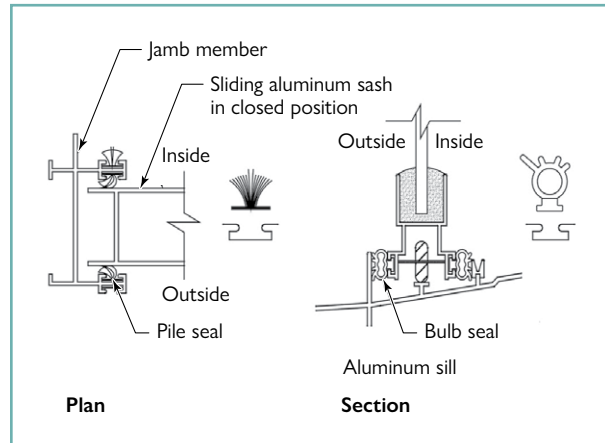


Figure 4-11 Weatherstripping profiles

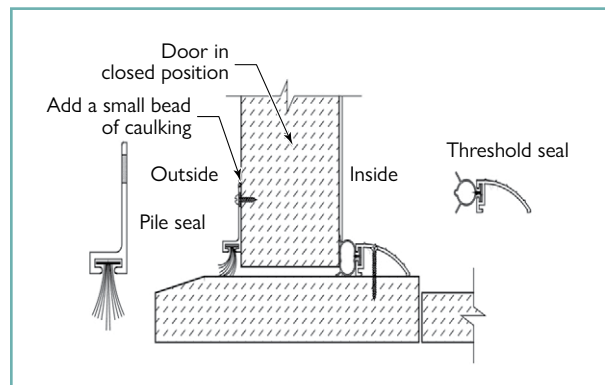


Figure 4-12 Typical door sweep and threshold seal on outward opening door

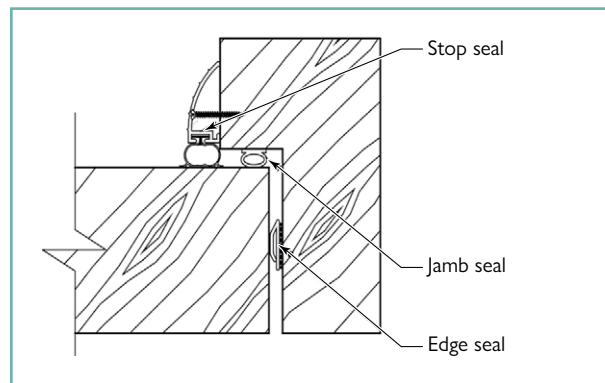


Figure 4-13 Weatherstripping options



## Seals for the threshold

Sill seals can be divided into two main categories: “sweeps” that are attached to the bottom of the door and “threshold seals” that are attached to the doorsill. Threshold seals are suitable when the door opens outward or when located in protected areas that are not exposed to rain or snow. Sweeps may be used for inward or outward swinging doors.

## Revolving entrance doors

Inspect the sweeps on revolving doors. It is recommended that the original equipment manufacturer’s air sealing products be used when servicing revolving doors.

## Membranes

Membranes include a range of sheet-applied and liquid-applied products. Membranes do not have the structural properties to transfer loads and should be applied over a masonry or board substrate for support.

Typical sheet products may include:

- self-adhesive peel-and-stick membranes;
- EPDM sheet products; and
- silicone sheet products.

Membranes are all air barriers, but come in two distinct forms: vapour impermeable and vapour permeable. Vapour permeable membranes allow water vapour to pass through the material but still resists air leakage while vapour impermeable membranes control both air and water vapour.

Also note that exterior air barrier membranes often serve as the primary water barrier for the assembly and must be installed not only in an airtight manner but also with proper detailing to prevent water entry from the outside.

Strips of membranes may be used to seal materials together. For example, peel-and-stick membranes provide a durable transition between the air barrier on a roof and wall of a face-sealed building or the walls and window frames.

Liquid-applied membranes may include a range of trowel-, spray- or roller-applied air barrier products intended for air sealing walls. Liquid-applied membranes may be used to seal masonry walls between a parking garage and the building. In general, however, liquid-applied membranes are installed within a wall as part of a non-accessible air leakage control system. Therefore, use of liquid-applied membranes in a retrofit situation is most relevant when large-scale wall repairs or restoration work is occurring that includes removal of finishes or cladding to access the building structure.

A summary of air leakage control materials is presented in table 4-2.

### Caution

#### Use of flexible materials as an air barrier in MURBs

While polyethylene sheet is widely used as an air barrier in detached and low-rise MURB construction, it is not recommended as an air barrier for high-rise construction. Experience in the industry has shown that the higher loads imposed on an air barrier in high-rise MURBs frequently results in damage to polyethylene air barriers. Similarly, duct tape, foil tape and contractors tape are not recommended to seal or join air barriers in high-rise construction as there is little information available concerning the lifespan of such materials in these applications.



Table 4-2 Summary of recommended air leakage control materials

Product	Durability	Application	Comments
<b>Spray foam</b>			
Polyurethane and icynene foam	High	<ul style="list-style-type: none"> <li>• Suitable for filling holes in a range of locations where protected from ultraviolet light.</li> <li>• Must be used in conjunction with other materials to obtain fire rating for non-combustible applications.</li> <li>• Must not be applied under cold conditions—consult manufacturers' instructions regarding minimum temperature application restrictions.</li> </ul>	<ul style="list-style-type: none"> <li>• Includes one- and two-part urethane and icynene foam products.</li> <li>• Bonds to a range of materials except for polyethylene, Teflon™ or silicone plastics.</li> <li>• Should be covered by non-combustible material when installed within a fire separation assembly.</li> </ul>
<b>Caulking</b>			
Low-movement caulking	Low	<ul style="list-style-type: none"> <li>• Suitable when low movement is expected</li> </ul>	Includes <ul style="list-style-type: none"> <li>• Butyl rubber</li> <li>• Synthetic rubber</li> <li>• Oil-based</li> </ul>
Medium-movement caulking	High	<ul style="list-style-type: none"> <li>• Indoor applications suitable for small joints where limited movement occurs</li> </ul>	Includes <ul style="list-style-type: none"> <li>• Acrylic latex</li> <li>• Thermoplastic elastomeric</li> </ul>
High-movement caulking	High	<ul style="list-style-type: none"> <li>• Suitable for indoor or outdoor applications</li> <li>• Long service life expected</li> </ul>	Includes <ul style="list-style-type: none"> <li>• Neutral cure silicones</li> <li>• Acetoxy silicone</li> <li>• Polyurethanes</li> <li>• Polysulphides</li> </ul>
<b>Weatherstripping and gaskets</b>			
Felt	Low	<ul style="list-style-type: none"> <li>• Door jamb and heads</li> </ul>	<ul style="list-style-type: none"> <li>• Easily deformed</li> <li>• Poor adhesion to substrate</li> <li>• Poor air sealing qualities</li> </ul>
Open-cell foam tape	Low	<ul style="list-style-type: none"> <li>• Door jamb and heads</li> </ul>	<ul style="list-style-type: none"> <li>• Easily deformed</li> <li>• Poor adhesion to substrate</li> <li>• Poor air sealing qualities</li> </ul>
Closed-cell foam tape	Low to high	<ul style="list-style-type: none"> <li>• Door jamb and heads</li> </ul>	<ul style="list-style-type: none"> <li>• Performance of these products vary.</li> </ul>
Spring-loaded metal	High	<ul style="list-style-type: none"> <li>• Door jambs, heads, casement windows</li> </ul>	<ul style="list-style-type: none"> <li>• Adjusts to irregularities of windows and doors.</li> <li>• Adjusts to seasonal changes in gaps.</li> <li>• Suitable for cold weather applications.</li> </ul>



Table 4-2 Summary of recommended air leakage control materials (*Continued*)

Product	Durability	Application	Comments
<b>Weatherstripping and gaskets</b>			
V-type polypropylene strips	High	<ul style="list-style-type: none"> <li>• Door jambs, heads, casement windows</li> </ul>	<ul style="list-style-type: none"> <li>• Adjusts to irregularities of windows and doors.</li> <li>• Suitable for cold weather applications.</li> </ul>
Pile with fin	High	<ul style="list-style-type: none"> <li>• Suitable replacement seal for sliding windows and doors</li> </ul>	<ul style="list-style-type: none"> <li>• Provides suitable air leakage control, however, it does not provide acceptable seal for resistance to water penetration in locations with high wind-driven rain potential.</li> </ul>
Tubular bulb seal	High	<ul style="list-style-type: none"> <li>• Suitable replacement seal for sliding windows and doors</li> <li>• Available in a range of profiles</li> </ul>	<ul style="list-style-type: none"> <li>• Provides suitable air leakage control and rain penetration control.</li> </ul>
Door sweeps and thresholds	Low to high	<ul style="list-style-type: none"> <li>• Bottom of exterior doors and on exterior thresholds</li> </ul>	<ul style="list-style-type: none"> <li>• Wood, metal or plastic mounted strip to form seal between floor and door assemblies</li> <li>• Sealing interior partition doors requires consideration of suite ventilation requirements.</li> </ul>
Electric switch and outlet gaskets	High	<ul style="list-style-type: none"> <li>• Easily installed</li> <li>• Effective for air sealing electrical boxes that lack an effective air/vapour barrier behind the wall</li> </ul>	<ul style="list-style-type: none"> <li>• Polyurethane gasket precut to fit behind standard electrical cover plates</li> <li>• Ensure product is CSA approved.</li> </ul>
<b>Membranes</b>			
Bituminous and self-adhered flexible membrane	High	<ul style="list-style-type: none"> <li>• Used as part of a non-accessible air leakage control system.</li> </ul>	<ul style="list-style-type: none"> <li>• Requires structural backup.</li> <li>• Consideration of vapour diffusion through these materials is required.</li> </ul>
EPDM gaskets	High	<ul style="list-style-type: none"> <li>• Airtight friction seal around electrical and mechanical penetrations</li> </ul>	<ul style="list-style-type: none"> <li>• Suitable as part of an air leakage control system at most pipe and conduit penetrations.</li> </ul>
Liquid-applied membranes	High	<ul style="list-style-type: none"> <li>• Used as part of a non-accessible air leakage control system and concrete block walls.</li> </ul>	<ul style="list-style-type: none"> <li>• A range of products with variable air leakage and vapour diffusion characteristics is available.</li> </ul>
Polyethylene sheet	Low	<ul style="list-style-type: none"> <li>• Suitable for vapour barrier applications.</li> </ul>	<ul style="list-style-type: none"> <li>• Does not meet structural requirements for use as an air barrier in high-rise applications unless adequate structure provided by supporting members within the assembly.</li> </ul>



## 4.5 STEP 5: PERFORM THE AIR SEALING WORK

With the leakage locations identified and prioritized, the air sealing can begin. Emphasis should be placed on the largest holes (that is, massive and major) identified on the inspection checklist in appendix C. Smaller holes can be addressed as time and budget permit.

Air leakage control methods are described for typical locations in this section. In particular, information is presented on sealing:

1. at the bottom of the building;
2. at the top of the building;
3. exterior walls; and
4. interior partitions.

The reason emphasis is placed on the top and bottom of the building is because these are the areas that normally experience the greatest indoor-to-outdoor pressure differentials (attributable to the stack effect) and are therefore the most vulnerable to air leakage.

A number of general principles should be followed in all air sealing projects. Specifically:

1. Ensure that adequate structural support is provided for air barrier materials used including the seal between materials.
2. Ensure that all materials meet or exceed the requirements for fire resistance rating of the assembly and the flame spread and smoke generation requirements. Confirm plans with the local building code authority having jurisdiction.
3. In buildings with fireproofed steel structures, the fireproofing must be removed prior to air sealing then repaired upon completion of air sealing work.
4. Sealing at the plane of airtightness ensures continuity of the air leakage control system. Use materials compatible with the surrounding surfaces.

### 4.5.1 Air sealing at the bottom of the building

Numerous building services penetrate the air barrier at the base of the building including:

- electric and gas utilities;
- domestic water service pipes;
- sanitary service pipes (figure 4-14);
- fire protection service pipes;
- storm drainage pipes;
- communications wiring; and
- ducts.

These services are typically directed horizontally or vertically through a series of shafts, pipes and chases from the below-grade parking garages for distribution throughout the building. If not sealed where they enter the building, these penetrations can allow air to freely move from the garage to the building.



Figure 4-14 Plumbing penetrations



### Penetrations through parking garage ceiling to building

Gaps around pipes, wires and ducts penetrating the ceiling of the parking garage to the building should be sealed and finished with fire-rated materials. This includes plumbing pipes, fire sprinklers, standpipes and electrical services.

### Penetrations through building core walls

Seal mechanical and electrical service penetrations through building core walls (figure 4-15). Core walls are usually concrete block walls that separate the parking garage and other unoccupied service areas from occupied common areas, including the elevator, foyer and stairwells. Small gaps may be filled with caulking or foam sealant (figure 4-16). Larger holes may be covered with drywall sealed to the core wall and penetration or filled and sealed with concrete.

### Floor slab-to-wall joints

Air barrier materials used to seal interior walls should be terminated at the junction of the floor and ceiling slabs to ensure continuity. Cement parging may be used at the top and bottom of concrete walls. Gypsum board should be caulked or foamed. Fire-rated caulking may be used to seal cracks and gaps at the top or bottom of the wall, wall to door frame, wall to vent openings and other penetrations.

### Mechanical and electrical rooms

Walls and ceilings of service rooms, such as telephone switch gear, electrical, sprinkler valve and pump rooms, typically have multiple penetrations for pipes, ducts, cables and conduit. When these services penetrate the core walls or ground floor slab, adequate fire stopping and air seals must be provided, using a combination of foam, caulking and fire-stopping material. Where fire stopping has not been done, an ALC opportunity exists. Access doors to service rooms should be weatherstripped and provided with sweeps and have their frames sealed to adjacent walls.

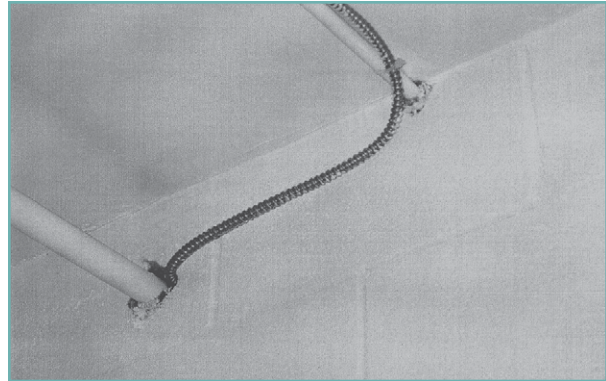


Figure 4-15 Plumbing penetrations of parking garage walls (photo: Proskiw Engineering Ltd.)

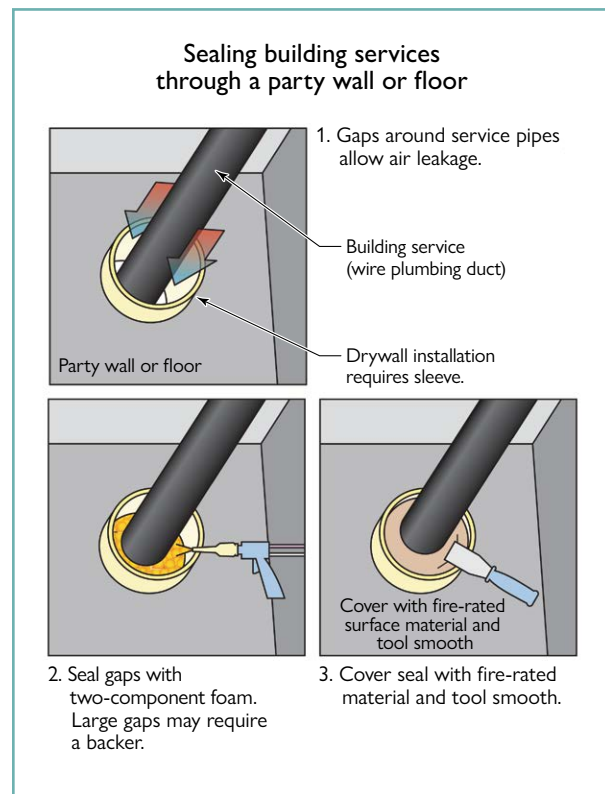


Figure 4-16 Sealing service pipes



## Garbage rooms

The garbage room is connected to the full height of the building by the garbage chute. The shaft enclosing the chute is a potential pathway for air movement that can cause the spread of odours and contribute to the stack effect. In general, floor slabs should be sealed tight to chutes. Sheet metal can be cut to fill the gap between the chute and the floor slab if it is too big to fill with sealants.

Specialized closures are available that can be installed at the base of the chute to seal it off. This not only prevents the chute from acting like a chimney, it also helps to prevent odour transfer through the building and seals off the chute in the event of a fire in the garbage compactor or dumpster.

Seal the garbage room access door with weatherstripping. Outdoor overhead doors can be provided with new weatherstripping if required.

Fill gaps between ducts and exterior garbage room walls with caulking or foam (figure 4-17). Note: if the duct penetrates an interior wall, there is likely a fire damper in the duct and a steel flange supporting the damper and duct as it passes through the wall. This is a fire-rated assembly. If it appears that additional sealing is required, consult with local building code authorities on acceptable methods and materials.

## Corridors, vestibules and elevator lobbies

Doors leading to corridors, stairwells, vestibules and elevator lobbies from the parking garage levels or the basement should be sealed to reduce air flow between the occupied floor levels and the basement or garage.

Weatherstrip lobby doors, vestibule doors and access doors to the corridor or vestibule leading from underground parking and fire exit stairs. Seal junctions of door frames and adjacent walls, seal tops and bases of walls using urethane foam or caulking depending on the size of gap.

Ensure materials used are appropriate for the fire rating of all assemblies.

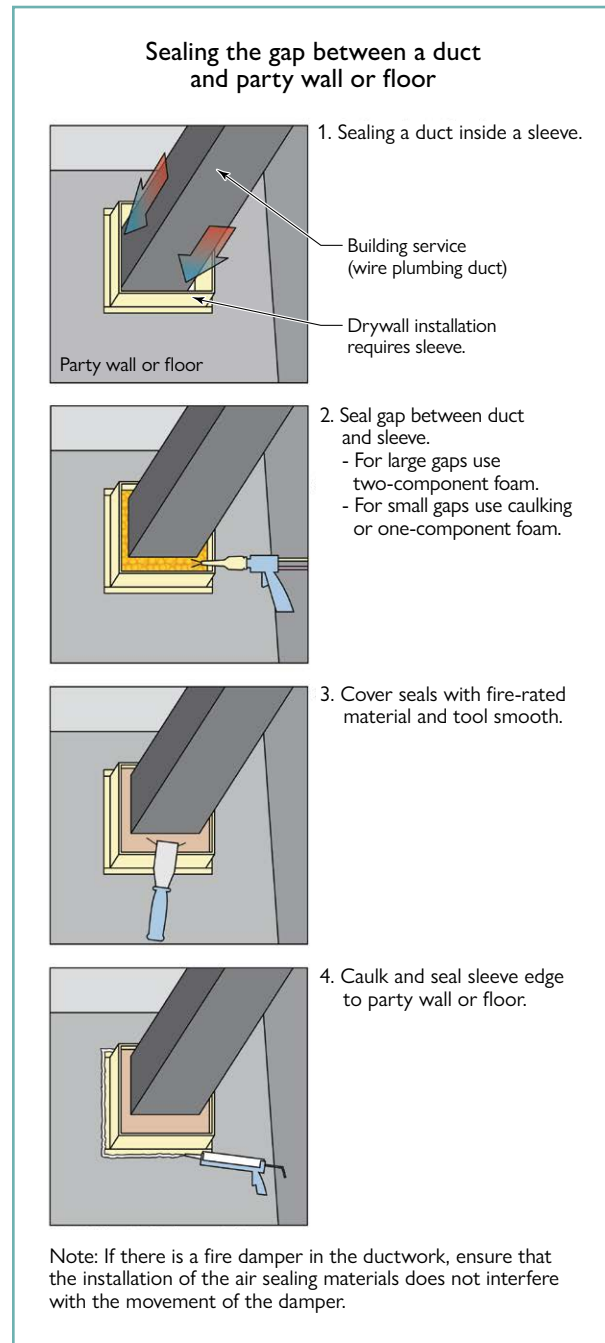


Figure 4-17 Sealing ducts



## 4.5.2 Air sealing at the top of the building

Numerous penetrations occur at the top of the building for mechanical equipment, elevators, roof access and skylights. If not sealed properly, these areas can be locations of significant air leakage and heat loss. Recommended approaches for sealing the top of the building are presented below.

### Mechanical penthouses

Mechanical penthouses are often located at the top of service shafts that rise from the base of the building, such as elevators, HVAC and service water. They are frequently poorly sealed as they are not considered to be part of the occupied and heated part of the building. However, there are often significant air leakage paths from the interior of the building into the penthouse and from the penthouse to the exterior.

Seal gaps around ducts, wires and pipes passing through the penthouse floor using caulking or foam. Larger holes may require gypsum board or metal closures. When sheet products are applied, ensure the transition from new to existing material is sealed. Weatherstrip doors in the penthouse using a weatherstripping or gasket material detailed in table 4-2. Inspect ductwork to ensure rough openings around ducts are sealed where they pass through floors and walls.

### Elevator penthouse

Reduce air leakage at the top of the elevator shaft by reducing the size of the opening around the elevator cables. Light gauge metal fastened and sealed with caulking to the slab may be installed around the elevator wires to reduce the size of the opening as shown in figure 4-18. Steel closures may be installed around the elevator cables but adequate clearance between the sheet metal and the cables must be maintained. Seal electrical raceways entering the elevator penthouse with caulking or foam (figure 4-19). Ensure that fire stopping is provided at penetrations of fire-rated assemblies.

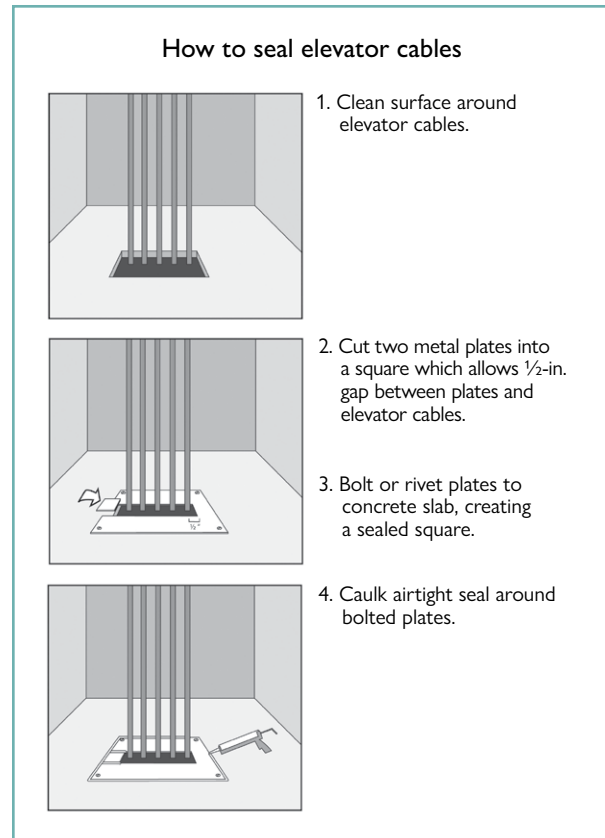


Figure 4-18 Sealing around elevator cables

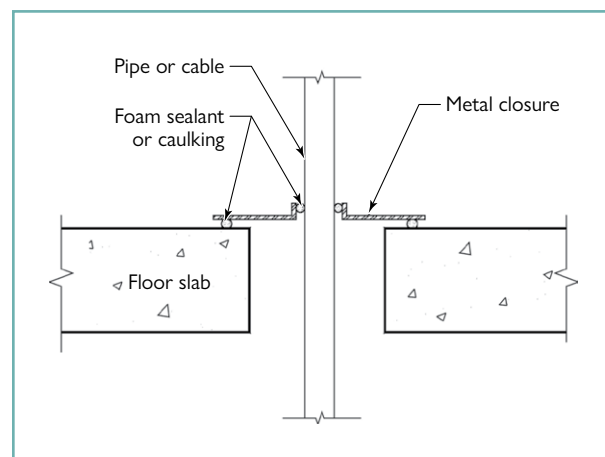


Figure 4-19 Air sealing at wiring

### Roof-to-wall interface

In most MURBs, the roof deck is constructed of concrete slabs. Open web truss joists with a poured concrete topping may also be used. Access to the wall-roof joint from within top floor apartments is generally not possible, or too difficult, unless major renovations are underway. However, there are often opportunities to seal the penthouse walls to the roof as the interiors of these spaces are not often finished.

Within mechanical penthouses or other areas where the roof-to-wall joint is accessible, ensure that the drywall or masonry block/concrete wall-to-ceiling joint is sealed with caulking or foam sealant. In larger projects, a strip of flexible membrane may be used to seal the roof-wall joint.

If the roof deck is fluted steel, spray-applied foam applied at the roof-wall joint is effective. However, the flutes must also be drilled and filled with foam sealant where the roof deck meets the exterior walls (figure 4-20).

Weatherstrip maintenance and equipment installation hatches and doors using compression seals such as closed-cell neoprene foam gaskets. Replace open grate maintenance hatches with solid metal. Ensure that hatchways are fitted with air seal gaskets.

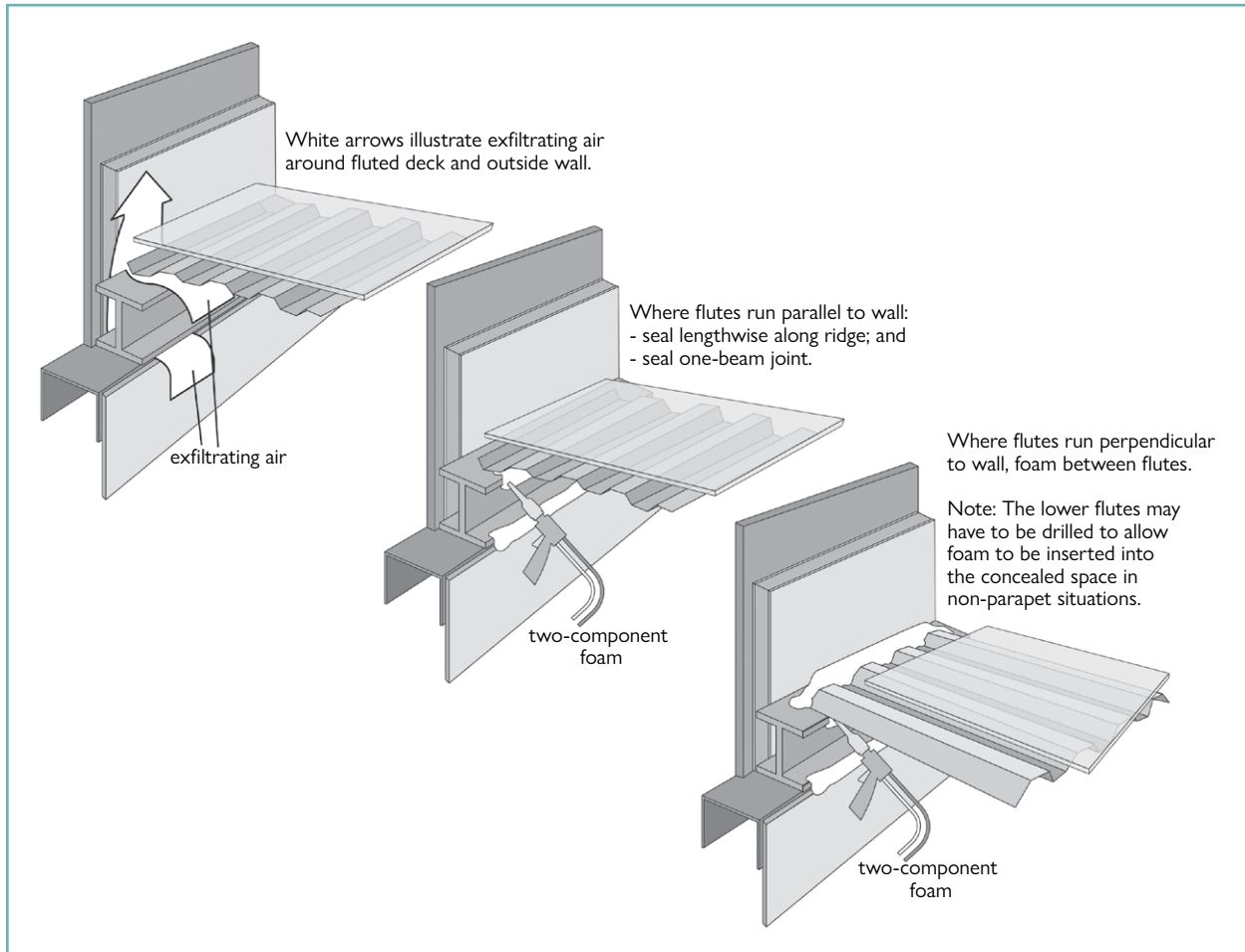


Figure 4-20 Air sealing roof-to-wall interface



### Roof openings

A waterproof roof membrane may provide the principal air barrier on the roof. Other times, the underside of a steel or concrete roof deck may provide the air leakage control system. Seal penetrations through this assembly. Remove or seal unused collars and vents.

### Drains and plumbing vents

When the joint is accessible from above (for example, system A in figure 4-21), seal the flange of the metal collar to the roof membrane using a compatible roofing membrane or mastic. When the system is accessible from below (for example, system B in figure 4-21), seal pipes and vents to the surrounding deck from below using foam sealant.

### Chimneys and hot vents

Seal flange of metal collar to the roof membrane using a compatible roofing membrane or mastic. Seal metal collar of hot vents to the vent with high temperature silicone caulking prior to installation of rain deflection flashing. Alternatively, if the underside of the roof deck is the air leakage control system, a metal collar can be applied around the chimney or vent. The collar may be made airtight using a high temperature caulking product.

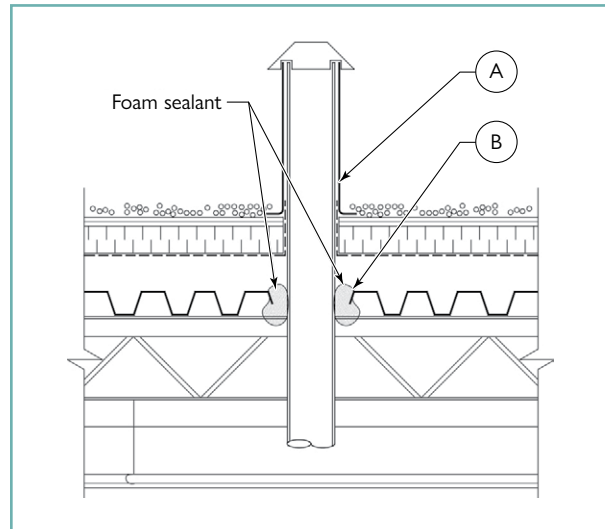


Figure 4-21 Air seal of roof penetration

### Wall to floor in penthouse

Cement parging may be used at the top and bottom of concrete walls to seal wall-floor joint. Gypsum board walls should be caulked or foamed to ceiling. If a block wall is used and is unfinished, fire-rated caulking may be used to seal cracks and gaps at the top or bottom of the wall, wall to door frame, wall to vent openings and other penetrations.

### Service penetrations of penthouse walls

Ensure wiring, duct and pipe penetrations are sealed where they penetrate the exterior walls of the penthouse. Fill gaps with caulking or foam depending on the size of the gap. Ensure louvres close tightly when exhaust fans are off. Caulk louvre frames to the surrounding walls.



## Other rooftop air sealing opportunities

### Garbage chute vent

Seal garbage chute vents using the same techniques as described above for drains and cold vents.

### Curb-mounted equipment and smoke and access hatches

If possible, lift curb-mounted equipment including exhaust fans, supply air fans, etc. to inspect for gaps between the duct and the curb as well as the curb-to-roof deck membrane. Seal gaps between ducts and roof deck with foam (backing may be required to support the foam until it sets). Clean and lubricate any linkages. Weatherstrip louvres, if necessary, to ensure they are tightly sealed when closed.

If re-roofing work is planned, curb-mounted equipment can be sealed to the roof air barrier system (figure 4-22). Any gaps between the duct and the roof curb should be sealed with metal closures, caulking and foam. Ducts can be sealed by forming a sleeve around the duct using an EPDM or peel-and-stick membrane material (ensuring the membrane is supported by plywood, sheet metal or drywall). Caulk gaps between the equipment and supporting curb.

### Access hatches

Check the weatherstripping seals of roof access hatches and replace defective gaskets.

### Stairwell doors to roof

Check for daylight around the perimeter of the closed door—any light will show where the weatherstripping is ineffective, worn or damaged. Weatherstrip the door, if required. Seal junctions of frames and walls as shown in figure 4-23 with caulking or foam depending on the size of the gap. Seal under the doorsill using a bead of compatible caulking or foam sealant.

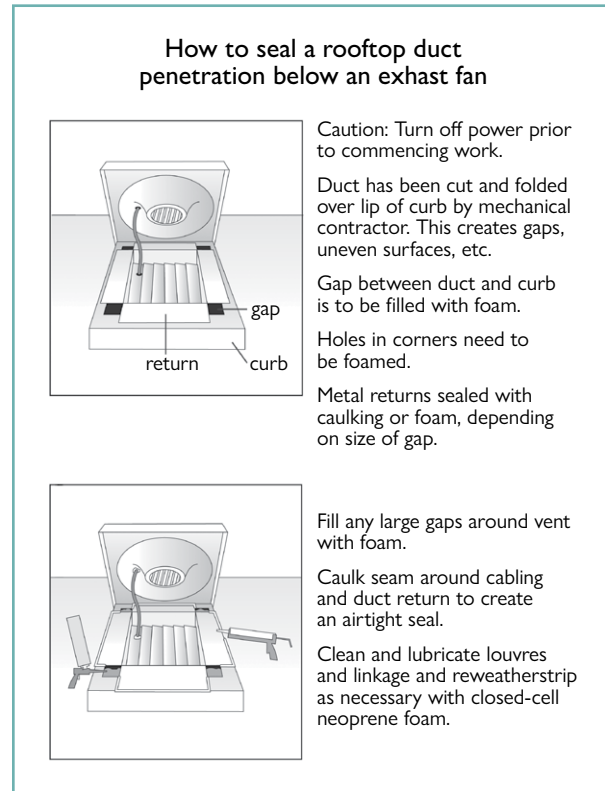


Figure 4-22 Curb-mounted equipment

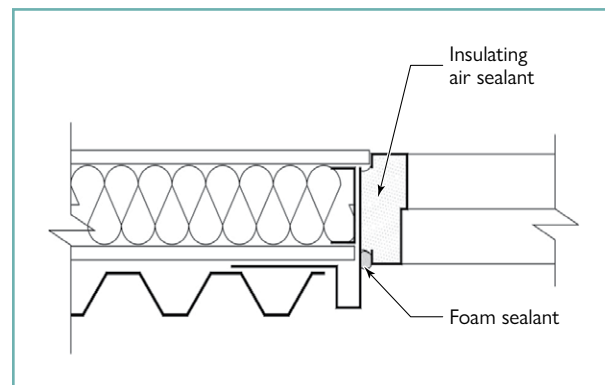


Figure 4-23 Air sealing metal door jamb

### 4.5.3 Air sealing of the exterior walls of the building

Junctions between assemblies are typically the location of air leakage on the exterior walls of a building. The primary locations on walls where this occurs include:

- floor-to-wall joints;
- wall-to-window joints;
- wall-to-soffit connections;
- wall-to-foundation junction; and
- mechanical and electrical penetrations through exterior walls.

The choice of how to air seal at these locations will be affected by the original design and construction of the air leakage control system and the surrounding envelope elements. As noted previously, two approaches are typical: the exterior air leakage control system and the interior air leakage control system. The methods described below provide options for both of these systems.

#### *Floor-to-exterior walls*

For exterior air leakage control systems (precast concrete panels, glass curtain walls, face-sealed exterior insulation finish systems), ensure that all joints in the cladding are sealed with a durable caulking product. Do not seal holes intentionally provided for water drainage.

For interior air leakage control systems, apply caulking along the base of the gypsum board between the gypsum board and the concrete floor slab. This may require the removal of baseboard trim and rolling back of carpet. At the underside of floors, the gypsum board may be sealed to the concrete or ceiling drywall. This work is most easily done during apartment turnovers or renovations.

#### *Window to wall*

Typical locations for air sealing windows are shown in figure 4-24. For exterior air leakage control systems, joints between cladding and window frames may be sealed with a durable caulking (as shown by Method A in figure 4-24). Ensure that drain holes in the window frames are not sealed over.

For interior air leakage control systems, the gypsum board may be sealed to the interior of the window frames with a continuous bead of caulking that seals the drywall to the window trim and the window trim to the window frame (as shown by Method B in figure 4-24).

Alternatively, it may be possible to remove the window trim to allow for foam or caulking to be installed to directly connect the drywall and window frame. This is a more durable and desirable sealing location but more disruptive to access. Therefore, this approach may only be possible during a window replacement, major renovation or during an apartment turnover.

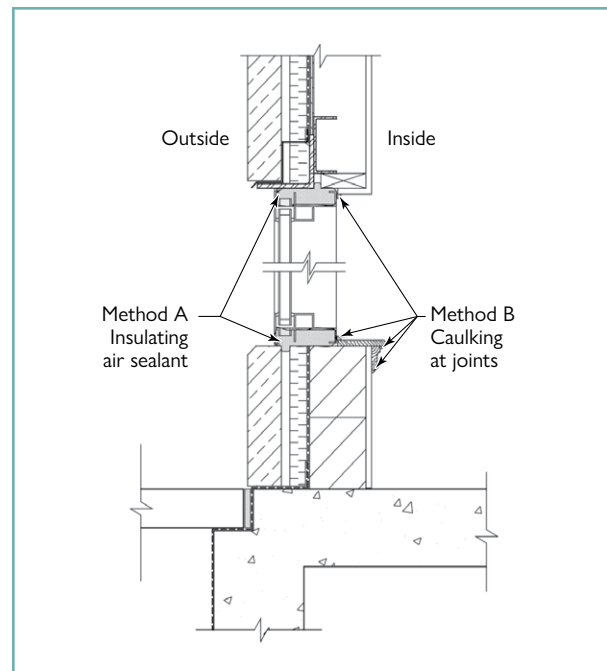


Figure 4-24 Air sealing windows



### Walls to soffits

Soffits are found under heated floor areas—typically where a floor of the building overhangs an unheated, or outside, area. “Hot soffits” that contain services, which must not be allowed to freeze, should be air sealed at the soffit face, as shown in figure 4-25. Hot soffits are also used to keep the floor area above warm. Air barrier materials, such as Type IV extruded polystyrene or exterior drywall, should be applied around the exterior perimeter of the soffit to prevent air leakage into and out of hot soffits. The drywall-to-concrete joints should be sealed as well as the joints in the extruded polystyrene. Protective cladding and soffit is then applied to cover the assembly.

“Cold soffits,” containing no services subject to freezing, offer greater flexibility for air leakage control. For exterior air leakage control systems, ensure that all joints and penetrations are caulked.

Recessed light fixture housings and access panels may be sealed with caulking. An interior, or accessible, air barrier system can be formed around a cold soffit by caulking the exterior wall above directly to the floor slab. On the floor below, it will also be necessary to caulk or foam the exterior wall adjacent to the soffit to the floor slab above.

Pipes or electrical conduit penetrating through the envelope into the soffit should be sealed with caulking or foam sealant.

### Walls at foundations

Air can leak through the joint between the ground floor slab and above-grade walls and through the junction of the ground floor slab and the top of the foundation walls. These joints may be caulked in exterior air leakage control systems with a durable sealant or caulked on the inside between the drywall and the floor slab.

### Doors (front entry, service room, balconies)

Check the perimeter of doors for light and the condition of the weatherstripping and seals. Replace as necessary. Ensure door frames are sealed to surrounding walls with caulking. Foam sealants can be sprayed between the door frame and rough wall opening and then be covered with a compatible caulking.

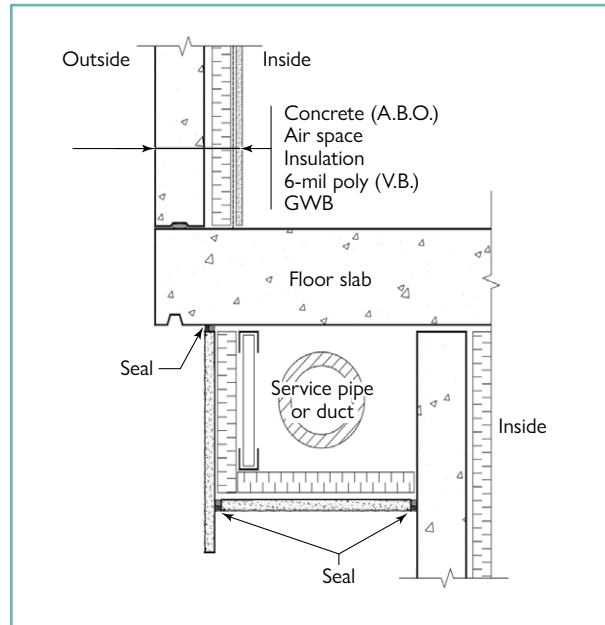


Figure 4-25 Air sealing a hot soffit



## Windows

Operable windows can be a major source of air leakage, particularly in older buildings. Casement and slider frame window weatherstripping may be removed and replaced. It is generally recommended to use the same material and profile for the replacement weatherstripping.

Awning style windows (figure 4-26) generally require weatherstripping in the following locations:

1. Between the check rails.
2. Between the bottom rail and sill on a lower sash (or the top rail and head jamb of an upper sash).
3. Between the stiles and the side jamb.

To seal, apply a plastic V-weatherstrip to the back of the check rail on the lower sash, so that the strip is concealed when the sash is closed. If appearances are not important, the V-weatherstrip can be applied to the upper sash rail, with the open end of the “V” pointing downward, to the outside. This will leave the weatherstripping visible when the window is open, but it provides a better seal.

To weatherstrip at the sill, apply a compression weatherstrip (for example, closed-cell sponge or hollow core tubular) to the width of the sash. Attach to the bottom rail of the sash. V-seals can also be used.

To weatherstrip the sides of the sash, use self-adhesive plastic V-weatherstrip. Apply material to the side jambs, running up from the sill to the full height of the lower sash. The weatherstripping should be positioned as close to the outside of the frame as possible, with the open end of the “V” facing to the outside.

Check to ensure that the window can still be opened easily. If not, apply a dry lubricant to the rails and adjust the stops as required. Check to ensure the sash clamp is operable. If not, adjust the clamp or install a new clamp.

In many older MURBs with operable windows, the sash closure locks may no longer be able to properly close the window. Or, they can only be closed with an excessive amount of force, which poses a major problem for many residents, particularly seniors. In these situations, the hardware should be replaced.

For fixed windows, install a bead of caulking into the trim mitre joints, where required. Remove excess caulking and wipe clean. Inspect glazing compound, tape or gaskets of window panes. Replace if the material has deteriorated.

If the windows are being replaced, then the location of the wall air barrier needs to be identified so that the windows can be sealed to it to provide a continuous air seal across the window installation.

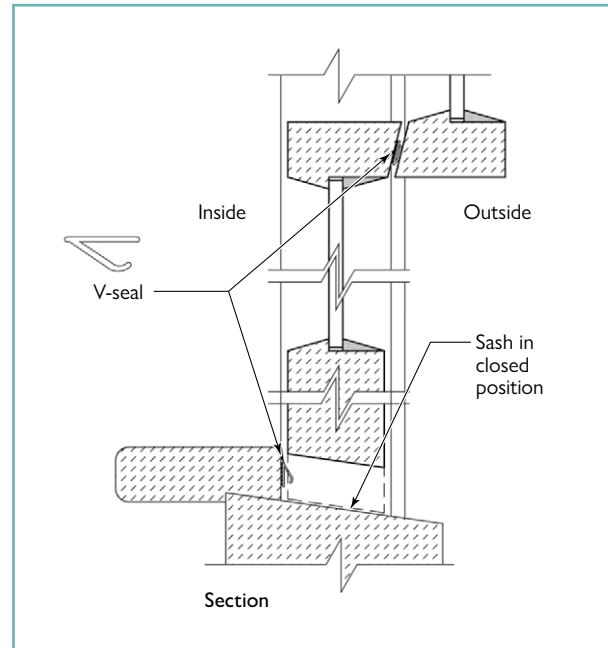


Figure 4-26 Air sealing awning windows

### Electrical penetrations in exterior walls

Install a receptacle gasket between the electrical box and the cover plate, as shown in figure 4-27. Place the knock-outs from the gasket over childproof plugs to seal the outlets when not in use.

Disconnect power and remove electric baseboard heaters to inspect and, if necessary, seal the wire penetration through the wall. Seal the wall-floor joint with caulking.

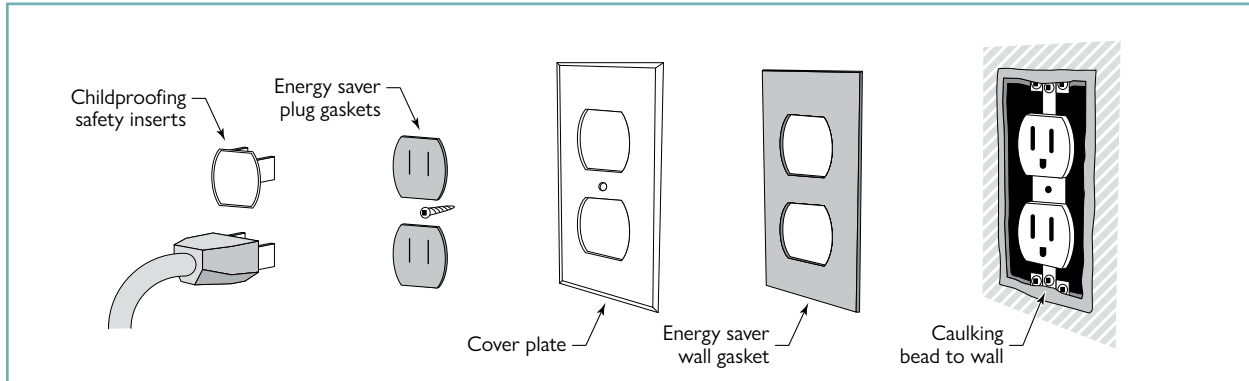


Figure 4-27 Air sealing electrical penetrations

### Service penetrations in exterior walls

Dryer vents, exhaust fan ducts, water pipes, gas pipes, oil filler pipes and almost all other penetrations can be sealed using caulking or foam sealant where accessible. However, these services are frequently hidden in walls, soffits or chases.

For an exterior air leakage control system, caulking should be installed at the exterior of the building, around the pipe and wire penetrations. Ensure that installation of air sealing will not result in water ingress into the building.

For hoods, grilles or louvres, if they are removable, check to see if the duct is sealed where it passes through the air barrier system. If not, try to seal the gap between the duct and the surrounding wall area with spray-applied foam or caulking. Replace hood, grille or louvre and seal the edges to the wall with caulking. Check to see that operable backdraft dampers work and seal well when shut. Ensure that motorized outdoor air dampers operate and are sealed when in the fully closed position. Replace gaskets between the vanes of the louvre if necessary.

For an inaccessible system, air sealing may be attempted from either the interior or exterior, and depends on the accessibility of the air barrier and the level of disruption required (or that would be tolerated) to access it.

For an interior air leakage control system, foam or caulk around the penetration from the interior. Seal penetrations of pipes and ducts at the plane of airtightness (if possible) and again at the exterior face with caulking to prevent water penetration and pest entry (figure 4-28).

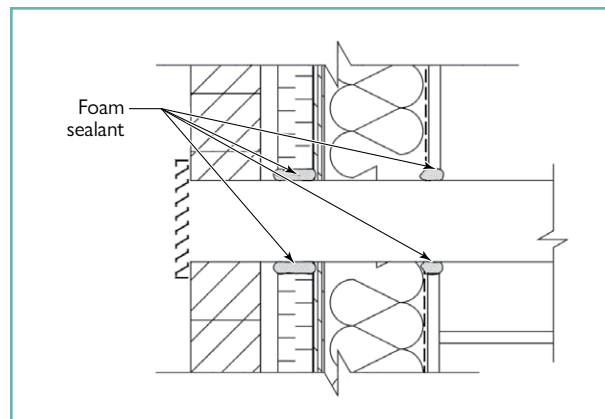


Figure 4-28 Air sealing of louvres



#### 4.5.4 Air sealing of interior walls and floors

The following locations and details can be sealed to prevent the movement of air through the building. Sealing penetrations, cracks and holes in floor slabs and partition walls will help reduce air flow from floor to floor and from apartment to apartment. This will prevent air leakage out of the building, will help to prevent odour transfer between apartments and will limit smoke movement during fire emergencies. Foam applied in wall and floor assemblies may have to be covered with non-combustible material (for example, fire barrier mortar) if the assembly is fire rated. As most floors and walls are fire-rated assemblies, the air sealing details should be reviewed and approved by local building code authorities.

Shafts that allow for the passage of plumbing, ductwork and wiring between floors can allow a significant amount of air movement if not properly sealed. Two approaches can be taken to seal shafts. The first approach involves sealing between the shaft and the floors or walls it passes through and where the plumbing, ducting or wiring exits the shaft as shown in figure 4-29. This way, the shaft is made into a sealed element that air cannot enter or exit.

The second approach involves gaining access into the shaft to install internal partitions at each floor level or wall penetration. This involves installing rigid board material, such as drywall, within the shaft as tightly as possible around the ducts, wiring or plumbing that is installed within the shaft. The edges of the drywall would be caulked or foamed to the interior walls of the shaft and to the plumbing, wiring or ducts. This prevents air movement within the shaft itself. The exterior of the shaft must also be sealed where it passes through the floor and wall partition.

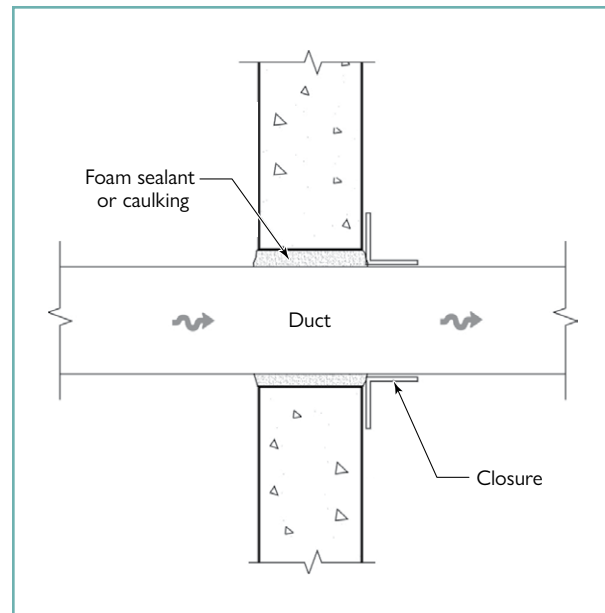


Figure 4-29 Air sealing pipes and ducts within shafts

#### Vertical shafts

##### Garbage chute

On each floor, weatherstrip chute access hatches with self-adhered, close-cell foam tape. Seal the hatch frame to the surrounding wall in the garbage room on each floor by caulking all joints. The door to the garbage room on each floor should be weatherstripped using the instructions for weatherstripping doors presented earlier. This will help to stop air movement up the shaft and to contain odours. Caulking the floor-wall and wall-ceiling joint in the garbage chute access room on each floor will also help prevent the movement of air into (or from) the chase containing the shaft.

##### Stairwells

Install weatherstripping on stairwell-to-corridor doors. Caulk or foam door frames to adjacent walls. Install door sweeps. Caulk wall-to-ceiling and wall-to-floor joints if a gap is visible.

**NOTE:** Sealing stairwell doors may make them harder to open as a result of the difference in air pressure between the stairwells and the adjacent corridors especially in cold weather. This should be monitored by building staff after the retrofit.



### Service closets

Seal wiring raceways as they pass through the floors of service rooms on each floor. If the gap is large, install a steel closure around the wiring and caulk and fasten it to the surrounding floor. Install a backer material between the wire and the walls of the steel closure and apply a sealant to seal between the wire and closure.

Seal ducts where they pass through walls and floors. If a fire damper flange is present, caulk the flange-to-duct and flange-to-floor joints. Ensure that the work does not interfere with the operation of the fire damper.

### Seal pipe risers

Install steel closure if the gap is large. Install a backer material and caulk or foam over to seal between the closure and pipes.

### Corridor ventilation/central exhaust air system risers

Caulk the corridor supply air grilles to the surrounding wall on each floor level. If the corridor air duct is visible where it passes through the mechanical penthouse floor (or other floor levels), caulk supporting flanges to the duct and to the surrounding floor level. If large gaps exist between the duct and the floor, install a steel closure and seal.

For central exhaust systems, remove bathroom and kitchen grilles and caulk between the duct and surrounding wall area. If the grille cannot be removed, caulk the joint between the exhaust grille and the surrounding wall area. For rooftop exhaust fans, ensure that the exhaust duct is sealed to the roof deck as discussed in section 4.5.2.

### Fire hose – standpipe cabinets

Caulk or foam around pipes as they enter the cabinets on each floor. Caulk between the cabinet and the surrounding wall.

### Pipe, duct and conduit penetrations

A typical floor penetration is shown in figure 4-30. Penetrations are found under kitchen and bathroom counters, behind toilets and in the walls and floors of service rooms. Pipe and duct penetrations through walls and floors can leave holes for air movement even when partially fire stopped with mineral fibre. Pack joints with non-shrink grout and seal gaps with foam sealant or caulking (figure 4-31).



Figure 4-30 Typical conduit penetration

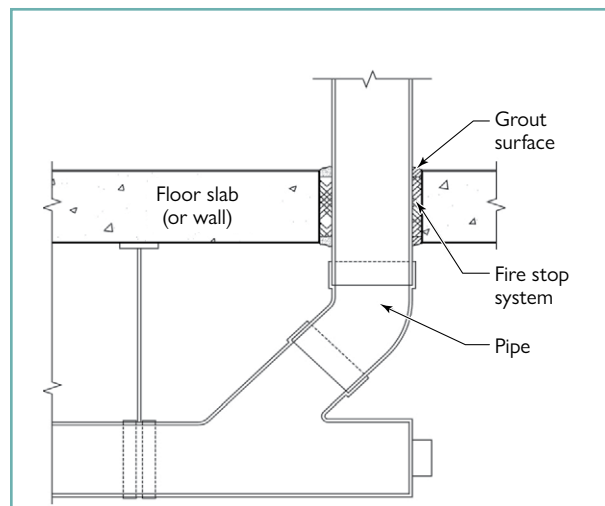


Figure 4-31 Air sealing plumbing penetration





### *Service and inspection hatches*

Access hatches in ceilings and walls for plumbing cleanouts, electrical panels, mechanical inspection, garbage or laundry chutes and smoke hatches located in ceilings or walls should be provided with foam gaskets to ensure an airtight fit.

### *Corridor-to-suite doors*

Weatherstripping suite access doors is not recommended in general, as the undercut is typically used to provide ventilation air to suites. If in-suite ventilation is provided, weatherstripping could be installed on a trial basis to determine if this improves conditions in the corridors and in the apartments.

### *Ductwork penetrations*

The passage of ductwork through walls and floors can create the same unwanted holes in fire separation as pipes and conduit. With ductwork there are a greater number of joints to be sealed. A fire damper is located within the duct where it penetrates fire-rated assemblies—both walls and floors. Metal frames are supposed to be installed that surround the duct and the fire damper and seal the entire assembly to the wall or floor it passes through—but sometimes this is not done. Once installed, the ALC contractor can ensure that a seal is made between the partition and the support frame and between the frame and the duct using approved caulking or foam sealants.



## 5 Appendix A – Air leakage control resources



A range of resources are available to air leakage contractors to obtain information, education and tools. Information resources include the following:

### **BUILDING ENVELOPE COUNCILS**

Most provinces have local building envelope councils (BECs) that put on regular educational events and are an excellent opportunity to meet others working in air leakage control. A full list of provincial BECs is available at:

National Building Envelope Council  
Website: <http://www.nbec.net/>

### **CANADA MORTGAGE AND HOUSING CORPORATION**

CMHC  
700 Montreal Road  
Ottawa, ON K1A 0P7  
Phone: 613-748-2000  
Website: <http://cmhc.ca/>

### **NATURAL RESOURCES CANADA**

NRCan  
580 Booth Street  
Ottawa, ON K1A 0E4  
Website: <http://nrcan.gc.ca/>

### **FAN DEPRESSURIZATION EQUIPMENT MANUFACTURERS**

Retrotec  
1060 East Pole Road,  
Everson, WA, 98247, USA  
Website: <http://retrotec.com>

Minneapolis Blower Door Company  
2801 21st Ave. South, Suite 160  
Minneapolis, MN 55407, USA  
Website: <http://products.energyconservatory.com>

Infiltec  
108 South Delphine Avenue  
PO Box 1125  
Waynesboro, VA 22980, USA  
Website: <http://www.infiltec.com/inf-catb.htm>



## 6 Appendix B – References



ASHRAE. *2013 ASHRAE Handbook – Fundamentals*, Chapter 16, American Society of Heating Refrigerating and Air-Conditioning Engineers, Inc., Atlanta Georgia.

Bahnfleth, W.P., G.K. Yuill, B.W. Lee. *Protocol for Field Testing of Tall Buildings to Determine Envelope Air Leakage Rate*, American Society of Heating Refrigerating and Air-Conditioning Engineers, Inc., Atlanta Georgia, 1998.

J.F. Burrows Consulting. *Incompatible Building Materials: A Report Documenting Premature Failure in Residential Construction Resulting From Material Incompatibility*, CMHC, 2003.

City of Calgary. *Fire Stopping Service Penetrations in Buildings*, Version 1.0, 2003.

Diamond, R.C., H.E. Feustel, D.J. Dickerhoff. *Ventilation and Infiltration in High-Rise Apartment Buildings*, Lawrence Berkeley National Laboratory, LBL-38103, 1996.

Knight, K.D., B.J. Boyle. *Guidelines for Delivering Effective Air Leakage Control Systems*, CMHC, Ontario Association of Architects, 2003.

National Energy Conservation Association. *Air Leakage Control Manual*, 1989.

Public Works Canada. *Air Leakage Control: Guidelines for Installation of Air Leakage Control Measures in Commercial Buildings*, 1992.

Red River College. "Airtightness in Existing Multi-Unit Residential Buildings: Field Trials of a New Test Protocol," report prepared for Canada Mortgage and Housing Corporation, 2015.



Scanada Consultant Inc. *Development of Design Procedures and Guidelines for Reducing Electric Demand by Air Leakage Control in High-Rise Residential Buildings*, CMHC, 1991.

Shaw, C.Y. "Methods for Conducting Small-Scale Pressurization Tests and Air Leakage Data of Multi-Storey Apartment Buildings," *ASHRAE Transactions*, Vol. 86 (1), 1980, pp. 241-250.

Shaw, C.Y. "Air Tightness: Supermarkets and Shopping Malls," *ASHRAE Journal*, March 1981, pp. 44-46.

Shaw, C.Y., S. Gasparetto and J.T. Reardon. "Methods for Measuring Air Leakage in High-Rise Apartments," *Air Change Rate and Airtightness in Buildings*, ASTM STP 1067, 1990, pp. 222-230.

Shaw, C.Y., R.J. Magee, J. Rousseau. "Overall and Component Airtightness Values of a Five-Storey Apartment Building," *ASHRAE Transactions*, Vol. 97 (2), 1991, pp. 347-353.

Sheltair Group. *Healthy High-Rise, A Guide to Innovation in the Design and Construction of High-Rise Residential Buildings*, CMHC, 2001.

Sherman, M.H. *Building Airtightness: Research and Practice Draft Report*, Lawrence Berkeley National Laboratory Report No. LBNL-53356, 2005.

Woods, T. "Does Your Building Suck?", CanAm Building Envelope Specialists Inc., 2003.



# 7 Appendix C – Air leakage control checklist form



This form can be used during an initial inspection of the building to record basic building features, the presence of pre-existing problems and other building characteristics. The checklist provides a systematic, location-by-location approach to recording if certain features are present in the building and whether or not there is air leakage control work in each location.

## Building Air Leakage Control Checklist

**Building address:** \_\_\_\_\_

### Building Characteristics

Age: \_\_\_\_\_

Number of storeys: \_\_\_\_\_ Number of units: \_\_\_\_\_ Wall construction: \_\_\_\_\_

Occupancy: rental apartment    condominium

### Space heating system:

electric baseboard    central hot water    in-suite fan coil    gas-fired forced air (in-suite furnace or combo system)  
other: \_\_\_\_\_

Corridor air ventilation system: \_\_\_\_\_ Suite exhaust: in-suite exhaust fans    central rooftop exhaust fans

Space heating individually metered?    Y    N

### Building envelope type:

brick veneer – stud wall    brick veneer masonry backup    TTW masonry    precast concrete panels  
glass curtain wall    stucco

Air leakage: low    medium    high

### Building performance problems:

water penetration    indoor air quality    combustion spillage potential in suites  
comfort problems    other: \_\_\_\_\_



Leakage Class	Indicators	Potential Impact on the Building Envelope, Energy Costs or Indoor Environment
Trivial	Barely detectable using a smoke puffer	Of no practical significance
Minor	Easily detectable using smoke puffer, or barely detectable by hand	May have an impact, particularly if leak is exposed to sustained pressure differentials
Major	Easily detectable by hand	Good possibility that it could lead to problems
Massive	Detectable by hand, 0.3 m (1 ft.) from the leak	Very good possibility of problems

### Building Air Leakage Control Checklist

Location	Potential Leakage Site	Leakage (1 to 5) 1 = Trivial Leakage 5 = Massive Leakage
<b>Top of building</b>		
Elevator penthouse	Roof-wall joint	
	Roof penetrations – wiring	
	Roof penetrations – ducts	
	Roof penetrations – pipes	
	Wall penetrations – wiring	
	Wall penetrations – ducts	
	Wall penetrations – louvres	
	Wall penetrations – pipes	
	Exterior doors	
	Stairwell doors	
	Elevator hoist cable	
	Elevator service wiring	
	Other	
Mechanical penthouse	Roof-wall joint	
	Roof penetrations – wiring	
	Roof penetrations – ducts	
	Roof penetrations – pipes	
	Roof penetrations – boiler vent	
	Wall penetrations – wiring	
	Wall penetrations – ducts	
	Wall penetrations – louvres	
	Wall penetrations – pipes	
	Exterior doors	
	Stairwell doors	
	Floor penetrations – wiring	
	Floor penetrations – pipes	
	Floor penetrations – ducts	
	Other	



<b>Building Air Leakage Control Checklist</b>		
<b>Location</b>	<b>Potential Leakage Site</b>	<b>Leakage (1 to 5)</b> 1 = Trivial Leakage 5 = Massive Leakage
<b>Top of building</b>		
Rooftop	Stairwell door	
	Access hatch	
	Garbage chute vent	
	Exhaust fans	
	Corridor air unit	
	Plumbing stacks	
	Parapets	
	Other	
<b>Bottom of building</b>		
Parking garage	Ceiling/floor above – pipe penetrations	
	Ceiling/floor above – wiring penetrations	
	Ceiling/floor above – duct penetrations	
	Wall to building core – elevator vestibule doors	
	Wall to building core – floor-wall joint	
	Wall to building core – wall-ceiling joint	
	Wall to building core – pipe penetrations	
	Wall to building core – wiring penetrations	
	Wall to building core – duct penetrations	
	Garage ventilation system – supply air louvres	
	Garage ventilation system – exhaust air louvres	
	Garage ventilation system – duct penetrations	
	Overhead vehicle doors	
	Garage exit doors	
	Underground service penetrations	
	Other	

*(Continued)*

Building Air Leakage Control Checklist		
Location	Potential Leakage Site	Leakage (1 to 5) 1 = Trivial Leakage 5 = Massive Leakage
<b>Bottom of building</b>		
First floor	Garbage room – overhead doors	
	Garbage room – exterior exit doors	
	Garbage room – exhaust fan duct	
	Garbage room – exhaust fan louvres	
	Garbage room – wiring penetrations	
	Garbage room – garbage chute to floor	
	Garbage room – interior door	
	Loading bay – exterior overhead door	
	Loading bay – exterior exit door	
	Loading bay to building door	
	Loading bay – wiring penetrations	
	Loading bay – plumbing penetrations	
	Loading bay – duct penetrations	
	Hose bib penetrations	
	Stairwell doors	
	Front entry doors	
	Rear or patio doors	
	Laundry exhaust louvres	
	Laundry exhaust ducts	
	Other	
<b>Exterior walls</b>		
Apartments	Windows	
	Balcony doors	
	Wiring	
	Electric baseboards	
	Pipes	
	Exterior lighting	
	Electric outlets, switches	
	Ducts	
	Exterior hoods, louvres	
	Through-the-wall sleeves	
	Other	

(Continued)





<b>Building Air Leakage Control Checklist</b>		
<b>Location</b>	<b>Potential Leakage Site</b>	<b>Leakage (1 to 5)</b> 1 = Trivial Leakage 5 = Massive Leakage
<b>Exterior walls</b>		
Common rooms	Windows	
	Exterior doors	
	Wiring	
	Electric baseboards	
	Pipes	
	Exterior lighting	
	Electric outlets, switches	
	Ducts	
	Exterior hoods, louvres	
	Through-the-wall sleeves	
	Common room – other	
Stairwells	Windows	
	Exterior doors	
<b>Interior partitions</b>		
Service rooms	Wiring penetrations	
	Duct penetrations	
	Plumbing penetrations	
	Service room door	
	Other	
Service closets (in corridors)	Wiring penetrations – ceiling and floor	
	Plumbing penetrations – ceiling and floor	
Corridors	Stairwell doors	
	Garbage chute room door	
	Garbage chute access hatch	
	Garbage chute hatch-wall joint	
	Floor-wall and wall-ceiling joints	
Basement/garage service rooms	Penetrations through slab above – wiring	
	Penetrations through slab above – pipes	
	Penetrations through slab above – ducts	
	Penetrations through slab above – other	





# Alternative Text and Data for Figures

**Figure 2-1 Component heat loss in MURBs**

Component heat loss in MURBs	(%)
Window	30% to 35%
Roof	5% to 10%
Doors	3% to 5%
Air leakage	20% to 25%
Ventilation	15% to 25%
Walls	20% to 25%

