CSA Unit 14- The Building as a System

Chapter 1

Significant advances in home building technologies and materials over the past several decades, including energy conservation, air leakage control, improved insulation, etc., also indicate that a gas technician/fitter must take a new approach. Gas technicians/fitters must be thoroughly familiar with prevailing construction methods and technologies that support the concept of a building as a series of interdependent parts. This concept is generally known as "the building as a system".

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Created

by Mike Kapin

Purpose and Objectives

Purpose

This chapter describes the key components of building-as-a-system construction and how they affect the gas technician/fitter.

Objectives

At the end of this chapter you will be able to:

- Define key components of the building as a system
- Describe the relationship between key components to heat, moisture, and air flow
- Describe how to minimize negative impacts of heat, moisture, and air flow on the building

Key Terminology

Term	Abbreviation (symbol)	Definition
Absolute humidity		The actual amount of water vapour contained in a given amount of air, regardless of the temperature of the air. This is also called "humidity ratio".
Backdrafting		The reverse flow of gas in the flues of fuel-fired appliances that results in the intrusion of combustion by-products into the living space.
Condensation		The process by which dew, or condensate, is formed. In this process, moisture changes state from a gas (water vapour) to a liquid (water).
Dew point		The point at which any body of air is saturated with water (100% RH).
Exfiltrate		Exit
Infiltrate		Enter
Interstitial condensation		Indoor air leaking into the walls or attic may drop water within the structure as it is cooled below its dew point.
Relative humidity	RH	The amount of water vapour contained in the air expressed as a percentage of the maximum amount that could be contained in the air at the same temperature.
Water vapour		Microscopic water molecules that are suspended in air.

Components of the Building System

A system consists of a number of distinct parts or components that are linked together, such that a change in one usually causes a change in others. You will deal with systems every day and—whether you realize it or not—the only way you begin to understand how things work (sports teams, work sites, cars, etc.) is by approaching them as a system. You will recognize that they consist of several parts and take action or make judgments based on how the parts are related.

Dynamic Systems

Systems are dynamic. They are constantly changing in response to internal and external forces. Each time a change is made to one component, the entire system is affected.

Building as a System

The building is a system. A systems approach is essential in order to understand how it works. The purpose of the building is to provide comfort for the occupants.

Interconnected Parts

Taking a systems approach to any complex problem means considering the role of each component not simply for its individual purpose or operating characteristics but also for its larger purpose or operation within the system.

Four Major Subsystems

Building Envelope

Consists of the upper ceiling, walls, windows, doors, basement walls, and basement floors. The envelope separates the indoors from the outdoors.

Outside Environment

Includes climatic conditions, shade, location, age of the building, gravity, and orientation of the building.

Mechanical and Electrical Equipment

Includes all equipment and appliances that contribute to the generation of heat or moisture or cause the movement of air.

Occupants

Includes all the people, pets, plants, and other non-mechanical/electrical components that occupy the building envelope.

Building Envelope

Figure 1-1

The building envelope—identified by dark shading—includes exterior doors/ windows

The building envelope consists of the upper ceiling, walls, windows, doors, basement walls, and basement floors. The envelope separates the indoors from the outdoors!

Defines Indoor Space

The building envelope defines the indoor space, which is governed by other systems and devices that relate to the activities taking place inside the building.

Controls Flow

Besides supporting the walls and roof, the envelope helps to control the flow of heat, air, and moisture between the inside of the building and the external environment.

Determines Heat Loss

It is primarily the components of the building envelope that determine the rate of heat loss from the building. The better it is insulated and sealed from air and moisture movement, the less heat, air, and moisture are transferred.

Construction Type Impact

Heat Flow Impact

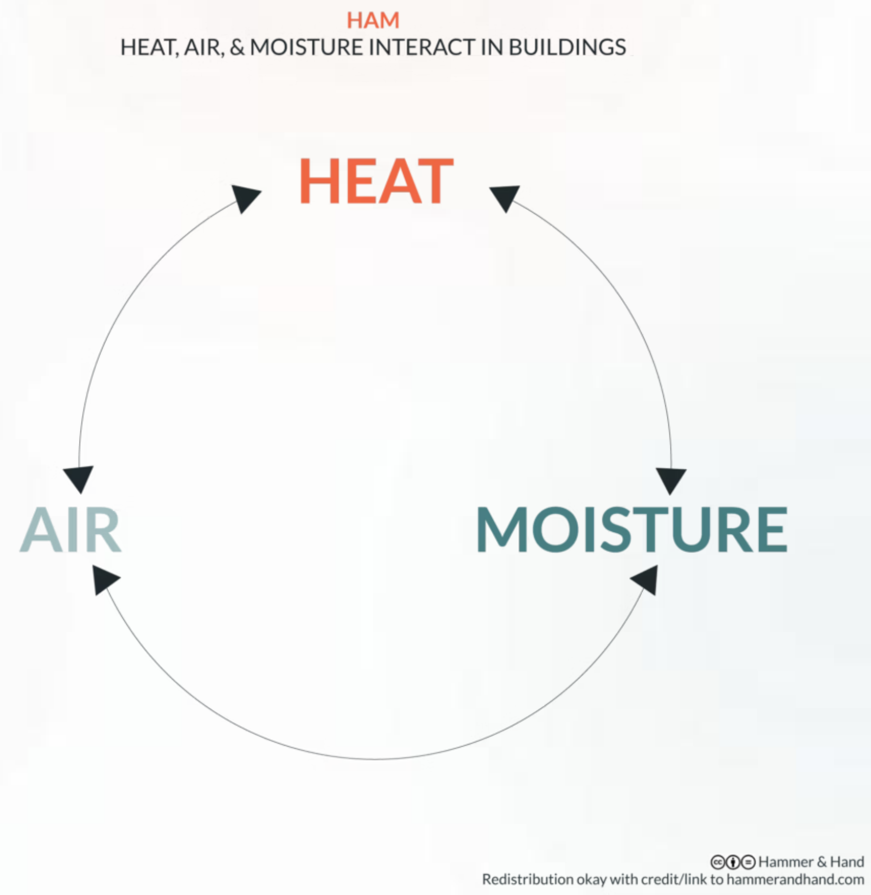
The type of construction has a great effect on the flow of heat. Knowledge of the component parts in various types of construction and how they influence heat flow is necessary for controlling comfort in the indoor environment.

Air Flow Impact

Construction methods directly affect how air moves through the building envelope. Proper sealing and barriers are essential to control air movement between indoor and outdoor environments.

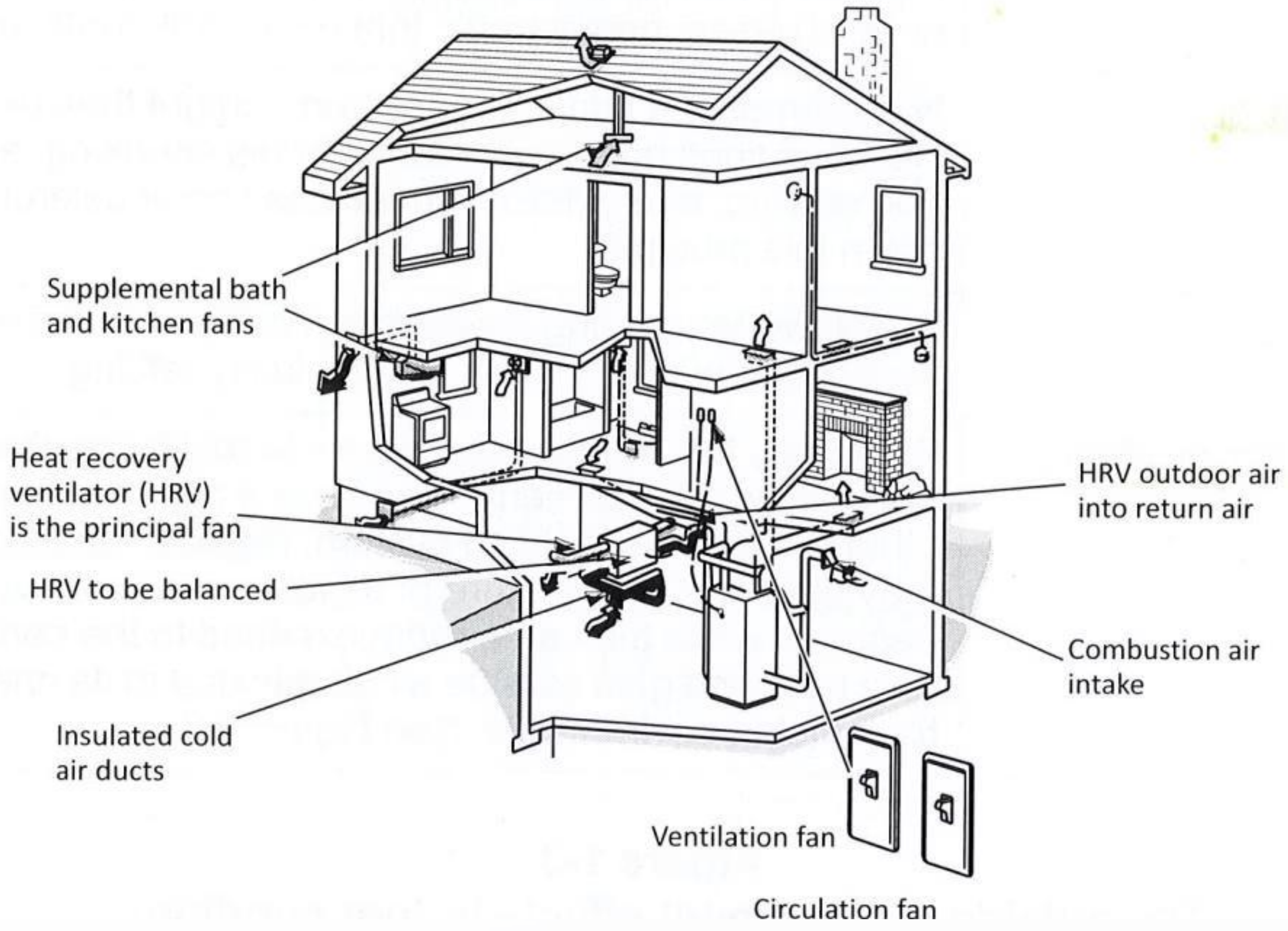
Moisture Flow Impact

Different construction materials and techniques handle moisture differently. Understanding how moisture moves through various building components is critical for preventing damage and maintaining indoor air quality.



Mechanical and Electrical Systems

Figure 1-2
A building's mechanical systems



The separation from outdoors provided by the building envelope allows for the creation of a separate indoor environment with its own temperature, humidity level, and air characteristics. The mechanical and electrical systems are responsible for creating that indoor environment to a large extent.

Heating and Cooling

- Space heating and cooling equipment

Appliances

- Ranges and ovens

Air Management

- Exhaust and supply fans

Impact of Mechanical Systems

Add Heat

Heating systems, appliances, and lighting all contribute heat to the indoor environment

Transfer Heat

Distribution systems move heat from one area to another within the building

Move Air

Ventilation systems, fans, and blowers create air movement patterns throughout the building

Affect Moisture

Many systems add or remove moisture, impacting indoor humidity levels

All of these devices add, transfer, or remove heat, air, or moisture to and from the building. Their individual operation affects the operation of the entire building system and can help or hinder the ultimate goal of achieving a comfortable indoor environment.

Occupants

People

Release heat, moisture, and pollutants into the indoor space

Pets

Contribute to indoor air quality and moisture levels

Plants

Affect humidity and air quality within the building

Control

Occupants control mechanical systems and modify the building envelope

The range and timing of the effects on the building system that are caused by the occupants vary widely and are difficult to predict or control. However, these effects should never be neglected or underestimated if proper functioning of the building system is to be achieved.

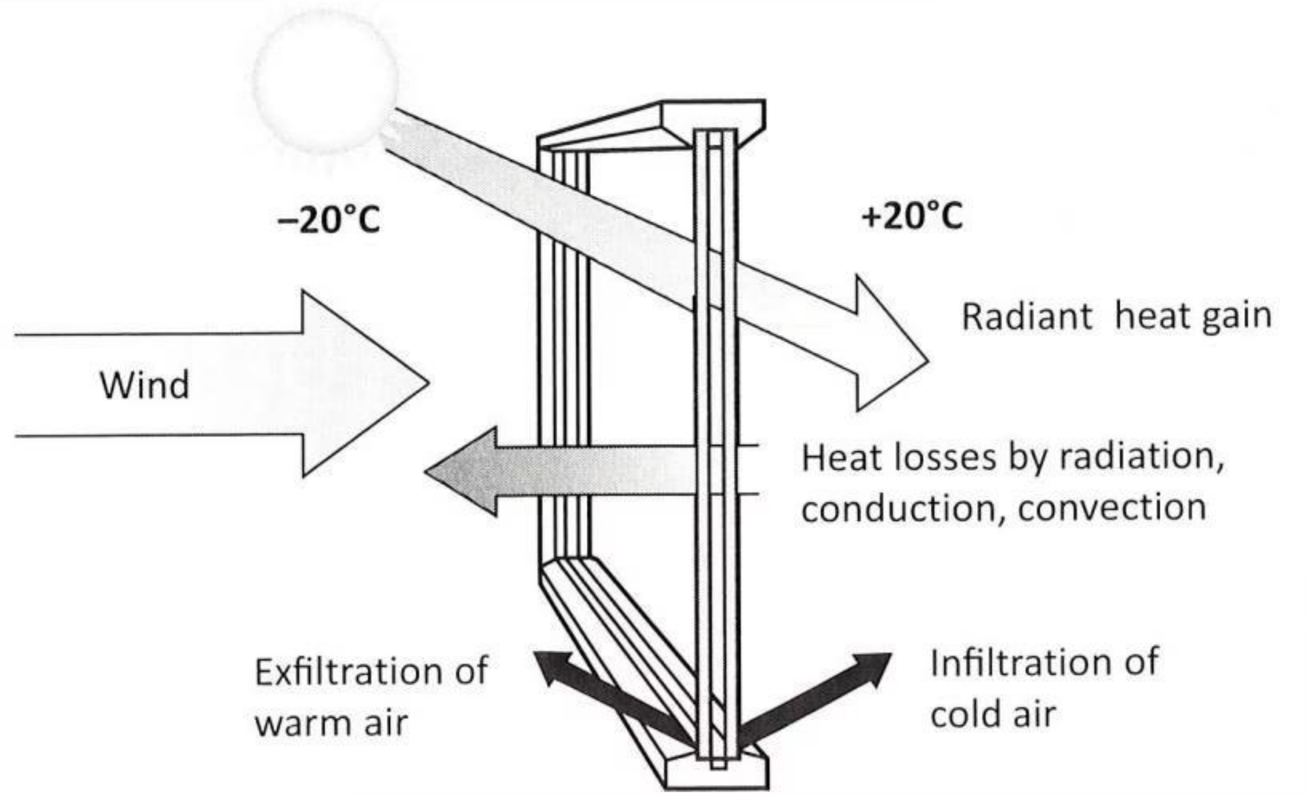
External Environment

Figure 1-3
The outside environment affects indoor conditions

No building envelope can or should completely separate the indoors from the outdoors. The outside environment has both positive and negative effects on the functioning of the other subsystems of the building, just as those subsystems affect the outside environment (to a lesser degree).

Outside features	Description or examples
Climatic and seasonal conditions	Frequency of exposure to sun, wind, rain, snow, etc.
Shade	Shade trees and other shade elements
Location	Above/below steep slopes, proximity to bodies of water, ground gases, heavy traffic that emits pollutants, etc.
Age of the building	New homes are considerably more airtight than older homes. New buildings are subject to materials shrinking, expanding, and settling, and external conditions can accelerate or slow down this process.
Gravity	Affects water running downwards, as from a roof or down a windowpane, door frame; also building settling.
Orientation of the building	Especially the window exposure-in relation to the forces of the outside environment-can have a significant effect on the other parts of the building system.

Building Orientation Effects



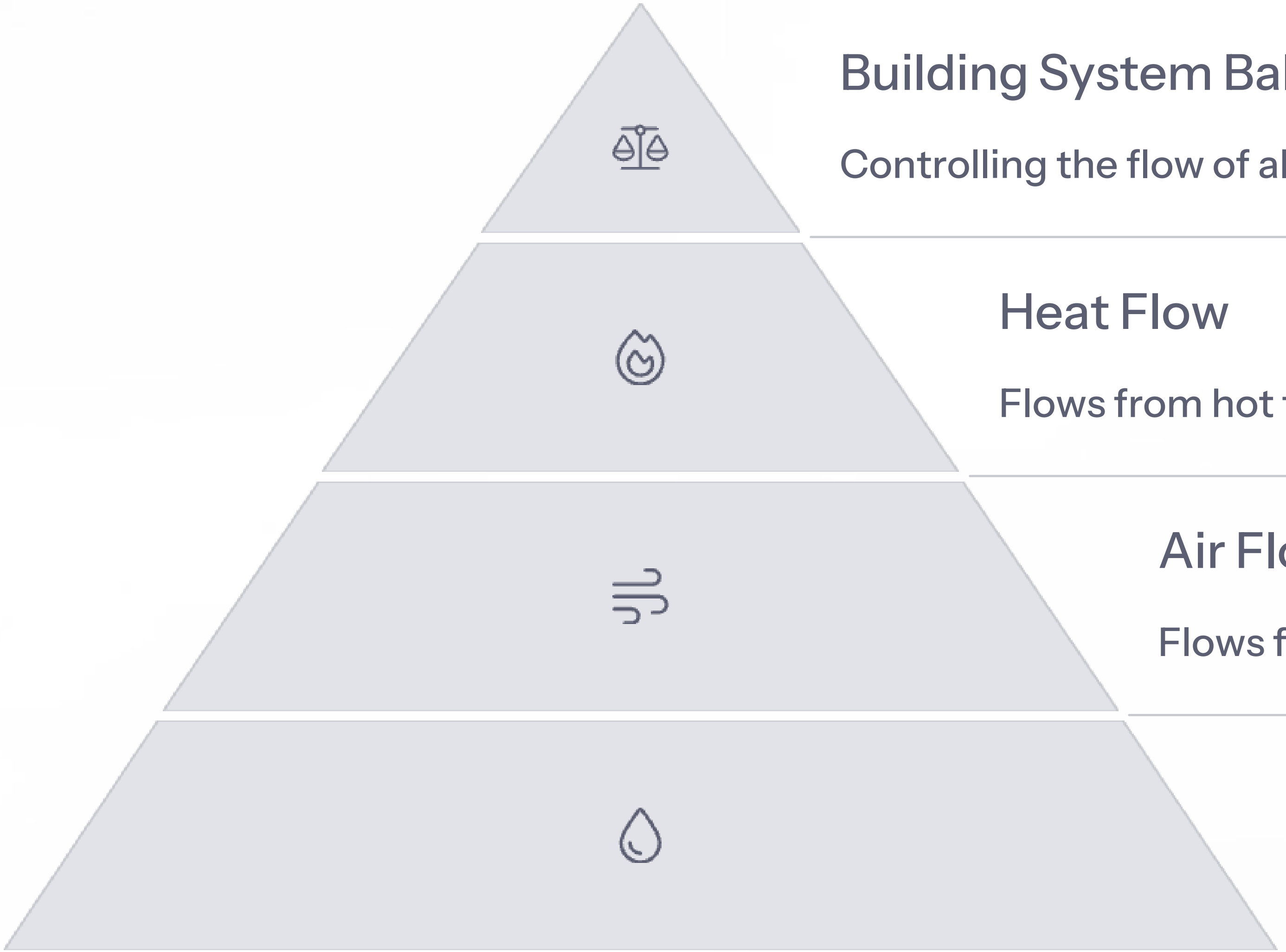
Summer Conditions

Window shaded to avoid overheating

Winter Conditions

Window exposed to admit radiant energy

Flow of Heat, Air, and Moisture



Building System Balance

Controlling the flow of all three elements

Heat Flow

Flows from hot to cold

Air Flow

Flows from high pressure to low pressure

Moisture Flow

Flows from high water pressure to low water pressure

The key factors determining heat comfort, indoor air quality, and the structural "health" of the building are the flow of heat, air, and moisture. Although the three flow factors are interrelated, they are best understood for purposes of control in the building system by focusing on their root cause (i.e., what principle causes heat, air, or moisture to move when all other factors are kept the same).

Five Forces Affecting Flow

Stack Effect

Temperature differences between indoor and outdoor air create pressure differences that cause air movement vertically through the building

Wind Effect

Wind creates positive pressure on windward sides and negative pressure on leeward sides of the building

Flue and Ventilation Effect

Operation of combustion appliances and exhaust devices creates pressure differences

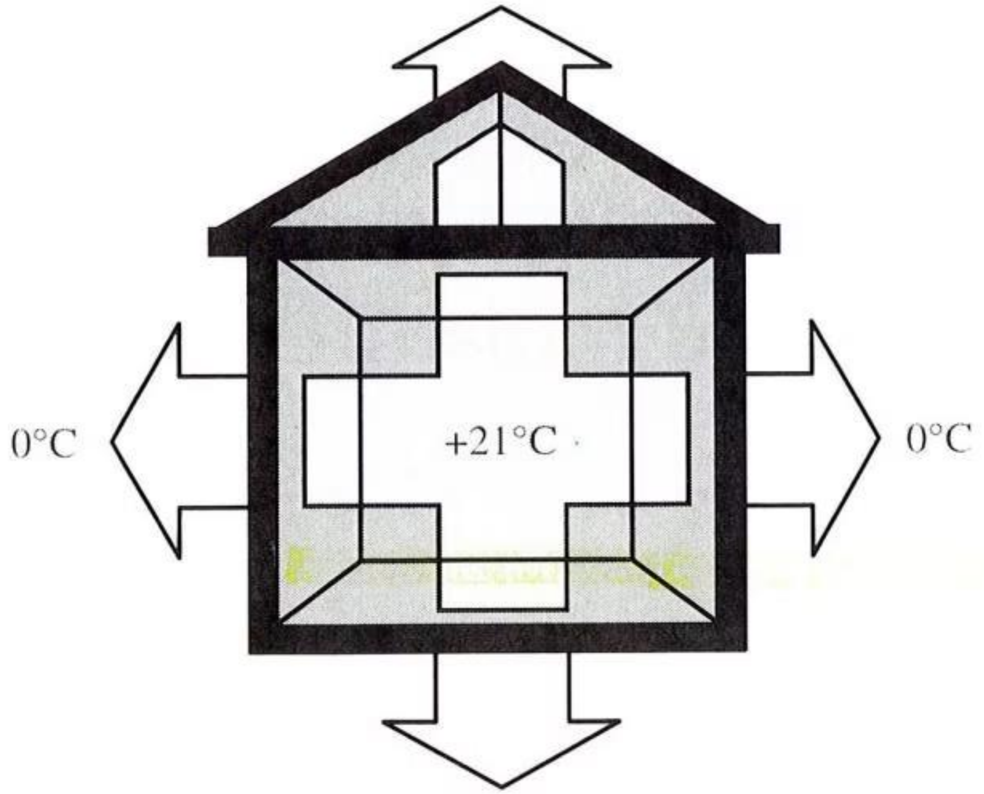
Distribution Effect

Central ventilation and forced air heating systems create air flow patterns

Combined Effect

All forces working together in a dynamic system

Heat Flow Principles



Heat flows from hot to cold by conduction, convection, and radiation. If you want to reduce or increase heat flow, you have to reduce or increase exposure between hot and cold substances.

Conduction

Heat transfer through direct contact between materials. Insulation reduces conductive heat transfer by creating air pockets that slow the movement of heat.

Convection

Heat transfer through the movement of fluids (air or water). Warm air rises and cool air falls, creating natural circulation patterns in buildings.

Radiation

Heat transfer through electromagnetic waves that travel through space. Radiant barriers reflect heat back toward its source rather than absorbing it.

To maintain a warm indoor environment during winter, the building envelope must reduce heat losses by reducing hot and cold contact between surfaces of thermally conductive materials and between fluid masses of different temperatures, and by controlling the direct exposure between radiant heat surfaces.

Typical Heat Loss Through Building Envelope

30-40%

Air Leakage

The largest source of heat loss in most buildings

20-25%

Basement

Heat loss through foundation walls and floors

15-20%

Doors and Windows

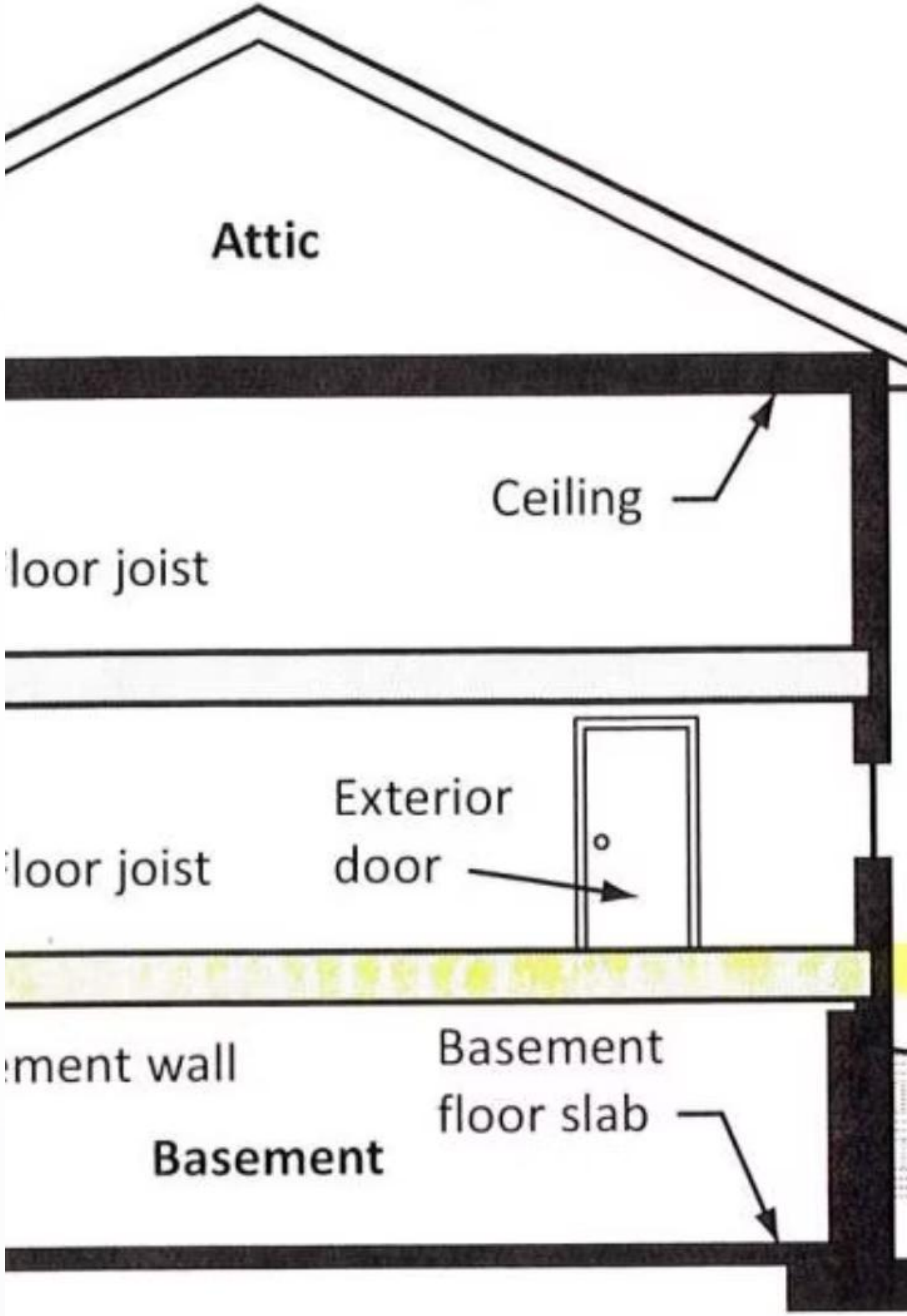
Heat loss through glazing and frames

10-20%

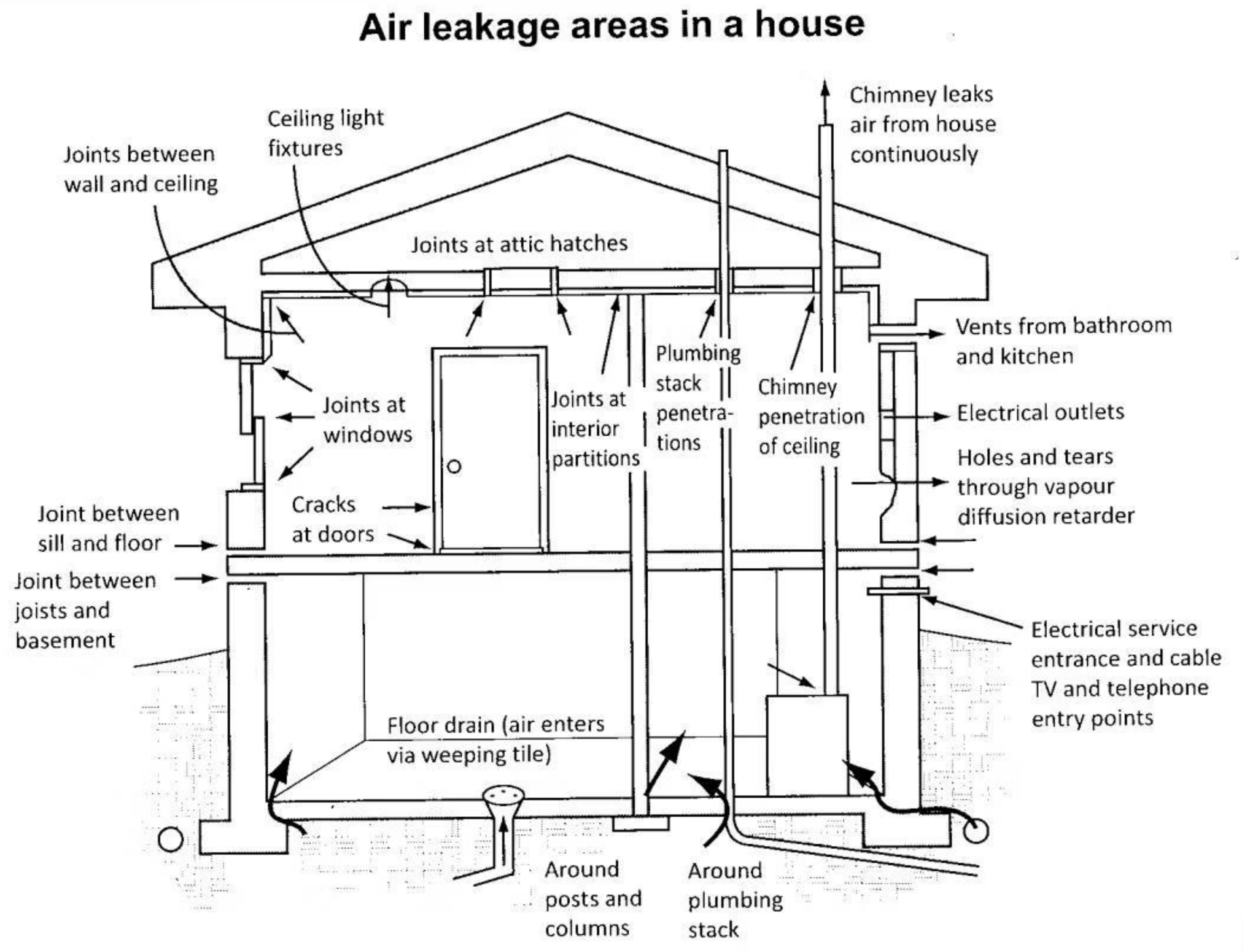
Walls and Ceiling

Heat loss through insulated assemblies

It is primarily the components of the building envelope that determine the rate of heat loss from the building. The better it is insulated and sealed from air and moisture movement, the less heat, air, and moisture are transferred.



Air Flow Principles



Air flows from high pressure to low pressure. Ideally, a balance between the outdoor and indoor pressures would limit cold air flow into the building to the amount and areas needed for replacement of air exhausted from the building or consumed by occupants and appliances.

Air Barrier Function

Balanced Air Flow

Pressure Implications

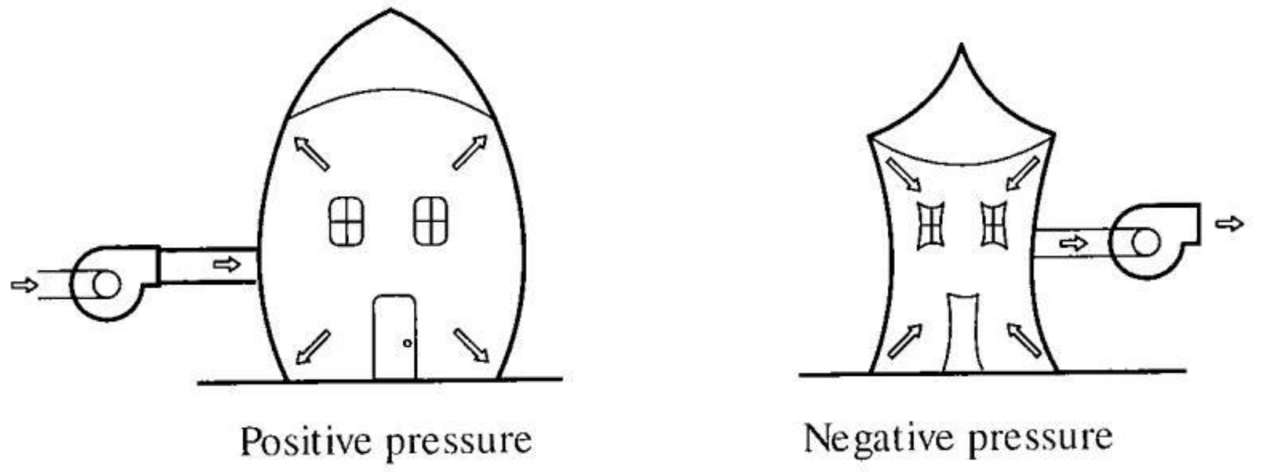
Air Flow Balance

Undersupply of Air

Figure 1-8
Unbalanced houses with positive and negative air pressures

Removal of more air than is supplied creates a negative pressure in the building that leads to inward pressure on the walls and venting system.

Oversupply of Air



Oversupply of air to the building can drive the warm, moist indoor air into the wall cavities. It may also increase combustion air supply and venting action, thus reducing efficiency.

A balanced flow of incoming and outgoing air is required for comfort and safety. New, air-sealed buildings having vapour barriers that effectively protect occupants from external air flow can also drastically reduce fresh air and increase moisture and heat inside the building, sometimes to health-threatening levels. The thermal envelope must therefore allow for a controlled amount of air to be brought into and exhausted from the building.

Air Flow and Exhaust Considerations

Exhaust Fan Effects

Although an exhaust fan removes moisture or pollutants from the indoors, it can adversely affect air quality and create a health or safety hazard.

Draft Impacts

This can result from the effects of draft upon a naturally drafted furnace or from expelled gases or vapours re-entering the house through floor drains or below-grade cracks.

System Perspective

It is, therefore, important to view exhaust equipment or appliances in relation to other parts of the building as a system.

Uncontrolled air flow through the envelope can be a major source of heat loss, which may lead to other problems. Since warm air can carry large amounts of water vapour, air flow is also the main means by which moisture is carried into the envelope.

Moisture Flow Principles

Figure 1-9
A hundred times more moisture will travel by air flow than by diffusion

Moisture flows from a high-water-pressure area to a low-water-pressure area. Similar to and often combined with air flow, liquid or vapour moisture moves to equalize water pressure between two connected areas.

Gravity

Water flows downward through holes in the roof or cracks in the foundation

Capillary Action

Water moves through narrow passages or porous materials in any direction

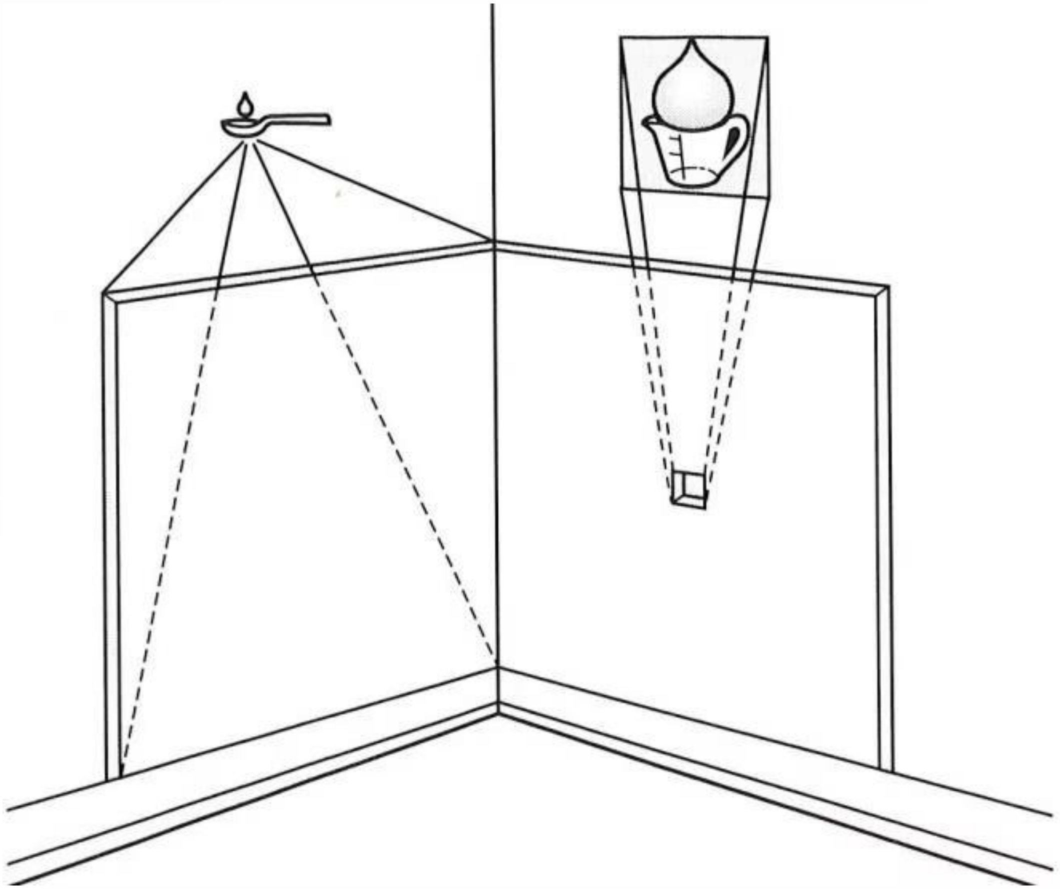
Air Movement

Water vapor is carried by air flow to areas it couldn't otherwise reach

Diffusion

Water vapor moves through materials based on vapor pressure differences

Moisture Control



To control moisture flow between the outdoor air and the indoor air, a moisture or vapour barrier must be installed in the building envelope. The mechanical equipment can then control moisture levels indoors.

Necessary Moisture

There must always be a certain amount of moisture inside a building for the health and comfort of the building's occupants.

Moisture Barriers

Without adequate moisture barriers built into the envelope, a great deal of moisture in vapour form can be carried from the outdoors by air flow during the summer or into the wall cavity from high indoor humidity during the winter.

Moisture Damage

Moisture crumbles concrete, rots wood, and makes paint and other coatings crack and peel. In vapour or liquid form, it attacks the building envelope from the outside through exposed cracks, holes, and spaces.

Moisture Terminology

Term	Definition
Water vapour	Consists of microscopic water molecules that are suspended in air.
Relative humidity (RH)	The amount of water vapour contained in the air expressed as a percentage of the maximum amount that could be contained in the air at the same temperature.
Absolute humidity	Refers to the actual amount of water vapour contained in a given amount of air, regardless of the temperature of the air. This is also called "humidity ratio".
Dew point	Refers to the point at which any body of air is saturated with water (100% RH).
Condensation	The process by which dew, or condensate, is formed. In this process, moisture changes state from a gas (water vapour) to a liquid (water).

Relative Humidity Considerations

Ideal Levels

The ideal relative humidity level in a home is 35%-50%. Below that level, wood furniture cracks from excessive drying. Above that level, mould growth and condensation on windows increases.

Heating Effects

If a sealed house is heated, the RH decreases since the higher the temperature, the more the air can contain moisture. The humidity ratio remains the same since the amount of water vapour in the given volume of air has not changed.

Cooling Effects

If the sealed house is cooled, the relative humidity will increase until it reaches saturation at 100% RH. This temperature is called the "dew point". Continued cooling below the dew point will result in some of the water vapour condensing into liquid water on a cooling surface.

Interstitial Condensation

As the temperature decreases below the dew point, the humidity ratio of the remaining water vapour/air mix will decrease, since some of the water vapour has been removed from the air as condensate. The relative humidity, however, remains at 100%.

Cold Surface Condensation

An example of this scenario occurs in winter, where house air may cool below its dew point as it passes over cold indoor surfaces, such as windows, around doors, or cold corners, causing condensate on these surfaces.

Interstitial Condensation

Indoor air leaking into the walls or attic may drop water within the structure as it is cooled below its dew point. This is called "interstitial condensation".

Structural Damage

This hidden moisture can lead to mold growth, wood rot, and deterioration of insulation and other building materials, often without visible signs until significant damage has occurred.

Stack Effect

The difference in temperature between indoor and outdoor creates a pressure difference due to the difference in air densities. This pressure difference causes the building to act as a large chimney. Air infiltrates through holes in the lower portion of the building envelope, rises, and exits or exfiltrates through the holes in the upper building envelope. This is called the "stack effect".

Warm Air Rises

Indoor heated air becomes less dense and rises through the building

Pressure Differences

Creates negative pressure in lower levels and positive pressure in upper levels

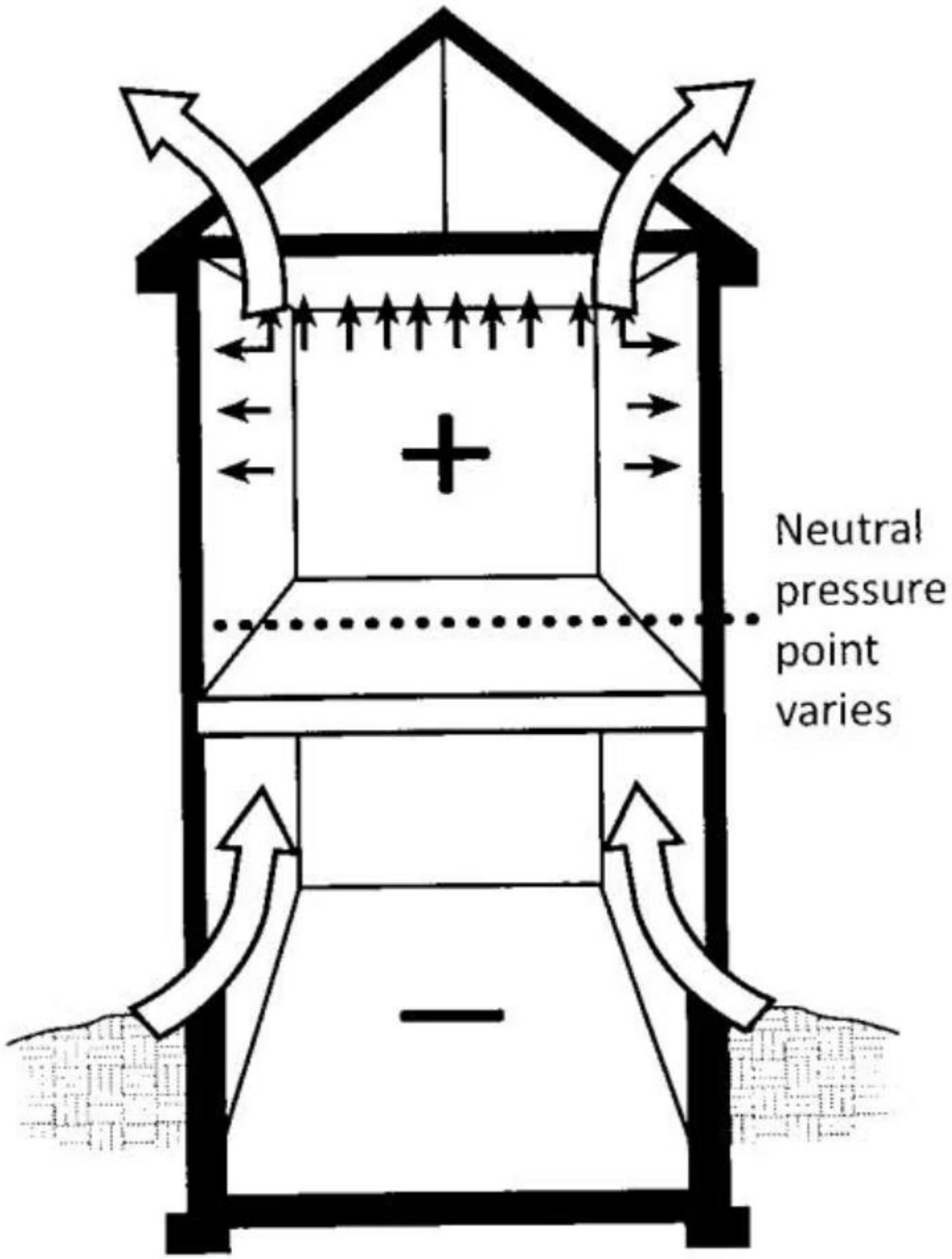
Cold Air Enters

Outside air is drawn in through openings in the lower building envelope

Warm Air Exits

Indoor air escapes through openings in the upper building envelope

Figure 1-10
The stack effect



Stack Effect Variables

The flow pattern created by the stack effect draws air away from our appliances, which are typically located in the lower levels. As shown in the previous figure, the stack effect creates a negative condition in the lower levels and a positive condition in the upper levels. The neutral pressure point (where the pressure is zero) varies depending on two factors:

Temperature Difference

The temperature difference between indoors and outdoors affects the strength of the stack effect. On cold days, the outside air is denser and heavier, so the stack effect is increased. The warm, light indoor air rises, creating a suction effect on the lower levels.

Building Tightness

The relative tightness of the upper to lower portions of the building influences where the neutral pressure point occurs. An open window on the top floor may allow more air to exfiltrate than can infiltrate through the lower levels. This creates a different flow pattern, and the neutral point is raised and the negative pressure in the basement is increased.

Pressure-Induced Backdrafting

Nature is always trying to equalize pressure, so if the basement is at a significantly lower pressure, air will flow in through any available opening—including the chimney or vent serving our appliance(s). This condition is called "pressure-induced backdrafting".

Reversal of Draft

The reversal of draft due to building depressurization can simply draw cold air down the chimney during off-cycle, making it difficult to establish draft when the appliance fires.

Negative Pressure

The negative pressure at the base of the chimney may actually overcome the buoyant force of the hot flue gases.

Dangerous Result

In either case, the result will be the spillage of flue gases to the indoors and the reduced delivery of combustion air to the appliance.

House Depressurization Limits

Appliance type	Unlined chimney on exterior wall	Metal insulated or interior chimney or sidewall vent
Oil or gas, natural draft with dilution air	5 (0.02)	5 (0.02)
Fireplace—wood or gas	5 (0.02)	5 (0.02)
Airtight wood stove or fireplace	10 (0.04)	10 (0.04)
Mechanical draft (induced or forced) for any fuel-fired appliance	10 (0.04)	15 (0.06)

Table 1-1 shows the maximum backdraft pressures that various types of appliances can withstand before spillage occurs. Since these limiting pressures refer to building pressures, they are called "house depressurization limits".

Preventing Backdrafting

To prevent this dangerous backdrafting, a balanced air flow throughout the building is essential. The stack effect will still occur, but the degree of negative in the building area can be reduced to acceptable levels for appliance operation.

Warning Signs

Any time spillage is indicated by fumes, odours, sickness, or excessive moisture in the house, pressure-induced backdrafting must be investigated and resolved.

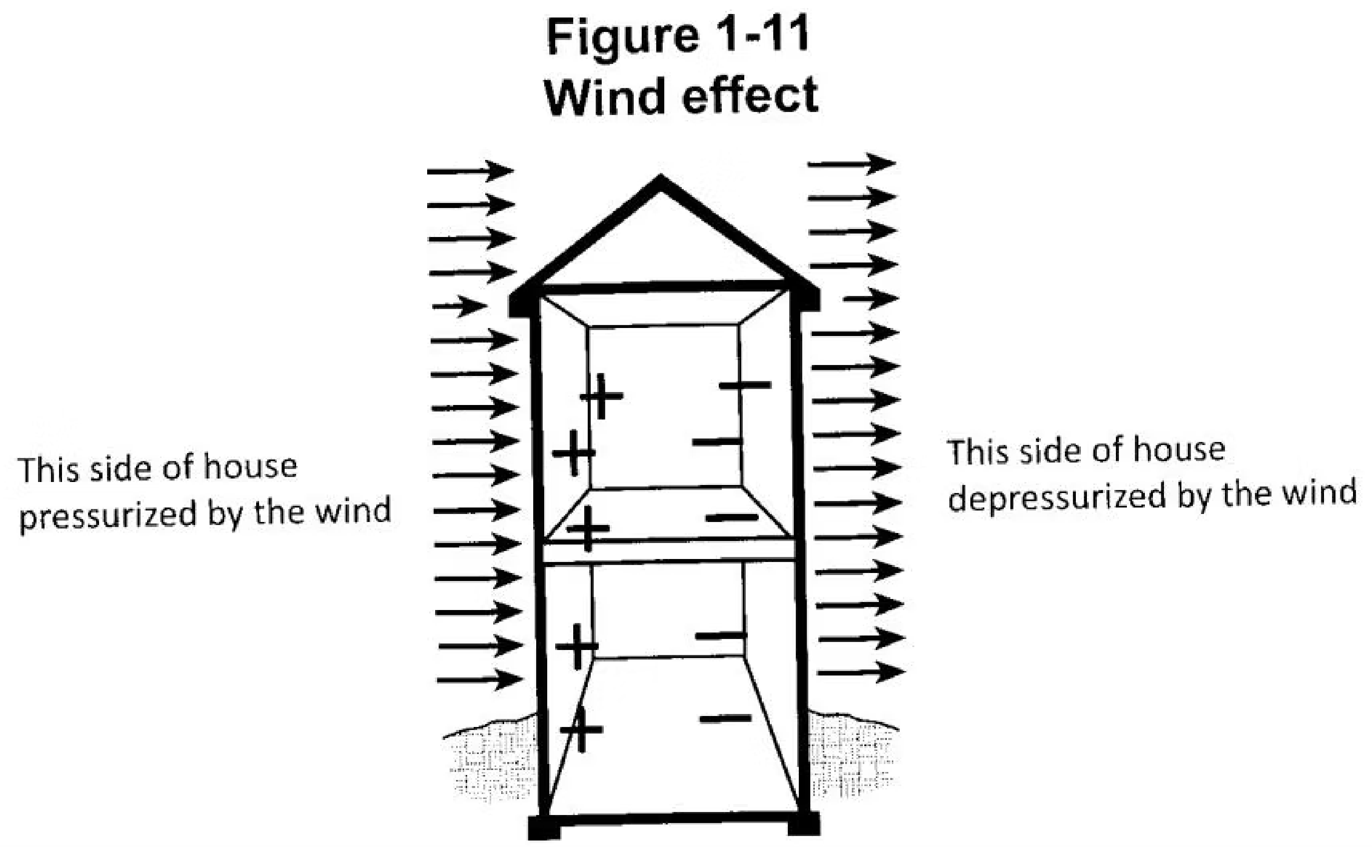
Comfort Impact

Beyond the immediate safety concerns of our appliance operation, the stack effect also tends to make lower levels in the building colder both in terms of temperature and air movement.

Humidity Effects

The relative humidity in the lower building areas is directly influenced by the outside humidity, while the warmer, moist air is drawn upward and exits the upper portions of the building.

Wind Effect



Wind can cause a positive pressure on the windward side of the building and a negative pressure on the leeward side and on the sides parallel to the wind flow. Depending on the relative airtightness of the pressurized side compared to the other three sides, the building pressure may increase, decrease, or vary between separated rooms.

Positive Pressure Side

If a natural draft vented appliance is in a room on the positive side of a building that is not tightly sealed from the rest of the building, the combustion air delivery may actually increase, causing a decrease in efficiency.

Negative Pressure Side

A more dangerous condition may occur if the appliance and combustion air intake are in a room on the leeward side. The suction effect of the wind may cause pressure-induced backdrafting.

Wind Effect on Appliances

The stronger the wind, the stronger the negative condition on the leeward side. The air movement caused by the wind also has significant effects on heating comfort and moisture levels in the building.

Identifying the Cause

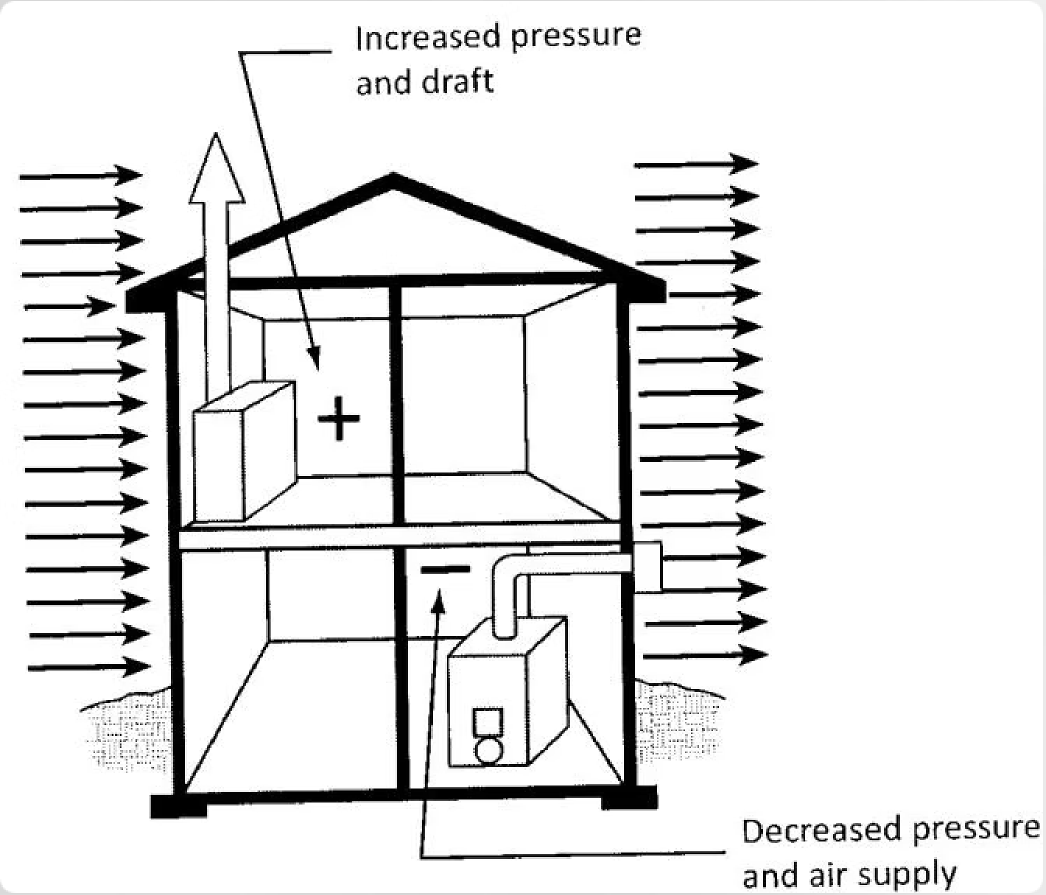
By identifying the wind as the cause of the discomfort, you can advise the owner that an increase in temperature will not solve the problem—only air sealing can do that.

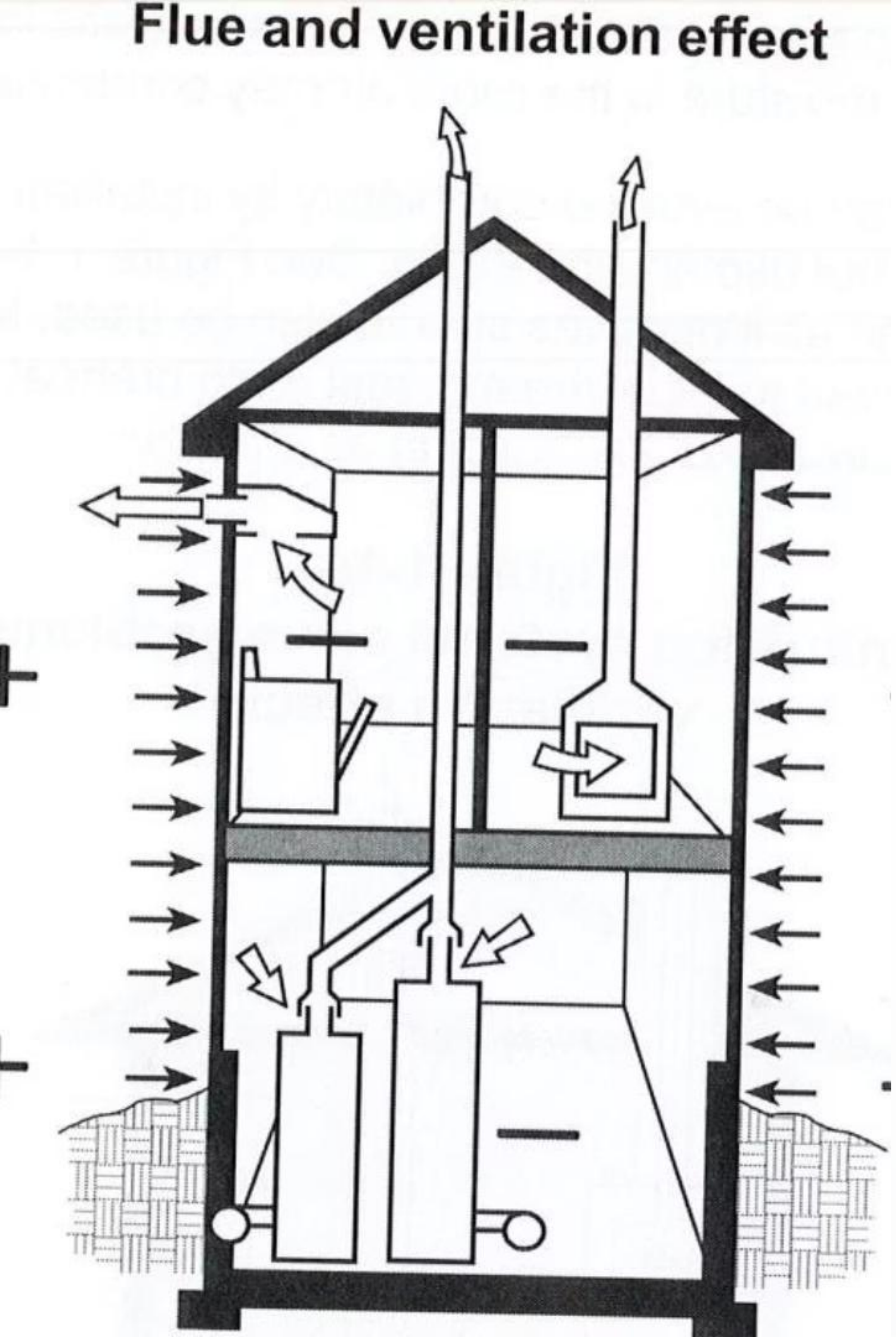
Reducing Wind Exposure

Reducing the building's exposure to the wind will reduce the draft. This can be accomplished through landscaping, windbreaks, or architectural features.

Balancing Pressures

Ensuring adequate air pathways between rooms can help equalize pressure differences caused by wind effects throughout the building.





Flue and Ventilation Effect

Heat, air, and moisture also flow due to the operation of any combustion appliances and any mechanical exhaust devices, such as bathroom fans, kitchen range hoods, clothes dryers, and central vacuum systems. All of these devices remove air from the building, creating a negative pressure.

Bathroom Fans

Remove moisture-laden air from bathrooms

Range Hoods

Extract cooking odors and moisture from kitchens

Clothes Dryers

Exhaust large volumes of warm, moist air

Central Vacuums

Remove air along with dust and debris

Building Pressure Balance

The building pressure may not be adversely affected if sufficient combustion and makeup air enters the building by natural infiltration or mechanical means. However, the depressurization may be localized if more air is removed from a specific room and there is inadequate communication between that room and the rest of the structure.

Appliance Room Concerns

Appliance rooms are the major concern, since depressurization can cause backdrafting and spillage of flue gases.

Combustion Air Supply

The combustion air supply openings required by CSA B149.1 are designed only to replace the air used in combustion, dilution of flue gases, and ventilation of gas appliances that use indoor air.

Balanced Pressures

These requirements are based on the building pressures already being balanced, so the air flow from the openings will replace the air used by the gas-fired appliance.

Air Flow Challenges

There is no guarantee that the air from these openings will get to the appliance. If there is a greater negative pressure elsewhere in the house, the air will flow to balance that area. The appliance will not only be bypassed but also may experience backdrafting by supplying air through its vent.

500

CFM

Some range hoods can remove over 500 ft^3/min of air

200+

CFM

Wood fireplaces without doors can consume large volumes of indoor air

50-100

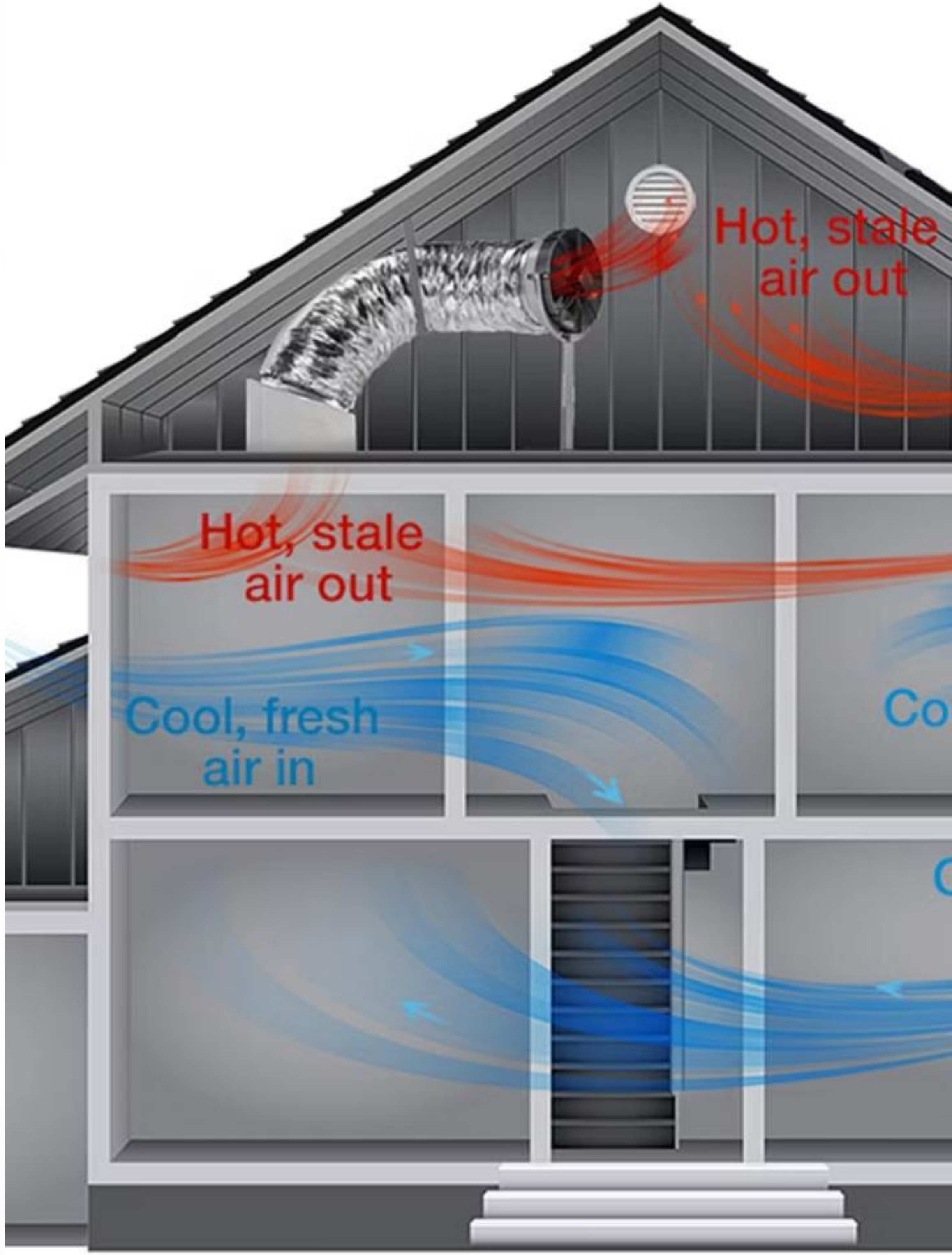
CFM

Typical bathroom exhaust fans remove moderate amounts of air

100-200

CFM

Clothes dryers can exhaust significant volumes of air



Fireplace Effects

When the fireplace is not operating, the open fireplace flue draws air from the building by thermal draft. During full operation, the apparent heat contributed by the radiant fire masks the massive heat loss from the building that is contributed by the fireplace.

Tight Houses

The flue and ventilation effect is most significant in tightly sealed houses. Even in "loose" houses that have sufficient cracks and openings in the building envelope to prevent pressure-induced backdrafting, the outside air with its lower temperature and its moisture applies pressure to the building envelope in response to the removal of indoor air.

Heat Loss

Heat loss increases as the cold air infiltrates to the inner walls and moisture in the room air may condense on the cold surfaces.

Sealed Combustion

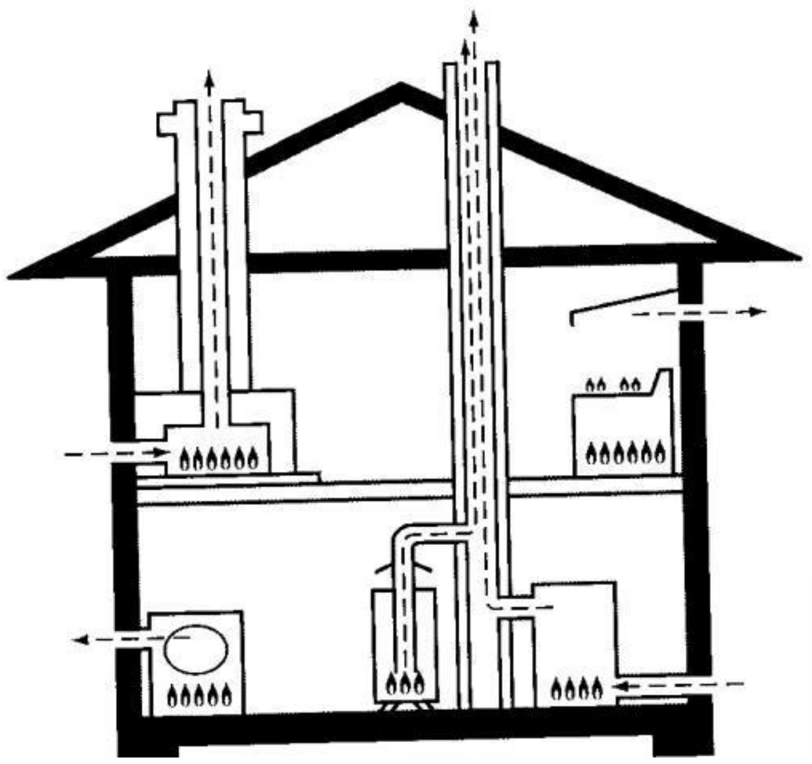
The flue and ventilation effect can be avoided completely by installing direct-vent, sealed combustion appliances that do not use any indoor air.

Balanced Ventilation Systems

Figure 1-14
Direct-vent, sealed combustion systems solve problems caused by flue and ventilation effect

A balanced ventilation system that supplies as much air as it removes should also be used. Ideally, a heat recovery ventilator should also be employed to allow the exhaust air to preheat the supply air.

Direct-Vent Appliances



Direct-vent, sealed combustion appliances draw combustion air directly from outside and vent combustion products directly outside, eliminating the risk of backdrafting.

Heat Recovery Ventilators

Heat recovery ventilators (HRVs) provide balanced ventilation by exhausting stale indoor air while bringing in fresh outdoor air. The heat exchanger core transfers heat from the outgoing air to the incoming air, improving energy efficiency.

- Reduces heating costs
- Maintains indoor air quality
- Prevents pressure imbalances

Distribution Effect

Any building with a central ventilation and/or forced air heating system has air flow problems due to the supply and return air ducts. These distribution systems are intended to control air flow, but often create the problems they are intended to solve. The flow of heat, air, and moisture is both positively and negatively impacted by the distribution effect.

Supply Air

Delivers conditioned air to rooms

Room Pressures

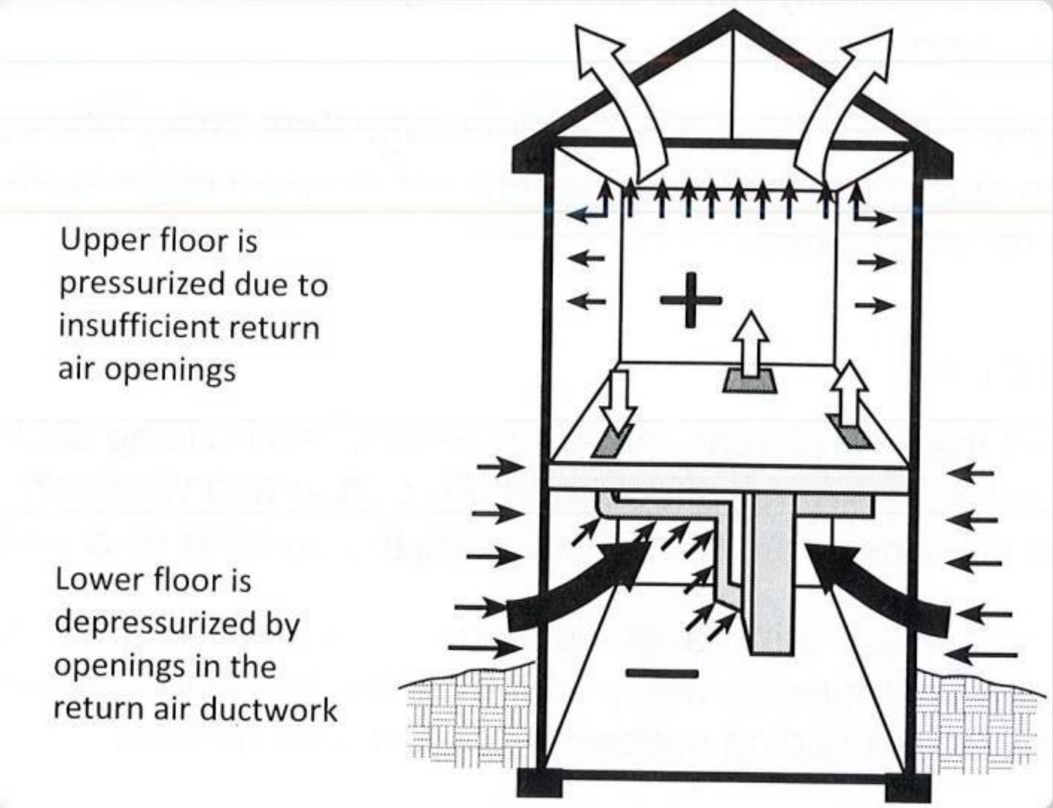
Creates pressure differences between spaces

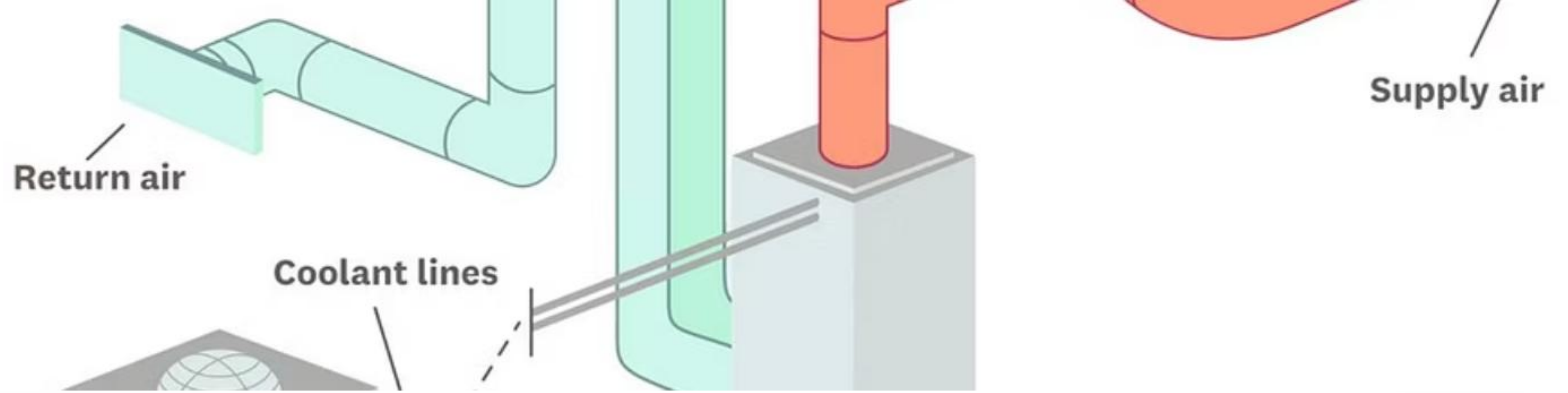
Return Air

Draws air back to the air handler

System Balance

Determines overall pressure relationships





Distribution System Design Problems

Problems created by the distribution effect can be grouped into ones of design or workmanship. The most common problems relate to improper design. The size and location of supply and return ducts and registers may cause numerous problems including:

Confined Space Returns

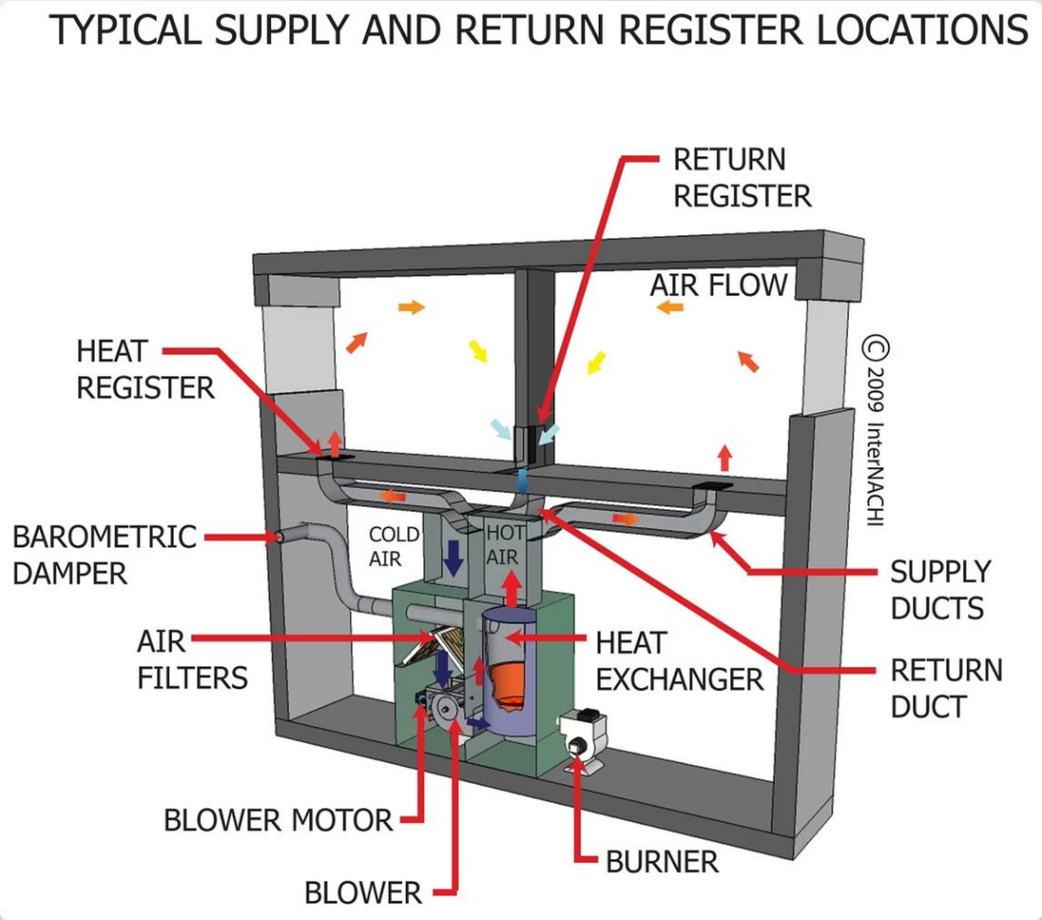
Return air registers in confined spaces where combustion air and/or dilution air is also consumed by a fuel-fired appliance

Unbalanced Air Removal

Removal of more air from one floor or room than can be supplied to that area, resulting in depressurization and increased infiltration

Excessive Pressurization

Increasing the pressure in a room or floor that is already pressurized due to other forces, such as the stack effect, resulting in increased exfiltration



More Distribution System Issues

Short-Circuiting

Short-circuiting of the ventilation or heating effect by having the supply and return registers too close

Natural Air Flow Conflicts

Failing to counteract the natural air flow in the room, which causes outside walls, windows, and floors to remain cool in winter rather than "washing" them with warm air to decrease radiant heat losses

System Conversion Issues

This last problem may occur when changing a gravity air system to a forced air system. Older gravity systems commonly had the warm air supply registers on the inside walls and the return registers on the outside walls.

Workmanship Problems

The second set of problems created by some distribution systems is closely related and deals with workmanship. Even if the system is properly designed, poor workmanship can cause depressurization of the lower levels in the building.

Return Air Leakage

Return air ducts are depressurized; air is being sucked through them to the air-circulating blower. Any leaks at the joints cause air to be drawn in, usually from the basement, thus depressurizing this area.

Joist Space Returns

The use of joist spaces as return ducts further aggravates this problem since joist spaces are notoriously leaky.

Component Leakage

Loose-fitting filter frames and leaky blower doors compound the basement depressurization.

Distribution System Solutions

The solution is good workmanship. Sealed return ducts and tight-fitting filters and doors will minimize the negative effects of the distribution effect. An opening in the warm air supply duct in the furnace area is also recommended.

Seal All Duct Joints

Use appropriate duct sealing materials to ensure all connections are airtight, especially on the return side of the system.

Ensure Proper Filter Fit

Install filters in properly designed frames that prevent air bypass around the edges of the filter.

Secure Access Panels

Make sure all furnace and air handler access doors are properly secured and sealed to prevent air leakage.

Balance the System

Properly balance supply and return airflow to each room to prevent pressure imbalances throughout the building.

Combined Effect

The four forces that affect the flow of heat, air, and moisture in a building seldom act alone. The stack effect, wind effect, flue and ventilation effect, and distribution effect—must be considered when assessing the building as a system.

Stack Effect

Temperature differences create vertical air movement

Wind Effect

Wind creates pressure differences on building surfaces

Distribution Effect

HVAC systems create air movement patterns

Flue Effect

Combustion and exhaust devices remove air

The flow of air, heat, and moisture will change continuously with the outdoor environment and the operation of the mechanical equipment. Although there are many variables, the key is to step well back from the appliance and look at the entire building system with a focus on air flow.

Preventing Backdrafting and Spillage

The greatest danger to the occupants is backdrafting of the chimney or vent. Spillage to the indoors must be prevented by observing the entire building for possible depressurization effects, and if in doubt, testing for flue gas spillage.

ACT Testing

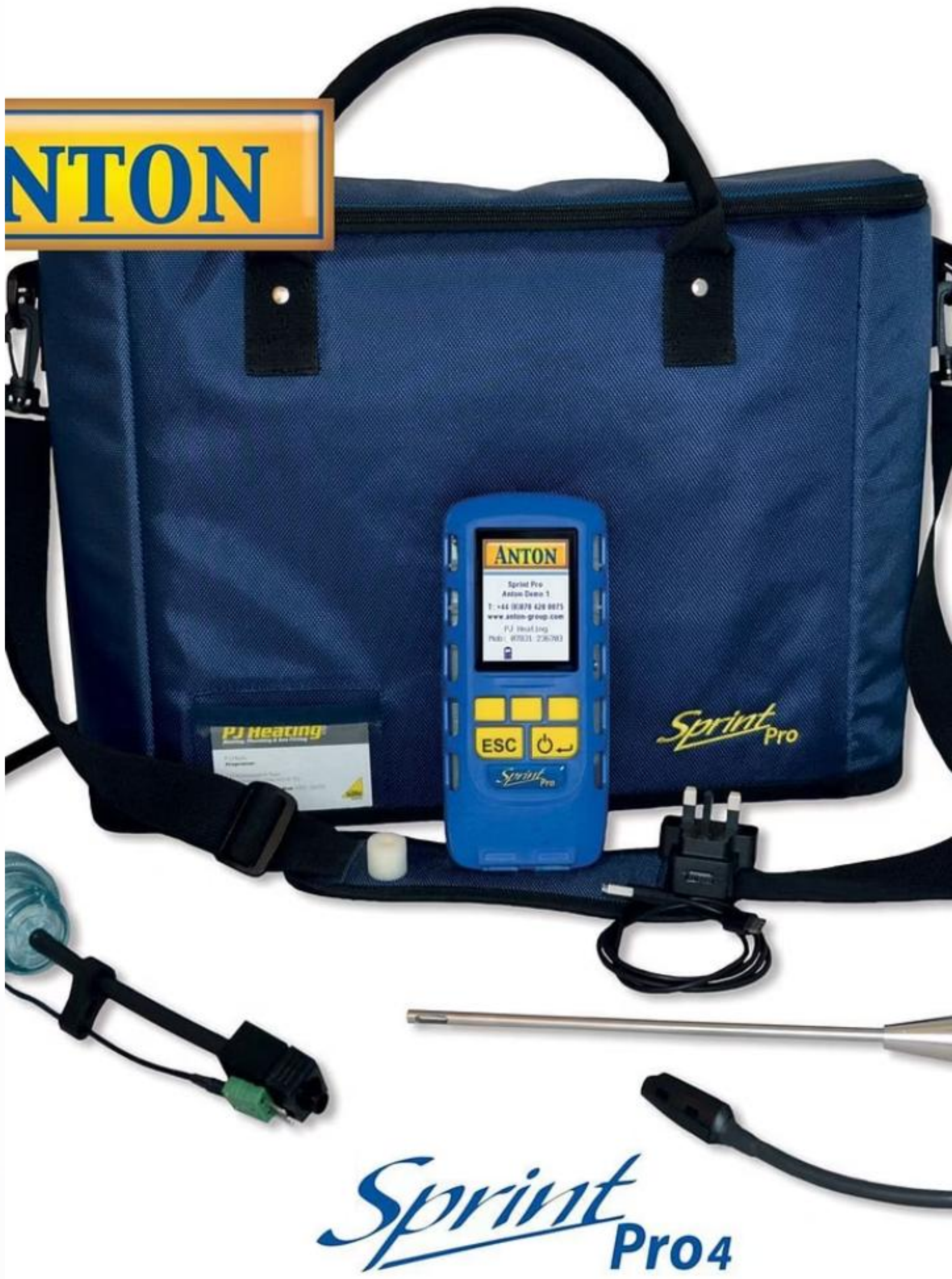
The ACT (Appliance Combustion Testing) procedure, developed by Canada Mortgage and Housing Corporation (CMHC), is discussed in the Assessment tools for the building as a system chapter.

Whole-Building Approach

A comprehensive assessment looks at all factors that could affect appliance operation, not just the appliance itself.

Safety First

When in doubt about potential backdrafting conditions, always conduct appropriate testing to ensure occupant safety.



Red Seal Alignment

CSA Gas Trade Unit	Red Seal Block	Red Seal Task
14	A - Common Occupational Skills	Task 1 Performs safety-related functions. Task 2 Maintains and uses tools and equipment. Task 3 Plans and prepares for installation, service and maintenance.
The Building as a System	B - Gas Piping Preparation and Assembly	Task 4 Fits tube and tubing for gas piping systems. Task 5 Fits plastic pipe for gas piping systems. Task 6 Fits steel pipe for gas piping systems.

This chapter on the Building as a System aligns with multiple Red Seal blocks and tasks, emphasizing the importance of understanding building science principles for gas technicians/fitters.

Heat Flow Through Building Materials

Understanding how heat flows through different building materials is essential for gas technicians/fitters to properly assess and address comfort and efficiency issues in buildings.

Thermal Resistance (R-Value)

Different materials have varying abilities to resist heat flow. Insulation materials have high R-values, while metals have very low R-values and readily conduct heat.

Thermal Bridging

When materials with low thermal resistance (like metal studs) create a path for heat to bypass insulation, it's called thermal bridging. This can significantly reduce the overall effectiveness of insulation systems.

Continuous Insulation

Modern building practices often include continuous insulation layers to minimize thermal bridging and improve overall building envelope performance.

Air Barriers vs. Vapor Barriers

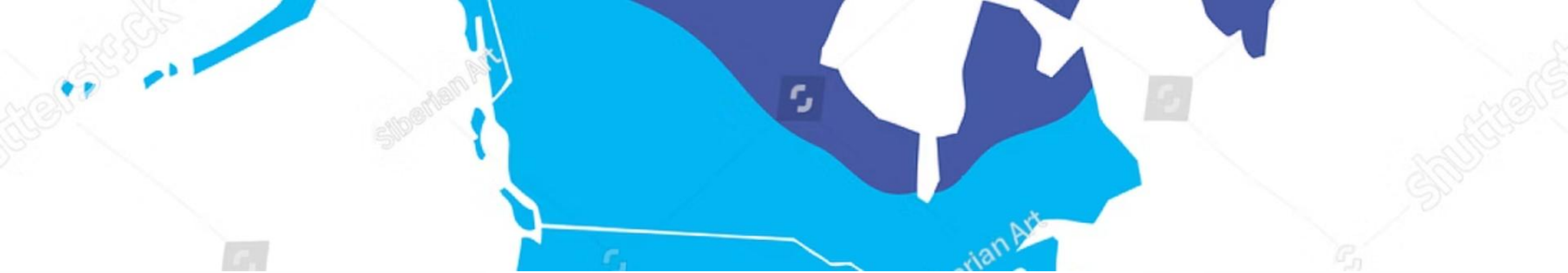
Air Barriers

- Control air movement
- Must be continuous around entire building envelope
- Can be permeable or impermeable to water vapor
- Examples: house wrap, taped sheathing, certain membranes

Vapor Barriers

- Control water vapor diffusion
- Placement depends on climate zone
- Must have appropriate permeability for the application
- Examples: polyethylene sheet, vapor retarder paint

Understanding the difference between air barriers and vapor barriers is crucial for gas technicians/fitters. While they serve different purposes, both are essential for controlling the movement of heat, air, and moisture through the building envelope.



Climate Zone Considerations

Building envelope design and mechanical system requirements vary significantly based on climate zone. Gas technicians/fitters must understand these regional differences to properly assess building performance.

Cold Climates

In cold climates, vapor barriers are typically installed on the warm side of the insulation (interior) to prevent indoor moisture from condensing within wall assemblies. Heating systems are the primary concern.

Hot-Humid Climates

In hot-humid climates, vapor barriers may be installed on the exterior side or omitted entirely. Cooling and dehumidification systems are the primary concern.

Mixed Climates

Mixed climates present unique challenges as buildings must perform well in both heating and cooling seasons. Vapor barrier selection and placement requires careful consideration.

Modern Building Envelope Technologies

Smart Vapor Retarders

Materials that change permeability based on ambient humidity conditions

Spray Foam Insulation

Provides both insulation and air sealing in one application

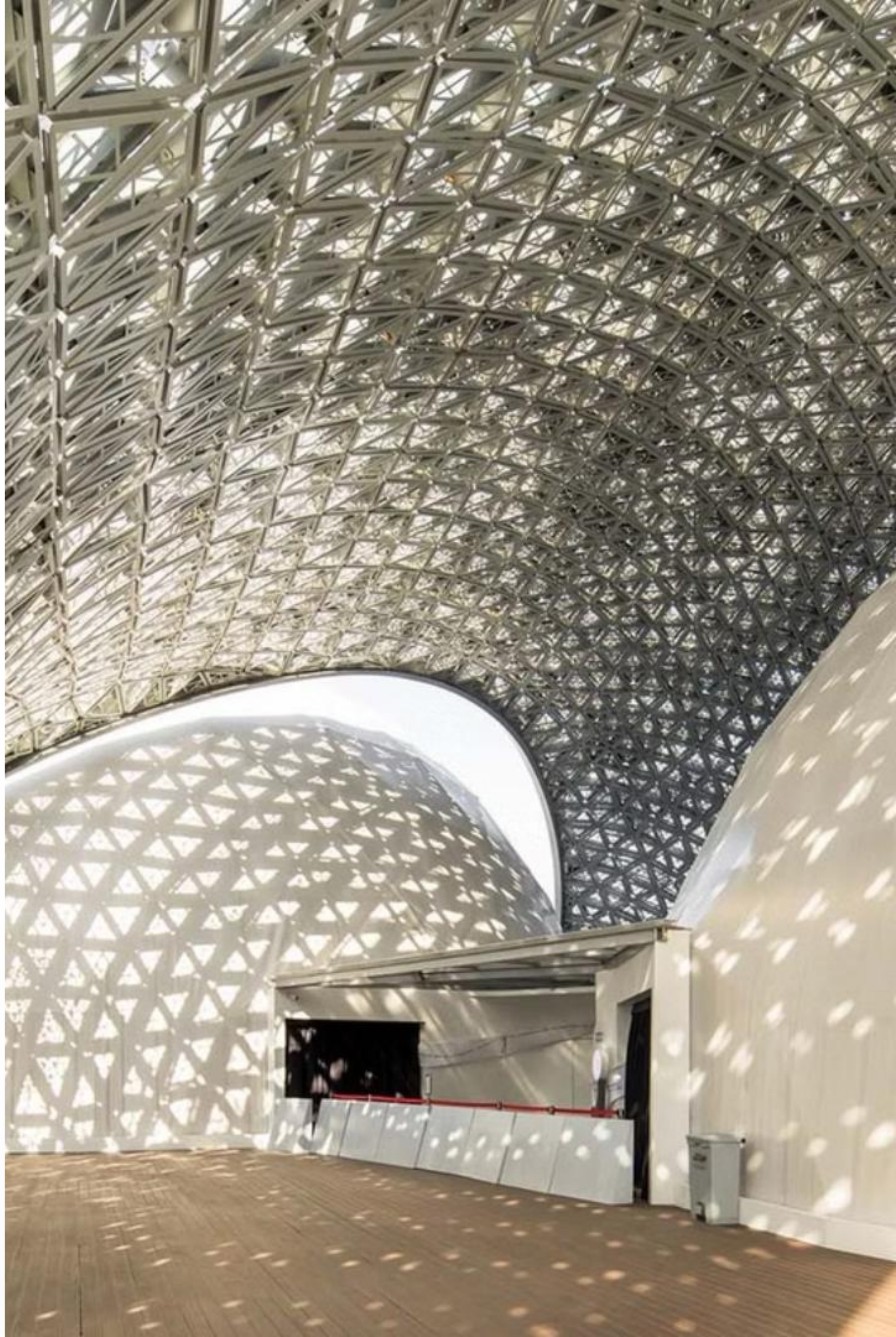
High-Performance Windows

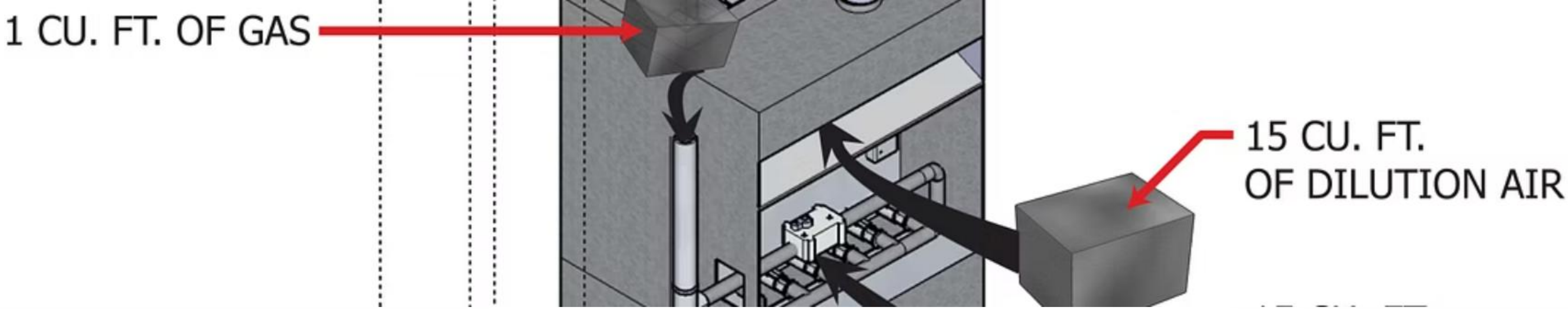
Multi-pane windows with low-e coatings and insulated frames

Thermal Break Materials

Specialized materials that prevent thermal bridging in building assemblies

Gas technicians/fitters should be familiar with modern building envelope technologies as they significantly impact how mechanical systems interact with the building as a system.





Combustion Air Requirements

As buildings become more airtight, providing adequate combustion air for fuel-burning appliances becomes increasingly important. Gas technicians/fitters must understand how building tightness affects combustion air requirements.

Calculate Requirements

Determine combustion air needs based on appliance input ratings and building volume

Assess Building Tightness

Evaluate the building's air leakage characteristics to determine if natural infiltration is sufficient

Install Appropriate Openings

Size and locate combustion air openings according to code requirements

Verify Proper Operation

Test appliance operation to ensure adequate combustion air is available

Ventilation Strategies

Natural Ventilation

Relies on operable windows, doors, and building leakage to provide fresh air. Increasingly insufficient in modern airtight buildings.

Exhaust-Only Ventilation

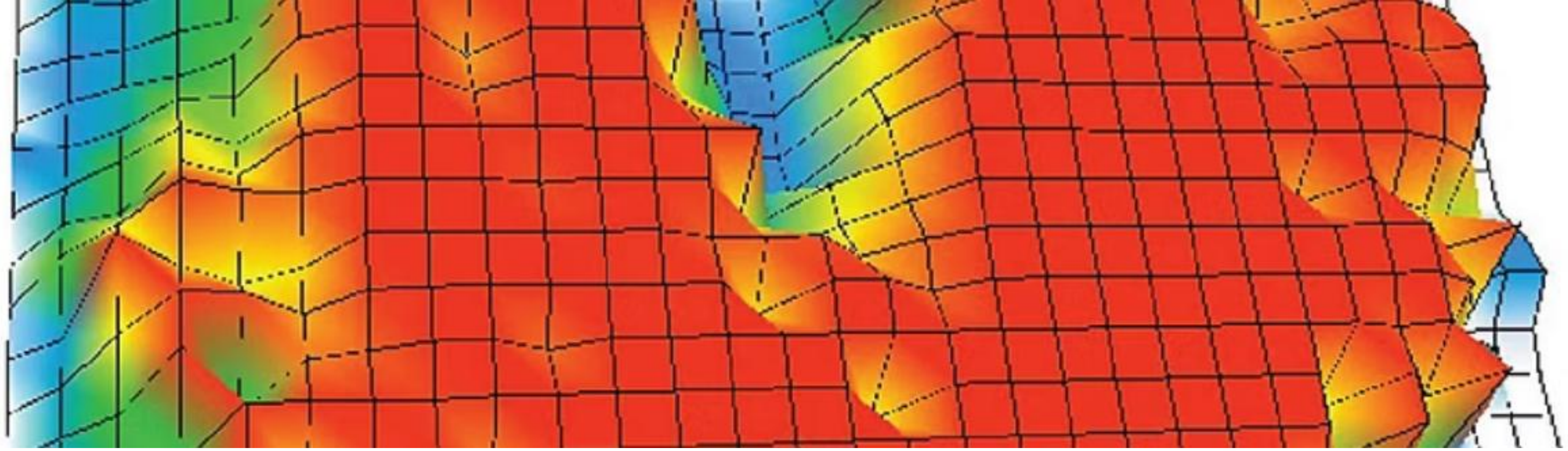
Uses exhaust fans to remove stale air, creating negative pressure that draws fresh air in through leakage points. Simple but can cause depressurization issues.

Supply-Only Ventilation

Uses supply fans to introduce fresh air, creating positive pressure that pushes stale air out through leakage points. Can help prevent backdrafting but may cause moisture issues in cold climates.

Balanced Ventilation

Uses both supply and exhaust fans in equal measure to maintain neutral pressure. Often includes heat recovery to improve energy efficiency.



Pressure Mapping

Pressure mapping is a diagnostic technique used to understand air flow patterns and pressure relationships within a building. Gas technicians/fitters can use this approach to identify potential issues with combustion appliance operation.

Establish Baseline

Measure pressure differences between rooms and to outside with all systems off

Test Individual Systems

Activate each mechanical system separately and measure its impact on building pressures

Test Combined Operation

Operate multiple systems simultaneously to identify worst-case scenarios

Document Findings

Create a pressure map showing how air flows through the building under different conditions

Combustion Safety Testing

Gas technicians/fitters must be able to perform comprehensive combustion safety testing to ensure appliances operate safely within the building system.

1. ### Worst-Case Depressurization Test

Configure the building to create maximum negative pressure in the appliance room

Spillage Test

Check for proper draft establishment and absence of flue gas spillage

Draft Measurement

Measure draft pressure in the vent connector to ensure adequate venting

Combustion Analysis

Analyze flue gases to verify proper combustion and carbon monoxide levels

Indoor Air Quality Considerations

Gas technicians/fitters must understand how combustion appliances can affect indoor air quality and how building systems interact to maintain healthy indoor environments.

Combustion Byproducts

Carbon monoxide, nitrogen oxides, and other combustion byproducts must be properly vented to maintain good indoor air quality.

Moisture Management

Combustion produces water vapor. In high-efficiency appliances with cooler flue gases, proper condensate management is essential.

Ventilation Requirements

Adequate ventilation is necessary to dilute and remove indoor pollutants, including those from combustion appliances and building materials.

Filtration Systems

Air filtration can help remove particulates but does not address gaseous pollutants from combustion or other sources.

Energy Efficiency and Building Performance

Modern buildings must balance energy efficiency with proper system operation and indoor air quality. Gas technicians/fitters play a key role in achieving this balance.

Building Envelope

Improved insulation and air sealing reduce energy consumption

Mechanical Systems

High-efficiency equipment reduces energy use while maintaining comfort

Ventilation

Controlled ventilation maintains air quality with minimal energy loss

Monitoring

Regular assessment ensures continued performance and safety

Building Codes and Standards

Gas technicians/fitters must be familiar with relevant building codes and standards that govern the installation and operation of combustion appliances within the building system.

Code/Standard	Scope
CSA B149.1	Natural gas and propane installation code
National Building Code	Building construction requirements including ventilation
ASHRAE 62.2	Ventilation and acceptable indoor air quality in residential buildings
Local Codes	Municipal or provincial requirements that may exceed national standards

These codes and standards are regularly updated to reflect advances in building science and safety requirements. Gas technicians/fitters must stay current with these changes.

Diagnostic Tools for Building Assessment

Blower Door

Measures building air leakage and helps identify leakage points

Infrared Camera

Visualizes temperature differences to locate insulation gaps and air leaks

Manometer

Measures pressure differences between spaces and across the building envelope

Smoke Pencil

Visualizes air movement to identify draft patterns and leakage points

Gas technicians/fitters should be familiar with these diagnostic tools to better understand how the building system affects combustion appliance operation.

Retrofitting Considerations

When retrofitting existing buildings with new combustion appliances or improving building envelope performance, gas technicians/fitters must consider the impact on the entire building system.

Existing Conditions

Thoroughly assess the current building envelope, mechanical systems, and ventilation before making changes

System Interactions

Consider how improvements to one system will affect others (e.g., air sealing may require additional ventilation)

Phased Approach

Plan retrofits in a logical sequence to avoid creating interim safety or performance issues

Post-Retrofit Testing

Verify that all systems operate properly after changes are complete

Future Trends in Building Systems

Gas technicians/fitters should be aware of emerging trends in building systems that will affect their work in the coming years.

Net Zero Buildings

Buildings that produce as much energy as they consume

Smart Building Controls

Integrated systems that optimize comfort, energy use, and air quality

Electrification

Transition from combustion to electric heating and appliances

Remote Monitoring

Connected systems that enable predictive maintenance and diagnostics

Professional Development

To effectively work with modern building systems, gas technicians/fitters must commit to ongoing professional development.

Building Science Training

Develop a deeper understanding of heat, air, and moisture movement in buildings and how they affect combustion appliance operation.

Advanced Diagnostics

Learn to use modern diagnostic tools and techniques to assess building performance and troubleshoot complex system interactions.

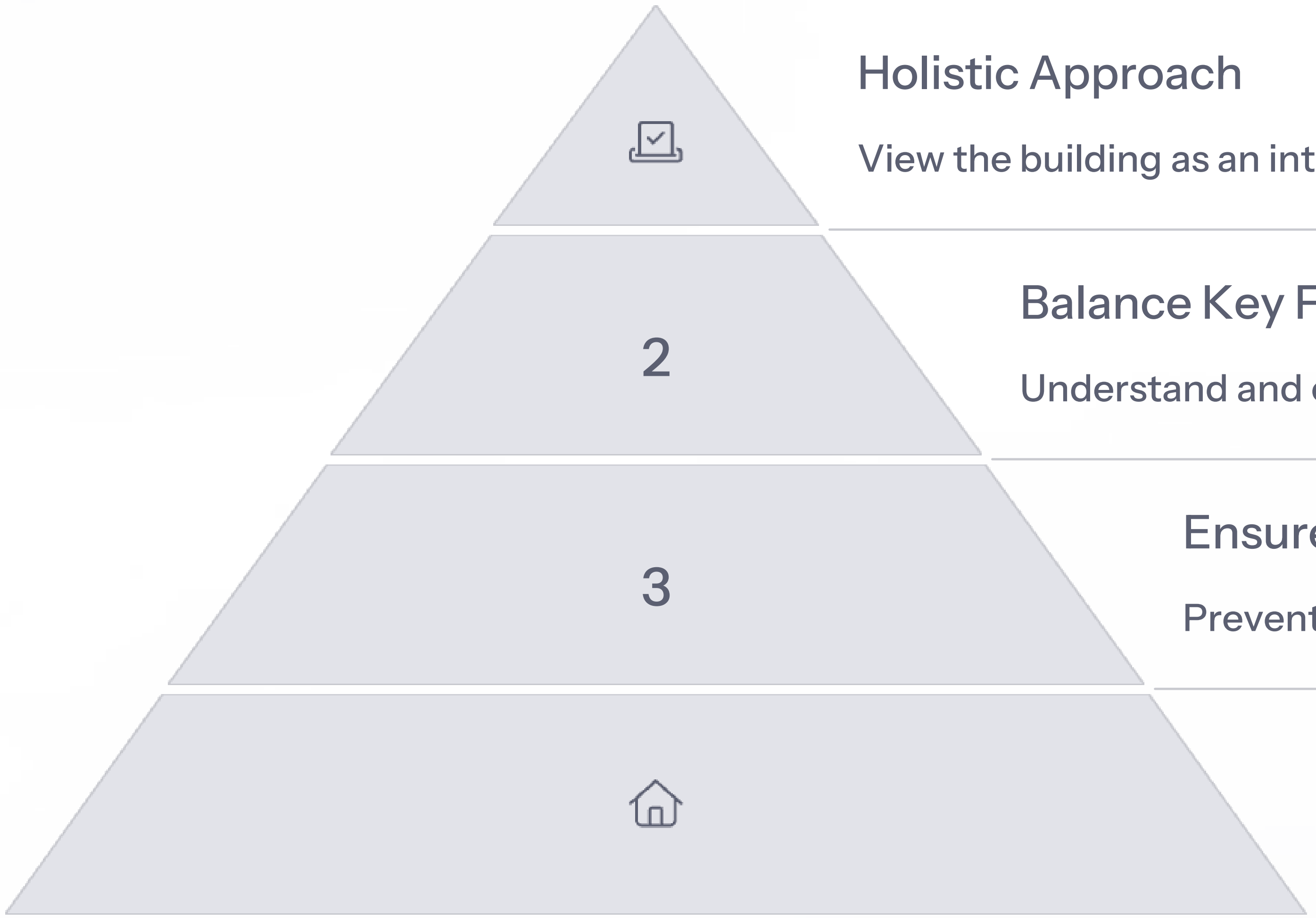
Code Updates

Stay current with changes to relevant codes and standards that govern combustion appliance installation and operation.

New Technologies

Familiarize yourself with emerging technologies in both building envelope systems and combustion equipment.

Summary: The Building as a System



Holistic Approach

View the building as an integrated system of interdependent components

Balance Key Flows

Understand and control the flow of heat, air, and moisture

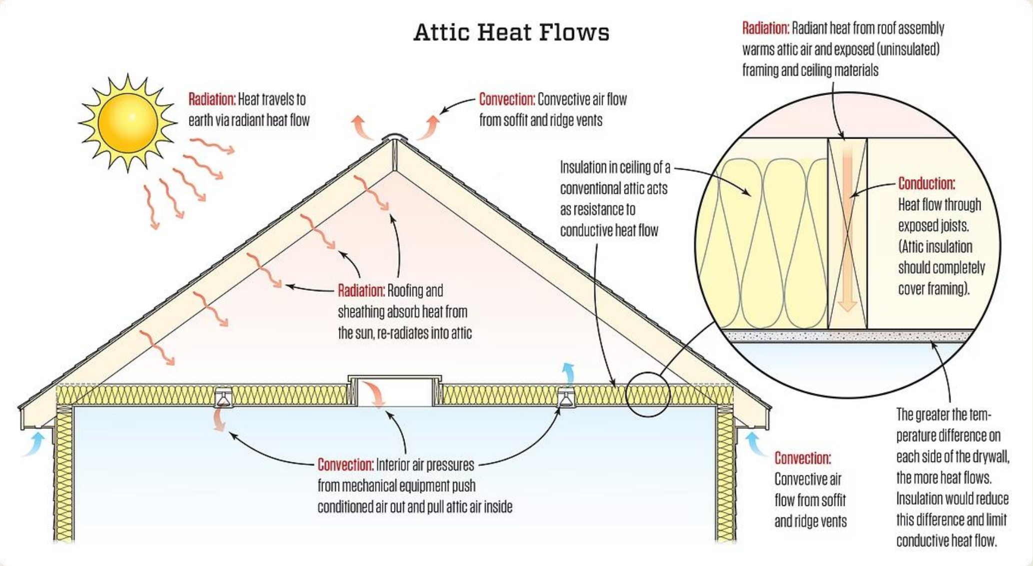
Ensure Safety

Prevent backdrafting and maintain proper combustion and ventilation

Optimize Performance

Balance efficiency, comfort, durability, and indoor air quality

Gas technicians/fitters must thoroughly understand the building as a system concept to properly install, service, and troubleshoot combustion appliances. By considering how all building components interact, technicians can ensure safe, efficient, and comfortable operation while maintaining good indoor air quality and building durability.



CSA Unit 14 - Building as a System
Chapter 2
Understanding Air, Heat, and Moisture Flow

The focus is on what effect each of the four subsystems of the building (outside environment, building envelope, mechanical/electrical systems, and the occupants) have on the flow of air, heat, and moisture. With this information, a gas technician/fitter can anticipate problems than may arise and prevent or resolve any negative effects on customer comfort or safety rolation to gas appliances.

Learning Objectives

Outside Environment

Describe the role of the outside environment on the building as a system and on gas appliances

Building Envelope

Describe the role of the building envelope on the building as a system and on gas appliances

Mechanical/Electrical Equipment

Describe the role of the mechanical/electrical equipment on the building as a system and on gas appliances

Occupants

Describe the role of the occupants on the building as a system and on gas appliances

Key Terminology

Term	Abbreviation (symbol)	Definition
Energy rating	ER	Energy value for new windows, measured in watts per m^2 and given a value from -50 to +15, with 0 being a neutral point of heat gains balancing losses.
Heat recovery ventilator	HRV	Common installation method used for preheating supply air with the exhaust air.
Indoor air quality	IAQ	The air quality within and around buildings and structures.
Thermal resistance value	RSI (metric) R (imperial)	Value scale for insulation, measured in RSI units (resistance system international) for the metric system and in R units for the imperial system.

Figure 2-1
es/landscape may affect air

Outside Environment: Air Flow Considerations

Wind Exposure

Exposure to predominate wind direction affects air flow patterns around and into the building

Terrain Features

Is the house in a gully or on a hill? These terrain features can significantly impact air movement

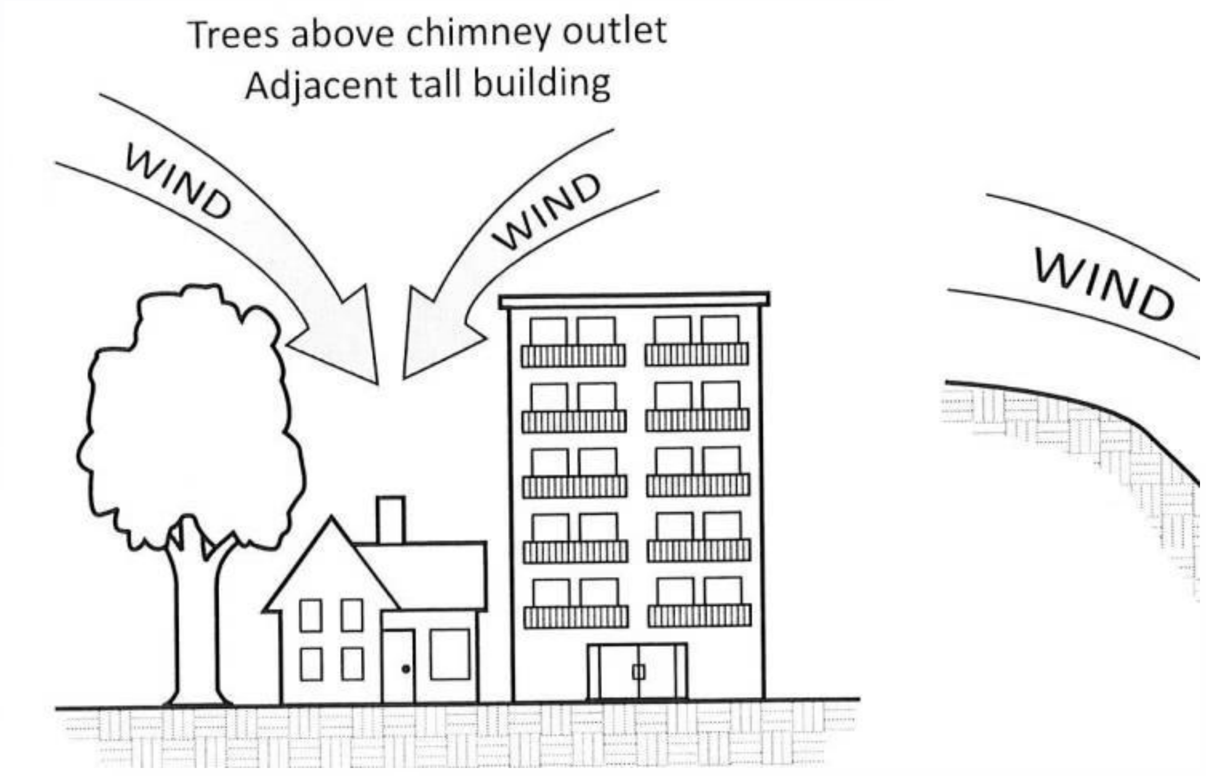
Natural Sheltering

Is it sheltered by other structures, trees, etc.? Natural barriers can affect air flow patterns

Downdraft Potential

Could downdrafts occur due to the landscape? This can affect venting systems

Outside Environment: Air Quality Factors



Proximity to Pollution Sources

Is the house close to a major road, industry, etc.? These external sources can introduce contaminants into the building through infiltration points.

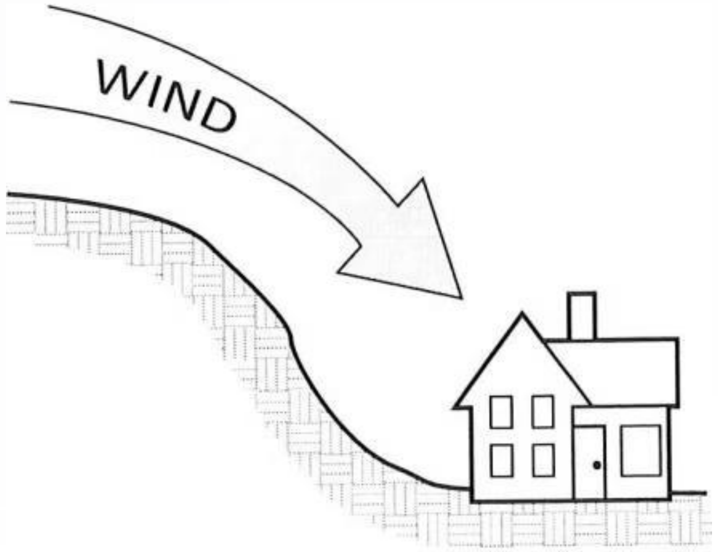
The quality of outdoor air directly impacts indoor air quality, especially in buildings with high air exchange rates or mechanical ventilation systems drawing in outside air.

Attached Garage Considerations

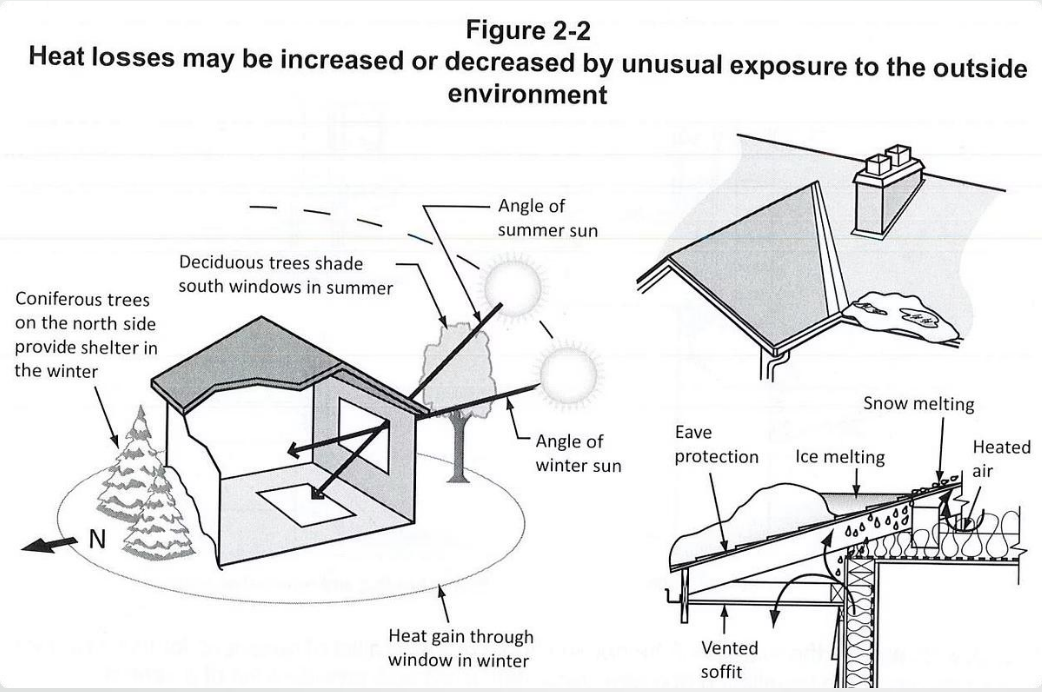
Is there an attached garage that would provide easy access for vehicle fumes to enter the house?

Garages can be a significant source of carbon monoxide and other vehicle-related pollutants that can enter the living space, especially when there is negative pressure in the house relative to the garage.

Outside Environment: Heat Flow Considerations



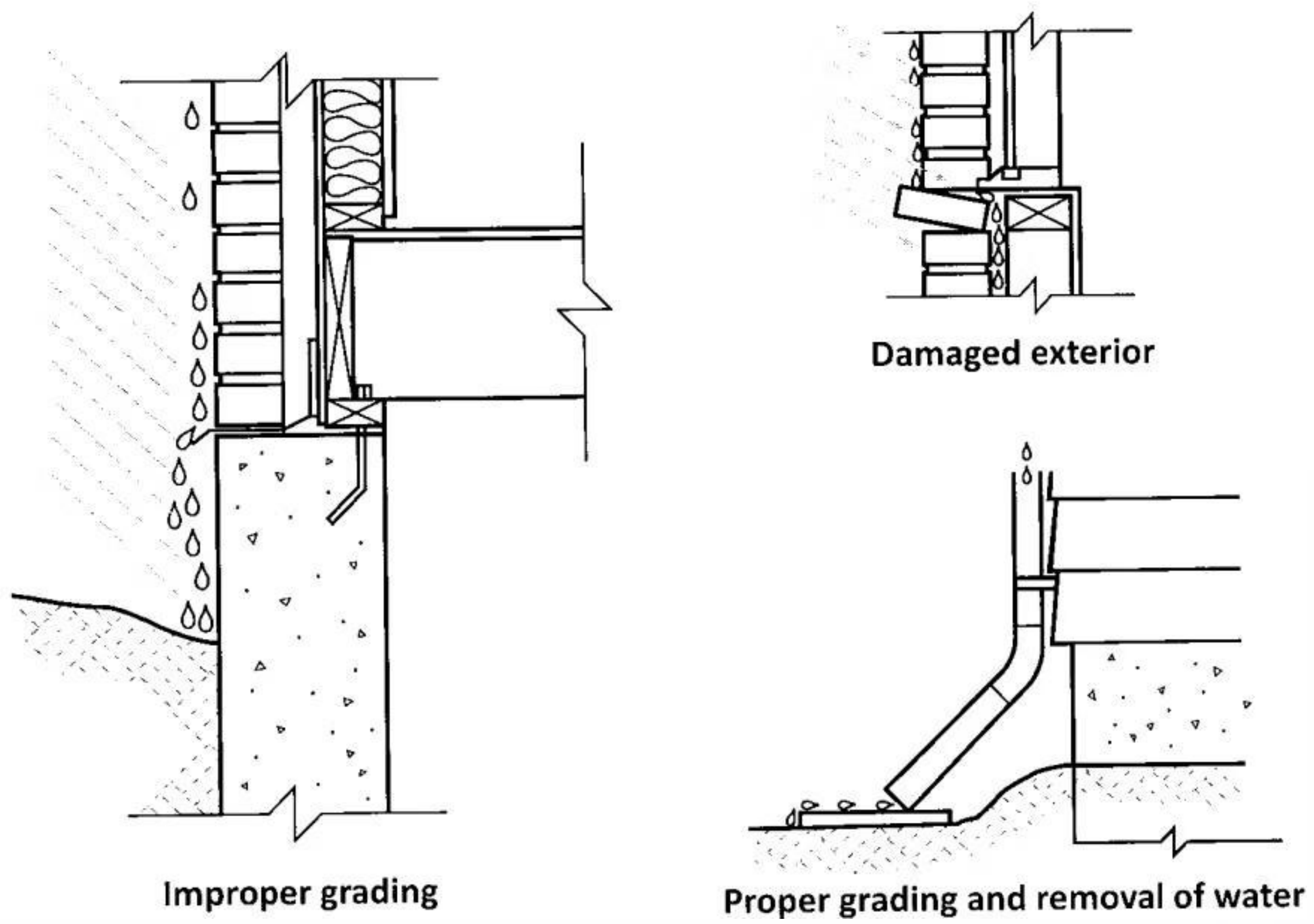
Heat Loss Issue	Variable
Conductive Heat Loss Issues	· How many sides of the house are exposed to the outdoors? · How large are the exposed sides? · Is there a basement below grade or is the crawl space exposed? · During winter, is there even snow coverage on the roof or are there ice dams indicating conductive heat loss through the attic?
Convective Heat Loss Issues	· How many windows/doors are on the sides of the house facing the predominant wind direction? · Will the surrounding structures, landscape, vegetation, etc., help or hinder heat loss by air currents?
Radiant Heat Loss Issues	· What is the colour of the house and roof? Dark will increase radiant heat gain while light will reflect it. · Is there an unusual exposure to the sun during winter? · Is there any unusual window exposure on the south and west sides?



Outside Environment: Moisture Flow Considerations

Moisture Flow on	Variable
Grading of the land for water runoff	Will precipitation be removed from around the house?
Building characteristics	· Are there window wells below grade? · Is the eavestrough flow directed away from the house? · What is the condition of the building's skin, especially on the side of the prevailing winds? · Are there signs of moisture damage-rot, mould, etc.?

Outside Environment: Importance for Gas Technicians



Installation Planning

A quick walk around the exterior of the house should produce a list of questions for the customer before installation of a new appliance. For example, if your purpose is to install a new furnace and you have noted that the landscape may create downdrafts, problems may be prevented by installing a sidewall-vented appliance with the termination on a wind-sheltered side.

Troubleshooting

It will also provide a list of potential issues that will help you to resolve a customer complaint during a service call. For example, if the customer raises concerns about carbon monoxide in the house after you have noted the proximity to a major roadway or an attached garage, then investigating the influence of outside CO sources may shorten your service call.

Starting Point

The effect of the outside environment on the building as a system cannot be underestimated. As with all preventative and problem-solving techniques, starting at the beginning saves time and money. The outside environment is the starting point for all comfort issues inside the house.

Building Envelope: Overview

Building Type

Issues related to the building envelope can be separated into type of envelope (building type) and materials used in the envelope. Since the envelope separates the inside and outside environment, a close study of the issues will help you prevent and solve many comfort concerns and appliance problems.

Buildings can be categorized by construction method or by historical construction and insulation features.

Construction Methods

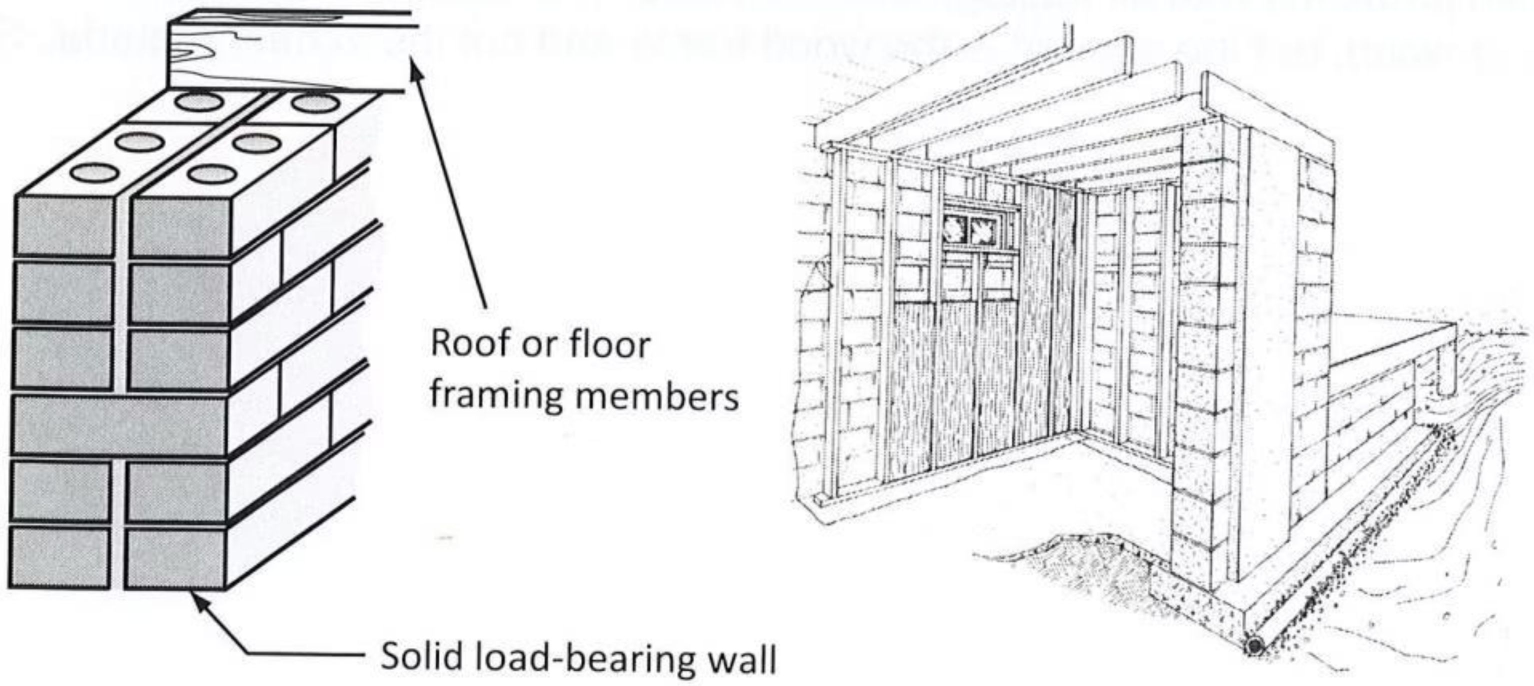
There are three main types of building construction:

- Solid construction
- Balloon frame
- Platform frame

Each construction type has different implications for air, heat, and moisture flow that can affect gas appliance operation.

Building Envelope: Solid Construction

Figure 2-4
Solid brick construction



Characteristics

Solid building construction includes stone, double or triple brick, and cement block or poured structures. Solid brick or stone was probably the most common residential construction type in central and eastern Canada until mid-1940.

Foundations were often stone, and either two or three layers of brick were used to form the upper building envelope with joists and rafters supported directly by the brick.

Insulation Challenges

On the inside, thin strapping (3/4 inch) supports lathe and plaster walls. The only wall insulation is the dead air cavities between the layers of brick and between the brick and lathe.

This type of construction, which is still employed in the block construction of basements, is very difficult to retrofit with air, heat, or moisture barriers except by interior or exterior surface application.

Building Envelope: Balloon Frame Construction

Figure 2-5

Balloon framing can easily be retrofitted with insulation blown into the wall cavity

Characteristics

Balloon frame homes are an older construction type that is now seldom encountered. These homes have continuous wall cavities from the first floor to the attic.

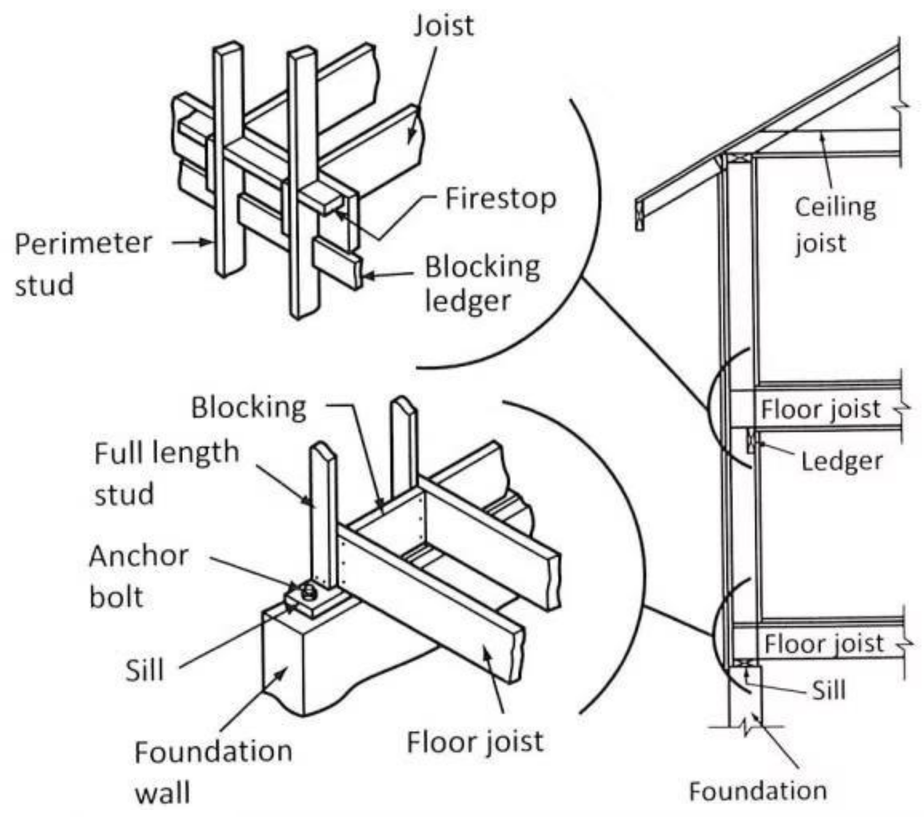
Wood siding or brick veneer is common on the exterior and plaster or drywall is directly attached to the wood frame on the inside.

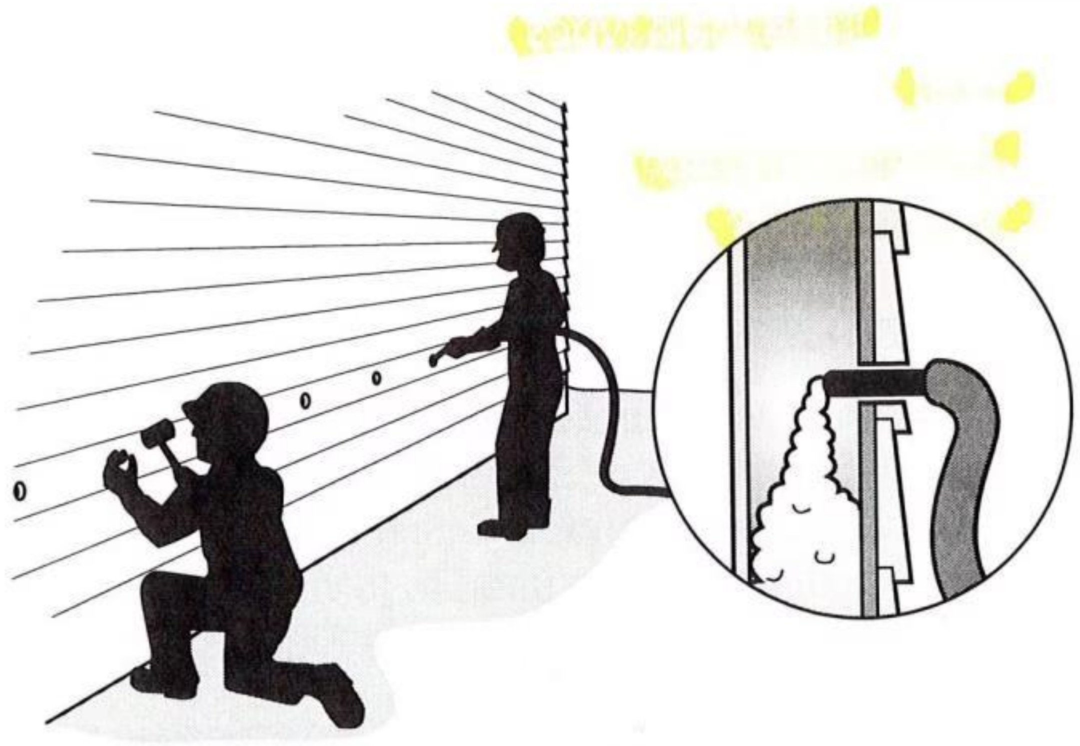
Insulation Considerations

Since this type of house was popular during the late 19th century, insulation of the wall cavity was uncommon (and the continuous cavities encourage air convection heat loss and are a serious fire concern).

In most cases, these houses have been easily retrofitted with blown-in insulation.

Building Envelope: Platform Frame Construction





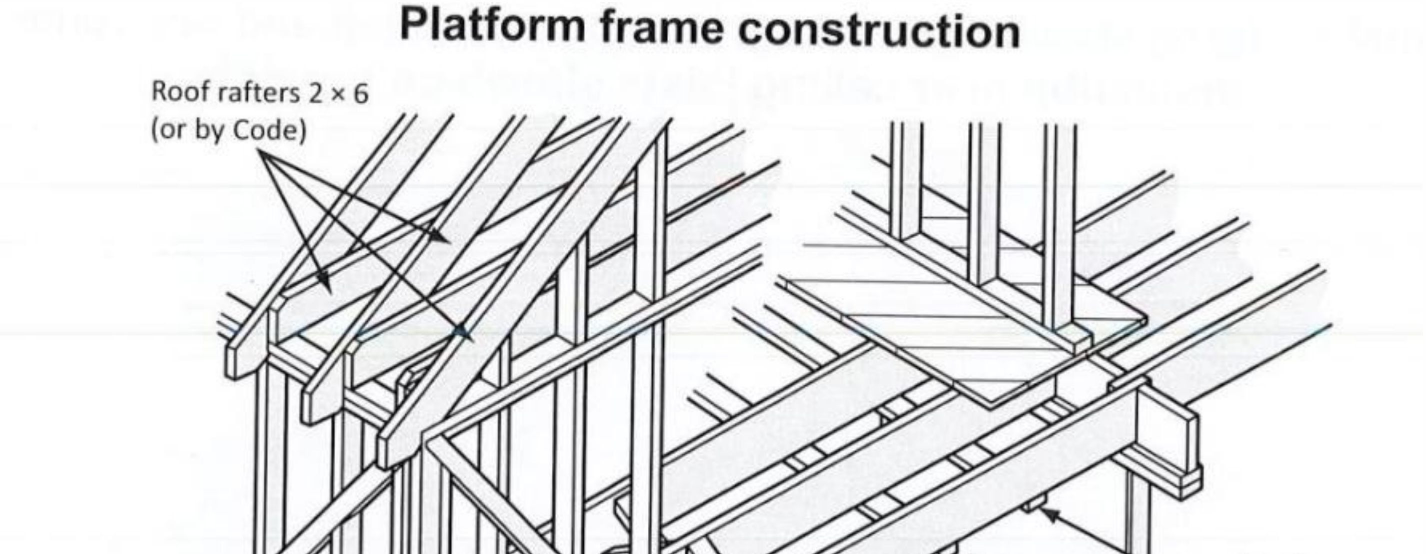
Characteristics

Platform frame construction is undoubtedly the most common type used for the last 60 years. Each floor is built separately as a platform for supporting the next floor.

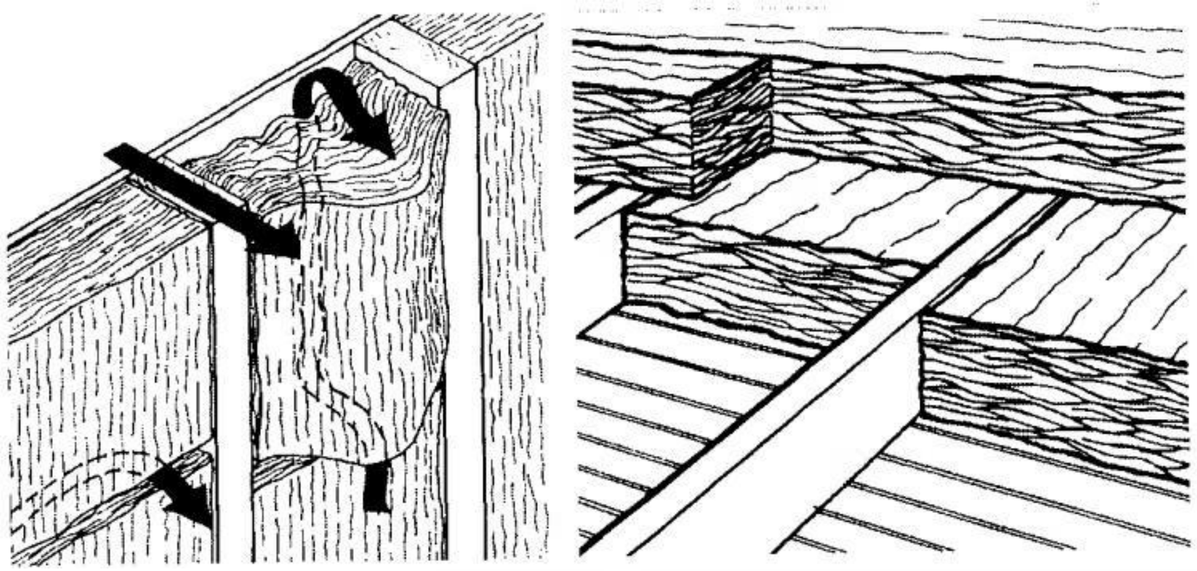
Unlike balloon framing, platform framing has floor and ceiling joists that are good for stopping air flow (or fire travel) but pose problems with air leakage and heat loss.

Construction Details

The exterior may be brick veneer, wood, aluminum, or vinyl siding, but the support is the wood frame and not the veneer material.



Building Envelope: Thermal Bridging



What is Thermal Bridging?

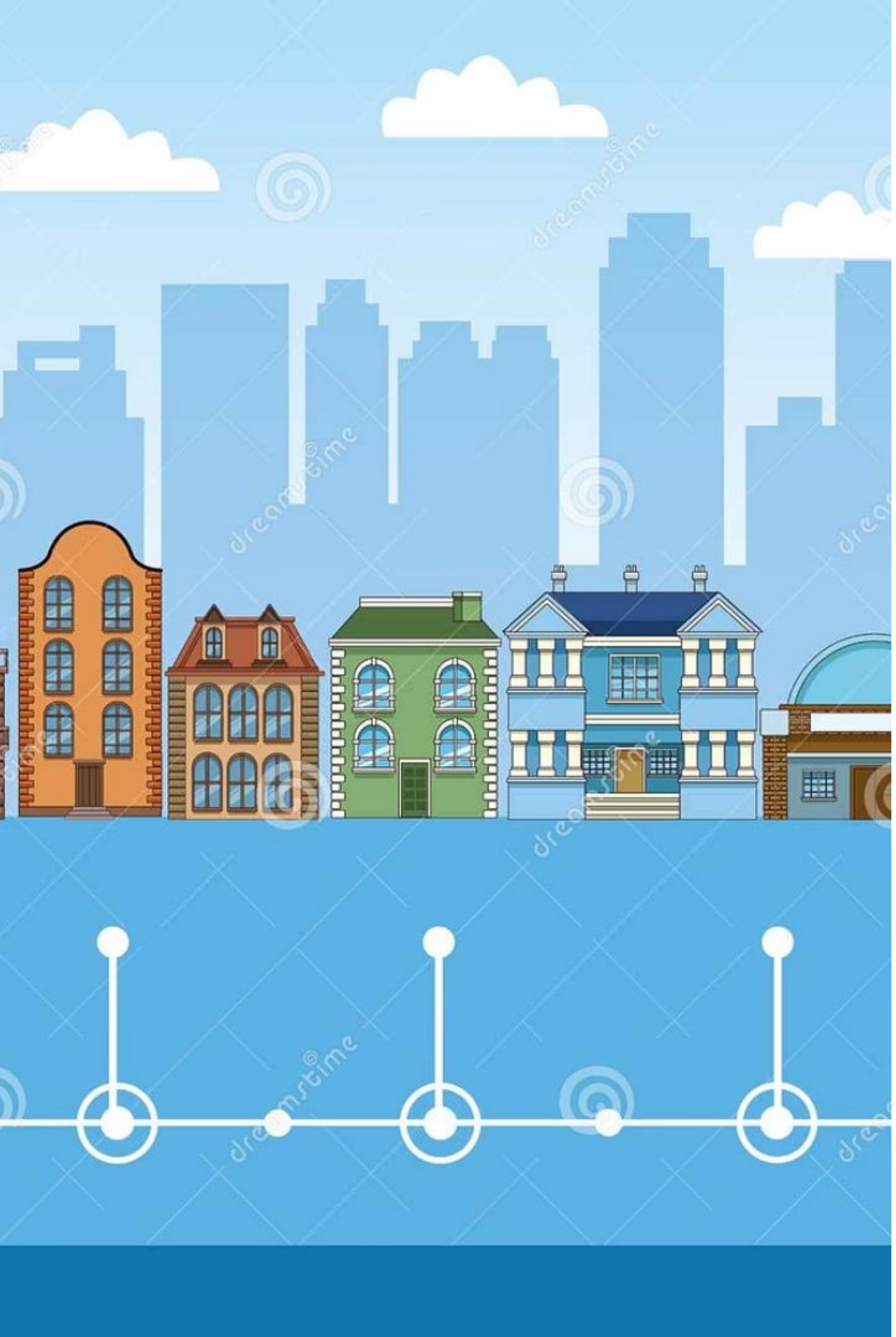
Whichever construction type is employed, the structural material usually causes a direct transfer of indoor temperatures to the outdoors by conduction.

Known as thermal bridging, this conduction heat transfer through the solid members of the building envelope acts to "short circuit" the benefits of any insulation between the structural members.

Reducing Thermal Bridging

The lower the conductivity of material, the less heat loss; wood studs cause less heat loss than steel beams or concrete.

Air gaps or insulated breaks between the outside and inside walls reduce thermal bridging. The image shows thermal bridging with a straight arrow on the left and one remedy of insulation over ceiling joists shown on the right.



Building Envelope: Historical House Types

Construction date	General characteristics	Insulation level in R value (Walls/Attics/Basement)
Pre-1920	Solid brick; no central heating, plumbing, or wiring	0/0/0
1920-1950	Solid brick, gravity central heating, knob and tube wiring, galvanized plumbing	0/7/0
1950-1960	Platform frame gaining acceptance; leaky envelope, especially windows	7/8/0
1960-1974	Same as above, but increasing use of insulation. The first Building Code requirements came into effect in 1965.	8/10/0
1975-1980	Gradual increase in air sealing materials and insulation.	10/12/0

Building Envelope: Modern Construction Standards

Construction date	General characteristics	Insulation level in R value (Walls/Attics/Basement)
1981-1982	Building Code significantly increases insulation requirements.	12/20/8
1983-1989	Same as above plus air and moisture barriers required, but only overlapping required-not sealing.	12/32/8
1990-1993	R-2000 construction techniques first introduced in mid-1980s are generally accepted and used.	19-22/31-38/12
1994-present	Air tightness problems begin to be recognized, so ventilation requirements addressed by Building Code.	19-22/31-38/12
2012	ENERGY STAR® for New Homes Standard Version 12. Approximately 20% more energy-efficient than minimum NBC requirements.	Based on climate zone

Building Envelope: Layers and Functions

Figure 2-8
Common components of the building envelope

Purpose of Building Envelope

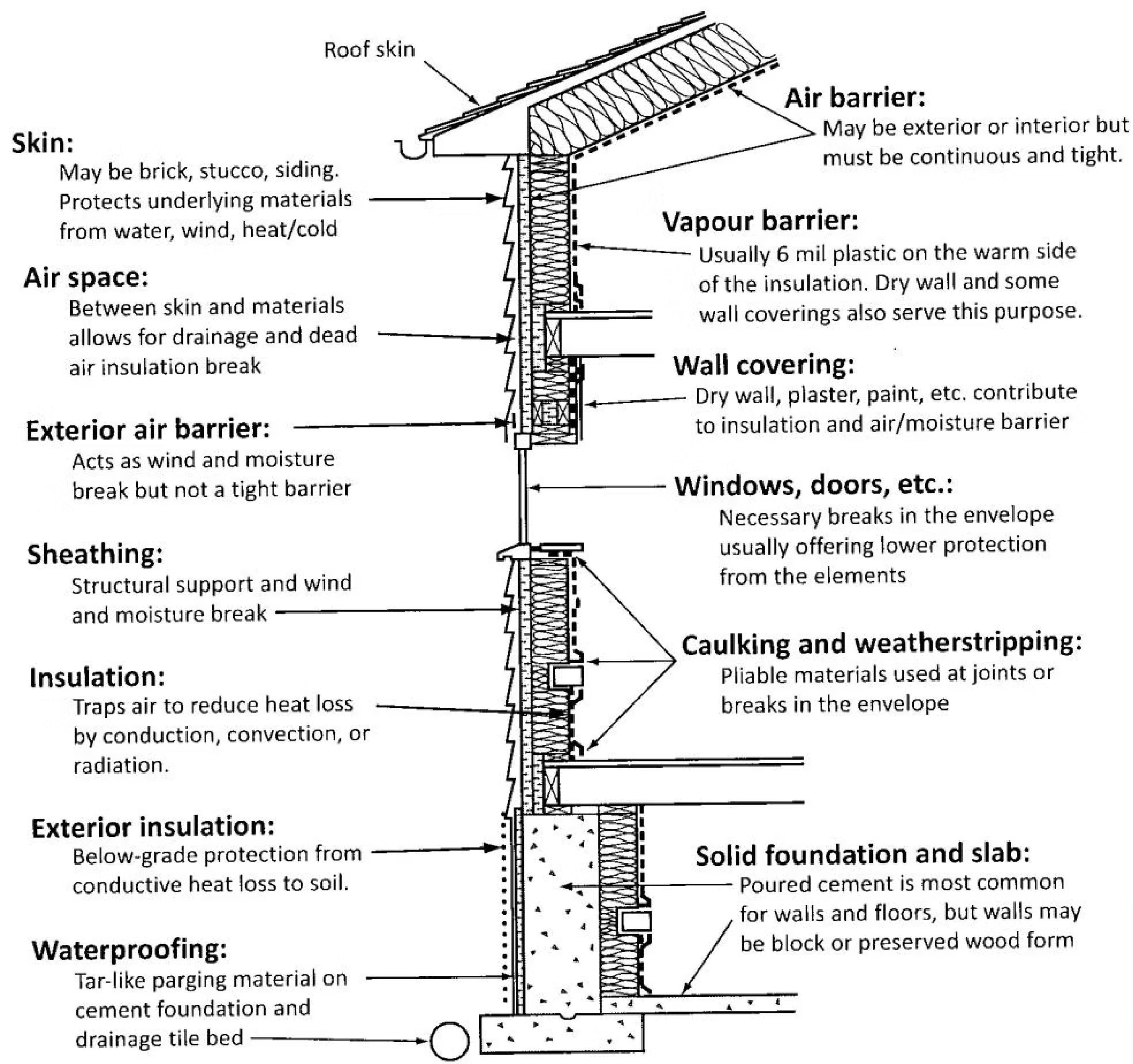
The building envelope has the primary role in controlling the flow of heat, air, and moisture; it functions to separate the indoors from the outdoors. Its success depends on the quality of its layered materials and their installation method.

Assessment Approach

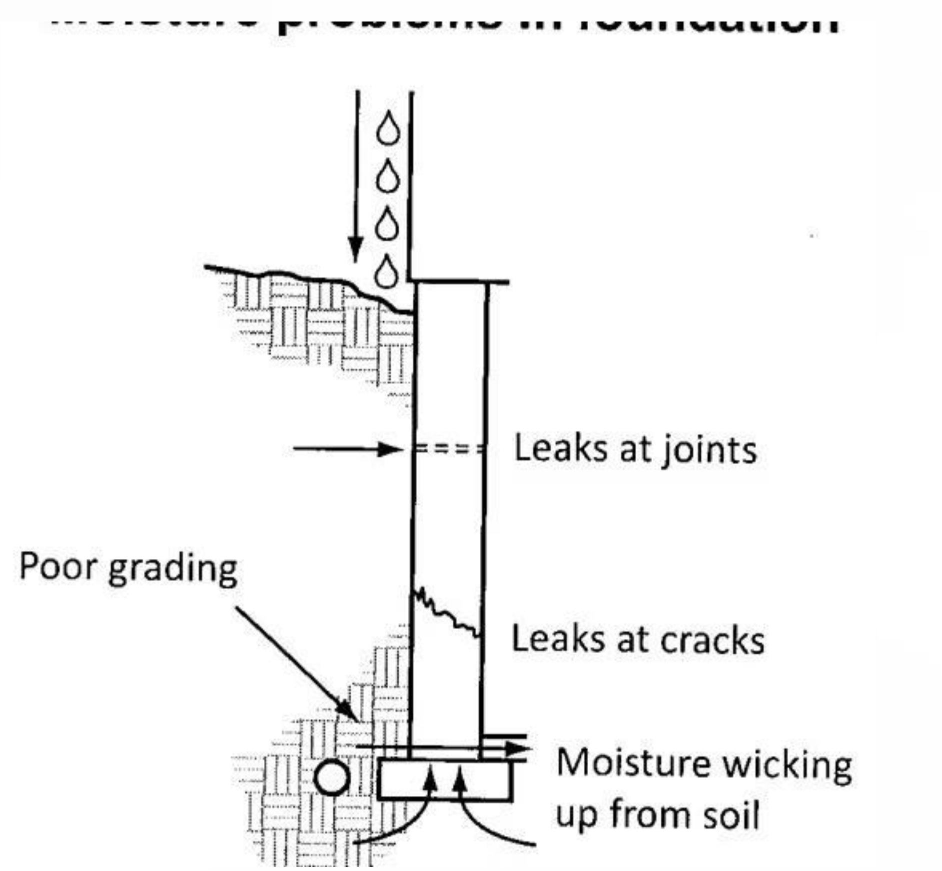
Each layer of the envelope has its purpose and place. An assessment of those layers can be made directly or by questioning the owner or builder. The key concerns are how the envelope controls the flow of air, heat, and moisture.

In many cases, one material serves many control functions, so each layer moving from the outside inwards will be discussed.

Building Envelope: Building Skin



Building Envelope: Foundation Assessment



Below-Grade Assessment

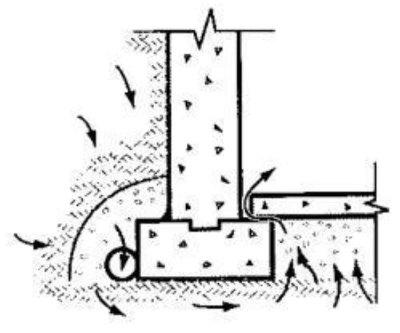
Below-grade skin assessment can be conducted indirectly from the exterior and interior. Outside grading that removes the surface water is critical.

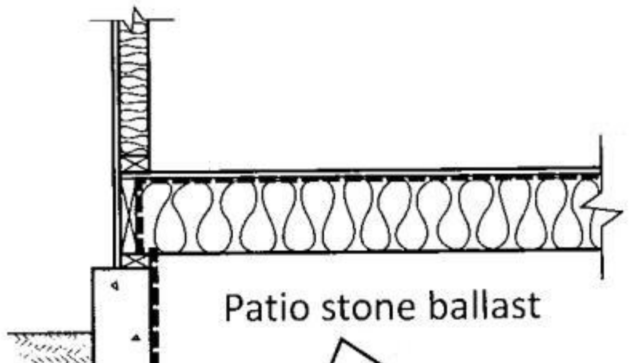
Inside, any cracks, white chalking, mould growth, or dampness are indications of improper drainage, which should be brought to the attention of the owner.

Basement Floor Considerations

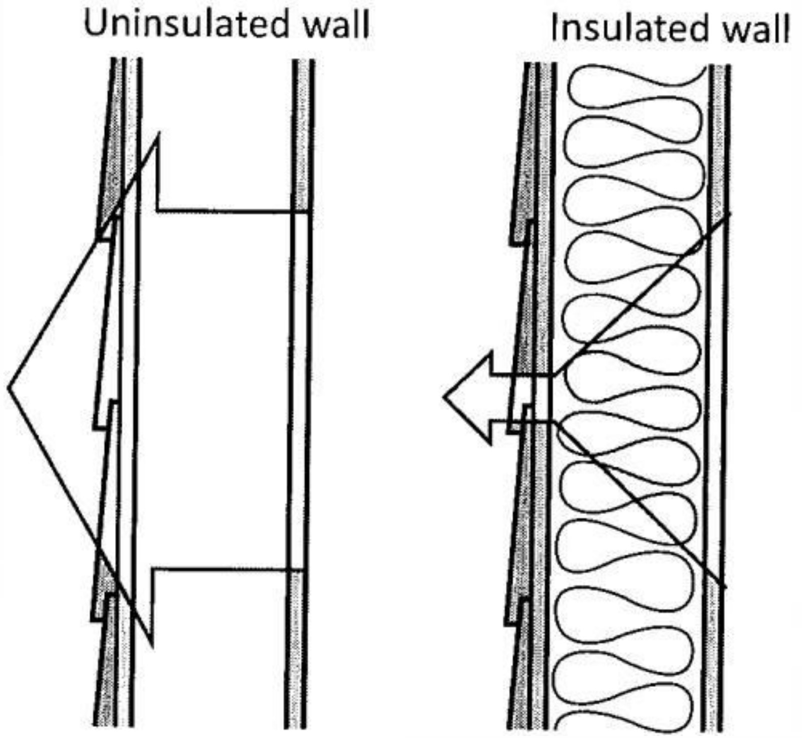
The basement floor also forms part of the skin and must be air- and water-tight. Well-drained concrete slab floors are the best if properly air-sealed at the joints.

Earthen floors will always create moisture problems for the rest of the structure. A solution for an earthen floor can be as simple as a layer of 6 mill polyethylene moisture barrier held in place by patio slabs and sealed at the edges.





Building Envelope: Air and Moisture Barriers



1

Exterior Air Barrier

An exterior air barrier is found directly behind the skin on modern buildings and consists of a film of spun bonded olefin cloth that allows air flow in only one direction—out of the wall cavity.

Older buildings may employ a tar paper below the skin as a partial air barrier but depend on the vapour barrier on the interior to serve the dual function as an air and vapour barrier.

2

Sheathing

The sheathing also provides an air and moisture break, although its primary purpose is structural strength.

Newer, less dense materials with tight-fitting joints also provide some insulation benefits and help create the pressurized dead air space in the wall cavity that is necessary for the main insulation.

3

Insulation

Insulation is the one material in the envelope whose main function is to keep the heat in during winter or out during summer.

Insulation acts like a giant sleeping bag wrapping the house in a layer of material that slows the rate of heat loss or gain. Still, air does not conduct heat well and is a relatively good insulator.

4

Vapour Barrier

A vapour barrier must be installed on the warm side of the insulation to prevent warm moist air from passing into the insulated wall cavity and condensing as the water vapour reaches the cold outside surfaces.

Building Envelope: Insulation Requirements

Effective Insulation Requirements

To be effective, insulation must be:

- Resistant to heat flow
- Able to fill the cavity completely and evenly
- Installed to prevent thermal bridging of conductive solid materials
- Durable, especially in locations directly exposed to heat and moisture

Thermal Resistance Values

Insulation is assigned a thermal resistance value using a scale measured in RSI units (Resistance System International) for the metric system and in R units for the Imperial system.

Thickness of different materials with the same RSI or R value varies, so assessment must be based on the thermal resistance value of the specific material multiplied by its thickness.

Building Envelope: Types of Insulation

Types of insulation	Characteristics / Locations	Approximate RSI Value per mm	Approximate R Value per inch
Fibreglass batts or blankets	Easy to cut/install; friction fit so it will not settle; some types have paper wind barrier backing; non-combustible	0.022	3.2
Loose fill cellulose fibre	Can be poured in attic joists or blown into wall. Fills uneven spaces well and may be chemically treated to resist fire and fungal growth. Can reduce air leakage	Poured - 0.024 Blown - 0.025	Poured - 3.4 Blown - 3.6
Loose fill glass fibre	Chopped up fibreglass material with same advantages as cellulose fill but not as resistant to heat flow	Poured - 0.021 Blown - 0.020	Poured - 3.0 Blown - 2.9

Building Envelope: More Insulation Types

Types of insulation	Characteristics / Locations	Approximate RSI Value per mm	Approximate R Value per inch
Mineral or rock wool	Cross between cellulose and glass in appearance. Treated with oil and binders to suppress dust and to make pouring and blowing easier	Poured - 0.022 Blown - 0.021	Poured - 3.2 Blown - 3.0
Vermiculite	Expanded mica. Available as treated or untreated with the latter absorbing moisture while treated repels moisture. Heavy and prone to settling. Treated type used in high moisture areas.	Treated - 0.017 Untreated - 0.016	Treated - 2.5 Untreated - 2.3
Rigid board	Made of glass fibre or foam plastic. Lightweight, easy to cut, but difficult to form to completely fill irregular spaces.	Glass fibre - 0.03 Expanded poly (high) - 0.028 Expanded poly (low) - 0.026	Glass fibre - 4.3 Expanded poly (high) - 4.0 Expanded poly (low) - 3.7

Building Envelope: Spray Foam Insulation

Spray Foam Characteristics

Spray foam insulation is mixed on site and sprayed onto surface or into cavities. It expands and sets in seconds.

Between 1977 and 1980 urea formaldehyde (UFFI) was used but application problems caused noxious odours. Currently either polyurethane or semi-flexible isocyanurate plastic foam are commonly sprayed on interior basement walls of old houses.

Thermal Resistance Values

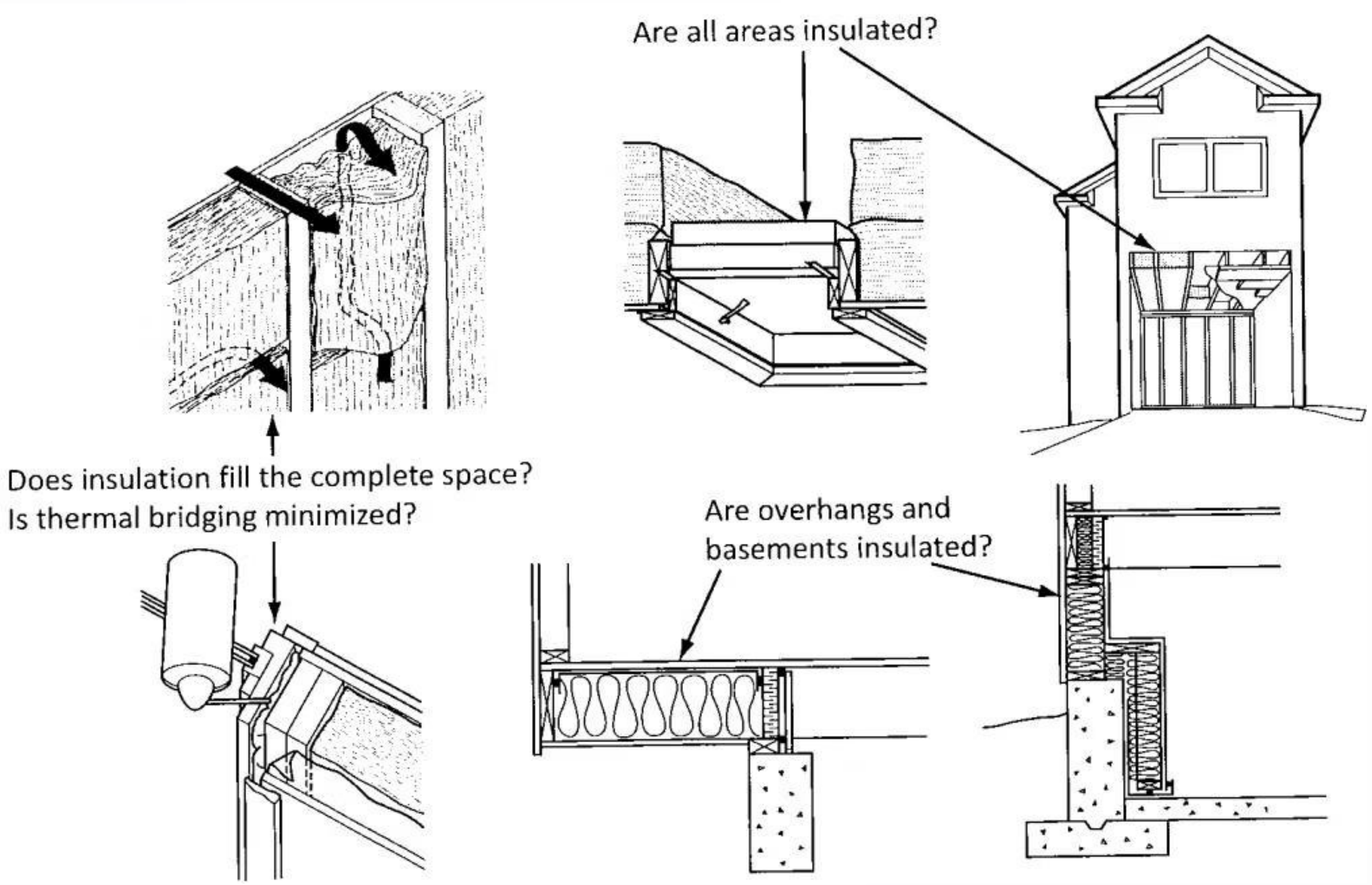
Type	RSI Value per mm	R Value per inch
Polyurethane	0.042	6.0
Isocyanurate	0.030	4.3

Conversion factors:

To get RSI overall: Multiply R Overall by 0.1761

To get R overall: Divide RSI overall by 0.1761

Building Envelope: Insulation Installation Quality



Installation Assessment

Building Codes have specified the minimum amount of insulation required for residences since 1965. However, the assessment conducted by the gas technician/fitter must be site-specific, so the builder or owner should be questioned as to the actual insulation level and method of installation.

This is of critical importance since the area of coverage, and the quality of the installation

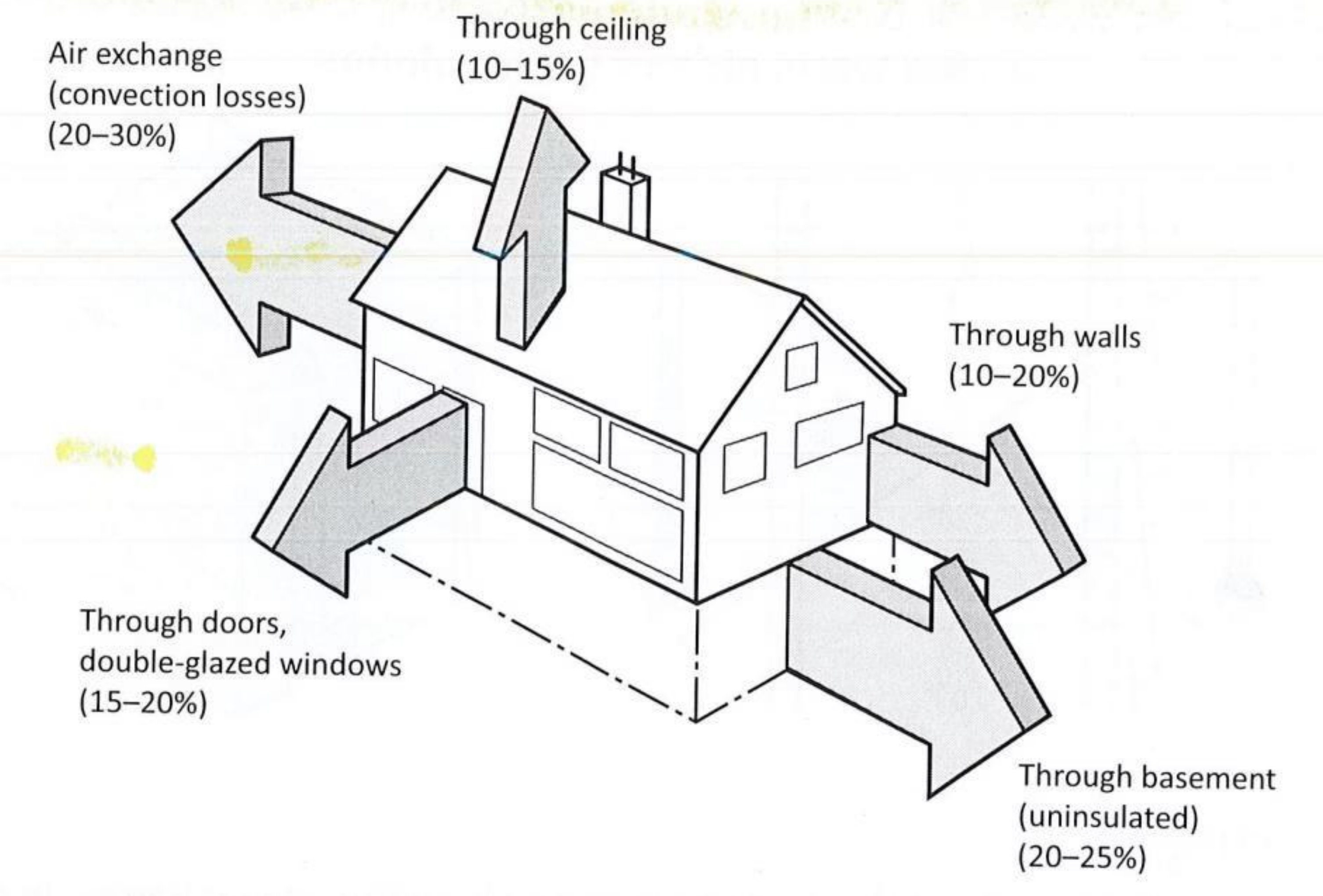
Areas of Concern

The image shows areas of concern related to installation method. Although you will not be removing the insulation, you should be investigating the method used with an eye to completeness and quality.

Poor installation can create thermal bridges, air leakage paths, and areas where condensation can form, all of which can affect gas appliance operation.

Building Envelope: Typical Heat Loss Distribution

Figure 2-15
Typical heat losses from a single family residence



Common Misconceptions

It is a common misconception that most of the heat escapes through the roof. The image shows typical heat losses from a house based on information collected by the CMHC.

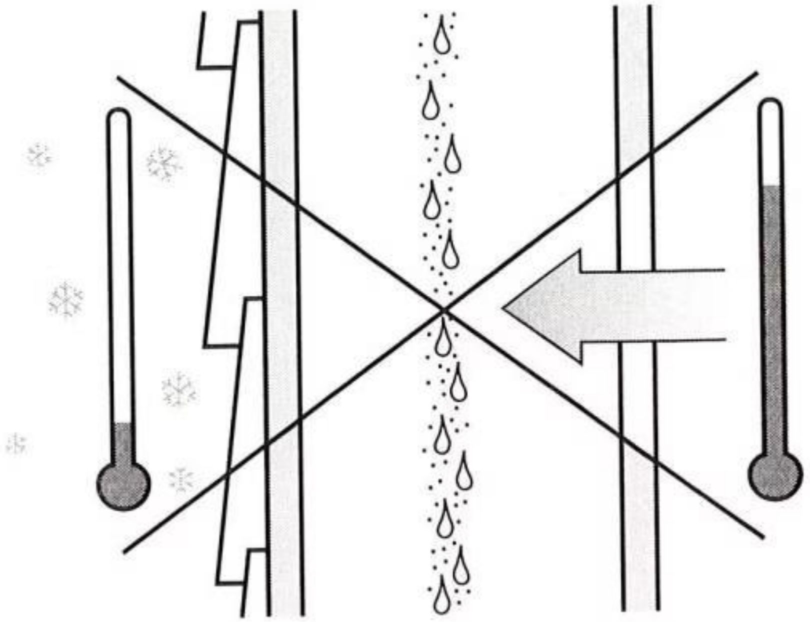
The early focus for insulation was on the attic, so the typical heat losses are less there than in the

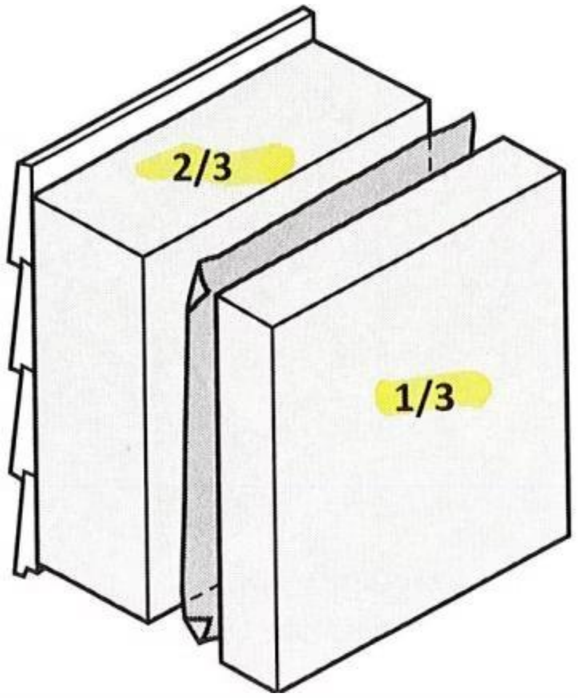
Implications for Gas Technicians

Awareness of typical heat losses can help a gas technician/fitter in assessing the house and advising the customer about increasing comfort levels by increasing insulation.

A disproportionate heat loss in one area of the house makes it difficult to balance heat delivery to all

Building Envelope: Vapour Barrier Function





Purpose and Placement

A vapour barrier must be installed on the warm side of the insulation to prevent warm moist air from passing into the insulated wall cavity and condensing as the water vapour reaches the cold outside surfaces.

Without a vapour barrier, condensation occurs in the wall cavity. A vapour barrier may be installed as much as one-third into the insulation but is normally directly on the warm side of the insulation.

Materials and Installation

It is common practice to use 6 mil polyethylene plastic as both the air and vapour barrier, although the two functions may be served by different materials.

The vapour barrier must be impervious to moisture in any of its forms, but it does not have to be as tightly sealed or as rigid as the air barrier.

Building Envelope: Wall Coverings and Openings

Wall Coverings

Wall coverings can add insulation value and serve as an air and/or vapour barrier. In older homes, the oil base paint, varnish, or vinyl wallpaper can act as an adequate vapour barrier.

Drywall with gaskets or plaster will also serve as a vapour and air barrier. Special attention should be given to ensure that high moisture areas, such as kitchens, bathrooms, and earthen basements are covered by a vapour barrier.

Windows, Doors, and Vents

Windows, doors, and vents are necessary breaks in the building envelope that unfortunately allow less control over air, heat, and moisture flow. An assessment of these openings is important to identify problem areas for your appliances.

Air tightness and thermal resistance are the key factors to assess. Any signs of condensation, frost, or drafts indicate a problem with the window and/or the humidity control in the house.

Building Envelope: Window Energy Ratings

Energy Rating (ER) System

Windows can have an insulating value measured on the RSI and R scales or newer windows are rated using the Energy Rating (ER) value. The ER value is based on a calculation of the window's ability to:

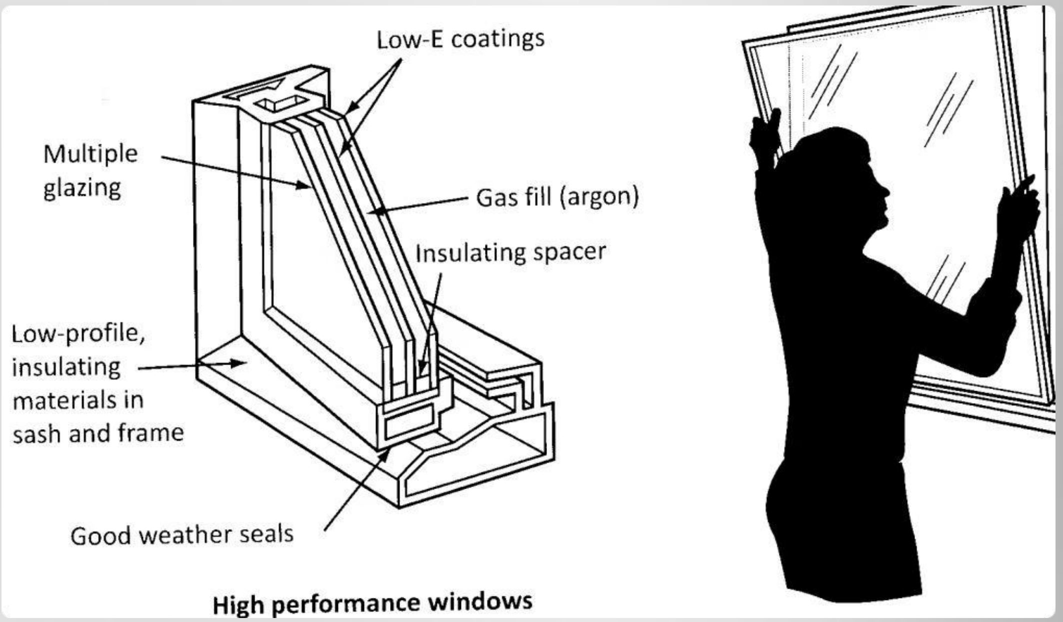
- Admit solar heat
- Prevent heat loss by conduction
- Resist air leakage losses

The ER is measured in watts per m^2 and given a value from –50 to +15, with 0 being a neutral point of heat gains balancing losses.

Window Performance Factors

The ER value of a window is determined by the number of panes, the thickness of the air space between the panes, and the coatings or gases employed.

A low emissivity (Low-E) coating allows sunlight to pass through but inhibits heat from radiating out. The image shows the components of a high-performance window.



Building Envelope: Window Thermal Resistance

Window description	Fixed (RSI/R/ER)	Operable (RSI/R/ER)
Single glaze, wood frame	RSI: .2 R: 1.14 ER: -45	RSI: .17 R: .9 ER: -50
Thermally broken aluminum frame, double-glazed, aluminum spacer	RSI: .3 R: 1.7 ER: -35	RSI: .25 R: 1.4 ER: -50
Wood frame, double-glazed, aluminum spacer	RSI: .4 R: 2.3 ER: -15	RSI: .35 R: 2.0 ER: -30
Wood frame, double-glazed, insulating spacers, Low-E, argon fill	RSI: .55 R: 3.1 ER: +5	RSI: .5 R: 2.8 ER: -8

Building Envelope: Door Thermal Resistance

Heat Loss Through Doors

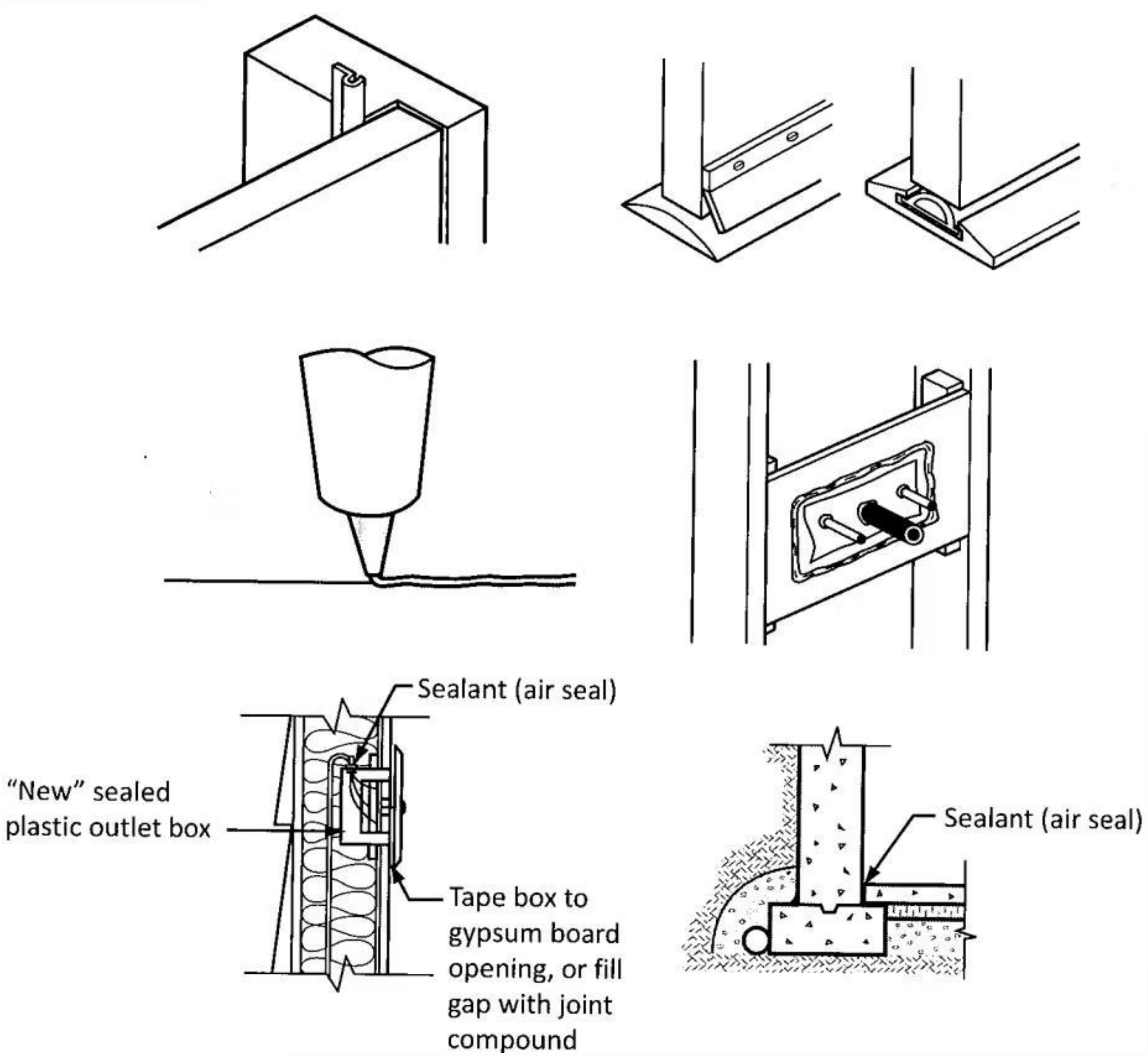
Doors are also part of the building envelope and come in a variety of insulating materials and sealing mechanisms that have to be considered by the heating technician.

Generally of higher insulating value than windows, doors are more commonly the source of air leakage, so the joint sealing method is of critical importance.

Door Types Comparison

Door description	RSI value	R value
Solid wood, 44 mm, 1.75 inch	0.53	3
Solid wood as above with storm door	0.71	4
Insulated metal with polystyrene core	1.1	6.25
Insulated metal with polyurethane or isocynurate	1.6	9.1

Building Envelope: Caulking and Weather Stripping



Importance for Air Sealing

Caulking and weather stripping are the final components of the building envelope. The volume of air movement through

Customer Education

During your assessment of the building envelope, it is worthwhile pointing out the areas to the customer where caulking

Mechanical/Electrical Equipment: Overview

Role in Building System

Behind the protection of the building envelope, the mechanical and electrical equipment plays a primary role in creating the indoor environment.

The heating and ventilation systems are the gas technician's/fitter's key interest, but other equipment in the house—lighting, kitchen appliances, washers, dryers, etc.—cannot be ignored since they also affect the flow of air, heat, and moisture.

Equipment Categories

Although the heating and ventilation systems may share components, as is the case with forced-air heating systems, they will be addressed separately. The focus is on how each equipment group affects the flow of air, heat, and moisture and how the groups interact with the rest of the building as a system. The groups are:

- Heating equipment
- Ventilation equipment
- Other mechanical and electrical equipment

Mechanical/Electrical Equipment: Heating System Sizing

Importance of Proper Sizing

The heat lost by the building must be replaced by the space heating system at a rate and in a manner that provides consistent comfort to the occupants.

If	Then
An undersized heating system is installed	The heat loss on the coldest days will be greater than the heating equipment can supply and the desired indoor temperature cannot be attained.
An oversized heating system is installed	Its rate of heat production causes it to short cycle since it will satisfy the thermostat before it reaches steady-state efficiency. As a result, fuel costs will be excessive.

Common Sizing Methods

Common but inadequate methods for determining heating system size include:

- Guess
- Use a "rule of thumb" method based on square footage
- Use a "rule of thumb" method based on types of houses (two-storey, ranch, bungalow, etc.)
- Replace with the same size of furnace removed
- Let the customer decide

What is needed is a tried and true method that takes into account as many of the site-specific heat loss variables as possible. Various methods do exist and are collectively known as heat loss calculation methods.

Mechanical/Electrical Equipment: Consequences of Improper Sizing

Comfort Issues

Improperly sized space heating equipment can cause heating discomfort to customers. Undersized systems can't maintain temperature on cold days, while oversized systems create temperature swings.

Structural Damage

Damage to the structure can occur, such as frozen pipes if undersized and condensation in the chimney if oversized. This condensation can lead to chimney deterioration and potential safety hazards.

Equipment Damage

Damage to the appliance can result from long cycles (undersized) or short cycles (oversized). Short cycling particularly causes excessive wear on components and reduces equipment lifespan.

Energy Waste

Inefficient and costly energy use occurs with improperly sized systems. Undersized systems may cause excessive electricity use from supplemental heating, while oversized systems waste fuel through inefficient operation.

Mechanical/Electrical Equipment: Heat Distribution Systems

Figure 2-19
Heat distribution patterns in room heated by radiant floor systems and forced-air systems

Types of Heating Systems

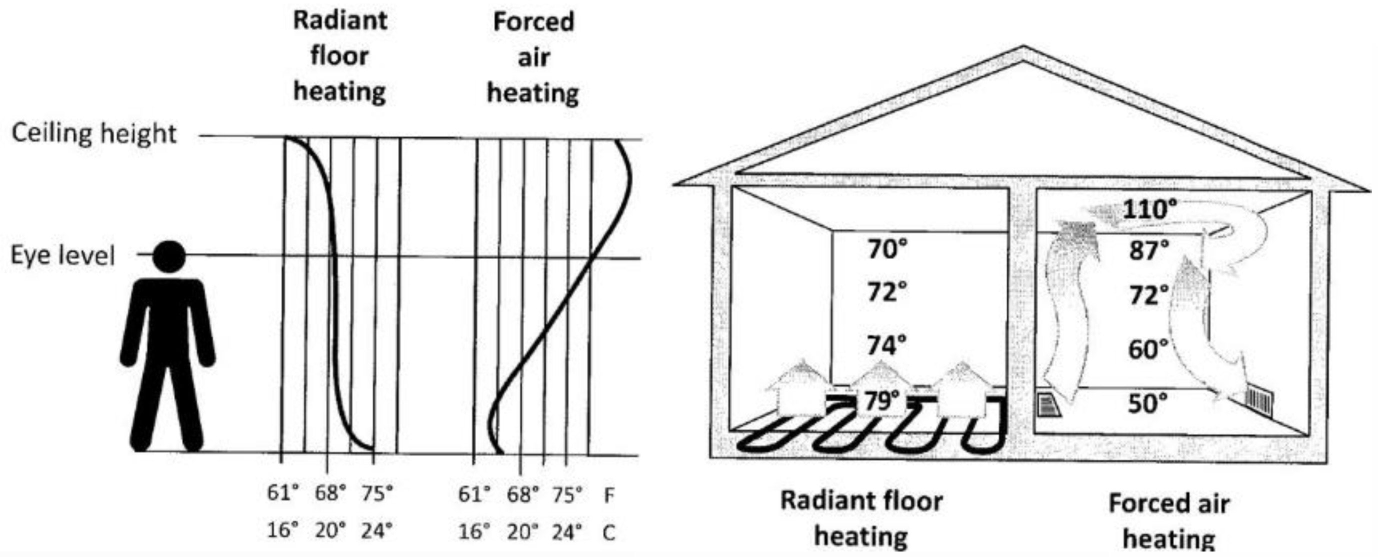
Heat distribution depends partly on the type of heating system (forced air, radiant baseboard, radiant floor, etc.) and partly on installation issues common to all types of heating systems.

The image compares forced-air systems to radiant heating systems to illustrate the effects that the type of heating system can have on the flow of air, heat, and moisture as well as on other comfort issues in the house.

Temperature Stratification

Different heating systems create different temperature patterns in a room:

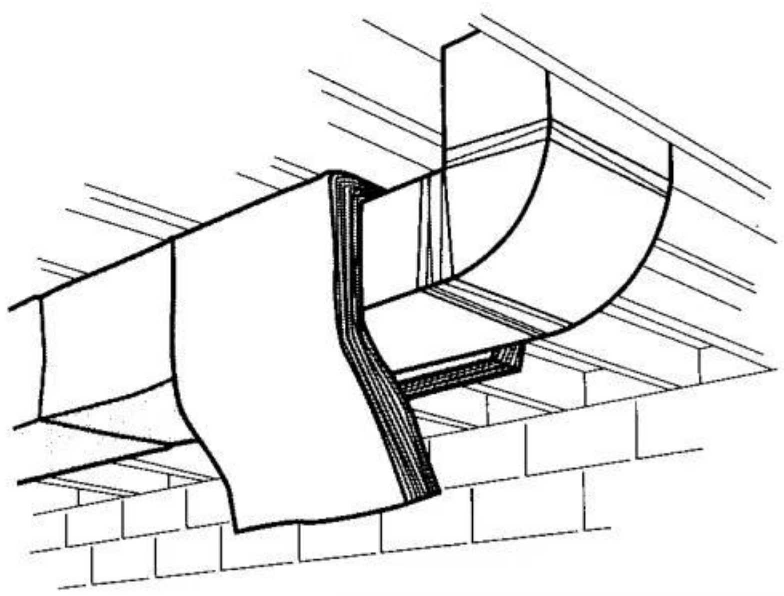
- Forced air systems tend to create stratification with cold floors and warm ceilings
- Radiant systems (especially in-floor) create more even temperature distribution with warmer floors

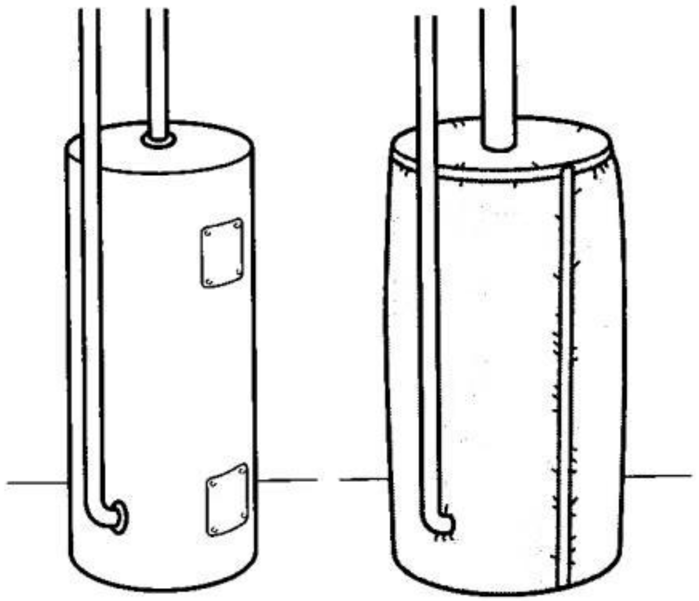


Mechanical/Electrical Equipment: Heating System Comparison

Comfort issue	Forced-air system	Radiant system
Air flow	Significant volume of air mechanically redistributed throughout the house either intermittently during heating cycle or continuously at varying speeds. Potential for pressure differences between rooms and levels requiring careful balancing.	Relatively minor redistribution of air within or between rooms. Constant air flow patterns created by convection of air contacting radiant surface. Minimal potential for pressure differences.
Heat flow	Primary method of heat flow is air temperature, thus emphasizing heat transfer by convection over conduction and radiation. Heat distribution within a room is relatively uneven with a stratification pattern of cold floors and warm ceilings.	Primary method of heat flow is surface temperature, thus emphasizing heat transfer by radiation over conduction and convection. Heat distribution within a room is relatively even, with a stratification pattern of warm floors and cold ceilings.
Moisture flow	Relative humidity during winter is decreased, resulting in drier air due to higher air temperature. Significant ability to improve winter humidity levels by means of add-on humidifier.	Relative humidity is less affected due to lower air temperature. Minor ability to improve winter humidity levels by means of add-on humidifier to radiant surface.

Mechanical/Electrical Equipment: Heat Distribution Issues





Balanced Delivery

As previously discussed in relation to input size, the heat gain must balance the heat loss. This applies to delivery on a room by room basis - the heat loss from a particular room must be balanced by an equivalent heat gain from the heating system.

The size and design of ducts or piping and the flow rate of the heated medium to each room are the key factors in delivering the calculated heat gain.

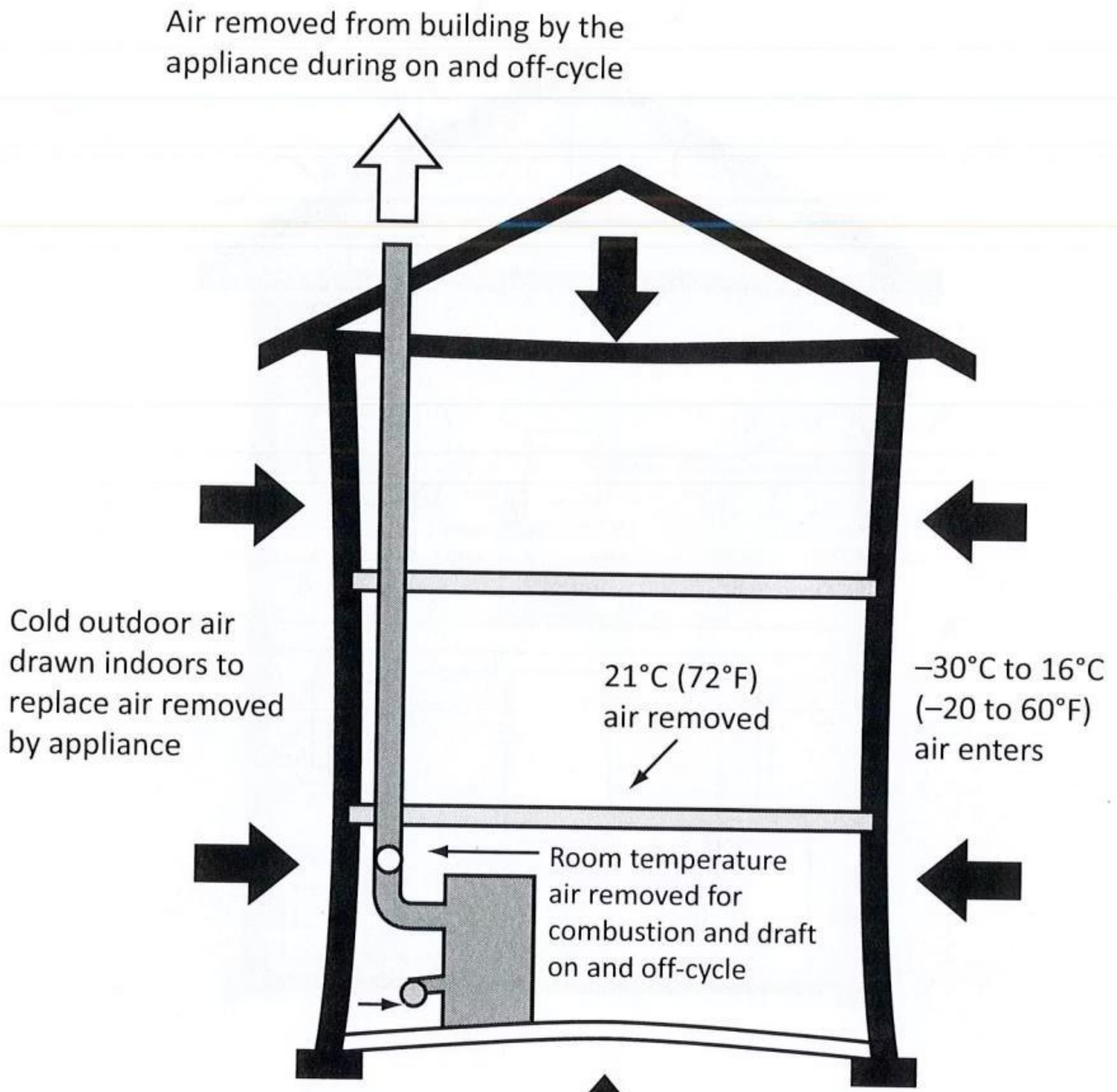
Focused Delivery

Control over the flow of air, heat, and moisture requires that the distribution system delivers heat (whether space heat or domestic water heat) only to the end use location.

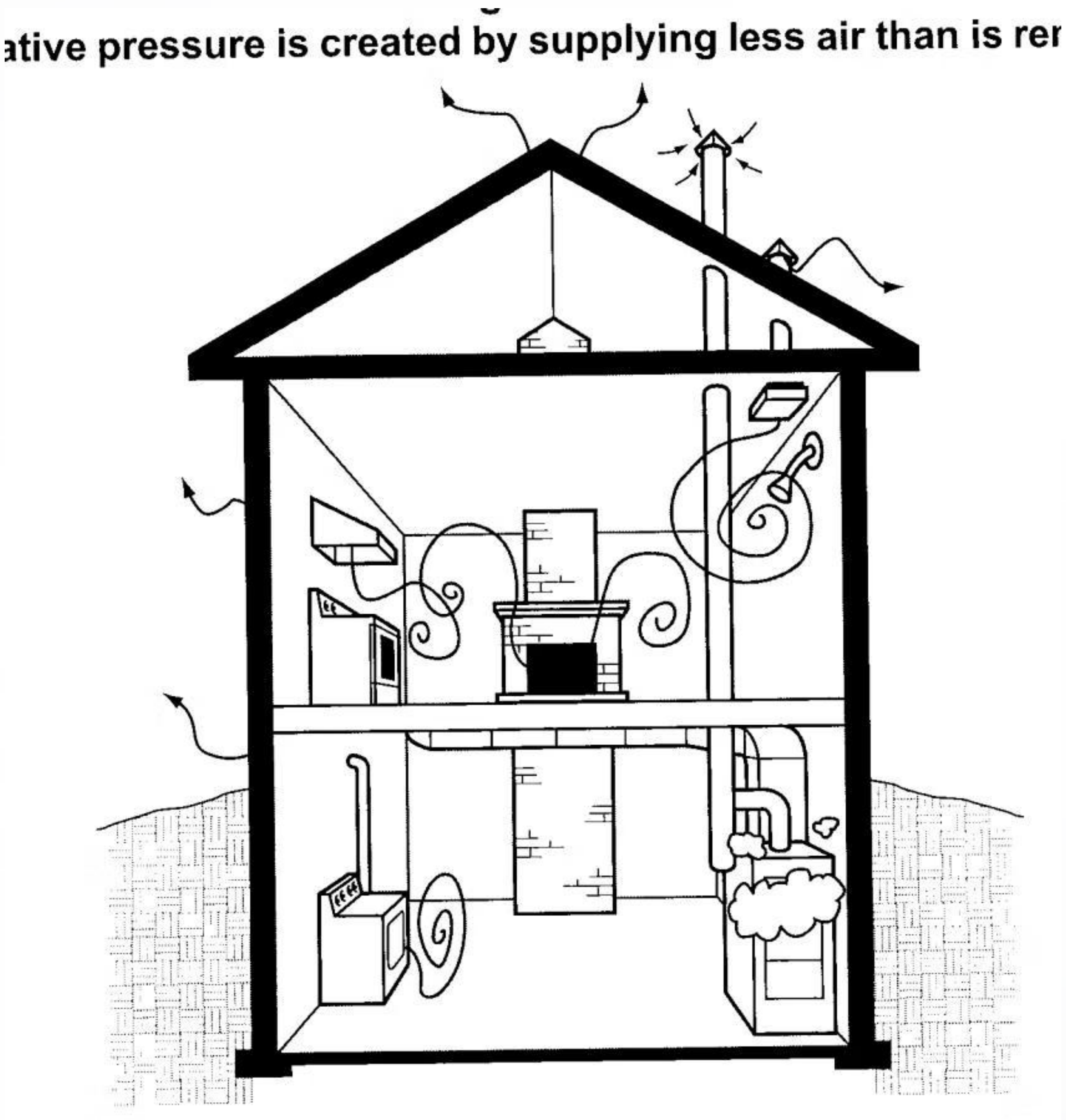
Uncontrolled losses and condensation caused by jacket heat loss or distribution heat losses must be minimized. The greatest losses occur in unheated spaces; insulation is required to focus heat delivery and prevent condensation.

Mechanical/Electrical Equipment: Air Consumption

Figure 2-21
Air consumed by appliance and venting system is replaced by outdoor air



Mechanical/Electrical Equipment: Negative Pressure Issues



Causes of Negative Pressure

Competing Exhaust Devices

Mechanical/Electrical Equipment: Signs of Backdrafting

Unusual Odors

Unusual odours from any combustion appliance may indicate incomplete combustion or flue gas spillage

Operational Issues

Noisy starts or delayed ignition problems can be caused by improper draft conditions

Combustion Problems

Difficulty starting or maintaining a fire in fireplaces or wood stoves when other exhaust devices are operating

Physical Evidence

Moisture or soot in the appliance, vent, or building indicates improper venting

Health Symptoms

Indications of carbon monoxide poisoning such as headaches, nausea, or dizziness that improve when away from home

Mechanical/Electrical Equipment: Ventilation Systems

Purpose of Ventilation

Ventilation is the process of supplying or removing air from a space. Until recently, it was assumed that natural ventilation through leaks, cracks, and openings in the building envelope was sufficient for the control of indoor air quality (IAQ) and humidity.

Tighter building envelopes and awareness of IAQ problems have led to the increased use of mechanical ventilation equipment.

Ventilation System Categories

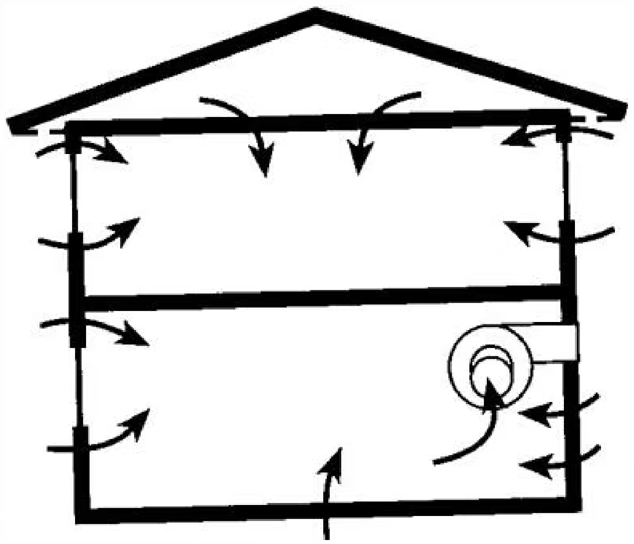
Mechanical ventilation systems can be categorized and assessed by how they perform two important functions:

1. Control building pressure
2. Distribute air through the building

For each function, there are three basic types:

Pressure control types	Distribution types
Exhaust-only	Direct-ducted
Supply-only	Recirculating
Balanced	Through-the-wall

Mechanical/Electrical Equipment: Exhaust-Only Ventilation



System Operation

The exhaust-only system is probably the most common mechanical ventilation system used. A negative or suction pressure is created by exhaust fan(s) and fresh air enters the building by infiltration due to the negative pressure.

This system is dependent on the building having sufficient air leakage in the envelope. A dedicated exhaust fan may be installed for the sole purpose of removing air at a predetermined rate to bring about a certain air change.

Advantages and Disadvantages

Advantages	Disadvantages
Easy and cheap to install	Can cause pressure-induced backdrafting and spillage
Can remove contaminants at source	May increase infiltration of contaminants from soil or walls
Dries out building envelope in winter	Increases moisture in envelope during summer
Preheating not required	Uneven distribution of fresh air
No distribution system required	Minimal control over the flow of air, heat, and moisture

Mechanical/Electrical Equipment: Supply-Only Ventilation

Figure 2-24
Supply-only system (left) and its normal installation with a forced-air heating system

System Operation

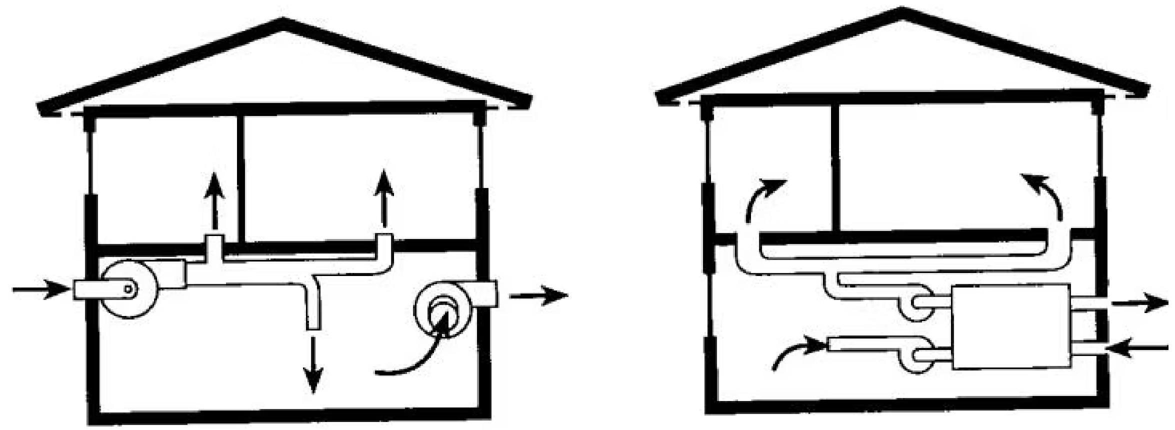
A supply-only system creates a positive pressure in the building envelope and, like the exhaust-only system, depends on sufficient air leakage for proper operation.

This type of mechanical ventilation system commonly uses the circulating fan and distribution system of the forced-air furnace or the cooling system ductwork if radiant heating is used.

Advantages and Disadvantages

Advantages	Disadvantages
Easy and cheap to install	Preheating of air supply required
Compatible with natural draft appliances	Increases moisture in envelope during winter
Filtration of outside air supply possible	Heat recovery from exhausted air not possible
Can use existing distribution system	Requires distribution system
Even distribution of fresh air	May require relief air system

Mechanical/Electrical Equipment: Balanced Ventilation



System Operation

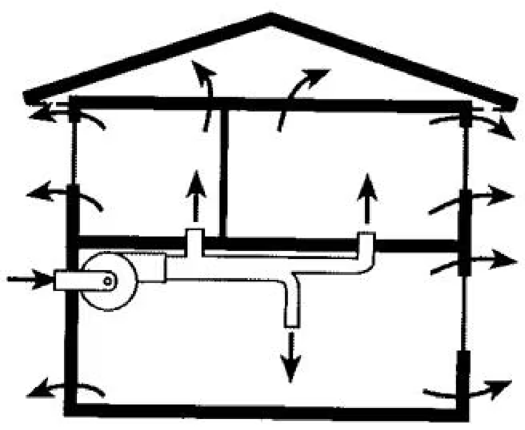
A balanced system is a term given to a mechanical ventilation system that supplies and exhausts air mechanically. The use of the word "balanced" may be misleading. These systems can be designed to create a significant positive or negative pressure, or, ideally, a neutral pressure in the building.

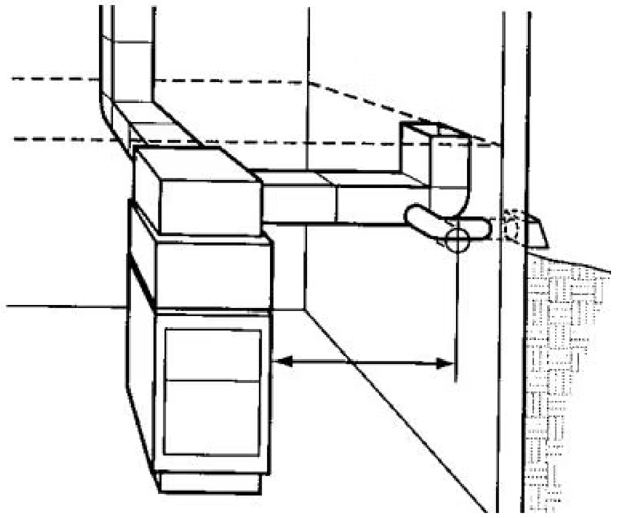
Preheating of the supply air with the exhaust air using a heat recovery ventilator (HRV) is the most common installation method. An HRV is required by the Ontario Building Code for any new house with a fireplace, electric heat, or a natural draft appliance installed.

Advantages and Disadvantages

Advantages	Disadvantages
Recaptures heat from exhaust air	Expensive in terms of cost and space
Maximum control over the flow of air, heat, and moisture	Freeze-up potential during coldest weather requires defrost cycle
Compatible with natural draft appliances	May cause negative pressure during defrost cycle
Even distribution of fresh air	Requires a distribution system

Mechanical/Electrical Equipment: Heat Recovery Ventilators





HRV Components and Operation

An HRV consists of two fans—one to bring in air, the other to exhaust air—creating a balanced air flow. The heat exchanger is a static device that recovers the temperature difference between the two air streams.

Energy recovery ventilators (ERVs) are a type of HRV that give more control of moisture in the building. During warm and humid weather, incoming outside air transfers its moisture to the outgoing exhaust; whereas in the winter, it will recover some of the moisture that would be exhausted to the outdoors by a regular HRV.

HRV System Diagram

Figure 2-26
Balanced ventilation system using an HRV and furnace combo

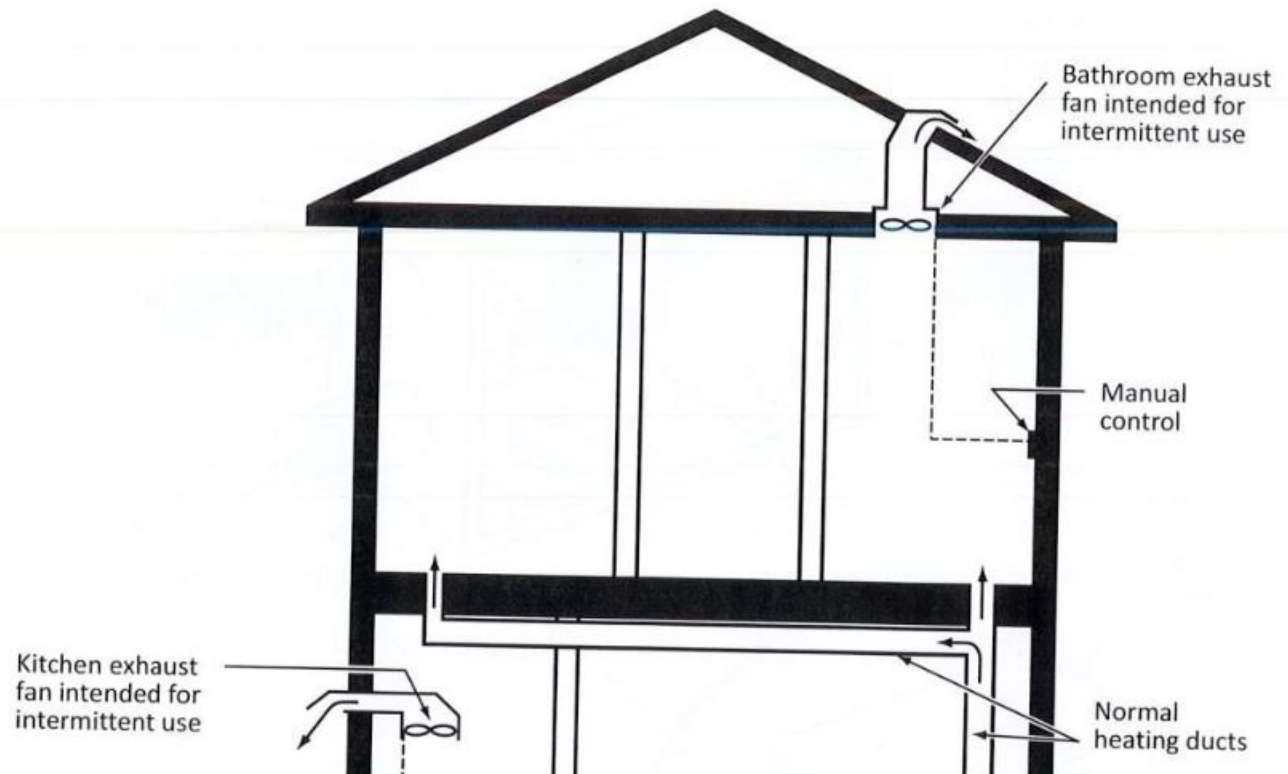
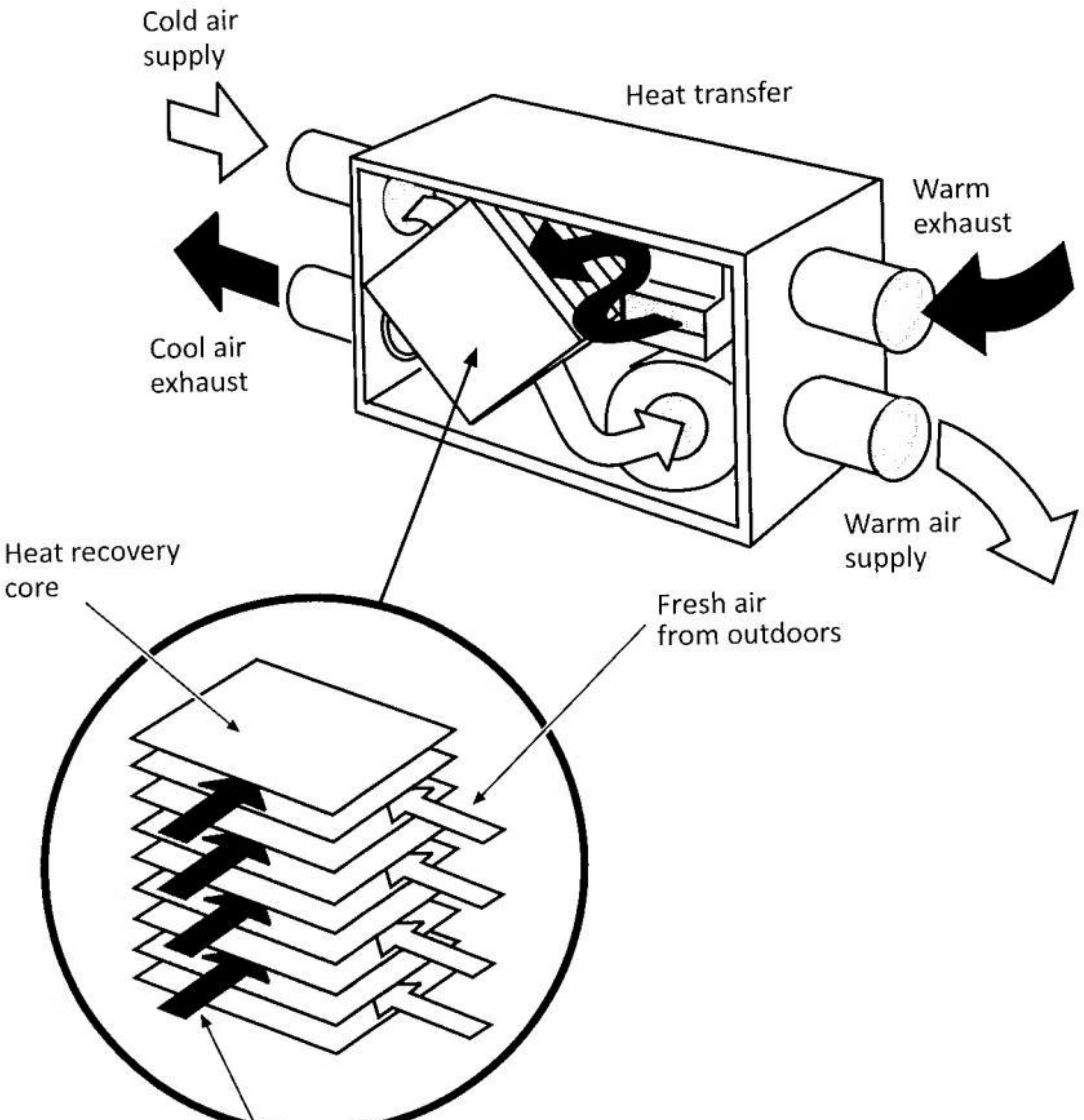
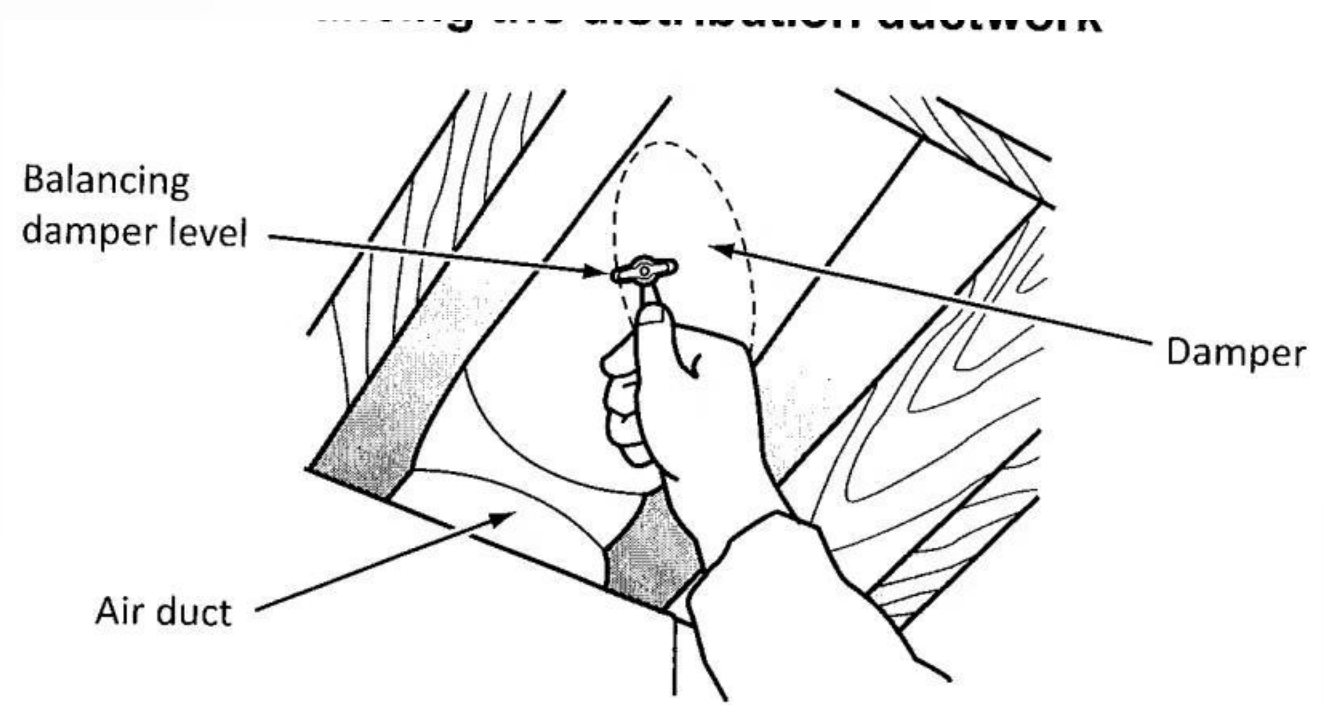


Figure 2-27
A typical HRV system



Mechanical/Electrical Equipment: Duct Balancing



Importance of Balancing

Direct-ducted systems provide the greatest control over the flows of air, heat, and moisture that is possible for each of the pressure control types.

Balancing of each duct is required for best results. This ensures that the right amount of air is delivered to or removed from each space according to its requirements.

Recirculating Distribution Systems

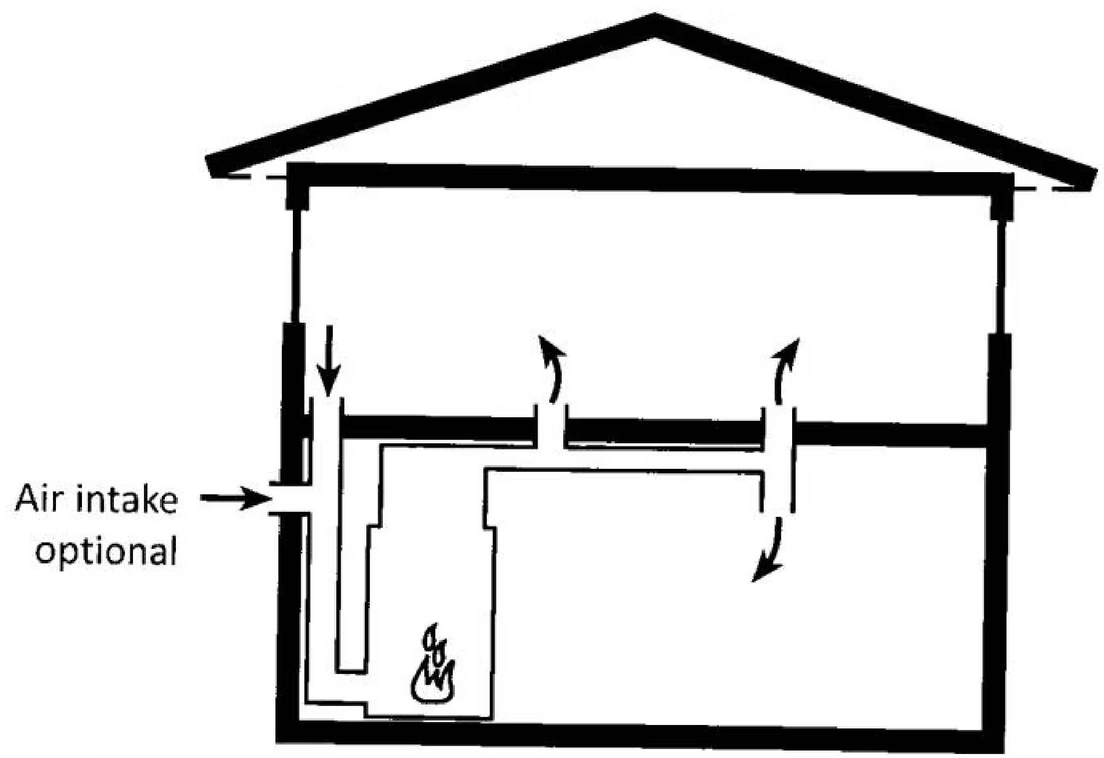
Recirculating (or combination) distribution systems have as their primary purpose the recirculation of air between parts of the house. These systems also employ ductwork to deliver and remove air from each room or area and may have a connection to outside air for exhaust or supply.

However, the percentage of outside air supply moved through the ductwork is minor compared to the volumes recirculated within the house.

Figure 2-28
Balancing the distribution ductwork

Mechanical/Electrical Equipment: Through-the-Wall Systems

Figure 2-29
Recirculating distribution system



System Operation

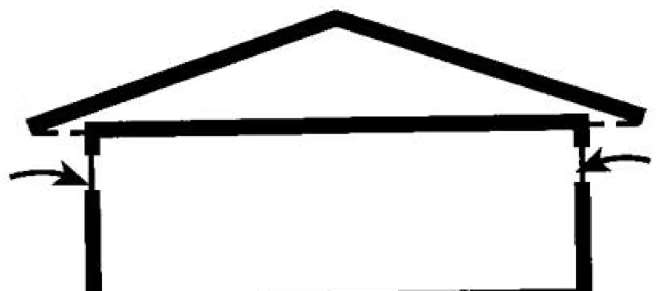
Through-the-wall distribution systems are only used with exhaust-only mechanical ventilation systems. These systems consist of air intake openings positioned high on exterior walls to allow a more controlled outside air supply compared to accidental infiltration.

The negative pressure created by the exhaust fan(s) causes air to enter through the designed inlet diffusers. Less air is drawn through cracks in the building envelope and the negative pressure in the house is reduced.

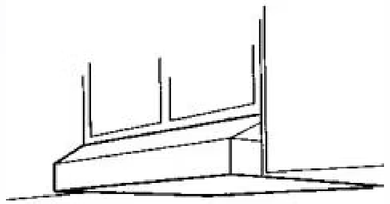
Design Considerations

The high inlets move the warm air away from the ceilings and allow some preheating before reaching the occupants. A separate circulation system is necessary for even distribution of fresh air.

These systems are never used in houses taller than two storeys, because the upper inlets would be overwhelmed by the stack effect, thus increasing negative building pressure.

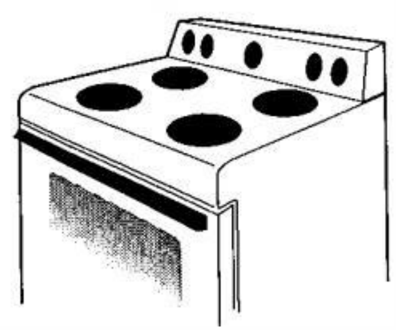


Mechanical/Electrical Equipment: Other Household Devices



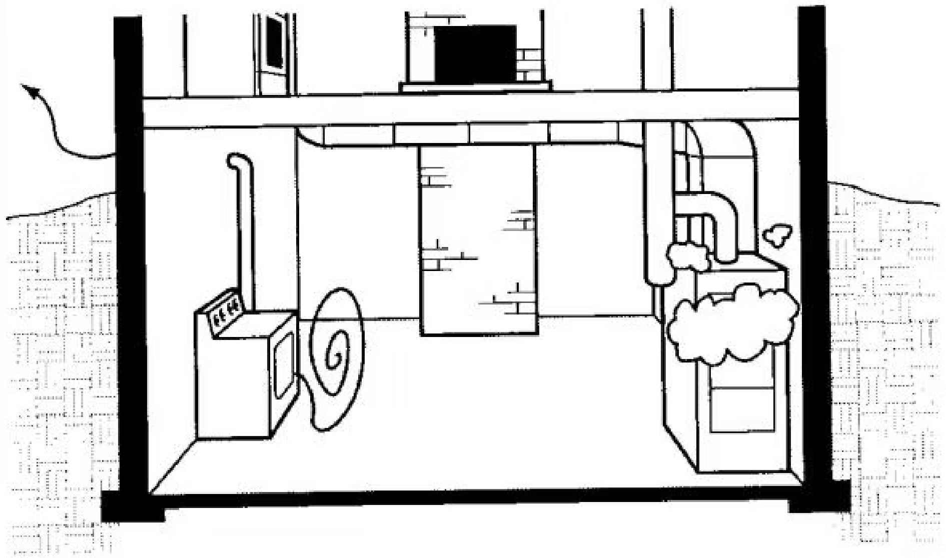
Device	Description
Ranges and ovens	These cooking devices contribute not only heat and odours to the house but also dangerous gases in the case of gas units.
Clothes dryers	The exhaust capacity of most clothes dryers exceeds 85 L/s (180 cfm). For a 1200 ft^2 bungalow, the clothes drier alone would effect a 0.6 air change per hour. The clothes dryer vent must terminate outdoors. The practice of drying clothes indoors or venting the drier indoors can add 10 L of moisture per week to a house with a family of four. Venting gas-fired dryers outdoors is critical for preventing recirculation of combustion gases within the house.
Washing machines	Whether washing clothes or dishes, these machines can add as much as 4 L of moisture per week to a house with a family of four. Added ventilation to the area may be required.
Refrigerators	The heat and moisture effects of a refrigerator add another variable. Some older units may add 3 or 4 times as much moisture to the building as newer, better-insulated models.

Mechanical/Electrical Equipment: More Household Devices



Device	Description
Humidifiers and dehumidifiers	The presence or absence of these devices will affect the level of control over the flow of moisture in a house. Proper installation and maintenance are essential.
Air cleaners	If or where these devices are installed and how they are maintained will have a great effect on air, heat, and moisture flow. Filters on recirculating kitchen fans or supply intake fans are as important to consider as the one on the forced-air furnace.
Central vacuum cleaners	If these devices are vented outdoors, they can cause significant building depressurization during operation.
Lighting and electrical appliances	The heat produced from all electrical devices, especially incandescent lighting, has a significant effect on comfort levels. Exceptional usage should be factored into any assessment of the building system.

Occupants: Impact on Building Systems



Occupant Variability

The effect of the occupants on the other components of the building system and on the flow of air, heat, and moisture is the most variable and difficult to predict. It is that variability and unpredictability that the building envelope and mechanical/electrical equipment have to respond to in maintaining a comfortable indoor environment.

Occupant Categories

Although the greatest variance in conditions comes from the activities of the human occupants, other items in this occupant category must also be considered. These include:

- Animals
- Plants
- Furnishings, carpets, and fabrics
- Food, cleaning products, chemicals (cosmetics, hobby supplies)
- Firewood or other moisture-laden material stored indoors

Occupants: Assessment Considerations

Issue	Description
The number and age of the human occupants	The range of flow effects created by an elderly couple will be significantly different from that created by a young family of four. An elderly couple usually wants the room temperature and humidity higher, opens doors less, and has fewer activities that have a negative impact on indoor air quality. The flow of air, heat, and moisture will be more difficult to control with more and younger occupants.
Activities of the human occupants	Activities that require extensive use of exhaust systems can have a significant effect on the building and appliance operation. These activities may include hobbies such as woodworking and commercial or home-based businesses such as cooking. The gas technician/fitter should note and consider unusual activities that could potentially affect the flow of heat, air, or moisture and/or affect air quality.
Unusual number or special characteristics of plants and animals	A building with a large number of plants or animals will alter the building as a system. An increased moisture level is the main concern, but air quality and air consumption issues may also pose problems for gas appliances.

Occupants: More Assessment Considerations

Issue	Description
Type and condition of the furnishings	A home full of antique wood furniture will require more attention to heat distribution and humidity levels compared to a home with metal or plastic furniture. The position of the furniture in relation to the heating and ventilation distribution registers should also be observed, as blocked registers can adversely affect the operation of a gas appliance.
Type and location of the floor coverings	The occupant's choice of tile or carpet over a radiant floor heating system can affect the performance of the appliance. Area rugs or carpets that block forced air registers can adversely affect the operation of a gas appliance.
Odours and use of chemicals	Warning signs of inadequate ventilation or improper use or storage of chemicals are quickly detected by the technician's/fitter's nose when entering the building. Consideration should be given to how these odours indicate problems that may affect the building as a system as well as any gas appliances.
Unusual water uses	Maintaining large open aquariums and drying clothes indoors are just two activities that can adversely increase moisture levels in a building.

Occupants: Advice on Air Flow

Figure 2-33
Sidewall vent terminations must remain unobstructed

Recommendations for Occupants

In most cases, the resolution to problems created by the occupants is education. The gas technician/fitter should be able to explain why the effects require correction and give advice on how the problems can be resolved by the occupants.

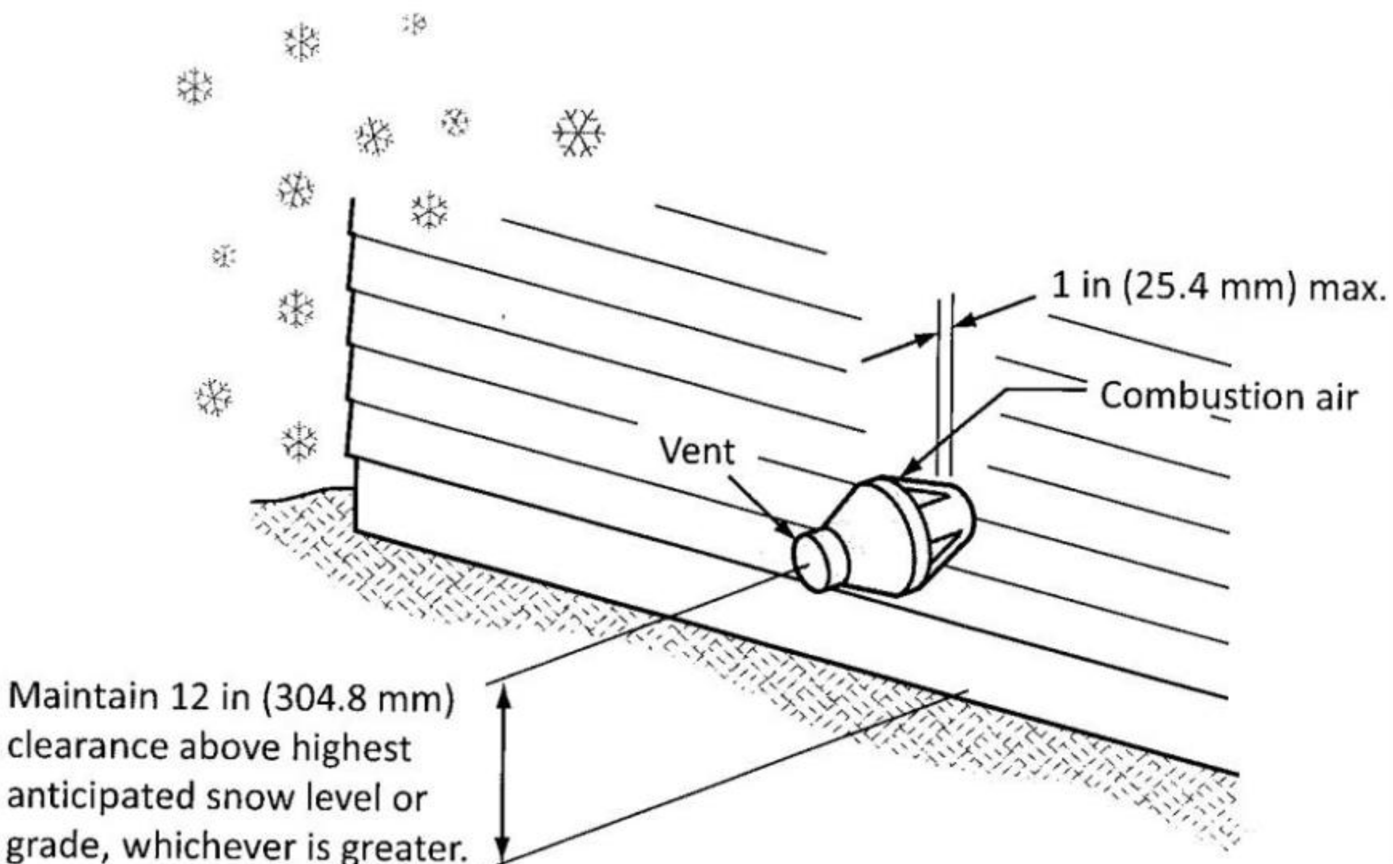
The following recommendations can help occupants improve air flow in their homes:

- Provide wind breaks on the windward side of the house
- Air seal the house, especially the upper floors and ceiling
- Install, use, or maintain a mechanical ventilation system
- Open a window when using a wood fireplace
- Keep air supply inlets clear to an appliance or appliance room

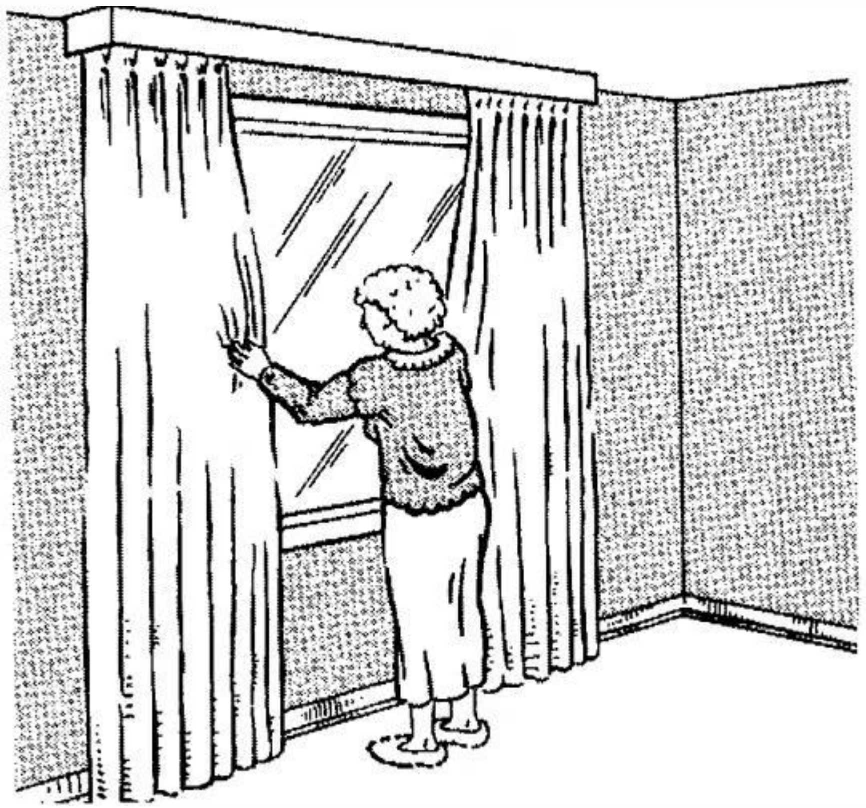
Air Supply Inlet Maintenance

The outside termination of the air supply inlet to the appliance or to an appliance room must remain unobstructed by plants or snow.

For appliances that use indoor air supplied from the outdoors by a vent or duct, the inside termination must also remain unobstructed. If you find that it is intentionally blocked and the customer complains about the continuous cold air draft proceeding from the opening, this may indicate that there is a negative building pressure or prevailing wind problem.



Occupants: Advice on Heat Flow



Heat Flow Recommendations

The following are examples of advice that can be given to the occupants regarding their effect on heat flow:

- Provide the building with better exposure to sunlight
- Install insulation or better windows in the building envelope
- Replace an exhaust-only or supply-only ventilation system with a heat recovery ventilator
- Do not obstruct return or supply air registers with furniture/carpets
- Open drapes/curtains during the day and close them at night

Window Management

The image shows how occupants can positively affect heat loss/gain by use of drapes. Opening curtains during the day allows solar heat gain, while closing them at night reduces heat loss through windows.

This simple practice can significantly improve comfort and reduce heating costs, especially in homes with older, less efficient windows.

Occupants: Advice on Moisture Flow

Exterior Water Management

Direct eavestrough flow away from house and grade lawn away from foundation to prevent water infiltration

Building Maintenance

Repair water leaks in building envelope, especially basements, to prevent moisture damage

Ventilation Use

Install and operate exhaust fans in bathrooms and kitchen to remove moisture at the source

Indoor Moisture Sources

Cover aquariums and do not dry clothes indoors to reduce indoor humidity levels

Dryer Venting

Never vent a clothes dryer into the building - this is especially dangerous for gas-fired dryers as combustion gases with potentially poisonous gases are also emitted

Occupants: Advice on Air Quality

Vehicle Exhaust Management

Reduce exposure to vehicle exhaust by not running vehicle in the garage. Install tight-fitting, self-closing door to attached garage to prevent exhaust gases from entering living spaces.

Pollutant Control

Eliminate, separate, ventilate, or filtrate any pollutants. This may include proper storage of chemicals, adequate ventilation during activities that produce pollutants, and use of air filtration systems.

Safe Storage

Remove contaminants to a safe outdoor storage location. Many household chemicals, paints, and solvents release volatile organic compounds that can affect indoor air quality and potentially interfere with proper combustion in gas appliances.

Regular Maintenance

Ensure regular maintenance of all combustion appliances and ventilation systems to maintain proper operation and prevent air quality issues from developing.

Building as a System: Integrated Approach

Outside Environment

Climate, terrain, and outdoor air quality affect the building's performance

Building Envelope

Controls the flow of air, heat, and moisture between inside and outside

Occupants

Activities and choices significantly impact building performance

Mechanical Systems

Heating, ventilation, and other equipment maintain comfort and air quality

The building-as-a-system approach is based on the principle that every change that occurs in and around the building has the potential for improving and/or deteriorating the system. As such, the wide range of changes by the occupants—human and other—must be considered for their effects on the entire building system, especially gas-fired appliances.

Gas Technician's Role in Building System Assessment

Comprehensive Assessment

Evaluate all four subsystems (outside environment, building envelope, mechanical/electrical systems, and occupants) to understand their interactions

Problem Identification

Recognize how issues in one subsystem can affect gas appliance operation and safety

Appropriate Solutions

Implement solutions that address the root cause rather than just symptoms

Customer Education

Provide guidance to occupants on how their actions affect building performance and appliance operation

Summary: Building as a System

Key Principles

Understanding the building as a system requires recognizing that all components interact with each other. The flow of air, heat, and moisture through a building is affected by:

- The outside environment (climate, terrain, outdoor air quality)
- The building envelope (construction type, insulation, air/vapor barriers)
- Mechanical/electrical systems (heating, ventilation, appliances)
- Occupants (activities, choices, lifestyle)

Gas Technician's Perspective

For gas technicians/fitters, this systems approach is essential for:

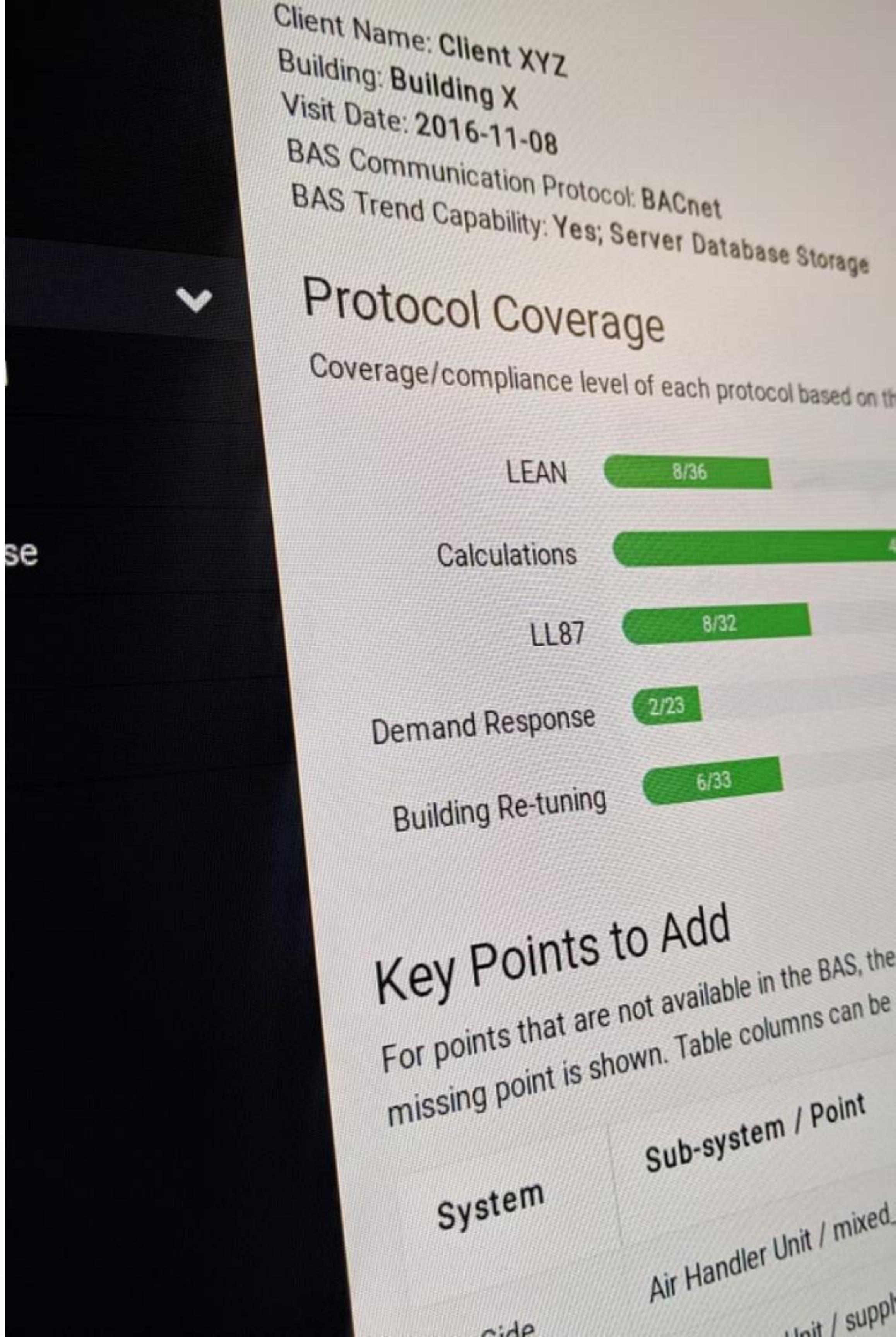
- Proper appliance selection and sizing
- Safe installation practices
- Effective troubleshooting
- Ensuring customer comfort and safety
- Preventing problems before they occur

By understanding how each subsystem affects the flow of air, heat, and moisture, gas technicians can anticipate problems and provide solutions that address the root causes rather than just symptoms.

CSA Unit 14

Chapter 3
Assessment Tools for the Building as a System

This presentation provides an overview of important procedures that gas technicians/fitters should be aware of to carry out their duties and responsibilities to the customer. These procedures require an appreciation of the building-as-a-system approach, focusing on heat loss calculation methods and ensuring safe venting of gas appliances.



Purpose of Assessment Tools

Heat Loss Calculation

Introduces and encourages the use of heat loss calculations to ensure that space-heating appliances are appropriate for the installation.

Safe Venting Procedures

Ensures the safe venting of gas appliances given the variables of a specific building system or renovation.

Building-as-a-System Approach

Addresses the interrelationship between all components of a building that affect combustion and venting.

Key Assessment Procedures

Heat Loss Calculation Methods

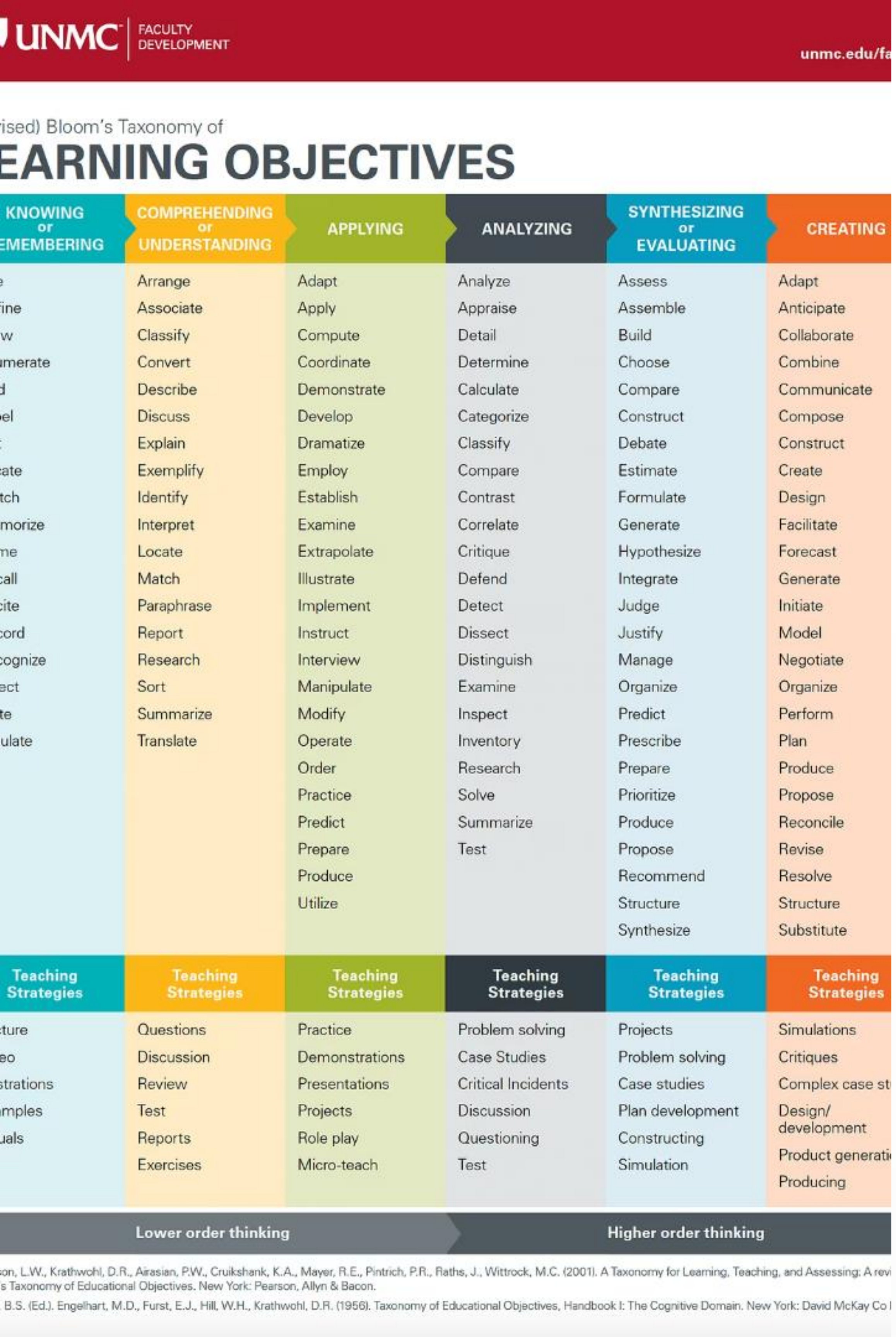
Employed to ensure that the space-heating appliance is appropriate for the installation.

Assessment, Check, Test (ACT) Procedure

Created by Canada Mortgage and Housing Corporation (CMHC) to provide simple tools to ensure safe venting at every installation.

House Depressurization Field Test

Conducted if spillage was detected during the basic test and/or there is reason to suspect a spillage problem exists.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ised) Bloom's Taxonomy of

EARNING OBJECTIVES

KNOWING or EMEMBERING	COMPREHENDING or UNDERSTANDING	APPLYING	ANALYZING	SYNTHESIZING or EVALUATING	CREATING
e	Arrange	Adapt	Analyze	Assess	Adapt
ine	Associate	Apply	Appraise	Assemble	Anticipate
w	Classify	Compute	Detail	Build	Collaborate
umerate	Convert	Coordinate	Determine	Choose	Combine
d	Describe	Demonstrate	Calculate	Compare	Communicate
el	Discuss	Develop	Categorize	Construct	Compose
:	Explain	Dramatize	Classify	Debate	Construct
ate	Exemplify	Employ	Compare	Estimate	Create
tch	Identify	Establish	Contrast	Formulate	Design
morize	Interpret	Examine	Correlate	Generate	Facilitate
me	Locate	Extrapolate	Critique	Hypothesize	Forecast
call	Match	Illustrate	Defend	Integrate	Generate
cite	Paraphrase	Implement	Detect	Judge	Initiate
cord	Report	Instruct	Dissect	Justify	Model
cognize	Research	Interview	Distinguish	Manage	Negotiate
ect	Sort	Manipulate	Examine	Organize	Organize
te	Summarize	Modify	Inspect	Predict	Perform
ulate	Translate	Operate	Inventory	Prescribe	Plan
		Order	Research	Prepare	Produce
		Practice	Solve	Prioritize	Propose
		Predict	Summarize	Produce	Reconcile
		Prepare	Test	Propose	Revise
		Produce		Recommend	Resolve
		Utilize		Structure	Structure
				Synthesize	Substitute
Teaching Strategies	**Teaching Strategies**	**Teaching Strategies**	**Teaching Strategies**	**Teaching Strategies**	**Teaching Strategies**
ture	Questions	Practice	Problem solving	Projects	Simulations
eo	Discussion	Demonstrations	Case Studies	Problem solving	Critiques
strations	Review	Presentations	Critical Incidents	Case studies	Complex case st
mples	Test	Projects	Discussion	Plan development	Design/ development
uals	Reports	Role play	Questioning	Constructing	Product generati
	Exercises	Micro-teach	Test	Simulation	Producing

Lower order thinking | Higher order thinking

on, L.W., Krathwohl, D.R., Airasian, P.W., Cruikshank, K.A., Mayer, R.E., Pintrich, P.R., Raths, J., Wittrock, M.C. (2001). A Taxonomy for Learning, Teaching, and Assessing: A revi
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Learning Objectives

Describe Heat Loss Calculation

Understand the principles and purpose of heat loss calculation methods.

Explain ACT Procedure

Describe how to assess, check, and test a building for negative effects on gas appliances.

Measure House Depressurization

Describe how to measure house depressurization and interpret the results.

Key Terminology

Term	Abbreviation (symbol)	Definition
Assessment, check, test	ACT	Procedure designed by CMHC to assist technicians/fitters in determining when and how to investigate pressure-induced backdrafting using the building-as-a-system approach.
Heat loss ΔT	HL ΔT	The difference between indoor design temperature and outdoor design temperature.
Total ventilation capacity	TVC	The total amount of air being exhausted from a building.

Heat Loss Calculation Methods

The primary function of a space-heating appliance is to replace the heat lost by the building at a rate and in a manner that provides consistent comfort to the occupants. An improperly sized heating system will create significant problems.

Heating Discomfort

Occupants may experience inconsistent or inadequate heating.

Structural Damage

Frozen pipes if undersized and condensation in the chimney if oversized.

Appliance Damage

Damage resulting from long cycles or short cycles.

Energy Inefficiency

Excessive electricity use if undersized and excessive fuel use if oversized.

Basic Principles of Heat Loss Calculation

Room-by-Room Calculation

Although the overall calculation for the heat loss of the building is necessary to determine the size of the furnace or boiler, a calculation of heat loss on a room-by-room basis is required to size the distribution system.

Most methods use a room-by-room calculation and add the individual room requirements to determine the total heat loss.

Sizing Guidelines

The output of the heating appliance must never be less than the total calculated heat loss nor exceed it by more than 40%.

This ensures the system is neither undersized (causing discomfort) nor grossly oversized (causing inefficiency and potential damage).

Organizations Developing Heat Loss Methods

ASHRAE

American Society of Heating, Refrigeration and Air Conditioning Engineers

Hydronics Institute

Division of the Gas Appliance Manufacturers of America (GAMA)

CIPH

Canadian Institute of Plumbing and Heating

HRAI

Heating, Refrigeration and Air Conditioning Institute

HRAI is probably the most detailed and commonly used method in Canada. Some municipalities require submission of a heat loss calculation conducted using a recognized method before permitting construction or renovation of a residence.

Heat Loss Coefficient is Heat Loss Parameter per unit area

Floor	U_{floor}	A_{floor}	$U_{floor} * A_{floor}$
Roof	U_{roof}	A_{roof}	$U_{roof} * A_{roof}$

Heat Loss Calculation Example

Heat loss calculations are based on maintaining a design indoor temperature (18, 20, or 22 °C) against a design outdoor temperature. The design outdoor temperature is based on data from the local weather department or a list provided with the heat loss training manual.

Average temperatures in Ottawa

Outdoor design temperature	°C	Mean soil design temperature	°C
-25	-13	10	50

Design Temperature Difference

Definition

The difference between the selected indoor design temperature and the outdoor design temperature is the design temperature difference.

This will be used in calculating heat losses through all above-grade walls and ceilings directly exposed to the outdoor temperature.

Calculation Example

For a house in Ottawa that desires an indoor temperature of 22 °C:

Heat loss ΔT = Indoor design temp. - Outdoor design temp.

Heat loss $\Delta T = 22\,°C - (-25\,°C) = 47\,°C$

Heating System Sizing Considerations

Thermal Resistance

Thermal resistance of walls, ceilings, floors, windows, and doors directly exposed to outdoor temperatures

Air Change

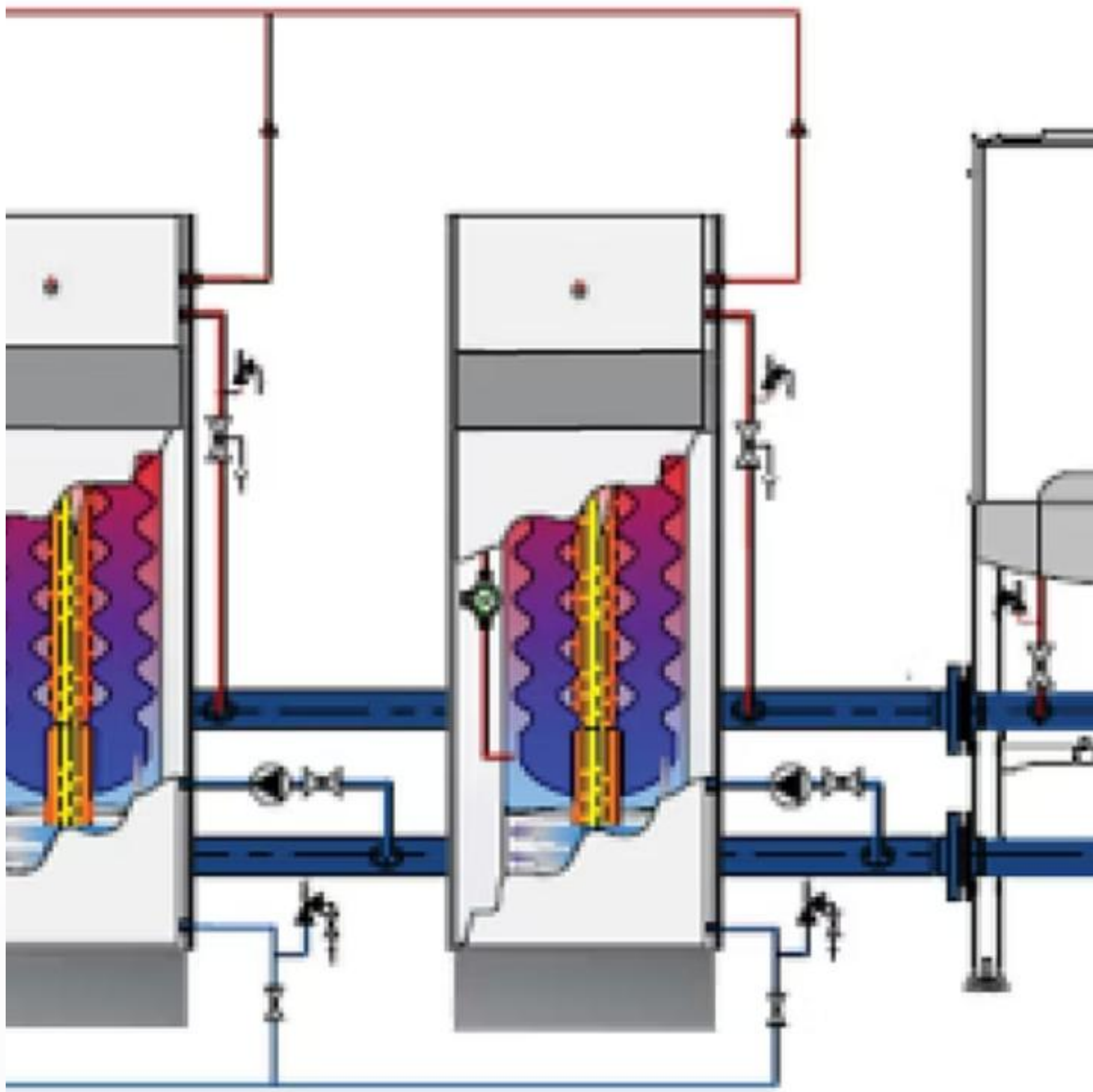
Air change caused by uncontrolled air leakage through cracks and openings in the building

Distribution Heat Loss

Duct or pipe heat loss from the distribution system passing through unheated spaces

Ventilation Heat Loss

Heat loss from mechanical ventilation systems



Calculating Thermal Resistance

Wall Construction Example

The thermal resistance of walls, ceilings, floors, and headers is calculated using reference data on wall types and building envelope materials.

The RSI value is the sum of the resistance of each layer of material in the wall, floor, etc.

Wall material	Thermal resistance (RSI)
10 cm brick	0.08
2 cm air space	0.18
2 cm plywood	0.18
10 cm fibreglass	2.11
2 cm gypsum board	0.09
Total thermal resistance of wall	2.64

Calculating Conductive Heat Loss

Calculation Method

A thermal resistance for each type of wall, ceiling, or floor construction is determined and then converted to a heat loss multiplier by dividing the design temperature difference by the total thermal resistance.

This factor can be multiplied by the wall area in m^2 or ft^2 to determine the conductive heat loss in Btu/h or kW/h for that particular section.

Example Calculation

For a 2 m high × 3 m long wall with a 1 m square window in Ottawa:

Wall heat loss = HL ΔT × (Wall area – Window area) ÷ RSI

Wall heat loss = 47 °C × 5 m^2 ÷ 2.64 RSI = 89 Watts (304 Btu/h)

Note: Watts can be converted to Btu/h by formula: 1 W = 3.412 Btu/h

Window Heat Loss Calculation

Window Heat Loss

The heat loss from windows is calculated using the same method with reference to information tables on the thermal resistance of common window types.

Example Calculation

For a 1 m square double-glazed window with Low-E having an RSI value of 0.49:

Window heat loss = HL ΔT × Window area ÷ RSI

Window heat loss = 47 °C × 1 m^2 ÷ 0.49 RSI = 96 Watts (328 Btu/h)

Therefore, the total heat loss from the room with one exposed wall and a window is 185 Watts (632 Btu/h).

Calculating Air Leakage

Air Leakage Factors

Air leakage heat loss is determined by reference to:

- Building types (very loose, loose, average, tight, very tight)
- Exposure to wind categories (sheltered, partially sheltered, exposed, extremely exposed)
- Number of storeys (1 to 3)

Example

A house in Ottawa might have an air leakage heat loss factor of 0.3 W/m^2-°C (0.053 Btu/ft^2-°F) because it falls into these categories:

- "Very tight" - new building with a continuous air barrier with sealed joints
- "Partially sheltered" - rural area with low buildings, trees, etc.
- 2-1/2 storeys

This may add another 30% to the heat load for the room.

Distribution and Ventilation Heat Loss

Distribution Heat Loss

Distribution heat losses are factored in by multiplying the room net heat load by a multiplier that considers:

- Type of unheated space the duct or pipes pass through
- How much they are insulated

Reference to simple tables is required for these calculations.

Ventilation Heat Loss

Mechanical ventilation heat loss is calculated by multiplying the total ventilation capacity (TVC) with a constant factor and the HL ΔT.

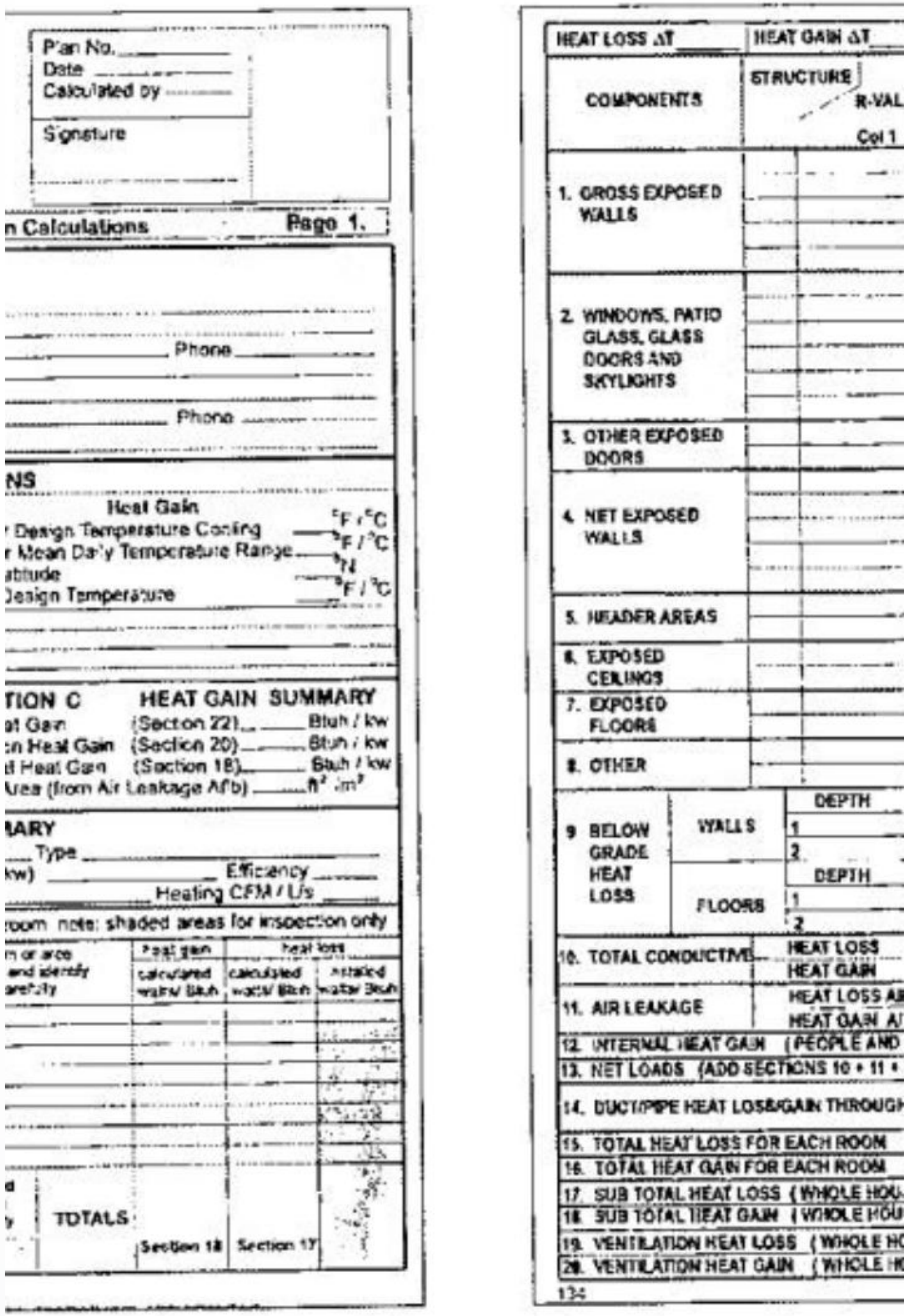
For new homes built to meet the current National Building Code of Canada (NBC), the TVC is the room ventilation required by the NBC.

The furnace/boiler must be sized to heat this outdoor air infiltration to the design indoor temperature.

Heat Loss Calculation Worksheets

Heat loss worksheets are commonly employed to organize calculations. The total heat losses from conduction through walls, windows, etc., accidental air leakage, distribution system, and ventilation are added together to arrive at the total heat loss per room.

The heat loss calculation is much simpler than it may first appear. There are computer programs that simplify the process by filling in basic information gathered from blueprints or simple measurements taken at the site.


Plan No.
Date
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Heat Gain
Design Temperature Cooling °F / °C
Mean Daily Temperature Range °F / °C
Design Temperature °F / °C
HEAT GAIN SUMMARY
(Section 22) Btuh / kw
(Section 20) Btuh / kw
(Section 18) Btuh / kw
Type
Efficiency
Heating CFM / L/s
note: shaded areas for inspection only
TOTALS
Section 18
Section 17
HEAT LOSS ΔT
HEAT GAIN ΔT
COMPONENTS
STRUCTURE
Col 1
1. GROSS EXPOSED WALLS
2. WINDOWS, PATIO GLASS, GLASS DOORS AND SKYLIGHTS
3. OTHER EXPOSED DOORS
4. NET EXPOSED WALLS
5. HEADER AREAS
6. EXPOSED CEILINGS
7. EXPOSED FLOORS
8. OTHER
9. BELOW GRADE HEAT LOSS
WALLS
FLOORS
DEPTH
10. TOTAL CONDUCTIVE
HEAT LOSS
HEAT GAIN
11. AIR LEAKAGE
12. INTERNAL HEAT GAIN
13. NET LOADS
15. TOTAL HEAT LOSS FOR EACH ROOM
16. TOTAL HEAT GAIN FOR EACH ROOM
17. SUB TOTAL HEAT LOSS
18. SUB TOTAL HEAT GAIN
19. VENTILATION HEAT LOSS
20. VENTILATION HEAT GAIN

Importance of Heat Loss Calculations

Understanding Principles

Not every gas technician/fitter has to be able to complete the calculations, but every gas technician/fitter must understand the principles underlying the calculations and why the calculation is absolutely necessary.

System Assessment

It is necessary not only for new installations or replacements but also for an assessment of the performance of an existing system.

Identifying Weaknesses

The process of calculating heat losses exposes the strengths and weaknesses of the building system. In some cases, the problems in the system would be better corrected by caulking or insulation than by increasing the size of the heating appliance.

Depressurization Tests

One of the most important uses of the building-as-a-system approach is to ensure safe combustion and effective venting for fuel-fired appliances. The approach highlights the interrelation between venting and air flow caused by all components of the building system.

Depressurization can occur when the air pressure inside a house is lower than it is outside. It is more frequent in existing houses after they have been retrofitted and airsealed.

ACT Procedure Overview

Purpose

The CMHC ACT procedure is designed to assist technicians/fitters in determining when and how to investigate pressure-induced backdrafting using the building-as-a-system approach.

ACT stands for Assessment, Check, Test.

When to Use

This procedure can be used on:

- New installations
- Service calls where a spillage-susceptible gas-fired appliance is installed
- Whenever flue gas spillage is suspected by the occupants or the gas technician/fitter

Spillage-Susceptible Appliances

Natural-Draft Appliances

Especially susceptible to flue gas spillage due to negative building pressure

Fan-Assist Appliances

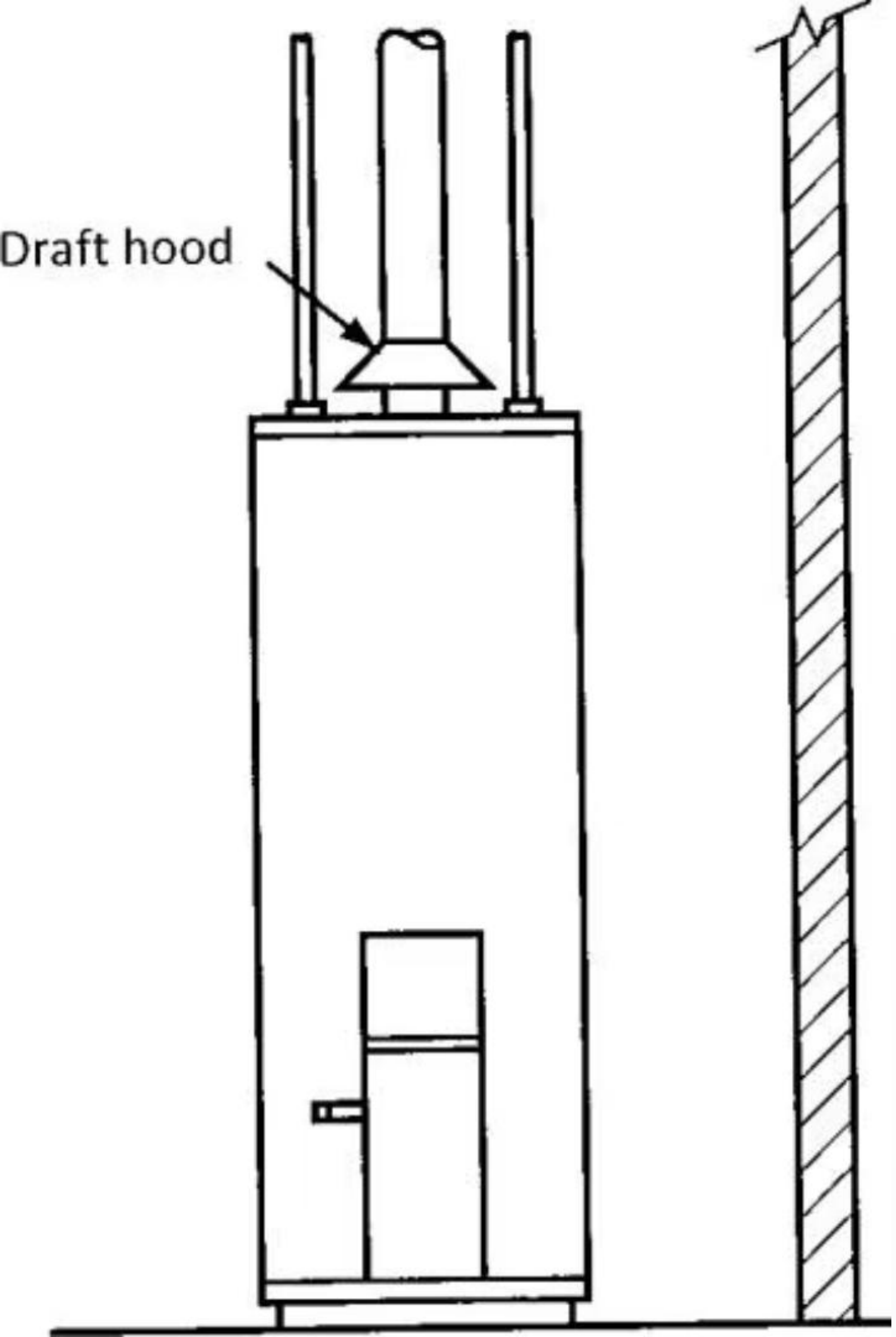
Not as spillage susceptible, but may still spill if negative pressure is severe

Direct Vent Appliances

May leak flue gases if the heat exchanger is cracked or the vent is damaged

Positive-Pressure Vented Appliances

Less susceptible, but any appliance using indoor air for combustion may spill flue gases

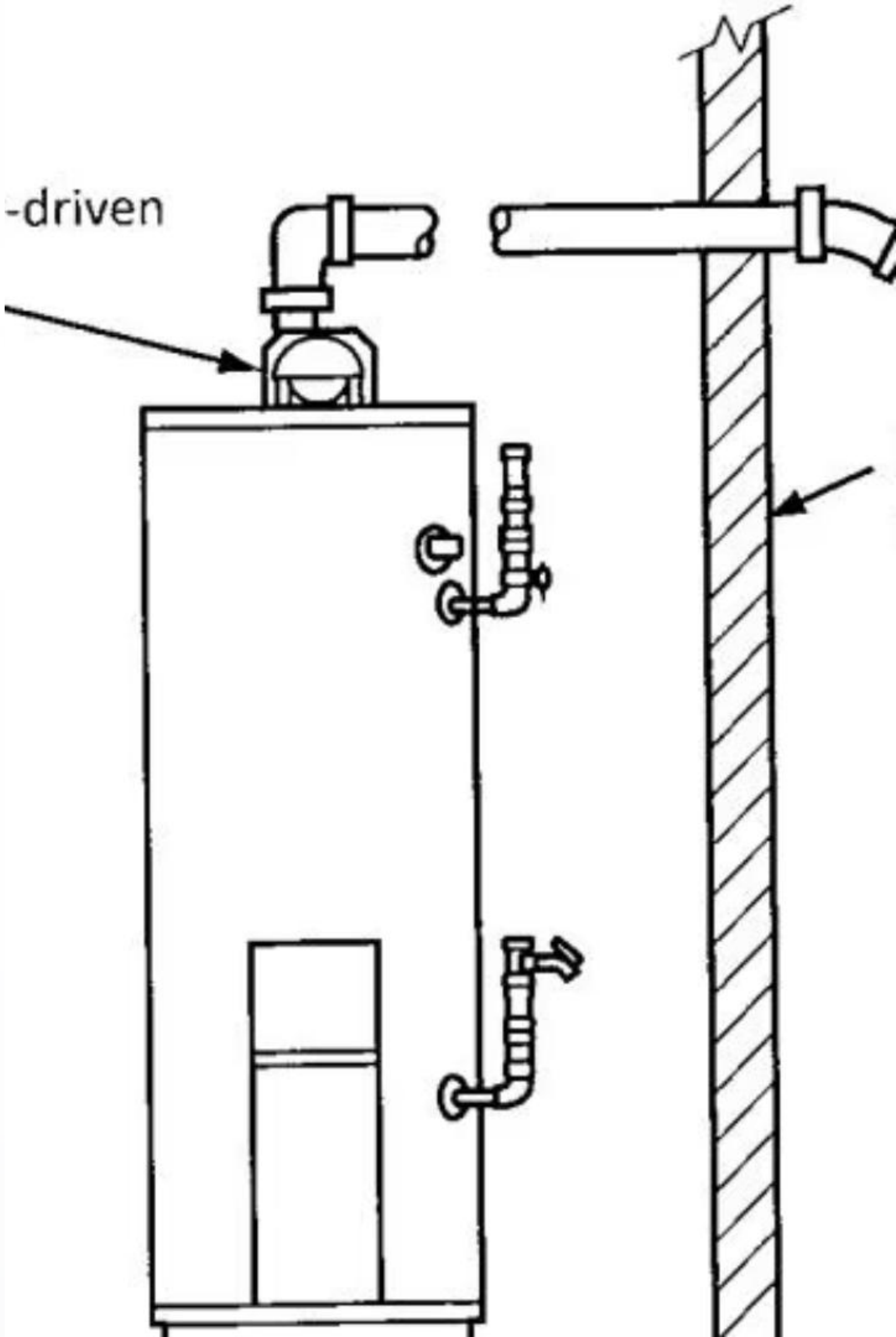


Natural Draft Water Heater

This image shows a spillage-susceptible natural draft water heater. These appliances are particularly vulnerable to backdrafting when negative pressure conditions exist in the building.

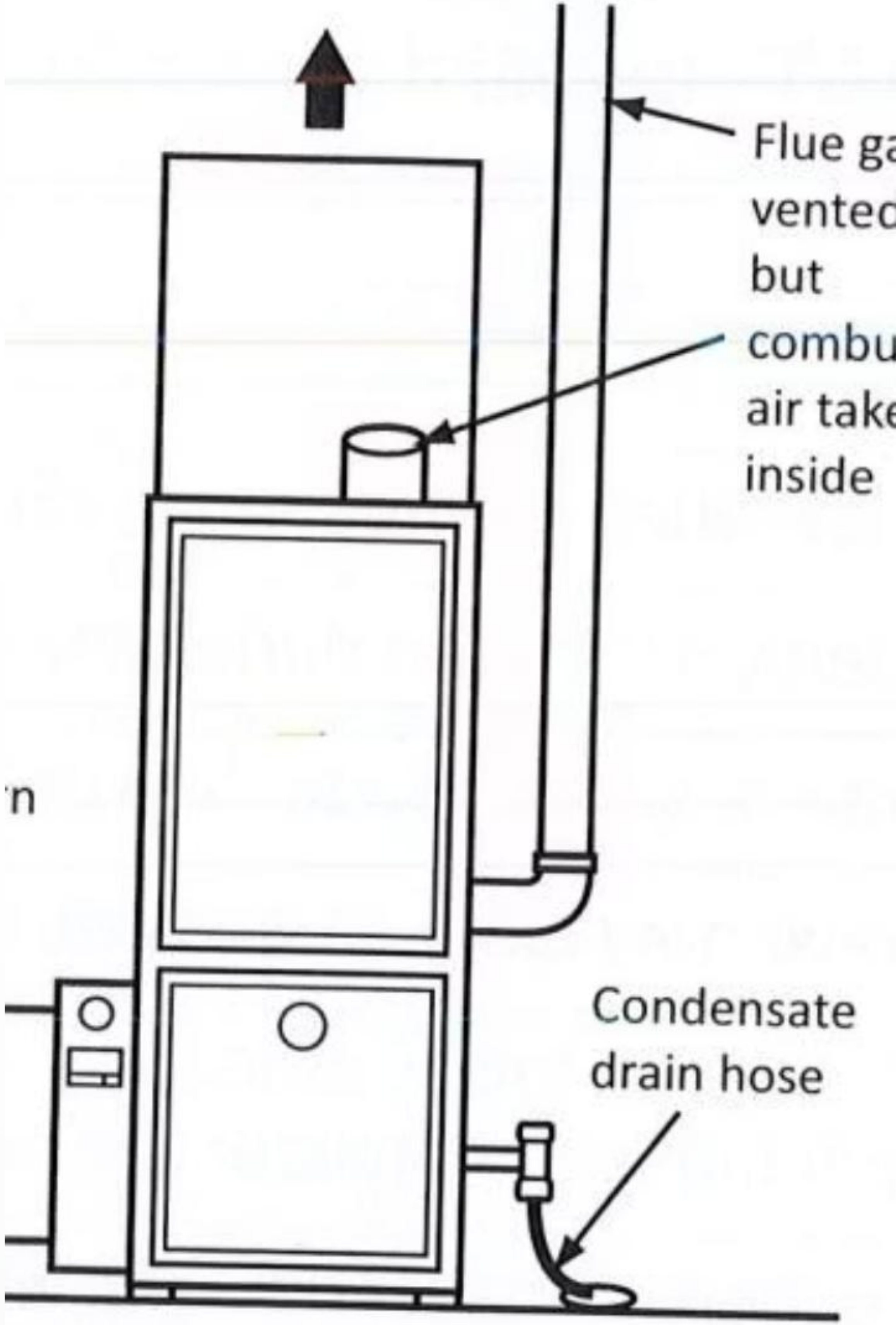
Fan Assist Water Heater

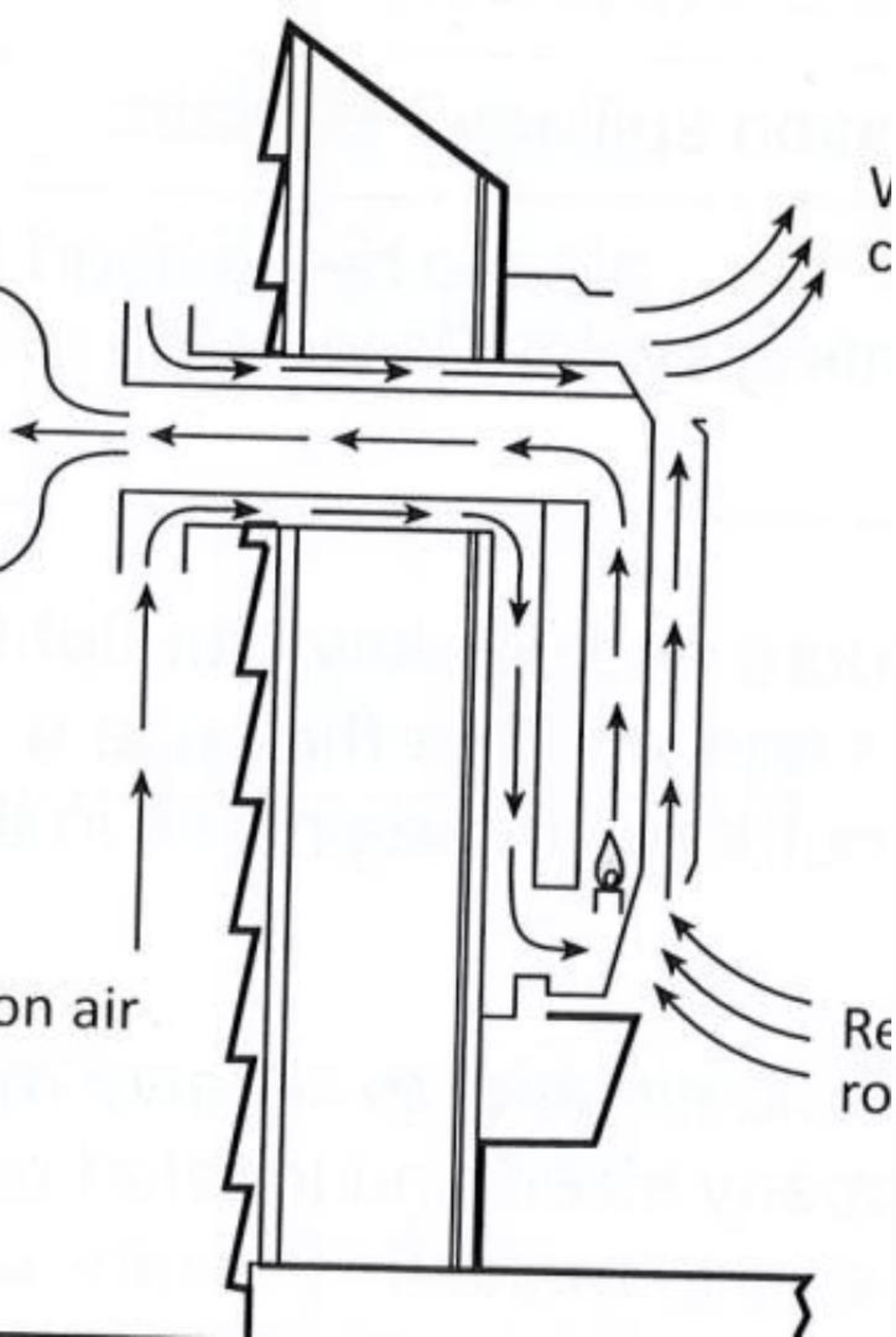
This image shows a less spillage-susceptible fan assist water heater. The fan helps overcome some negative pressure, but these units can still experience spillage under severe conditions.



Positive-Pressure Vented Furnace

This image shows a less spillage-susceptible positive-pressure vented furnace using indoor air for combustion. These units are designed to overcome some negative pressure, but can still be affected by severe depressurization.





Direct Vent Fireplace

This image shows a non-spillage-susceptible direct vent fireplace. These units are designed to bring in combustion air from outside and vent directly to the exterior, making them highly resistant to indoor pressure conditions.

ACT Procedure: Assessment Phase

The assessment phase requires no physical tools but does require a sound understanding of the building as a system. The gas technician/fitter asks the customer a few leading questions, listens carefully to the answers, and conducts a quick visual assessment to determine if the house is tight or loose.

As you approach the house, take note of the environmental conditions, orientation and protection of the house regarding wind and sun, the exterior condition of the envelope (especially exterior vents/chimneys), and any condensation on the window or eaves.

Assessment Checklist Questions

Questions	Yes	No
Are there unusual smells in the house when the heating appliance comes on?		
Has the humidity in the house suddenly increased during the winter months?		
Is the house stuffy? Do family members suffer headaches or flu-like symptoms?		
Has the house been tightened or have new exhaust devices been installed?		
Was the house built after 1970, the exterior totally stuccoed, or has a continuous sealed air barrier been installed such that you consider the house to be tight?		

More Assessment Checklist Questions

Questions	Yes	No
If the house appears to be tight, are there exhaust devices with a combined capacity greater than 75 L/s (150 cfm) and/or an operating wood fireplace?		
If the house does not appear to be tight, are there exhaust devices with a combined capacity greater than 125 L/s (250 cfm) and/or a wood fireplace?		
Are there any symptoms of combustion spillage? Explain:		

If the answer to any of the above is 'Yes', please be advised that our company provides an extra service to ensure that the venting system is working properly. A short test will be performed.

Interior Assessment

Doors and Windows

Check for tightness and proper sealing

Exhaust Devices

Ask about number, type, and usage patterns

Fireplaces

Determine if and when wood fireplaces are used

Odors and Moisture

Note any unusual odors, excessive moisture, or staining around supply air registers

Definition of a "Tight House"

Stucco Exterior

A house in which all exterior walls are entirely covered with stucco

Air-Sealed Older Home

Any older house that has been tightened through air-sealing techniques and has exhaust fans with a total capacity exceeding 125 L/s (250 cfm)

Modern Home with Exhaust

A house built after 1970, with a total exhaust fan capacity exceeding 75 L/s (150 cfm)

Recent Construction

A house built after 1993, no matter what exhaust fans are employed

ACT Procedure: Check Phase

The check portion of the ACT procedure is even easier and quicker to complete. You may already have conducted the outside inspection, shown in the following checklist, on your approach to the house.

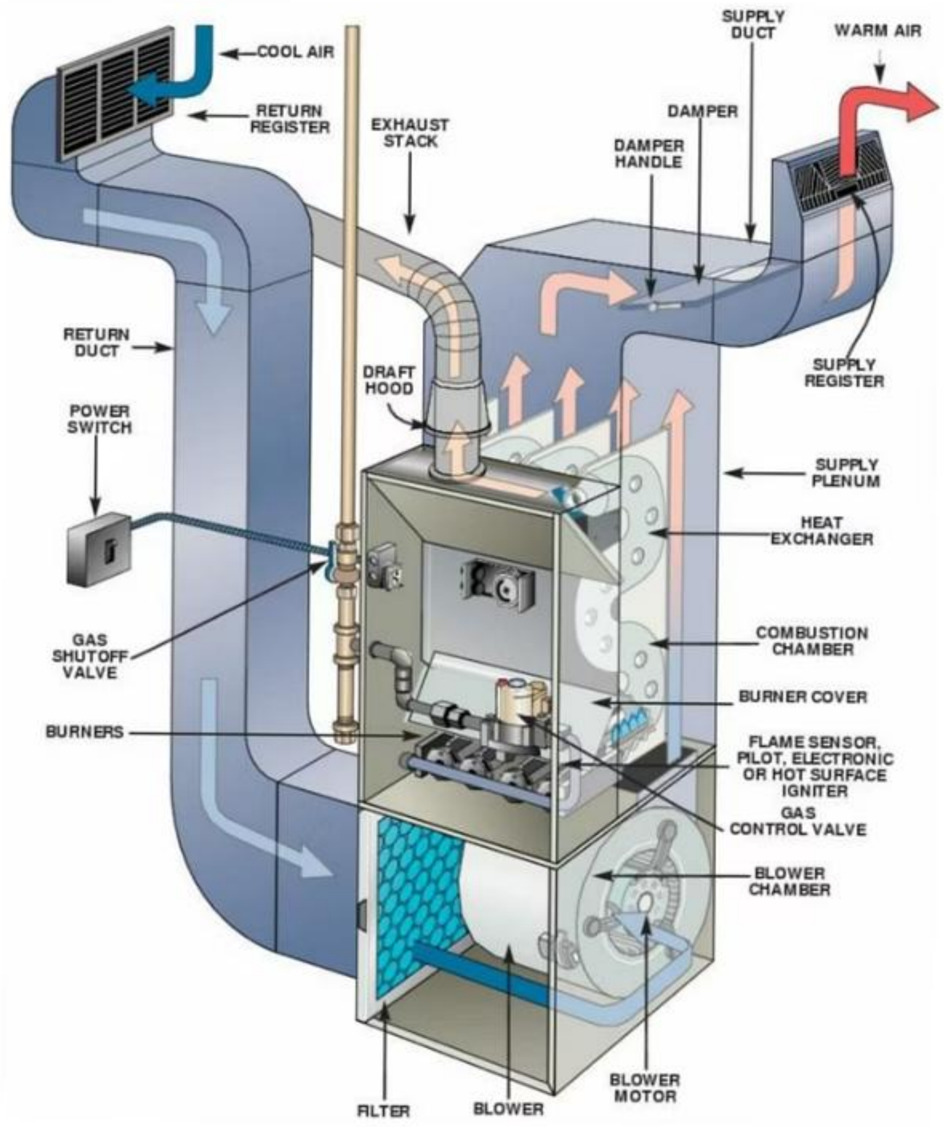
Questions	Yes	No
Does a visual inspection of the chimney or vent exterior indicate:		
· Damage to bricks, mortar, joints or cap?		
· Efflorescence or moisture?		
· Corrosion of exposed metal vent especially the base tee?		

Chimney and Vent Inspection

Questions	Yes	No
Does an inspection (directly and with a mirror) of the chimney or vent clean out indicate:		
· Blockage or obstruction?		
· Pieces of bricks, clay tile or metal dust?		
· Moisture or white sediment?		
· Excessive soot buildup?		

Vent Connector and Heat Exchanger Inspection

Questions	Yes	No
Does an inspection of the vent connector indicate:		
· Moisture or soot stains at the joints?		
· Corrosion?		
· Excessive soot buildup?		
Are there any symptoms of a cracked heat exchanger such as:		
· Occupants report odours during appliance operation or startup.		



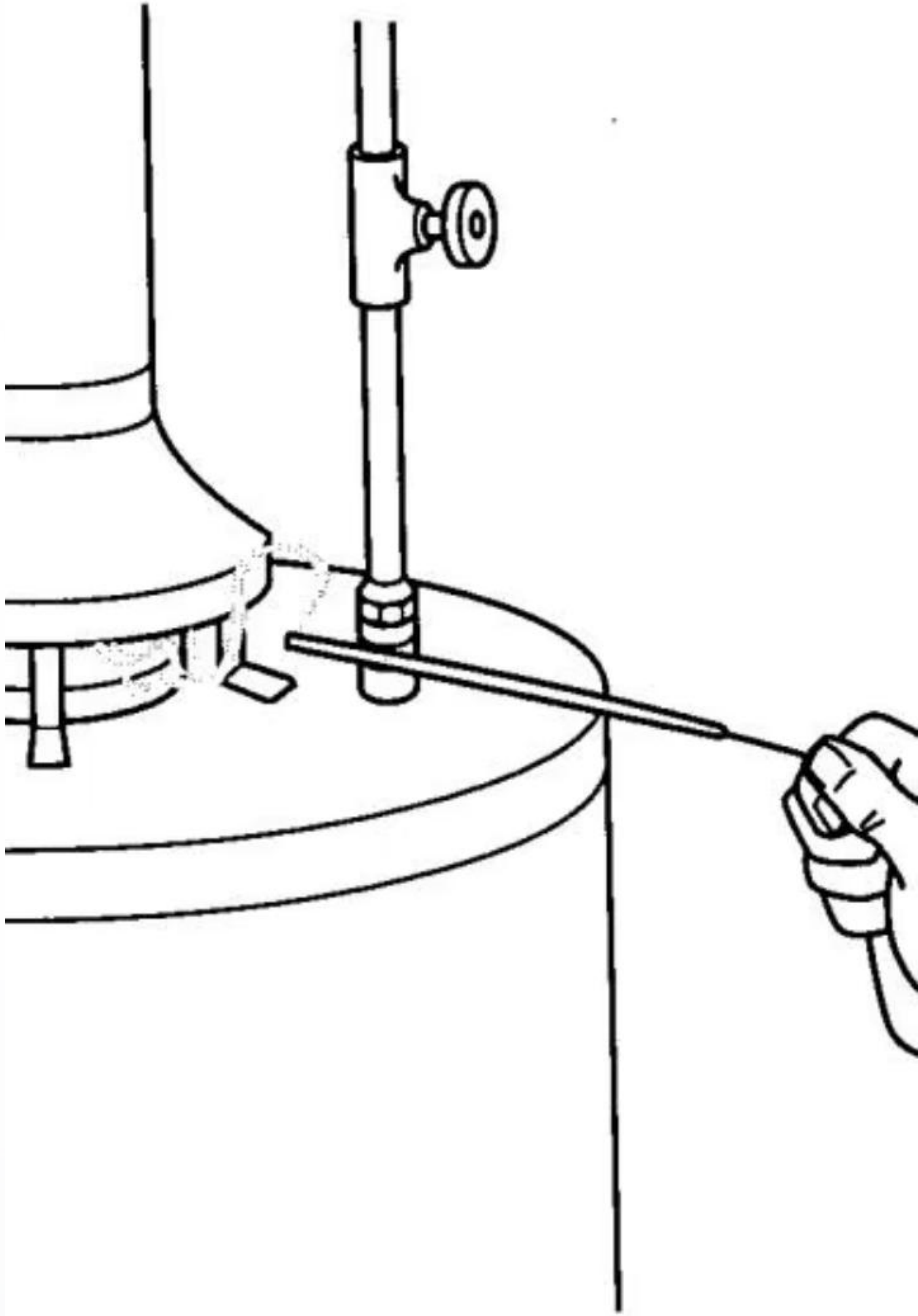
Additional Heat Exchanger Symptoms

Questions	Yes	No
· An O_2 or CO_2 test indicates dilution of the flue gases after the air circulating blower starts or, in the case of all appliance types, the O_2 or CO_2 values cannot be reduced and are higher over-the-fire compared to at the breech.		
· Soot or oily deposits at the duct joints or supply registers.		
· There are other indicators of spillage: excessive moisture or health complaints from the occupants.		

If the visual assessment of the chimney or vent and connector indicates any significant problems, a more detailed assessment may be required to determine the cause.

Smoke Test for Spillage

This image shows a smoke test conducted at the draft hood to indicate whether flue gases are spilling into the room or venting properly. Draft tests or a smoke test may be conducted during the Check portion of the ACT procedure. Any signs of spillage may justify a basic venting test to determine the cause of spillage, such as blockage in the chimney.



ACT Procedure: Test Phase

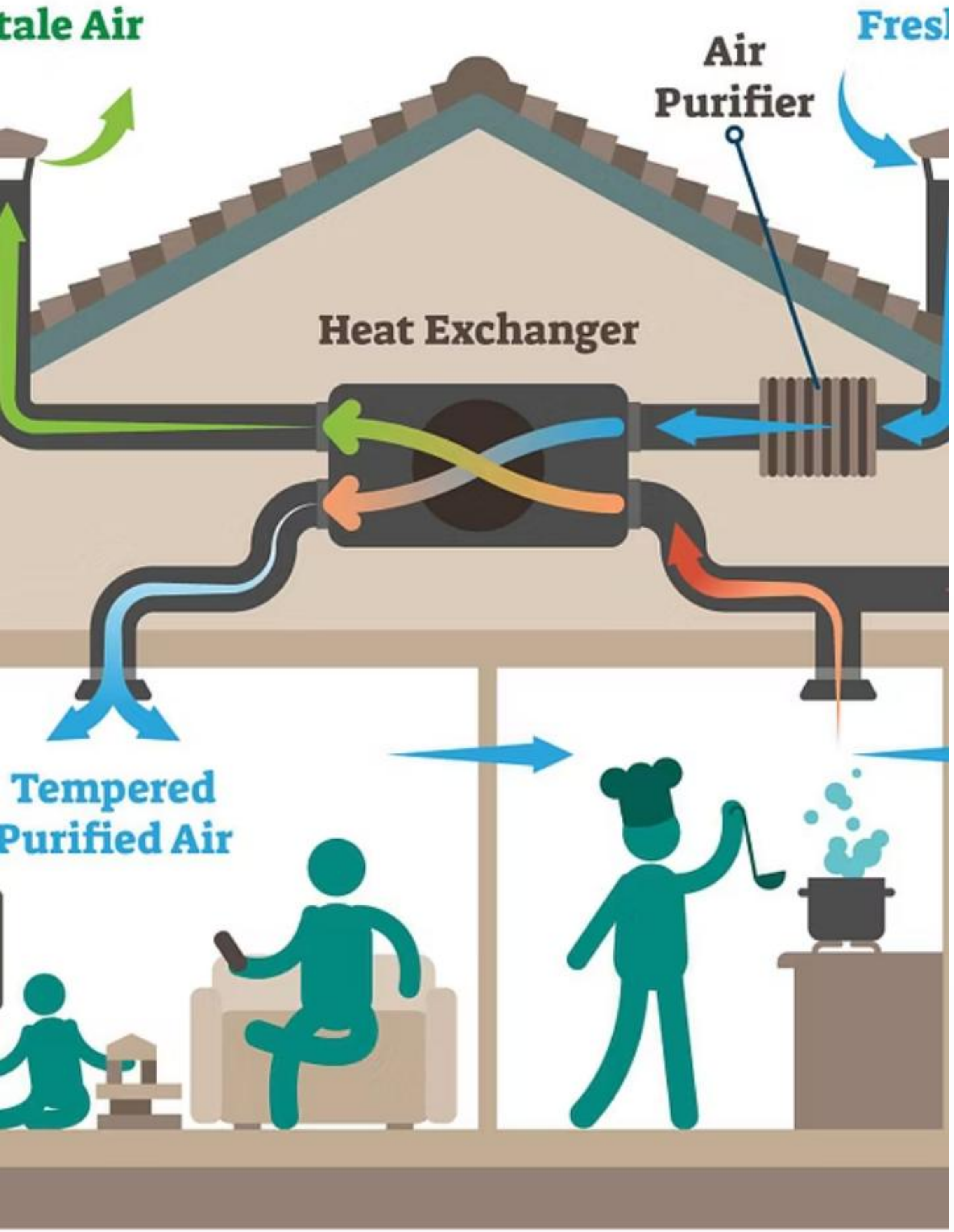
Two simple tests may be conducted if flue gas spillage is suspected. A CO test and a basic venting test are recommended for all new installations and combustion odour service calls.

CO Test

The test for CO in the ambient air around fuel-fired appliances should be conducted if flue gas spillage is suspected. Ensure that a reliable CO detector is employed and that it is calibrated correctly. Zero adjust it in fresh air before entering the test area.

Basic Venting Test

The basic venting test requires that all doors are closed and all exhaust appliances activated. A draft gauge or smoke pencil is employed to determine if the negative pressure in the building affects venting.



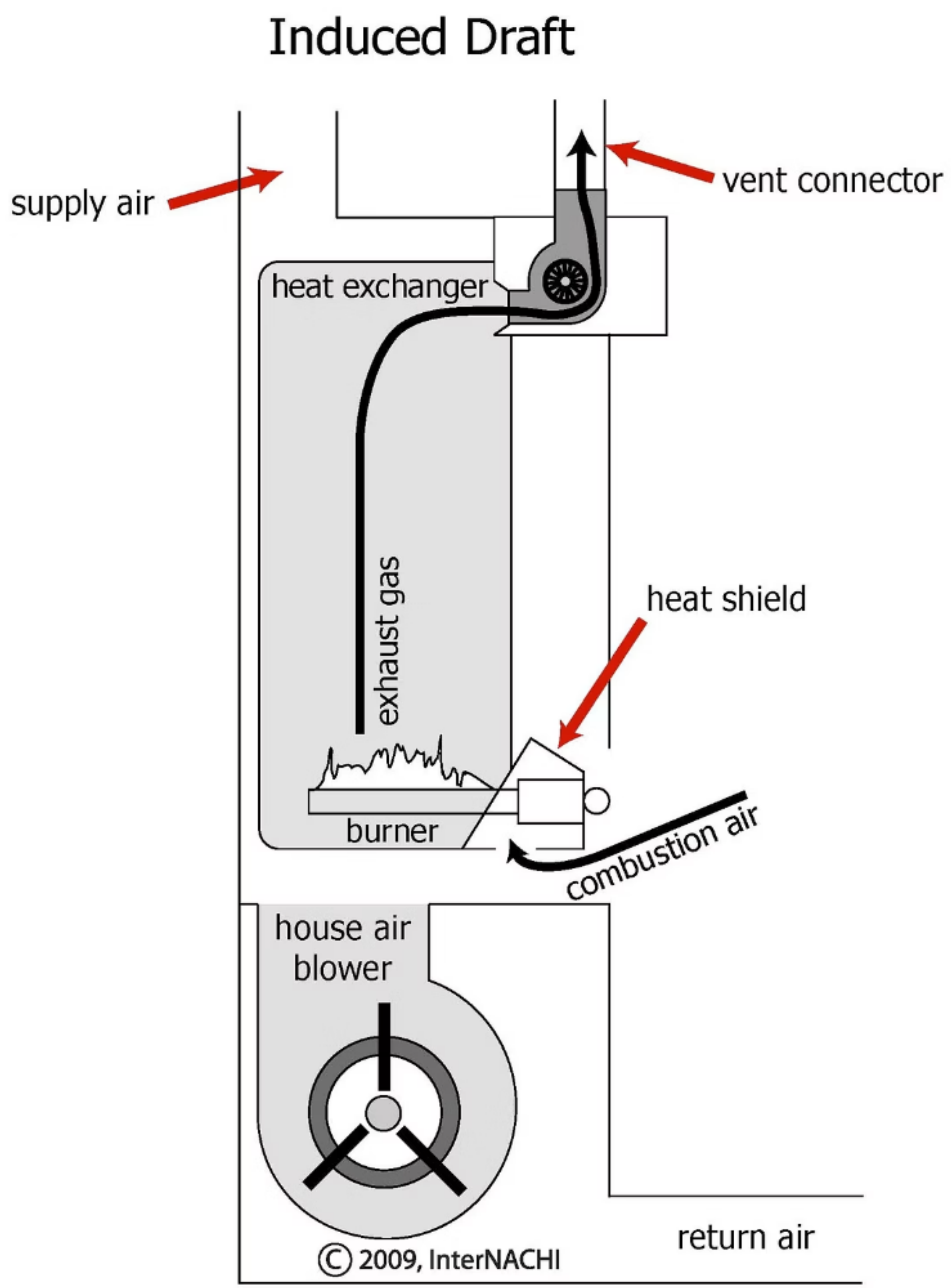
Basic Venting Test Preparation

Preparation checklist	
1. Close all doors and windows except interior doors to rooms with exhaust fans.	5. Turn up thermostat
2. Check wind speed. Light winds are desirable*	6. Turn off hot water valve on gas hot water heater
3. Turn on all exhaust devices - dryers, range hood, fans, central vacuum, HRV on exhaust only mode etc.	7. Prepare draft gauge or smoke pencil
4. Turn off heating appliances by their disconnect switch.	

* If weather conditions are unsuitable (too windy or very cold) for the basic test to simulate worse case conditions, recommend that the basic test be conducted at another time.

Basic Venting Test Results

Test Results	Yes	No
With the heating appliances off and cool, is there spillage from the draft hood, barometric damper or inspection port of any of the appliances?		
Turn on each appliance starting with the smallest input and immediately check for spillage. Leave each appliance on as you activate the next one so all are firing by the end. After each activation check for spillage at all test points of all appliances. Does spillage occur at any time?		
If spillage occurs, does it cease within 30 seconds?		

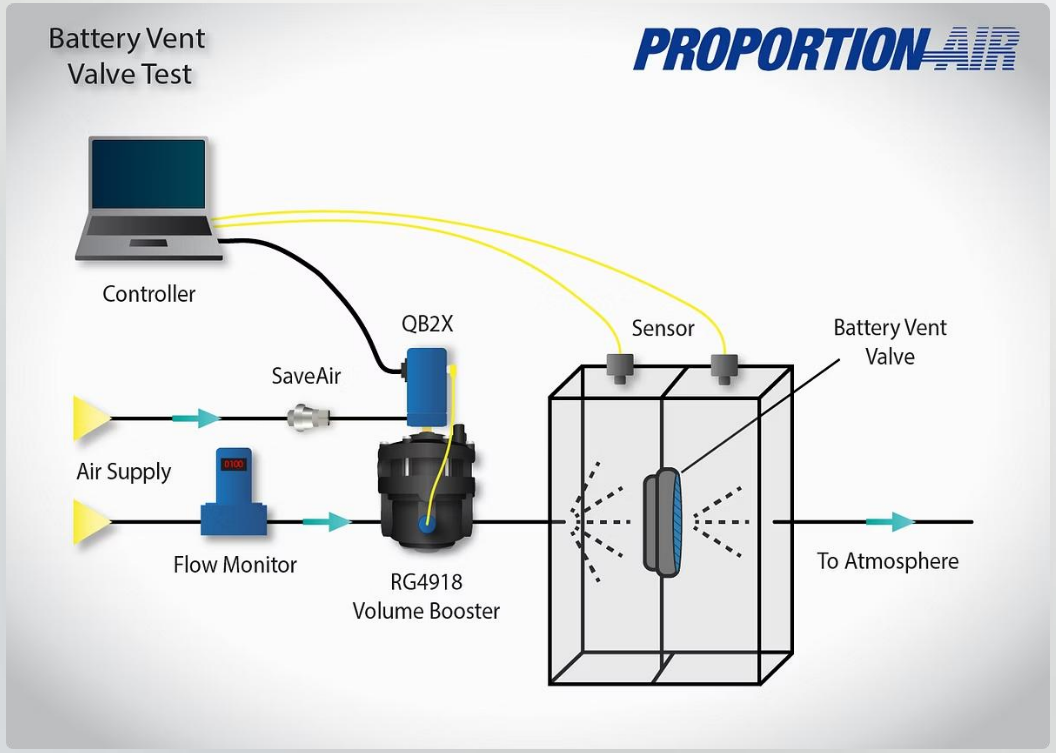


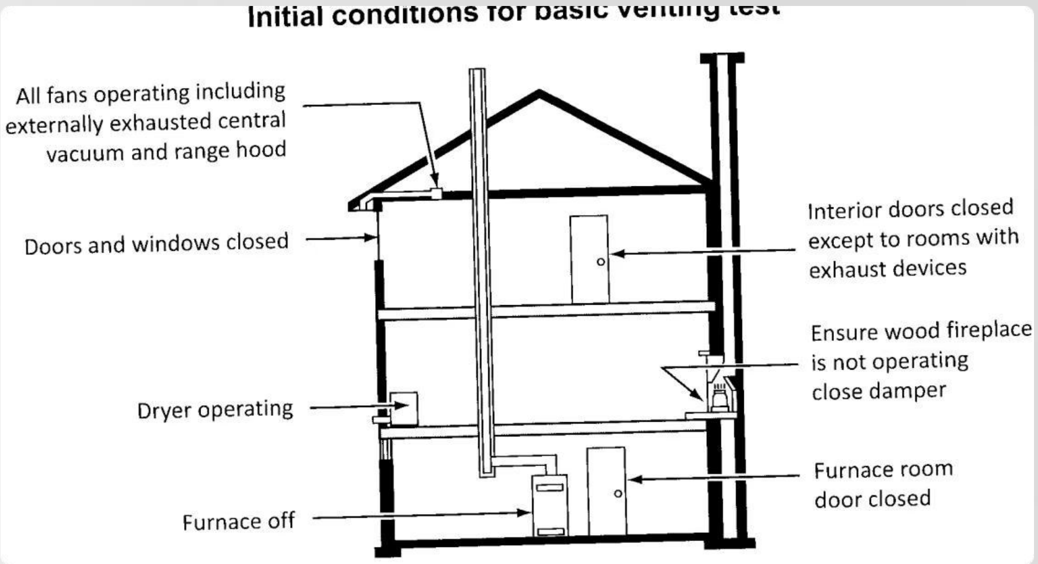
Completing the Basic Venting Test

Test Results	Yes	No
Re-open the water valve and return the thermostat to the original setting.		
Did the System pass the spillage test?		

If spillage ceased, test is complete and the house passes. If spillage continues, the house has failed the test. A written notice of the failure must be given the owner/occupants and the fuel supplier along with a recommendation to conduct a depressurization test and/or take specific remedial action (listed on form).

Highest carbon monoxide level detected, when/where: ______





Initial Conditions for Basic Venting Test

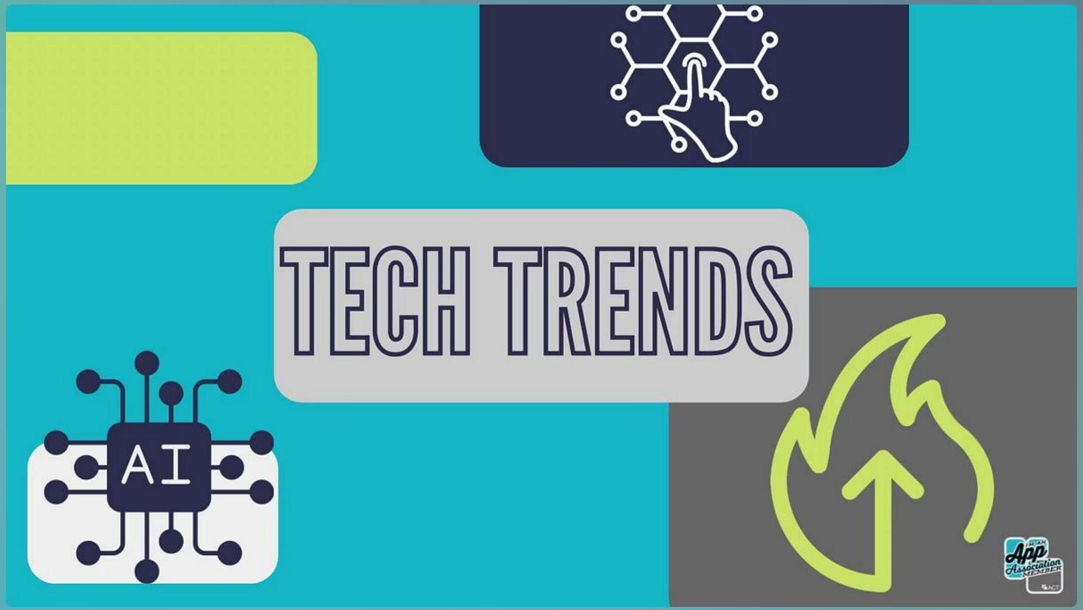
This diagram shows the initial conditions for the basic venting test. The sequence of preparation steps should be followed to prevent problems. The spillage tests must be conducted as each appliance is activated.

If possible, conduct the spillage tests again after 15 minutes (or more) of operation as well. If there is more than one appliance, start the smallest one first and test all spillage points and vent connections. Then activate the next largest appliance and check for spillage at all points again.

Test Results and Next Steps

If no spillage is found during this test and if you are confident that there is no spillage problem, the customer is simply informed of the results. However, if spillage was detected during this basic test and/or you have reason to suspect that a spillage problem exists, a heat exchanger leak test may be warranted or a depressurization test should be conducted by a qualified tester.

The "Comments and Recommendations" table on the ACT form assists in informing the customer of the ACT results.

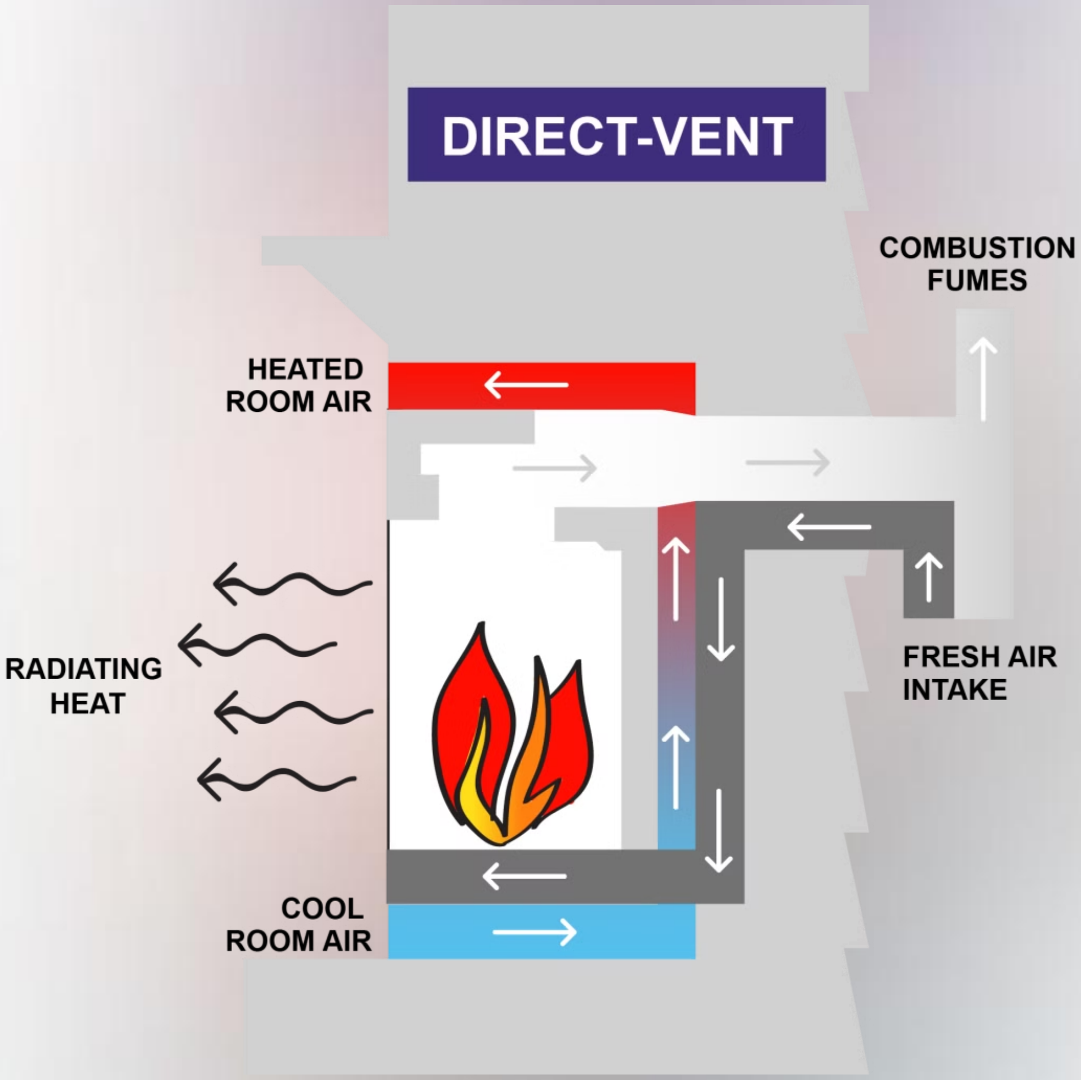


ACT Form: Comments and Recommendations

Comments and Recommended Action:			
As a result of the above Assessment, Check and Test, the following action is:	Required	Recommended	N/A
A depressurization test to be conducted.	Y	Y	Y
A heat exchanger leak test be conducted.	Y	Y	Y
Additional combustion air be introduced.	Y	Y	Y
Additional ventilation air be introduced.	Y	Y	Y
Additional make up air be introduced.	Y	Y	Y

ACT Form: Venting System Recommendations

Comments and Recommended Action:			
As a result of the above Assessment, Check and Test, the following action is:	Required	Recommended	N/A
The following changes to the venting system:			
Replace vent connector.	Y	Y	Y
Repair masonry chimney.	Y	Y	Y
Install metal chimney liner.	Y	Y	Y
Replace metal chimney or vent.	Y	Y	Y
Install raincap or flashing.	Y	Y	Y
Relocate sidewall termination.	Y	Y	Y



Importance of ACT and Depressurization Tests

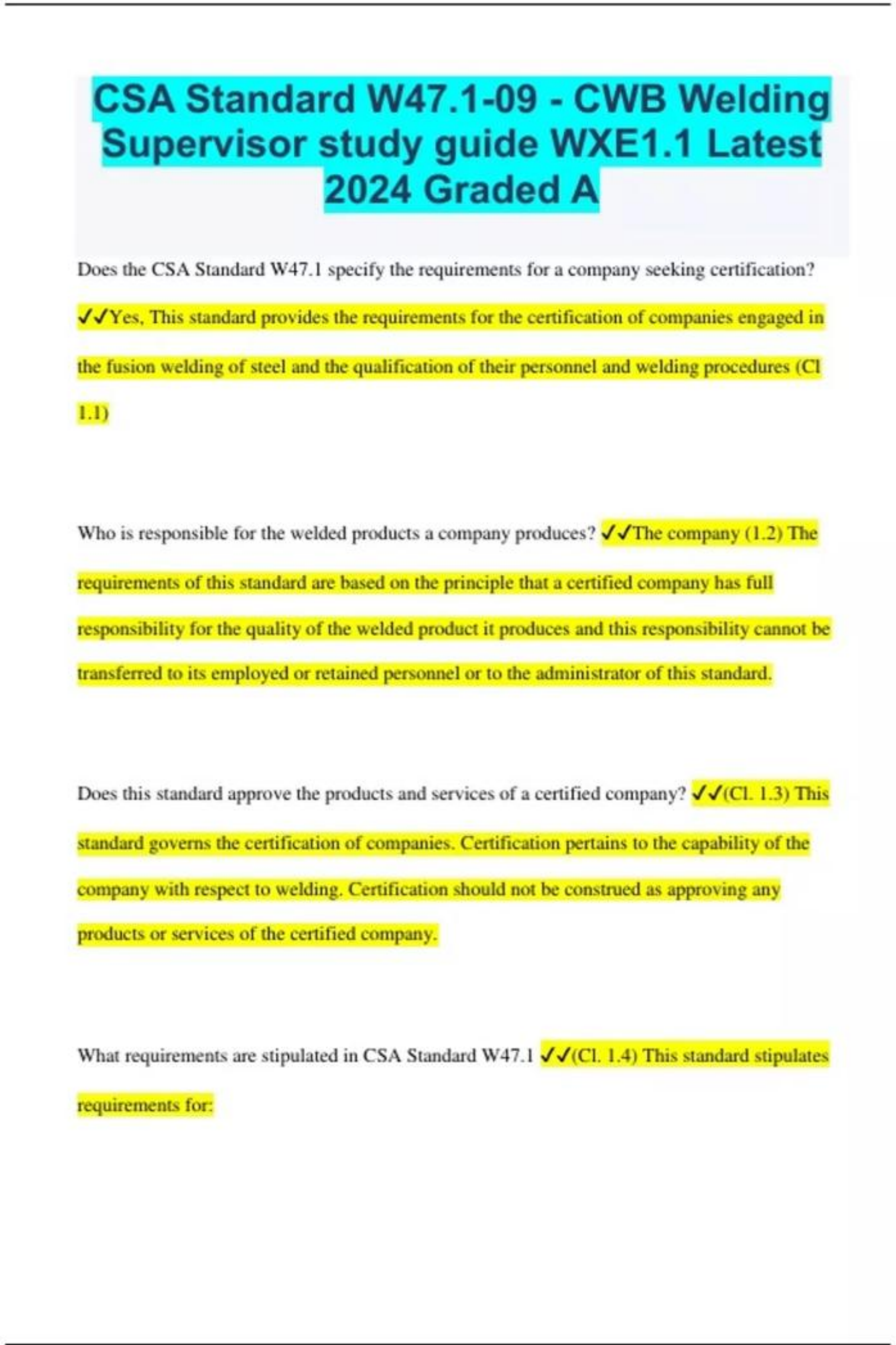
The ACT procedure and depressurization tests are neither commonly used nor well-known by gas technicians/fitters. You are a new generation of gas technicians/fitters on whom the gas industry and customers depend on to identify and resolve new problems.

As building envelopes became more airtight and appliance efficiency increased by giving up less to the vent, depressurization problems have increased. The trend toward tighter houses and more efficient appliances continues, so the spillage problems created by house depressurization will probably increase.

House Depressurization Testing

Field tests can be performed to determine the amount of negative pressure appliances and exhausting equipment are creating. The test is performed with a hand-held Magnahelic or inclined manometer. These instruments can measure pressure differences in the 0–60 Pa (0.0–0.25 in w.c.) range.

This field test is not meant as an alternative to the airtightness test required for the construction and certification of R-2000 and ENERGY STAR® homes. Those require that a licensed tester confirm the airtightness of the building envelope by way of a controlled standardized fan depressurization test, typically using a blower door.



CSA Standard W47.1-09 - CWB Welding Supervisor study guide WXE1.1 Latest 2024 Graded A

Does the CSA Standard W47.1 specify the requirements for a company seeking certification? ✓✓Yes, This standard provides the requirements for the certification of companies engaged in the fusion welding of steel and the qualification of their personnel and welding procedures (Cl 1.1)

Who is responsible for the welded products a company produces? ✓✓The company (1.2) The requirements of this standard are based on the principle that a certified company has full responsibility for the quality of the welded product it produces and this responsibility cannot be transferred to its employed or retained personnel or to the administrator of this standard.

Does this standard approve the products and services of a certified company? ✓✓(Cl. 1.3) This standard governs the certification of companies. Certification pertains to the capability of the company with respect to welding. Certification should not be construed as approving any products or services of the certified company.

What requirements are stipulated in CSA Standard W47.1 ✓✓(Cl. 1.4) This standard stipulates requirements for:

CSA F300 Standard

CSA F300 was developed to address issues and concerns that arise from the depressurization of existing houses. The standard describes methods for determining the level of depressurization and solutions to mitigate risk arising from depressurization.

The level of depressurization shall be determined when additions or modifications are made to any of the following:

Building Envelope

Changes to the airtightness of the structure

Exhaust Device

Addition or modification of exhaust equipment

Combustion Appliance

Changes to heating or other combustion equipment

Appliance Enclosure

Modifications to the space containing combustion equipment

Depressurization Test Overview

Test Purpose

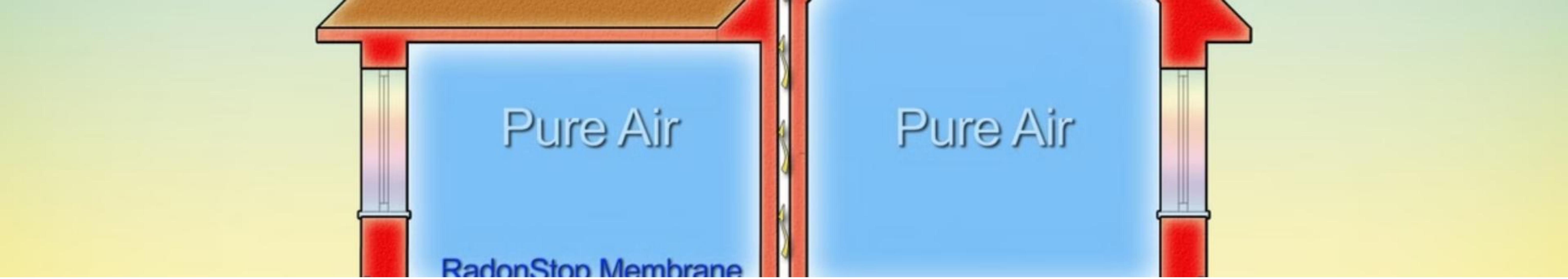
A depressurization test measures the negative pressure in the building under test conditions. The test conditions may be:

- Passive - using only the exhaust equipment in the building (like the basic venting test)
- Active - using a large fan to create a specific negative pressure (usually -10 Pa or -0.05 inch w.c.)

Safety Warning

Performing depressurization tests, including the basic venting test, can create dangerous conditions with flue gas spillage. A CO detector must be employed throughout these tests.

This ensures that any carbon monoxide released during testing is detected immediately for safety.



House Depressurization Test Procedure

Prepare the Building

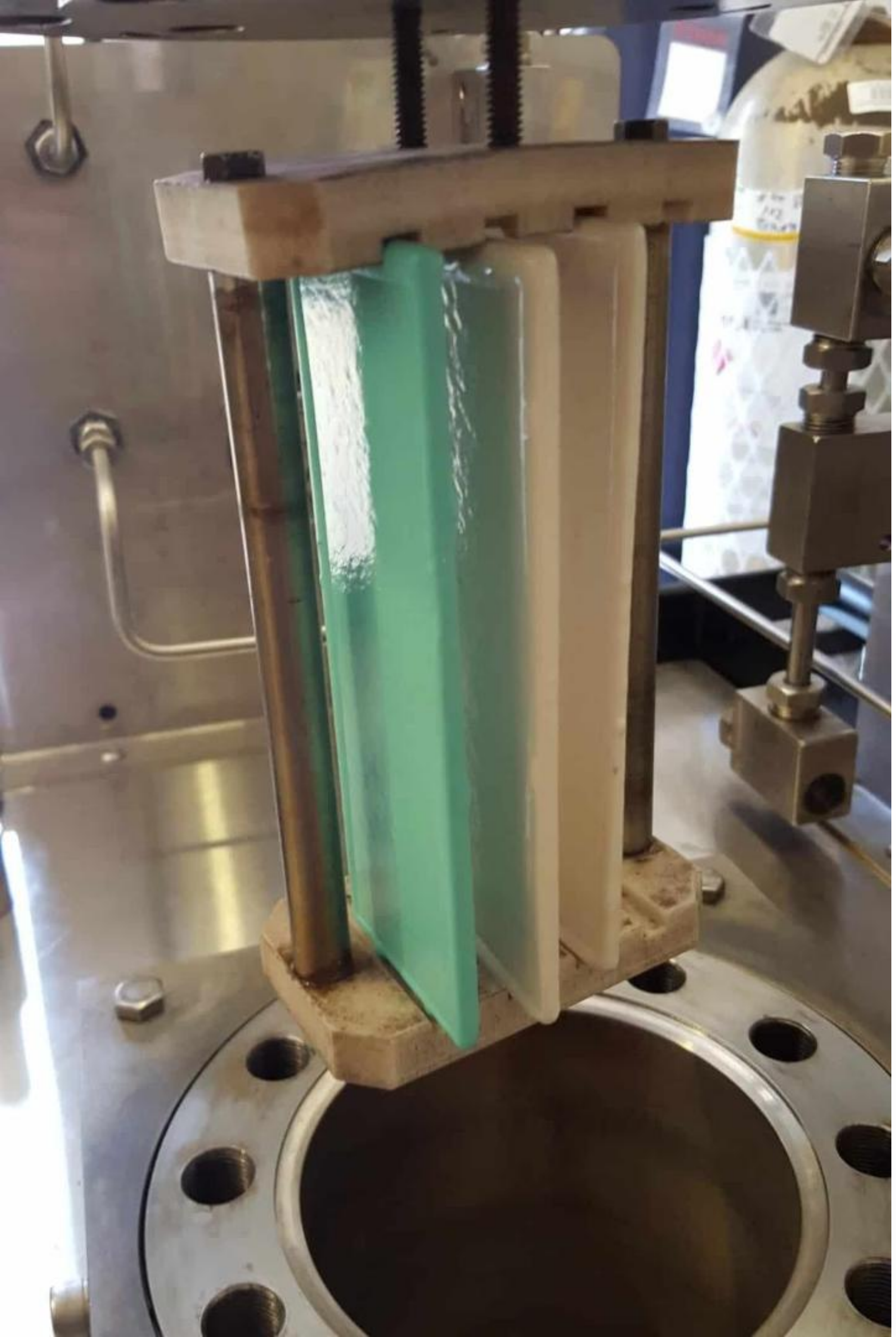
Close and latch all windows, doors, and other openings. Fill floor drains and plumbing traps with water or seal. Seal combustion air inlets and chimneys of flues for combustion appliances, including fireplaces and wood stoves.

Set Up Pressure Measurement

Set an exterior pressure tap approximately at least 3 m (10 ft) from the building and connect to the measuring device at or near grade level inside the building.

Establish Baseline

Switch off the ventilation equipment and any other appliances that exhaust air to the exterior. This is the starting or "rest" pressure.



Conducting the Depressurization Test

Activate Foundation Exhaust

Turn on all foundation exhaust fans (e.g., radon fans) designed for continued operation.

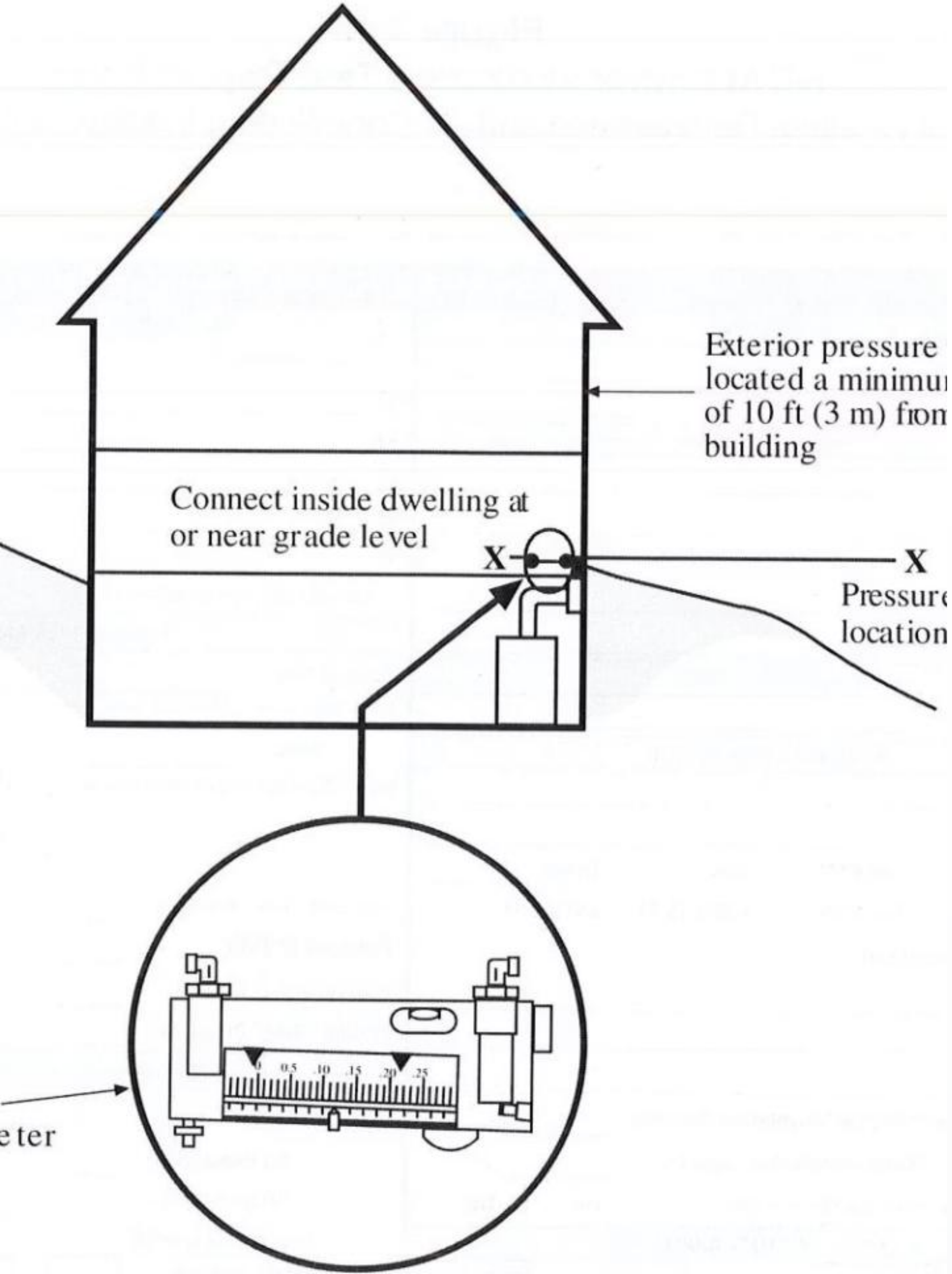
Add Required Ventilation

Turn on all equipment used to provide the ventilation capacity as required by the NBC. Record the pressure difference.

Add All Exhaust Equipment

Switch on the dryer and all exhaust equipment with a capacity over 75 L/s. Record the pressure difference. The difference between this measurement and the rest pressure is the maximum house depressurization.

Figure 3-13
Depressurization testing



Depressurization Test Setup

This diagram shows the setup for a depressurization test. The pressure difference between inside and outside the building is measured using a manometer connected to pressure taps. The exterior pressure tap should be placed at least 3 meters (10 feet) from the building to avoid local pressure effects.

Interpreting Test Results

Acceptable Limits

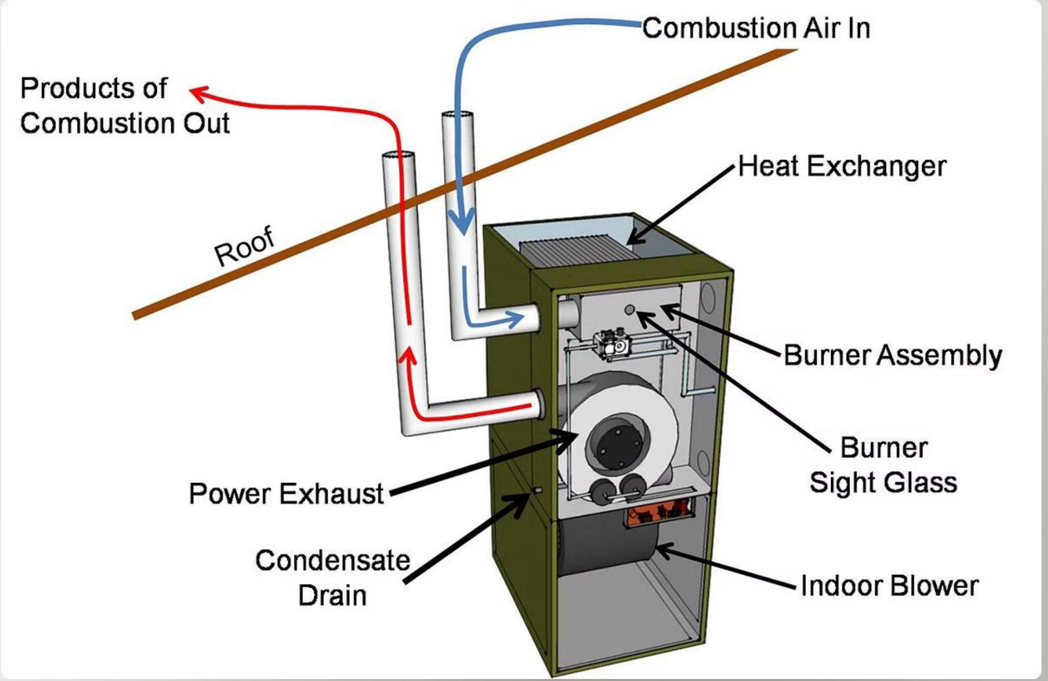
The values you measure must fall within these acceptable limits:

- Maximum allowable pressure difference is 5 Pa in all conditions if any non-direct vent fuel fired, vented combustion appliances are present.
- Maximum allowable pressure difference for other rated appliances set by the manufacturer.

Exceeding Limits

If the values exceed the acceptable limits, remedial action must be taken to reduce the depressurization or modify the combustion appliances to be less susceptible to spillage.

This ensures that combustion gases are properly vented and do not pose a safety hazard to building occupants.



Solutions for Excessive Depressurization

Adapt Appliances

Determine which appliance can be adapted or changed

Upgrade Furnace

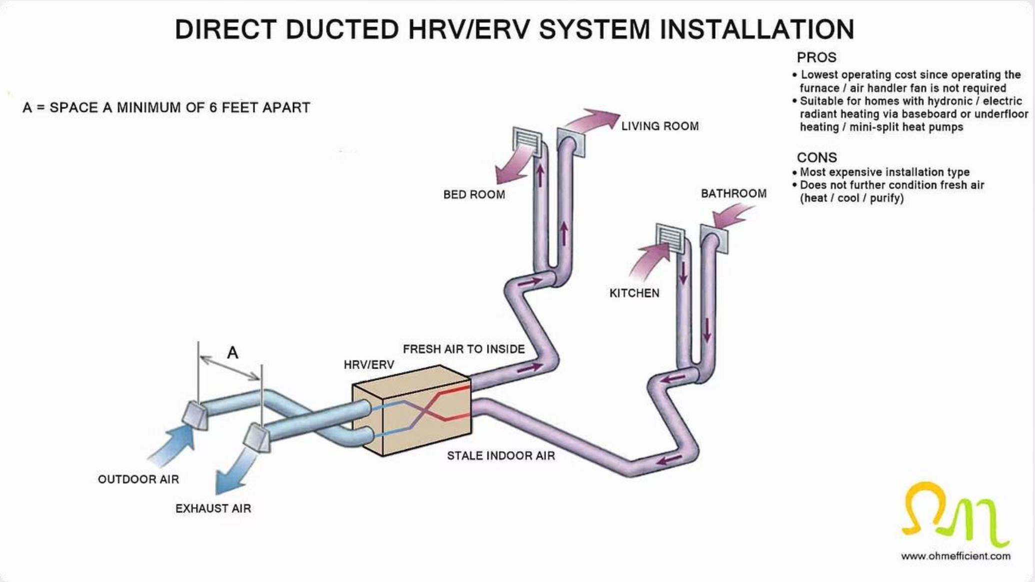
Replace or upgrade a standard furnace with a balancing ventilation non-spillage appliance

Replace Fireplace

Replace a standard fireplace with direct vent fireplace

Upgrade Water Heater

Replace a conventional domestic water heater with a direct vent water heater



Additional Depressurization Solutions

Replace Exhaust Fans

Replace bathroom and kitchen exhaust fans with an HRV (Heat Recovery Ventilator)

Revent Central Vacuum

Revent the central vacuum system indoors

Dryer Venting Warning

Do not vent dryers indoors, since this introduces contaminants (odours, dust, and moisture) into the house

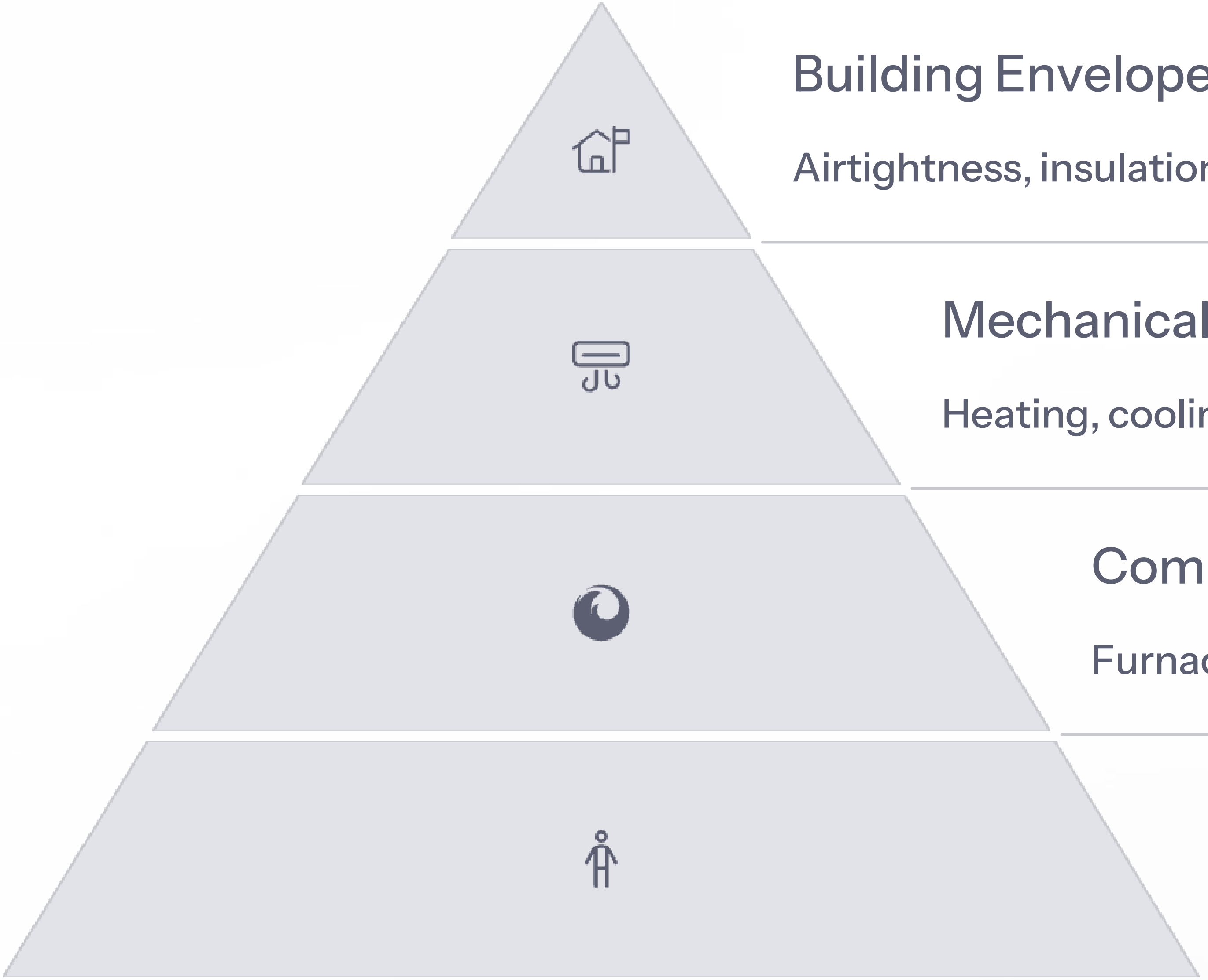
HRAI Depressurization Test Report Form

The HRAI Depressurization Test Report Form is a standardized document used to record the results of depressurization testing. It includes sections for:

- Building and client information
- Test conditions and equipment used
- Baseline pressure readings
- Pressure readings with various exhaust equipment operating
- Calculated depressurization values
- Recommendations for remedial action if needed

This form provides documentation of the test results for both the technician and the homeowner.

Importance of Building-as-a-System Approach



Building Envelope

Airtightness, insulation, and construction

Mechanical Systems

Heating, cooling, ventilation, and exhaust

Combustion Appliances

Furnaces, water heaters, fireplaces

Occupant Behavior

How the building is used and maintained

Understanding how these components interact is essential for ensuring safe and efficient operation of all building systems.

Trends in Building Construction

Increasing Airtightness

Modern building codes and energy efficiency standards are driving the construction of increasingly airtight building envelopes. This reduces energy consumption but can create challenges for combustion appliances.

Higher Efficiency Appliances

Modern combustion appliances extract more heat from combustion gases, resulting in cooler flue gases with less natural buoyancy. This makes proper venting even more critical.

These trends make understanding depressurization and proper venting increasingly important for gas technicians.

The Role of Gas Technicians

Safety Guardians

Gas technicians are on the front line of ensuring combustion safety in increasingly complex building systems.

System Evaluators

Understanding the building as a system allows technicians to identify potential issues before they become safety hazards.

Technical Advisors

Technicians must be able to explain complex building science concepts to homeowners and recommend appropriate solutions.

Continuing Education

Stay Current with Codes

Building and gas codes are regularly updated to address new technologies and safety concerns.

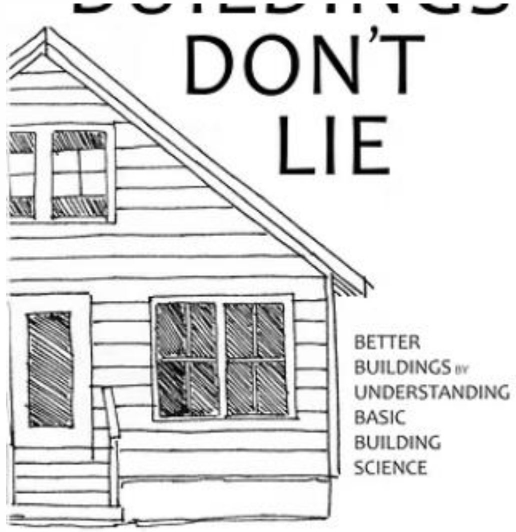
Learn New Testing Methods

As testing equipment and procedures evolve, technicians must stay current with best practices.

Understand New Technologies

New combustion appliances and ventilation systems require ongoing education to install and service properly.

Resources for Gas Technicians



A variety of resources are available to help gas technicians understand and apply building science principles, including technical manuals, standards documents, and specialized training programs.

Summary: Building as a System

Heat Loss Calculation

Ensures properly sized heating systems for comfort and efficiency

ACT Procedure

Systematic approach to identify potential venting issues

Depressurization Testing

Quantifies building pressure conditions that affect combustion safety

Remedial Solutions

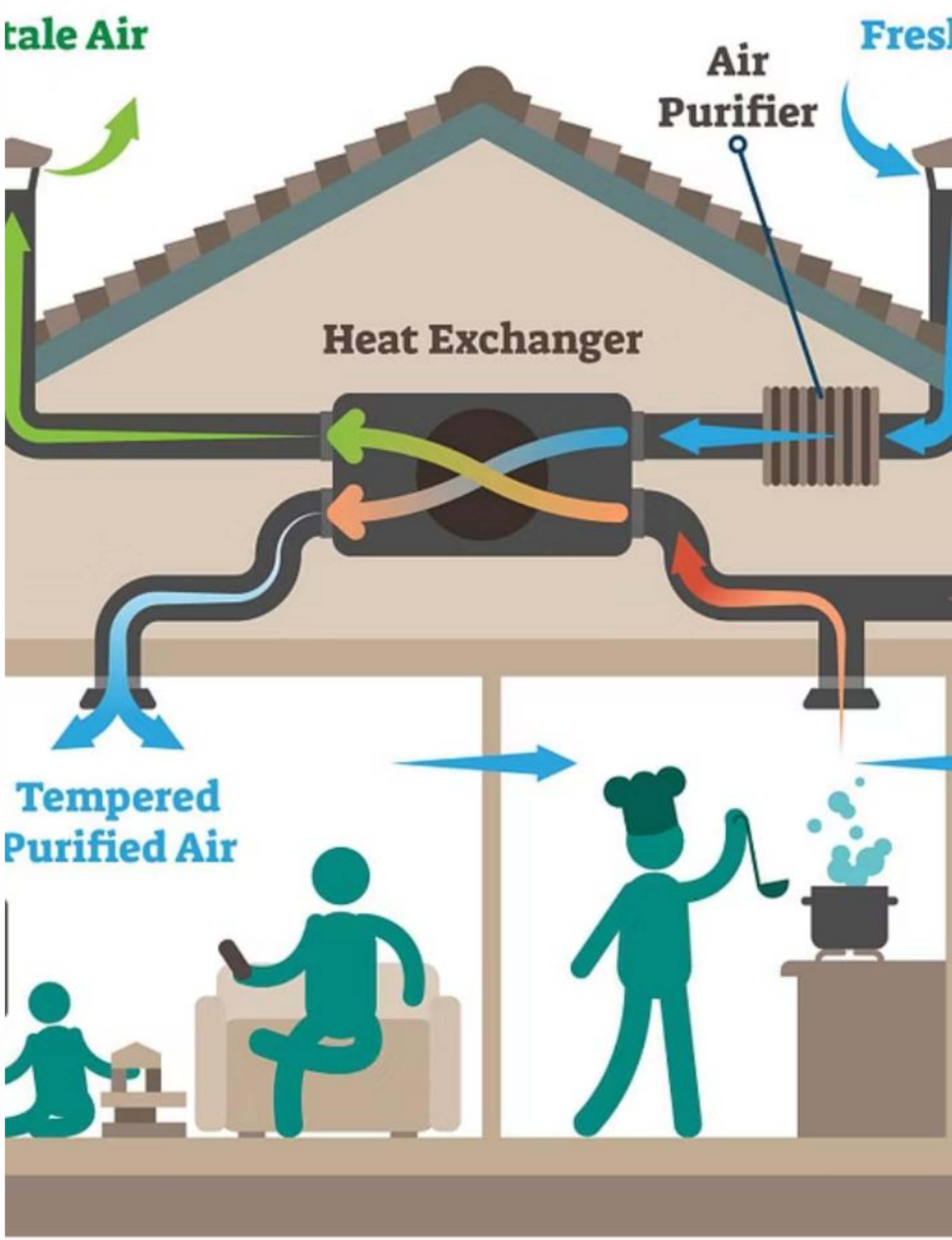
Addresses identified issues to ensure safe operation

Understanding and applying these assessment tools is essential for gas technicians to ensure safe and efficient operation of combustion appliances within the building system.

CSA Unit 14

Chapter 4
Indoor Air Quality

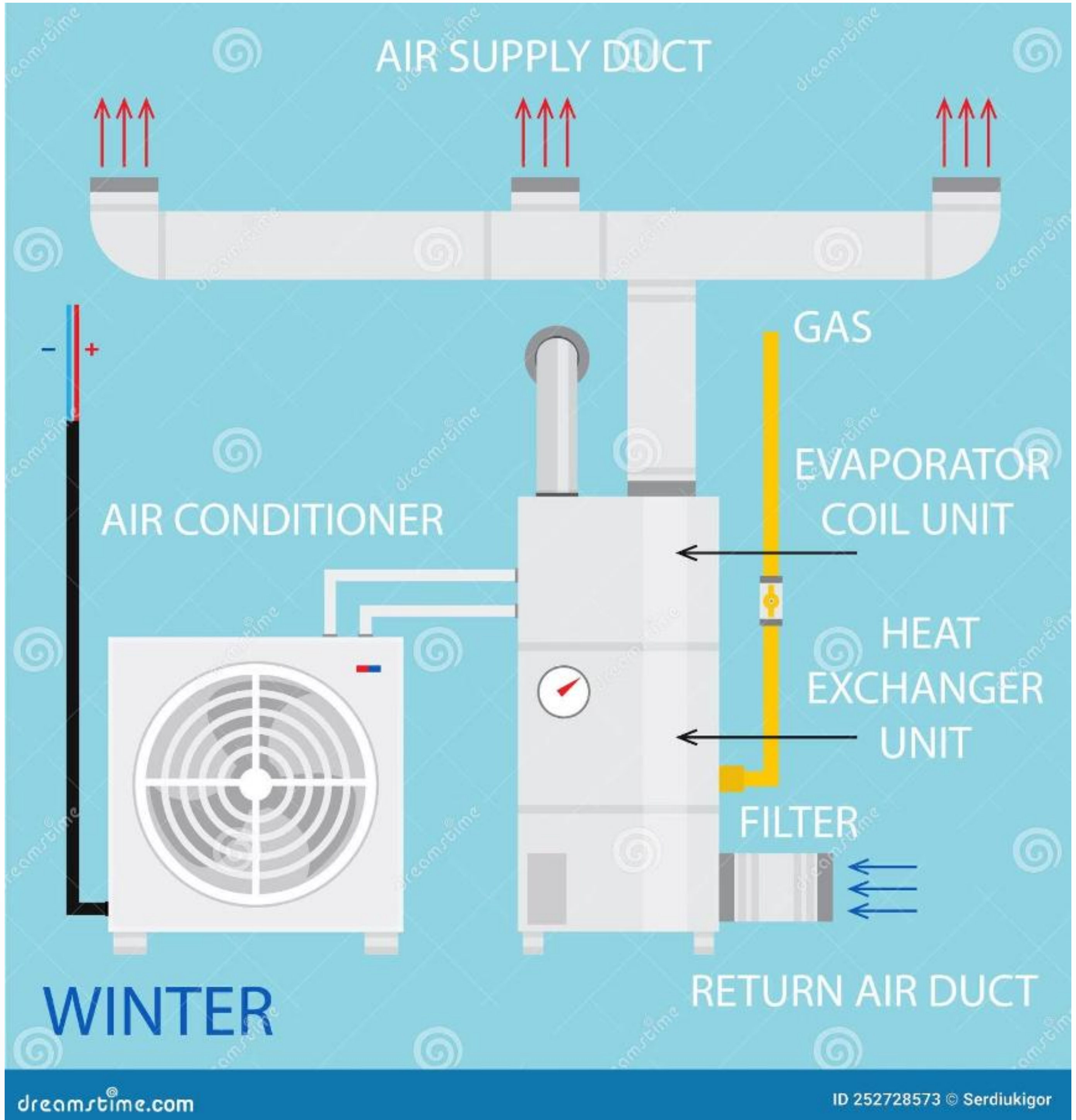
Indoor air quality is directly related to levels of air pollution. Ventilation and moisture control must work in conjunction with all gas equipment to provide a high level of air quality.



Purpose of Indoor Air Quality

Overview

Indoor air quality is directly related to levels of air pollution. Ventilation and moisture control must work in conjunction with all gas equipment to provide a high level of air quality.



Learning Objectives

Describe Indoor Pollution

Learn about sources of indoor pollution and methods of controlling it

National Building Code Requirements

Understand the National Building Code requirements for ventilation

Key Terminology

Term	Abbreviation (symbol)	Definition
Heating, Refrigeration and Air Conditioning Institute of Canada	HRAI	A non-profit national trade association of manufacturers, wholesalers, and contractors in the Canadian heating, ventilation, air conditioning, and refrigeration (HVACR) industries.
Poor indoor air quality		When the inside air contains enough of a substance to adversely affect the comfort, health, or safety of the occupants.

Understanding Indoor Air Pollution

HRAI Definition

Poor indoor air quality occurs "when the inside air contains enough of a substance to adversely affect the comfort, health, or safety of the occupants".

Causes

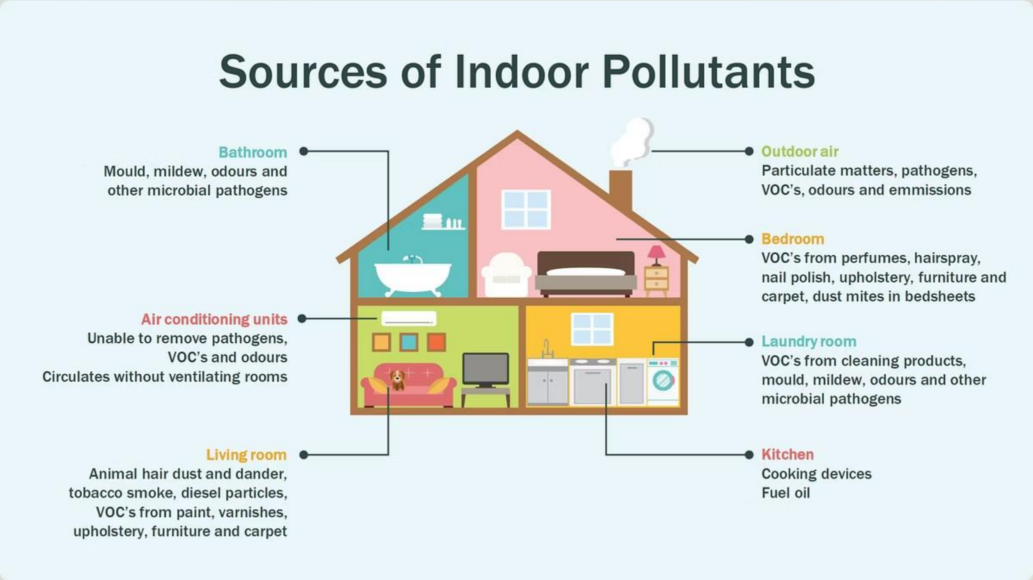
Poor air quality is a direct result of the combination of high pollutant levels and inadequate ventilation and other control methods that exhaust or neutralize polluted indoor air.

Importance of Air Exchange

Frequent air exchange ensures that pollutants from household air are removed with speed and efficiency.

Main Sources of Indoor Air Pollution

Figure 4-1
Sources of indoor air pollution



Chemical Pollutants Overview

Chemical pollutants come from various sources in our homes and can significantly impact indoor air quality. The following sections detail the main chemical pollutants and their sources.

Radon as a Chemical Pollutant

Radon (Rn)

Colourless, odourless, radioactive gas, generated from the decay of radium, a mineral in the earth's crust

Sources

Air leakage from the ground or rock beneath the building, from ground water, or construction products (concrete and masonry)

Formaldehyde as a Chemical Pollutant

Formaldehyde (HCHO)

Strong-smelling, colourless gas

Sources

Construction materials; glues in particleboard, plywood, furniture, and textiles; also in tobacco smoke

Carbon Monoxide and Carbon Dioxide

Carbon Monoxide (CO)

Colourless, odourless, tasteless gas, at times released during combustion

Sources: Fireplaces, woodstoves, unvented gas appliance, automotive engines in attached garages

Carbon Dioxide (CO2)

Colorless, odorless gas

Sources: Respiration, fuel, burning equipment, tobacco smoke

Other Chemical Pollutants

Pollutant	Abbreviation	Description	Source
Nitrogen dioxide	NO2	Colourless, odourless, tasteless gas	Combustion appliances (kerosene heaters), smoking
Volatile organic compounds	VOCs	Visibly undetectable, but detectable odour	Furnishings, adhesives, solvents, pesticides, cleaning and cooking products
Water	H2O	Humid, condenses on walls and windows	Cooking, showering, new furnishings and leaky basements
Respirable particulates	RSP	Particles less than 0.25 microns in air that can be drawn into lungs	Unvented combustion appliances, some humidifiers, house dust, wood smoke, and tobacco smoke

Biological Pollutants Sources

Human Sources

Human hair and skin flakes

Animal Sources

Animal dander

Plant Sources

Pollen

Microbial Sources

Mould spores, dust mites and dust mite debris, fungi, bacteria and viruses

Particulate Sources

Tobacco and wood smoke, lint, household dust

Bacteria as Biological Pollutants

Types

Legionella, Thermoactino-myces, endotoxin, proteases

Airborne Units

Organisms, spores, products-toxins, antigens

Human Effects

Pneumonia, pontiac fever, hypersensitivity, pneumonitis fever, chills, asthma

Main Indoor Sources

Cooling towers, hot water sources, stagnant water reservoirs, industrial processes

Fungi as Biological Pollutants

Types

Alternaria, Histoplasma, Cladosporium, Aspergillus, Penicillium, aflatoxins, aldehydes

Airborne Units

Organisms, spores, antigens, toxins, volatiles

Human Effects

Asthma, rhinitis, allergies, systemic infection, cancer, mucous membrane irritants

Main Indoor Sources

Damp surfaces, bird droppings

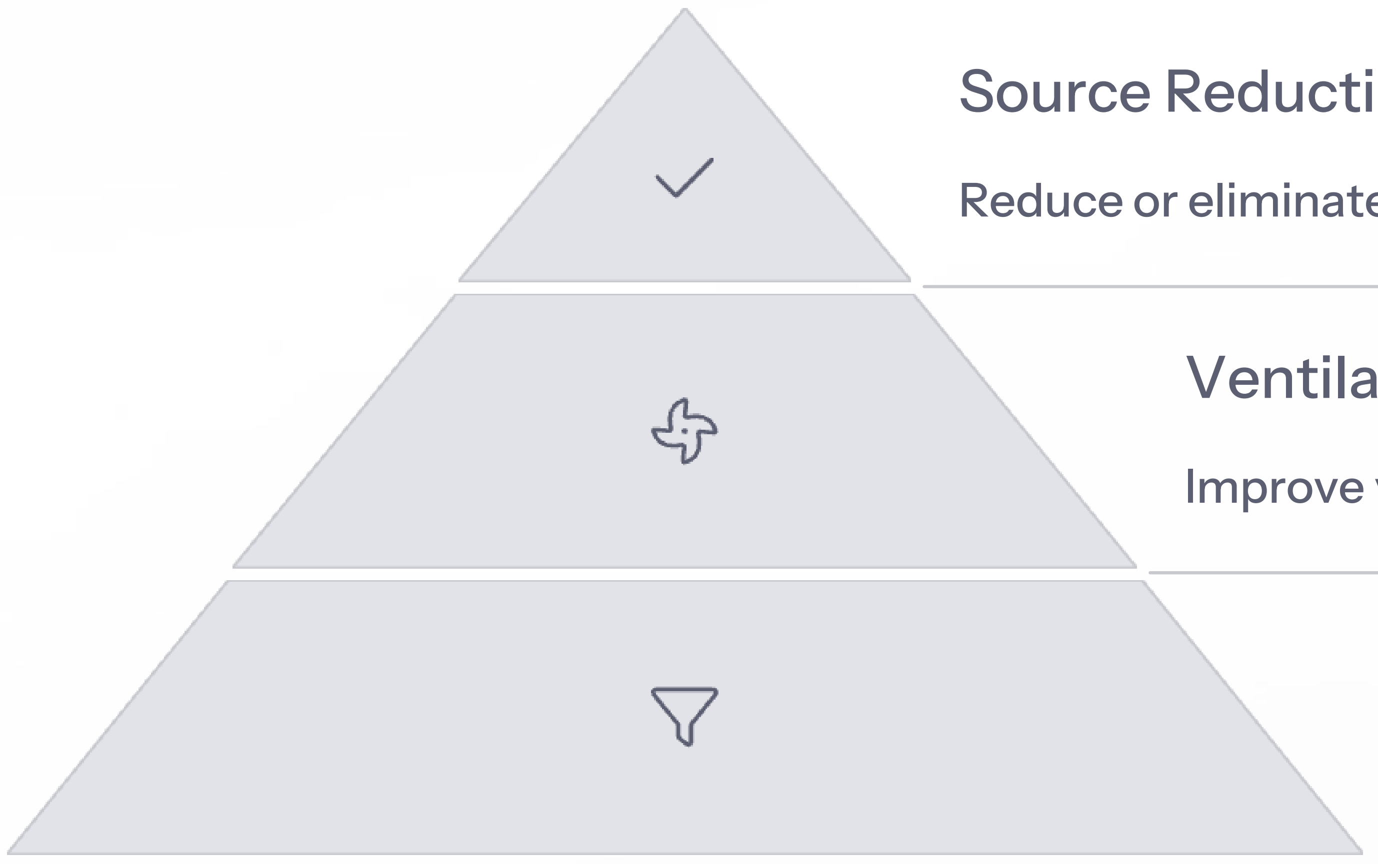
Other Biological Pollutants

Source	Airborne unit	Human effects	Main indoor sources
Protozoa (Naegleria, Acanthamoeba)	Organisms, antigens	Infection, hypersensitivity, pneumonitis	Contaminated water, reservoirs
Viruses (influenza)	Organisms	Respiratory infections	Human hosts
Algae (Chlorococcus)	Organisms	Asthma, rhinitis, allergies	Outdoor air
Green plants (Ambrosia)	Pollen	Asthma, rhinitis, allergies	Outdoor air
Arthropod (dust mites, cockroaches)	Feces	Asthma, rhinitis, allergies	House dust
Mammals (humans, horses, dogs, cats)	Skin scales, saliva, urine	Asthma, rhinitis, allergies	House dust

Impact of Moisture and Dust

It can be seen from the preceding tables that excess moisture, dust, and inadequately vented air contribute in varying degrees to increased chemical and biological pollution of the indoor environment. Most control methods relate to ways of removing indoor contaminants and replenishing stale or over-moist air with fresh air drawn from the external environment.

Control Priorities for Indoor Air Quality



Source Reduction

Reduce or eliminate the source of pollutants

Ventilation

Improve ventilation to remove pollutants

Filtration

Filter air to remove contaminants

Methods of Controlling Indoor Air

Removal

Store chemicals outside the living space

Substitution

Non-polluting products should be chosen in preference to polluting products

Containment

Store household chemicals in an airtight, vented cabinet

Control

At the design stage of new construction or renovation

Air treatment/ventilation

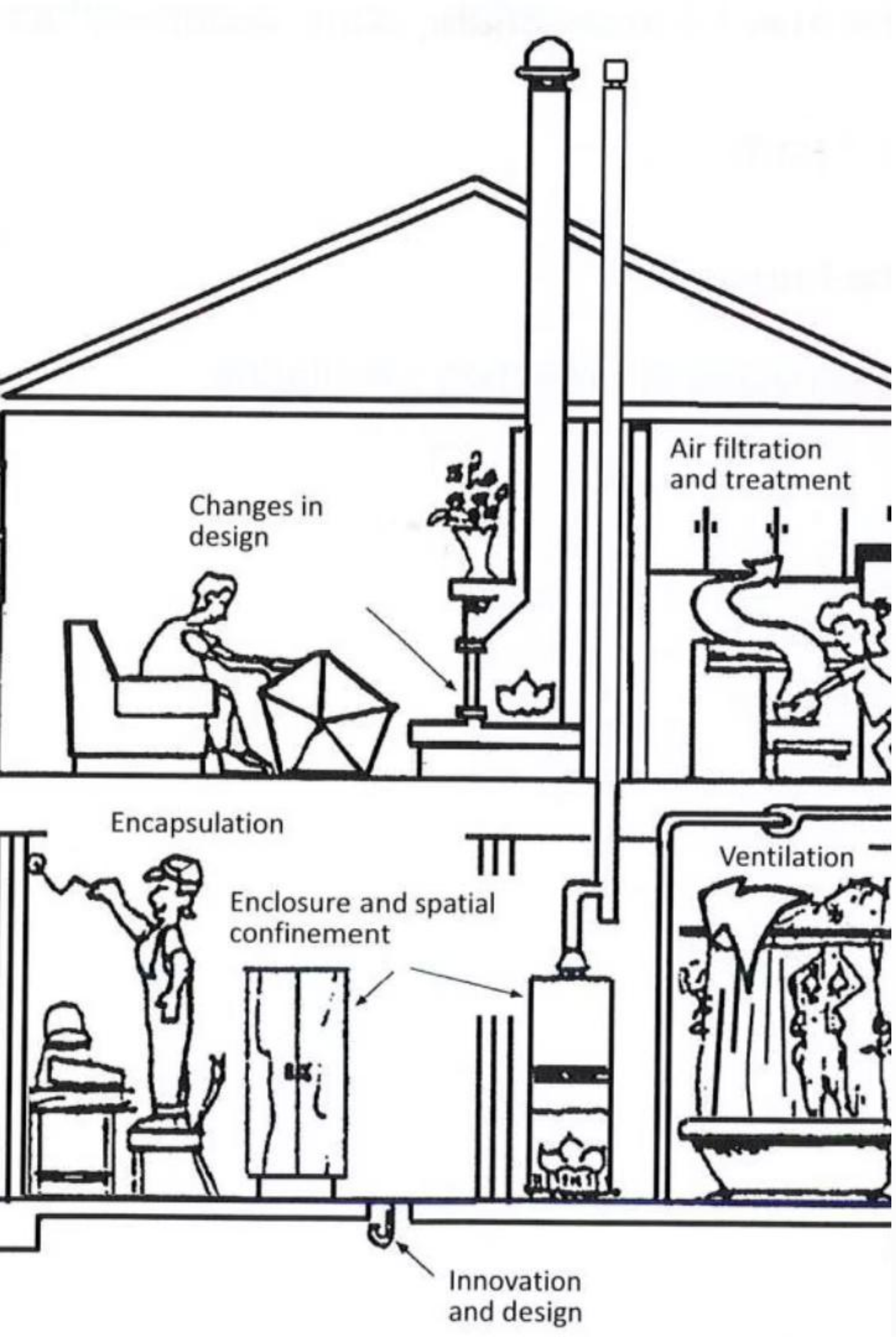
Filtration, HVAC (heating, venting, and air conditioning)

Humidification and dehumidification

Add or remove moisture

Local exhaust

Range hoods, bathroom exhausts use filtration and ventilation



Methods of Controlling Air Contaminants

The diagram above illustrates various methods for controlling air contaminants in indoor environments. These approaches can be used individually or in combination to achieve optimal indoor air quality.

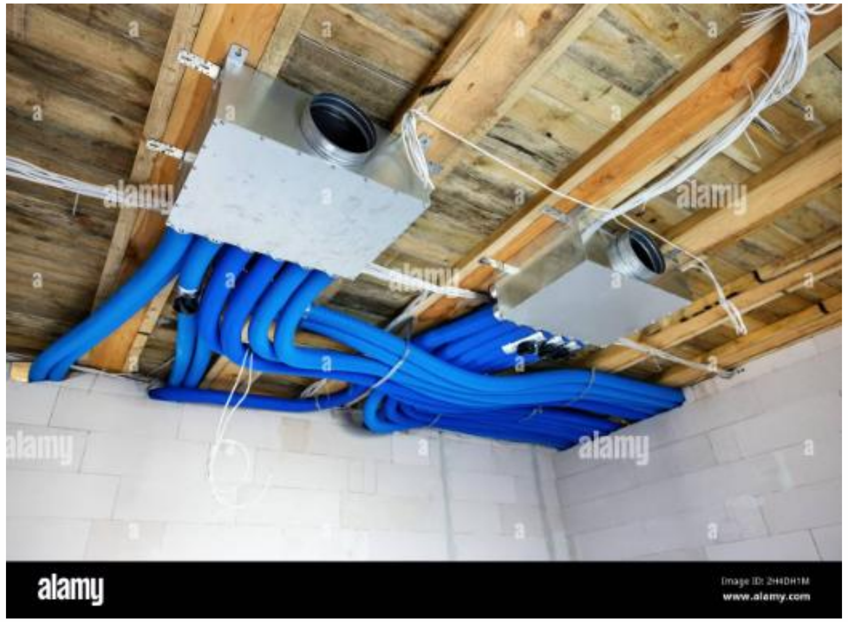
Ventilation and Filtration

Ventilation

A good ventilation system has the overall capacity to ventilate the house, distribute fresh air to habitable rooms, include mechanisms to control pollutants through removal at source, provide for makeup or relief air, if necessary, and include an appropriate ducting and control system.

Filtration

Filtration is the process of passing a liquid through a device or porous substance to remove solids or impurities-the removal of particulates (not gases) from the air stream.



Gas Technician Responsibilities

Code Familiarity

Be familiar with the current National Building Code of Canada (NBC) and the Heating, Refrigerating and Air Conditioning Institute (HRAI) requirements related to the mechanical ventilation of residential buildings

CSA Standards

Understand CSA B149.1 requirements pertaining to air supply (covered in Unit 22 Venting Practices)

Factors Influencing Ventilation System Choice

Heating System Type

The type of heating system(s) installed in the home

Equipment Availability

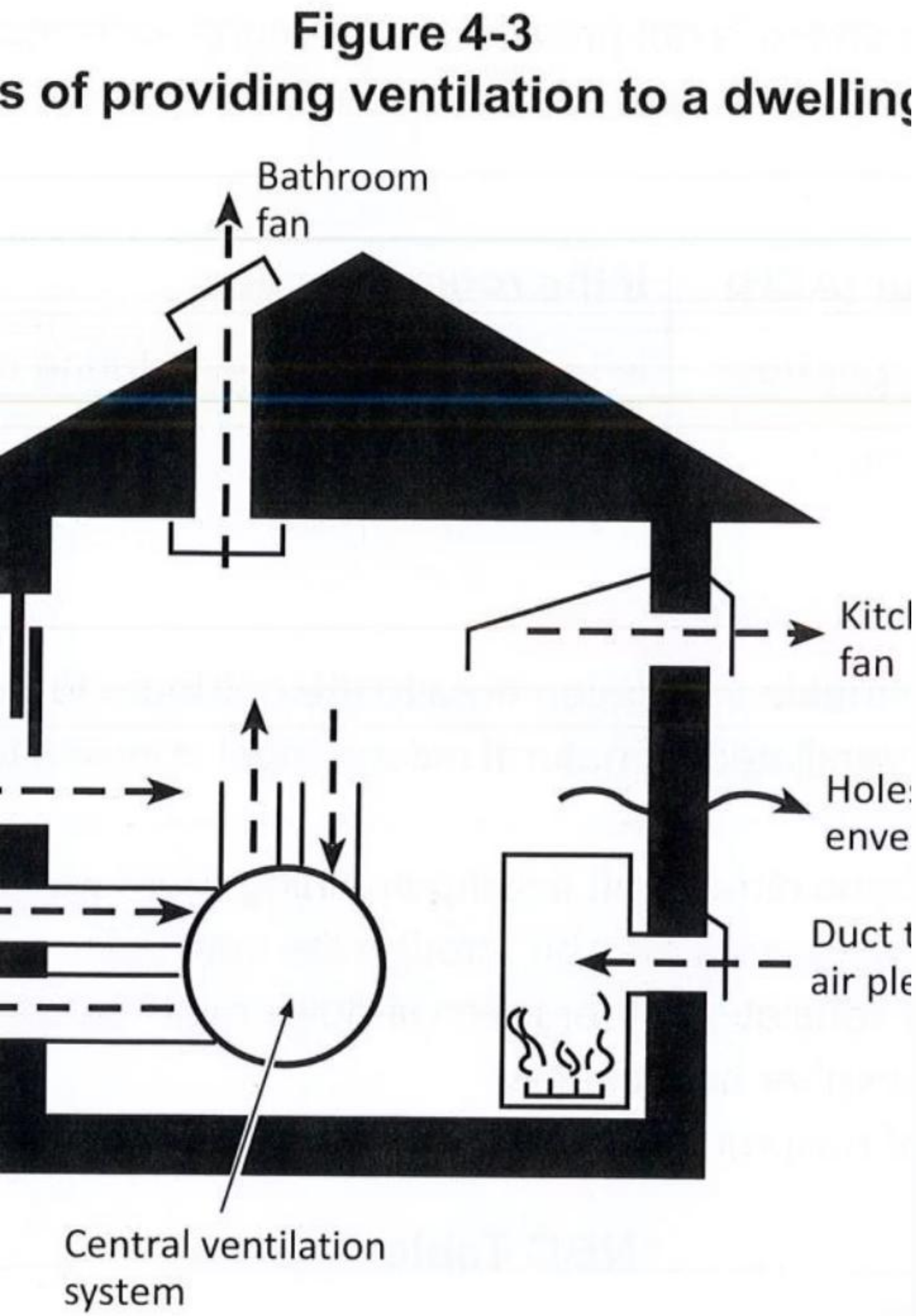
Availability of equipment and parts

Owner Preferences

The preferences of the homeowner

House Characteristics

Size, type, and budget of the house



Common Ventilation Methods

The image above shows some common ways of providing ventilation in residential buildings. These methods can be adapted to suit different building types and ventilation requirements.

National Building Code Requirements

Scope

The National Building Code of Canada (NBC) and province-specific codes, such as the Ontario Building Code, establish requirements for the ventilation of rooms and spaces in residential occupancies by natural ventilation and by mechanical ventilation systems serving only one dwelling unit.

Purpose

In a typical house, these target ventilation rates will dilute air pollutants generated within the house (carbon dioxide, humidity, and odours).

Considerations

In the case of a home located in an area with poor outdoor air quality, increasing ventilation may not improve indoor air quality. Ventilation may need to be scheduled during periods of low outdoor pollution levels, such as early morning.

Caution

Some caution should be exercised as reduced ventilation can lead to increased levels of indoor air contaminants.

Air Quality Index

Check the Air Quality Health Index (AQHI) in your community, especially during "smog season" from April to September.

General Ventilation Requirements

1 Dwelling Unit Requirements

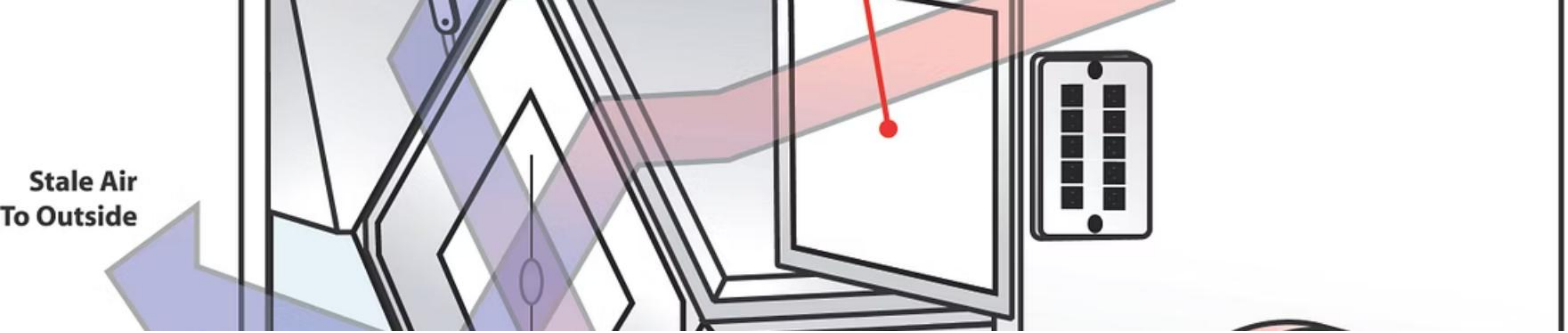
Every dwelling unit shall incorporate provisions for non-heating-season ventilation in accordance with the NBC. If supplied with electrical power, provisions for heating ventilation must be in accordance with the Code.

2 Non-heating-season Ventilation

Rooms or spaces in dwelling units must be ventilated during the non-heating season by natural ventilation or by conforming mechanical ventilation systems.

3 Alternative Ventilation

If a habitable room or space is not provided with natural ventilation as described above, mechanical ventilation must be provided to exhaust inside air from, or to introduce outside air to, that room.



Air Change Requirements

0.5

ACH for Cooled Spaces

One-half air change per hour if the room or space is mechanically cooled during the non-heating season

1.0

ACH for Non-Cooled Spaces

One air change per hour if the room or space is not mechanically cooled during the non-heating season

Natural Ventilation Requirements

Unobstructed Openings

The unobstructed openable ventilation area to the outdoors for rooms and spaces in residential buildings ventilated by natural means must conform to Table 9.32.2.2 of the NBC.

Vestibule Ventilation

Where a vestibule opens directly off a living or dining room within a dwelling unit, ventilation to the outdoors for such rooms may be through the vestibule.

Opening Protection

Openings for natural ventilation other than windows must be constructed to provide protection from the weather and insects.

Screening Requirements

Screening must be of rustproof material.

Natural Ventilation Area Requirements

Location	Minimum unobstructed area
Within a dwelling unit – Bathrooms or water closet rooms	0.09 m^2 (0.97 ft^2)
Within a dwelling unit – Unfinished basement space	0.2% of the floor area
Within a dwelling unit – Dining rooms, living rooms, bedrooms, kitchens, combined rooms, dens, recreation rooms, and all other finished rooms	0.28 m^2 (3 ft^2) per room or combination of rooms
Other than within dwelling unit – Bathrooms or water closet rooms	0.09 m^2 (0.97 ft^2) per water closet
Other than within dwelling unit – Sleeping areas	0.14 m^2 (1.5 ft^2) per occupant
Other than within dwelling unit – Laundry rooms, kitchens, recreation rooms	4% of the floor area
Other than within dwelling unit – Corridors, storage rooms, and other similar public rooms or spaces	2% of the floor area
Other than within dwelling unit – Unfinished basement space not used on a shared basis	0.2% of the floor area

Heating Season Ventilation Requirements

Mechanical Ventilation Requirement

Every dwelling unit that is supplied with electrical power must be provided with a mechanical ventilation system complying with CAN/CSA F326, and various articles and sections in the NBC.

Design and Installation Standards

Good Practice Guidelines

Aspects of mechanical ventilation systems not specifically detailed in the NBC must be designed, constructed, and installed in accordance with good practice as described in such publications as:

ASHRAE

ASHRAE Handbooks and Standards

HRAI

HRAI Digest

Hydronics Institute

Hydronics Institute Manuals

SMACNA

SMACNA Manuals

2. CONVERT TO SQUARE INCHES:

REQUIRED VENTING AREA X 144 SQ. IN.

$12 \text{ SF} \times 144 \text{ IN}^2 = 1{,}728 \text{ IN}^2$

3. DETERMINE LOW (SOFFIT) & HIGH (RIDGE) VENTING:

Total Ventilation Capacity

Minimum Capacity

The minimum total ventilation capacity of the ventilation system required in the NBC must be the sum of the individual room capacities specified in the NBC.

Air Change Rate Requirements

Room or space	Rate, L/s
Master bedroom	10
Other bedrooms	5
Living room	5
Dining room	5
Family room	5
Recreation room	5
Basement	10
Kitchen	5
Bathroom or water-closet room	5
Laundry room	5
Utility room	5
Other habitable rooms	5

Evolution of Mechanical Ventilation

Past Assumptions

Until recently, mechanical ventilation was not considered important in residential buildings

Natural Ventilation

It was assumed that natural ventilation through wind, "stack effect," and heating appliance operation would create sufficient air movement

Modern Construction

In new houses or older homes brought up to current air tightness standards, it is no longer sufficient to rely solely on accidental ventilation

HRAI Basic Ventilation Concerns

Proper Air Volume

Bringing in the proper amount of ventilation air

Air Distribution

Distributing the air to the required locations

Pressure Balance

Avoiding excessive pressurization or depressurization

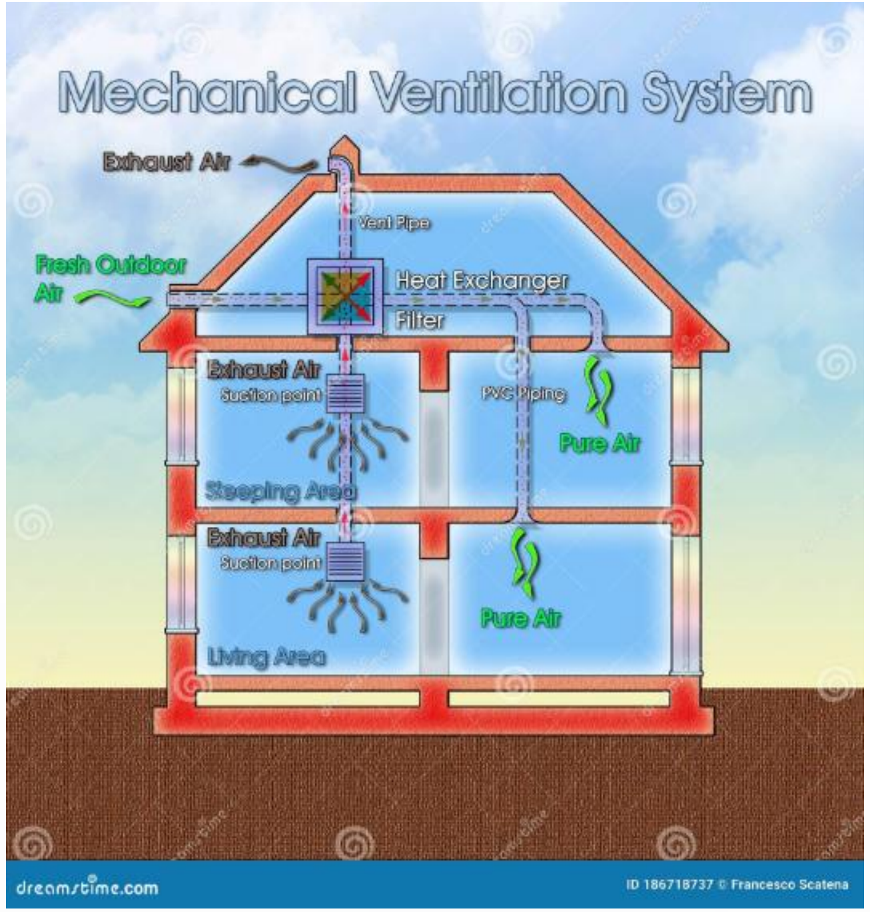
Types of Ventilation Systems

Exhaust-Only Systems

Remove air from the home, creating negative pressure that draws in fresh air through leaks and intentional openings

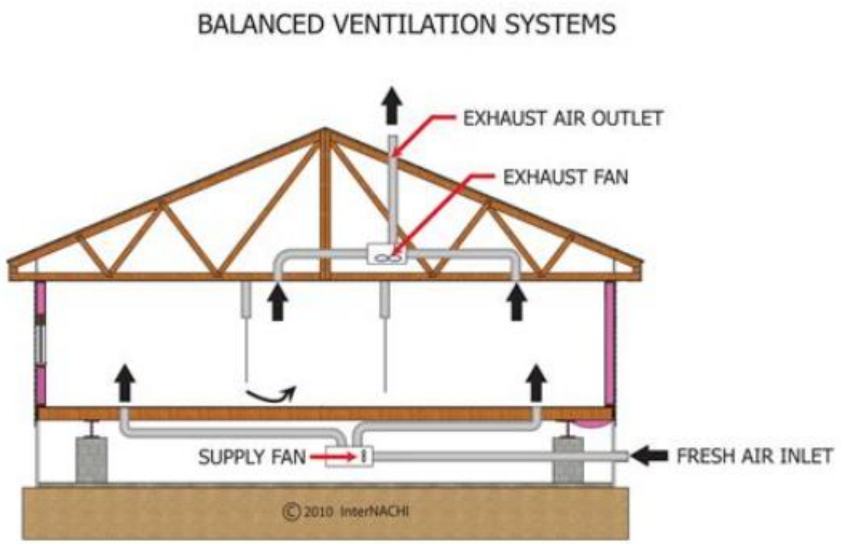
Supply-Only Systems

Force fresh air into the home, creating positive pressure that pushes stale air out through leaks and intentional openings



Balanced Systems

Provide both supply and exhaust in equal amounts, maintaining neutral pressure in the home



Types of Distribution Systems

Direct Ducting

Dedicated ductwork delivers fresh air directly to living spaces

Recirculating

Uses existing HVAC ductwork to distribute fresh air throughout the home

(a) (b) (c)

Through-the-Wall

Individual units installed through exterior walls provide ventilation to specific rooms

Ventilation System Hazards

Supply-Only in Leaky Houses

Can lead to problems with moisture-laden air being driven into wall cavities

Exhaust-Only in Sealed Houses

Can lead to serious health hazards since the depressurization could cause the furnace or fireplace to backdraft and draw poisonous gases into the house

Excessive Ventilation

Can cost the homeowner more than necessary and may lead to the system being turned off

Insufficient Ventilation

Can lead to a buildup of pollutants in the air, such as formaldehyde from new furnishings

Gas Technician Scope of Work

Awareness Requirements

A gas technician/fitter must be aware of the effects that the ventilation system has on the building as a system and on gas appliance operation

Certification Limitations

A gas technician/fitter certificate does not authorize the holder to install ventilation systems

Additional Training

Further training is required to design, install, and service ventilation systems that are part of the gas appliance

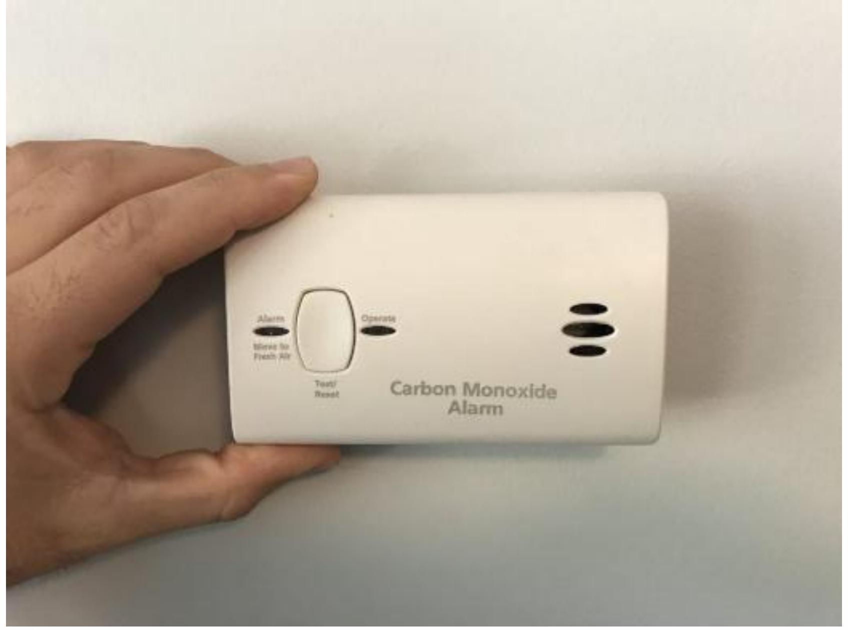
Carbon Monoxide Safety

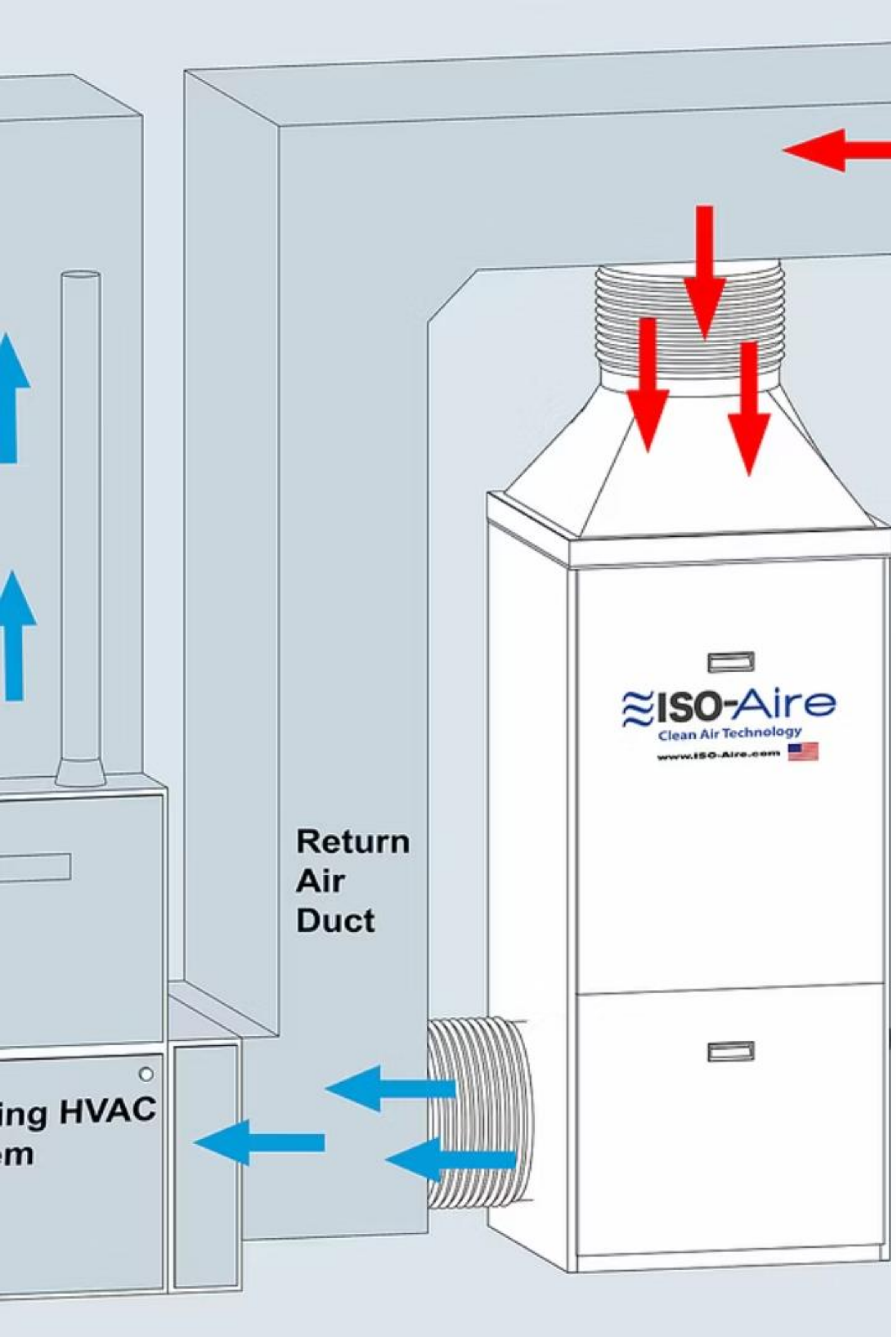
Gas Appliance Operation

Although gas-fired appliances do not normally produce CO, appliances can malfunction or backdraft

Building Code Requirements

Therefore, the NBC has requirements for the installation of CO alarms as a low-cost backup safety measure





Filtration Systems Overview

Role of Filtration

Filtering the air can reduce some indoor air pollutants, but air cleaning is rarely effective on its own and should be used in conjunction with ventilation and reducing contaminants at the sources

Residential Filters

Although there are many types of furnace air filters available for the residential market, the majority are designed to protect coils and heat exchangers of mechanical equipment and have little impact on air quality

MERV Ratings for Filters

MERV Definition

Filters have a minimum efficiency reporting value (MERV) rating that indicates how effectively they trap particles

Rating Scale

The scale is designed to represent the worst-case performance of a filter when dealing with particles in the range of 0.3-10 μm

Rating Range

The MERV rating is from 1 to 16. Higher MERV ratings correspond to a greater percentage of particles captured on each pass, with a MERV 16 filter capturing more than 95% of particles over the full range

Common Ratings

MERV 8 filters are common although an R-2000 home requires a minimum MERV 13 filter

Portable Air Cleaners

HEPA Filters

Portable air cleaners, particularly high-efficiency particulate air (HEPA) filters and electrostatic precipitators, can reduce some air contaminants

HEPA filters collect 99.95% of particle pollutants that have a size greater than or equal to 0.3 µm

Limitations

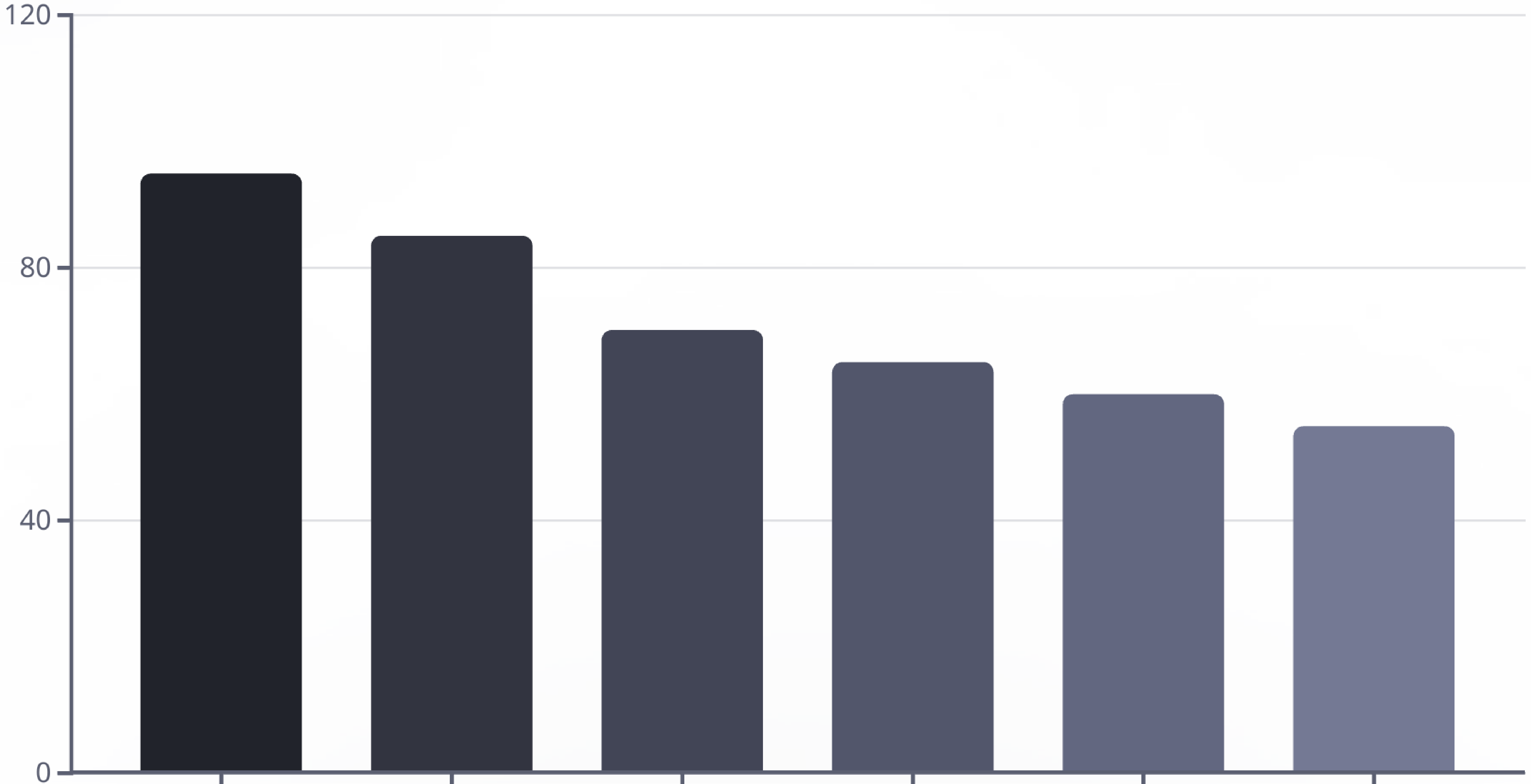
Air cleaners can be effective in removing particles, but most do not remove gases

Additional Information on Air Filters

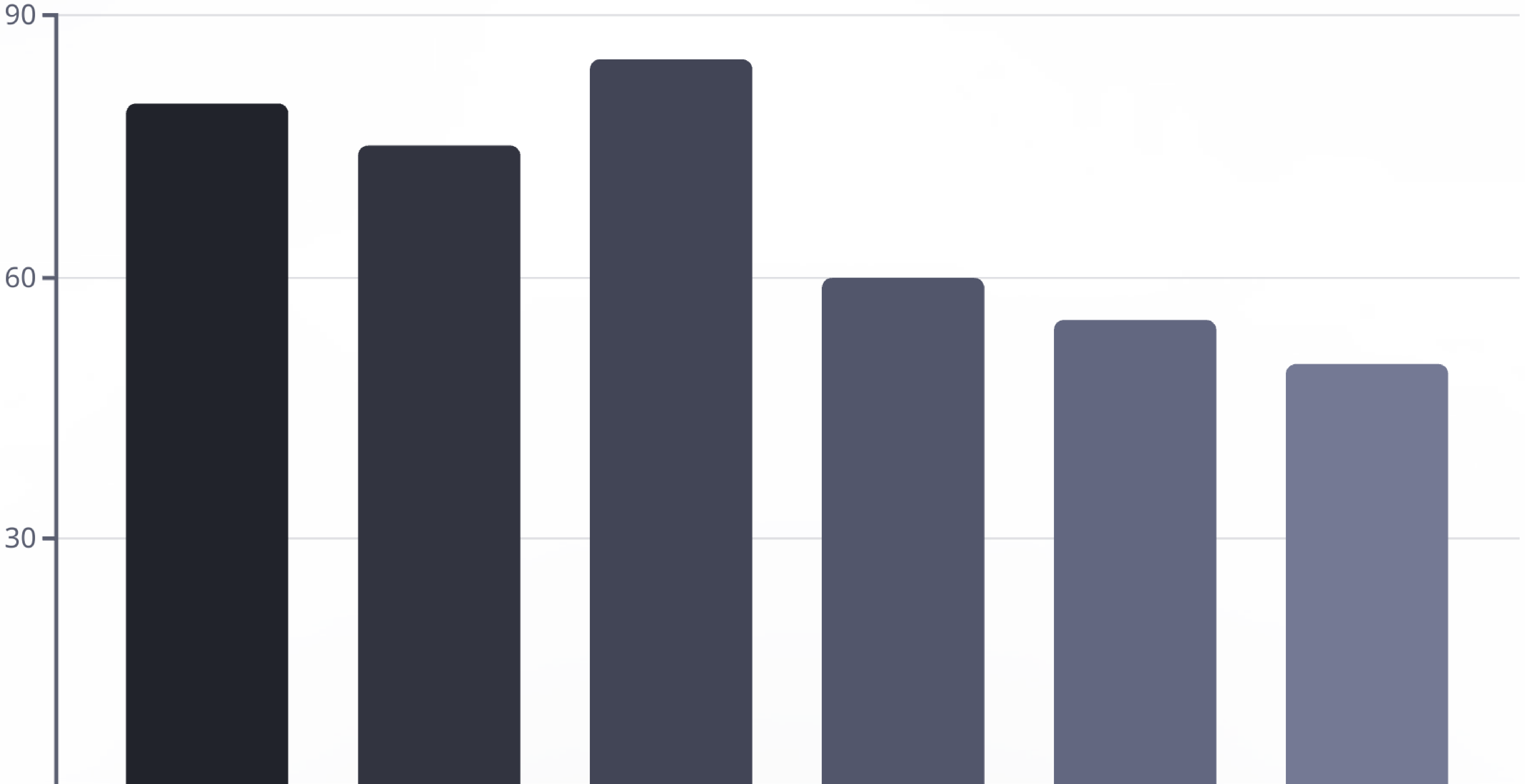
Further Learning

Detailed information on air filters and cleaners is provided in Unit 23 Forced-air Add-on Devices

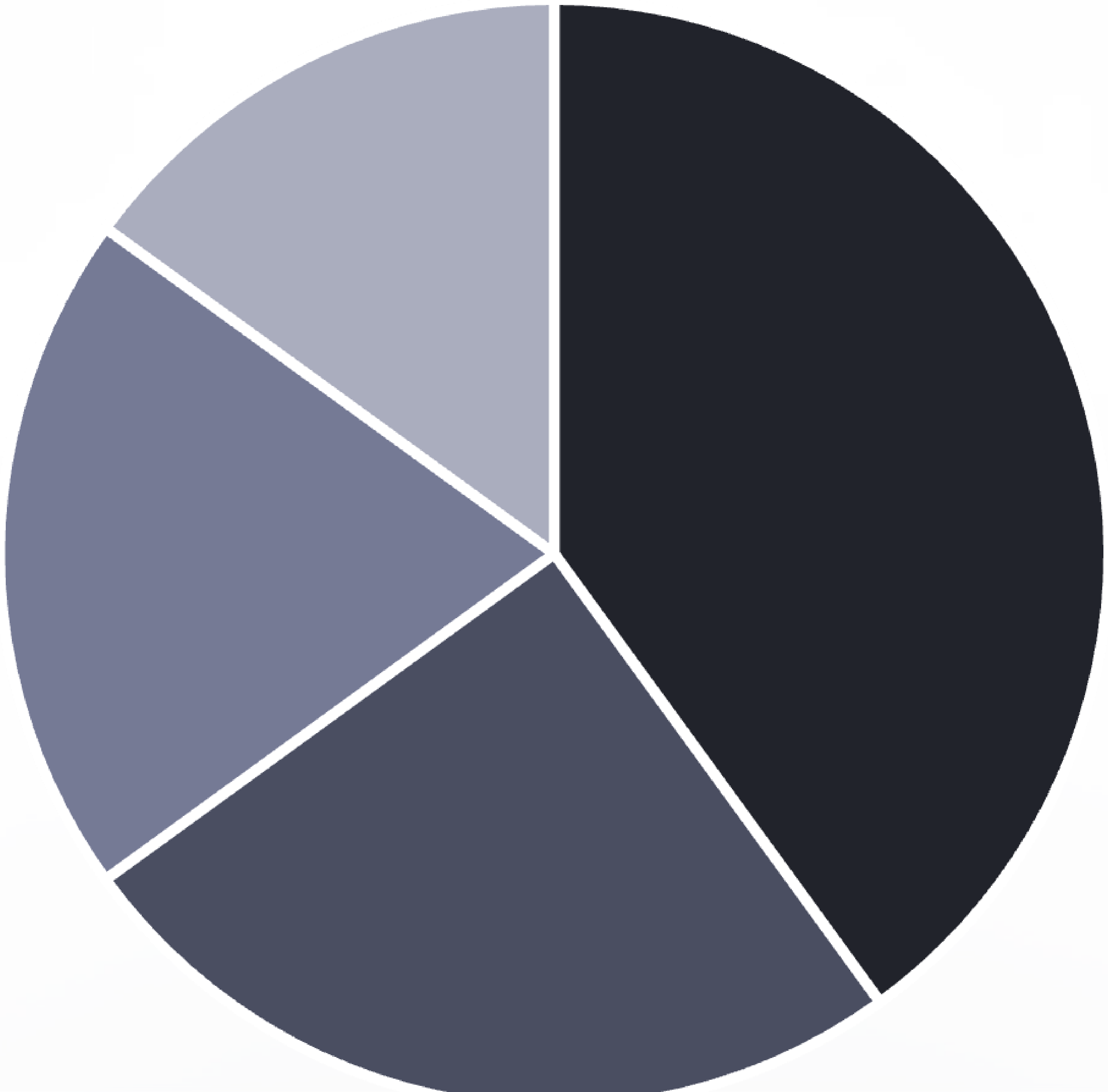
Chemical Pollutants Impact on Health



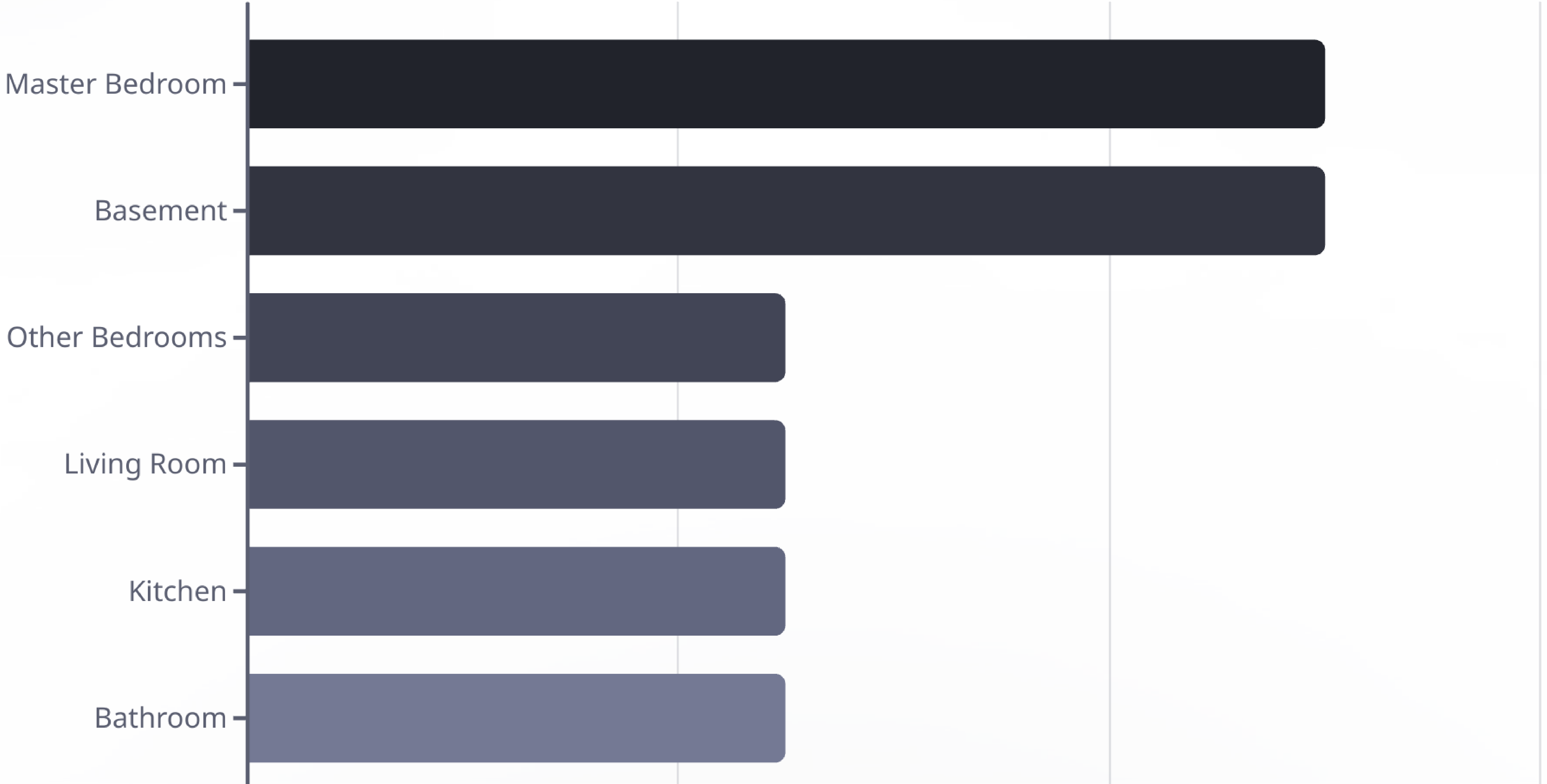
Biological Pollutants Impact on Health



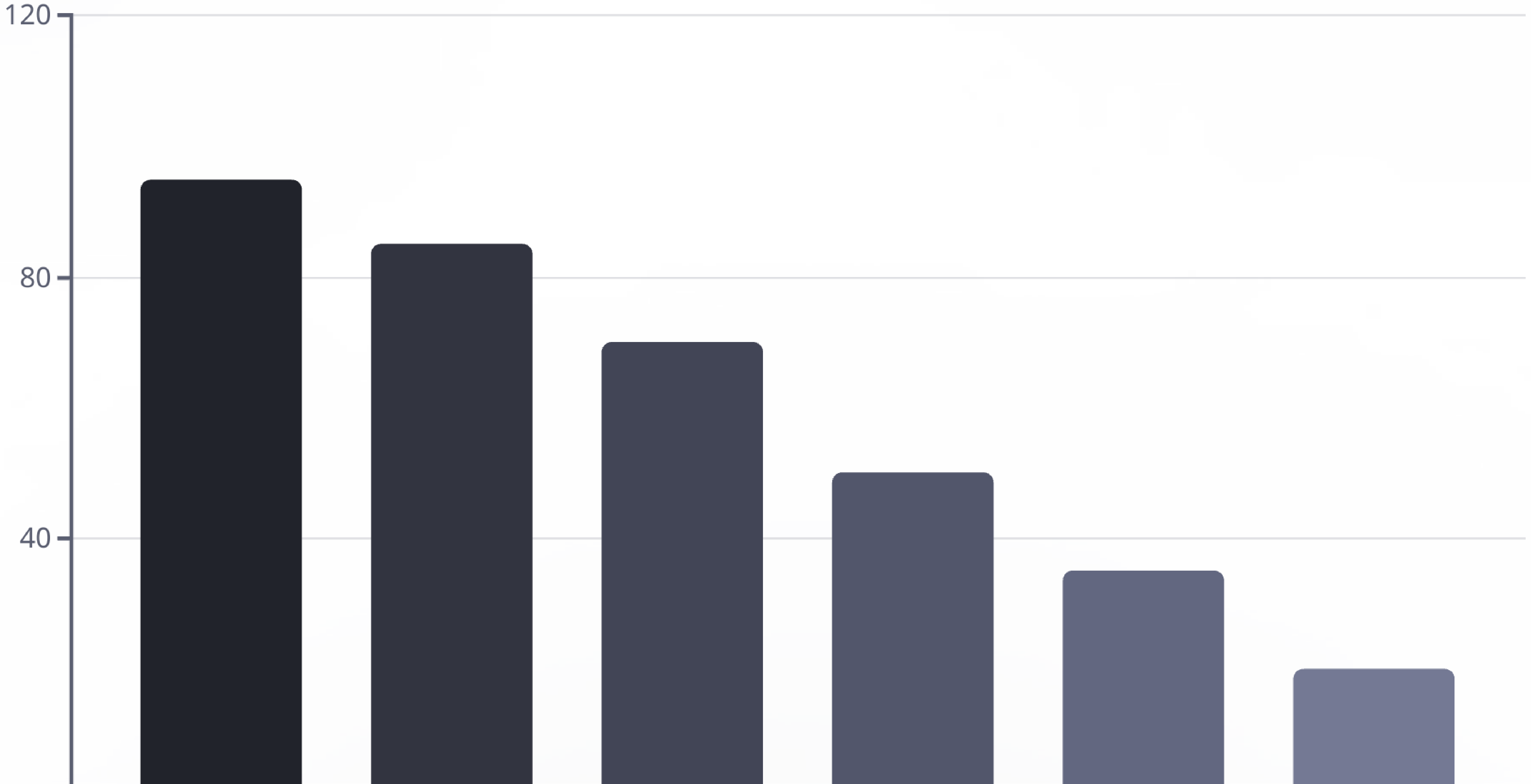
Ventilation System Effectiveness



Air Change Requirements by Room



Filter MERV Rating Effectiveness



Indoor Air Quality Components

Ventilation

Bringing fresh air in and removing stale air

Humidity Control

Maintaining proper moisture levels

Filtration

Removing particulates from the air

Temperature Control

Maintaining comfortable temperature

Source Control

Reducing or eliminating pollutant sources

Ventilation System Selection Process

Assess Building Needs

Evaluate the size, layout, and occupancy of the building

Review Code Requirements

Understand the NBC and local code requirements for ventilation

Select System Type

Choose between exhaust-only, supply-only, or balanced systems

Size the System

Calculate the required ventilation rates for each room

Installation

Install the system according to manufacturer specifications and code requirements

Testing and Balancing

Ensure the system is operating correctly and delivering the required ventilation

Indoor Air Quality Testing Methods

Carbon Dioxide Monitoring

CO2 levels can indicate the effectiveness of ventilation systems. Levels above 1000 ppm suggest inadequate ventilation.

Radon Testing

Short-term and long-term test kits can measure radon levels in homes. Levels above 4 pCi/L require mitigation.

VOC Monitoring

Specialized monitors can detect volatile organic compounds from building materials, furnishings, and cleaning products.

Ventilation System Maintenance

Regular Filter Replacement

Replace filters according to manufacturer recommendations, typically every 1-3 months

Duct Cleaning

Have ducts professionally cleaned every 3-5 years or as needed

Fan Maintenance

Clean fan blades and motors annually to ensure proper operation

Vent Inspection

Check exterior vents for blockages from debris, nests, or snow

Professional Inspection

Have the entire system professionally inspected annually

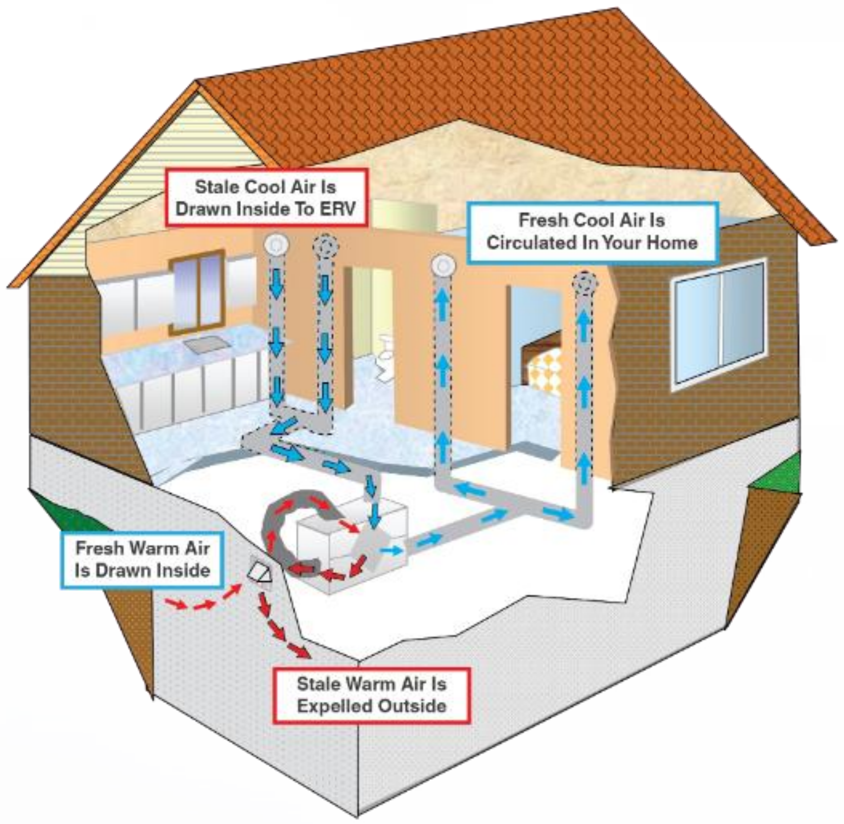
Energy Recovery Ventilators (ERVs)

Function

Energy Recovery Ventilators (ERVs) provide fresh air while recovering both heat and moisture from exhaust air

Benefits

- Reduces energy costs
- Maintains indoor humidity levels
- Improves indoor air quality
- Reduces condensation issues



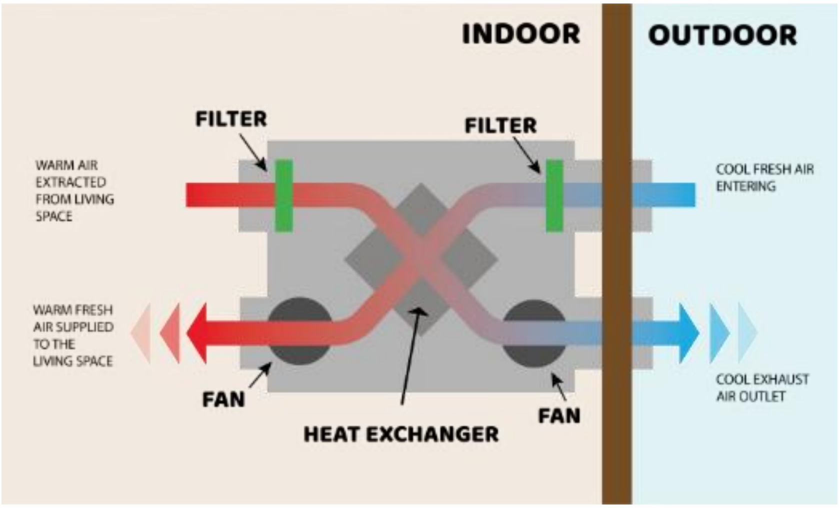
Heat Recovery Ventilators (HRVs)

Function

Heat Recovery Ventilators (HRVs) provide fresh air while recovering heat from exhaust air, but do not transfer moisture

Benefits

- Reduces heating costs
- Improves indoor air quality
- Helps control excess humidity in winter
- Ideal for cold, dry climates



Ventilation for Gas Appliances

Combustion Air

Gas appliances require adequate combustion air to operate safely and efficiently

Dilution Air

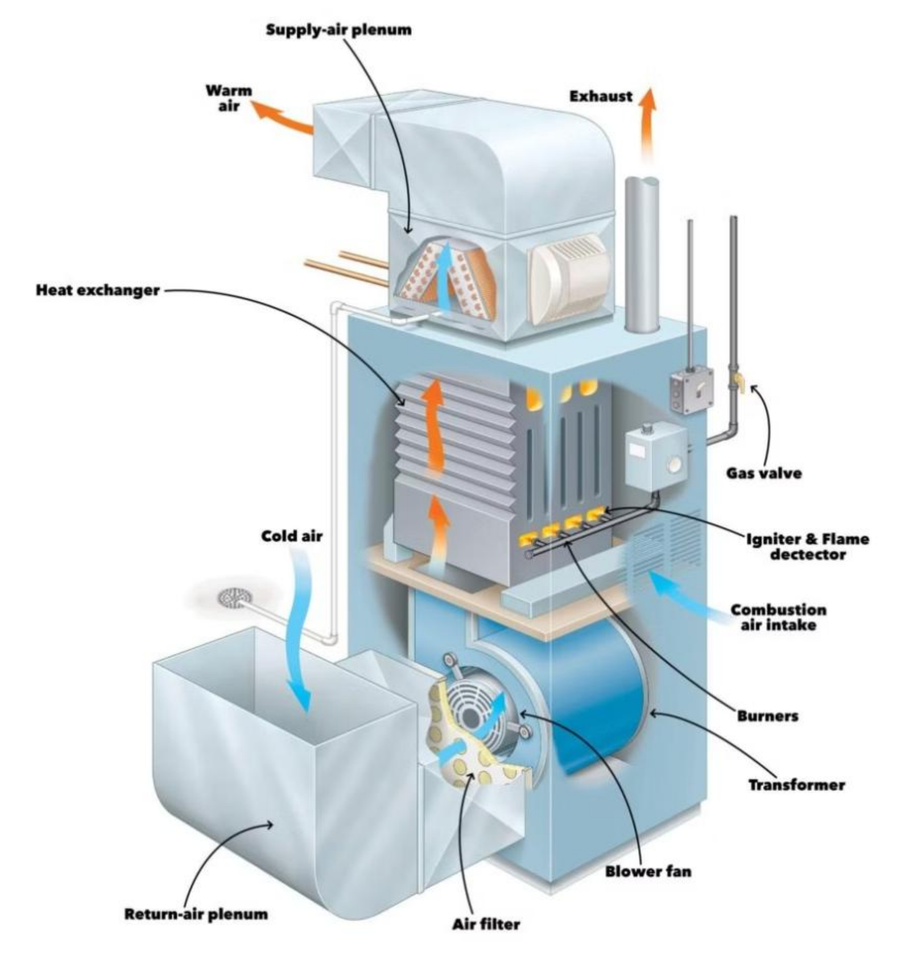
Dilution air helps cool flue gases and prevent condensation in venting systems

Makeup Air

Makeup air replaces air exhausted by appliances and ventilation systems

Code Requirements

CSA B149.1 specifies requirements for air supply to gas appliances



Depressurization Risks

Exhaust Fans

Kitchen and bathroom fans can create negative pressure

Fireplaces

Wood-burning fireplaces can draw large volumes of air

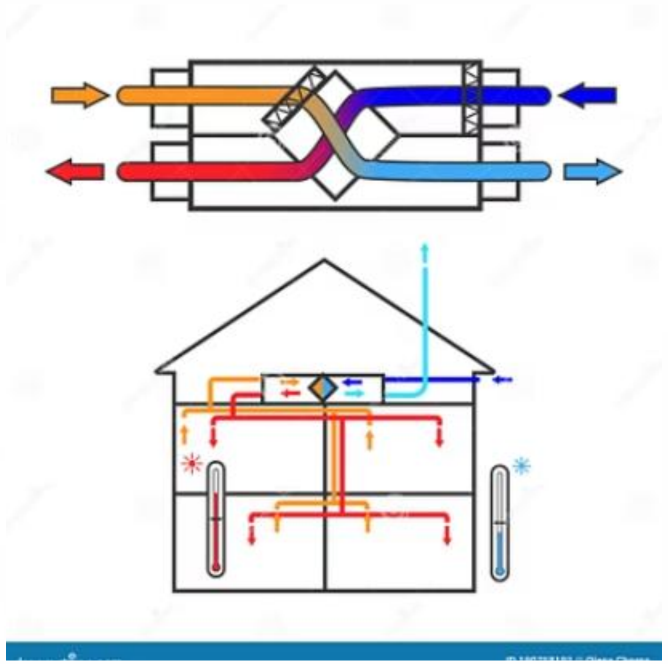
Clothes Dryers

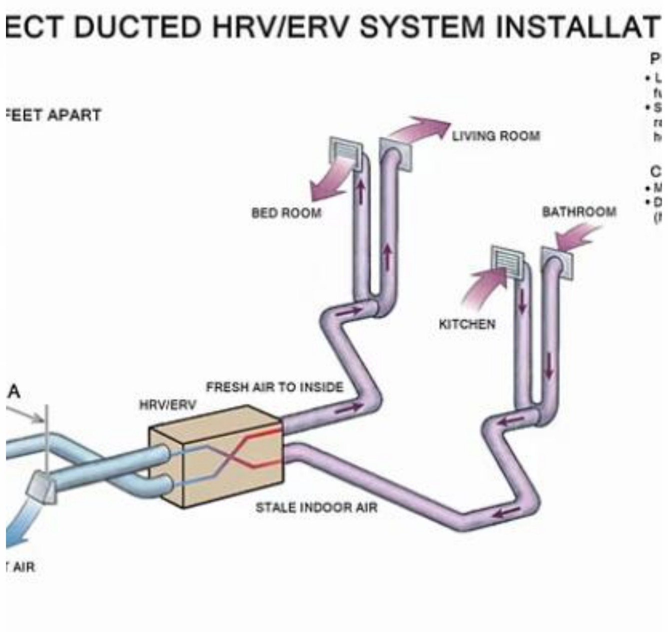
Dryers exhaust significant amounts of air

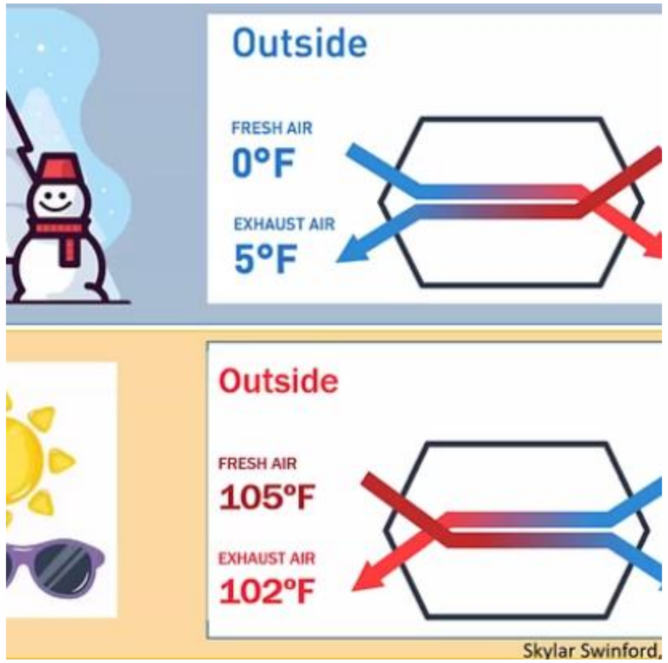
Backdrafting

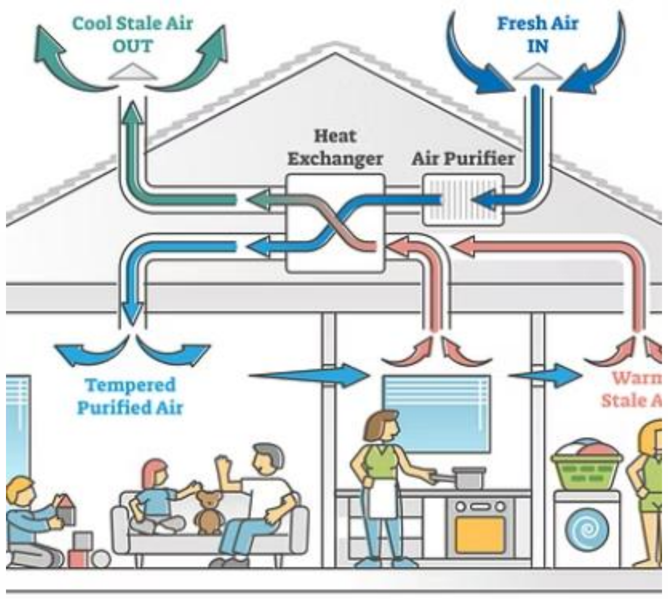
Negative pressure can cause combustion gases to enter living spaces

Ventilation in Tight Buildings



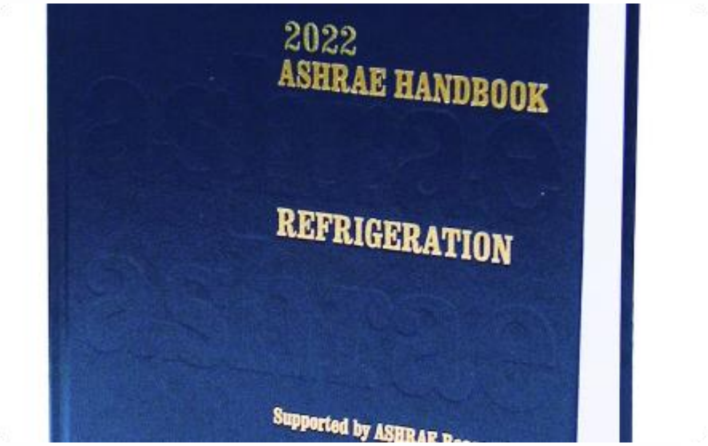






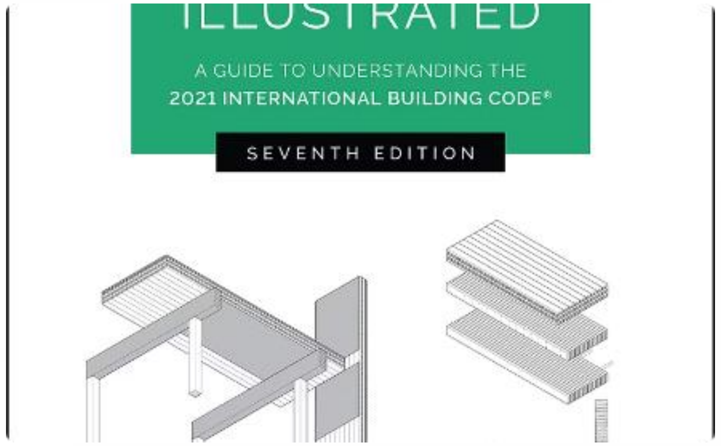
Modern, energy-efficient buildings require carefully designed mechanical ventilation systems to ensure adequate fresh air while maintaining energy efficiency. These systems often incorporate heat or energy recovery to minimize energy losses.

Indoor Air Quality Standards



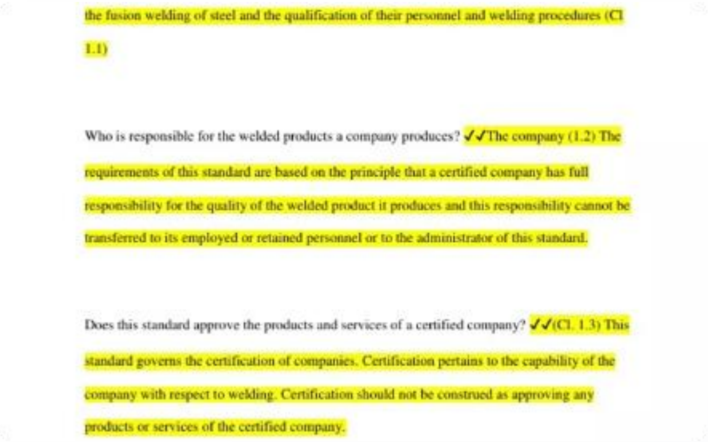
ASHRAE Standard 62.2

Establishes minimum requirements for ventilation and acceptable indoor air quality in residential buildings.



National Building Code

Provides requirements for ventilation of rooms and spaces in residential occupancies by natural ventilation and mechanical ventilation systems.



the fusion welding of steel and the qualification of their personnel and welding procedures (Cl 1.1)

Who is responsible for the welded products a company produces? ✓✓The company (1.2) The requirements of this standard are based on the principle that a certified company has full responsibility for the quality of the welded product it produces and this responsibility cannot be transferred to its employed or retained personnel or to the administrator of this standard.

Does this standard approve the products and services of a certified company? ✓✓(Cl. 1.3) This standard governs the certification of companies. Certification pertains to the capability of the company with respect to welding. Certification should not be construed as approving any products or services of the certified company.

CSA F326

Canadian standard for residential mechanical ventilation systems, specifying design, installation, and performance requirements.

Future Trends in Ventilation

Smart Ventilation

Systems that automatically adjust based on occupancy, humidity, and pollutant levels

Advanced Sensors

Improved detection of VOCs, particulates, and other pollutants

Higher Efficiency

More efficient heat and energy recovery systems

Integration

Ventilation systems integrated with home automation and HVAC controls

Summary of Indoor Air Quality

Health and Comfort

Good indoor air quality is essential for occupant health and comfort

Balanced Approach

Effective IAQ requires source control, ventilation, and filtration

Code Compliance

Following building codes ensures minimum ventilation requirements are met

System Integration

Ventilation must work with gas appliances for safe, efficient operation