RESEARCH REPORT

Housing Technology Series

Air Leakage Control Manual
Existing Multi-Unit Residential Buildings

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December 2007

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Cette publication est aussi disponible en français sous le titre : Guide de réduction des fuites d’air dans les tours d’habitation existantes, décembre 2007

The research and preparation of this guide was funded by Canada Mortgage and Housing Corporation and the Program for Energy Research and Development (PERD), Natural Resources Canada.

The contents of this is guide largely based on research conducted by The Sheltair Group Vancouver, British Columbia. Final revisions were prepared by CMHC.

This project was funded under Part IX of the National Housing Act and by the Program for Energy Research and Development (PERD), Natural Resources Canada

Library and Archives Canada Cataloguing in Publication

Air leakage control manual for existing multi-unit residential buildings.

Issued also in French under title: Guide de réduction des fuites d'air dans les tours d'habitation existantes.
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

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

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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 provides information on air barrier systems in building envelopes, instructions on how to diagnose air leakage and seal leaks based on currently available materials and technologies. The manual identifies the many benefits that result from ALC projects.

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.
- MURBs can experience high moisture loads and widely varying occupant expectations for comfort.

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 trades-people and reflect the unique conditions found in each building.

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.

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.

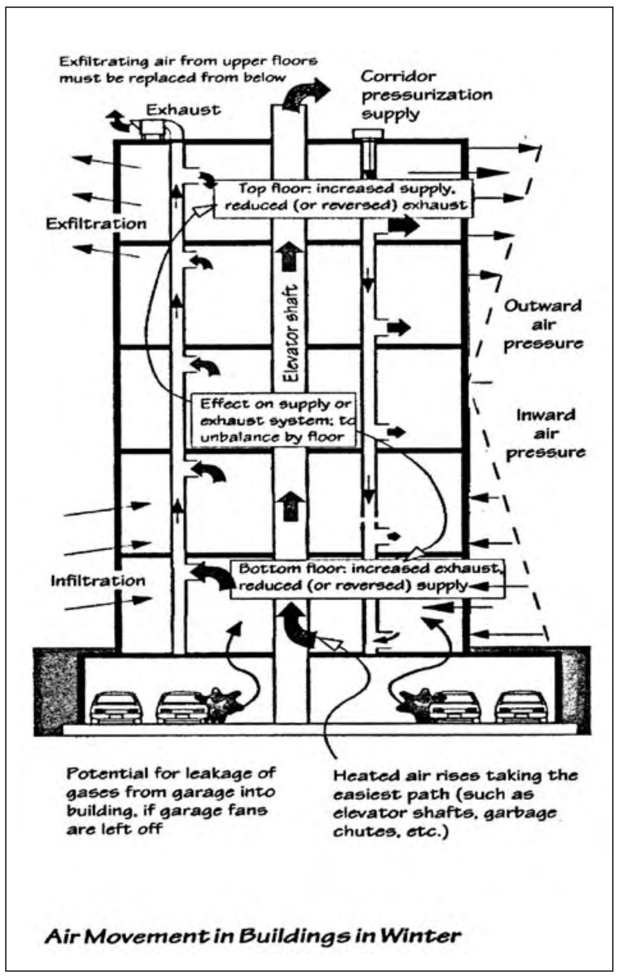

Figure 1-1 Air leakage in MURBs

2. Benefits of Air Leakage Control (ALC)

Most MURBs are very leaky. Air tends to move with relatively ease into, through, and out of the building. Figure 1-1 shows typical airflow movement in high-rise residential buildings. There is usually a great deal of opportunity to reduce air leakage to provide the following benefits:

- space heating energy and cost savings;
- improved envelope durability;
- enhanced occupant comfort; and
- better HVAC system performance.

Each of these issues is further discussed below.

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 24% of space heating energy use.

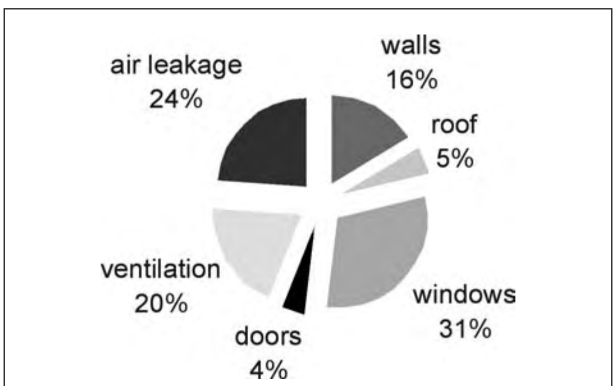

Figure 2-1 Component heat loss in MURBs

During design winter conditions, air leakage can be as much as 40% 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.

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).

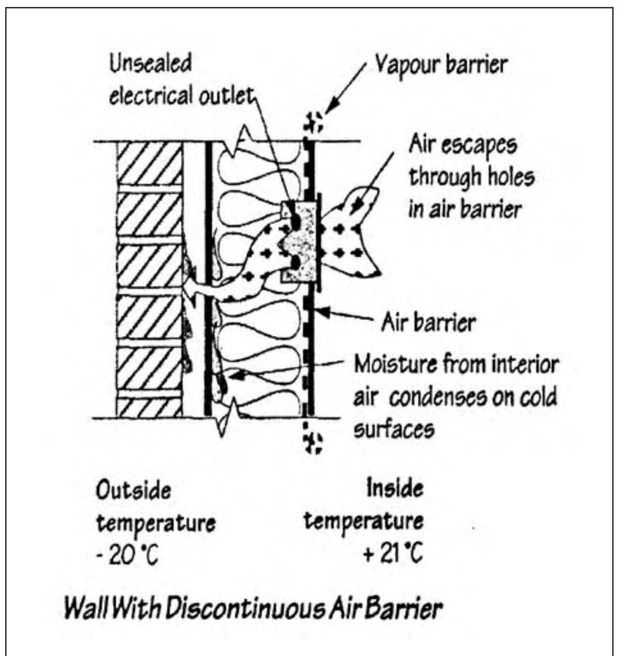

Figure 2-2 Air leakage and building durability

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

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 mold growth which may be a health concern.

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 counter-intuitive, 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 provided with bathroom and kitchen exhaust. 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

2.4.1 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.

2.4.2 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 airflow 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 to allow parking garage odours and pollutants including car exhaust into the building.

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

3.1 Air leakage: Why it happens

For air leakage to occur there must be a ***force*** (that is, an air pressure difference) and a ***hole*** (that is, 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.

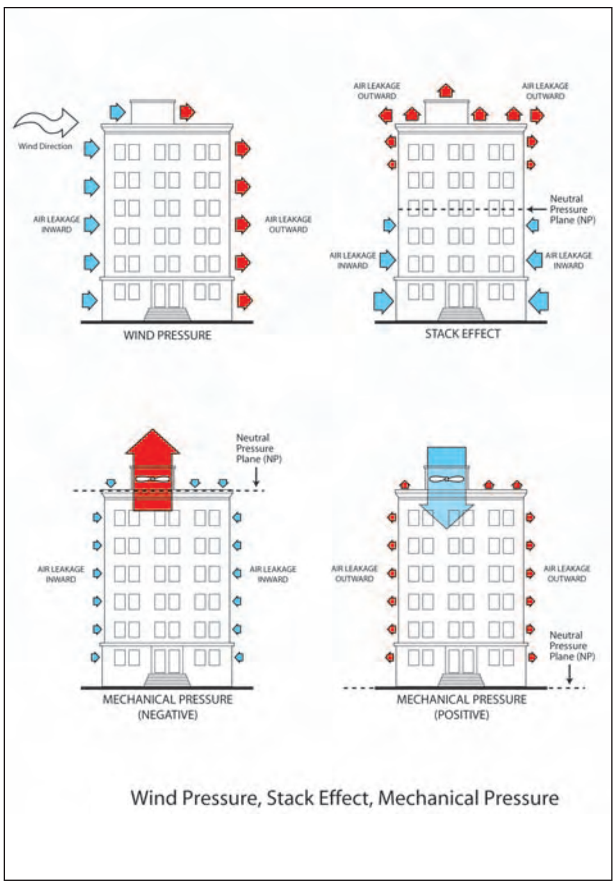

Figure 3-1 Wind pressure, stack effect and mechanical pressure

3.1.1 The "Forces"

- *Wind:* figure 3-1 depicts the direction of air leakage that wind forces impose on a building. Wind can exert significant pressures—positive pressures on the windward side and negative pressures on the leeward side of the building. These pressures will force air into the side of the building the wind hits and draw air out of the opposite side through any leaks in the building envelope. This forces air horizontally from apartment to apartment or from apartment to corridor.
- *Stack Effect:* figure 3-1 depicts the direction of air leakage that stack effect imposes on a building. In winter, air movement is also caused by stack effect. Stack effect causes air to leak into the lower levels of buildings, and rise through the floor levels as it is warmed and becomes more buoyant. The warmed air then leaks out of the building at the top (much in the same way warm air moves up a chimney). The higher the building, and the greater the indoor-outdoor temperature difference, the greater the stack pressures will be.
- *Mechanical Forces:* figure 3-1 depicts the direction of air leakage that mechanical exhaust and mechanical air supply imposes on a building. The operation of exhaust fans such as bathroom fans, range-hoods, clothes dryers, utility room exhausts and the venting of combustion gases from fuel-fired appliances can impose negative pressure in buildings. This negative pressure will draw outside air into the building through leaks in the building envelope. The operation of corridor ventilation systems can pressurize buildings and force warm, humid indoor air into the building envelope through available leakage points. In-suite exhaust systems will draw air from outside the building as well as from adjacent suites and corridors.

3.1.2 Typical Leakage Paths—the "Holes"

The following list details common locations of air leakage. While each building will be somewhat different, the location of significant air leakage is usually the same. While some leakage will be readily apparent through visual inspection, others have to be detected using depressurization equipment and smoke puffers (see section 4.2.2).

When locating holes and cracks in the building envelope, it is important to consider where the plane of airtightness (that is, the continuation of the air barrier system around the building) is in the building. For instance, if the plane of airtightness extends up to the mechanical penthouse on the top of a building, it may not be worthwhile sealing cracks and holes that exist between the penthouse and the rest of the building. An exception to this can be found when it is desirable to seal the partitions between different areas of a building to control air movement through the building and to improve smoke and fire safety.

If the building has an underground parking garage, most often the plane of airtightness will exist at the floor separating the ground floor from the parking garage and extend to the walls that separate the core of the building (usually containing the elevator, stairwells, storage rooms and vestibules) and the parking garage at the different garage levels. Holes in the floor slab above the parking garage and in the partition walls between the parking garage and the core of the building must be found and sealed.

At the bottom of the building:	**Exterior walls:**
■ Parkade to building interface (walls, ceilings, floors, doors) ■ Overhanging soffits ■ Service penetrations of core walls and floor between garage and ground floor—wiring, plumbing, ducts garage doors, garage exit doors	■ Windows ■ Doors ■ Joints between different materials and envelope elements ■ Overhead doors and service bays ■ Backdraft dampers and louvres ■ Sleeves for through wall HVAC units ■ Electrical penetrations (electric baseboard heaters, switches, outlets, exterior wall mount lights, outlets, etc.) ■ Plumbing penetrations—hose bibs ■ Duct penetrations
At the top of the building:	**Interior Partitions:**
■ Mechanical penthouses ■ Roof-top penetrations—wiring, plumbing, ducts ■ Parapets ■ Rooftop HVAC equipment and plumbing penetrations, garbage chute stack ■ Stairwell and roof access doors ■ Roof hatches (in stairwells and penthouses) ■ Roof-to-wall joint ■ Elevator cables, wiring	■ Stairway-corridor doors ■ Plumbing risers, and stack penetrations through floor levels ■ HVAC duct risers through partition walls and floors ■ Garbage chute door and access hatches ■ Wiring raceways through walls and floors ■ Wall-floor and wall-ceiling joint in service areas such as garbage room, mechanical room, electrical room and common areas and suites ■ Elevator doors

Table 3-1 Air leakage locations in MURBs

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:

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

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;
- prioritizing the order in which the work should be done.

4.1.1 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 air barrier 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 assemblies. In the walls of high-rise MURBs, air leakage control systems may be made up of sheet polyethylene (poly) installed over the wall framing. The poly is then sealed to the window frames, door frames, and the ceiling and floor slabs. It is important to remember that the air barrier on the walls must be sealed to the air barriers on the roof as well as the system that encloses the foundation 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.

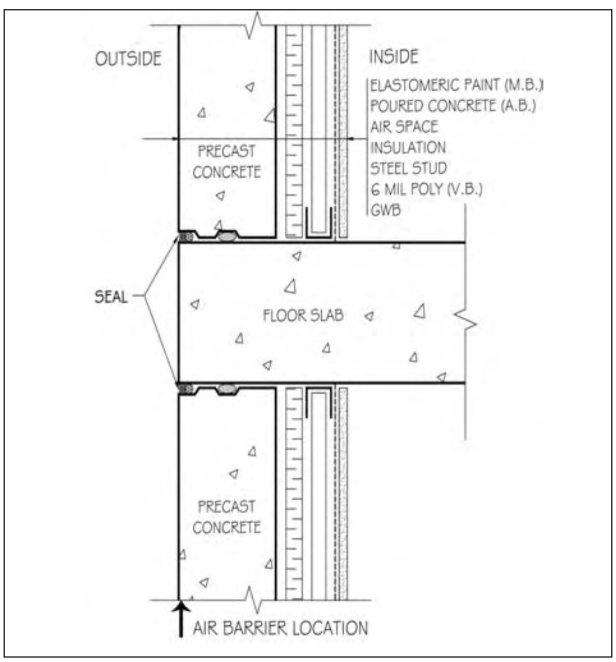

Figure 4-1 Exterior air leakage control system

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 air-tight drywall approach (ADA). If the original air barrier utilizes an accessible system, then the air-sealing work will involve interior components, materials and finishes.

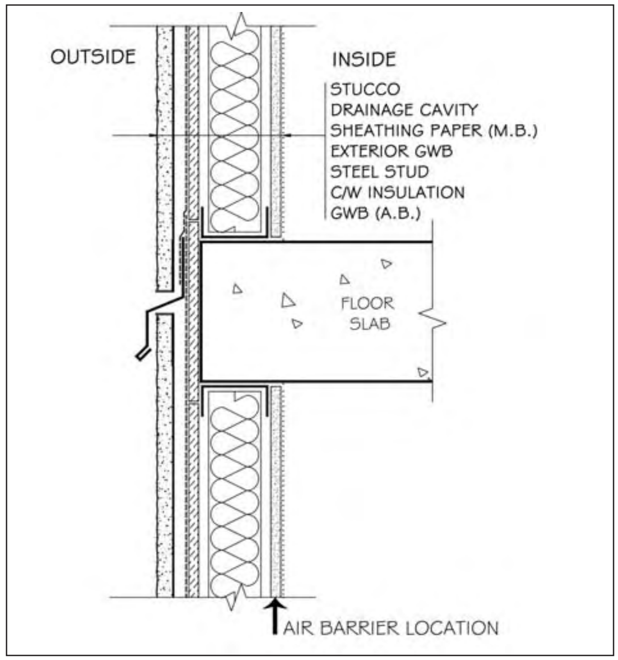

Figure 4-2 Interior air leakage control system

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 wall-board, 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.

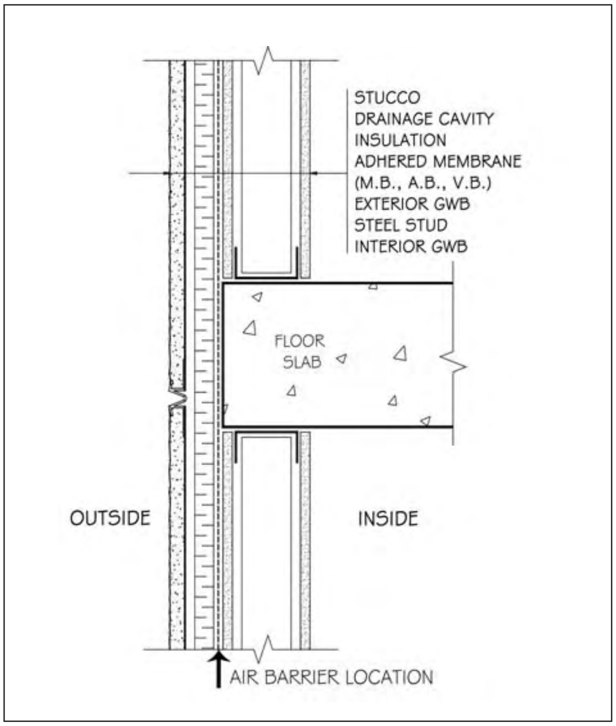

Figure 4-3 Inaccessible air leakage control system

Air-sealing an inaccessible system may require that elements of the assembly be dismantled or that an alternative air barrier approaches 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.

4.2 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*—fiberglass makes a fine filter but is not acceptable as a air barrier material.
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 another).
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.
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.

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, of the materials to deteriorate and fail. Examples of incompatible materials include:

- 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.

4.2.1 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 re-applied 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.

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.

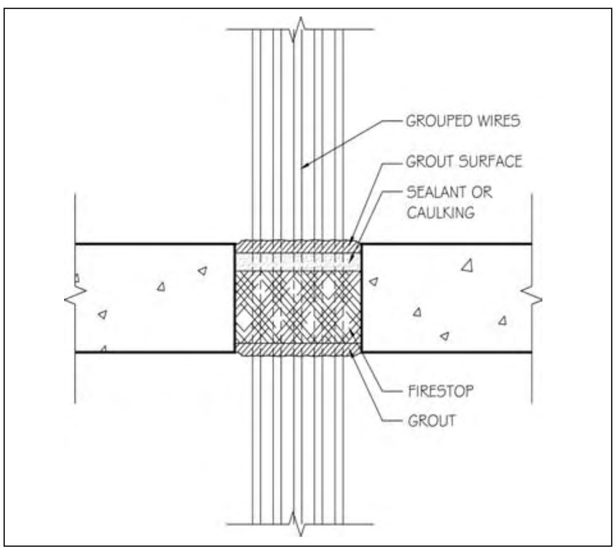

Figure 4-4 Fire-stopping and air-sealing of penetrations

4.2.2 Locating Leaks and Testing for Air Leakage Control

A range of visual techniques and tests procedures may be used to find leaks and quantify air leakage characteristics of MURBs. These tests are useful during initial phases of an assessment to identify the location and significance of air leakage, and to demonstrate air leakage to the property manager or building owner. These tests may also be used as part of a quality assurance program after air-sealing is complete to confirm the effectiveness of air leakage control measures.

Quantitative test methods include:

- whole building or floor by floor airtightness testing using a calibrated fan in accordance with CGSB149.15[1] or ASTM E779[2];
- component leakage testing using a calibrated fan in accordance with CGSB149.10[3] or ASTM E779; or
- tracer gas techniques in accordance with ASTM E741-00[4].

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1 Canadian General Standards Board (CGSB), CAN/CGSB 149.15 1996, *Determination of the Overall Envelope Airtightness of Buildings by the Fan Pressurization Method Using the Building's Air Handling Systems*, 1996

2 ASTM, ASTM E779-99 *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*, 1999

3 Canadian General Standards Board (CGSB), CAN/CGSB 149.10 1986, ***Determination Of The Airtightness Of Building Envelopes by the Fan Depressurization Method***, 1986

4 ASTM, ASTM E741-00 *Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution*, 2000

In general, fan depressurisation methods use a large calibrated fan to depressurize a building, entire floor, suite and selected wall sections or a particular building envelope detail. The testing and analysis provide an estimate of how leaky the building is and provide an opportunity to identify air leakage locations. Window airtightness test rigs can demonstrate how leaky windows are and how rebuilding seals and weatherstripping can reduce leakage.

Finding companies that conduct air leakage testing can sometimes be a challenge as they are not all that common. Engineering/architecture firms that specialize in building science and building envelope engineering may be able to offer the service. Some window manufacturers have personnel capable of conducting window air leakage tests. Firms, or individuals, who conduct residential and commercial building energy evaluations, such as the R-2000 or ecoENERGY for Houses Programs, may also have the equipment and skills to conduct building or component air leakage tests.

The costs and complexity of whole building and whole floor tests is generally beyond the scope of most ALC projects. Suite tests and component tests can be more easily completed using readily available blower door systems or window test rigs. Manufacturers of fan depressurization equipment can offer training and equipment for contractors to conduct this testing themselves (see Appendix B).

Qualitative methods to locate air leakage include:

- visual inspections for cracks and gaps;
- thermography (infrared scan);
- smoke pencils, or puffers, (figure 4-5) with or without the use of blower doors to pressurize and depressurize the space being assessed, and;
- inspection for dust streaking or dust accumulation at baseboards, doorways, cracks etc. as shown in figure 4-6. Sometimes the dust streaking patterns can also provide clues as to the direction of the airflow.

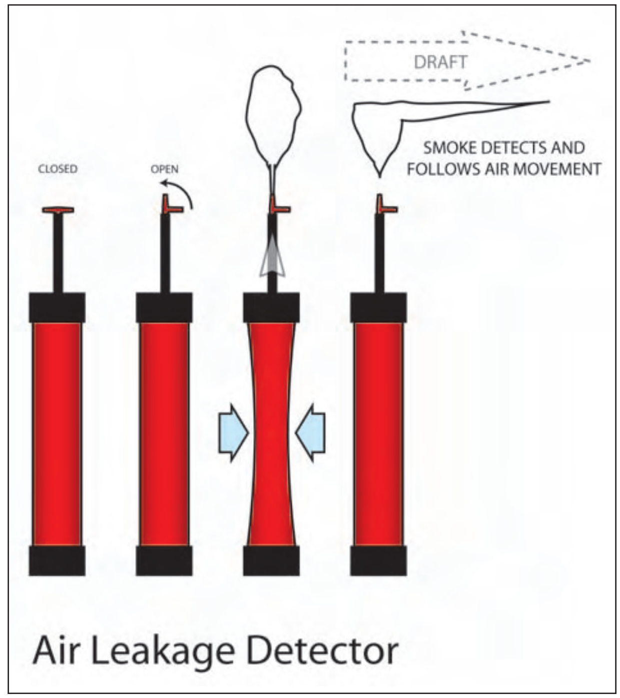

Figure 4-5 Smoke puffer air leakage detector

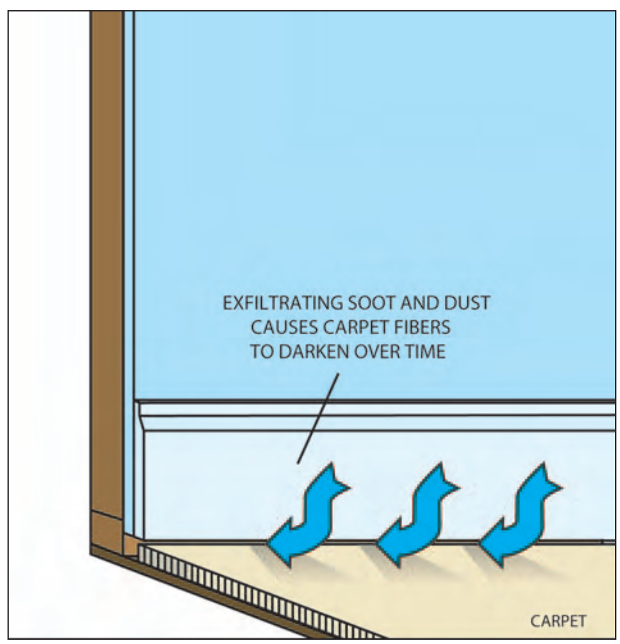

Figure 4-6 Dust soot streaking

For many air-sealing applications, visual inspections for gaps, in conjunction with a smoke pencil test provide sufficient information to locate leaks particularly during cold weather when leaks are more evident. Drafts and cold spots may also be used to locate leaks. In addition to locating leaks, these techniques may later be used to confirm the effectiveness of the repairs.

Table 4-1 provides a checklist to use to help locate typical air leakage locations in multi-unit residential buildings. Blank Checklist forms can be found in the Appendix D for use in actual projects.

Location	Area	Leakage
Bottom of Building	**Parking Garage**	**Ceiling/ Floor above**: Pipe penetrations Wiring penetrations Duct penetrations **Wall to Building Core:** Elevator vestibule doors Floor-wall joint Wall-ceiling joint Pipe penetrations Wiring penetrations Duct penetrations **Garage Ventilation System** Supply air louvres Exhaust air louvres Duct penetrations Garage overhead door Garage Exterior Exit doors Other:
	First Floor	**Garbage Service Room**: Overhead doors Exterior exit door Exhaust fan duct Exhaust fan louvre Wiring penetrations Garbage chute to floor Service room door Other: **Loading Bay** Exterior overhead door Exterior exit door Bay to building door Wiring penetrations Plumbing penetrations Duct penetrations Other: Hose bib penetration Stairwell doors Front entry door Laundry exhaust louvre Laundry exhaust duct Other exterior doors Other:
Top of Building	**Elevator Penthouse**	Roof-wall joint Roof penetrations: Wiring Ducts Pipes

Table 4-1 Air leakage location checklist

Location	Area	Leakage
Top of Building	**Elevator Penthouse**	Wall Penetrations: Wiring Ducts Louvres Pipes Exterior door Stairwell door Elevator hoist cable Elevator service wiring Other:
	Mechanical Penthouse	Roof-wall joint Roof penetrations: Wiring Ducts Pipes Boiler vent Wall penetrations: Wiring Ducts Louvres Pipes Exterior door Stairwell door Floor penetrations: Wiring Pipes Ducts Other
	Rooftop	Stairwell door Access hatch Garbage chute vent Exhaust fans Corridor air unit Plumbing stacks Parapets Other:
Exterior Walls	**Apartments**	Windows Balcony doors Wiring Electric baseboard Pipes Exterior lighting Electric outlets, switches Ducts Exterior hoods, louvres Through-wall sleeves for HVAC equipment Other:
	Common Rooms	Windows Exterior doors Wiring Electric baseboard Pipes Exterior lighting Electric outlets, switches Ducts

Table 4-1 Air leakage location checklist (con't)

Location	Area	Leakage
Common Rooms	**Common Rooms**	Exterior hoods, louvres Through-wall sleeves Other
	Stairwells/corridors	Windows Exterior doors
Interior Partitions	**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, wall-ceiling joint
	Basement/garage Service Rooms	Penetrations of floor slab above: Wiring Pipes Ducts Other:

Table 4-1 Air leakage location checklist (con't)

4.3 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:

4.3.1 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 sub-grade 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.

4.3.2 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.

4.3.3 Seal the Exterior Walls of the Building

Sealing exterior walls is often difficult to do due to problems with access into individual apartments. 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.

4.3.4 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 Table 4-1 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 (see Appendix "E" - Dealing with Odour Transfer Problems). 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.

4.4 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.

4.4.1 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.

4.4.2 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, mold 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.

4.4.3 Indoor Air Quality Problems

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

- under-ventilated;
- over-occupied, or;
- experiencing moisture source control problems;
- or 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 underway, recommend that the problem be solved before any air-sealing measures are installed.

4.4.4 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 mold 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.

4.4.5 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 exhaust 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 a space undergoing air-sealing, it is recommended that a test be completed to assess the potential for spillage in accordance with CGSB 51.71[5]. These tests should be completed after the air-sealing work is complete, however, they may also be performed prior to commencing a project to determine whether a pre-existing combustion venting hazard exists.

4.5 Step 4: Select Materials

After it has been decided which components of the building envelope will be sealed, their priority and any building problems or other issues are addressed, the actual work to air seal the building can begin. As a first step the materials and methods for sealing the locations should be identified. A variety of materials are available that can be used to seal the joints between materials that make up the air leakage control system, including:

- spray applied foam sealants, including one- and two-part polyurethane foam systems;
- caulking, providing a range of joint movement and durability options;
- weatherstripping and gasket materials; and
- membranes.

4.5.1 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 polyicynene (figure 4-7). 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.

[5] CGSB, CAN/CGSB-51.71-95 *The Spillage Test, Method to Determine the Potential for Pressure-Induced Spillage from Vented, Fuel-Fired, Space Heating Appliances, Water Heaters and Fireplaces*. 2004

Insulating foam is available in a range of densities and expansion characteristics. For air barrier applications, densities of 16 kg/m³ to 50 kg/m³ are recommended. While lower density foams have cost saving benefits, the open cell structure of such products reduce the cohesive and adhesive strength.

Foam expansion can range from 10% to over 100% 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.

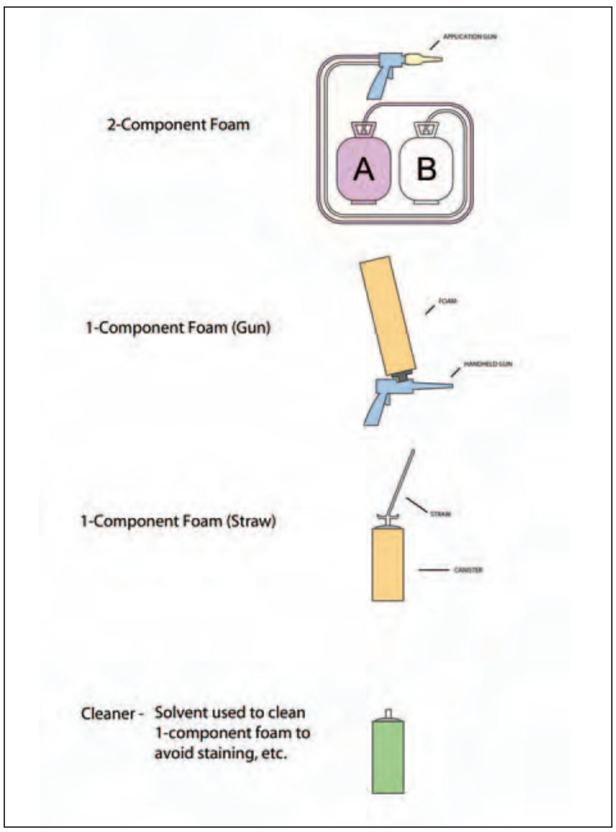

Figure 4-7 Spray-applied foam products

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.

4.5.2 Caulking

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

- high-performance neutral cure silicone caulking
- polyurethanes
- polysulphide caulking
- thermo-plastic 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, material it will seal together), expected life, proper joint design and if used indoors, the potential impact on indoor air quality as the material cures.

4.5.3 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% 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 2 to 5 years when used in exposed exterior applications.

4.5.4 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 elastomerics (kreytons). These products perform adequately in slow moving joints such as masonry control joints. Recommended maximum movements are usually below 25 % of the joint width. When installed properly the service life may range from 5-15 years for plasto-elastic material and 10-20 years for elasto-plastic material.

4.5.5 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.

4.5.6 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 4-8 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 4-9.

4.5.7 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 4-10;
- heavy duty “v”-seal products and foam compression materials for air-sealing doors into their frames;
- doorway sweeps (figure 4-11)

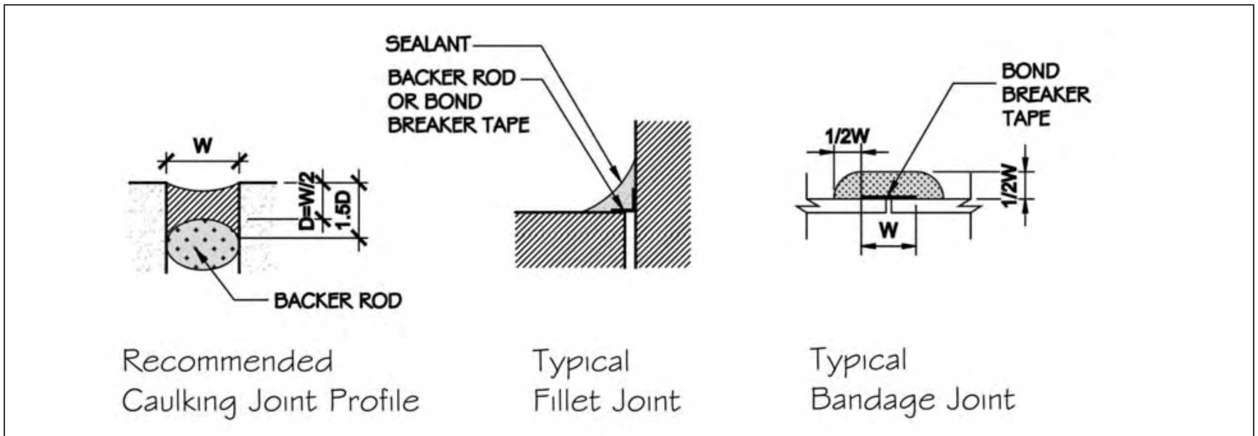

Figure 4-8 Caulking joint design[1]

[1] Ref CMHC, *Wood Frame Envelopes in the Coastal Climate of British Colombia*, 2001

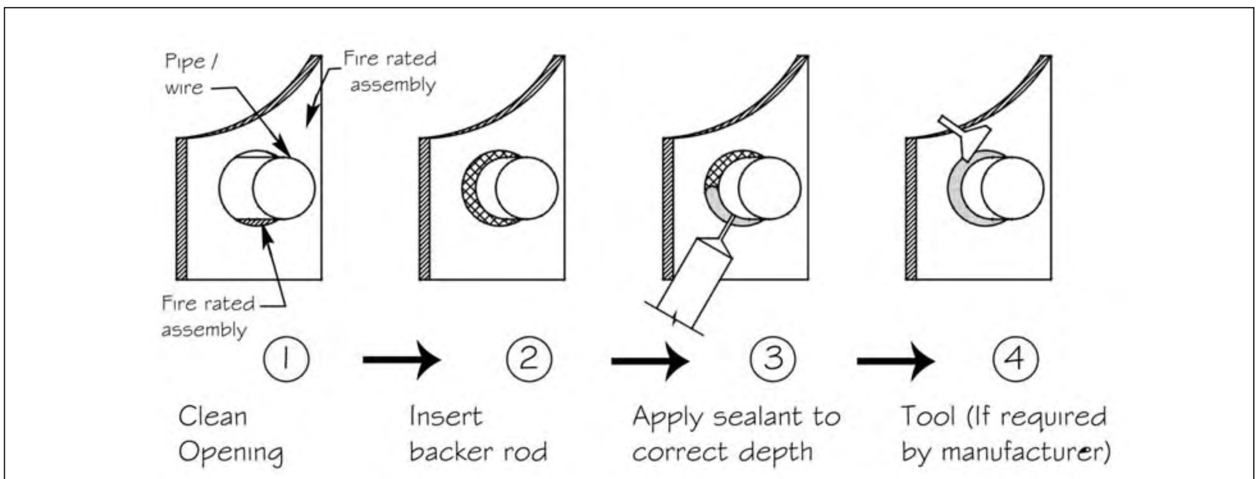

Figure 4-9 Typical installation sequence for caulking

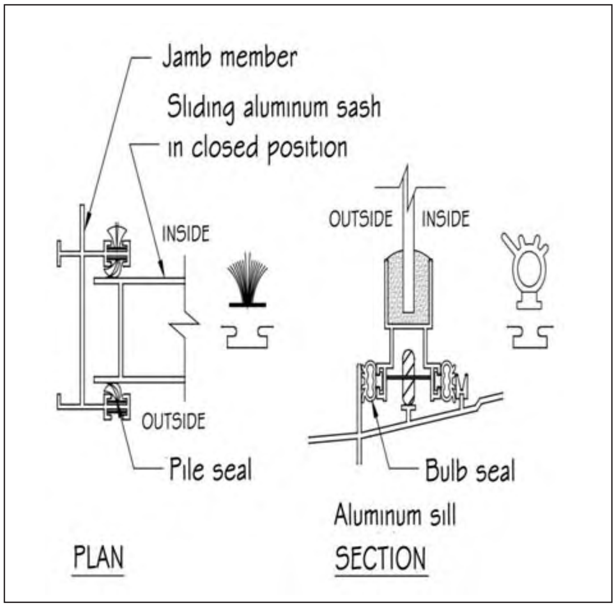

Figure 4-10 Weatherstripping profiles

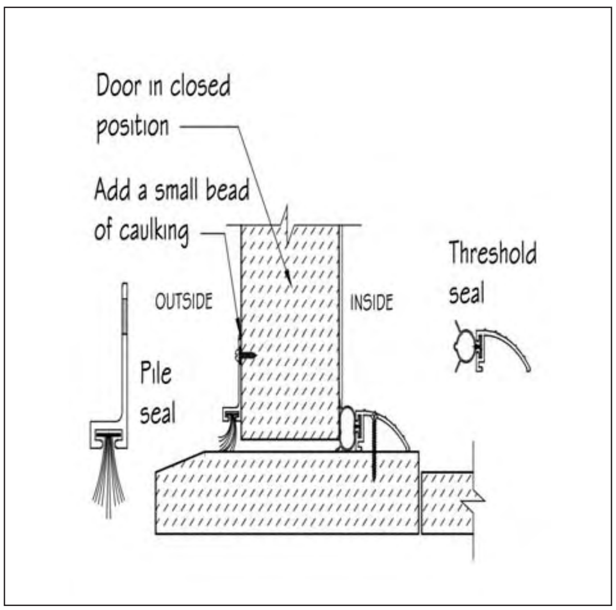

Figure 4-11 Typical door sweep and threshold seal on outward opening door

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 which can accommodate changes in gap width 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 4-12. The jamb seal is a tubular type of weatherstripping. The edge seal is a "v" type weatherstripping. The stop seal is hollow tubular.

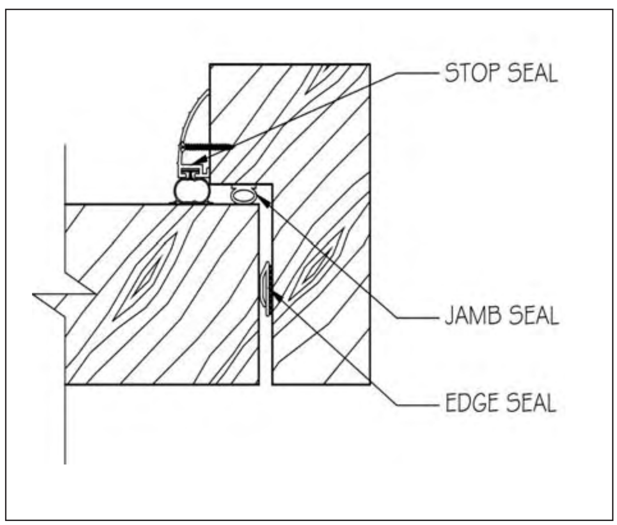

Figure 4-12 Weatherstripping options

Depending on the direction of door swing, 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 movement of the seal up to about 6 mm (1/4 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.

4.5.8 Seals for the Threshold

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

4.5.9 Revolving Entrance Doors

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

4.5.10 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.

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 walls to window frames.

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.

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.

Product	Durability	Application	Comments
Spray Foam			
Polyurethane and icynene foam	High	■ Suitable for filling holes in a range of locations where protected from ultraviolet light ■ Must be used in conjunction with other materials to obtain fire rating for non-combustible applications ■ Must not be applied under cold conditions—consult manufacturers instructions regarding minimum temperature application restrictions.	■ Includes 1- and 2-part urethane and icynene foam products ■ Bonds to a range of materials except for polyethylene, Teflon or silicone plastics ■ Should be covered by non combustible material when installed within a fire separation assembly
Caulking			
Low movement caulking	Low	■ Suitable when low movement is expected	Includes ■ Butyl rubber ■ Synthetic rubber ■ Oil based
Medium movement caulking	High	■ Indoor applications suitable for small joints with limited movement occurs	Includes ■ Acrylic latex ■ Thermoplastic elastometrics
High movement caulking	High	■ Suitable for indoor or outdoor applications ■ Long service life expected	Includes ■ Neutral cure silicones ■ Acetoxy silicone ■ Polyurethanes ■ Polysulphides
Weatherstripping and Gaskets			
Felt	Low	■ Door jamb and heads	■ Easily deformed ■ Poor adhesion to substrate ■ Poor air-sealing qualities
Open cell foam tape	Low	■ Door jamb and heads	■ Easily deformed ■ Poor adhesion to substrate ■ Poor air-sealing qualities
Closed cell foam tape	Low to high	■ Door jamb and heads	■ Performance of these products vary
Spring loaded metal	High	■ Door jambs, heads, casement windows	■ Adjusts to irregularities of windows and doors ■ Adjusts to seasonal changes in gaps ■ Suitable for cold weather applications

Table 4-2 Summary of recommended air leakage control materials

Product	Durability	Application	Comments
Weatherstripping and Gaskets			
"V"-type polypropylene strips	High	■ Door jambs, heads, casement windows	■ Adjusts to irregularities of windows and doors. ■ Suitable for cold weather applications
Pile with fin	High	■ Suitable replacement seal for sliding windows and doors	■ 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
Tubular bulb seal	High	■ Suitable replacement seal for sliding windows and doors ■ Available in a range of profiles	■ Provides suitable air leakage control and rain penetration control
Door sweeps and thresholds	Low to High	■ Bottom of exterior doors and on exterior thresholds	■ Wood, metal or plastic mounted strip to form seal between floor and door assemblies ■ Sealing interior partition doors requires consideration of suite ventilation requirements
Electric switch and outlet gaskets	High	■ Easily installed ■ Effective for air-sealing electrical boxes that lack an effective air/ vapour barrier behind the wall	■ Polyurethane gasket pre-cut to fit behind standard electrical cover plates ■ Ensure product is CSA approved
Membranes			
Bituminous and self-adhered flexible membrane	High	■ Used as part of a non accessible air leakage control system	■ Requires structural back-up ■ Consideration of vapour diffusion through these materials is required
EPDM Gaskets	High	■ Air tight friction seal around electrical and mechanical penetrations	■ Suitable as part of an air leakage control system at most pipe and conduit penetrations
Liquid applied membranes	High	■ Used as part of a non accessible air leakage control system and concrete block walls	■ A range of products exist with variable air leakage and vapour diffusion characteristics
Polyethylene sheet	Low	■ Suitable for vapour barrier applications	■ 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

Table 4-2 Summary of recommended air leakage control materials (Con't)

4.6 Step 5: Perform the Air-sealing Work

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.
4. Interior partitions.

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 fire-proofed 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.

4.6.1 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 4-13);
- fire protection service pipes;
- storm drainage pipes;
- communications wiring;
- ducts.

Figure 4-13 Plumbing penetrations

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.

4.6.2 Penetrations through Parking Garage Ceiling to Building

Gaps around pipe, 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 sprinkler, standpipes and electrical services.

4.6.3 Penetrations through Building Core Walls

Seal mechanical and electrical service penetrations through building core walls (figure 4-14). 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 4-15). Larger holes may be covered with drywall sealed to the core wall and penetration or filled and sealed with concrete.

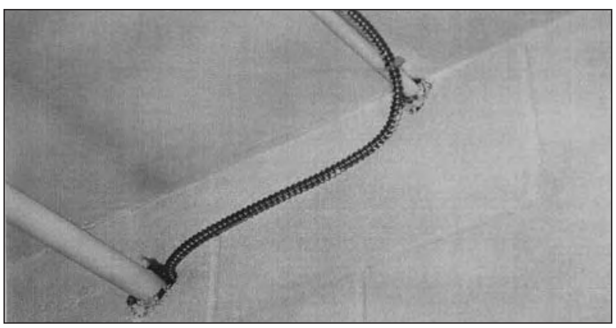

Figure 4-14 Plumbing penetrations of parking garage walls (photo: Proskiw Engireering Ltd.)

4.6.4 Floor-slab to Wall Joints

Air barrier materials used to seal interior walls should be terminated at the junction of 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.

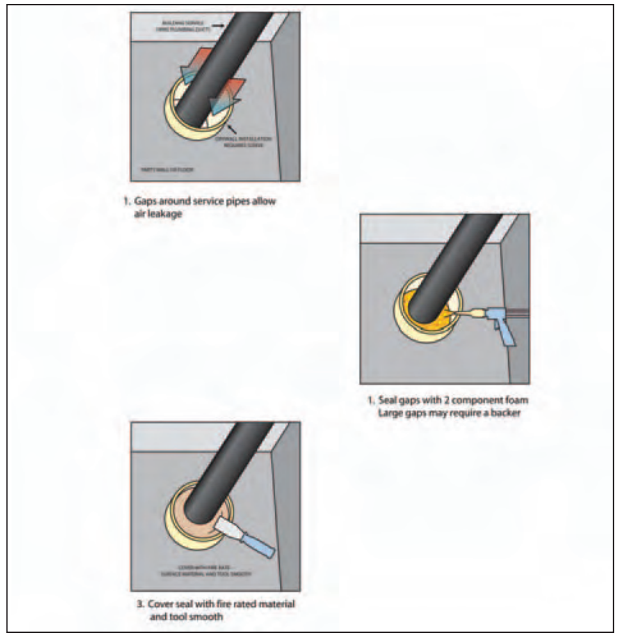

Figure 4-15 Sealing Service Pipes

4.6.5 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.

4.6.6 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 stack affect. In general, floor slabs should be sealed tight to chutes. Sheet metal can be cut to fill the gap between the chute and 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 4-16). 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.

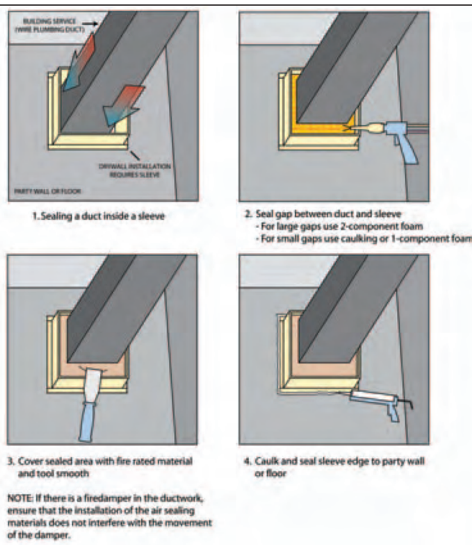

Figure 4-16 Sealing ducts

4.6.7 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 airflow 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.

4.7 Air-sealing 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.

4.7.1 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 penthouses 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 4-17. 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 4.18. Ensure that fire-stopping is provided at penetrations of fire rated assemblies.

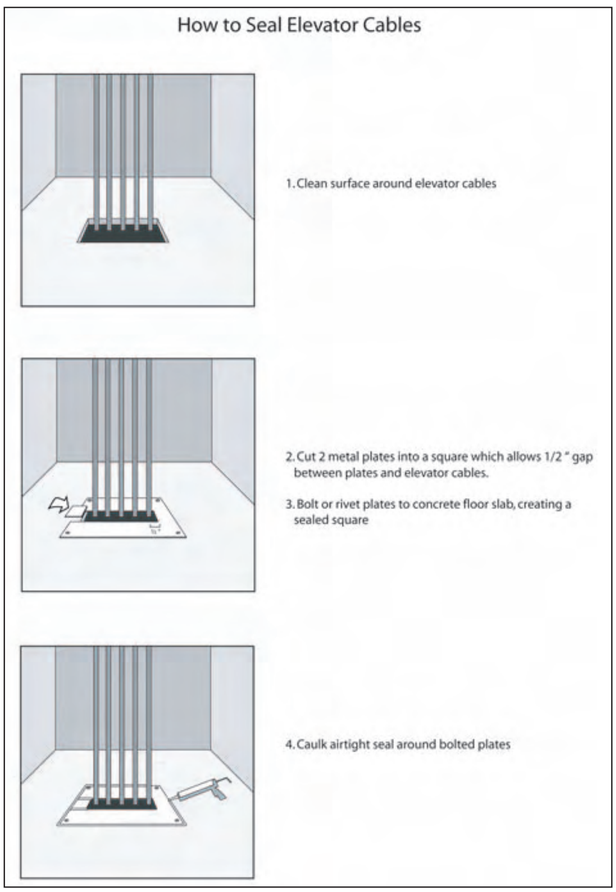

Figure 4-17 Sealing around elevator cables

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.

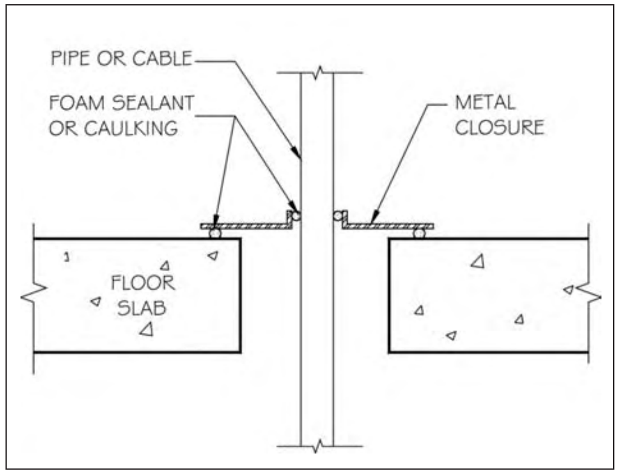

Figure 4-18 Air-sealing at wiring

4.7.2 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 roofs 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 4-19).

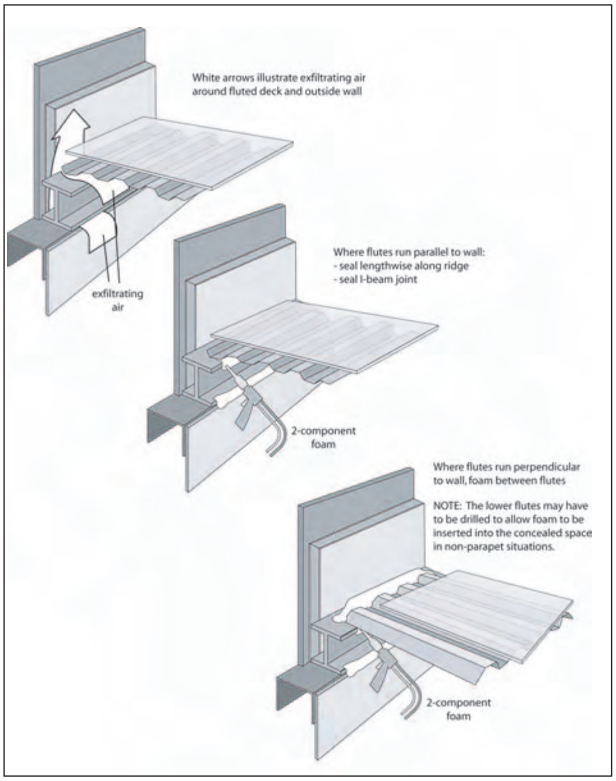

Figure 4-19 Air-sealing roof-to-wall interface

4.7.3 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.

4.7.4 Drains and Plumbing Vents

When the joint is accessible from above (for example, System A in figure 4-20), seal the flange of the metal collar to roof membrane using a compatible roofing membrane or mastic. When the system is accessible from below (for example, System B in figure 4-20), seal pipes and vents to the surrounding deck from below using foam sealant.

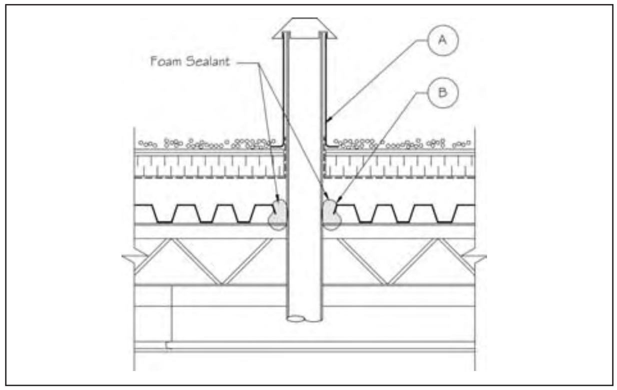

Figure 4-20 Air seal of roof penetration

4.7.5 Chimneys and Hot Vents

Seal flange of metal collar to 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 air-tight using a high temperature caulking product.

4.7.6 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.

4.7.7 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 caulk or foam depending on the size of gap. Ensure louvres close tightly when exhaust fans are off. Caulk louvre frames to the surrounding walls.

4.7.8 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 4-21). 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.

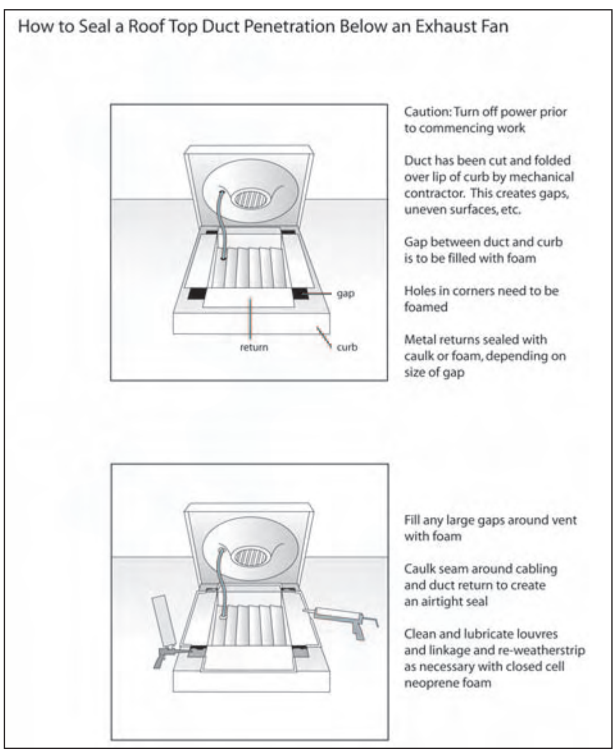

Figure 4-21 Curb-mounted equipment

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 4-22 with caulk or foam depending on the size of the gap. Seal under door sill using a bead of compatible caulking or foam sealant.

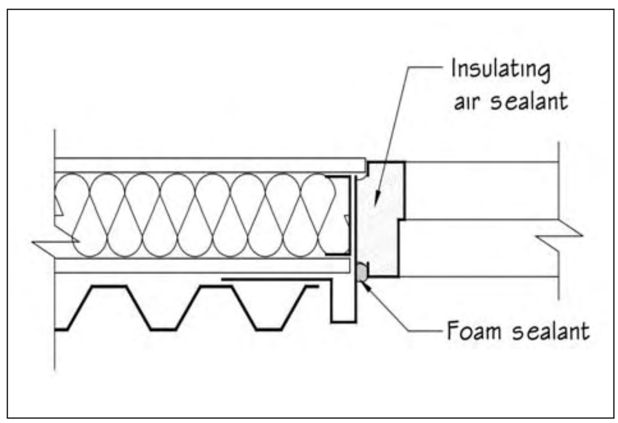

Figure 4-22 Air-sealing metal door jamb

4.8 Air-sealing for 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; 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.

4.8.1 Floor-to-exterior Walls

For exterior air leakage control systems (precast concrete panels, glass curtain walls, faced 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 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.

4.8.2 Window to Wall

Typical locations for air-sealing windows are shown in figure 4-23. 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 4-23). Ensure that drain holes in the windows frames are not sealed over.

For interior air leakage control systems, the gypsum board may be sealed to the interior of 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 4-23).

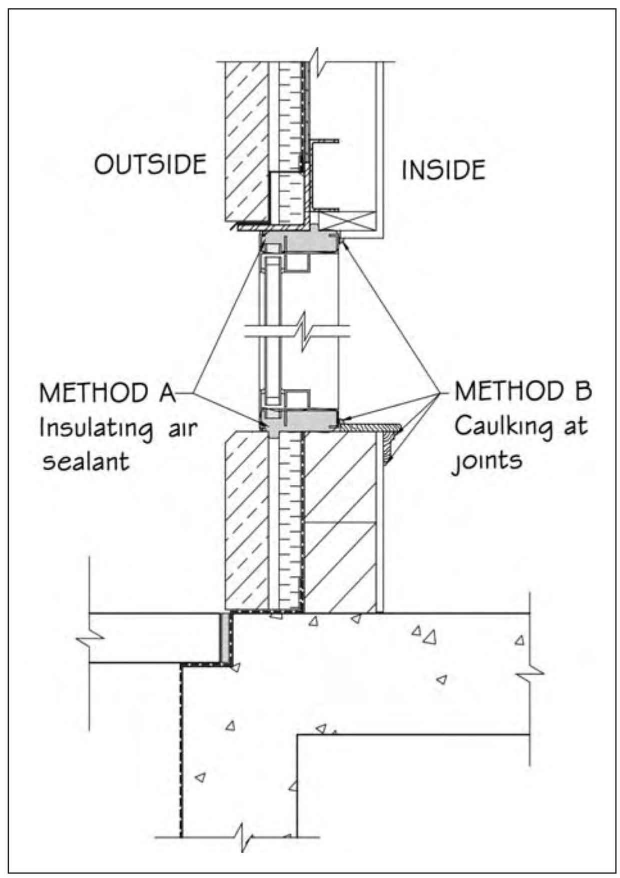

Figure 4-23 Air-sealing windows

Alternatively, it may be possible to remove 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 turn-over.

4.8.3 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 4-24. 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 suffix should be sealed with caulking or foam sealant.

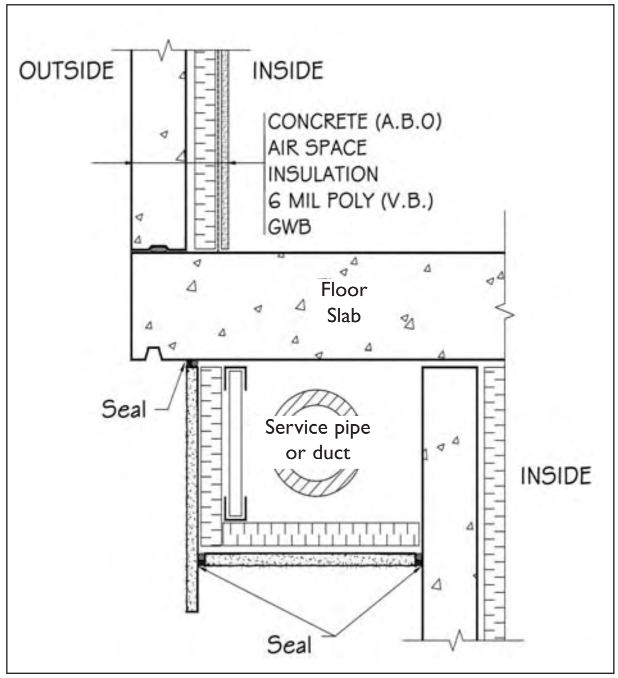

Figure 4-24 Air-sealing hot soffit

4.8.4 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 top of 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.

4.8.5 Doors (front entry, service room, balconies)

Check the perimeter of doors for light and the condition of 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.

4.8.6 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 4-25) 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 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 downwards, to the outside. This will leave the weatherstripping visible when the window is open, but it provides a better seal.

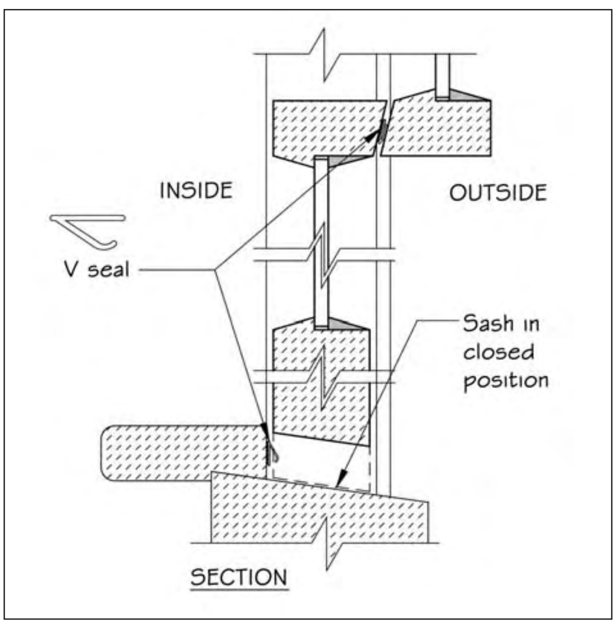

Figure 4-25 Air-sealing awning windows

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.

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.

4.8.7 Electrical Penetrations in Exterior Walls

Install a receptacle gasket between the electrical box and the cover plate, as shown in figure 4-26. Place the knock-outs from the gasket over child-proof plugs to seal the outlets when not in use.

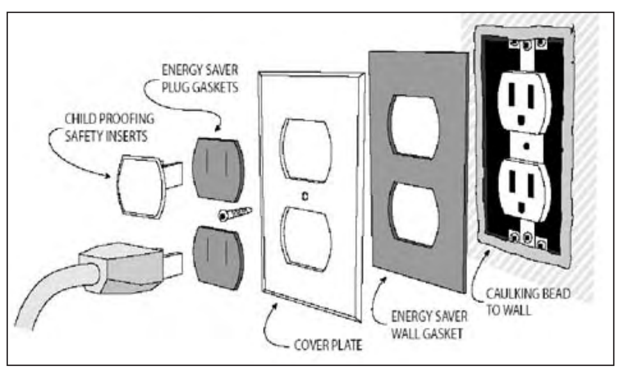

Figure 4-26 Air-sealing electrical penetrations

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 caulk.

4.8.8 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 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 pipe and ducts at the plane of airtightness and again at the exterior face with caulking (to prevent water penetration and pest entry). (figure 4-27)

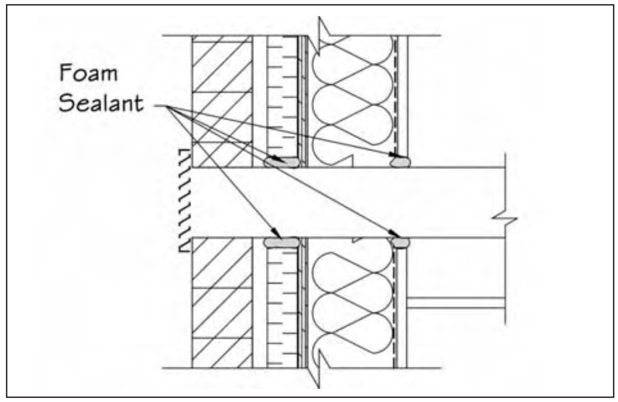

Figure 4-27 Air-sealing of louvres

For through-wall space heating/air conditioning units, apply spray foam between the wall rough opening and the through-wall sleeve. Seal between the sleeve and the unit with foil tape or closed cell gaskets. For air conditioning units, fabricate insulated panels closures that can be applied to the exterior of the units during the winter months.

4.9 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 4-28. In this way, the shaft is made into a sealed element that air cannot get into or out of.

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.

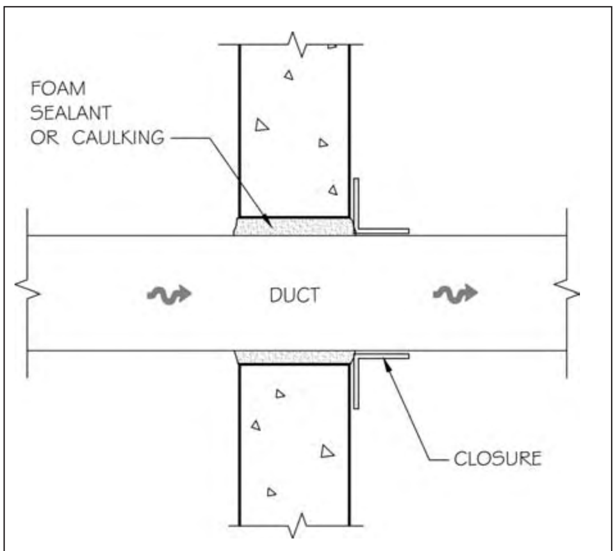

Figure 4-28 Air-sealing pipes and ducts within shafts

4.9.1 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 rooms on each floor by caulking all joints. The doors to the garbage rooms 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 joint if a gap is visible. NOTE: sealing stairwell doors may make them harder to open due to 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 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 grilles 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.

4.9.2 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.

4.9.3 Pipe, Duct and Conduit Penetrations

A typical floor penetration is shown in figure 4-29. 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 4-30).

Figure 4-29 Typical conduit penetration

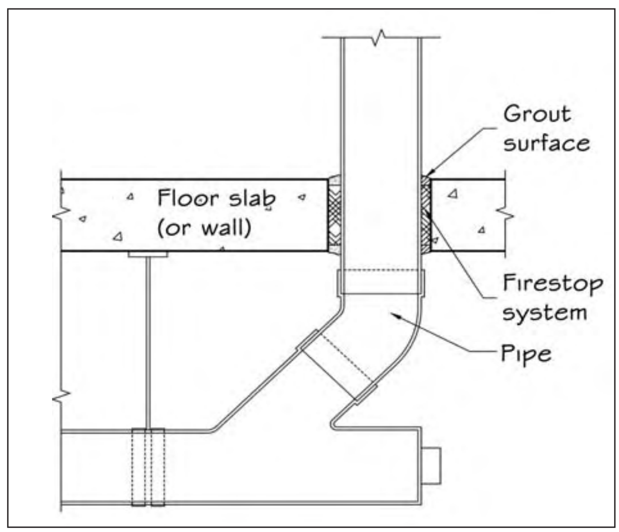

Figure 4-30 Air sealing plumbing penetration

4.9.4 Service and Inspection Hatches

Access hatches in ceilings and walls for plumbing clean-outs, 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 air-tight fit.

4.9.5 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.[6] 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.

4.9.6 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. If the frame is missing, it must be installed before any air-sealing work is 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.

[6] If there are complaints concerning odour transfer in specific apartments, refer to the CMHC About Your Apartment Publication "Solving Odour Transfer Problems in Your Apartment" Appendix "E"

Appendix A — Case Studies of Air Leakage Control Projects

While it is generally acknowledged that ALC will provide energy savings with attractive payback periods, there are a limited number of case studies available that quantify the costs and benefits of ALC projects alone. The case studies summarized below provide examples of buildings that have benefited from air leakage control projects.

A summary of the cost and impact of air leakage sealing by component is summarized in the table for Case Study Number 1. As part of the evaluation of air leakage control effectiveness, indoor air quality tests were completed. Tests showed that air-sealing had no adverse impact on comfort or air quality in either building. In fact, relative humidity conditions improved.

Case Study Number 1

Building Description

This building is a 21-storey apartment tower in Ottawa, Ontario. The building has 240 units, and is occupied by senior citizens. The building is approximately 30 years old. The building is heated by electric baseboards. The total floor area of the building is 14,300 square meters.

Envelope Construction

The structure of the building is cast-in-place concrete. The walls are insulated with 38 mm of extruded polystyrene insulation. The exterior cladding is brick.

Energy Audit

An initial audit of the building was completed that found that the total energy bills for 1989 were $141,700. An analysis of energy use was completed, and air leakage was estimated to account for 33% of the building heat loss.

Description of Air Leakage Control Measures

Air Leakage control measures used included:

- sealing all shafts (top and bottom)
- sealing exterior envelope leaks
- sealing exterior doors
- sealing exterior windows

Annual Energy Savings from ALC [KWh]	165,000 KWh, corresponding to a 12% reduction in energy use.
Peak Load Reduction [KW]	85 KW, corresponding to an 11% reduction
Annual Cost Savings [1990 $]	$9,650
Retrofit Cost [1990 $]	$54,800
Payback Period [years]	5.7

Impact of air leakage controls

Component	**Type of air-sealing**	**Cost of air-sealing [1990 $]**	**Demand reduction [kW]**	**Unit cost [$/kW]**	**Ranking**
Shafts	Caulking and Sealing	828	11.5	72	1
Building Envelope	Caulking and Sealing	2,719	5.2	523	2
Exterior Door	Weatherstrip-ping and caulking	15,180	22	690	3
Miscellaneous	Caulking and Sealing	7,879	10.3	765	4
Windows	Weatherstrip-ping and caulking	28,210	36	783	5
		$54,816	**85 kW**	**$645/kW**	

Estimated impact of air leakage by component at Ottawa case study building

Case Study Number 2

Annual Energy Savings from ALC [KWh]	63,000 KWh corresponding to a 6.5% annual reduction
Peak Load Reduction [KW]	45 KW corresponding to an 8.5% reduction
Annual Cost Savings [1990 $]	6,100
Retrofit Cost [1990 $]	38,000
Payback Period [years]	6.2

Building Description

This building is a 10-storey apartment building with 95 suites. The total floor area of the building is 9,830 square meters. The building is a condominium. The building is heated with electric baseboard heaters. The corridor air is heated by natural gas.

Envelope Construction

The walls of the building are brick insulated, on the inside, with 35 mm of extruded polystyrene insulation.

Energy Audit

An initial audit of the building was completed. Total energy bills for 1989 were $92,500. An analysis of energy use was completed, and air leakage was estimated to account for 34% of the building heat loss.

Description of Air Leakage Control Measures:

Work included

- sealing all shafts (top and bottom)
- sealing penthouse mechanical room
- sealing exterior envelope leaks
- sealing exterior doors
- sealing exterior windows

Appendix B — Air Leakage Control Resources

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

Canadian Urethane Foam Contractors Association

CUFCA

Box 3214
Winnipeg MB R3C 4E7
Phone: 204-956-5888
Toll Free: 866-467-7729 1-866-GO-SPRAY
Fax: 204-956-5819
E-mail: cufca@cufca.ca
Website: http://www.cufca.ca/

National Energy Conservation Association

National Energy Conservation Association
P.O. Box 2747
Winnipeg, MB R3C 4E7
Phone: 1-204-956-5888
Toll Free-: 1-866-268-NECA
Fax:1-204-956-5819
E-mail to:neca@neca.ca
Website: http://www.neca.ca/

Fan Depressurization Equipment Manufacturers

Retrotec
1540 West 2nd Avenue, Unit # 611
Vancouver, B.C. V6J 1H2
Phone: 604-732-0142
Fax: 604-737-0162
E-mail: sales@retrotec.com
Website: http://www.retrotec.com

Minneapolis Blower Door Company
2801 21st Ave., South, Suite 160
Minneapolis, MN 55407
Phone: 612-827-1117
Fax: 612-827-1051
E-mail: info@energyconservatory.com
Website: http://www.energyconservatory.com

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/

Appendix C — References

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Bahnfleth, W.P., Yuill, G.K., Lee, B.W, *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

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

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Appendix D — Air Leakage Control Checklist Forms

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 potential for 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 ❏ insuite fan coil ❏ gas-fired forced air (insuite furnace or combo system) ❏ other:______________

Corridor Air Ventilation System:________________________________

Suite Exhaust: ❏ insuite exhaust fans ❏ central rooftop exhaust fans

Space Heating Individually Metered?: ❏ Y ❏ N

Building Envelope Type:

❏ brick veneer – stud wall ❏ brick veneer masonry back up ❏ 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:

Building Air Leakage Control Checklist (Con't)		
Location	**Area**	**Leakage**

Top of Building	**Elevator Penthouse**	❑ Roof-wall joint
		❑ Roof penetrations
		  ❑ Wiring
		  ❑ Ducts
		  ❑ Pipes
		❑ Wall Penetrations
		  ❑ Wiring
		  ❑ Ducts
		  ❑ Louvres
		  ❑ Pipes
		❑ Exterior door
		❑ Stairwell door
		❑ Elevator hoist cable
		❑ Elevator service wiring
		❑ Other:

	Mechanical Penthouse	❑ Roof-wall joint
		❑ Roof penetrations
		  ❑ Wiring
		  ❑ Ducts
		  ❑ Pipes
		  ❑ Boiler vent
		❑ Wall Penetrations
		  ❑ Wiring
		  ❑ Ducts
		  ❑ Louvres
		  ❑ Pipes
		❑ Exterior door
		❑ Stairwell door
		❑ Floor Penetrations
		  ❑ Wiring
		  ❑ Pipes
		  ❑ Ducts
		❑ Other

	Rooftop	❑ Stairwell door ❑ Access hatch ❑ Garbage chute vent ❑ Exhaust fans ❑ Corridor air unit ❑ Plumbing stacks ❑ Parapets ❑ Other

Building Air Leakage Control Checklist (Con't)		
Location	**Area**	**Leakage**
Bottom of Building	**Parking Garage**	**Ceiling/ Floor above:** ❑ Pipe penetrations ❑ Wiring penetrations ❑ Duct penetrations **Wall to Building Core:** ❑ Elevator vestibule doors ❑ Floor-wall joint ❑ Wall-ceiling joint ❑ Pipe penetrations ❑ Wiring penetrations ❑ Duct penetrations **Garage Ventilation System** ❑ Supply air louvres ❑ Exhaust air louvres ❑ Duct penetrations ❑ Garage overhead door ❑ Garage exterior exit doors ❑ Other:
	First Floor	**Garbage Service Room:** ❑ Overhead doors ❑ Exterior exit door ❑ Exhaust fan duct ❑ Exhaust fan louvre ❑ Wiring penetrations ❑ Garbage chute to floor ❑ Service room door ❑ Other: **Loading Bay** ❑ Exterior overhead door ❑ Exterior exit door ❑ Bay to building door ❑ Wiring penetrations ❑ Plumbing penetrations ❑ Duct penetrations ❑ Other: ❑ Hose bib penetration ❑ Stairwell doors ❑ Front entry door ❑ Laundry exhaust louvre ❑ Laundry exhaust duct ❑ Other exterior doors Other:

Building Air Leakage Control Checklist (Con't)		
Location	**Area**	**Leakage**
Exterior Walls	**Apartments**	❑ Windows ❑ Balcony doors ❑ Wiring ❑ Electric baseboard ❑ Pipes ❑ Exterior lighting ❑ Electric outlets, switches ❑ Ducts ❑ Exterior hoods, louvres ❑ Through-wall sleeves ❑ Other:
	Common Rooms	❑ Windows ❑ Exterior doors ❑ Wiring ❑ Electric baseboard ❑ Pipes ❑ Exterior lighting ❑ Electric outlets, switches ❑ Ducts ❑ Exterior hoods, louvres ❑ Through-wall sleeves ❑ Other:
	Stairwells	❑ Windows ❑ Exterior doors
Interior Partitions	**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, wall-ceiling joint
	Basement/Garage Service Rooms	❑ Penetrations of floor slab above: ❑ Wiring ❑ Pipes ❑ Ducts ❑ Other:

Appendix E Dealing with Odour Transfer Problems

Canada Mortgage Housing Corporation prepared the About Your Apartment—Solving Odour Transfer Problems in Your Apartment to help occupants of Multi Unit problems to understand why odour transfer happens and what to do about it. This information is also of use to air leakage control contractors when they are asked to deal with such problems. The attached About Your Apartment can be used to develop an odour control plan or to inform occupants and the property management of their options.

ABOUT YOUR APARTMENT

SOLVING ODOUR TRANSFER PROBLEMS IN YOUR APARTMENT

AE 1

One of the most common problems experienced by the occupants of apartment buildings is the transfer of objectionable odours from one apartment to another. Tobacco smoke and cooking odours top the list of complaints. Other complaints are often heard concerning the transfer of odours, noise, light and sometimes pests, under apartment entry doors. The smell of car exhaust from underground parking garages can also be problematic.

Regardless of whether an apartment is rented or owned, there are steps you can take to solve, or at least improve, odour conditions in your apartment. However, before you take any actions that might affect your unit or other areas of the building, you should consult with the building's management and obtain their approval.

Understanding Air Movement in Your Building

For odours to transfer between apartments, two conditions must exist. First, there must be a *hole*, or pathway, for the air to move through and, second, there must be a *driving force* to push the air through the hole. The following sections will help you to better understand where the holes are and what forces act on your building. This, in turn, will enable you to determine the source of the odour problem in your apartment and what you might do about it.

The "pathways"

Despite appearances, apartment buildings can have relatively leaky interior ceiling, floor and wall partitions that allow air to move through the building. Odour transfer between apartments would not otherwise be possible. There may be leakage pathways through the walls and floors separating you from your neighbours beside, above and below your apartment at the following locations:

- Under the entry door from the corridor
- Electrical outlets and switches
- Wiring penetrations
- Plumbing penetrations
- Ducts
- Joints between the walls and floors that define your apartment's boundaries, and,
- Dropped ceilings

In the common areas of the building, stairwells, elevator shafts and garbage chutes serve as passageways for air movement throughout the building.

The "driving forces"

Figure 1 shows how air tends to move in apartment buildings in the winter months under the influence of the three primary driving forces: stack effect, wind effect and mechanical ventilation.

In the winter, air tends to move upward through your building driven by a force known as "*stack effect*" (see note A on Figure 1). Stack effect causes air to be drawn in from outside at the lower levels of the building, rise up through the floor levels and then leak out of the building at the upper floors. At the same time, wind will cause air to leak into the apartments on the windward side of the building, and flow across the common corridors to the apartments on the leeward side of the building. This is known as "*wind effect*" (B on Figure 1).

Ventilation systems can also cause the transfer of air to and out of your apartment. Most apartment buildings constructed since the mid-1960s have corridor ventilation systems that deliver outdoor air to the common corridors on each floor. This is done to ventilate the corridors, to contain odours in apartments and to provide make-up air for in-suite range hoods, bathroom fans and clothes dryers. Corridor air systems are operated either intermittently—usually on a regular schedule—or continuously.

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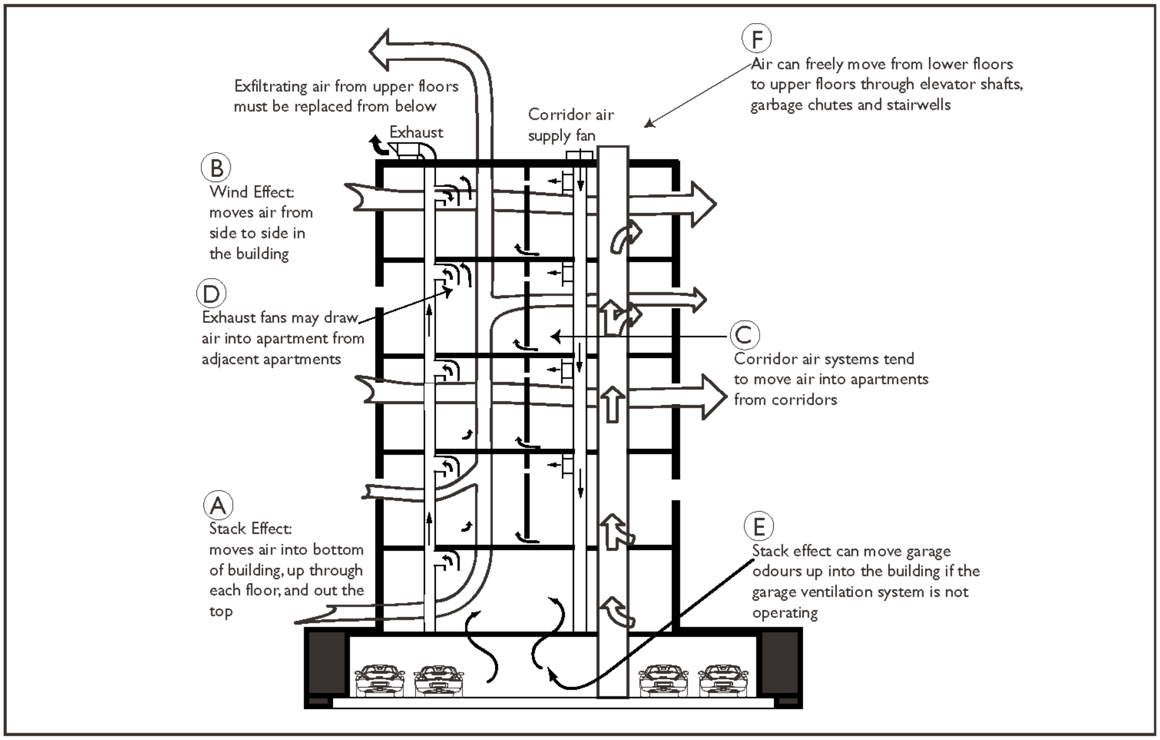

Figure 1 : Air movement direction in apartment buildings in winter

Corridor air ventilation systems tend to push air from the common corridors into adjacent apartments through the gaps that exist around apartment doors (C on Figure 1). Sometimes this gap also lets in objectionable odours, light and noise. CMHC research has found that corridor air ventilation systems will not necessarily improve air quality within individual apartments. Much of the air delivered to the corridors escapes the building through the elevator shafts, garbage chute and stairwells. Sometimes during the winter months, the corridor air system can be overpowered by strong stack and wind forces and may not effectively ventilate the corridor areas or prevent the spread of odours.

Apartments also usually have exhaust systems to ventilate the bathrooms and kitchens. The exhaust fans are either in the apartment or are located in a central location elsewhere in the building. The operation of bathroom and kitchen exhaust fans may effectively ventilate your bathroom and kitchen but their operation can draw unwanted air from other areas of the building into your apartment (D on Figure 1). Kitchen and bathroom fans can sometimes be noisy and ineffective.

Parking garages have ventilation systems that vent automobile exhaust outdoors. These systems can operate continuously, however, for energy conservation, they can be operated by controllers that turn the system off except when concentrations of car exhaust emissions exceed pre-set limits. When the systems are not running, sometimes stack effect can move exhaust odours from the garage up into the building (E on Figure 1).

Finally, elevator shafts, stairwells, wiring conduits, duct enclosures, plumbing chases and garbage chutes that run from floor to floor allow air, driven by stack effect, to move from lower levels to upper levels (See F on Figure 1).

Odour Transfer: What to Do About It

Helpful suggestions for reducing odour transfer from other areas of the building to your apartment are offered below. **It must be emphasized that you should discuss any measures you choose to try with the building's management in advance of taking action and obtain their approval.** The suggestions are divided between what you could do in your own apartment and what you could do outside it with the support of the property management.

Be aware that many of the measures provided below have a trial and error element to them—and are identified as such. The causes of odour transfer to your apartment, and the solutions, will be dependent on where your apartment is located in the building, the building's construction type, how the building is operated and maintained and other such factors. This guide cannot cover all the different scenarios. Thus, you will need to try certain measures to see if they improve the situation, make no difference, or make things worse. Fortunately, the trial and error measures are easily reversible and will cause no long-term problems in your unit.

Warning: The following suggestions DO NOT apply to apartments that have combustion appliances such as wood-burning fireplaces or natural gas fireplaces, hot water heaters and furnaces. The following suggestions can adversely affect the operation of combustion appliances leading to conditions that can threaten your health and, in extreme conditions, cause death. If your apartment has combustion appliances, it is recommended that you consult with a qualified wood burning or natural gas appliance installer prior to taking any actions to reduce odour transfer.

Within Your Unit:

1. Ensure the odor source is not in your apartment

If the odour is coming from your apartment, it is something that you can deal with. CMHC's *Clean Air Guide* has many ideas on how to improve the quality of your indoor environment. Ordering information is provided at the end of this publication.

2. Seal potential leakage pathways between your unit and other areas as follows:

a. Seal the gap around the corridor door to your apartment with weatherstripping. Note: This is a trial and error measure. In most buildings, corridor air systems force air from the corridor into your apartment. This can cause odour transfer problems. Install the weatherstripping and wait to see if this reduces odour transfer. After sealing the corridor door, watch to see if your apartment becomes stuffy or if odours and humidity linger in bathrooms or kitchen areas. Also watch for the appearance of condensation on your windows. Should any one, or all, of these problems occur after you have sealed your door, you may have to operate your exhaust fans more frequently. If this does not help, you may have to remove the weatherstripping to improve ventilation.

b. Seal plumbing penetrations in the walls and floors under sinks in kitchen and bathrooms, and behind toilet fixtures. Check in closets and utility closets for other pipe, duct and wiring penetrations and seal around these as well. Use low-odour, water-based caulking or spray-in foam to seal penetrations.

c. Install air-sealing gaskets behind the cover plates of light switches and electrical receptacles. Air-sealing gaskets can be found at most hardware stores.

d. For in-suite bathroom exhaust fans, remove the grille and caulk or seal with foil duct tape the gap between bathroom fans and the surrounding ceiling or wall areas. The sealed joint will be hidden when you replace the grille. If you only have an exhaust grille in your bathroom that is connected to a central exhaust system, sometimes the grille can be removed and the exhaust duct can be sealed to the surrounding ceiling or wall. Otherwise, gaps around the grille can be sealed with paintable caulking.

e. Caulk the bathtub and its surrounding enclosure to adjacent wall and ceiling areas with silicone caulking.

f. Remove baseboards and caulk the floor-wall joint around the perimeter of your apartment on both inside and outside walls. Note that this measure is a last resort that is difficult to do, is highly disruptive, and may, or may not, make a difference. The measure is recommended if renovations are planned in the apartment as it can be easily done when other work is underway or when flooring is being replaced.

3. Seal indoor-outdoor air leakage paths in your apartment

Air leaking through outside walls can cause air from neighbouring apartments and the common corridor to be drawn into your unit. Limiting air movement through exterior walls will not only prevent this from happening but will also reduce drafts, reduce heating costs and limit the amount of outdoor noise entering your apartment. Remember to discuss with your building's management what you intend to do before taking any action.

a. Ensure window and door gaskets are intact or in good condition — otherwise replace them. This is usually the building owner's or condominium's responsibility. Worn or flattened gaskets, windows that rattle in the wind, the presence of drafts or the movement of drapes and blinds are signs that your windows are leaky.

b. Caulk the wall-floor joint behind baseboards (similar to step 2 f. above)—this can be difficult to do but may be worthwhile if renovations are being considered.

c. Seal joints around through-wall or window-mount air conditioning units with caulking or spray-in foam. Be careful not to block any pipes that drain condensation from the unit to outdoors.

d. Seal wiring penetrations behind electric baseboard heaters. This will require the services of a contractor to disconnect the power and remove baseboard units.

e. Install air-sealing gaskets behind the cover plates for electrical outlets and switches.

4. Ventilate your unit with existing fans

Use the bathroom fan and kitchen fan to ventilate your unit. **Note:** This is a trial and error measure. Operating your exhaust fans can help dilute odours that enter your apartment. Kitchen fans tend to be noisy so try using the bathroom fans only at first. Ensure the fans are working—they should be able to hold a piece of tissue paper to their grilles when operating. If they are unable to do this, or little airflow is detectable, the exhaust fan, duct system or outside hood may require cleaning. Sometimes the age, condition or quality of the fan will require that it be replaced.

Be aware that operation of exhaust fans in your unit may draw more air from neighbouring apartments or the common corridor into your unit, making the problem worse, not better. Sealing between your unit and other areas of the building, as previously recommended, should help prevent this from happening. However, if exhaust fan operation does not improve conditions in your apartment, or seems to make matters worse, discontinue their use except as normally required.

In consultation with the building management

1. Try to identify and eliminate the source of the odour

Cooking and tobacco smoke odours can often be easily traced back to other apartments or common areas. Objectionable odours originating from other apartments may be resolved, with the help of the property manager, by coming to an agreement with the occupants to stop, or limit, the odour-causing activity.

The presence of car exhaust odours can be a sign that the parking garage or the parking garage vestibule ventilation systems are not working properly. The intake grille for the building's corridor air supply could be too close to street level or the outlet for the parking garage exhaust system.

Garbage odours may come from garbage chutes, garbage chute access rooms on each floor level and the compactor/dumpster room at the base of the chute. Garbage odours may be resolved by ensuring that the gaskets on garbage room doors and the chute hatchways are in good condition and the doors and hatches seal tightly when closed. Keeping the garbage rooms, chute and compactor clean and ensuring the compactor room is well ventilated can also help.

2. Ensure the building ventilation systems are operating correctly

Confirm with building management that the building's corridor air supply system is operational—particularly at the times when the odours of concern are being produced.

If the building has a central exhaust fan for the kitchens and bathrooms, ensure that it is working properly as well.

3. Ensure the areas or apartments where the odours are being produced have bathroom and kitchen fans that work

If you cannot stop the odours from being produced, as is often the case with smoking and cooking, try to arrange for more diligent or continuous use of in-suite exhaust fans (if installed) in the apartment where the odours are being produced. This will help to contain odours. The property manager will have to ensure that the apartment's exhaust fans work and are not so noisy that they will not be used. Increased fan use can be achieved through the installation of timers or occupancy sensors that can activate the in-suite fans as required.

4. Investigate the possibility of having the apartment where the odour is being produced sealed as previously mentioned

It may be possible, with the support of the property manager, to have the odour producing apartment's corridor door sealed with new weatherstripping. The other in-suite sealing measures will be too intrusive to be imposed on others. **Note**: This is a trial and error measure as the weatherstripping may adversely affect the indoor environment of the apartment.

5. Investigate the possibility of pressurizing your apartment

You can pressurize your apartment by introducing outdoor air directly into your apartment with a small ventilation unit. This will not only provide you with all the fresh air you need, but can also pressurize your apartment and prevent air leaking in from neighbouring apartments or common areas. It should be noted that this is one of the more expensive and intrusive options, as a ventilation unit will have to be purchased and installed. A hole will have to be made through the exterior wall or a portion of an existing window area for the outdoor air duct.

The ventilation unit will require space in your apartment and it could be relatively noisy to operate unless you take care to find a fan with a sound rating below 1 sone. Consideration will also have to be given to heating the outdoor air in the winter, or introducing it to your apartment in such a way that does not cause comfort problems.

Note: Overly pressurizing an apartment can force warm, moist indoor air into the exterior building envelope. This can cause problems with the structure, insulation and cladding systems. Additionally, windows and balcony doors may experience problems as frost may form on them. Also, pressurizing your apartment may force your odours into your neighbours' apartments—something *they* may find objectionable.

Despite these concerns, the installation of a ventilation unit can be very effective in preventing odours from entering your apartment and improving indoor air quality. This step will require the expertise of a qualified ventilation contractor to properly determine the capacity of the unit (i.e. how much air will it have to bring into your apartment), and the installation details required for safe, and effective operation.

There is a trial and error element to this measure. Should you install a ventilation system to pressurize your apartment, you and the property management must watch for warning signs such as the appearance of efflorescence (irregular white stains) on brick walls, the formation of icicles below weephole soffits or other penetrations in the cladding, the appearance of siding stain or paint problems, the deterioration of paint and drywall around windows, and the presence of musty smells. If any or all of these problems occur after the installation of a pressurizing fan in your apartment, discontinue its use until an investigation of the problems can be conducted and the source of the problem identified.

In summary...

Understanding how and why air transfer occurs will help you resolve odour problems in your unit. Sometimes, working with the building management and the other occupants in the building will help resolve the problem with little cost or effort. Other times, measures, such as those suggested in this guide, may be necessary. The highly varied nature of apartment buildings means that a trial and error approach must be taken so that, ultimately, the problem is resolved.

For further information on dealing with indoor air quality problems in your apartment, such as CMHC's *Clean Air Guide*, contact CMHC at 1 800 268-2648 or visit our website at **www.cmhc.ca.**

For problems where it may be appropriate to have an indoor air quality expert visit your apartment, contact CMHC for a list of professionals who have completed CMHC's Residential Indoor Air Quality Investigator Training Program.

To find more About Your Apartment fact sheets plus a wide variety of information products, visit our Website at www.cmhc.ca. You can also reach us by telephone at 1 800 668-2642 or by fax at 1 800 245-9274.

Priced Publications

The Clean Air Guide: How to Identify and Correct Indoor Air Problems in Your Home — Order No. 61082

Free Publications

About Your Apartment *fact sheets*

Reducing Noise in Your Apartment — Order No. 63904

About Your House *fact sheets*

The Condominium Owner's Guide to Mold — Order No. 62341

A Tenant's Guide to Mold — Order No. 63902

Printed in Canada
Produced by CMHC 20-06-05
Revised 2005

63419

Visit our website at www.cmhc.ca

65847 20/12/07