

# RENOVATOR'S TECHNICAL GUIDE

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# Preface

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Since the publication of the *Renovator's Business Guide* in 1994, a need for a text dealing with the building science of renovations has been recognized. This publication addresses those issues and is expected to be widely used as reference in the field across Canada. Both *Renovator's Business Guide* and *Renovator's Technical Guide* are publications that complement the many how-to renovation manuals available.

This guide does not attempt to explain how to perform renovations but deals instead with why renovations become necessary. It looks at the performance of the house and the normal and abnormal conditions that can drive the need to renovate. The guide looks at the systems within the house, how they interact and how an alteration to one can cause another to malfunction. It explores both the existing problems of houses to be renovated and the implications of any changes being considered.

The guide is intended as a reference that permits the reader to move through the document from beginning to end. However, the convenient format of the publication also allows for quick reference of specific problems or renovations on an “as needed” basis.

The inclusion of building science “Insights” throughout this guide is meant to increase awareness of important building science issues that are sometimes misunderstood or forgotten during renovation procedures. These and the Healthy Housing Information contained in each chapter reflect growing concerns about occupant health and environmental impacts in the renovation industry.

This latest addition to the renovation publications from CMHC is a further effort towards providing accessible, affordable and sustainable housing in Canada.

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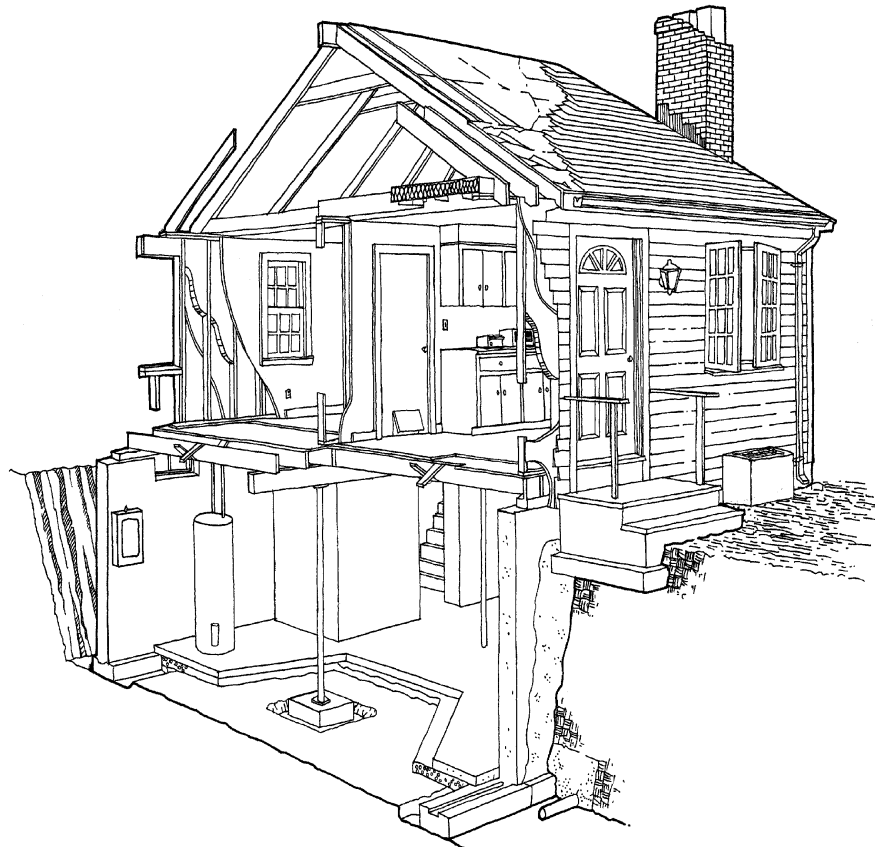


# Assessing the Renovation Project

**W**hen preparing to perform a renovation within an existing home, there are a number of administrative details that need to be addressed. This chapter introduces these concerns and provides advice about where to look for information on a particular topic. It also introduces you to the basic functions of a home and the expectations of its users, as well as the house-as-a-system approach to renovating. The contents of the other chapters are also described.

The chapter also features a discussion of basic business skills to help you to succeed as a renovator. These include the need to understand contracts, financing, approvals and other business management topics. It concludes with a discussion of Healthy House requirements to help you make responsible choices when renovating.

This guide is not a how-to manual. It does not explain how to complete a renovation project. Rather, it focuses on why problems occur, how to avoid them and how to avoid creating new ones as you renovate the house.



### INTRODUCTION

---

The modern home should fulfil the basic needs of the home-owner by providing shelter, comfort and aesthetic pleasure. A successful home also provides privacy and is a place for family and friends to gather, socialize and engage in family life. It fulfils a range of physical, psychological and social needs.

The primary role of a building is to provide shelter from wind, snow, sun and rain. The home protects occupants as well as their belongings. Buildings have been providing this function for many centuries.

Modern houses are also expected to provide comfort for the occupants. Fifty years ago, home-owners had lower expectations for their houses. Drafts, damp basements, uneven temperatures and other discomforts were common and widely tolerated. Heating systems were inefficient and cooling systems were largely non-existent in Canadian houses. Advances in mechanical technology have improved our control of the indoor environment. Heating and ventilating equipment is now installed in every new home. Many also contain cooling equipment.

Home-owners have also become more demanding in terms of the aesthetic requirements of their homes. The home is seen as an expression of personality and a reflection of the status of the occupants. Many people want their home to be distinctive from their neighbours' houses. The aesthetic demands of the home-owner also increase the need for quality construction and materials. A beautiful home will be spoiled by staining, rusting and other unsightly problems.

Over the last half century, we have come to better understand how buildings function and perform. Construction techniques and building technology have undergone rapid changes. Along with these changes, home-owners have come to expect more of their homes, and their expectations about performance and comfort continue to increase. All the same, the expectations of people living in older homes are also increasing, creating the demand for renovation work.

Developments in construction techniques in the last century have led to a diverse range of house types. Renovators have to be familiar with the range of construction methods as they work on these homes. They also have to be capable of integrating new techniques into old buildings without negatively affecting the existing systems.

Lately, we have also come to appreciate that buildings have an impact on our environment. The construction and maintenance of buildings generates waste and consumes energy. These environmental costs should affect decisions made on a project. Building practices need to be more sustainable to ensure a bright future for subsequent generations.

### ***Building Science***

Building science is the study of how buildings perform. It looks at how the systems, components and materials of the building affect the building as a whole. Building scientists tend to focus on the movement of heat, moisture and air in and through buildings.

Understanding building science will help you diagnose and remedy any defects you encounter in building. Fixing a symptom of a larger problem without finding the real cause can result in the reoccurrence of problems after the renovation. Building science will help you find the underlying cause of the defects you discover. It will also help you predict what effects your work will have on the house as a whole. This can help avoid problems you might cause unknowingly. The knowledge you develop about the science of how buildings work will help make your renovation projects successful and trouble-free.

Each system in the house is related to, and affects, other systems. This interrelationship demands that a different approach be taken in understanding how buildings work and in diagnosing how building problems are caused. The approach is commonly referred to as the *house-as-a-system* approach. The key to a successful renovation is to understand and consider the relationships that exist among the various systems in the house.

This book will help you determine what those relationships are and how to avoid upsetting them. It will guide you in considering the whole

house when planning the renovation and carrying out the work. It will also introduce building science fundamentals as a primer for dealing with real renovations.

The following chapters describe common types of renovations. Each one discusses potential and unexpected problems that might result from the renovation itself. The guide also applies the building science principles presented to specific types of problems.

### ***Top 10 Renovations***

The 10 renovations discussed in this book are based on common types of renovations performed across Canada. These include basement, kitchen, bathroom and attic space renovations, as well as building additions. Changes to exterior and interior finishes, to doors and windows and to mechanical systems are also covered. Opportunities to improve the energy efficiency of the home are explored in Chapter 11.

Chapter 2 presents the basics of building science. It deals with how houses are expected to perform and all of the systems that separate the interior environment from the exterior.

Chapter 3 discusses issues that relate to in-ground basement spaces. These include soil-gas entry, structural settlement, water infiltration from the surrounding soil, and headroom and escape requirements.

Kitchen and bathroom renovations have many shared concerns because of the similar activities that take place within these spaces. Water- and moisture-related activities, like dishwashing, cooking and bathing, make moisture damage an important issue in these renovations. Ventilation of odours and problems with plumbing are also common to both renovations. Chapter 4 addresses all of these concerns.

Chapter 5 discusses the repair or replacement of windows and doors and the relationship between windows and doors and the interior environment. Air leakage, light, heat, indoor air quality, ventilation and other issues are also covered. The relationship between the openings and the rest of the building envelope, as well as issues relating to safety and security, are also discussed.

Problems with the interior finishes of the home are usually linked to another faulty component or system in the building. Chapter 6 outlines the types of defects that are usually found and what their causes may be. It also looks at problems that may occur when new finishes are introduced to the home. These problems can include nail pops, poor indoor air quality and cracked drywall. Prevention techniques are discussed to reduce their occurrence.

Chapter 7 considers exterior renovations, such as painting, eavestroughing, roofing or siding replacement. Problems can relate to the lack of durability, improper installation of materials, or structural support. Changes to exterior finishes can cause problems with other components of the building envelope.

Chapter 8 covers the conversion of the attic space to a living area. Other topics include the function of the roof as part of the building. Construction, ventilation, insulation, noise, structure and mechanical systems will also be discussed.

Additions can affect buildings by putting extra loads on structural, mechanical, electrical and plumbing systems. Chapter 9 deals with proper planning for an addition.

The guide takes a slightly different approach with Chapter 10. Its discussion of mechanical systems includes troubleshooting. The chapter looks at how changes to mechanical systems impact the rest of the building and the effects of other renovations on existing mechanical systems.

Energy efficiency retrofits are the subject of Chapter 11. Special attention is paid to how the building envelope separates the interior and exterior environments. The chapter links heat, air and moisture flows to insulation, air-barrier and vapour-retarder systems.

### ***Steps to a Trouble-free Renovation***

Each chapter presents the five steps to a trouble-free renovation. These are:

1. observation;
2. diagnosis;
3. solution formulation;
4. remediation; and
5. renovation.

By observing defects in the building, diagnosing their causes, determining appropriate solutions and performing remedial action before renovating, you can help to ensure that problems do not recur in the new work.

Observing defects is an important first step in any type of renovation. Other systems may be at the root of problems you find. You will need to examine the building carefully to determine the true cause of any defects you discover. Careful assessment can reveal whether the problem is on-going or a one-time event. Note the materials, components and systems that are involved. Is the problem evident in other parts of the house?

Asking questions and assessing the lifestyles of the occupants can give clues about the causes of some types of problems. The importance of occupant lifestyle assessment is discussed later in this chapter.

Diagnosing defects involves determining which mechanisms are at work. It is important to know if problems relate to moisture movement, air movement or heat movement. If a problem is moisture-related, the type of moisture — bulk, vapour or capillary — will provide clues about the nature of the problem. Are other systems affecting the defect? Be sure to look for hidden problems and indirect causes.

Problems can be related to poor support from the structure or soil or to improper installation or material defects. A number of problems in a variety of systems relate to the age of the building. Always check to see if this is a possibility. Finally, understand how the material, component or system should have behaved.

When developing solutions to defects, focus on long-lasting solutions. Solutions that deal with the cause of the problem rather than providing symptomatic relief are preferable in the long run. Although these solutions may be more expensive and time consuming now, they will prevent replacing or repairing the new work in the future.

If you are unsure about how to remedy a defect, it is important to call in a specialist for advice. Bad repairs will show up later, disappointing the home-owner and possibly harming your reputation.

Remedy a defect by fixing the problem so that it will not reoccur. Good workmanship is essential. The remedy to a defect may seem only peripherally related to the renovation at hand. Left unattended, however, it will shorten the life of your renovation work.

Renovate the building only after completing the first four steps identified above. In all cases, understand the implications of your proposed renovation and how other systems might be affected.

In many parts of the country, renovations need only be constructed to the standards of the original construction. Going beyond these standards may provide additional benefits.

### ***More on Property Assessment***

Proper inspection, preparation and pre-planning are important to the success of your renovation. You need to ensure that the planned renovation is practical and economical. Planning the renovation well before starting the work will help you avoid surprises and conflicts later in the project. Assessing the condition of the existing building will give you an indication of how much of the budget will have to be spent on remedial work.

Your assessment of the building should answer one question that needs to be asked of every renovation project: Is it worth performing the renovation? If the renovation will cost more than is reasonable for the building, or if the project is unrealistic, it may be wise to reconsider it with the client. In some cases, the owner may be happier with a new or different house than with the renovation.

Determine whether there were previous renovations to the house. This may affect your ability to make changes. The age of the house is another issue to consider. If the house is very old, some of the materials or features may have a historical value, and the home-owner may not want, or be allowed, to remove or alter them. The age of the house will also give some hints about the type of construction and the quality of materials that were used.

When planning a renovation, you may want to replace items that are likely to soon fail in order to prevent later problems. The age of the materials may indicate that they are not compatible with present-day materials. If

restoration work is required, or if the building is historically important, it may be wise to consult a restoration expert before continuing. All of these issues should be considered when advising the client and accepting the project as they can add time and money.

Assessing the lifestyle of the occupants will help you determine if they are the cause of any of the problems in the house. If a particular area is subject to high use, or if the occupants prefer an unusual indoor climate, problems with the existing house may be evident. Figuring out the specific needs of the client will help you to prepare for these factors when planning the new renovation. Materials with better durability or a whole-house ventilation system may be useful in these areas to eliminate problems.

The lifestyle assessment will also give clues about design and layout needs. This is an important part of planning the renovation. Your suggestions as an outside observer may be useful in helping home-owners discover needs they have overlooked.

Your defect recognition and home-owner lifestyle assessments will help the client realize that you are interested in doing the job properly. Explaining the need for the remedial work, communicates to the client that you are not just trying to sell them additional work but are genuinely concerned about the quality of renovation.

Establishing a good relationship in this part of the process will increase the customer's trust in your abilities. If an unexpected problem does occur, they will be more likely to understand the cause of the oversight.

Before starting the renovation, or even confirming the contract, be sure that you completely understand your client's expectations. Clients may plan to inhabit the building during the renovation. This will affect your scheduling of the work and may affect your performance. They should be made aware of what interruptions to expect. Shut-off water, noise early in the morning and construction dust can upset an occupant who isn't properly prepared to live with the effects of a renovation. The work can be trying on people who have to live with the construction mess, so you will need to be sensitive to these issues. Renovations

with live-in clients may cost more because of heating needs, limited work schedules and interruptions. The client should also be made aware of these factors.

You should make sure that you communicate your expectations to the client, as well as understanding theirs. As a renovator, you are there to work on a specific project and costs of delays and interruptions that are caused by the client can not be absorbed by you. The client is also paying you only for the work described in the contract and should not expect you to provide other services while you are on site.

Good communication before the project begins can prevent headaches and problems later. If the expectations of the client seem unreasonable, now is the time to let them know. It may be better to walk away before the contract is signed and the situation gets difficult than to leave in the middle of a project or deal with the effects of a dissatisfied client.

## ASSESSMENT CHECKLISTS

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The Assessment Checklist outlines problems that are often detected in renovation projects. Each item is discussed in detail on the referenced pages.

Remember that problems may be rooted in a number of causes. Always follow the five steps to a successful renovation:

- Observe defects carefully;
- Diagnose the true cause of any problems;
- Find appropriate solutions;
- Remedy the problem and the cause; and
- Then start the renovation work.

Assess the condition of the entire building at the beginning of the process, focusing on specific aspects related to the renovation. Include in your assessment all of the structural elements like foundations, roofs, floors, exterior and interior walls and lintels over openings. Be sure to check the non-structural elements of the building as well. Work through the building systematically to ensure you don't miss anything. Working from the bottom up and from the inside out is a common approach.

Although a complete and detailed assessment can be time consuming, it can uncover

unanticipated problems that can play havoc with your renovation. In addition, it can often be used to alert the home-owner to necessary work that was not initially considered, increasing the value of the total project.

Note the problems you encounter carefully. Summarize these for the home-owner and describe whether any of these will adversely affect the performance of the new work. Consider what you will do if the home-owner is not interested in remedying any of the existing problems. Know that your reputation rides on the quality of your work.

### BASIC BUSINESS SKILLS

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Some basic business skills are required by the renovator for successful practice. Office and job-site management are important for proper execution of a project. Getting proper approvals, keeping track of budgets, maintaining insurance and Worker's Compensation and other administrative functions are those aspects of good office management that should not be overlooked.

Renovator's public liability insurance covers bodily injury or death suffered as the result of an accident at the renovation site. All renovators are required to carry this insurance. It will help to cover any lawsuits or expenses that may result from these types of problems. Practising without insurance is dangerous and may be unlawful. Insurance fees are typically paid as an annual sum and can be considered an overhead expense.

Maintaining a clean, hazard-free environment, using labour and materials properly and controlling quality will ensure the job site is as efficient as the office. You should refer to Canada Mortgage and Housing Corporation's *Renovator's Business Guide* 60944 for more information about these and other business practice-related issues.

Estimating the cost of the work and the time and effort required are essential for the successful renovator. There are many sources of information available from libraries, bookstores, colleges, and universities as well as CMHC. Ensure you understand how to perform

estimates properly before you set about securing work.

A checklist of appropriate steps to follow is given in the *Renovator's Business Guide*. You should refer to that manual for more information about the preparation of estimates.

There are a few different types of contracts that are typically used by renovators. Fixed-price contracts, cost-plus contracts and unit-price contracts are among the most popular. Learn about them and choose the type that is most suitable. Your local home builder's association will be able to provide you with more information. Your lawyer should be able to prepare a contract for you to use.

A complete set of dimensioned drawings will often be required for the project to begin. These drawings can be used for estimating purposes and for obtaining permits and approvals. An architect or designer can be retained to produce these drawings. He or she may be the first of many professionals involved in the project.

Whether you are refinishing an interior or adding on to a building, approvals are often required from local municipalities. Building permits may be required. Plans will need to be examined for zoning purposes, building code conformance and possibly fire code approvals.

Your reputation and business success are based on your reliability as a renovator. In order to be a reliable renovator, sound business practices should be maintained.

Doing the job right and getting it done on time is one business practice that is indispensable to the professional renovator. Proper installation and workmanship build your reputation, and word-of-mouth is often your best advertising.

Timeliness and schedules show that you understand how long a project should take and that you work well within a time constraint. Overruns and delays increase the cost of a project. Your relationship with the client will be improved if you stick to the schedule.

Third-party consultation is advisable when you are unsure about how to proceed on a project. Allowing the home-owner to know where your limits are shows you are honest and gains their trust.

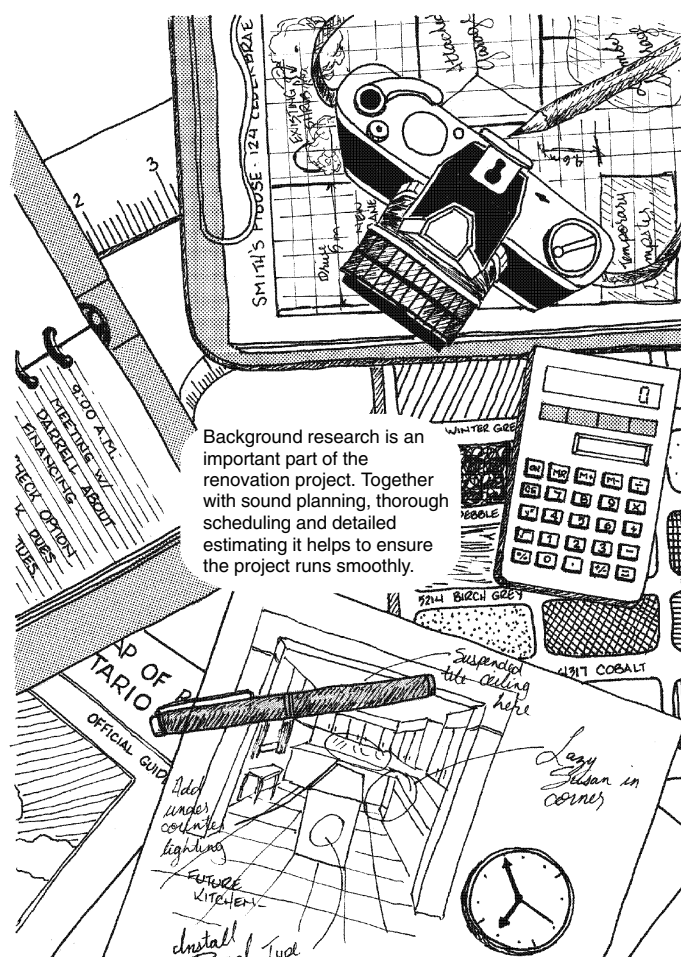


Expert advice can be used to inform home-owners when they are unwilling to fix defects in a house before renovating. An independent third-party advisor—such as a recognized home inspector—can be your ally. Literature from manufacturers or regulatory bodies may also help to convince them of the importance of the work. This guide is one reference that may be used for this purpose. There are a number of other bodies that may also provide advice or literature. These include CMHC, new home warranty programs, local utilities, local, provincial and national home builders' associations, building product manufacturers, and suppliers.

## HEALTHY HOUSING

Renovating a house to provide a healthy indoor environment for its occupants should be a priority for every renovator. Unfortunately, time and economics are often given more importance at the expense of occupants' health and environmental preservation. However, incorporating Healthy Housing elements may not cost more and may save money by reducing the operating cost of the home. There are five principles you should observe when planning a healthy renovation:

**Figure 1-1: Background Research Helps Plan a Proper Renovation**



1. occupant health;
2. energy efficiency;
3. resource efficiency;
4. environmental responsibility; and
5. affordability.

A Healthy House should provide a healthy, clean and hazard-free environment for its occupants. Indoor air quality is a specific concern with respect to occupant health. Indoor air can become polluted due to poor ventilation, high humidity or chemical and biological contaminants. These issues need to be considered when selecting products, installing mechanical systems and doing any air-tightening work on the house.

A Healthy House should be energy efficient. Using as little energy as possible reduces the impact on the environment, indirectly improving the occupants' quality of life. Consider improving the thermal resistance and airtightness of the building envelope and select energy-efficient appliances and light fixtures.

A Healthy House should be resource efficient. Using as few resources as possible and reusing or reworking parts of the design to incorporate recycled or reused items will reduce the environmental impact of the renovation. Using durable materials that have to be replaced less often and choosing plumbing fixtures with low water consumption are other ways of conserving our natural resources. Proper handling and disposal of construction waste also falls under this principle.

A Healthy House should be an environmentally responsible house. Heating systems with improved efficiency will burn less fuel and emit less pollutants. Sewage can be reduced and wastewater can be used for dual purposes like watering lawns or plants. Community-planning and site-planning issues are also considered in an environmentally responsible house. Land use and density affect the community, while landscaping, orientation and siting are issues that relate to the specific site. Proper disposal of construction waste, especially hazardous materials, is also an important issue in environmentally conscious house renovations.

Finally, a Healthy House needs to be affordable. There is no sense performing renovations that

are not affordable for the client. Healthy Housing is about making choices based on knowledge about materials and systems.

When working in the home, consider the health of the workers and the occupants. Making yourself or the home-owner sick is not part of a good renovation.

A number of toxic chemicals are contained in both new and old construction materials. When installing potentially harmful or toxic products, read the labels and Material Safety Data Sheets (MSDS) and follow ventilation and other safety precautions carefully.

Painter's colic was a common problem with professional painters years ago. The problem was linked to the use of lead in paints. When renovating, you should consider that the paint you are removing in the house may contain lead. If the house was built before 1980, small amounts of lead may be in the paint. If the house was built before the mid-1950s, paint will usually contain substantial amounts of lead. Lead levels are highest in exterior paint.

Be informed about all materials you are working with. Inform the occupants of the house and your employees that products should be used and removed with care.

With materials that already exist in the house, care should be taken when disturbing or removing them. If you don't know what a product is, you should attempt to find out before removing it — some materials can be hazardous. This precaution should not be taken too lightly.

Materials that might cause health problems or irritate existing ailments can be natural or man-made. Natural materials can include red woods like cedar, redwood or red oak. Gypsum dust from sanded drywall, exposed mold particles and household dust are other examples. Materials that are often associated with health hazards include asbestos, paints and paint strippers, solvents and adhesives. Use care when handling any of these materials.

Refer to Insight 1 — Sustainable Development — for further discussion. Also read each chapter carefully and consider the building science implications of each renovation project. You should also review how the changes that are made to the house can adversely affect its performance. Finally, consider the steps you

### Insight 1 — Sustainable Development

Sustainable Development is a concept first proposed in a 1987 United Nations Report entitled *Our Common Future*. In moving towards development that is sustainable, we must evaluate the impact of human activities on the biosphere and on future generations. In terms of building, this implies responsible approaches to development that consider all resource requirements, their renewability and all of the waste that results from processes and end uses. It means applying the three Rs (reduce, reuse and recycle) to construction materials. Sustainable Development also focusses on:

- the selection of environmentally appropriate materials;
- energy efficiency; and
- water efficiency.

Some common “green” measures that can be incorporated into every building renovation include the careful selection of environmentally benign materials and the reuse of existing materials and resources. The selection of energy-efficient appliances, including lighting and space heating equipment is an important component of sustainable building practices. The use of renewable energy sources, such as passive and active solar space and water heating, wind energy and small hydro reduces the environmental damage caused by more conventional sources. The selection of low

water consumption fixtures makes better use of a resource that has the potential to be in short supply.

During renovation, Sustainable Development also involves minimizing site disruption in order to preserve natural systems. It implies reducing landfill loads by reducing material waste through reusing, recycling and waste management strategies.

Because decisions made in the design of buildings or building renovations have long-term implications for occupant health and safety, designers and renovators help owners become aware of these important issues. Consider that of the total building and operating costs over a 30-year period, the initial building cost accounts for only 25 percent of the total, while operating and maintenance costs account for the other 75 percent. It is clear that significant savings can be achieved by analyzing and understanding building-related costs over the life span of the building. The responsibility of renovators does not end with the renovation of the home but goes on to include educating the owners on how best to use their homes.

Our homes and the processes we use to construct them are the legacy this generation leaves for others that follow. We need to become responsible in the choices we make and in the houses we construct.

need to take to ensure the renovation is a healthy one — for everyone.

## FLEXHOUSING

The key to FlexHousing is that it is easily adapted to meet specific needs rather than relying on custom designs. FlexHousing dwellings provide the initial occupants and subsequent occupants with accessibility, safety,

security, ease-of-operation, convenience, comfort and access to in-home services as their needs and preferences change over time.

To ensure that a dwelling will be flexible enough to meet a broad range of individual needs over time, certain features could be incorporated at the time of renovation. These include features such as barrier-free access, space for maneuverability, and wide doorways.

**Checklist****CHAPTER 3 — FOUNDATION AND BASEMENT RENOVATIONS****FOUNDATION PROBLEMS AND CONSTRUCTION TECHNIQUES (page 53)**

- ☐ cracks in slabs, walls and footings
- ☐ uneven settlement
- ☐ headroom problems
- ☐ inadequate support of main floor system, inadequate footings for walls and columns (deflection, bounce)
- ☐ aggregates settled to bottom, uneven mix, honeycombing

**CONCRETE CURING AND SHRINKAGE (page 54)**

- ☐ spalling concrete
- ☐ porous or powdery concrete
- ☐ stable cracks (no water leakage)
- ☐ cracks at openings

**BACKFILLING PRACTICES (page 54)**

- ☐ warped or bowed foundation walls
- ☐ cracks with and without movement

**ADFREEZING AND FROST HEAVE (page 55)**

- ☐ cracked brickwork
- ☐ uplift with cracking

**FOUNDATION PROBLEMS AND SOIL BEARING CAPACITY (page 56)**

- ☐ unstable or weak soils (75 kPa bearing capacity)
- ☐ settlement cracks in walls with or without movement

**SOIL GASES (page 56)**

- ☐ soil gas or radon infiltration
- ☐ bad smells or odours, nausea, headaches, poor indoor air quality
- ☐ high humidity

**INSECT INFESTATION (page 57)**

- ☐ termite soil tubes visible
- ☐ carpenter ant damage
- ☐ rodent damage

**Checklist (Cont'd)****PROBLEMS FROM WATER VAPOUR (page 58)**

- ☐ high humidity
- ☐ condensation on windows, pipes and other fixtures
- ☐ condensation on or behind the vapour barrier
- ☐ damp spots, mold on walls
- ☐ stuffy damp smells

**PROBLEMS FROM CAPILLARY WATER (page 60)**

- ☐ damp walls and floors
- ☐ musty or damp carpets
- ☐ sill decay in window wells
- ☐ wet or decaying wood in contact with the foundation walls or slab
- ☐ stuffy damp smells
- ☐ white powdery stains (efflorescence) on exposed concrete walls and floors (interior or exterior)
- ☐ presence of mold

**PROBLEMS FROM BULK WATER (page 62)**

- ☐ stuffy damp smells
- ☐ wet insulation
- ☐ concrete cracks with water leakage or staining
- ☐ standing water in the basement
- ☐ decaying sill plate
- ☐ presence of mold

**CHAPTER 4 — RENOVATING KITCHENS AND BATHROOMS****DESIGN CONSIDERATIONS (page 74)**

- ☐ problem of kitchen and house-entry relationship
- ☐ congested traffic paths
- ☐ circulation problems in food preparation, storage, counter space, eating and clean-up areas
- ☐ inadequate natural light

**STRUCTURAL CONSIDERATIONS (page 78)**

- ☐ notched or drilled framing members
- ☐ unknown location of load-bearing walls
- ☐ cracked ceramic tile
- ☐ bulging floor over beams

**Checklist (Cont'd)****MOISTURE DAMAGE (page 78)**

- ☐ condensation on surfaces
- ☐ frosting on windows or sills
- ☐ blistering and peeling paint
- ☐ mold growth
- ☐ dusting on walls
- ☐ rotting fixtures
- ☐ chipped or cracked grout or caulking
- ☐ staining of walls and finishes
- ☐ musty smells within walls or cupboards

**INDOOR AIR QUALITY (page 81)**

- ☐ poor indoor air quality
- ☐ lingering odours and contaminants
- ☐ high humidity
- ☐ no exhaust fans

**PLUMBING PROBLEMS (page 81)**

- ☐ galvanized steel, cast iron or lead piping found in older buildings
- ☐ corroded piping
- ☐ leaks at pipe joints
- ☐ condensation on cold pipes
- ☐ poor drainage
- ☐ odours
- ☐ poor water pressure

**DAMAGED MATERIALS OR FINISHES (page 82)**

- ☐ deterioration of floor finishes
- ☐ deterioration of other materials

**CHAPTER 5 — REPLACING WINDOWS AND DOORS****WATER DAMAGE (page 92)**

- ☐ lifting, flaking or blistering paint on window trim
- ☐ water stains on walls under windows or on window trim or frame
- ☐ frost on door hardware
- ☐ window condensation or frosting

**Checklist (Cont'd)****WATER DAMAGE (cont'd)**

- ☐ condensation or mold growth on the wall or window frame around the window or door
- ☐ condensation between panes

**AIR LEAKAGE (page 96)**

- ☐ drafts around openings
- ☐ dust and dirt staining around windows

**STRUCTURAL SUPPORT (page 96)**

- ☐ cracks in wall finishes at the corners of window or door
- ☐ sticking or binding windows
- ☐ cracked glass panes
- ☐ door frames out of plumb
- ☐ binding or warped doors

**OTHER PROBLEMS (page 96)**

- ☐ water sitting on window or door sills
- ☐ worn or damaged weather stripping
- ☐ deformed plastic window frames
- ☐ discolouration of doors, windows, skylights or frames
- ☐ squeaking hinges or sticking doors
- ☐ cracked caulking
- ☐ deterioration or rot of wood frames
- ☐ deformed plastic panels on exterior doors

**CHAPTER 6 — RENOVATING INTERIOR FINISHES****WATER DAMAGE (page 110)**

- ☐ lifting or flaking paint
- ☐ blistering paint
- ☐ water stains on upper floor ceilings
- ☐ blackened or swollen hardwood floors
- ☐ dusting on interior finishes
- ☐ shadowing at stud or truss locations
- ☐ swelling of floor underlay
- ☐ moldy carpets and other finishes
- ☐ water staining on walls, window trim or window frame
- ☐ soft, rotten or bulging drywall or plaster

**Checklist (Cont'd)****STRUCTURAL SUPPORT (page 116)**

- ☐ cracks in wall, ceiling or floor finishes
- ☐ warped or squeaking floors

**CONSTRUCTION TECHNIQUES (page 118)**

- ☐ squeaking, sagging, warped or crowning floors
- ☐ nail pops
- ☐ cracking of tile floors
- ☐ resilient floor finish shows dents and joints of underlay below
- ☐ swelling of floor underlay
- ☐ ripples or bubbling of carpets
- ☐ telegraphing of floor finishes

**DURABILITY OF MATERIALS (page 121)**

- ☐ faded or peeling paint and wallpaper
- ☐ carpeting stained, dampened or rotting
- ☐ lifting of sheet vinyl or vinyl tile
- ☐ panelling
- ☐ worn resilient or vinyl flooring
- ☐ resilient floor discolouration

**CHAPTER 7 — REPAIRING AND REPLACING EXTERIOR FINISHES****INADEQUATE RAIN-AND-SNOW-SHEDDING SYSTEM ON ROOF (page 129)**

- ☐ asphalt shingles — warped, uneven, curled, or missing surface granules
- ☐ wood shingles — ragged, rotting or broken
- ☐ built-up roofing — blistered, brittle or soft in spots
- ☐ damaged or corroded flashing at chimneys, plumbing stacks, valleys, dormers, and so on
- ☐ eavestroughs — overflowing, sagging, rusting, corroding or clogged with debris
- ☐ soil erosion around downspout
- ☐ shingle granules under downspout outlets
- ☐ interior water damage (ice damming)

**INADEQUATE RAIN-AND-SNOW-SHEDDING SYSTEM ON WALLS (page 136)**

- ☐ uneven staining on exterior finish
- ☐ open joints in siding



**Checklist (Cont'd)****INADEQUATE RAIN-AND-SNOW-SHEDDING SYSTEM ON WALLS (cont'd)**

- ☐ stained or damaged window or door frames and sills
- ☐ decay under window sills
- ☐ interior water damage
- ☐ paint peeling or blistered
- ☐ clogged or plugged weepholes
- ☐ missing mortar

**INDIRECT CAUSES OF FINISH DISTRESS (page 137)****Structural or Attachment Deficiency**

- ☐ uneven shingles or roof finish
- ☐ missing shingles (wind)
- ☐ warped siding — compressible insulation
- ☐ buckled siding

**Adfreezing or Frost Heave**

- ☐ cracked exterior masonry veneer on unheated garages
- ☐ cracked or warped siding on unheated garages

**Inadequate Dampproofing or Rain Diversion System**

- ☐ efflorescence
- ☐ brick spalling

**Grading**

- ☐ damaged wood or other siding material at or near grade
- ☐ soiled brick at or near grade

**Other Deficiencies**

- ☐ melted shingles
- ☐ dented siding
- ☐ insect or pest damage

**CHAPTER 8 — ATTIC CONVERSIONS****STRUCTURAL DAMAGE AND FOUNDATION SUPPORT (page 147)**

- ☐ inadequate footings
- ☐ weak foundation
- ☐ superstructure instability
- ☐ sagging ceiling or floor joists
- ☐ deflected floor joists

**Checklist (Cont'd)****WATER DAMAGE (page 147)**

- ☐ peeling or blistering paint
- ☐ wet or damaged ceiling finish on ceiling below attic
- ☐ leaky roof
- ☐ leaks around penetrations in the roof

**AIR AND VAPOUR PROTECTION (page 148)**

- ☐ condensation problems
- ☐ hoar frost
- ☐ mold

**ATTIC VENTILATION (page 149)**

- ☐ heat-deformed shingles
- ☐ inadequate soffit or roof venting

**SERVICES (page 149)**

- ☐ inadequate heating of parts of the house
- ☐ deteriorated or substandard plumbing and electrical system

**CHAPTER 9 — NEW ADDITIONS****DESIGN, APPROVALS AND PERMITS (page 162)**

- ☐ zoning bylaw review (site coverage, sideyard and setbacks)
- ☐ building code review (compliance and compliance alternatives)
- ☐ property survey (dimensions of property lines)
- ☐ interior and exterior traffic patterns
- ☐ site use restrictions and limitations

**SITE AND FOUNDATION CONDITIONS (page 162)**

- ☐ surface water not diverted away from the building
- ☐ poor soil conditions

**EXISTING STRUCTURAL CONDITIONS (page 163)**

- ☐ foundation problems
- ☐ roof structure problems
- ☐ floor structure problems
- ☐ wall structure problems

**Checklist (Cont'd)****SERVICES (page 165)**

- ☐ inadequate capacity of existing heating system
- ☐ inadequate capacity of existing air conditioning system
- ☐ inadequate capacity of existing ventilation system
- ☐ inadequate capacity of existing plumbing and septic systems
- ☐ inadequate capacity of hydro panel and electrical system

**CHAPTER 10 — RENOVATIONS AND MECHANICAL SYSTEMS****DISCOMFORT (page 176)**

- ☐ discomfort in house — some areas too warm, other areas too cool
- ☐ house is too dry or too humid

**POOR ENVELOPE CONSTRUCTION (page 180)**

- ☐ poorly insulated or leaky envelope
- ☐ uncomfortable drafts
- ☐ cold wall surfaces with or without condensation

**HIGH ENERGY BILLS (page 180)**

- ☐ faulty equipment
- ☐ inefficient building envelope
- ☐ inefficient heating or air conditioning system

**POOR MAINTENANCE (page 181)**

- ☐ dirty ducts, clogged filters
- ☐ dirt around air registers or vents
- ☐ smoky smell

**FAULTY EQUIPMENT (page 181)****Gas Furnaces**

- ☐ no heat or insufficient heat
- ☐ pilot light out
- ☐ delayed burner ignition
- ☐ woofing or exploding noise during start-up
- ☐ yellow burner flame

**Oil Furnaces**

- ☐ no heat or intermittent heat
- ☐ noticeable fuel odour
- ☐ woofing or exploding noise during start-up

**Checklist (Cont'd)****Hydronic Systems**

- ☐ no heat or too much heat
- ☐ heat in system but not in radiators or convectors
- ☐ water leaks
- ☐ cloudy water in the water gauge
- ☐ gurgling or hammering noise from convector or radiator

**Water Heaters**

- ☐ calcium or magnesium build-up
- ☐ pilot light out
- ☐ odour

**Heat Pumps**

- ☐ runs but does not heat or cool
- ☐ heats but does not cool, or cools but does not heat
- ☐ low air-flow
- ☐ unusual noise

**Air Conditioners**

- ☐ compressor does not turn on
- ☐ system will run but does not cool
- ☐ visible leaking water
- ☐ unusually high operating costs
- ☐ noise
- ☐ leaking water

**VENTILATION (page 184)**

- ☐ too much noise
- ☐ insufficient air flow
- ☐ poor indoor air quality
- ☐ poor air distribution

**CHIMNEYS (page 184)**

- ☐ settlement cracking or spalling
- ☐ creosote build-up on chimney liner
- ☐ damaged chimney liner
- ☐ soot or blockage
- ☐ rusting
- ☐ leakage

**Checklist (Cont'd)****CHAPTER 11 — ENERGY-EFFICIENT RETROFITS****BUILDING ENVELOPE (page 195)****Air Sealing**

- ☐ air seal floor headers and rim joists
- ☐ seal basement penetrations
- ☐ seal ceiling joints, attic and ceiling penetrations
- ☐ seal around all pipes and wires penetrating the air barrier
- ☐ seal electrical panels and electrical fixtures
- ☐ weather-strip or seal around doors, windows and skylights
- ☐ install draft stop and glass doors in fireplace
- ☐ caulk or seal gaps in exterior finishes

**Insulation**

- ☐ insulate attics
- ☐ insulate basement walls and slabs
- ☐ insulate floors over unheated spaces
- ☐ insulate exterior walls
- ☐ insulate window and door frames and wall joints
- ☐ insulate crawlspaces
- ☐ cover crawlspace floor with polyethylene vapour barrier

**Windows and Doors**

- ☐ replace glazing units
- ☐ install energy-efficient low-E, gas-filled windows
- ☐ install energy-efficient sliding glass doors
- ☐ install energy-efficient double- or triple-glazed skylights
- ☐ install insulated entry doors
- ☐ install insulated overhead garage door
- ☐ replace weather stripping around windows and doors

**MECHANICAL SYSTEMS (page 210)****Space Heating and Cooling Systems**

- ☐ furnace tune-up and safety check
- ☐ install combustion air duct for heating appliances
- ☐ install multi-speed furnace or fan motor
- ☐ fuel switch central or unitary heaters

**Checklist (Cont'd)****Space Heating and Cooling Systems (cont'd)**

- ☐ upgrade to energy-efficient furnace
- ☐ install programmable thermostat
- ☐ install energy-efficient gas fireplace
- ☐ install efficient wood-burning fireplace insert
- ☐ seal joints and seams on air plenums and ducts
- ☐ clean chimneys of wood-burning appliances
- ☐ upgrade oil-burning equipment
- ☐ upgrade space heating — bathrooms and vestibules
- ☐ install a ground-, water- or air-source heat pump
- ☐ install or upgrade efficiency of window air conditioning units
- ☐ repair or upgrade existing central air conditioners

**Ventilation**

- ☐ install bathroom fans, dehumidistat controls and timers
- ☐ install kitchen rangehoods to vent directly to outside
- ☐ install central or room-unit heat recovery ventilators

**Domestic Hot Water Heating**

- ☐ fuel switch electric water heater to natural gas or oil where cost effective
- ☐ insulate water heater and hot water pipes
- ☐ install toilet flush water-saving devices, aerator faucets and showerheads
- ☐ replace existing toilet with ultra-low-flush toilet
- ☐ replace washing machine with water-conserving type

**OTHER FACTORS (page 211)****Lighting**

- ☐ install energy-efficient light fixtures or bulbs (interior and exterior)

**Controls**

- ☐ install timers, dimmers and motion sensors
- ☐ install power saver cord on automobile block heater

**Appliances**

- ☐ replace with energy-efficient models
- ☐ fuel switch — clothes dryers and stoves

***Checklist (Cont'd)*****Lifestyle Choices**

- ☐ turn off lights in rooms when not in use
- ☐ reduce use of appliances and powered equipment within the home
- ☐ reduce use of clothes washing and drying appliances
- ☐ improve daily home operation, such as drawing curtains in evenings

Other choices are available in the literature from provincial and local utilities and Natural Resources Canada.





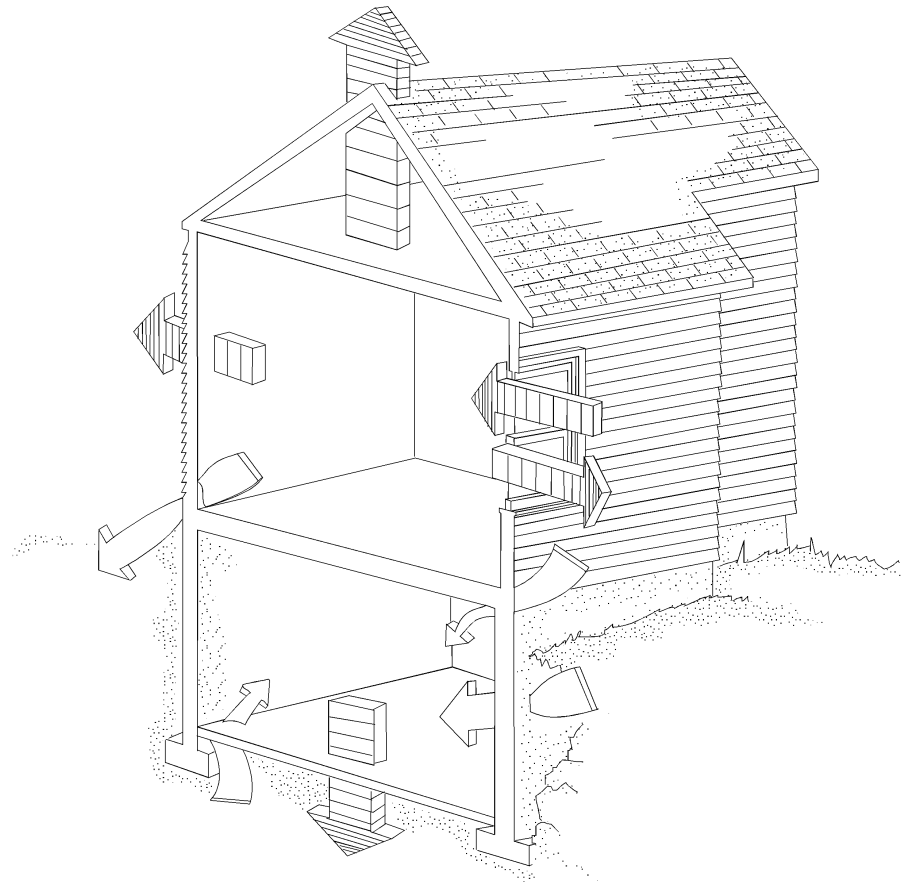
# The Building Science of Renovations

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**T**his chapter reviews building science basics. It considers the relationship between building science and house performance. It also reviews the science that will be applied in subsequent chapters to the most common renovation projects.

*The focus is on heat, moisture and air, how they interact with the building and their relationship with its occupants. The chapter considers how each of these flow into and out of the building, and how each can be controlled and managed to prevent building performance problems.*

*Read this section carefully. You may want to refer to it from time to time as you move through the rest of the guide.*



## INTRODUCTION

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The science of how buildings function and perform is a relatively new field of study. Formally referred to as building science, it involves understanding what buildings are intended to do and how they interact with the physical and living environment.

Central to the building science field are issues relating to human comfort. Human comfort can be broadly defined in terms of both physical and psychological needs. Thermal comfort is one of many aspects of human comfort and an integral part of building science. Indoor conditions, such as temperature and relative humidity, are important determinants of comfort and are critical to any discussion of building science.

Building science is commonly associated with strategies for saving energy by adding insulation or reducing air leakage. It is, however, a much broader field. A good understanding of building science fundamentals includes an appreciation of how all of the building's systems, its components and materials function as a whole. The building science practitioner — a role renovators need to assume — uses a number of tools to identify and diagnose building performance problems and predict how any alterations made to the building will affect its performance. Understanding building science can help to properly correct problems and avoid unexpected difficulties from changes made to the building.

At the outset, the renovator has to understand why the building has been chosen for renovation. It may be a simple redecoration, a change of use, an addition or the need to remedy a problem. The renovator is expected to recognize building problems, decipher any symptoms, establish causes for the problems and formulate solutions, often in a matter of minutes, while the home-owner looks on. The renovator acts like a detective trying to collect clues to solve a case. Solving building performance problems is almost impossible without understanding building science. The renovator who doesn't understand building science, risks creating building performance problems where none existed before.

## THE HOUSE — SYSTEMS, COMPONENTS AND MATERIALS

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The building is often characterized as a collection of systems. The heating, structural, and thermal envelope system are just a few examples within a house. The occupants are often also considered one of the systems. Each system determines, to some extent, the performance of the building.

Each system is an assembly of components. For instance, a floor system might include beams, floor joists, subfloor, underlay, finish floor, connectors and fasteners. Each component plays a role, and together they establish the performance of each system.

At the same time, each component is made from various materials, such as wood, glass or steel. The characteristics of each material are utilized to achieve the required performance for each component. How well a material behaves as part of a component will influence how well that component works within the system, affecting, of course, the overall system performance and ultimately the performance of the building. Building science is concerned with how the materials, components and systems function individually and as part of the entire building.

It is also important to understand that all of the house systems influence one another. Solving and preventing performance problems often depends on this understanding. This new view of the building has often been called the house-as-a-system concept. It will be presented in detail later in this chapter.

The building's systems, components and materials all interact with both the external and the internal environments. The building interacts with the external climate and weather. It is exposed to rain, snow, wind, sunlight, heat and cold. The interaction with the internal environment often relates to how the building is used. Building problems often stem from the conditions of use. Understanding the relationship between the conditions of use and the building's performance is an important tool when unravelling problems. You will need to develop this understanding in order to establish the implications of the renovation project on the building.

## BASIC REQUIREMENTS OF BUILDINGS

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The primary role of the house envelope, including the exterior roofs, walls and floors, is to separate the interior and exterior environments. The envelope permits indoor conditions to be maintained and adjusted. In general, modern buildings are expected to:

- control heat, air and water vapour flow;
- control rain penetration and water infiltration;
- control light and solar radiation;
- control the spread of fire;
- control noise transmission;
- be durable, strong and rigid;
- be economical to construct and maintain;
- be aesthetically pleasing; and
- meet the psychological and social needs of the occupants.

Whenever undertaking a renovation, among the most important considerations is the structural stability of the existing building. Any possible consequences of the proposed alteration must be addressed. If the existing building shows signs of structural distress, such as sagging roof lines, sloping floors, cracked or settling foundations, these have to be addressed with competent professional help. These issues will be discussed in detail in chapters to come.

Durability is a particularly important requirement for buildings. Materials, components and systems used within a building should be able to withstand normal environmental or user-related conditions for a reasonable period of time, provided they are properly maintained.

For a building to function properly, it needs to be designed to meet the specific criteria of its occupants and location. Special measures will need to be taken, for example, if the house is in a zone susceptible to earthquakes, high radon concentrations or termite infestation.

The requirements for modern Canadian houses change as the needs and expectations of the occupants change. While this list is not comprehensive, it is a starting point for the building science basics. The requirements are further illustrated in Figure 2-1.

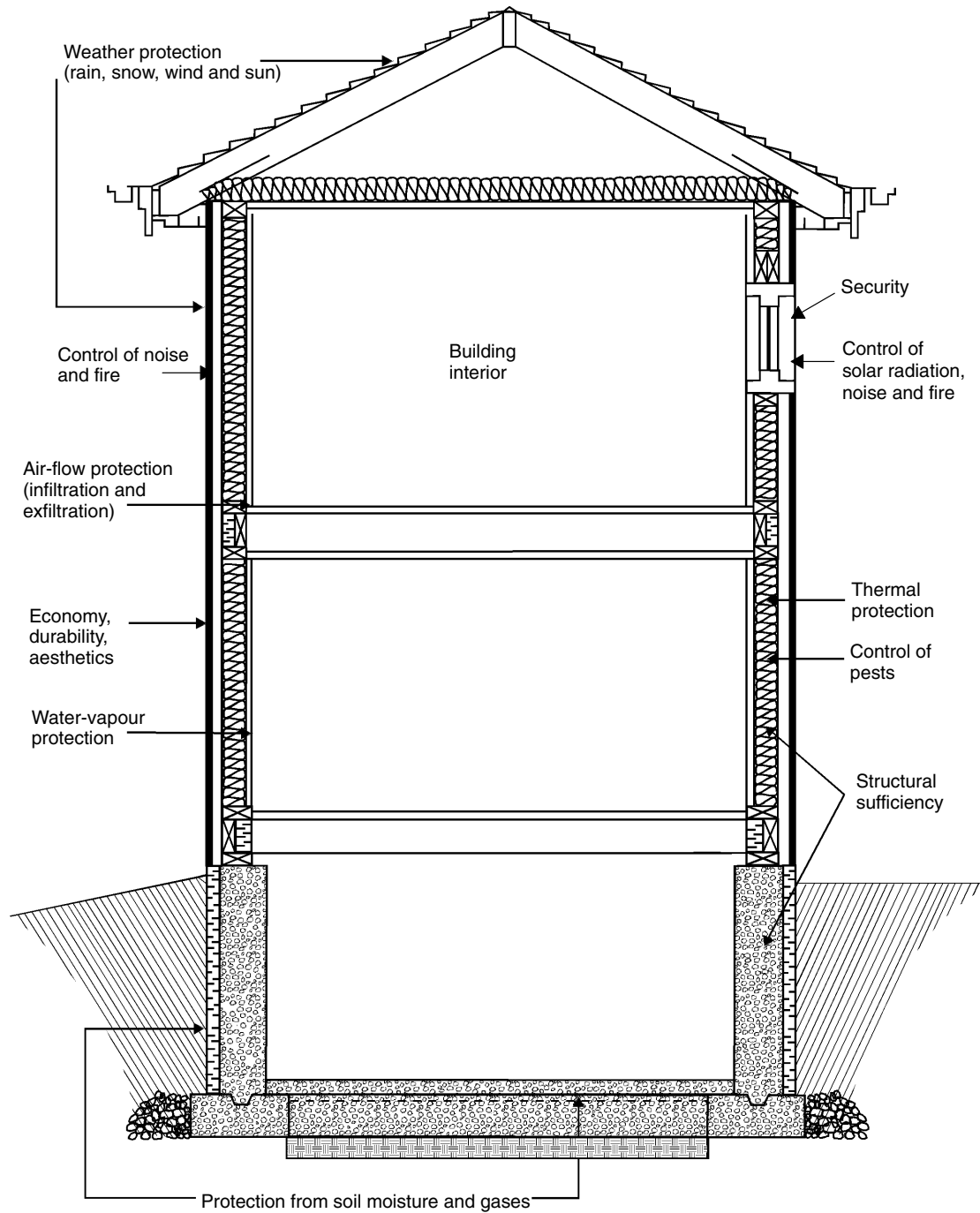
Houses built 50 years ago were assessed using different criteria. Drafts, inefficient energy systems, damp basements and other discomforts were tolerated and common. Those houses were constructed using state-of-the-art technology current at the time. Construction techniques have experienced rapid changes in the last half century. Renovators have to be familiar with both old and new methods. They also have to be capable of integrating new methods and materials into old houses, while understanding how the existing systems may be affected by the new work.

### *Heat, Moisture and Air Flows*

Perhaps the most important building science principles deal with heat, moisture and air flows in buildings. Understanding heat, moisture and air flow mechanisms is important because they each have a profound effect on a building's performance. These flows affect the materials, components and systems of the building. Each type of flow is related to and influences the others. Each mechanism will be examined in turn. But again, it is important to appreciate that they interact so fundamentally that altering one flow will often affect the others.

The movement of moisture, air and heat is driven by gradients — differences in concentration, pressure or energy. Water moves from wet to dry (e.g., from high to low concentration); air moves from high to low pressure; and heat moves from warm to cold. To a great extent, the house envelope is expected to resist or control the movement of each of these. The envelope's moderating effect helps to create a comfortable indoor environment.

The heating, ventilating and air conditioning (HVAC) system is often asked to pick up where the envelope leaves off. It provides cooling, warmth, brings fresh filtered air indoors and, at times, adds or removes moisture. In general, the HVAC system is expected to establish and maintain indoor levels of comfort.

*Figure 2-1: Basic Requirements of Buildings*

## HEAT FLOW

One of the most obvious influences on the performance of buildings is the flow of heat. As a form of energy, it flows from hot to cold. It can also flow in any direction, as illustrated in Figure 2-2. Temperature is normally used to measure the amount of heat energy.

Heat moves from hot to cold in any of three ways — conduction, convection and radiation. Each has a varying effect on the building's heat loss or gain and on the occupants' comfort. Understanding all three transfer modes is important to avoiding house performance problems. Each is described in detail on the pages that follow.

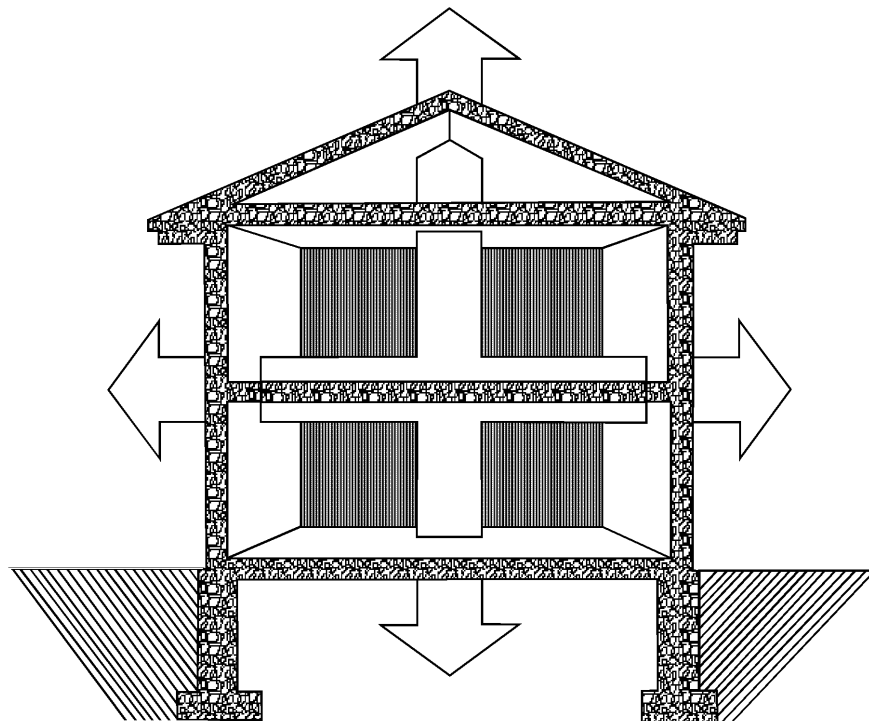
Heat will flow when there is a difference in temperature. It will always flow from hot to cold. Cold is defined as having less heat than something warm or hot. Cold does not flow into a house in the winter, heat flows out. This

premise has fundamental implications for devising strategies for retaining heat in the house. When trying to understand what is happening to a building, or when educating customers, remember that heat flows out from heated spaces into colder spaces (areas of less heat).

The design of the building envelope and mechanical systems intended to control the flow of heat are often based on the difference in temperature between indoors and outdoors. These systems are expected to maintain minimum indoor temperature conditions as set out in applicable building codes.

To design the HVAC and envelope systems, the exterior design temperature is particularly important. It determines how much heat will need to be supplied by the heating systems to compensate for the heat that flows out of the building. Outdoor design temperatures used for building design in Canada are provided for

**Figure 2-2: Heat Flows in All Directions**



specific locations in the national and provincial building codes.

At the heart of any discussion of heat flow is thermal comfort. Thermal comfort (whether we feel warm or cold in our controlled environment) is affected by ambient room temperature. Thermal comfort also depends on the temperature of the wall, floor and ceiling surfaces in the room, the relative humidity and the air circulation. These issues will be considered in later sections in more detail.

Heat and cold affect buildings in one other important way. The heating and cooling of the shell of the building will cause it to expand and contract. The thermal expansion and contraction forces can be quite strong. When the shell of the building is prevented from moving in response to these forces, large internal stresses develop that can easily crack materials. Crack control joints in concrete foundation walls and slabs are an example of an attempt to accommodate natural movement due to these forces. Cracking is encouraged at the joint where it can be properly sealed to prevent water leakage. Failure to include these types of joints will invariably result in uncontrolled cracking with the potential for water entry.

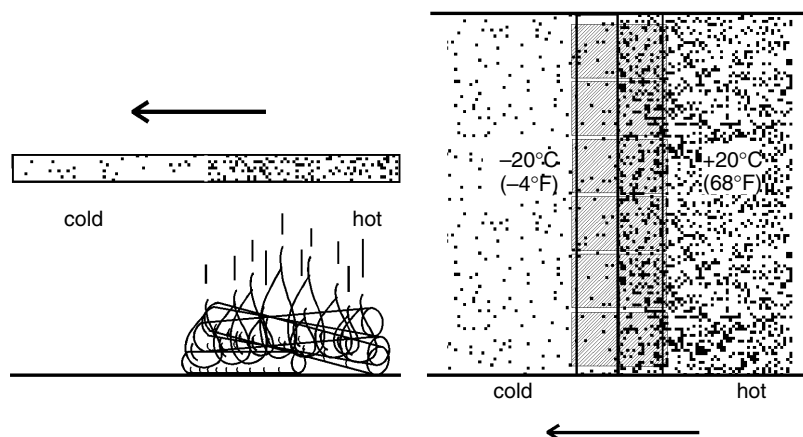
### Conduction

Conduction is the flow of heat through solid materials due to a temperature difference across the material. Conductive heat flow involves the transfer of energy from one molecule to another molecule in the same or other solid material that it comes into contact with. For example, heat applied to a frying pan heats food that sits in the pan by conduction. Figure 2-3 shows another example of conduction.

Conductive heat flow is driven by differences in temperature. The difference in temperature between the hot burner and the cold frying pan establishes the amount of heating that goes on. In terms of houses, the temperature difference between indoors and outdoors establishes the amount of heating that is required. In practical terms, two identical houses, one in Saskatoon and one in Toronto, will consume different amounts of space heating energy. In order for both to have the same space heating energy consumption, the house in Saskatoon, where the outside temperature is colder, would require more insulation in its envelope than the one in Toronto. The insulation resists the movement of heat across it by reducing conduction.

In a house, the conductive heat flow occurs through the envelope — the exterior walls, basement walls and floors, ceiling, windows and

**Figure 2-3: Conductive Heat Flow**



Conductive heat flows from hot to cold

doors. The envelope and its components separate the warm interior of the house from the cold outside. Any heat energy must pass through the materials in the envelope before reaching the outside. Each of the materials in the envelope will let heat pass through them to some extent.

Some materials allow heat to move through them more easily than others. Materials that are good at resisting the flow of heat are normally called insulators. The ability of a material to resist the flow of heat is measured by its R-value (or RSI value in metric). The greater the R-value, the better the ability of the material to

resist the flow of heat. Materials can be compared in terms of their R-value per unit thickness. This can become an important consideration, which together with cost, material availability, ease of use and environmental impact may determine the materials to be used. Table 2-1 lists common building materials and their corresponding R-values.

In addition to temperature difference and R-value, heat loss also depends on the area exposed. Radiator fins are a practical example of an attempt to increase heat loss into the room by increasing the exposed area. From a designer's

**Table 2-1: Thermal Resistances of Common Insulation Materials**

Material	Thermal Resistance (avg.)	
	Imperial R/inch	Metric RSI/mm
<b>Batt or Blanket</b>		
Glass Fibre	3.5	0.024
Mineral Wool	3.6	0.025
<b>Loose Fill</b>		
Cellulose Fibre	3.6	0.025
Glass Fibre	2.9	0.020
Mineral Wool	2.9	0.020
<b>Loose Fill (poured)</b>		
Cellulose Fibre	3.4	0.024
Glass Fibre	3.0	0.021
Mineral Wool	3.0	0.021
Vermiculite	2.3	0.016
<b>Blown</b>		
Cellulose Fibre	3.4	0.024
Glass Fibre	3.0	0.021
<b>Rigid Board</b>		
Glass Fibre Board	4.2	0.029
Low-density Expanded Polystyrene Beadboard	3.8	0.026
High-density Expanded Polystyrene Beadboard	4.0	0.028
Extruded Polystyrene	5.0	0.035
Polyurethane	6.0	0.042
Phenolic	4.2	0.029
<b>Foamed in Place</b>		
Polyurethane Foam	6.0	0.042

perspective, houses that have irregular shapes will normally have greater heat loss than more regularly shaped houses of the same height and floor area. This concept is illustrated in Figure 2-4.

Conductive heat flow relies on molecule-to-molecule energy transfer. Air or other gases, whose molecules are widely spaced, are poor conductors of heat energy. Thermal insulation uses this principle and works primarily by trapping pockets of still air or other gases in confined spaces, thereby restricting the movement of heat.

Because thermal insulation relies on pockets of still air to reduce heat transfer, it is important to keep batt insulation uncompressed. Compressing insulation reduces the amount of air in the insulation. So, squeezing a 140-mm (5 1/2-in.) fibreglass batt into a 38 x 89-mm (2 x 4-in.) stud cavity does little to improve the insulating value of that space. As described in the section that follows, poorly fitted batts will

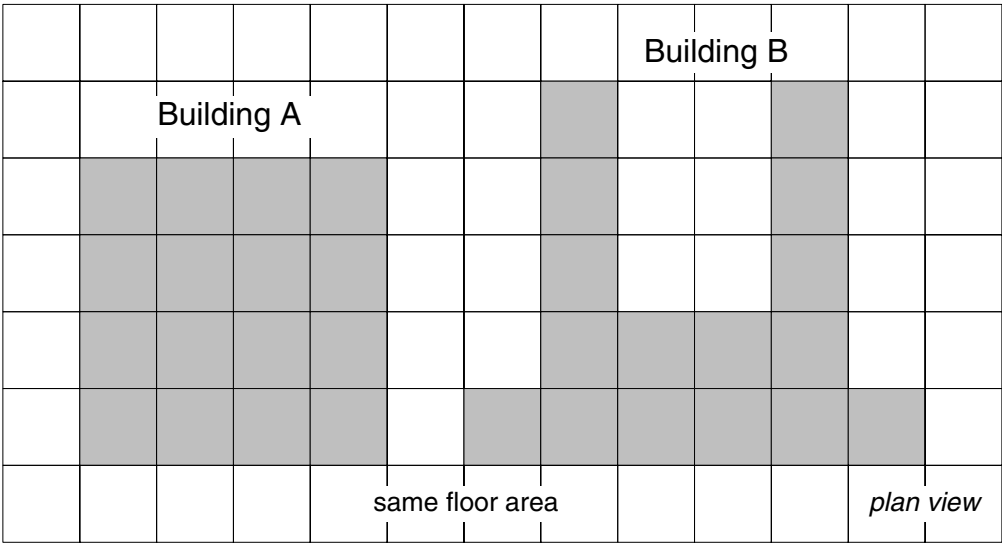
also increase heat loss by convection. Remember to use appropriate materials for each application.

Thermal bridging can also be an important source of heat loss in the thermal envelope, causing a number of associated problems. A thermal bridge is created when a conductive material, like a wood or steel stud, extends from the interior of the house to the exterior, uninterrupted by insulation. The material acts like a bridge allowing heat to move quickly from the inside to the outside. It not only results in the loss of heat, it can also lower the temperature of interior finishes, resulting in condensation and staining. This phenomena will be discussed in more detail in the sections that follow.

Convection

Unlike solids, where molecules are at rest, gases and liquids are able to move and carry heat with them. This movement can result from natural pressures, such as wind or differences in density.

Figure 2-4: Heat Loss and Building Shape



Height = 1 unit	Height = 1 unit
Floor area = 16 units	Floor area = 16 units
Perimeter = 16 units	Perimeter = 28 units
Envelope area = 48 sq. units	Envelope area = 60 sq. units
Heating costs = \$1600	Heating costs = \$2800

Higher heating costs for the same floor area.

Note: heat loss approximately equal through ceiling and floor for both buildings



It can also be driven by mechanically induced pressures like fans.

Convection that results from a pressure exerted by an external force — often referred to as forced convection — is a common means of distributing heat throughout a house. Forced air furnaces, air conditioners and heat pumps, as well as many other household systems and appliances, commonly use forced convection to move heat in, out or through the building.

Differences in density are also able to cause air movement. The rising warm air in a hot air balloon is an example of movement of a gas driven by differences in density. When people speak of heat rising, what they really mean is that warm air rises. The warm air is more buoyant than the surrounding air and thus rises. In houses, natural convection of this type can be a strong heat transfer mechanism.

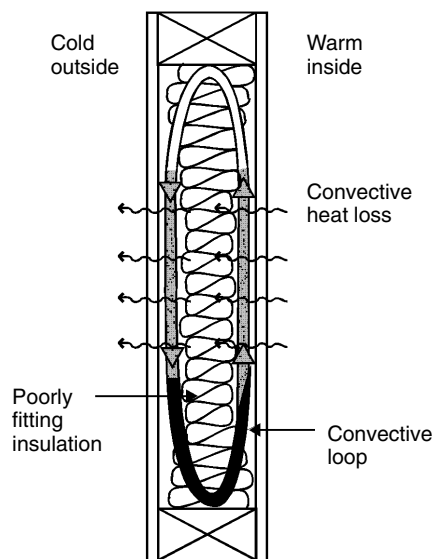
The rising and falling of air can create circular convection currents in an enclosed space that can transfer large amounts of heat. For example, natural convection can occur in houses in empty stud wall cavities. Air in the cavity is heated by the inside of the house. It rises along the back of the interior wall finish and moves across the top of the cavity. When the air reaches the opposite

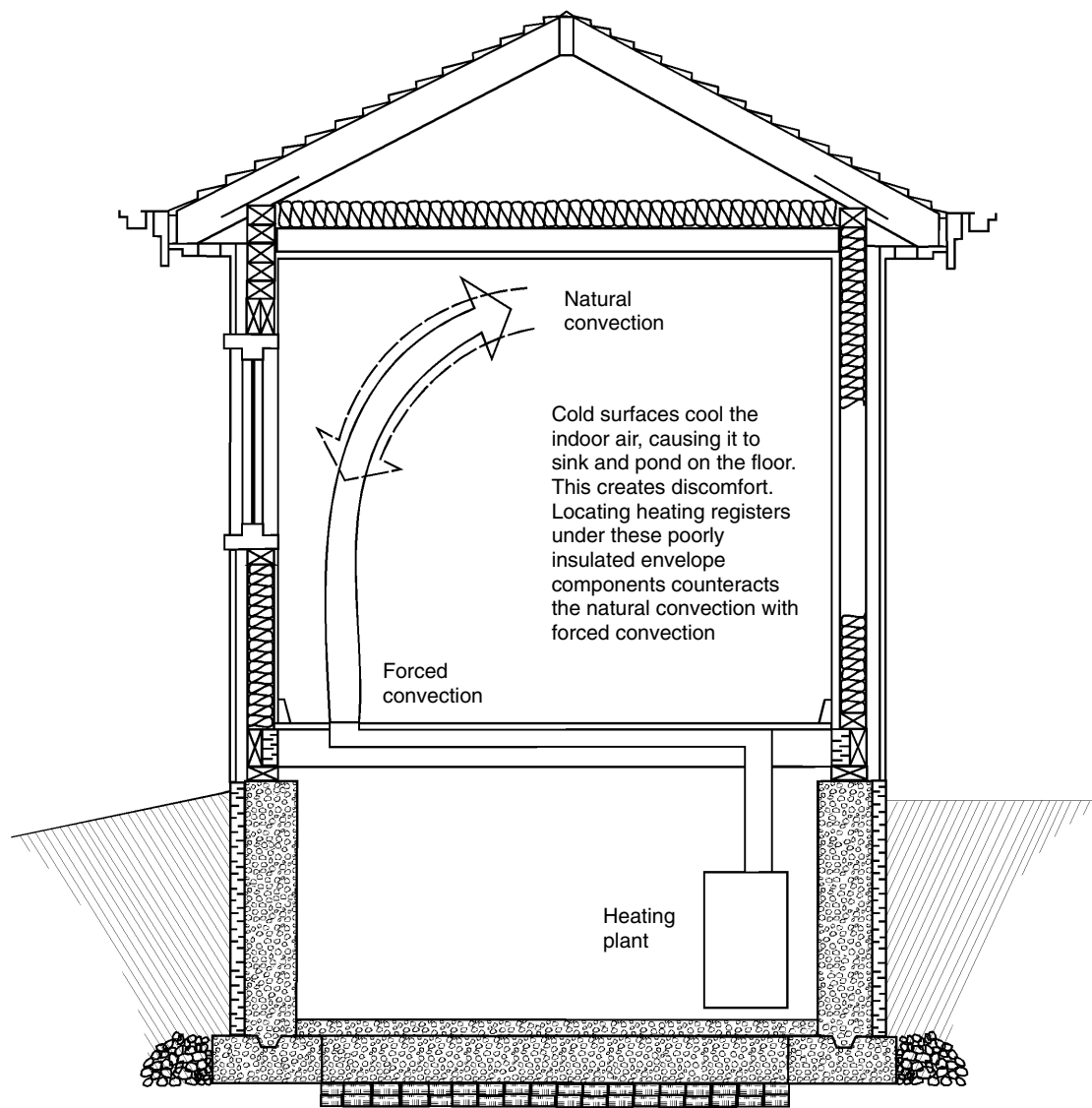
side of the cavity, it gives off heat to the cool outside wall. The air continues to cool and descends to the bottom of the cavity. When it nears the warm side of the wall cavity, it again warms and begins to rise. This circular, continuous pattern of heat loss is called a convective loop and is illustrated in Figure 2-5.

To prevent convective heat loss, it is important to try to restrict the movement of air within the envelope cavity. Properly installed insulation tends to do this. However, if insulation is installed poorly, leaving voids or unfilled edges along the studs and especially around window and door frames, convection has an opportunity to take place. Thermal insulation must be installed snugly against the outside sheathing or against an air barrier.

Forced convection commonly occurs within a house. Convection currents result from forced air heating systems that blow hot air upward into a space. These often counteract natural currents that result from cold interior surfaces and cause discomfort. Typically, houses have forced air heating registers under windows. They are placed there to counter the convective currents that could result as air cooled by the window sinks and pools on the floor, resulting in uncomfortable drafts. See Figure 2-6.

**Figure 2-5: Convective Loops**



**Figure 2-6: Room Convection Currents****Radiation**

Radiation is the transfer of heat from one surface to another without contact (conduction) or air movement (convection). An object that has more heat radiates this heat through space to an object that is colder. Radiant heat can be felt when warming yourself by a stove or suntanning. The stove sends heat to your body without you having to touch its hot surface.

Radiation affects the thermal comfort within a building. If the temperature of a surface near to the body is cold, the body will lose heat to that

surface by radiation. This means that a person standing beside a cold window, for instance, will feel cold as heat is drawn from the body. The sensation often feels like a draft, without air movement. This heat loss may cool the person to the point of being uncomfortable.

Designing houses to eliminate this source of discomfort should always be an objective. Ensuring the envelope is well insulated with energy-efficient windows and doors is the first step. Bathing cold surfaces, like windows, with

warm air from heating supply registers has been the traditional way of dealing with this problem.

The sun is also a source of radiant heat energy. Heat gain from solar radiation is an important consideration when designing houses. Solar radiation through windows can reduce the amount of space heating energy that needs to be provided during the day. However, it can also cause overheating in summer.

A number of technologies are available to better use the energy of the sun for space heating while avoiding overheating. Some of these include advanced technology glazing systems, window shading devices, increased thermal mass and specially designed mechanical systems. Extensive information is available on passive strategies for northern climates.

This may be a topic you want to research further. If you do, CMHC has a number of useful publications such as *Tap the Sun: Passive Solar Techniques and Home Designs (2000E)*, you can refer to.

When selecting building materials, consider the effects of solar radiation carefully. Some materials will degrade over time when exposed to sunlight, ultraviolet light or heat. This is often a concern when selecting materials for the exterior of the building. Care should also be given to materials that are stored uncovered on-site.

Prolonged exposure to sunlight can seriously affect the function and the aesthetics of the envelope. Plastics, in particular, tend to be especially susceptible. Deterioration can appear as cracking or brittleness or as discolouration and fading. This issue is discussed in more detail in Chapter 11.

## MOISTURE FLOWS

Understanding how moisture interacts with the house is fundamental to the proper design and operation of a dwelling. Controlling and managing moisture is the key to providing a durable envelope and a healthy living space.

Moisture accounts for much of the damage and complaints related to houses. It can exist within the house in any of its three states: gas, liquid or solid.

### Water Vapour

Water vapour, the gaseous form of water, is always present as part of the air inside and outside of all houses. We feel its presence in the air around us, particularly when it's too dry or too humid.

A term often used to describe the amount of water vapour in the air is relative humidity. Loosely defined, relative humidity is the amount of water vapour in the air relative to the maximum amount of water that air can hold at that temperature. At 100% relative humidity, air cannot hold any more water vapour. It is considered saturated.

The amount of water vapour that the air can hold depends on temperature. Warm air is able to hold more water than cold air.

When you lower the temperature of air at 100% relative humidity, the water vapour will begin to condense out of the air onto cool surfaces and appear as liquid water. The air remains at 100% relative humidity, but because it has cooled, it is not able to hold all of the water vapour it had suspended at the warmer temperature.

Air conditioners and mechanical dehumidifiers operate on this principle to remove moisture from interior air. Air is forced over cold coils that cause the water vapour to condense. As the air warms again, its relative humidity is lowered.

The temperature where a mixture of air and water vapour reaches 100% relative humidity, or saturation, is notable because it defines when condensation will occur. This temperature is called the dew-point temperature. An Insight has been provided to explain dew-point temperature in more detail. (See Insight 2 — What is Dew Point?)

Moisture content in air also has an affect on health and thermal comfort. For people at rest or doing light work, 30-60 % is an acceptable range of relative humidity. Conditions above this range are too wet, ideal for mold growth and cause discomfort. Conditions below this range are too dry and can trigger a number of health ailments in the occupants. Of course, activities that occur within the house will also affect the range of relative humidities in which we feel comfortable.

Water vapour within the house can be produced from a number of different sources, including

### Insight 2 — What is Dew Point?

Air contains a number of different gases. Nitrogen, hydrogen, oxygen and water vapour each play a role in the surrounding air. Water vapour plays a particularly important role. Too much moisture can cause a damp, musty atmosphere inside a space, while too little can cause a number of health problems. The amount of water in the air is directly affected by the temperature of the air.

As the temperature changes, so does the amount of vapour that the air is capable of holding. Air can hold more vapour at high temperatures than low. The ratio of the amount of actual vapour suspended in the air to the potential amount is the relative humidity. This is normally expressed as a percentage. A volume of air that can hold two pounds (0.91kg) of water vapour but holds only one pound (0.45kg) is at 50% relative humidity. It holds 50% of the total possible water.

When the air holds all of the water vapour it is capable of suspending, it is at 100% relative humidity and is considered saturated. If saturated air is further cooled, the water vapour will begin to condense out. For a given mixture of air and vapour, the temperature where condensation begins is called the dew-point temperature. Note that if the dew-point temperature occurs below the point of freezing, the water will appear as frost.

Often in winter, temperatures in wall and roof cavities fall below the dew-point temperature of the interior air. When this happens, the moisture in the wall or roof cavity condenses. You can

protect the envelope by reducing the amount of vapour in the cavity or by increasing the temperature of the cavity space. In both ways, the air and vapour mixture in the cavity is prevented from reaching its dew point.

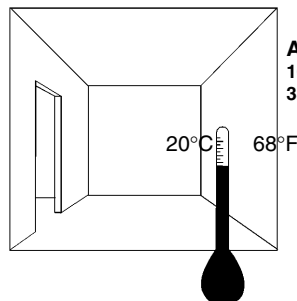
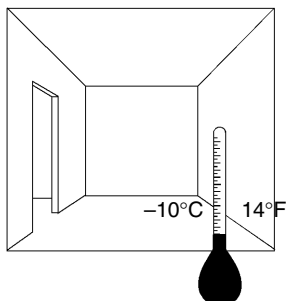
The envelope can be protected by installing air and vapour barriers in the wall. Both of these elements limit the movement of water vapour into the cavity space, keeping the space dry and preventing condensation. Increasing the temperature of the cavity space can also reduce the potential for condensation. Installing insulated sheathings often accomplishes this.

The vapour barrier must be kept warmer than the dew point to prevent water from condensing on it. That means it can be buried inside the insulation, but traditionally it is placed on its warm side. As a rule of thumb, two thirds of the total R-value of the insulation must be placed on the cold side of the vapour barrier, with one third or less on the warm side to prevent condensation. In colder parts of Canada, a ratio of 3/4:1/4 is more appropriate.

A final issue concerning dew point is surface condensation. In a room with high humidity, water will condense on any surface that is below dew point. This often means that surfaces only a few degrees cooler than the surrounding air will support condensation. Windows are often among the first surfaces on which condensation becomes visible. It can be prevented only by increasing the temperatures of these surfaces by adding insulation, improving the efficiency of the window or reducing the indoor humidity.

### Air Temperature, Relative Humidity and Moisture Content

**Air at 14°F (-10°C) holds:**  
1.6 lbs (.75 Kg) at 50% RH  
3.3 lbs (1.5 Kg) at 100% RH



**Air at 68°F (20°C) holds:**  
16.5 lbs (7.5 Kg) at 50% RH  
33 lbs (15 Kg) at 100% RH



The air in the room at 68°F (20°C) can hold 10 times the amount of water that the room at 14°F (-10°C) can hold.

occupants, pets, plants and building materials. Humans and animals produce moisture through respiration. Indoor plants also release moisture. Activities such as dish washing, laundry, bathing and cooking release a lot of water vapour into the air. Water can also diffuse into the house from the surrounding soil through the basement walls and slabs. Finally, humid air makes its way into the house from the outdoors during the summer, thereby increasing the amount of water vapour in the house. Normally, interior materials and furnishings will store some of the summer moisture and release it in the fall as the humidity drops.

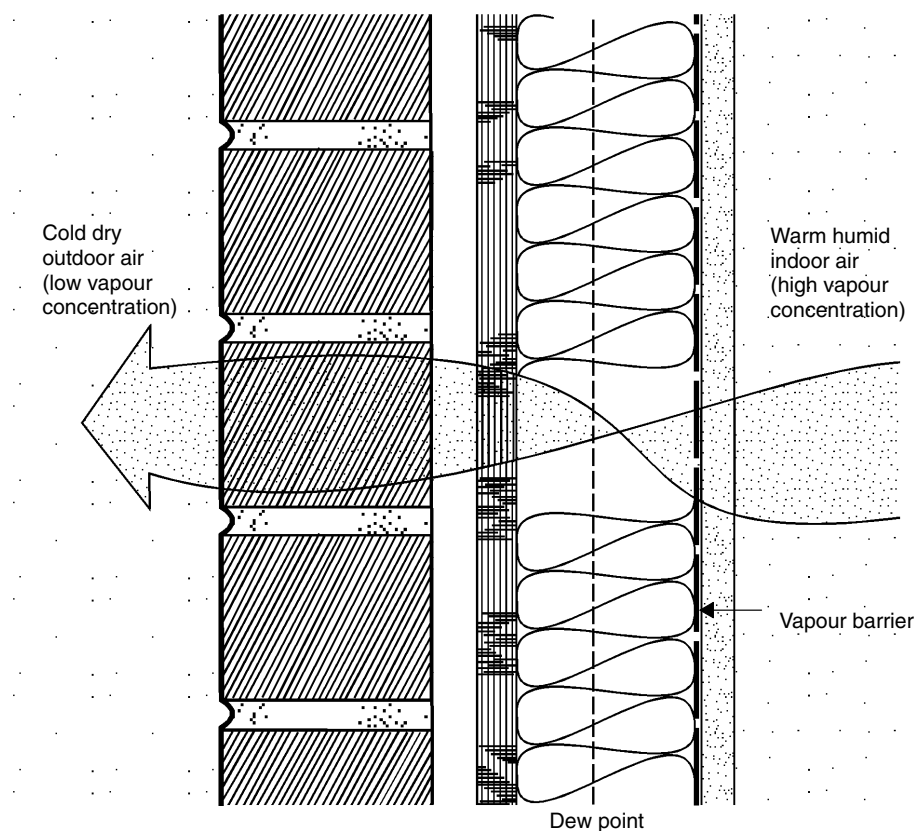
Two processes account for the movement of water vapour. Either it diffuses from one space to another through a material or it is carried by moving air from one space to another. Understanding both vapour transport mechanisms is important for the design,

construction and renovation of durable building envelopes.

Water vapour in the air will tend to move from high to low concentration. If two spaces with different vapour concentrations are separated by a material, the vapour will tend to exert a pressure as it tries to move from the high-concentration side to the low-concentration side. The pressure, referred to as vapour pressure, drives the vapour-diffusion mechanism — the greater the difference in concentration, the greater the vapour pressure. Figure 2-7 illustrates vapour diffusion.

The material that separates the two spaces may let more or less vapour through. The amount of vapour that actually passes through depends to a large extent on the vapour permeability of the material. All materials allow vapour to pass through them to some extent.

**Figure 2-7: Vapour Diffusion**



The design of durable building envelopes focusses on preventing the condensation of water vapour and the accumulation of bulk water within the envelope, where decay and deterioration can result. A well-constructed building envelope will include materials and finishes that provide enough resistance to protect against damaging levels of vapour diffusion. The traditional approach is to provide a membrane of low permeability to reduce the concentration of water vapour in the assembly so that no condensation can occur at the design temperature of the building's location.

The material with the lowest vapour permeance in the envelope assembly is normally designated the vapour barrier. This really is a misnomer since no material is a true barrier to vapour diffusion. It only retards the movement of vapour and lowers the concentration, thereby preventing condensation. The vapour-barrier component is the one that provides the predominant resistance to vapour diffusion within the envelope.

Water-vapour permeance ratings are available for a wide range of construction materials. These ratings indicate how quickly vapour passes through the material. The lower the permeance rating, the less vapour will penetrate the material.

Polyethylene film is the most common vapour-retarding material. Other materials that have been used include vapour-barrier paint, foil-backed drywall, some types of extruded polystyrene and some thicknesses of plywood or waferboard. Table 2-2 lists the vapour permeance of different materials. Each of these materials can be used to protect the wall assembly from condensation damage caused by trapped vapour cooling below the dew-point temperature.

To function properly, the vapour barrier needs to be installed on the warm side of the insulation or, more specifically, on the warm side of the dew-point. Refer to Insight 2 — “What is Dew Point?” — for more details.

**Table 2-2: Vapour Permeance of Various Materials**

Material	Vapour Permeance	
	Imperial (grain/ft <sup>2</sup> hr(in.Hg))	Metric (ng/Pa.m <sup>2</sup> s)
<b>Common Vapour Diffusion Retarders (VDRs)</b>		
0.01 (0.35 mil) aluminum foil	0.05	2.9
0.15 mm (6 mil) polyethylene	0.06	3.4
0.10 mm (4 mil) polyethylene	0.08	4.6
0.05 mm (2 mil) polyethylene	0.16	9.1
<b>Paints and Wallpaper</b>		
2 coats asphalt paint on plywood	0.40	23
2 coats aluminum paint	0.30 - 0.50	17-29
1 coat latex VDR paint	0.45	26
2 coats oil-based paint on plaster	1.58 - 2.99	91-172
<b>Insulations</b>		
25 mm (1 in.) extruded polystyrene	0.40 - 1.60	23 - 92
25 mm (1 in.) polyurethane	1.20	69
<b>Other Building Materials</b>		
100 mm (4 in.) glazed-tile masonry	0.10 - 0.16	6 - 9
6.4 mm (1/4 in.) CDX plywood	0.70	40

### ***Liquid Water***

Water in the liquid state interacts with the building in a number of ways. Water can originate from inside or outside the building. When liquid or bulk water comes from inside the building, it is usually from a leaking pipe or other plumbing problem. Liquid water can also result from accumulated condensation from water vapour as discussed earlier. When water comes from outside the building, it can be traced back to wind driven or infiltrating rain or snow, soil moisture or a high water table.

In order to prevent mold growth, rot and the deterioration of the building and its contents, the envelope must be able to stop rainwater from entering the house. Rainwater is normally managed by the building's rain shedding system — the roof, eavestrough, downspouts, wall system and foundation drainage systems shed, collect and direct water away from the building. As well, overhangs and ground sloped away from the building help to keep water from entering the house.

Rain or snow, driven horizontally by wind, needs to be prevented from making its way into the building envelope and causing damage. A recent innovation in building technology is the rainscreen wall. There are three elements to the rainscreen wall that allow it to prevent the penetration of wind-driven rain to the indoors — a penetrable outer-wall finish, a compartmentalized air cavity and a sealed inner-wall layer. Rainwater that is not able to cross the air space, is gravity-drained and discharged out of the wall system.

Snow, another form of precipitation, also needs to be addressed in house design. The house must be able to accommodate snow that may accumulate over the winter months, as well as the resulting water when melting occurs. Snow and ice is dealt with in more detail in the section on solid water.

Rainwater and melting snow will seep into the soil around the house, and, by gravity, can often move through any existing cracks or openings in the foundation wall. Drainage layers on foundation walls are used in some parts of the country. They are intended to direct water away from cracks and openings to the drain tile at the base of the foundation wall. The drainage layer

offers the water an easier path of travel than through foundation cracks and openings. At the base of the foundation, the drain tile collects the infiltrating rainwater and directs it to a sewer, dry ditch or sump.

Water can be drawn into a material through a surface tension. Like water in a straw, surface tension is able to draw water through the tiny pores or capillaries in the material. This effect, sometimes referred to as capillary action, allows oil to rise through the wick of a lamp. Capillary action can overcome gravity, causing water to rise to great heights. The size of the capillaries determines the strength of the wicking effect — the smaller the capillaries, the stronger the capillary rise. Some materials are more conducive to capillary action. Concrete, masonry, porous rock, wood and some insulations all permit water to wick through them. Glass, metals and other non-porous materials do not support capillarity. In materials like crushed stone and gravel, the pores are too large for capillary action to occur. Capillary action is explained further in Figure 2-8.

The strategy for preventing water from moving into the building by capillary action involves separating the source of the water from building materials that support wicking. Foundations that include dampproofing use this approach to prevent capillarity. As a coating, dampproofing plugs the pores in the concrete or masonry that would otherwise wick water from the soil. As a membrane, dampproofing isolates the foundation from the surrounding wet soil. This type of membrane is sometimes called a capillary break because it breaks the connection between the capillaries in the foundation material and the capillaries in the soil. Polyethelyene (or similar plastic sheeting) is sometimes used as the capillary break.

Some water wicks into the foundation wall through the footings. Knowing this, it is important to also isolate the foundation from materials inside the building that can wick water and deteriorate as a result. Wood framing members should not come into direct contact with the concrete or masonry foundation or slab but should be isolated from it using a capillary break.

Capillarity can also cause a number of other building problems. Efflorescence and spalling are often direct consequences of uncontrolled

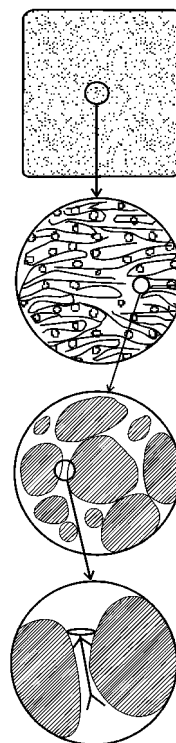
**Figure 2-8: Capillarity**

Some materials contain many small pores

These pores will hold water

Pores and cavities between particles create tubes within the material

These tubes act like straws to draw water into the material



wicking of water through concrete and masonry. Insight 7 — Efflorescence — discusses this issue in more detail.

Keep in mind that dampproofing and materials used as capillary breaks are not intended to waterproof the basement. They are used solely for the purpose of preventing soil moisture wicking into the foundation. Waterproofing systems are normally used where liquid water is present and exerts a pressure on the foundation.

Ground water in soil is normally associated with a high water table. High water tables can be localized or extend across a large area. A water table higher than the basement floor can exert a pressure or hydrostatic force on the foundation that can drive water through cracks, openings or joints in the foundation system. The pressure can be strong enough at times to cause structural damage as it pushes on the foundation. The pattern of pressure that a high water table exerts on a foundation is shown in Figure 2-9.

The foundations of houses expected to be subjected to hydrostatic pressure from high

water tables must be waterproofed.

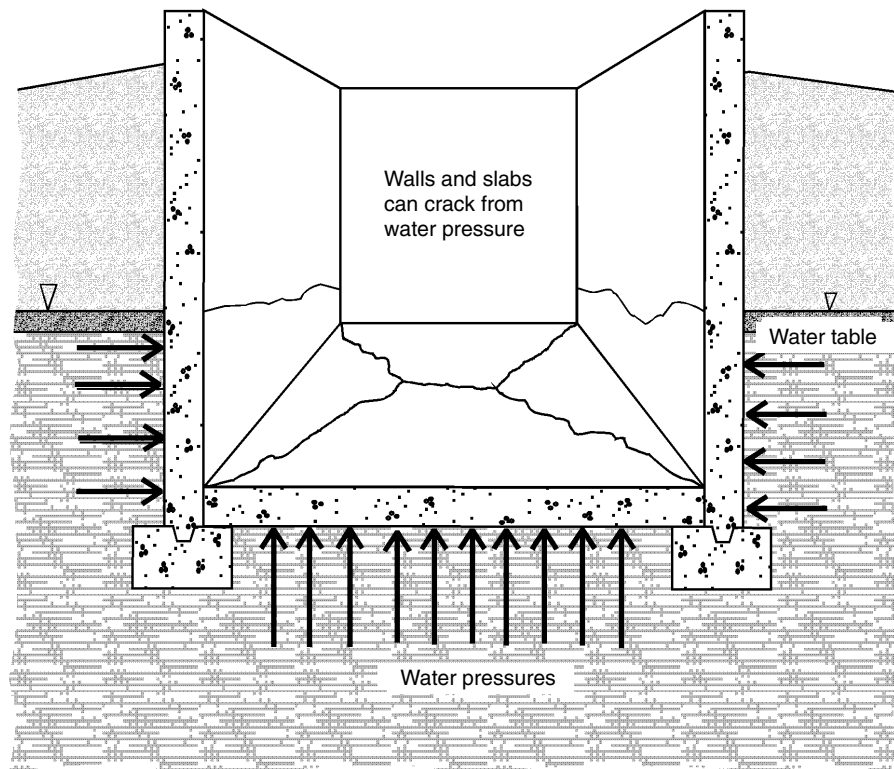
Waterproofing treats the foundation much like the hull of a ship. The foundation is sealed with a number of layers of membrane to prevent the infiltration of water. The structure in these buildings must be designed to resist the pressures that the water table exerts. In most cases, a pressure-relief system is required. This usually consists of a sub-slab network of drainage tile connected to a sump pit and pump. When facing a waterproofing situation, advice from a professional is recommended.

### **Solid Water**

In winter, standing water becomes ice, rain turns to snow and vapour turns into frost. The ice, snow and frost can cause significant damage to the building.

Water, as it turns to ice, expands and increases in volume. Ice and snow add weight to different elements. Vapour can condense, freeze, accumulate and cause damage when the accumulated frost melts.



*Figure 2-9: Pressure on Foundations from High Water Tables*

The loads imposed on a building by precipitation increase in winter because frozen water can accumulate over time. As snow and ice build up, they increase the mass that has to be supported by the building structure. Other non-structural elements (i.e., eavestroughs) also have to carry an increased load. The structure and elements can deform or fail if not designed to carry these increased winter loads, particularly if snow drifts from blowing wind are not accounted for.

The depth of frozen soil usually extends only a few feet below the surface, depending on the depth of snow cover. Ground freezing can lead to the heaving of parts of the house located above or adjacent to the heaving ground. The uplift forces can be very powerful and can cause considerable damage to houses.

The heaving mechanism requires three conditions:

- freezing temperatures;
- water in the soil in sufficient quantities; and
- water can move freely through the soil by capillarity.

If any of these conditions do not exist, no heaving can take place.

The water freezes in a lens-like structure that grows as it is fed by the water from the unfrozen soil below. The growing lens pushes upwards on the soil above it, making the soil at the surface rise and heave. Where water tables are high, water can wick up through the soil to the plane where freezing temperatures are encountered. This is commonly referred to as the freezing plane. The capillary water freezes and turns into

ice. Capillary action continues to draw water upward to the freezing plane within the soil.

The conventional approach to foundation design to prevent frost heave damage is to place the foundation below the freezing plane so that the soil beneath the bearing surface will not freeze. This measure alone, however, does not always prevent frost heave damage. If the excavation is backfilled with frost-susceptible soil, damage from adfreezing may occur.

Adfreezing damage occurs when heaving soil that surrounds a building freezes and adheres to the foundations of the building, lifting the building or portions of the building with it. The bond created can be strong enough to cause extensive damage as the soil around the building moves. A bond break such as rigid insulation placed around the building is sometimes used to prevent the damage that adfreezing can cause.

Frost susceptibility is related to the size distribution of particles in the soil. In general, coarse-grained soils, such as sand or gravel, do not heave. Clays, silts and fine sands, on the other hand, will support ice lensing even when they are present in small amounts in coarse-grained soils. Using non-frost-susceptible backfill material is another way of dealing with the problem.

Another important building science consideration relating to solid water is ice damming. Ice damming is a phenomenon often seen in winter. Ice formations at the eaves of sloped roofs are common in many parts of the country. Ice damming results from melting snow and freezing temperatures. Solar radiation and building heat loss can melt some of the snow on the roof of the house. The water runs down the surface of the roof to the eaves. At the eaves, the water normally encounters colder temperatures where it refreezes. Ice can build up at the eaves and cause the meltwater to back up under the roof covering and, in some cases, make its way into the roof space. Icicles that form at the eaves can also be a hazard to passers by and to property below. Ice damming is shown in Figure 2-10.

Typical approaches to dealing with ice damming problems involve maintaining uniform roof surface temperatures and preventing initial snow melt. Generally, this implies ensuring adequate

venting of attic space, especially at the eaves, and ensuring adequate insulation is uniformly applied across the entire ceiling area, particularly at the top plates. Uninsulated top plates are notorious for losing heat and causing roof snow to melt and likely form ice dams. Finally, a means of preventing backed-up water from entering the roof assembly is required on all houses. Eave protection, consisting of a membrane sheet, can help to prevent meltwater from entering into the roof space. See the CMHC publication *Moisture in Atlantic Housing* 61092 for more information.

The systems that have evolved over the years to control and manage water inside and outside of the building are complex and interrelated. Problems that result from uncontrolled water are by far the most common. By understanding how water interacts with the building, you will be able to correct problems that exist and avoid new ones.

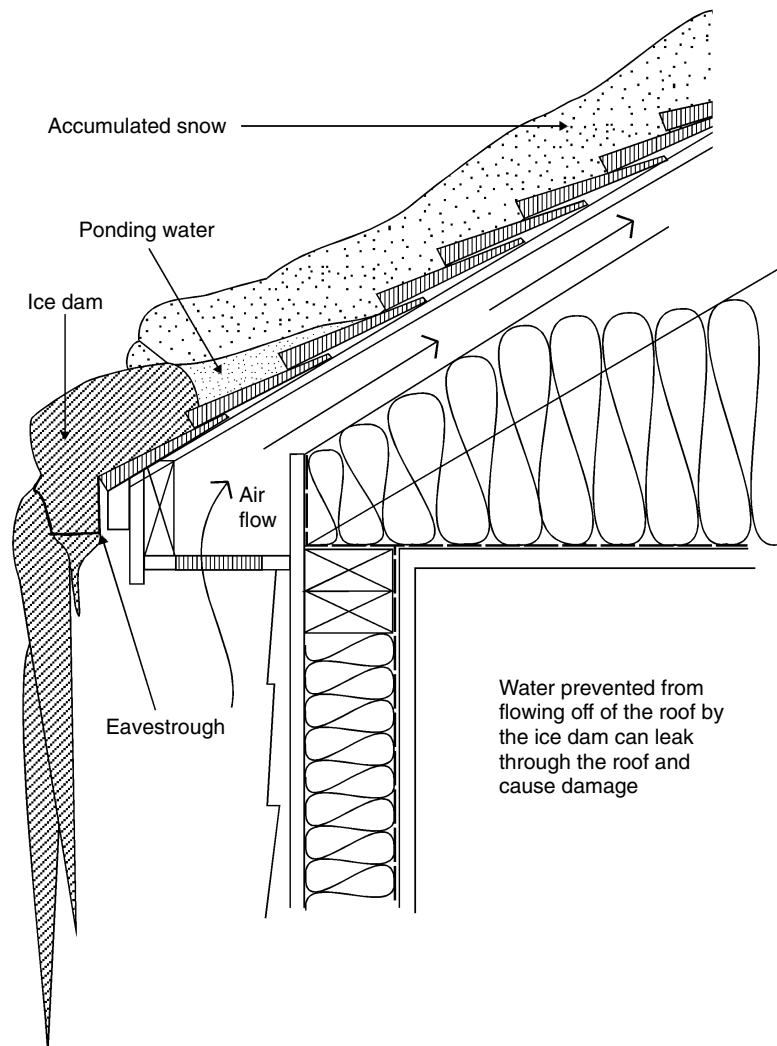
## AIR FLOW

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Controlling the flow of air in and out of buildings is another important function of the building envelope. Uncontrolled air leakage can result in excessive heat loss, drafts, moisture damage and inefficient operation of mechanical ventilation systems.

As air flows out of the building, it carries heat with it. Incoming air from the outdoors requires energy to warm it to indoor temperatures. Another concern is the discomfort the cold incoming outdoor air can cause for the occupants. The design of modern housing must account for both the comfort of the occupants and the energy required to maintain that thermal comfort.

Moisture damage to the envelope of the building is always a concern, and air exfiltration can result in serious and often hidden problems. As discussed in the previous section, water vapour can move through the envelope by diffusion or be carried by moving air currents. Moving air currents are responsible for most water vapour movement in buildings. Air that leaks out of the house carries with it suspended water vapour. As the air moves outward, it cools, becomes less capable of carrying the vapour and begins to form liquid water. Trapped within the envelope,

**Figure 2-10: Ice Damming**

the liquid water can cause mold growth, decay and deterioration to building materials.

The relationship between uncontrolled air leakage and mechanical ventilation is more complex. To avoid overventilation or underventilation, the volume of air that a mechanical system provides needs to be controlled. The air that naturally leaks into and out of the building through the envelope varies at any time of the day, month or year. It depends on the outdoor temperature and whether the wind is blowing — factors that can't be controlled. The uncontrolled natural air leakage into and out of the building interferes with the operation of the mechanical ventilation system. Natural air infiltration does not permit the

efficient control and operation of mechanical ventilation systems. Insight 9 — Airtightness and Ventilation — elaborates on this discussion.

Two conditions must be present to drive air through the shell of the building — an opening and a force. The openings in the shell of the building include cracks around windows, doors and band joists, as well as openings at penetrations, such as plumbing stacks and exhaust ducts, or at electrical boxes and light fixtures. These areas of the building's shell are most prone to leaking air.

Air leakage through the envelope can be driven by natural forces or by forces induced by the mechanical equipment within the building. These pressure-driving forces are illustrated in

Figure 2-11. Natural forces causing air flow, result from wind and stack effect. Mechanical forces result from the operation of fans, furnaces, fireplaces, dryers, central vacuums and other air-exhausting appliances. In all cases, the air moves because of a pressure difference between the inside and outside of the building.

The forces that drive air leakage need to be examined in more detail. Understanding what drives air leakage is important to diagnosing the problems you observe.

### Wind Pressure

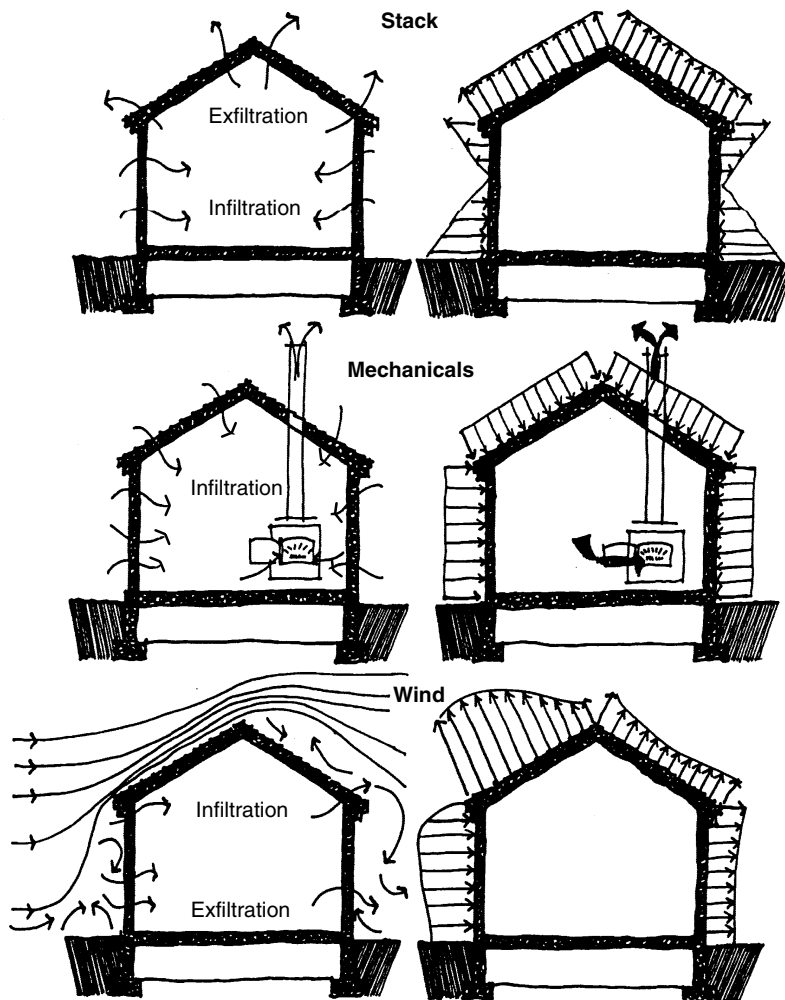
The most common naturally occurring air flow is wind. Wind cannot be avoided and can rarely

be controlled. It blows at various speeds and directions every day and influences all buildings. Wind blowing on a house will cause a positive pressure on the windward side of the building and a negative or suction pressure on the leeward side of the house. These pressures push air into or out of a building.

The most important effect of wind on building design is structural. The building must be able to withstand strong winds and gusts that can last only a few seconds but cause significant damage.

Moisture problems that are caused by wind-driven air sometimes appear as damage, predominantly on the side of the building where warm, moisture-laden air is being drawn out

**Figure 2-11: Forces That Drive Air Movement**



through the building's shell. Moisture problems can also appear on the building's windward side, where the wind blows through insulation and causes localized cooling on interior surfaces. Depending on the relative humidity, this can cause interior condensation, damage to interior finishes and mold growth.

A rain-screen wall is better able to cope with wind pressures. The outer shell of the building provides a first line of defence against the force of the wind, reducing overall air infiltration into the house while protecting against rain penetration.

### **Stack Pressure**

Stack effect refers to the natural tendency for warm (and less dense) air to rise. As in a warm-air balloon, as the air rises, it exerts an upward and outward pressure on the building envelope. The pressure can drive air out of the building at the upper levels and draw replacement air into the building at the lower levels. This pattern is often reversed on hot summer days.

The same principle helps chimney stacks to vent properly. The warm air in the chimney rises and helps to exhaust smoke and other products of combustion. This is where the stack effect gets its name.

Stack effect helps to explain why condensation problems tend to be more common in the upper parts of the house, especially in attic and roof spaces. Warm, moisture-laden air tends to be driven out of the house at the upper levels and is replaced by cold, dry outside air entering through the lower levels.

The relationship between infiltration openings and exfiltration openings is also important for renovators. Understanding the stack effect can help to explain why the most effective air sealing takes place at the top and bottom of the building. Complex interactions between air flow and pressure suggest that sealing leaks at the ground floor (for instance, at the sill plate) will effectively reduce stack pressures that drive leakage into the attic of the house.

### **Mechanically-generated Pressure**

Combustion appliances, exhaust fans, fireplaces, downdraft cooktops, central vacuums, dryers

and ventilators can cause air to flow by creating pressure differences across the shell of the building. Mechanical equipment can exhaust or supply air to the house. Equipment that exhausts air tries to draw replacement air in through the envelope by infiltration. Equipment that supplies air to the house forces air out through the building shell as exfiltration.

In an airtight house with a tight envelope, the negative pressure induced across the envelope by exhausting mechanical equipment could draw air down a flue used by combustion appliances to vent combustion by-products to the outdoors. Appliance performance and occupant health can be compromised in some cases. Insight 4 — Airtightness Depressurization and Combustion Appliances — discusses this concern in more detail.

Wind, stack and mechanically induced air pressures can all affect air flows. Since controlling air pressures is not practical, strategies for controlling air leakage are used. These include installing a continuous air-barrier system, which normally involves designating a membrane as the air barrier and ensuring it meets a number of requirements.

### **Air-barrier Systems**

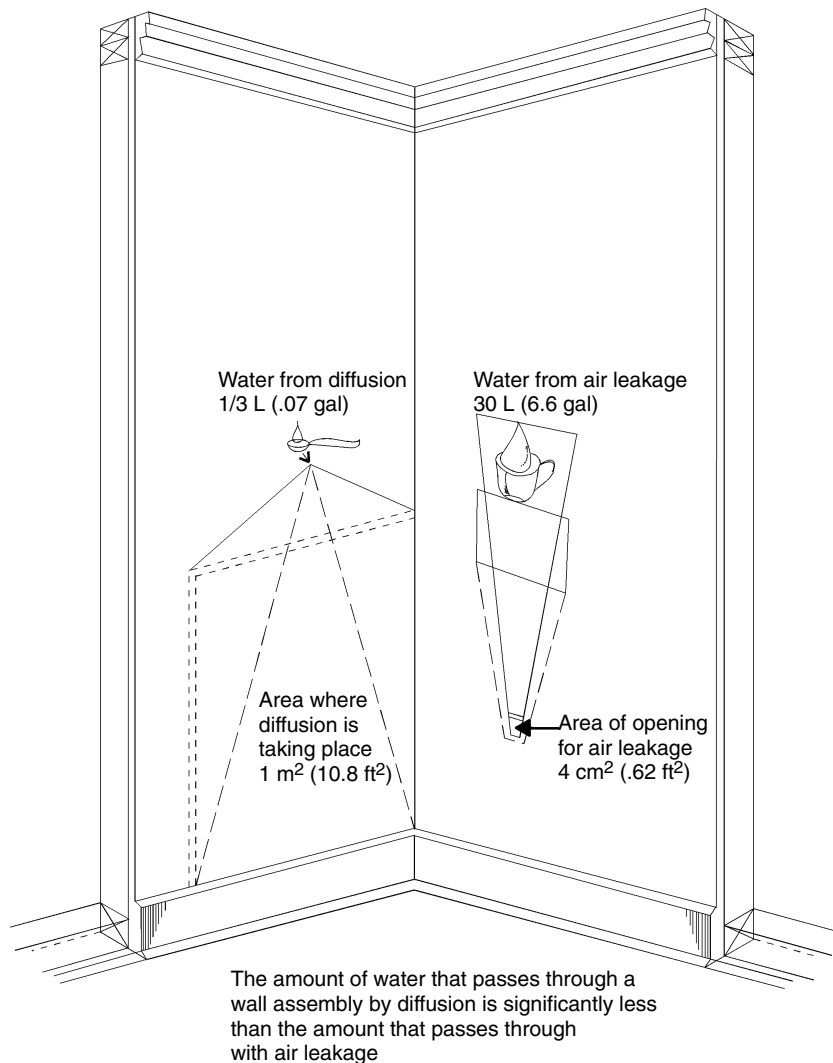
An effective air-barrier system is composed of carefully selected building materials that act together to restrict the movement of air between the indoor and outdoor environments. It has to be continuous, well supported and correctly installed to perform properly.

The air-barrier system normally consists of a membrane, panel or other airtight building components connected to restrict air leakage. Because air leaks through small openings subjected to air pressure, the primary requirement of the air-barrier system is that it be continuous. Unlike the vapour barrier, all openings in the air-barrier system, such as joints and penetrations, need to be sealed. The difference in the amount of moisture that can enter a wall through diffusion, compared to air leakage is illustrated in Figure 2-12.

The air-barrier system has to be able to withstand normal dynamic pressures placed on it during its life. Loads from air pressures and wind gusts, for instance, should not damage it.

The designated air-barrier system can be located anywhere within the building envelope.

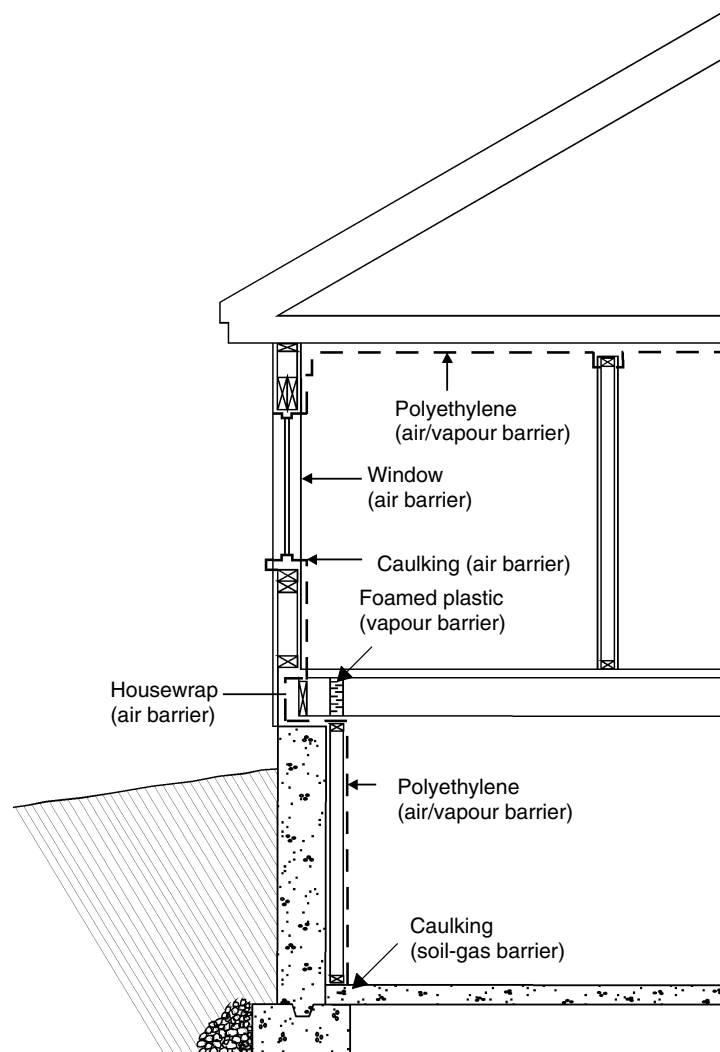
**Figure 2-12: Volume of Water Entering a Wall Through Different Movement Mechanisms**



(Figure 2-13 shows how a number of different elements can be connected to create a continuous air-barrier system.) However, air-barrier materials that have significant resistance to water-vapour diffusion should not be placed on the cold side of the insulation unless the potential for condensation has been calculated. The National Building Code of Canada provides detailed advice on how to avoid moisture problems caused by using a combined air and vapour barrier installed on the cold side of the insulation.

Air and vapour barriers traditionally used in housing have consisted of a single membrane, typically made from polyethylene. Modern approaches have evolved that use a variety of materials to control air movement and vapour diffusion as separate mechanisms. Wood framing, insulation boards, drywall, house wraps, structural elements, tape, caulking and gasketing, as well as other materials, have all been used in air-barrier systems but provide no protection against vapour diffusion. Similarly,

**Figure 2-13: Different Envelope Components Assembled to Create an Air-barrier System**



vapour-retarding paints have been used that do not provide protection from leaking air.

### **Weather Barriers**

The outer skin of the building envelope should be protected from weather, particularly blowing wind. An effective weather barrier prevents wind from blowing through the building's insulation, cooling interior surfaces and causing interior condensation. The weather barrier also prevents wind-driven rain and snow from entering the shell of the building.

A wide range of materials can be used to provide protection from the weather. Siding, masonry veneer and other exterior finishes often fulfil this role. House wraps, board insulations, structural sheathings and insulation baffles in attics have all been used as weather barriers in houses.

### **INDOOR AIR QUALITY**

Indoor air quality is an issue that has received much interest in the building community. Sick buildings, increased incidence of allergic reactions and hypersensitivities, asthma in

children, second-hand smoke and mold are just a few of the many issues that confront the building science practitioner. Poor indoor air quality has been linked to a host of health ailments. The relationship between the systems in the building, their operation and the quality of the indoor air have just begun to emerge. Researchers are hard at work trying to develop better approaches to deal effectively with the problem of poor indoor air quality.

In Canada, building codes have evolved quickly to address indoor air quality concerns by requiring all new housing to include mechanical ventilation. Ventilation strategies all focus on exhausting stale or contaminated air from the building and replacing it with fresh, outside air. Ventilation today deals with many types of contaminants, some of which did not exist 50 years ago. Contaminants from modern floor coverings, indoor paints and other coatings, furniture and cleaning compounds are just a few of many that exist.

We have come to realize that ventilation is an important part of houses today. The requirements for ventilation have evolved over the last 20 years in Canada. As our understanding of building science and building performance has improved, so have the specific requirements for ventilation in modern codes and standards. In the future, requirements intended to provide good indoor air quality may extend beyond ventilation, addressing new methods for dealing with indoor contaminants.

In the past, it was assumed that natural air leakage through the building was sufficient to control indoor air quality. It is now understood that natural air infiltration is not effective. As noted earlier, natural infiltration is driven by natural forces that cannot be controlled. Infiltration can vary from hour to hour, from day to day and from month to month. At times, it can provide too much ventilation while at others not enough. In today's houses, natural air infiltration does not satisfy the minimum health requirements of Canadian home-owners.

An airtight dwelling with mechanical ventilation is more energy efficient and more comfortable. It can provide controlled ventilation and proper distribution. The tight envelope prevents mother nature from dictating the amount of air that enters the building and when and where air

infiltration occurs. The tightened envelope allows the mechanical ventilation system to deliver just the right amount of needed ventilation at desired times. At the same time, high-pollutant sources are isolated with contaminants exhausted directly to the outdoors. This concept is discussed in more detail in Insight 9 — Airtightness and Ventilation.

## THE HOUSE AS A SYSTEM

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As discussed earlier in the chapter, changes to one system can affect other systems in the building. This can be summarized by thinking of the house as a system — one complex, interconnected entity where changes to any one part of the building affect, to one degree or another, the rest of the building. The interactions can be simple, as in the case of plumbing penetrations through structural elements, or they can be complex.

Complex interactions can involve many systems in the building, including the occupants. As an example of how complex and involved a change can be to the whole house and to the other building systems, consider the effect of tightening the air barrier of an existing structure. This can involve something as simple as replacing windows or replacing weather stripping. The air barrier has the obvious role of controlling air exfiltration or infiltration through the building.

Controlling air leakage reduces the damage that can be caused by moisture carried out of the building by leaking air. Moisture in the air (in the form of water vapour) has the potential to cause damage to the building if it condenses in the walls or ceiling. This could lead to wetting of the envelope components and deteriorating material and mold growth, under the right conditions. As well, reducing air leakage reduces energy consumption, leading to lower heating costs. Eliminating drafts also improves occupant comfort. The tighter building envelope reduces the volume of air flowing out of the building as well as the volume of incoming fresh air. Less fresh air can result in higher indoor humidity levels.

The tighter envelope can also lead to surface condensation that can cause many problems, including damage to materials and mold growth.



To control the level of interior humidity, ventilation must be provided in a controlled, energy-efficient manner. This is just a partial list of the many interactions that go on in the house as a system.

As a renovator, you need to understand how one change can affect the operation and performance of the entire series of systems within the building — how the house as a system will be changed by your renovation.

Will all situations be as complex as the examples above? Not often, but, invariably, more than one system will be affected by the changes you make in the building. Predicting how each system is affected is the key to trouble-free renovations and good customer service. What this example demonstrates is how solutions to problems can become very complex with far-reaching implications. If you do not understand how the house systems interact, a renovation can create many unforeseen problems. Take the time to think about the work you will be performing and how it might change the house or create new problems.

When you read the rest of this publication, keep in mind the basic principles of heat, moisture and air flow in buildings and how the situations described relate to these concepts. Avoiding performance surprises, unnecessary mistakes and callbacks depends on applying these principles.

## PUTTING IT INTO PRACTICE

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The best way of applying the principles of building science is to undertake a complete assessment of the building before any work is started or the design of the renovation is complete. An assessment allows for the systematic gathering of information on the state of the building, which will guide you in making the most appropriate design decisions. An assessment form or checklist will help prevent you from overlooking any vital areas. It can also become a handy tool for recording information about the building for future reference.

Assessment forms and inspection checklists can be obtained from many sources or can be customized to your needs. A comprehensive checklist has already been presented. In the chapters that follow, renovation-specific assessment checklists are provided for your use and guidance.

The first priority of the renovator is to understand how the house is performing as a system before the renovation is started. This understanding helps to identify any house problems that may already exist. If a problem is identified, it should be recorded so that it can be revisited during the design stage of the renovation when problems can be rectified. Take the time and energy to uncover what is causing, or has caused, the problem. Examine what has to be repaired or designed into the renovation to solve the problem and not just cover it up. As the solution is formulated, check how it will affect the performance of the rest of the building.

Common issues that have to be considered are how the changes undertaken will affect the existing flows of air, moisture and heat in the building. Has the renovation plan taken into account the consequences of changes in these flows? Is the renovation going to enhance the energy efficiency of the building when it is completed? Is the integrity of the air barrier maintained or threatened? Has moisture flow been thoroughly thought out? Has the renovation solved previous problems?

The need to preserve the integrity of the air barrier cannot be stressed enough, whether in the design of the renovation or in the implementation of the work. Material compatibility can also become an issue as old construction techniques and materials have to be joined with new materials to form an aesthetically pleasing, functional new system.

By practising the basics, learning from your experiences and using building science principles, you can deliver healthy, well-performing and economical housing renovations, free from callbacks and problems.

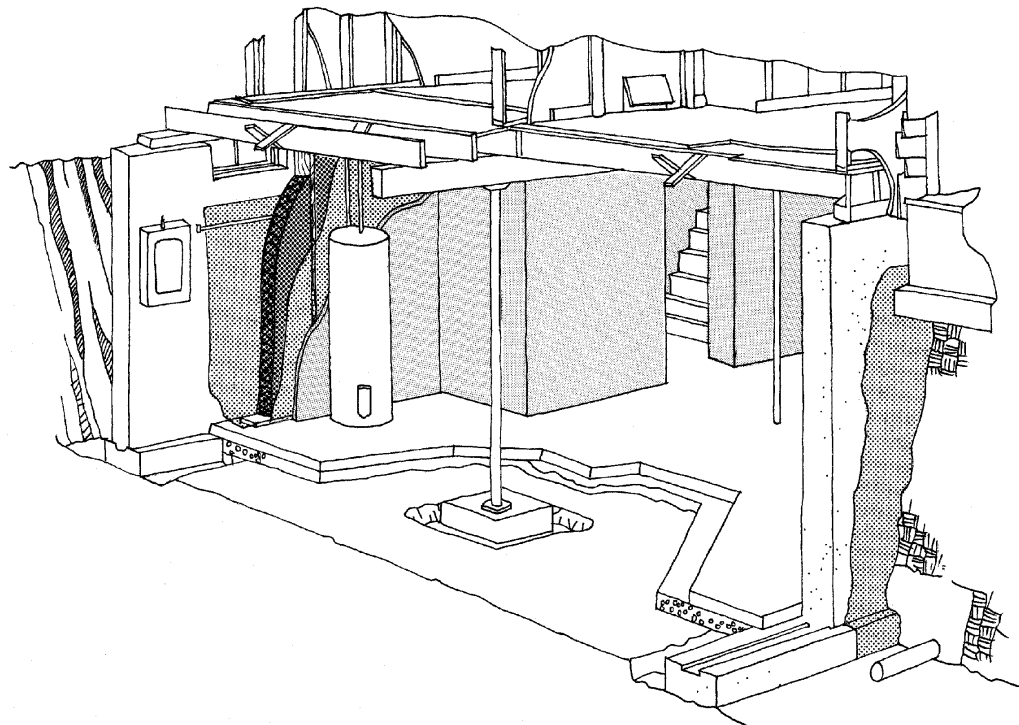


## Foundation and Basement Renovations

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**T**his chapter is intended to look at problems associated with renovating a basement. It introduces difficulties you might encounter and gives options for repairing or minimizing past and future damage. It also examines the role of a basement renovation in the overall functioning of the house. You should understand that there can be more than one possible cause of a symptom, and that the interactions between different systems of the building are important considerations. This chapter will increase your awareness of the house performance implications of renovating foundations and basements.

It also examines issues relating to renovating and refinishing a basement. Existing basement conditions and proposed changes are explored in detail. It applies to renovations of partially finished, fully finished and unfinished basements. This chapter may also be useful when problems with the foundation are detected while working in or assessing other areas of the house.



### INTRODUCTION

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Each basement presents the renovator with a unique situation and should be treated as such. Location, age of construction, surrounding terrain and occupant lifestyles are different for every job. For this reason, it is important to properly assess each home before beginning work. Doing the job right, properly estimating costs and preparing a price will depend on this assessment.

When assessing a basement, there are a number of key aspects with respect to foundation and basement performance that should be examined. These include:

- structural stability;
- soil conditions; and
- any moisture problems.

Every aspect should be carefully considered as each can have a major impact on a basement renovation.

Other aspects, of course, are also important. Assessing the indoor air quality of the space is extremely important, particularly in the basement. These spaces tend to be more humid than other areas of the house and more susceptible to mold growth.

This chapter covers a number of aspects of proposed work, including headroom requirements, noise, safety, lighting, plumbing, air quality, insulation, vapour protection, air leakage protection, ventilation and structural issues. It will look at how these aspects can be affected by the renovation.

The assessment of mechanical systems is also important. This will be discussed in detail in Chapter 10. Refer to it before you begin renovating.

Some basic building science principles have been discussed in Chapter 2. These concepts should be understood before reading on. This will help when applying the principles to the renovation problems discussed.

The building science Insight in this chapter cover issues that relate to basements and other types of renovations. References to Insights in other chapters are included and reading them is

encouraged. A list of Insights is provided at the beginning of this guide.

### EXISTING FOUNDATION CONDITIONS

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The foundation of a house is the single most important consideration in any renovation. The foundation supports the structure of the house above it and resists the pressure from the soil around it. Without a sound foundation, problems are inevitably going to occur.

If problems with the foundation exist, they will often affect other parts of the building. Likewise, problems with other parts of a home will at times appear as symptoms in the basement. Problems you discover in the basement should be remedied prior to the renovation. Any problems need to be investigated to determine how the house is affected and how urgently repairs are needed.

Always remember the five steps to a trouble-free renovation:

1. *observe* carefully;
2. *diagnose* the cause of the problem;
3. *propose* solutions;
4. *remedy* the problem; and
5. *renovate*.

A proper assessment is needed to address the condition of the foundation structure and the surrounding soil as well as detect any moisture problems that exist.

A variety of foundation types exist that you will need to become familiar with. These include poured concrete, unit masonry, preserved wood, slab-on-grade, crawlspace and rubble. Each type has its own associated problems. Only the most common are detailed below.

Foundation structural problems take many forms. They result from improper construction practices or material defects. Design inadequacies can also lead to foundation structural problems.

The surrounding soil can hide unexpected surprises and be a source of major problems in basement renovations. The assessment should uncover problems such as improper grading, poor draining soils, high water tables and other

potential concerns (e.g., rodent and insect infestation).

Moisture is a key concern with any basement renovation, the most common complaints are related to moisture problems. Record any moisture-problem symptoms that you observe.

An assessment checklist has been provided for your use. It summarizes problems you may encounter in the foundation or basement. This guide addresses most of these issues in this and other chapters.

Remember that the goal should be to remedy the cause of problems and not just treat the symptoms. Eliminating the causes will help prevent the problems from recurring.

### ASSESSMENT CHECKLIST

The checklist for foundation and basement renovations includes symptoms that should be checked when assessing existing basements. Refer to the section identified for more information.

## Checklist

### STRUCTURAL CONSIDERATIONS

#### FOUNDATION PROBLEMS AND CONSTRUCTION TECHNIQUES (page 53)

- ☐ cracks in slabs, walls and footings
- ☐ uneven settlement
- ☐ headroom problems
- ☐ inadequate support of main floor system, inadequate footings for walls and columns (deflection, bounce)
- ☐ aggregates settled to bottom, uneven mix, honeycombing

#### CONCRETE CURING AND SHRINKAGE (page 54)

- ☐ spalling concrete
- ☐ porous or powdery concrete
- ☐ stable cracks (no water leakage)
- ☐ cracks at openings

#### BACKFILLING PRACTICES (page 54)

- ☐ warped or bowed foundation walls
- ☐ cracks with and without movement

#### ADFREEZING AND FROST HEAVE (page 55)

- ☐ cracked brickwork
- ☐ uplift with cracking

### SOIL CONDITIONS

#### FOUNDATION PROBLEMS AND SOIL-BEARING CAPACITY (page 56)

- ☐ unstable or weak soils (75 kPa bearing capacity)
- ☐ settlement cracks in walls with or without movement

**Checklist (Cont'd)****SOIL GASES (page 56)**

- ☐ soil gas or radon infiltration
- ☐ bad smells or odours, nausea, headaches, poor indoor air quality
- ☐ high humidity

**INSECT INFESTATION (page 57)**

- ☐ termite soil tubes visible
- ☐ carpenter ant damage
- ☐ rodent damage

**MOISTURE PROBLEMS****PROBLEMS FROM WATER VAPOUR (page 58)**

- ☐ high humidity
- ☐ condensation on windows, pipes and other fixtures
- ☐ condensation on or behind the vapour barrier
- ☐ damp spots, mold on walls
- ☐ stuffy damp smells

**PROBLEMS FROM CAPILLARY WATER (page 60)**

- ☐ damp walls and floors
- ☐ musty or damp carpets
- ☐ sill decay in window wells
- ☐ wet or decaying wood in contact with the foundation walls or slab
- ☐ stuffy damp smells
- ☐ white powdery stains (efflorescence) on exposed concrete walls and floors (interior or exterior)
- ☐ presence of mold

**PROBLEMS FROM BULK WATER (page 62)**

- ☐ stuffy damp smells
- ☐ wet insulation
- ☐ concrete cracks with water leakage or staining
- ☐ standing water in the basement
- ☐ decaying sill plate
- ☐ presence of mold

## STRUCTURAL CONSIDERATIONS

Symptoms that indicate structural problems must be carefully examined prior to any renovation work. Look for signs of previous repairs or renovations that may be hiding problems. Point out any problems to the home-owner.

Cracking, spalling, crumbling concrete and uneven settlement suggest a problem with the foundation. A variety of causes can be responsible for the same symptoms. Further investigation is often required to pinpoint a specific cause. A number of poor construction or finishing techniques during the original installation of the foundation can account for many basement problems. Settlement and shrinkage of the foundation can cause cracking. Cracking can allow water to penetrate into the basement space, while severe settlement can result in structural collapse.

### ***Foundation Problems and Construction Techniques***

Poor construction techniques are commonly responsible for structural problems. Inadequate footings, walls and slabs, poor concrete placement and poor backfilling practices are typical of the problems you will encounter.

The foundation footings transfer the weight of the structure and its contents to the soil below. The footings are used to spread the loads over a larger area of soil. The size of the footing depends on the amount of load that is being carried, the bearing capacity of the soil and the height of the site water-table.

The bearing capacity of the soil is its ability to support loads. Soils with poor bearing capacity include soft clay or silt, soils with high organic content, loose sand or gravel, and soils saturated with water from high water tables. Development is restricted on some soils with unusually poor bearing capacity. When a renovation is expected to increase the loads supported by the footings (i.e., additions or attic renovations), it is important to ensure that the existing footing is adequate. This concept is discussed further in Chapter 8.

Cracks in slabs and walls can be the result of uneven soil settlement. Settlement can also

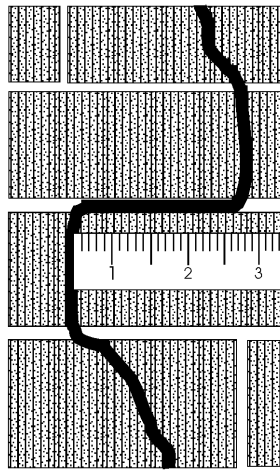
cause floor joists and beams to be uneven. If one section of the footing rests on a different type of soil or carries a concentrated load, differential settlement can occur. In this case, the soils will compress differently, causing uneven loading in the footings. If cracking is severe, professional help is required to design a solution tailored to the specific problem at hand.

In an older home, small cracks may mean very little because the house has probably finished settling. In newer homes, however, cracks may be an indication of future problems. Monitoring the crack over time can determine if there is still active movement. Crack movement may require a few months to monitor, but, in some cases, this information may be available at the outset of the project. Active cracks should be investigated by a professional who can prescribe a suitable course of action. Figure 3-1 illustrates two methods that can be used to test for active cracks. Small, inactive cracks can usually be repaired without concern.

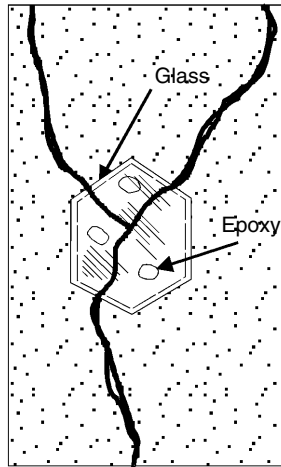
The foundation walls carry the live and dead loads of the structure to the footings and resist the horizontal pressure of the surrounding soil. Pressure from the soil surrounding the foundation can cause cracking or bulging of foundation walls that are not designed or constructed properly. Inadequate foundation design, understrength concrete, improper backfill material or hydrostatic pressure from a high water table can all result in similar symptoms. Large window openings (anything wider than 1.2 m (4 ft.)) can also weaken the foundation wall and will normally need to be considered in the design of the wall system. Finally, reinforcement may have been neglected or improperly placed, making the concrete susceptible to cracking.

Poor placement and finishing of concrete can cause separation of the fines and the aggregates in the concrete mix. The aggregates settle to the bottom if the mix is dropped from too high or if the screeding or finishing process is too vigorous.

Too much water in the concrete mix also weakens the final product. Adding water on site for extra workability usually results in a poor quality mix. When the concrete foundation is weakened by poor construction techniques, the only solutions are often reinforcement or replacement. Often, renovating the foundation

**Figure 3-1: Testing for Active Cracks**

Note change in crack width



Shattered glass may indicate movement

becomes extremely difficult and at times ill-advised for structurally precarious foundations. A structural engineer should be consulted in these instances.

### **Concrete Curing and Shrinkage**

Concrete that was properly placed and finished may have been weakened by improper curing techniques. Poor curing is often related to temperature, from pouring on very hot or very cold days or from removing the form work too early. Protecting the concrete from freezing or drying rapidly allows concrete to cure properly and achieve the necessary strength. Improperly cured concrete can sometimes be identified by spalling or its soft powdery surface and porous texture.

One way to assess the strength of the concrete in the foundation is by rapping it sharply with a hammer in several places. Weak concrete usually yields a dull thud while a stronger mix causes the hammer to ring and bounce off.

All concrete shrinks to some extent as it cures. Shrinkage can cause cracks in foundation walls and slabs. Shrinkage can be aggravated by adding too much water to the concrete mix.

Installing crack control joints in new concrete walls and slabs ensures that, when cracking does take place, it does so in a location that doesn't cause problems. Once the foundation is completed, remedial work will be time consuming and costly. Cracks in the concrete should be repaired to prevent moisture and soil gas infiltration. If cracks are wet, additional steps will be necessary. See the section on Water Problems later in this chapter.

### **Foundation Problems from Backfilling Practices**

Backfilling too early, with inadequate lateral support or improper materials, can affect the foundation wall. Backfilling too early will put stress on understrength concrete. If the wall was not supported correctly during the curing and backfilling processes, cracking may have resulted. Poor backfill practices have been known to cause foundation collapse. Running heavy equipment adjacent to the foundation will also cause similar problems. Cracks and bulging are often difficult to remedy after the basement has been backfilled. Reinforcement or replacement are often the only way to improve these conditions. In some instances, patching cracked walls may be sufficient.



### ***Cracking from Adfreezing and Frost Heaving***

Cracks and uneven movement can also be the result of adfreezing of soil to foundation walls and frost heaving. As frozen soil expands, it can lift the foundation of the house. The cracking that results from the uplift pressures are most often seen on exterior below-grade basement entries without frost protection and at garage and house connections. The soil may not return to its original position when it thaws. This means that the house can move randomly from season to season, causing it to shift unevenly. Different soils under different parts of the house can aggravate this problem. A soil expert may be required to determine if frost heave or adfreezing is the cause of the foundation cracking. An engineer may be needed to determine a suitable course of remedial action.

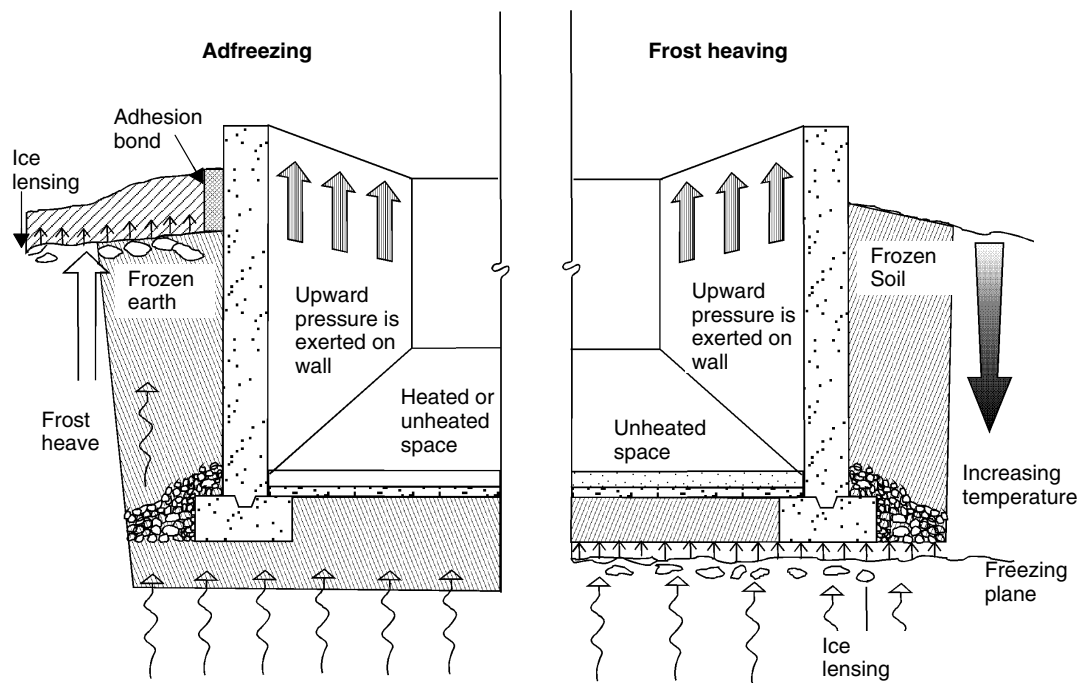
Strategies to minimize adfreezing damage focus on preventing the frozen soil adjacent to the building from adhering to the foundation and

lifting it as the soil heaves. Often adfreezing can be solved by installing a drainage layer or a polyethylene sheet or by free draining backfill material around the perimeter of the basement to prevent the soil from adhering to the foundation. On the other hand, preventing frost heave usually involves installing footings below the depth of frost penetration, particularly in frost-susceptible soils. Refer to Figure 3-2 — Adfreezing and Frost Heaving.

### **SOIL CONDITIONS**

A number of soil conditions can adversely affect the performance of the house, including high water tables, low soil-bearing capacity, contaminated lands and hazardous gases. This section focusses on two issues that you should be aware of: soil-bearing capacity and soil gases. Soil issues that relate to water are discussed in the section that follows.

***Figure 3-2: Adfreezing and Frost Heaving***



Water moves upward through capillary action in unfrozen soil

### **Foundation Problems and Soil-bearing Capacity**

Weak soils may create problems for the foundation of a house. The footing is meant to spread the weight of the house over the soil. If the soil is unusually weak or unstable, it may not be able to support the loads of the structure. The foundation can experience sinking, uneven settlement and cracking. If unstable soils are suspected, a soil test is a must. Even if no problems are suspected, a soil test is advisable to ensure adequate conditions for any new work. A number of quick tests are available to determine the strength of the soil. Soils with a bearing capacity of less than 1,570 lbs/sq. ft. (75 kPa) require professional advice. These include soft clays, loose sands or gravels.

Organic, discoloured and fill soils should also be of concern for the renovator. Foundations should not be built on this material because of its weak and unstable characteristics. Settlement problems can result in cracking, movement and water leakage into the basement. Leakage is a water-related concern and is discussed in the section that follows. Minor cracking without water leakage may not be a problem if the soil around the foundation is stable. These cracks can be patched without consequence. If settlement is ongoing and cracks are unstable, professional help is recommended.

Foundations built on fill or disturbed soils may also experience similar problems. Foundations for houses built on these materials should be designed by a competent professional.

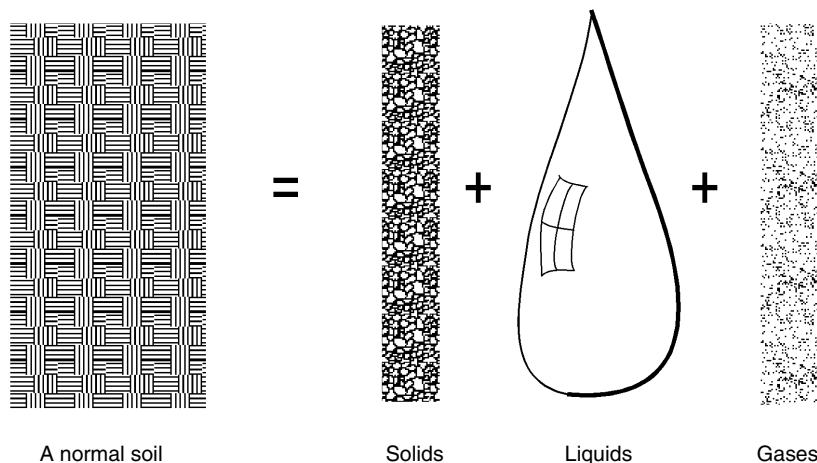
### **Soil Gases and Poor Indoor Air Quality**

Soil gases present problems for all basements. Soil gases, such as radon or methane, are site-specific and can have serious implications for the occupants. Basements are typically at a lower air pressure than the air in the surrounding soil in winter. Gases in the soil are often drawn through the foundation and slabs into the basement. Home-owners who are planning to finish a basement or who are concerned about indoor air quality, can test their homes for soil gas infiltration.

During the last decade, radon has become a concern in the building industry. It is a harmful, naturally occurring, radioactive gas with no colour, odour or flavour. Radon is produced by the decay of radium and uranium found in rocks and soils. This gas can accumulate in houses, causing unsafe exposure levels for occupants and a higher risk of lung cancer. Occupants should measure average levels of radon concentrations in the home over a period ranging from one month to a year.

Radon and other soil gases can enter a home through stone foundations and dirt crawl spaces,

**Figure 3-3: Composition of Soils**



or around floor drains, open sump pits, cracks in basement walls and floors, pipe penetrations, expansion joints and slab-to-wall joints.

Figure 3-4 shows the typical routes radon takes in entering the home.

A complete air barrier is the first line of defence against soil gas infiltration. If a barrier already exists, it should be examined, where possible, to make sure it is continuous. Cracks, tears or other openings should be sealed. For many homes, the air barrier will be sufficient for reducing soil gas entry.

In homes with an unusually high gas concentration, a basement sub-slab depressurization system may be required. Sub-slab depressurization systems include venting under the floor slab. This can involve removing the existing slab and installing crushed stone or gravel with a polyethylene cover beneath a replacement slab. A vent pipe is inserted into the crushed stone or gravel that

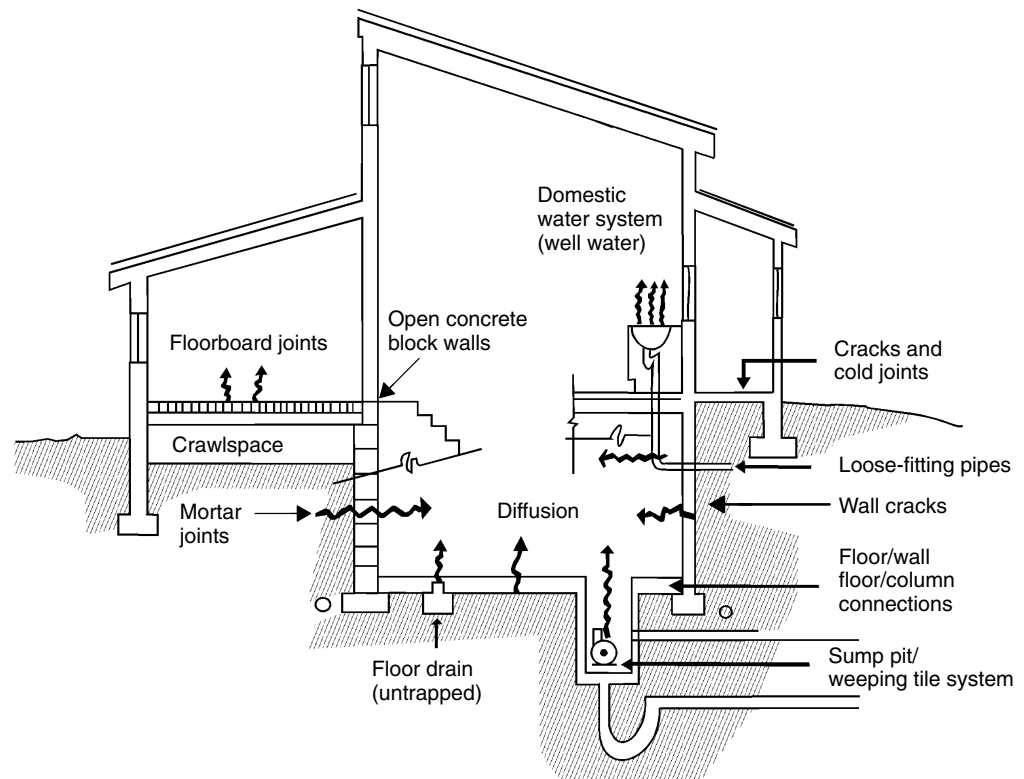
draws soil gases through the gravel bed to the outdoors. In most cases, professional advice is recommended to remedy radon problems.

When a house with a radon problem is served by a well, the water may present a source of gas. The well water will have to be tested and may require a treatment system. Radon may also be introduced through openings in the sump pit. A radon expert should be consulted for the design and installation of these systems. After a house has been treated for radon, a second follow-up test is advisable. This will ensure that the measures taken have been successful and will provide the home-owner with a greater degree of comfort about the safety of the home.

### ***Insect Infestation***

Check for termite, carpenter ant and rodent damage. These problems can undermine good work and should be remedied before you renovate.

***Figure 3-4: Radon Entry Routes***



## MOISTURE PROBLEMS

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Bulk water, capillary water and water vapour cause different types of damage to basement areas because they enter the building in different ways. Water vapour, in its gaseous state, easily travels through air. Capillary water moves in small volumes through the pores of a material by moving from cavity to cavity. Bulk water, on the other hand, is substantial in volume and moves because of gravity or water pressure. The movement of each type of water needs to be managed or controlled to prevent it from entering the house.

### *Problems from Water Vapour*

Moisture is generally harmless as suspended vapour but can cause a variety of problems when it condenses. Mold, stuffy and damp smells, wet walls, windows or water pipes can be symptoms of condensation. In some cases, mold growth can occur without visible condensation in areas of high relative humidity.

Water vapour can condense in a number of locations. Condensed moisture can lead to the decay of wood and reduce the thermal resistance of batt insulation. Condensation generally indicates that there is a problem in the basement with either high humidity or surfaces that are too cold.

There are some common sources of basement moisture that should be investigated when diagnosing moisture problems. Water vapour is released into the space by people, plants and pets, stored firewood and by some building materials. People produce moisture by exhaling water vapour into the air when they breathe and through daily activities. Cooking, dish washing, laundry and bathing are typical examples of moisture-producing activities. Construction materials, some furnishings and other objects give off stored moisture to the space as they dry out. Moisture can also enter the basement from the surrounding soil through capillary action or enter the building interior directly as evaporation from exposed soils. This is discussed in depth later in the chapter.

Any bulk water that finds a way into the basement can also evaporate into the ambient air, increasing the humidity of the space. Some

less common causes of indoor moisture can also cause problems. You should be alert to drying firewood in the basement or clothes dryers that are vented indoors or into attic spaces. These can produce unusually high amounts of water vapour in a space.

Determining whether a source of moisture is from the interior or the exterior of the building can be challenging. To determine if the source of moisture is from the outside of the house, place a sheet of polyethylene, sealed around the edge, on the suspect wall or floor and observe whether condensation appears on its underside. If it does, this is a strong indicator that moisture is being driven by a vapour pressure from the outside into the basement.

The amount and temperature of the water vapour in the air determines the relative humidity of a space. Humidity can be lowered by reducing the amount of suspended moisture in the air. Examining sources of moisture and removing those that can easily be removed should be the first step of this strategy. Exhausting moisture from high-humidity rooms, such as bathrooms and laundry rooms, is extremely important. Dehumidifiers can also be used, although they tend to be most effective in summer when relative humidity levels are extremely high. Whole house or local basement ventilation can be very effective in lowering indoor humidity during the heating season. To a large extent, circulating the air in the house will help to reduce moisture buildup in specific locations. Running the furnace fan is one approach for providing this circulation.

A second strategy is to warm surfaces that exhibit condensation. In practical terms this can be achieved by wrapping cold pipes with insulation (protected with a vapour barrier), replacing single-pane windows with double- and triple-pane units and insulating cold envelope surfaces. Situating heating registers to bathe cold surfaces may also help to control condensation.

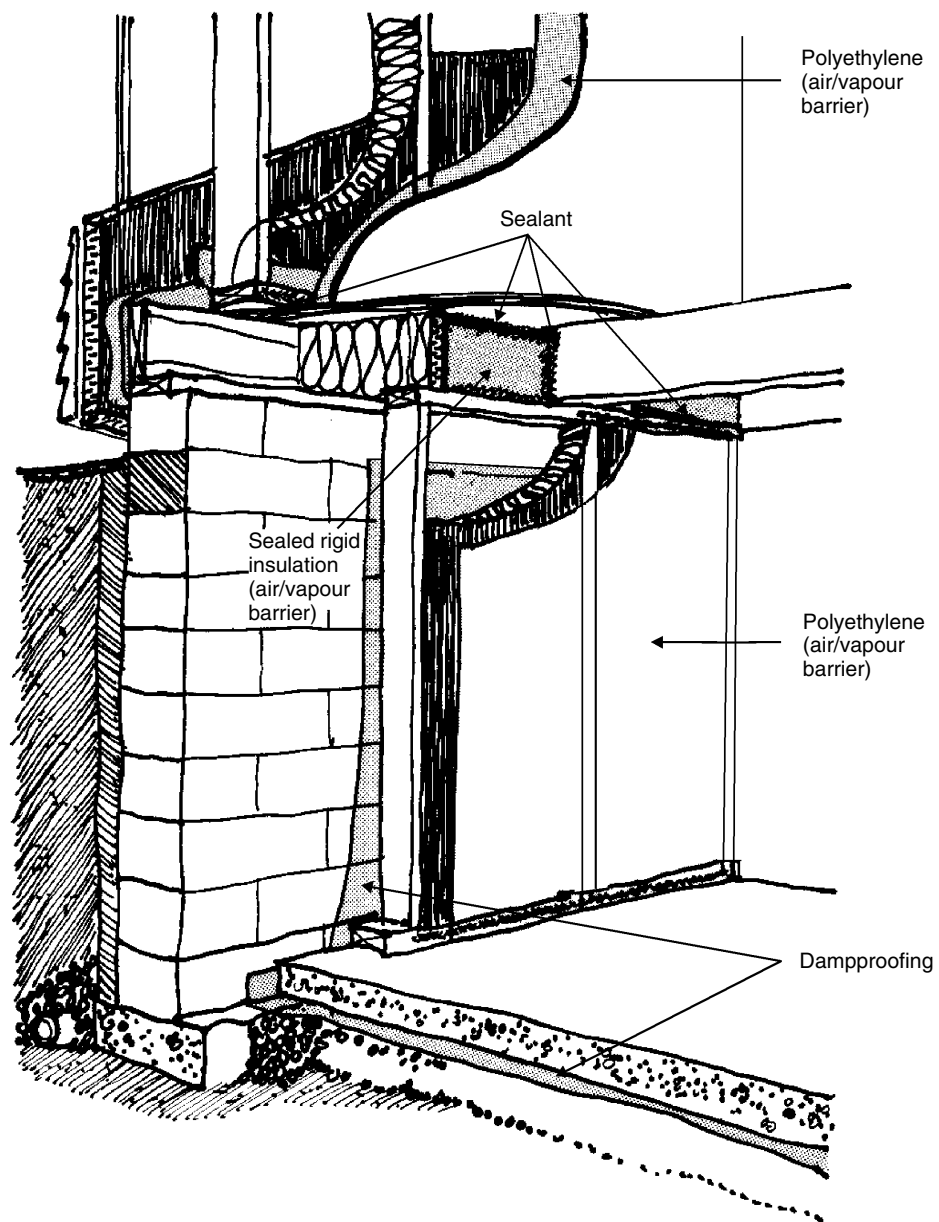
Water vapour in a warm, damp basement will attempt to move outside to drier, cooler conditions. If water vapour passes into basement wall assemblies on its journey outside, it may condense within the assembly and cause problems. To control vapour movement from the basement into the walls, air and vapour barriers are installed. The vapour barrier will protect

against vapour diffusing through the wall. The air barrier, on the other hand, will prevent the flow of warm, moist air into the wall. Both air and vapour barrier protection is required to prevent condensation of water vapour in basement walls. Often a combined air and vapour barrier, such as sealed or lapped and

clamped polyethylene, is used. Figure 3-5 shows a typical foundation wall with insulation and air and vapour protection.

Poorly installed air and vapour barriers can result in condensation, water damage and mold growth. The following checklist summarizes

**Figure 3-5: Foundation Insulation, Air and Vapour Barriers**



items that should be of concern when diagnosing condensation problems:

- Is there visible condensation?
- Are exhaust fans installed in bathrooms and laundry rooms?
- Are the exhaust fans effective?
- Is there indoor drying of firewood or indoor venting of dryer?
- Is the house construction tight?
- Is whole-house ventilation installed?
- Are there cold pipes that are uninsulated or without vapour protection?
- Is there condensation on basement windows?
- Is there condensation on wall or floor surfaces?
- Are wall air and vapour barriers installed properly?
- Are there open sump pits?

The water vapour carried by moving air can be controlled by sealing off leaks through the envelope assembly. The most common places for leaks to occur are around window openings, electrical boxes, beam pockets and at the sill plate. Any gaps between the foundation and sill should be sealed; this is a notoriously leaky part of the building's envelope.

In a basement with insulation and a vapour barrier installed, condensation can sometimes be observed on the exterior face of the vapour barrier (the side closest to the outside). Condensation behind the vapour barrier usually occurs in summer when the outside air is humid and contains a lot of moisture. If the basement air is drier than the outside air, water vapour will be driven into the basement. The water vapour condenses on the first surface below its dew point, often the exterior face of the vapour barrier. Sometimes this is most noticeable on south-facing walls or when new walls or slabs are poured. This normally does not pose real problems as the condensation soon evaporates without causing damage.

Research indicates that it is important to remedy moisture problems in a basement before renovating. If problems are not remedied, new

materials introduced to the space can be subjected to moisture damage that will limit their useful life. Mold can produce serious and, in some cases, fatal results in people living in the house. It can cause allergies and other lung-related ailments. Molds are discussed further in Insight 3 — Health Hazards from Mold.

Finally, the renovation can make an existing moisture problem worse. It can reduce the amount of moisture escaping from the basement. Finishing a space and introducing new activities can also add moisture. As part of the renovation, you should deal with cool surfaces, improperly installed air and vapour barriers, abnormal moisture sources and poor ventilation. This will reduce the likelihood of callbacks due to problems with water vapour. The following section — Renovation Implications — discusses the implications of new work in more detail.

### ***Problems Caused by Capillary Water***

Water can move through porous materials, including masonry and concrete, using a process called capillary action. This movement results from a suction pressure exerted by small tube-like pores in the material. Capillary action can lift water great distances. Tall trees, for instance, are able to take water from the ground and lift it hundreds of feet by capillarity.

Symptoms that indicate capillary water moving into the foundation are found both on the interior and exterior of the house. Inside, basement walls may exhibit signs of efflorescence; insulation and framing may be wet or moldy; the basement may smell musty; or interior partitions may be rotting from the base upwards. On the outside of the house, damage by capillary-driven water can be seen as efflorescence, crumbling mortar, spalling bricks and concrete or rotting, discoloured exterior finishes at the base of the house. A detailed discussion of the causes and effects of efflorescence can be found in Insight 7 — Efflorescence.

The slab and foundation walls wick water into the basement from the surrounding soil. This water can be drawn into carpets, framing or other porous materials in contact with the foundation. If the dampness is caused by capillary action, the mold and water stains will be most evident on the side of the material

### Insight 3 — Health Hazards From Mold

Molds are biological organisms that can become serious indoor pollutants and can lead to the deterioration of building materials. They live and grow from nutrients obtained from sources of organic matter. The spores and debris they produce can cause a number of health problems when they're inhaled.

Houses that contain mold tend to have a damp or musty smell. The odour can cause discomfort and headaches. Molds can also cause allergies, asthma and other significant reactions that are similar to allergic reactions to pollen. Mold induced allergies can become a lifelong affliction, particularly if exposure to the mold source is extended. Children are especially susceptible to mold-related health effects.

Moist environments create ideal conditions for mold growth. High humidity, (especially above 70% relative humidity), warm temperatures, a good oxygen supply, food and water are conditions that will encourage growth. Common sources of moisture for mold growth include damp ground in crawl spaces, seepage through basement walls, faulty roof flashing and condensation from activities within the house.

Mold needs to be prevented from becoming established. Once it starts to grow, it can produce water that allows it to sustain itself even in dry conditions. The simplest control measures involve reducing or eliminating known sources of moisture before mold can develop.

Basements are particularly susceptible to mold attack. Finished basements can hide mold and moisture problems in wall cavities that have not been adequately protected from moisture.

There are many sources of moisture in basements. Foundation cracks, leaky window wells, poorly installed dampproofing, perimeter drainage, eavestroughing and inadequate grade slope are all known to cause moisture problems in the basement. Interior sources of basement moisture can raise humidity levels and result in condensation. These include clothes washing, showering and dishwashing. Drying firewood for wood-burning appliances in the basement is an important source of indoor moisture that can easily be avoided. Wood should be stored and dried outdoors.

A year round goal of 40% relative humidity is reasonable. If there is too much humidity in the

house, check the list below for opportunities to reduce and control moisture.

- Keep all surfaces clean and dry
- Exhaust fans should be installed in bathrooms and dryers need to be vented directly to the outdoors.
- Vapour and air barriers need to be installed to prevent indoor moisture from moving into wall cavities.
- Proper dampproofing needs to be installed to prevent ground moisture from reaching framing members.
- Penetrations into the air barrier from electrical outlets and other penetrations should be sealed to prevent moisture movement.
- Rain-shedding systems should be inspected and repaired if necessary.
- Grade should be landscaped so that the ground directs water away from the house.
- In summer, air conditioners and dehumidifiers can be used to remove excessive moisture from the air.
- Plastic sheeting can be installed to prevent ground moisture from entering the house.
- The methods of removing or preventing moisture will depend on the individual problems within each home.

To eliminate mold that has established itself in your home, follow the steps outlined below.

- Kill off mold by using chlorine bleach solution.
- Clean other sites that may be storing mold.
- Eliminate sources of excessive water.
- Keep all surfaces clean.
- Provide continuous and controlled ventilation.

There is no singular solution to preventing mold growth, but by using common sense it can be significantly reduced.

For additional information, refer to CMHC's publication *Clean-up Procedures for Mold in Houses 61091*.

closest to the slab or wall. Any moisture marks on wood, paint or drywall finishes will appear to begin at the base or at the studs and spread outwards.

Capillary movement or “rising damp” is quite prevalent in houses built before 1920 with foundations made of clay brick or field stone. The same holds true for houses with older concrete-block foundations that have not been properly dampproofed from the outside.

Water in concrete or concrete-block foundation walls can be drawn upwards into materials above the basement level. Masonry veneer is particularly susceptible to capillary water movement when it sits directly on the foundation wall and not on top of a base flashing. Water in the bricks can freeze in winter causing spalling, cracking and crumbling mortar. In summer, wicking water can dissolve salts and discolour the wall as efflorescence. Other exterior finishes can also be affected by capillary movement of water through concrete or masonry foundations. Mortar droppings in the air space behind brick veneer can block the free movement of water in the space and, at times, serve as a wick, drawing moisture to the wood framing of the wall assembly. Proper construction practices are crucial to a trouble-free renovation.

Problems caused by water wicking through the concrete and masonry can be prevented by isolating the concrete masonry from the soil and from interior materials. Water can be prevented from moving from one material to another by installing a moisture barrier (often referred to as dampproofing), or by providing a space between materials. This capillary break blocks the water by stopping moisture from passing between the pores of adjacent materials. See Figures 3-6 and 3-7.

On the basement exterior, soil moisture can be prevented from coming into contact with the concrete or masonry walls by installing a dampproofing or waterproofing membrane. In some cases, a drainage layer can also isolate the foundation from soil moisture. Installing exterior dampproofing can be costly and time consuming for an existing basement. It may, however, be necessary in wet sites and is recommended when the foundation is excavated for the installation of weeping tile.

Concrete floor slabs wick water in the same manner as the walls and can easily transfer it to framing members. Dampproofing is required if none exists below the slab, between any interior partitions and the floor slab. Carpets, furnishings and other objects laid directly on the slab are also likely to experience some moisture damage. Contact with unprotected concrete should always be avoided. See Figure 3-8.

Joists and beams embedded in the foundation wall also need to be protected from capillary water, particularly if the beam or joist bottom is less than 6 inches (150 mm) from grade. Dampproofing an air space around the beam or joist ends, or pressure treatment, are normally required to protect the wood from decay. Refer to Figure 3-9.

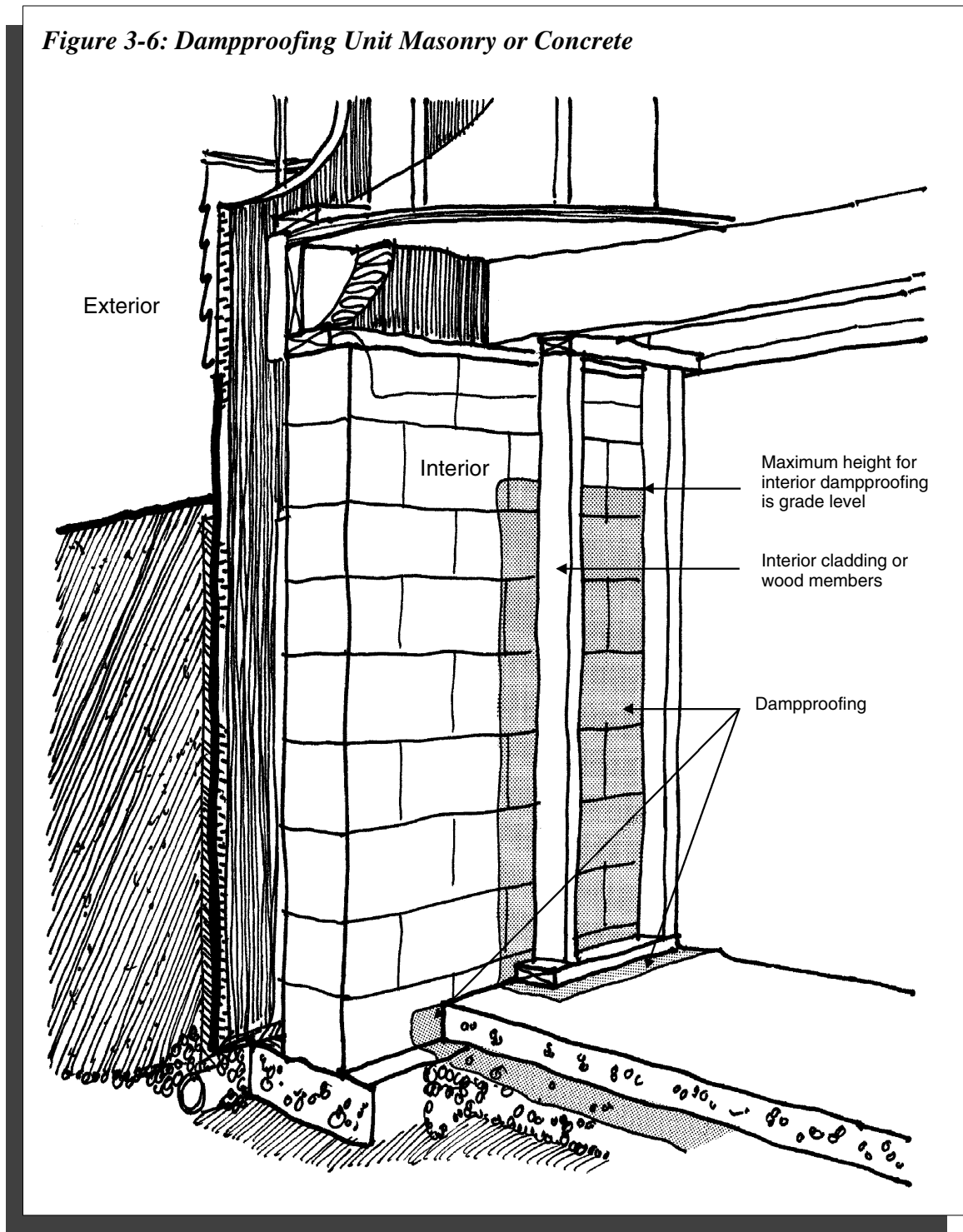
A final problem with capillary water is frost heaving. Soil contains water, and when the soil freezes in winter, so does the water. Any water below the frozen soil will continue to move upwards through capillary action. This water reaches the level where freezing occurs and adds to the ice already formed there. Frost heaving occurs when the level of freezing extends below the footing. Water expands when it turns into ice, and the upward force of the expanding ice formation acts directly on the footing. These conditions often result in large structural cracks and bowed retaining walls, among other problems. This is a substantial concern and solutions are described in the Existing Foundation Conditions section earlier in this chapter.

All of the conditions caused by the uncontrolled movement of capillary water should be remedied before a basement renovation takes place. The damage they can cause to the renovation can be significant and can lead to client dissatisfaction. Remedy all of the existing problems first before proceeding with the renovation. Inevitably, taking the right steps at the beginning will help save time and money on callbacks later on.

### ***Moisture Problems Caused by Bulk Water***

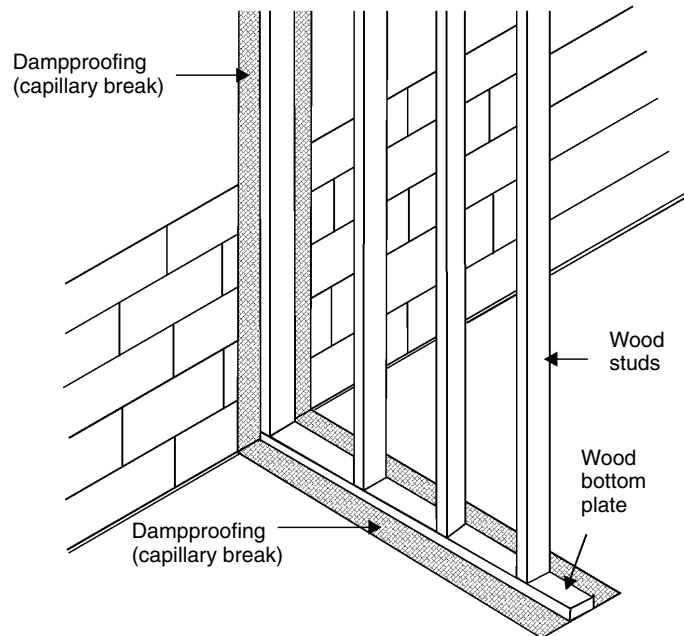
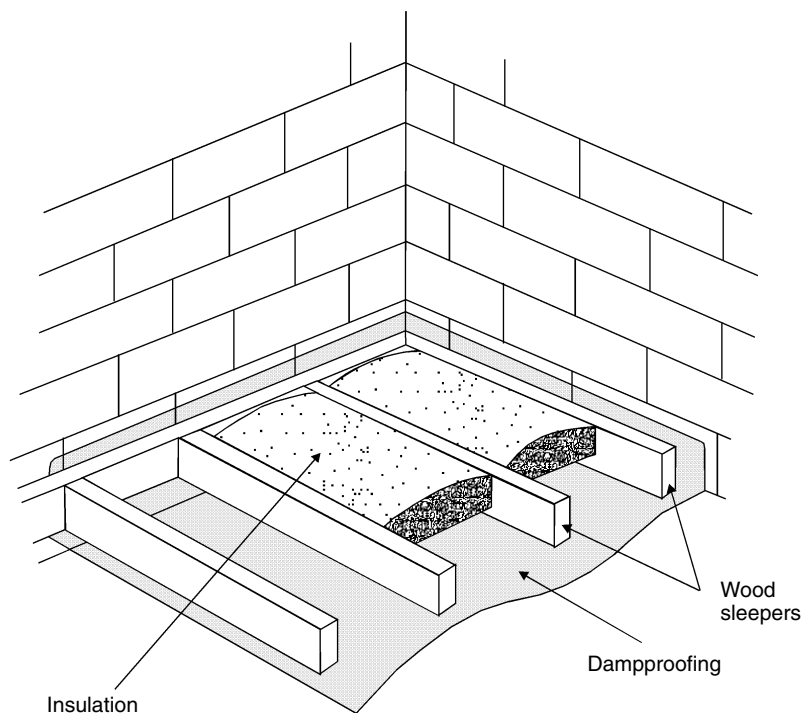
Free water that interacts with the house as a measurable volume of liquid is called bulk water. Ground water and precipitation are the two most common sources of bulk water. Water leaking through basement walls or collecting in

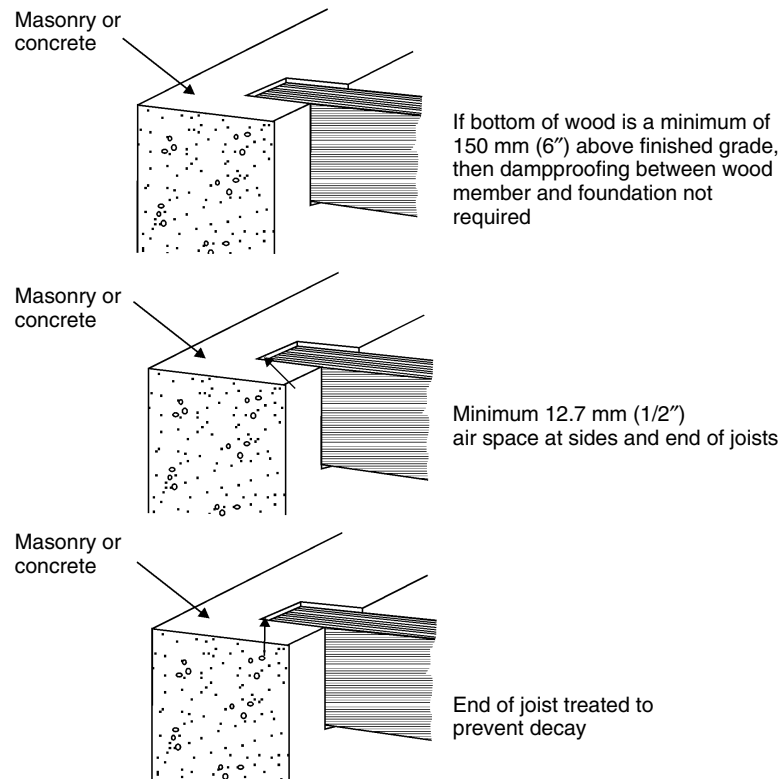


*Figure 3-6: Dampproofing Unit Masonry or Concrete*

window wells is the product of poorly diverted rainwater. Storm sewer backup during a rainstorm can be related to a diversion system problem or to the normal design storm exceeding the capacity of the storm water sewer. Water seeping in through the wall-floor

connection and overflowing sump pits may indicate a problem with a high ground-water table. Poorly diverted rainwater is the result of improperly installed rain-shedding systems or grading. Exterior building finishes, flashing, eavestroughs, gutters, downspouts, drainage

**Figure 3-7: Dampproofing and Basement Partition Walls****Figure 3-8: Dampproofing and Wood Sleeper Floors**

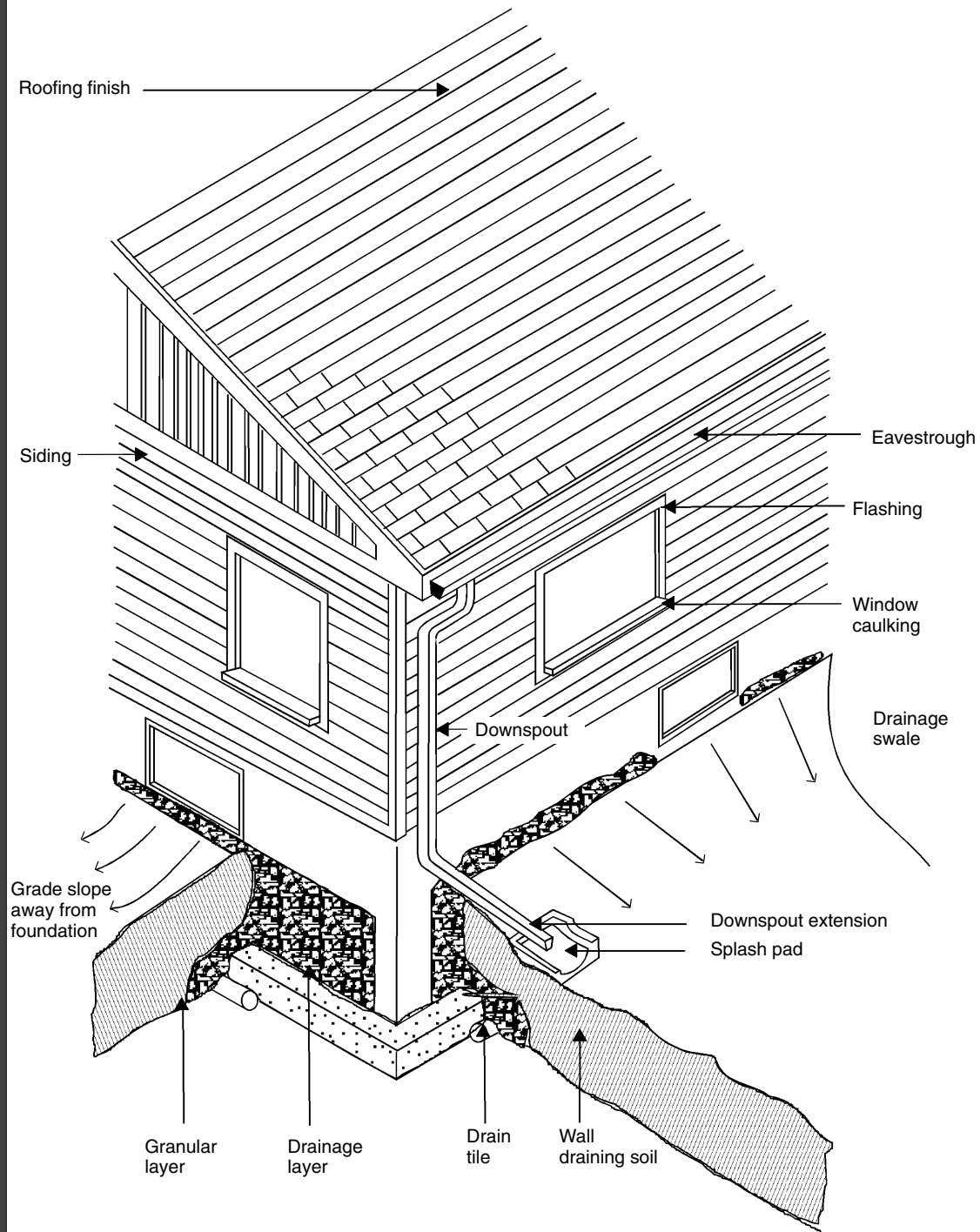
**Figure 3-9: Joist and Beam Embedment**

layers, drain tiles and grade slope are all part of the building's rain-shedding system. It is important that eavestroughing be sloped towards the downspout to ensure a smooth continuous flow of rainwater. Water that is allowed to pool can cause corrosion or can freeze in winter. A trough dam should be installed at valleys to prevent overflow. The downspout should be clear of debris and of adequate size. The downspout must direct the water away from the base of the house to prevent it from infiltrating down along the basement walls. The grade around the house should be sloped away from the house to ensure water is carried away and not allowed to puddle or saturate the soil around its perimeter. Water on the ground should never be allowed to run towards the building. A swale around the house can be used to direct water away. If problems with bulk water are detected in the basement, the rain-shedding system should be the first item inspected to ensure that water is being directed away from the house.

Figure 3-10 identifies the principle components of the rain-shedding system.

Other aspects of the rain-shedding system should also be considered. The basement may be surrounded by poorly draining soil, or the perimeter weeping tile may be damaged. Excavation may be required to remedy these problems. In older homes, the problem may be that the foundation was not designed to resist water leakage. Some older foundations may be made of stone. This type of construction is often not watertight, even with mortared joints. There are now a number of materials available to cover irregular, uneven surfaces that can be applied to the outside of the foundation wall to shed infiltrating water, including a number of membrane products.

A far more serious problem is water leaking into the basement driven by pressure from a high local water table. In this situation, waterproofing is required instead of dampproofing. Aside from

*Figure 3-10: The Rain-shedding System*

water leakage, high water tables also have implications on soil-bearing pressure and the foundation structure. A high water table can seriously reduce the soil's capacity to support loads. Footings normally need to be designed to account for the water table. In addition, the pressure that the water can exert on the foundation can result in very serious structural cracking. High water tables can sometimes be dealt with by an interior sub-slab drainage system and a sump pump. Always refer to a professional for specific advice.

Finally, bulk water problems can result from leaking pipes, overfilled condensate pans or leaking hot water tanks. Normally, these problems are easy to diagnose and solutions generally involve repairing the leak or emptying the pan. These problems should be repaired before you continue with the new renovation work.

For further information on basement moisture problems, refer to CMHC's publication *Investigating, Diagnosing and Treating Your Damp Basement* 61065.

## RENOVATION IMPLICATIONS

Finishing a basement often alters the size, temperature, moisture and contaminant levels in the house and can have an effect on the operation of the house as a whole. The renovation often alters the structure of the house and can also affect the plumbing, electrical and mechanical systems. It is important to know what the implications of the changes are before the renovation takes place. This will help you avoid problems or reduce their potential impacts.

### Headroom

One consequence that should be planned for is reduced headroom. Applicable building codes prescribe the minimum height requirements for basements. Installing sleepers, subfloors or suspended ceilings in an already low space may make it unsuitable as living space. If headroom requirements are not met before or after a renovation, the floor may have to be lowered and underpinning may be required. Underpinning requires care to prevent collapse.

Good coordination and professional advice is an essential part of the underpinning process.

### Altering Structural Systems

Home-owners who want to alter the basement by moving beams or columns, or adding door and window openings, may be greatly changing the structural system of their home. Small openings in the foundation wall may not seem to be a large change, but if they are incorrectly located or installed, the integrity of the entire foundation may be compromised. If the home-owner is convinced that they want to change the structure, advice from a structural engineer or architect is recommended.

Altering the space within the basement of a house affects the building in a number of different ways. Understanding the effects of a renovation can alleviate many of the problems that might occur. A safe, healthy environment can be provided for the family with proper headroom, good air and proper means of escape in an emergency. Read the Insights in this chapter. They explain some of the topics that have been covered and explore other related issues.

### Adding Insulation

Finishing a basement often involves adding insulation to reduce heat loss to the outdoors and improve comfort. Basement insulation can vary in type (rigid, batt, blown or foamed-in-place), in placement (inside or out) and in location (on floors or walls). The selection and placement of insulation depends on the specific needs of a particular basement. Each has its own advantages and disadvantages.

Rigid or batt insulations are usually chosen according to their intended use. Batt insulations are often used in wood-frame wall cavities because of their flexibility and ability to conform to cavity shapes. Rigid insulations are often used where floor or wall thickness is an issue since they provide better thermal resistance per unit of thickness.

Whether insulation is placed on the interior or exterior of the basement is often dictated by the costs associated with each option. When the basement is in place and surrounded by soil, decks and landscaping, it is costly to install exterior insulation. It is much less expensive to

add interior insulation. The main advantage to having exterior insulation is that the foundation structure is kept at constant temperatures. This means that the concrete can be used to store and radiate heat and that the foundation is not subjected to freeze-thaw cycles that can lead to cracking. This can be an important consideration in a rubble-type foundation that could be affected by the installation of interior insulation. In some cases, exterior insulation can also act as a drainage layer, reducing the incidence of water penetration.

Another decision when installing basement insulation is whether to insulate walls or floors or both. All are part of the house envelope and lose heat to the outside. Insulating all walls and floors would be ideal to conserve heat energy and increase comfort. Costs often dictate that only some elements be insulated. Insulating the elements that are responsible for the greatest amount of heat loss is normally recommended. The walls and floor do not lose heat at the same rate. Figure 3-11 shows which elements of the foundation lose heat at higher and lower rates.

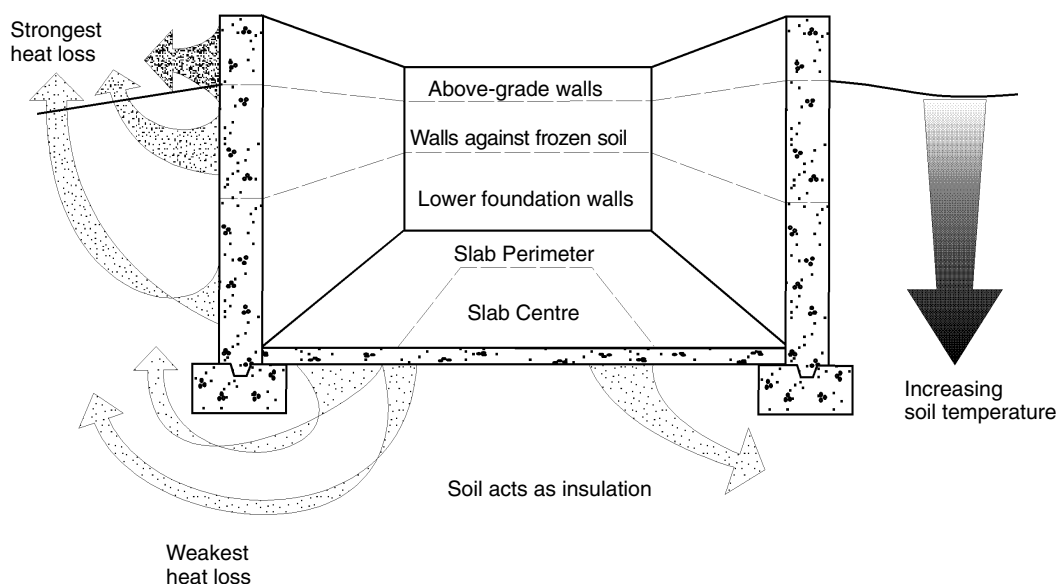
The portion of foundation walls exposed to freezing temperatures near the ground tends to lose more heat than any other foundation

element. Foundation-wall insulation installed to 600 mm (2 ft.) below the ground surface should be the first priority. In some regions, full-height basement-wall insulation is called for to minimize heat loss.

Concrete floor slabs tend not to lose as much heat as the walls because they are often thermally protected by the soil surrounding the foundation. For this reason, the centre of the slab loses less heat than the perimeter. The soil protects these elements from cold, ambient air temperatures. Floor insulation is not typical but, when installed under the floor slab, is often placed only around the perimeter. Minimum requirements for insulation placement can be found in applicable building codes.

When adding insulation during a basement renovation, there are a number of decisions that have to be made about the selection and placement of the insulation. Each basement will have different needs, so choices may change from house to house. You should be aware of the impact on the rest of the house when decisions are being made. Reduced heat losses lower the heating needs of the house. The furnace may become oversized to handle the new loads. An oversized furnace can cycle frequently, resulting in premature failure and

**Figure 3-11: Heat Loss Patterns in Cold Basements**



discomfort in some cases. Care must also be taken to ensure that the new insulation does not affect the proper functioning of the existing building envelope. Refer to Chapter 10 and Chapter 11 for a more comprehensive discussion of mechanical systems and retrofitting for energy efficiency.

### ***Vapour and Moisture Protection***

One common problem with newly insulated walls is the diffusion of water vapour into the wall assembly. When the wall is uninsulated, the water vapour either passes through, is absorbed by the concrete or evaporates away. When insulation is added to protect against heat loss, vapour protection is required. Installing a vapour retarder on the warm side of the insulation to prevent moisture from passing to the cooler side where it can condense is an important step in any foundation project.

In some circumstances, basements are already insulated, and a vapour retarder already installed. Adding insulation could cause the location of the vapour retarder to become a concern. The vapour retarder should be on the warm side of the dew point or as close to the warm side as practical.

Dampproofing needs to be added to the foundation between any wood members and the masonry or concrete foundation walls or slab. The dampproofing acts as a barrier to moisture, preventing damage to the wood. On walls, the dampproofing must terminate at grade to allow any moisture trapped in the cavity wall to escape to the outdoors. Alternatively, dampproofing can be omitted if stand-off frame walls are constructed that do not touch the foundation.

### ***Air Leakage Protection***

Another issue created when insulation is added to basements is air leakage. For the same reasons that insulated walls must be protected against vapour diffusion, they must also be protected against air leakage. Air that moves into the envelope can carry considerable amounts of moisture. This moisture can condense when the moving air reaches cooler parts of the assembly. The air barrier is often integrated with the vapour barrier, so that only one membrane is installed. In this case, the air and vapour barrier must be continuous to

prevent any openings. Remember that a completely sealed air-vapour barrier can significantly tighten the house.

### ***Indoor Air Quality and Ventilation***

Tightening a house by properly installing air barriers can affect the indoor environment. The newly tightened house will allow less basement moisture to escape to the outdoors, effectively raising indoor humidity levels. This could result in condensation, mold growth, dampness and other symptoms described earlier in this chapter.

Also, be aware that by tightening the house, odours, chemicals and other air contaminants can be trapped indoors. Tighter houses can require ventilation systems to remove moisture and contaminants. Mechanical ventilation systems are intended to deal with air contaminants or moisture problems and can be of the balanced or exhaust-only variety. Balanced ventilation systems usually include heat recovery ventilators, while exhaust-only systems can be as simple as bathroom fans with a separate make-up air. The system selected to address the problem will depend on other equipment in the home, home-owner preference, cost and other concerns.

Air quality in a renovated space can be negatively affected by a number of factors. The renovation materials being introduced to the space and the furniture can contribute to indoor air-quality problems. Many materials, such as carpets, underpads, glues and sealants, cabinets, paints, varnishes and furnishings can release harmful contaminants into the air. However, there are products available that release fewer contaminants. Renovators are encouraged to examine these new materials and methods.

When basement renovations are contemplated, basement ventilation becomes a serious consideration. The renovation can result in a tightening of the envelope, creating air-quality problems or exacerbating ones that already exist. Refer to Insight 9 — Airtightness and Ventilation — for a more complete discussion.

### ***Plumbing and Heating Systems***

It is often desirable to conceal ducting, electrical wires and plumbing in finished spaces. In basements, the floor joists normally provide adequate space for horizontal mechanical system elements to be hidden. Unfortunately,

piping and ducting running perpendicular to the joists or vertically can be difficult to conceal. Interior partitions are often too small to accommodate ducts and pipes and must be widened. Ducting and piping is occasionally run adjacent to exterior walls. However, this can cause a variety of problems. In basements that are to be insulated on the interior, the pipes interfere with proper insulation coverage, compressing insulation and possibly causing cold spots on the wall. Water pipes that are inadequately insulated may freeze and rupture. Hot air or water passing through these ducts or pipes can also suffer substantial heat loss to the exterior. Lost heat and malfunctioning water systems can cause discomfort and dissatisfaction for the home-owner. For these reasons, it is advised that all vertical plumbing and heating runs located adjacent to the foundation wall be concealed in chaseways or interior partitions. It is important to remember during the renovation that access to pipes, cleanouts and ducts must be maintained to reasonable extents for maintenance purposes. As well, do not conceal hose bibs, gas and electric meters and electrical junction boxes. Heating system changes and upgrades are discussed in Chapter 10.

### **Natural Lighting**

Windows allow sunlight to enter indoor spaces. The height of the window determines the amount of light penetration. Natural light should be a major concern when planning the basement layout. Often in basement renovations, it is easiest and cheapest to make use of existing window openings rather than create new ones. When new window openings are created, take special care with those greater than 1.2 m (4 ft.) wide or those that occupy more than 25 percent of the wall length. New windows installed in the foundation wall can significantly weaken it, causing cracking or structural difficulty.

Window wells can be used to introduce light into the basement space. Be sure that these are properly drained to the exterior weeping tiles. Often, improperly installed wells allow water to leak into the basement space, ruining interior finishes.

New windows near property lines are normally limited by the spatial separation requirements of building codes. Windows are generally not

permitted within 1.2 m (4 ft.) of a property line. Review the building code requirements that apply in your region.

### **Noise**

New activities and people occupying the basement can bring other changes that will need to be considered during the renovation. The basement can become a new source of noise for the spaces above. It will also be subjected to noise from surrounding rooms. The floors overhead can transmit sound as can any mechanical equipment located in the basement. Noise sources from outside the home are sometimes overlooked. A nearby transitway or subway line, for example, can cause a lot of noise in a basement. This should be planned for in the design stages of the renovation. Locating quiet spaces, such as bedrooms, adjacent to noisy spaces can result in discomfort for the occupants.

The amount of sound-transmission control required will be dictated by the layout of the house and the lifestyles of the occupants. Noise control can be achieved by adding insulation between the ceiling joists or acoustical ceiling or wall tiles and by well insulating exterior walls. Mechanical and plumbing equipment should be carefully installed and situated to minimize discomfort from operating noise.

### **Safety Concerns**

The finished basement should ensure the safety of the people occupying it. An important part of ensuring safety is providing a means for escape during an emergency. This escape route can be provided through properly constructed stairwells and adequately sized windows. The dimensions and locations of these escape routes will be prescribed by applicable building codes. The selection and size of windows to be installed may be governed by the ease of escape through them. Safety is the most important feature of any habitable space, and a way of escaping from that space is crucial.

## **HEALTHY HOUSING BASEMENTS**

There are a number of issues that relate to basement spaces and Healthy Housing. The effects of molds and soil gases on the occupants



are the most notable. Indoor air-quality concerns relating to the spillage of the products of combustion from appliances installed in the basement are also important considerations. In addition, the basement often accommodates activities in workshops or craft rooms that can produce contaminants which put the occupants at risk.

While many Healthy Housing issues are common to different types of renovations, those identified here tend to be most strongly associated with basements. Solutions to these problems often focus on providing proper ventilation in the basement space, exhausting concentrated contaminants to the outdoors and preventing their diffusion throughout the house. Effective ventilation can help to prevent or mitigate soil gas accumulation and moisture problems which can cause mold growth.

In addition, the use of low-emission products in the renovation helps to avoid poor indoor air quality. Using water-based paints and adhesives, avoiding the use of carpets and substituting solid wood for laminated products are ways of reducing building products that emit contaminants.

Basement spaces offer the best potential for improving energy efficiency. Try not to neglect the opportunity to improve the performance of the building and save the client money. Chapter 11 offers more details. In basements where natural light is limited or unavailable, there is an opportunity to install energy-efficient lighting.

An environmentally responsible basement renovation also uses space efficiently, minimizes

materials used on the project and manages construction waste. Try to use components that are reused or recycled. Scrap drywall, wood and metal can be reused or recycled in some regions. Investigating the opportunities available in the municipality will make it easier to implement waste management practices.

All of the opportunities to make the basement renovation healthy can mean savings for the home-owner. And converting an unused basement to liveable space means the house is more fully used and its resale value enhanced.

## **FLEXHOUSING CIRCULATION WITHIN DWELLING**

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Corridors should be wide enough to allow a person using a wheelchair to manoeuvre easily and have full access to rooms and closets. There should be no changes in floor level. In multi-level houses, provision should be made for the future installation of either an inclined stair lift or a vertical lift.

### ***Design Considerations***

- Easy-to-grasp continuous stair handrails
- Three-way switches in circulation areas to avoid moving in unlit areas
- Reinforced stairway walls to allow future installation of a stair lift, or vertically aligned closets and appropriate framing to allow future installation of a vertical lift



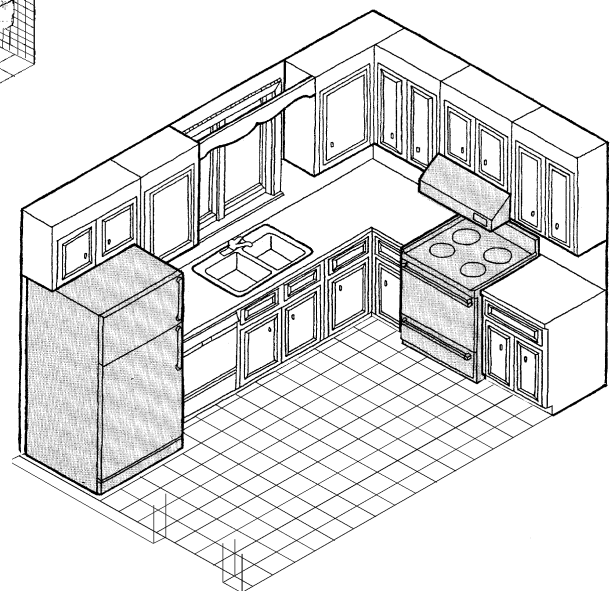
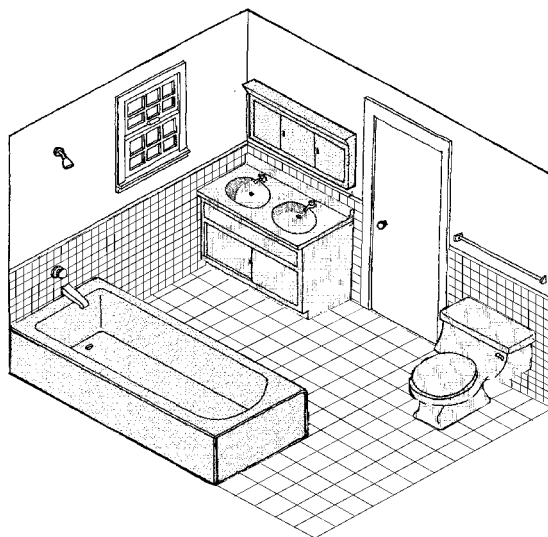
## Renovating Kitchens and Bathrooms

**K**itchens and bathrooms are often the focus of interior renovations. Both rooms accommodate activities that account for most of the moisture generated within the house. Often these rooms show symptoms of deteriorated components and materials.

Kitchens, and to a lesser extent, bathrooms demand special attention to design in order to ensure a proper functioning space. Kitchens that function poorly need to be analyzed and may need to be redesigned for greater efficiency. A number of design issues will be reviewed in this chapter.

This chapter discusses the implications of renovating kitchens and bathrooms, including typical problems found in these rooms, their causes and solutions.

An important step in the renovation of kitchens and bathrooms is ensuring the underlying structure is sound and able to accommodate the newly renovated room. Accommodating heating, plumbing and electrical services, fixtures and appliances is often a concern. Most important is the selection of appropriate and healthy finishes. These need to be durable and able to perform in a wet and humid environment. This chapter discusses these issues in detail.



## INTRODUCTION

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Kitchens and bathrooms are major amenity areas in a home. They meet the essential needs and reflect the lifestyle of the family. The relationship between the floorplan of the home and the location of the kitchen and bathroom is critical to the home's functional performance. Characteristics that make kitchens and bathrooms perform well include:

- economical and efficient layouts;
- adequate counter space and usable cabinets;
- updated and reliable appliances;
- good-quality lighting;
- carefully selected finishes; and
- efficient mechanical ventilation.

These characteristics of kitchens and bathrooms are often upgraded during renovations.

The bathroom is commonly located adjacent to the master bedroom or is a shared bath serving the other bedrooms. Powder rooms, or half bathrooms, are common on ground floors and in basements. Bathrooms today vary in size and offer a wide range of amenities to suit occupant lifestyles.

Before starting the renovation, carefully assess the condition of the existing kitchen or bathroom. Remember to consider the whole house and all of its systems when you diagnose any problems you observe.

The assessment checklist can be used as a guide when looking for symptoms of existing problems. While assessing the house for problems, be aware of other aspects of construction that may affect the proposed work. You should become familiar with the type of construction, as well as the structural, mechanical, electrical and plumbing systems, and any other aspects that may be important. Do not make any assumptions about the type of construction that was used in the house. Be aware also that walls may conceal hidden elements, such as structural supports, insulation, plumbing pipes and electrical wiring.

## CONDITION OF KITCHENS AND BATHROOMS

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It is important to recognize and understand any existing problems before performing new work. The cause of any observed problem should be determined before the renovation starts. Resolving the situation will prevent further damage and minimize the chance of the same problem occurring again.

Follow these steps when remedying a kitchen or bathroom:

1. Observe carefully . Try to assess what the problem is. Note the temperature of the room, whether there is water present and how the space is used. If there is adequate exhaust or ventilation, try to establish what the relative humidity is in the room. See Insight 10 — Measuring Humidity.  
  
Careful observation is likely the most important of all steps and often the one least attended to.
2. Try to establish the cause of any deterioration. Know that a number of mechanisms may be at work.
3. Formulate solutions to remedy the problem.
4. Repair or replace all deteriorating elements (e.g., finishes and leaking plumbing). Remedy the causes of the deterioration (e.g., repair the rain-shedding system, reduce humidity, install ventilation, repair plumbing, and so on).
5. Renovate the kitchen or bathroom using appropriate materials and components.

## ASSESSMENT CHECKLIST

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The assessment checklist for renovating kitchens and bathrooms outlines some of the problems often observed or detected in these rooms. Each item is discussed in detail on the pages indicated.

### *Design Considerations*

Before you renovate, perform an assessment to understand fully the client's needs and the purpose of the renovation. When planning a kitchen or bathroom renovation, consider

## Checklist

### DESIGN CONSIDERATIONS (page 74)

- ☐ problem of kitchen and house-entry relationship
- ☐ congested traffic paths
- ☐ circulation problems in food preparation, storage, counter space, eating and clean-up areas
- ☐ inadequate natural light

### STRUCTURAL CONSIDERATIONS (page 78)

- ☐ notched or drilled framing members
- ☐ unknown location of load-bearing walls
- ☐ cracked ceramic tile
- ☐ bulging floor over beams

### MOISTURE DAMAGE (page 78)

- ☐ condensation on surfaces
- ☐ frosting on windows or sills
- ☐ blistering and peeling paint
- ☐ mold growth
- ☐ dusting on walls
- ☐ rotting fixtures
- ☐ chipped or cracked grout or caulking
- ☐ staining of walls and finishes
- ☐ musty smells within walls or cupboards

### INDOOR AIR QUALITY (page 81)

- ☐ poor indoor-air quality
- ☐ lingering odours and contaminants
- ☐ high humidity
- ☐ no exhaust fans

### PLUMBING PROBLEMS (page 81)

- ☐ galvanized steel, cast iron or lead piping found in older buildings
- ☐ corroded piping
- ☐ leaks at pipe joints
- ☐ condensation on cold pipes
- ☐ poor drainage
- ☐ odours
- ☐ poor water pressure

### DAMAGED MATERIALS OR FINISHES (page 82)

- ☐ deterioration of floor finishes
- ☐ deterioration of other materials

carefully the relationship between the occupants, the room and the rest of the house.

By following the list of design considerations below, you can help to ensure that the renovation meets the needs of the occupants.

- Analyse the lifestyle of the occupants to understand how the kitchen and bathrooms are used.
- Examine the relationship among the kitchen, the bathrooms, the other rooms and the major entry points in the house. Note how supplies, food and other necessities are brought into the home.
- Check traffic patterns and understand how the kitchen or bathroom is being used. Record any problems that exist.
- In the kitchen, consider food preparation, storage, counter space, eating and cleanup. Avoid repeating any existing problems in the new kitchen. See Figure 4-1.
- Carefully consider existing services, such as the mechanical, electrical and plumbing systems. These systems influence the design of the kitchen or bathroom and the potential costs of the renovation.

Discuss completely the modifications that the owner is expecting. This might include upgrading the floor, wall and ceiling finishes; refacing existing cabinets with new doors and countertops; adding new appliances; or a complete gutting of the existing kitchen with a new design and new materials.

In some instances, the planning criteria for the whole house might dictate moving the kitchen or bathroom from its original location. New patterns of use must be planned and accommodated. Careful planning is essential before moving services such as plumbing, electrical, heating and ventilating, and air conditioning.

There are a number of building science and house performance aspects to consider when analyzing the existing conditions of kitchens or bathrooms. Issues related to structure, moisture, ventilation, plumbing and durability of materials must be understood in order to resolve problems and prevent their reoccurrence after the renovation.

### ***Bathroom Design Assessment***

#### **Design Considerations**

- Who uses the bathroom? When? How many users? Age of users?
- Is it used by anyone who has special needs, such as a child or a person with disabilities?
- Will the bathroom need to accommodate changes in the family in the near future (new baby, a grown child leaving home)?
- Do visitors use this bathroom? Overnight guests?
- Is the bathroom used for other activities (developing photos, washing the family dog, gardening, laundry)?
- What are those aspects of the current bathroom that need to be changed?
- What are the space, traffic, storage and layout considerations?
- Are there any fixture, accessories or hardware considerations?
- Are there any noise considerations? What types of spaces are adjacent to the bathroom?

#### **Heating, Cooling and Ventilation**

- Is the bathroom warm enough? Too warm?
- Where is the heat source? Can it be moved or changed if necessary?
- What type of heat is provided?
- What is the nature of the ventilation in the bathroom? Is it effective?

#### **Finishes**

- What are the wall, ceiling and floor coverings? Are they easy or hard to keep clean?
- Have the finishes chipped, peeled, mildewed, cracked or deteriorated in any other way? Have the surfaces worn well?

#### **Lighting and Electrical Outlets**

- Is there natural light? In what direction does the window face? Can new windows be accommodated?
- Is there artificial light? Is it incandescent or fluorescent? Check the light levels for dimness, harshness or glare.

- Are there enough electrical outlets? Where are they located? Are the outlets designated GFCI (ground fault circuit interrupter) as required in bathrooms?

### ***Kitchen Design Assessment***

#### **Cooking Habits**

- How many people cook at once?
- Is anyone left-handed?
- Is it difficult for the cook to bend over? Reach high?
- Does the client enjoy informal living, with many activities centred in the kitchen?
- Does anyone need wheelchair access?
- Do they bake often enough to require a separate baking centre?
- Do they engage in seasonal activities, such as canning, that require special equipment or extra space?
- Do they freeze quantities of food?
- Do they recycle?
- Is storage space for cookbooks or recipes required?
- Are dishes washed immediately or stored for some length of time?
- Is wine, dried or bulk food stored in the kitchen?

- Does the client constantly collect new cooking gadgets?
- Is there a need or desire for more than one oven or sink?

#### **Eating Habits**

- Does everyone eat meals together or at separate times? Do pets eat in the kitchen?
- Is an intimate area for dining or an open floorplan desired?
- Is morning sunshine at breakfast time a requirement?
- Do the occupants eat outside often?
- Are there several sets of dishes that take up a lot of storage space?
- Where do the occupants normally eat — in the kitchen or dining room?
- Is the access from the kitchen to the dining room adequate?

#### **Entertaining**

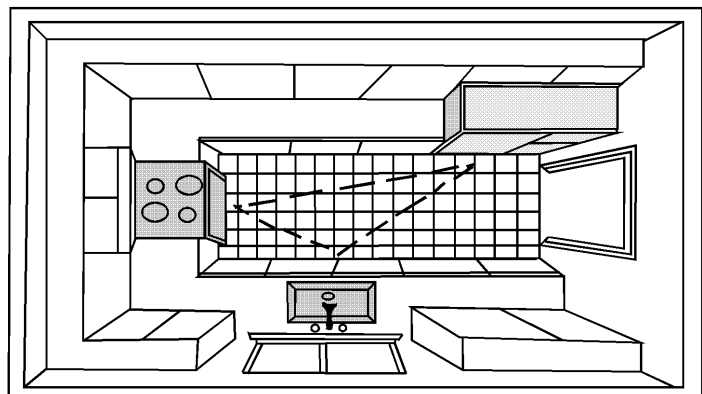
- Do they serve formal dinners?
- Do they like guests to come into the kitchen?
- Do they entertain outdoors?

#### **Home Environment**

- Is the kitchen used for other activities (watching television, homework and other projects, laundry or gardening chores, such as potting plants)?

***Figure 4-1: Efficient Kitchen Workspaces***

In the kitchen, a triangular layout between the sink, refrigerator and stove often provides an efficient working environment while controlling traffic patterns



- Do they want a home office in the kitchen?
- Does the house have a distinctive architectural style to maintain?
- Do they want art in the kitchen?
- Does anyone see the kitchen as his or her own private retreat?
- Does the home-owner want an open plan?

### Children

- Will someone be supervising children while cooking?
- Should children have access to counter space — either special low counters just for them or hidden steps to enable them to reach the regular counters?
- Are out-of-door play areas visible from the kitchen?

### Future Changes

- Are any changes in the family structure expected?
- Do the home-owners plan to stay in this home after they retire?
- Are they interested in resale?
- Are new appliances being added?

### Lighting and Electrical Outlets

- Is there natural light? In what direction does the window face? Can new windows be accommodated?
- Is there artificial light? Is it incandescent or fluorescent? Check light levels for dimness, harshness or glare.
- Are there enough electrical outlets? Where are they located? Are the outlets designated GFCI (ground fault circuit interrupter) as is required in kitchens?

### Structural Considerations

The renovations performed in kitchens and bathrooms may affect the existing structure of the building. An understanding of the nature of the building's structural system is important to preventing unexpected problems.

Try to measure the thickness of the wall and verify the sizes of framing members. Knowing the thickness of the walls is important if new windows, plumbing or duct work are to be installed. It is also important when framing members need to be drilled or notched to accommodate new services.

Try to establish whether walls are load bearing or not before any alterations are considered. (Refer to Insight 8 — Bearing Walls, Point Loads and Other Structural Concerns.) When planning any modification, treat all exterior walls as if they are load bearing unless you have determined otherwise.

Floors must be able to support the dead loads of furniture and fixtures in the kitchen or bathroom. Telltale signs, like cracked ceramic tile, bulging floors over beams or cracked ceiling finishes in the room below, are clues that the floor system may be inadequate to support new work.

Where the structural condition of the building is in question, the advice of a structural engineer or architect is normally recommended.

The success of a renovation always depends on the soundness of the underlying structure. Structural problems often telegraph through supported components and reveal themselves as unsightly finish defects. In extreme cases, problems can pose a hazard to life and property.

### Moisture Damage

Water-related damage is common in kitchens and bathrooms. It can come from the exterior or the interior walls of the house. In kitchens and bathrooms, moisture generated indoors is more of a concern than with most other rooms in a house. These are unique spaces where activities such as cooking, washing and bathing generate more moisture than in other rooms.

Water that penetrates the exterior envelope can cause water damage on interior surfaces. Poorly installed flashing, faulty or blocked eavestroughs, defective flashing over windows and poorly installed window sills can direct water to the inside. Similarly, cracks in masonry or exterior walls, windows and doors can allow water penetration to occur.

Ice damming, as discussed in Chapter 2, can cause water to penetrate the roof assembly.



Stains that result from ice damming usually occur at ceilings or on the upper portions of exterior walls. These problems will need to be resolved before work begins on the kitchen or bath renovation.

Interior sources of water in kitchens and bathrooms can include leakage from pipes or condensation. Water from leaking pipes is discussed later in this chapter. Water from condensed water vapour can occur in a number of places and for different reasons. High humidity levels can cause condensation and a variety of other symptoms, including frosting, blistering and peeling paint, the growth of mold, and rotting material around fixtures.

Roof spaces over kitchens and bathrooms are particularly susceptible to damage caused by condensation. Moisture-laden air leaking through penetrations into the attic is common in these rooms. Air leakage will typically occur around attic hatches, electrical wiring, joints at intersecting interior partitions and the ceiling, exhaust fans, recessed light fixtures, and plumbing stacks. Warm, moist air that enters the cold attic space through openings in the ceiling air barrier will cool, causing water to condense onto cold surfaces in the attic. This moisture can build up as water or frost. Sealing any penetrations to form a continuous air barrier will help prevent this problem.

Water damage on electrical fixtures, in the form of staining or corrosion, may be due to condensation on cold surfaces from air leaking through and around fixture openings. Openings around fixtures must be sealed, and an adequate amount of insulation should be placed on the cold side of the fixture.

Caution needs to be observed when installing insulation over recessed light fixtures. Too much insulation can cause overheating of the fixture. Always follow manufacturer's installation instructions and use only fixtures designed for that purpose.

High humidity levels cause windows in kitchens and bathrooms to be particularly susceptible to condensation, and cold window surfaces create an opportunity for condensation to occur. The use of energy-efficient, high-performance windows may help to eliminate the formation of condensation (see Chapter 5). Condensation on

windows during cold winter weather may appear as frost or ice.

Condensation may also form on uninsulated or poorly insulated walls and ceilings, especially in bathrooms. In these situations, as the condensation builds up, water droplets can fall from the ceiling. Repeated exposure to moisture may also stain the finish. Increasing ceiling and wall insulation increases the surface temperature and reduces the likelihood of condensation.

Blistering and peeling paint are usually an indication of moisture moving through the wall assembly. On exterior walls, this may be due to the lack of a tight air-vapour barrier on the warm side of the wall. Without this barrier, interior moisture can penetrate the wall assembly and adversely affect the exterior paint finish.

The source of the water could also be the exterior, with blistering occurring on interior painted surfaces. This problem tends to be most pronounced during summer months.

Blistering and peeling paint can often be traced to poor preparation prior to painting, poor-quality paint or poor application. Plaster or drywall which was not properly dried prior to prime painting can often cause problems with blistering and peeling paint. For further information, refer to Insight 6 — What Can Go Wrong With Paint?

Mold is often visible in the kitchen and bathroom as dark areas on walls, ceilings, paint and other finishes. Mold occurs in environments with high humidity. Insight 3 — Health Hazards From Mold — provides further details.

A sign of mold growth can be a musty smell within walls or cupboards. Mold is a health concern to you and the occupants. If humidity or moisture problems are suspected, track down the cause and fix it. After the moisture problem is eliminated, all deteriorated materials must be removed and all surfaces cleaned before renovating.

A problem related to mold on interior surfaces is the dusting phenomena. Dusting marks appear as streaks that are uniformly spaced and that correspond to the spacing of the wall- and roof-framing members. Chapter 6 — Renovating Interior Finishes — explains the causes of and solutions for this problem.

The lifestyle of the occupants is the most frequent source of moisture problems in the home. Showering, laundering, cooking and cleaning all generate large volumes of water vapour that the house must absorb or expel. The ability of the house to absorb moisture is limited. Exhausting excess moisture with bathroom and kitchen fans remains the most effective means of controlling indoor moisture and preventing future problems.

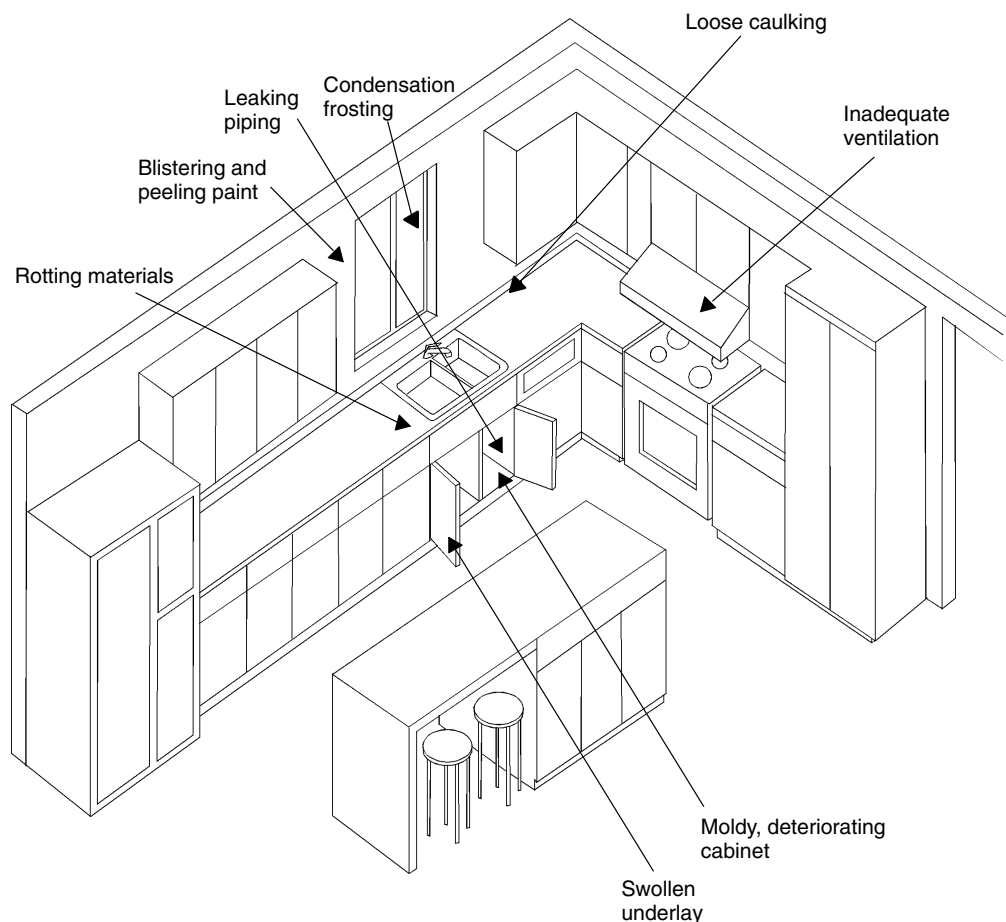
Laundry rooms, although not discussed in this chapter, can also be sources of moisture for the rest of the house. Indoor venting of dryers, in particular, can add very large volumes of water vapour to the indoor environment, as well as potentially harmful chemicals from fabric softeners. Venting dryers indoors should not be done. Additional exhaust fans in laundry rooms

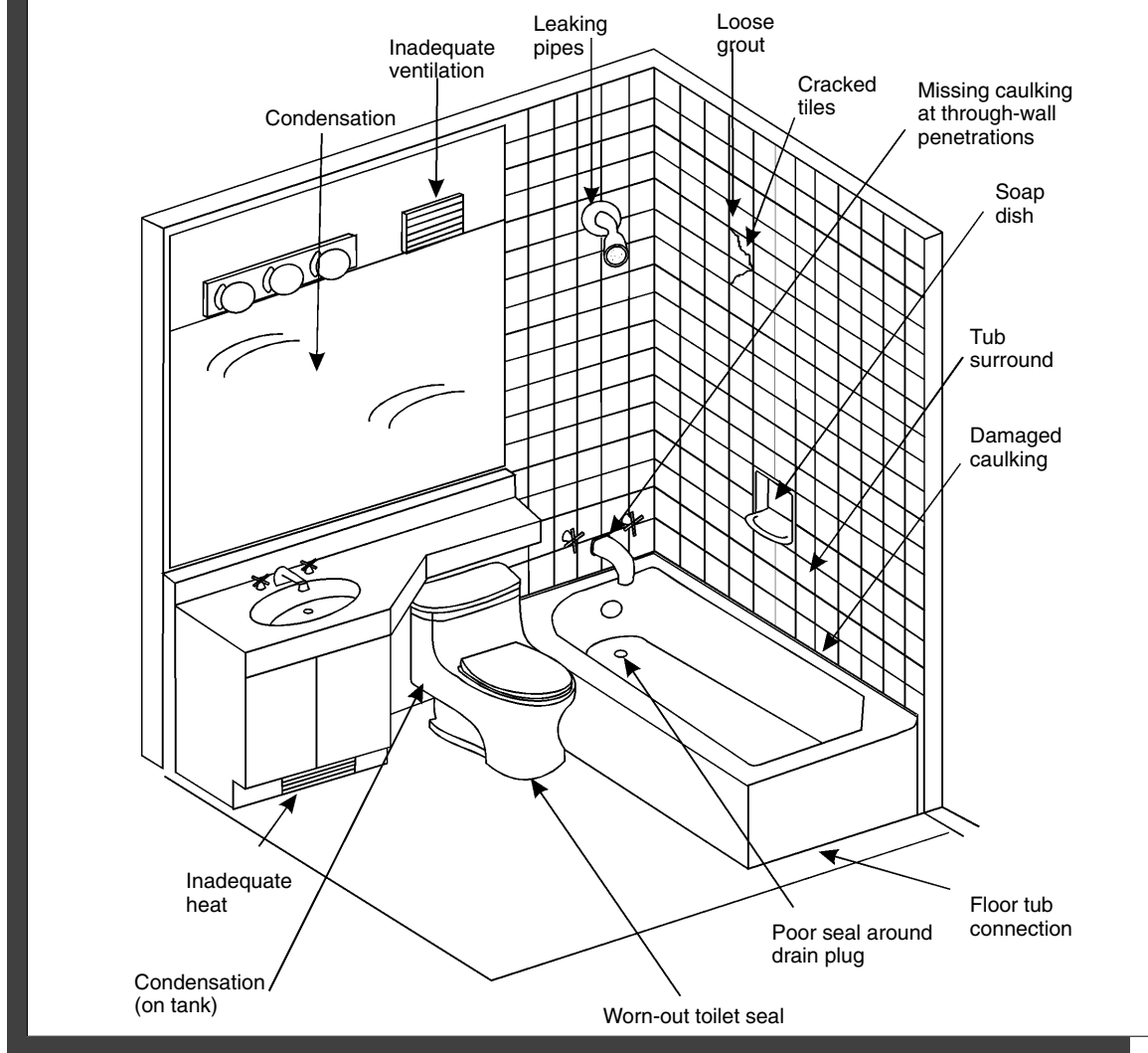
can be useful to control moisture, especially where moisture problems are evident.

Rotting or buckling countertops can result from moisture penetration at the seams and joints between the backsplash, sink and fixture cutouts. Bathtub surrounds that are not properly caulked or have not been adequately bedded in caulking during the installation process can also show symptoms of water damage. In some instances, the use of inappropriate materials can result in water damage. Moisture-resistant board must be used as a base for ceramic tile wall finishes in bathtubs and shower enclosures. The use of standard drywall as a backup material will, in most cases, increase the likelihood of water damage. (See Figures 4-2 and 4-3.)

Chipped or cracked grout or caulking in the kitchen and bathroom can also lead to water

**Figure 4-2: Moisture-related Problems in Kitchens**



**Figure 4-3: Moisture-related Problems in Bathrooms**

damage. Caulking and grout helps make surfaces that are often wetted impermeable to moisture. Damaged grout can let water penetrate into the assembly and cause deterioration of the wall and its finishes. Always replace damaged materials, and use only the appropriate types of grout and caulking for each application.

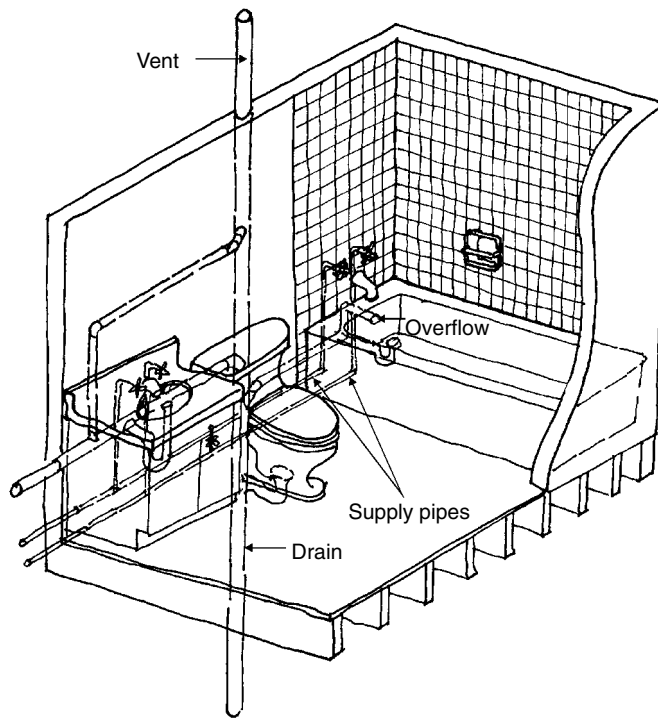
### **Poor Indoor Air Quality**

Rooms such as kitchens and bathrooms are a major source of moisture or water vapour in the home. Poor ventilation within these rooms can create indoor air quality problems. Inadequate ventilation can result in a buildup of moisture and contaminants, including odours, chemicals from cleaners and off-gassing from materials in the kitchen or bathroom.

Lingering odours are a telltale sign of poor ventilation. If a ventilation system does exist but is not performing adequately, a system with a greater capacity to move the air may be required. Always check for blocked vents or clogged filters before replacing a system which is suspected of being undersized. Educate the home-owner about the importance of proper maintenance practices.

### **Plumbing Problems**

Areas of concern that relate to plumbing invariably involve poor construction methods and the use of substandard materials. Piping must meet plumbing code requirements for material and installation. Galvanized steel, cast iron or lead piping are commonly found in older buildings. These types of piping can corrode

**Figure 4-4: Plumbing Elements in Walls of Bathrooms**

over time. Lead piping and corroded metals can contaminate water, creating a health hazard for the occupants. Carefully note the type and condition of any piping. Replacement of the entire system may be necessary in some situations.

Pipes are joined by glued, soldered or threaded connections. Leaks at pipe joints are usually due to poor workmanship or deterioration due to age. Minor condensation on cold-water lines can normally be tolerated. In some cases, however, an insulation jacket is recommended.

Poor drainage is another problem resulting from poor installation. An adequate gradient or slope is needed for waste water to drain properly.

Ensure that the drainage system is sufficiently vented and proper traps are installed to prevent sewer gas from entering through the fixture.

### **Damaged Materials or Finishes**

The lifespan of construction materials can be affected by product quality, installation techniques, wear and maintenance. In many

instances, the maintenance of a material is the key to its longevity. The selection of a material or component should be based, in part, on the amount of work required to maintain it.

Low-maintenance materials and components will be appreciated by the home-owner. In a kitchen or bathroom, maintenance needs will be reduced if materials and components have an appropriate surface or surface treatment to prevent water penetration. Floor and wall finishes in particular should be carefully selected and installed.

Finishes found in the existing space may give clues about how well a selected material will function after the renovation. The existing condition and age of the floor finish will indicate what type of finish would be most appropriate for the home-owner. Excessive wear on kitchen flooring may, for example, show that an extra-durable floor finish will be needed to withstand the amount of regular traffic in the room. Damaged finishes or materials provide the renovator with many indications of what types of challenges to expect with the

renovation. Very close attention should be paid to these kinds of details.

## RENOVATION IMPLICATIONS

During the renovation, the existing kitchen or bathroom may be dismantled. This could include removing plumbing fixtures, countertops, cabinets, wall or ceiling materials, floor coverings and electrical fixtures. Try to determine if any of these materials can be reused. Avoid damaging any materials or systems that can be reused. The renovation can include changes to structure, framing, services, lighting, acoustics, surface treatments, appliances and furnishings. A successful renovation includes not only making sound changes to existing systems but also knowing how those changes affect other systems.

### **Structural Changes**

A kitchen or bathroom renovation can impose new loads on the floors or walls of the building. For example, bearing walls may need to be moved or openings added to create the desired space. Refer to Insight 8 — Bearing Walls, Point Loads and Other Structural Concerns. The impact of any structural change will need to be assessed to ensure that settlement or collapse will not occur.

The floor system may be subjected to new loads from new appliances, cabinets, hot tubs or other items. For example, a large soaking tub with two people in it can weigh as much as 550 kg (1,200 lbs). It will be necessary to ensure that proper structural supports are provided for any areas subjected to new loads.

The position of walls, joists and rafters affect the way pipes, duct work and other services are run. Cutting or drilling holes into walls or rafters for electrical or plumbing services might damage the structural integrity of the system and the continuity of the air barrier. In new walls, remember to leave enough space for services, such as ducts, plumbing and wiring. These services must be installed before the walls are covered with drywall or finishes.

The installation of a skylight to bring in natural light can often alter the roof-framing system. Skylights usually interrupt the run of the

existing roof joists, rafters and trusses. Doubling the roof members that surround the new opening is generally necessary to maintain structural integrity. Do not, however, cut roof trusses without engineering design or consultation. Refer to Figure 4-5.

### **Rough-in framing**

In some instances, it may be necessary to provide framing for windows, cabinets, grab bars and wing or knee walls. Windows may require jamb extensions when additional insulation is added.

### **Services**

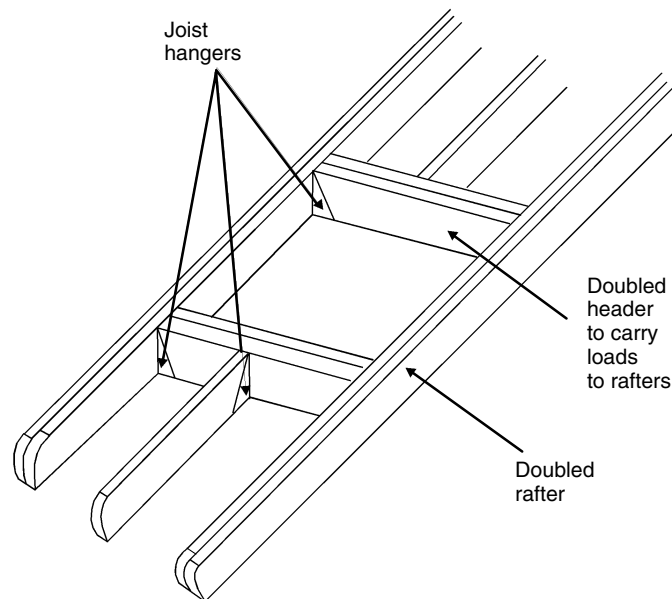
Services are the hidden elements of a kitchen and bathroom that contribute to its efficient operation. Understanding and considering how services such as HVAC systems, plumbing and electricity fit into the overall scheme of the kitchen or bathroom helps to minimize any potential problems. Always consider the capacity of the service available and whether the new renovated room will overload electrical, heating, ventilating or air conditioning equipment.

Verify the position of existing plumbing and gas lines before any renovation is contemplated. Ensure that if plumbing changes are made, the floor system is able to accommodate the changes and still maintain the proper slope of pipes for drainage.

When adding fixtures, ensure that the existing system can support any new supply or waste loads that may be created. Qualified plumbers are normally required to do plumbing work. Local codes will contain specific requirements for plumbing.

During the renovation, when the floors and walls are open, changes to poorly functioning heat distribution systems should be considered. Review whether enough heat will be supplied to the newly renovated rooms, particularly if new windows or skylights are being installed. As noted already, check the capacity of the heating system to ensure it can meet any new loads from the renovated rooms.

Bathrooms should be warmer than other rooms to provide comfort for disrobed users. Forced air heating registers located in toe kicks under sink cabinets have been used effectively to provide comfort in kitchens and bathrooms.

**Figure 4-5: Doubling Roof Rafters to Support a New Skylight**

Kitchens may impose an additional cooling load on air conditioning systems. Ensure the existing cooling system is able to accommodate any new load.

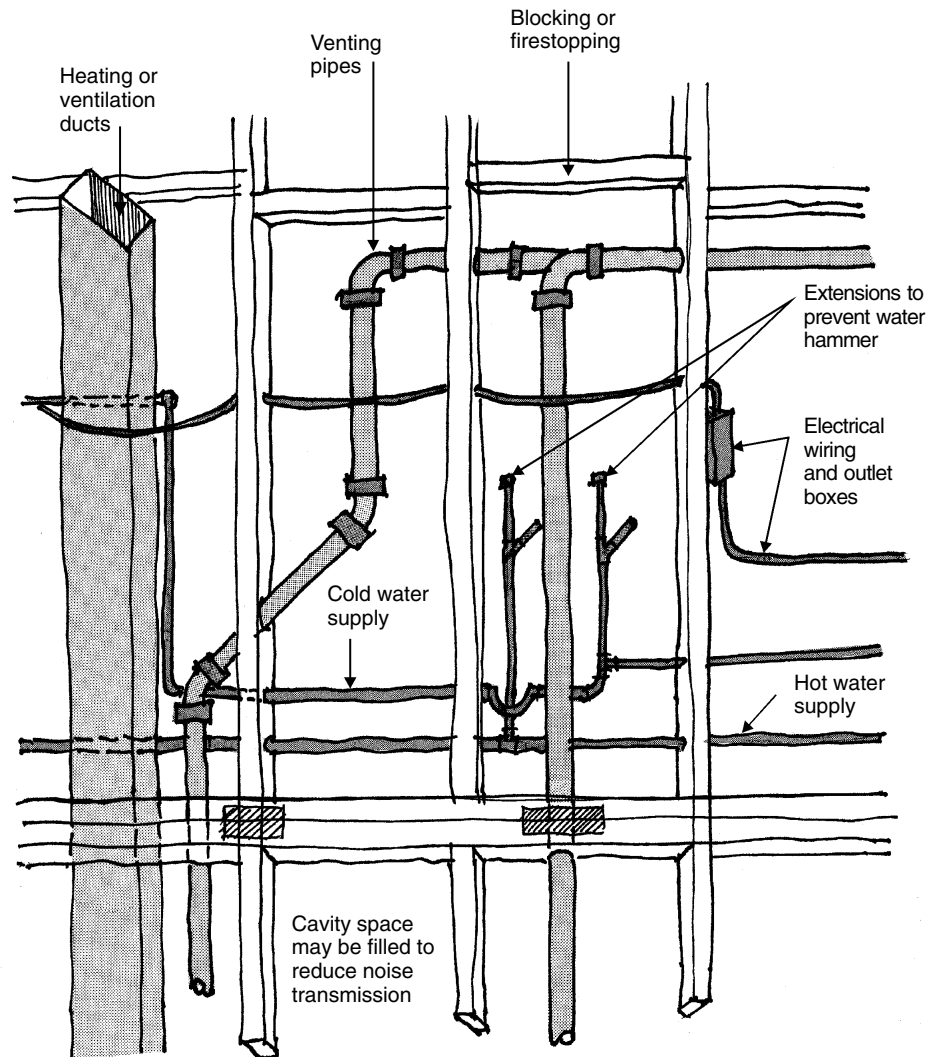
Ventilation of the kitchen or bathroom will help control moisture, odour and other contaminants. Kitchens and bathrooms can have two types of ventilation systems: an exhaust-only system that uses an exhaust fan or hood; or a central, balanced whole-house system that can incorporate heat recovery. Kitchen odours may be controlled by a recirculating fan or, more effectively, by an exhaust fan venting directly to the outdoors. Kitchen exhausts, especially those from downdraft cooktops, can cause serious depressurization problems within the house. Refer to *Insight 4 — Airtightness, Depressurization and Combustion Equipment* — for more discussion. Chapter 10 describes mechanical systems in greater detail.

You will also have to ensure that there is enough hot water available for the occupants. In some instances, an electric tank heater or instantaneous water heater can be added to supplement the capacity of the existing system. It is important that a heating contractor or utility be consulted in these instances.

When proposing changes to the electrical system, survey the existing systems in the kitchen or bathroom. Start at the main service entrance. Is the drop from the street line the old two-wire type or are there three wires? The type of wiring found will indicate whether the system can carry a 240-volt appliance. Similarly, check the amperage rating of the main breaker or fuse block. It should be at least 100 amps if a modern kitchen is to be accommodated. If it is less than 100 amps, a new main service should be considered before renovating.

A properly wired kitchen may have eight or more circuits for the various appliances, outlets and light fixtures. For each permanent appliance, a separate circuit is generally required. This may include circuits for electric ranges, cooktops, 240-volt ovens, garbage disposals, dishwashers, microwaves, trash compactors or freezers.

If the circuit breakers or fuses are labelled, note which ones control lights, outlets and appliances in the kitchen and bathroom. Are there enough blank spaces in the panel for additional breakers? If several circuits need to be added, it may be more economical and easier to install a new sub-panel than a new panel. Check that all outlets for the kitchen or bathroom are

**Figure 4-6: Typical Services in Walls**

grounded. For electrical services, a licensed electrician should be consulted, especially when rewiring the house to accommodate a new kitchen or bathroom.

### **Lighting**

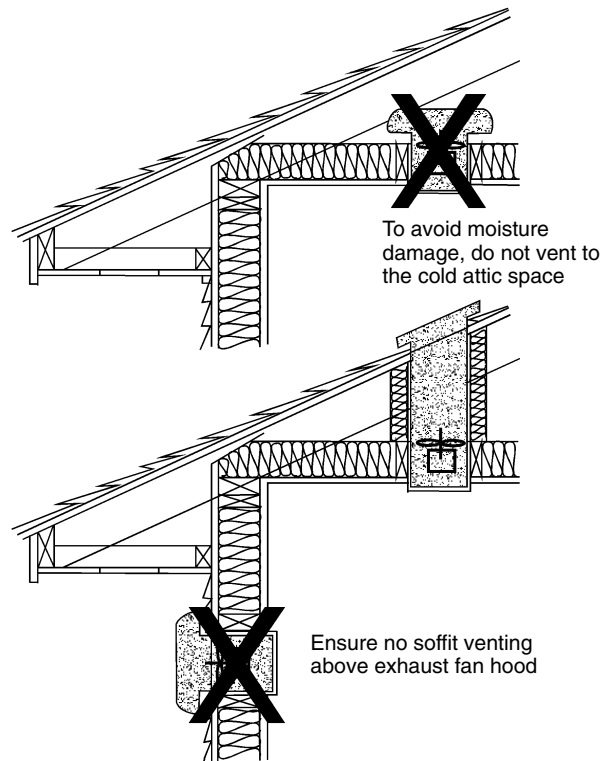
Lighting is an important element in a properly functioning kitchen or bathroom. When you survey the existing kitchen or bathroom, consider all forms of light, both natural and artificial. Where is the sun at various times of the day relative to the kitchen or bathroom? Can natural light in the space be enhanced? Is there glare or a harsh lighting problem in the existing room? Is the space too dim? How can the lighting be improved? Different fixtures have

different purposes, so be sure to use the fixture that suits the intended use. For example, task and ambient lighting fixtures are used in different situations.

### **Acoustics**

Acoustical control is a concern when renovating kitchens or bathrooms. Try to minimize sound transmission to other areas of the household.

Sound travels through walls, floors, ceilings or chases. To absorb some of the sound created by services, strap water pipes securely (allowing for expansion and contraction), wrap insulation around drainpipes and insulate around the bathtub and outside of ducts with fibreglass insulation.

**Figure 4-7: Proper Bathroom Fan Installation**

### Surface Treatments

The surface treatment of a material is determined by aesthetics and function. In many cases, style and colour are the determining factors for the selection of a finish. Maintenance requirements are equally important. Other characteristics to consider include resistance to moisture, impact resistance, comfort for standing, slip resistance, strength, stain resistance, susceptibility to ultraviolet light, durability, emissions, environmental impacts, indoor air quality, and vapour and air permeance.

Some flooring materials will raise the level of the finished floor above that of the floor in adjacent rooms. In cases where the flooring is thin, small differences in floor heights can usually be bridged by a threshold or a transition piece in the doorway.

### Appliances and Furnishings

The number of new appliances and furnishings to be located in the kitchen or bathroom can increase loads on the structural, plumbing, electrical and septic systems of a home.

New appliances can also change the air pressures found within a home. Exhaust fans and downdraft cooktops can depressurize the home, causing some chimneys to backdraft. Refer to Figure 4-8.

The choice in furnishings should also take into consideration the effects on indoor air quality. Some materials release chemical contaminants into the space after they have been installed. Ensuring that the furnishings are installed properly may help reduce some air pollution.

If you are helping the home-owner choose appliances and plumbing fixtures, consider those that consume less energy and water. The



**Insight 4 — Airtightness, Depressurization and Combustion Appliances**

The relationship between the airtightness of the house and the operation of the air-exhausting and combustion appliances can be quite complex. In older, leaky houses, as air was exhausted out of the house by fans or up through chimneys, replacement air was easily drawn in through the building envelope. As houses have become more airtight, more significant pressures have developed across the building envelope as fans fight against the tighter shell, which resists the air drawn in to replace the air pushed out by the fans.

The negative pressure created as air-exhausting appliances operate in the tighter house can affect the operation of some combustion appliances. The negative pressure not only draws air in through the shell but, in some cases, also down the vent of combustion appliances. This is especially true where the vent offers less resistance than the envelope to the movement of air.

Whether the combustion appliances backdraft will depend on the tightness of the building envelope, the amount of air being exhausted and the characteristics of the venting appliance. If the building envelope is leaky, air is easily drawn inside through the shell rather than down the chimney. Similarly, if little air is exhausted,

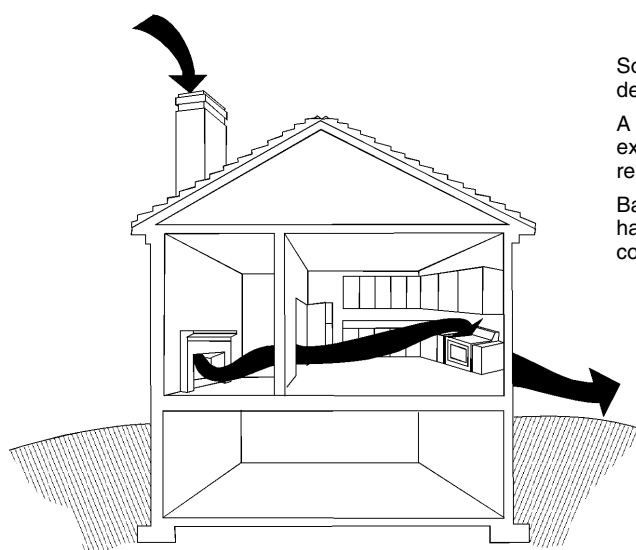
insignificant negative pressure develops.

Appliances that depend on the buoyancy of the flue gas to vent are of greatest concern since these can spill the product of combustion with small negative pressures. Appliances that vent due to fan pressure will generally not spill at typical household negative pressures. Direct-vent, induced-draft and power-vented appliances fall into this category.

The key to preventing natural draft appliances from spilling is to limit the negative pressure that can develop. Providing make-up air through an opening in the envelope accomplishes this. A make-up air vent limits the pressure that builds across the envelope, thereby reducing the potential for backdrafting combustion appliances. Home-owners should be aware of what this vent is for and should be warned not to cover or block it. The vent should be located to prevent discomfort from the cold incoming air. Ventilation system installers can usually provide sizing and installation details.

If the house is being made tighter or if new air exhausting appliances are installed, depressurization pressure may be of concern. Ventilation system installers can normally measure the pressures created and determine whether a problem exists.

**Figure 4-8: Air-exhausting Appliances and Backdrafting**



Some appliances may cause depressurization within the home

A newly installed down-draft cooktop can exhaust air out of the house and draw replacement air down a chimney

Backdrafting of combustion appliances can have serious health and safety consequences

**Depressurizing appliances:**

- Downdraft cooktops
- Exhaust fans
- Central vacuums
- Dryers
- Range hoods

**Spillage susceptible appliances:**

- Natural draft furnaces
- Natural draft water heaters
- Fireplaces
- Wood stoves

Energuide label can provide useful information that can help in the selection decision.

### HEALTHY HOUSING KITCHENS

The kitchen in a Healthy House should meet the needs of its users while promoting occupant health, energy and resource efficiency, environmental responsibility and affordability. Occupant health can be enhanced by improving construction techniques and selecting appropriate materials and finishes. It is important to ensure proper ventilation in these spaces by exhausting kitchen and bathroom contaminants directly to the outdoors.

Kitchens are often polluted by materials that emit volatile organic compounds (VOCs), like paints, stains, sealers, adhesives and other substances used during construction. Using natural materials or water-based adhesives, can help to reduce these emissions in the home. With the growing trend of installing particle board or laminate countertops, kitchens have become notorious for off-gassing materials. Hardwood cabinets and solid-surface countertops have few of the air quality disadvantages common to these materials. If using formaldehyde-based boards, seal or laminate the surfaces and edges to reduce off-gassing from the material.

Energy efficiency can be improved in a kitchen by the selection and installation of efficient lighting and appliances. Compact fluorescent bulbs are four times more efficient than standard bulbs. Be careful to select bulbs with good colour rendering, particularly in food preparation areas.

Resource efficiency involves using less of the natural resources available when constructing and operating the home. In a kitchen, a low-water-use dishwasher and an aerator on the faucet can reduce the amount of water used. Improved dishwashers can reduce water use by 50 percent and faucets by 60 percent. Materials used in construction can also be selected to be resource-efficient. Selecting lumber that is harvested from fast-growing trees, using materials with high recycled content and reusing components are ways resources can be used more efficiently.

An environmentally responsible renovation focusses on selecting durable materials that increase the lifespan of the renovation. This will minimize future replacements and preserve natural resources. It is also important to minimize construction waste by reusing or recycling wherever possible. An environmentally concerned family may even request a recycling centre in their kitchen to deal with the proper disposal of household bottles, cans, cardboard, papers and compostable wastes.

Finally, the home needs to be affordable. By making many of the healthy kitchen improvements suggested here, the operating costs of the home are reduced and the resale value is increased. Many healthy materials and components are competitively priced. Consider the long-term benefits of good health and a healthy environment when making decisions.

### HEALTHY HOUSING BATHROOMS

A bathroom in a Healthy House will have many of the same features as a healthy kitchen. Low-emission materials used for countertops and proper ventilation will contribute to occupant health. Because mold is a concern in bathrooms, hard surfaces such as tile floors are a good choice. Humidity in bathrooms can foster mold growth, so efficient ventilation is essential. Energy-efficient lighting and insulation upgrades will improve energy efficiency. Aerator faucets can help to reduce water consumption.

Other improvements to the bathroom can include the installation of an ultralow-flush toilet. These toilets use less than 1.6 US gallons (6 litres) of water for every flush. More than 70 percent of the water used for flushing can be reduced. Although the cost of the toilet may be more than a standard model, the savings on water bills will justify the upgrade. A low-flow showerhead will have similar savings. Reducing water consumption decreases utility bills and the burden you place on the local sewage treatment system.

Selecting products and materials designed for use in areas of high humidity will reduce the environmental impact of future maintenance and the replacement of damaged items. Management

of construction waste and selection of durable materials will also help preserve the environment. Like the healthy kitchen, the life-cycle costs of the improvements must be considered together with the benefits to occupant health and the environment when making healthy renovation decisions.

### **FLEXHOUSING KITCHENS**

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Because of the wide range of activities carried out in the kitchen, it is important to consider accessibility, safety, convenience, efficiency and ease of use for all family members, including those with disabilities.

#### ***Design Considerations***

- Non-slip flooring
- Task lighting at sink, stove and work surfaces
- Pull-out work boards
- Some electrical switches and outlets at front of counters
- Water temperature regulators
- Easy-to-use faucets (e.g., lever type)
- Adjustable-height counters/sink
- Open space under sink and cook-top to accommodate a wheelchair: initial provisions and/or provisions for adaptation
- Reachable shelves in upper cabinets (e.g., through adjustable height cabinets or pull-down shelving)
- Provision for installation of wall oven

- Colour contrasts for people with poor vision
- Tactile and colour contrasted controls

### **FLEXHOUSING BATHROOMS/WASHROOMS**

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At least one bathroom should be accessible and usable by a person in a wheelchair. This requires sufficient manoeuvring space to provide easy access to the toilet, sink, bathtub or shower. If an accessible bathroom is not located on the main living level in a dwelling, an accessible washroom should be provided on this level.

#### ***Design Considerations***

- Non-slip flooring
- Wall reinforcement for grab bars
- Water temperature regulator
- Easy-to-use faucets (i.e., lever type)
- Standard height toilet
- Mirror usable when standing or sitting
- Bathtub or shower accessible to wheelchair user: initial provisions and/or provisions for future adaptation
- Adjustable-height shower head
- Adjustable-height vanity/washbasin
- Open space under basin: initial provision and/or provisions for future adaptation
- Colour contrasts for people with poor vision

**SCHEDULE FOR DOING THE WORK****PRECONSTRUCTION**

- ☐ Complete the design
- ☐ Prepare a schedule
- ☐ Sign contract
- ☐ Hire subcontractors as needed
- ☐ Order materials and fixtures with scheduled delivery times
- ☐ Obtain permits and arrange for inspections
- ☐ Establish a temporary kitchen or make arrangements to use another bathroom
- ☐ Arrange for removal of debris and storage of materials

**DEMOLITION**

- ☐ Clear out the kitchen or bathroom
- ☐ Seal off the kitchen or bathroom from the rest of the house
- ☐ Remove necessary appliances and plumbing fixtures, shelves, built-in vents, countertops, cabinets and other built-ins
- ☐ Remove trim and mouldings
- ☐ Remove toilet and block the drain opening
- ☐ Remove floor covering if necessary
- ☐ Remove lights and electrical fixtures
- ☐ Remove wall and ceiling materials, such as panelling, plaster or wallboard, as needed
- ☐ Remove tub and shower pan and seal drain opening

**PREPARING THE SPACE**

- ☐ Remove or alter walls; shore up bearing walls as needed
- ☐ Repair subfloor or walls if necessary
- ☐ Complete rough framing for alterations, new walls, soffits, windows, doors and skylights
- ☐ Install new windows and exterior doors
- ☐ Install duct work for rangehood, ventilation and heating systems
- ☐ Alter or install rough plumbing
- ☐ Alter or install rough wiring
- ☐ Get preliminary inspections
- ☐ Install insulation, air and vapour barriers
- ☐ Install new tub, shower or shower pan
- ☐ Repair, replace or install wall surfaces; apply finish
- ☐ Install door and window trim, except where it is to be fitted around cabinets
- ☐ Paint ceiling, walls and trim
- ☐ Install flooring, including underlayment (some flooring is installed at the end of the project)
- ☐ Install blocking for cabinets, grab bars, and so on.

**INSTALLING FINISHES AND FIXTURES**

- ☐ Install cabinets, cabinet trim and other storage units
- ☐ Install countertops and back splashes
- ☐ Install baseboards and remaining prepainted trim pieces
- ☐ Install sink and plumbing fixtures, wash basin, faucets, toilet and shower
- ☐ Apply wall coverings
- ☐ Install light and electrical fixtures
- ☐ Install rangehood, dishwasher, cooktop, oven and microwave
- ☐ Install overhead racks, towel bars, window coverings and other accessories
- ☐ Install flooring if this has not already been done
- ☐ Caulk as required
- ☐ Install refrigerator, slide-in range, trash compactor and other movable appliances or fixtures
- ☐ Install grab bars
- ☐ Install interior doors

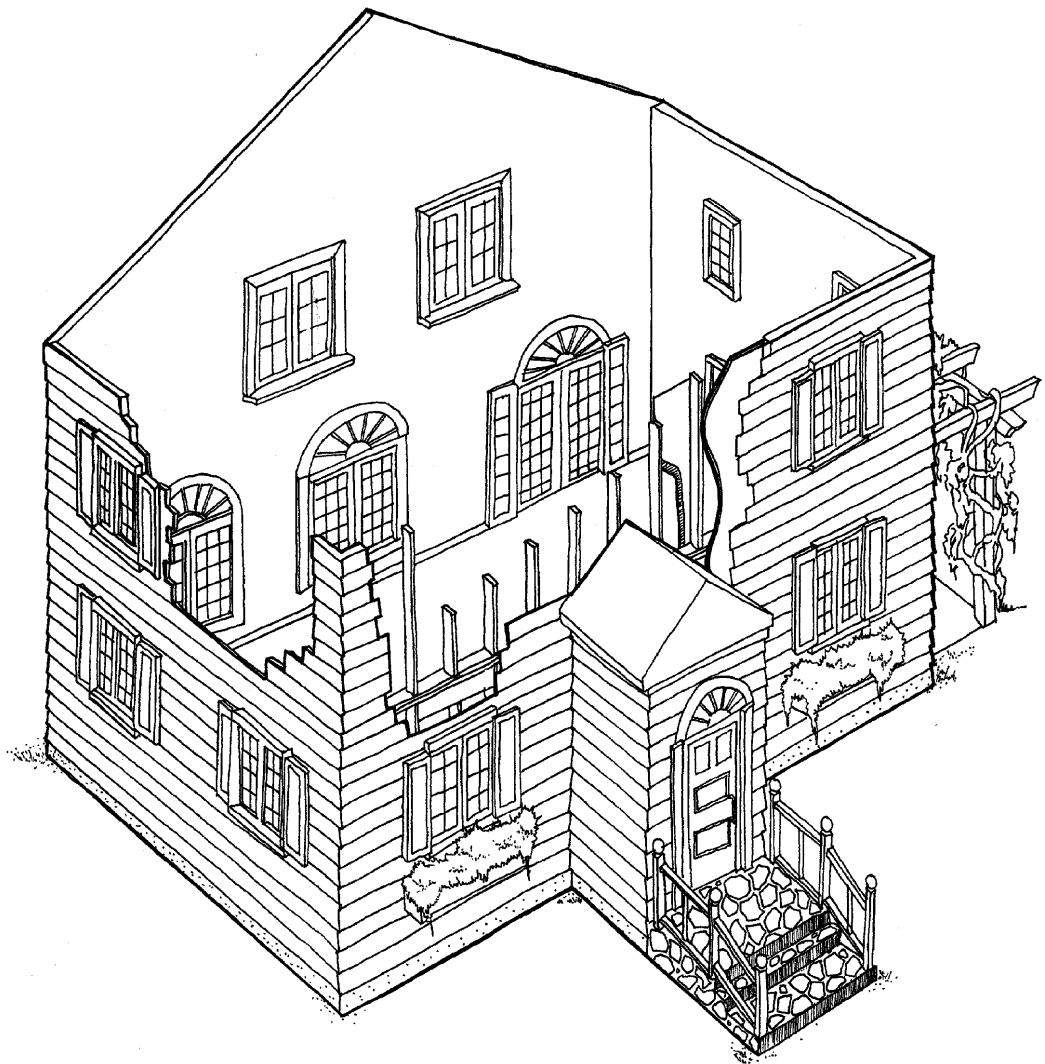
**CLEAN-UP**

- ☐ Clean up and remove debris
- ☐ Touch up paint and stains
- ☐ Test electrical and ventilation system, plumbing and appliances
- ☐ Obtain final inspections

## Replacing Windows and Doors

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**T**his chapter introduces problems that can be found when assessing a home's existing doors and windows and draws on information from earlier chapters to explain how they might have occurred. It also illustrates how altering windows or doors can affect the performance of other systems in the building. This information will be useful when solving and preventing problems encountered when windows and doors are upgraded. It may also be helpful when seeking solutions to problems discovered during other types of renovations.



## INTRODUCTION

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Window and door problems are often linked to other systems in the home. Assessing the defects or symptoms relating to the components will help to provide an overall picture of the building's performance.

In this chapter, the first issue addressed will be what to look for during a house assessment. The chapter then discusses probable causes of each defect and suggests actions you can take to remedy the problem.

An obvious window or door defect can be linked to many different types of causes. Structural deficiencies, building settlement, indoor environment and poor quality materials are just some of the possible explanations. A cracked window pane may be caused by increased structural loading on the window after the building settles. Condensation on handles and locks of exterior doors may be related to high indoor humidity or thermal bridging.

The remedies for window and door problems may be simple or complex. Proper diagnosis, following careful observation, is a crucial step before any remedy can be proposed. Understanding the situation and formulating a remedy before installing or upgrading windows will help to avoid the same problem and provide for the long-term durability of each product. Recurring problems after a renovation can damage your reputation and result in costly callbacks.

This chapter will describe issues relating to new window and door installations and their potential problems. New problems after a renovation can be even more frustrating to a home-owner than recurring ones.

The Renovation Implications section that follows discusses the effects on lighting, heating, ventilating, privacy, safety, security and sound transmission. It also discusses some of the different criteria that should be used when selecting new products.

Window and door changes can be made on their own or as part of a larger renovation project. In either case, it is important to remember the principles discussed in this chapter, along with those presented in other parts of the guide.

## EXISTING CONDITIONS

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Window and door problems can be caused by moisture, leaking air, inadequate structural support, poor maintenance or any number of defects or performance considerations.

A number of new window technologies have become popular in recent years. These new technologies demand a review of how windows have been traditionally accommodated in the house. As these efficient, high-performance components are used old rules of thumb need to be revised. Insight 5 — Solar Gains and Low-E Coatings — details a number of these issues.

## ASSESSMENT CHECKLIST

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The checklist for replacing windows and doors includes symptoms and problems you may encounter during your review of the house. These issues are explained in detail on the referenced pages.

### ***Water Damage***

When a home-owner notices water staining or flaking paint on the window or door trim, or experiences dripping water from an overhead skylight, they might assume that water leakage is the cause of the problem. However, water damage to windows and doors is usually related to condensation. Although bulk water from rain may cause damage if it penetrates through an opening or if it is allowed to pool on outside window sills, the majority of problems are related to condensation that occurs on the inside surface.

Windows and doors are prone to condensation because they tend to have a lower thermal resistance value than the surrounding wall assemblies. Moisture in the room's air will condense on cool surfaces that are below the dew point temperature. Dew points and condensation are explained in Insight 2. Door hardware, window panes and window frames are often below this temperature. During very cold outdoor temperatures, moisture may appear as frost rather than condensation on cool surfaces.

Energy-efficient windows, or doors with a higher thermal resistance, will help to relieve

**Insight 5 — Solar Gains and Low-E Coatings**

Windows have been described as the first integrated household appliance. They provide natural light and ventilation and, in many instances, free heat. Their affect on both the heat loss and the heat gains in a home is particularly important.

Windows lose heat to the outdoors by conduction, convection and radiation. They also allow solar radiation into the building. The solar radiation contributes to the heating of the house, reducing the load on the heating plant but sometimes making air conditioning necessary in the summer.

Low-emissivity (Low-E) coatings are used to reduce the amount of heat energy that passes through the glazed portion of the windows. The low-emissivity coating does not stop all light from passing through the window panes but restricts the passage of different types of light.

The reduction of light may have a negative effect on some individuals and may necessitate a larger window to compensate.

A low-emissivity coating is a transparent metallic coating applied to the surface of the glass to improve the window's thermal performance characteristics. Two types of coatings are commonly available: hard and soft coatings. These coatings differ in how they are manufactured and how they perform.

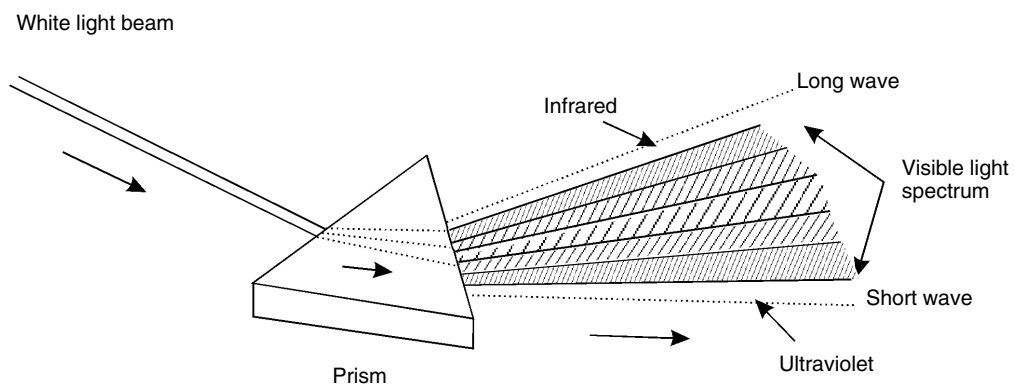
Light energy travels in waves of different lengths. Some light waves are visible to the eye while others are not. A simple prism can be used to separate the visible waves of light. Red, orange, yellow, green, blue, indigo and violet are the colours that are usually seen when light is separated. A rainbow is another example of this phenomena.

Heat energy radiates as an invisible light wave called infrared. Heat lamps used to heat food are an example of this type of light.

New selective coatings reflect the infrared light (or heat) that hits the window. However, they allow visible light to pass through largely uninterrupted. The low-E coating effectively acts as another pane of glass in reducing heat loss. In other words, a coated double-glazed window has approximately the same thermal resistance as an uncoated triple-glazed unit.

A variation on low-E coatings is a polyester film suspended between two panes of glass. This film also adds to the thermal resistance of the window assembly, acting as a third pane at a fraction of the weight.

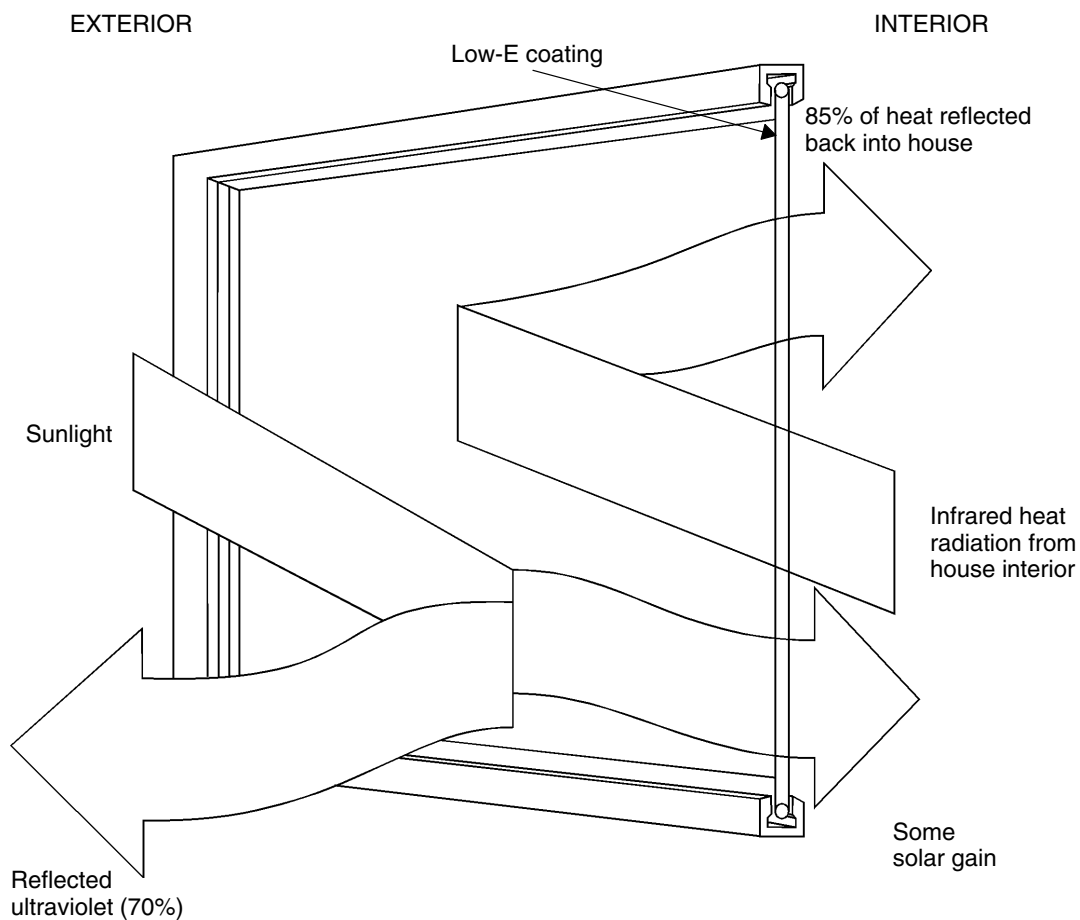
Low-emissivity coatings can be used for different reasons. They can be used on south-facing glazing to block heat from the sun that might otherwise overheat the building. Alternatively, they can be used to keep heat in the building from escaping to the outdoors.



**Insight 5 — Cont'd**

Coatings intended to reflect outside heat are normally located differently on the window panes than those intended to keep heat in. Low-E windows for heating climates are, therefore, different from those for cooling climates. In Canada, low-E windows are usually most effective on north and west window orientations where thermal resistance is more important than light transmission.

Often low-E windows are filled with an inert gas (argon or krypton) to further improve their thermal performance. Together with improved frames, insulated spacers and better installation and sealing techniques, windows available today dramatically outperform those of even the recent past. Ask your window supplier about the new window technologies being incorporated into the product that you specify.

**Low-E Coatings Reduce Heat Loss**



## Checklist

### WATER DAMAGE (page 92)

- ☐ lifting, flaking or blistering paint on window trim
- ☐ water stains on walls under windows or on window trim or frame
- ☐ frost on door hardware
- ☐ window condensation or frosting
- ☐ condensation or mold growth on the wall or frames around the windows and doors
- ☐ condensation between panes

### AIR LEAKAGE (page 96)

- ☐ drafts around openings
- ☐ dust and dirt staining around windows

### STRUCTURAL SUPPORT (page 96)

- ☐ cracks in wall finishes at the corners of windows and doors
- ☐ sticking or binding windows
- ☐ cracked glass panes
- ☐ door frames out of plumb
- ☐ binding or warped doors

### OTHER PROBLEMS (page 96)

- ☐ water sitting on window or door sills
- ☐ worn or damaged weather stripping
- ☐ deformed plastic window frames
- ☐ discolouration of doors, windows, skylights or frames
- ☐ squeaking hinges or sticking doors
- ☐ cracked caulking
- ☐ deterioration or rot of wood frames
- ☐ deformed plastic panels on exterior doors

condensation problems. Reducing the humidity in a room or house can also help to alleviate the problem.

Heavy drapes can contribute to the condensation problem in two ways: by preventing air from circulating against the glass; and by cooling the glass and increasing the potential for condensation. Allowing air to circulate at the window will help eliminate condensation problems.

Condensation on windows is most prevalent on those of the uppermost storey. These windows experience exfiltrating air pressures primarily due to the stack effect. Promoting good air circulation, controlling indoor humidities and sealing, particularly around the main floor header, can reduce the incidence of condensation on these windows.

When condensed water or frost is visible between the panes of glass in a sealed glass unit,

the problem is not related to high humidity but rather a broken seal around the air space between the panes. If the seal is broken, the unit will have to be removed and replaced. The problem is one of aesthetics, but it can also affect the thermal performance of the window. Before removing the unit, check to see if it is still under warranty. The manufacturer may cover part of the cost of replacement.

Condensation that occurs on the outside of the window during summer may also be caused by humid outdoor air coming into contact with a cool surface. In this case, the inside of the house is cooler than the outside air, and the outside surface of the window is lower in temperature than the dew point of the outside air. Installing better windows often eliminates this problem.

Finally, condensation can appear on the inside surface of skylights. This is a common complaint about skylights and is often confused with water leakage. Using ceiling fans or other mechanical means to circulate air around the skylights can help to eliminate or reduce the severity of any surface condensation.

Alternatively, installing an interior plastic storm will control the problem. Reducing the humidity in the house is another possible remedy. In any case, inspect the flashing around the skylight to ensure it is properly installed and not leaking.

Water sitting on exterior sills may be the result of an improper slope. Sills that slope towards the window or door will not drain water away. Improperly installed flashing around windows can also direct water into the envelope instead of away. Regular maintenance and checks will identify this problem and allow for correction before a larger problem results.

### **Air Leakage**

Drafts around windows and doors are common in older homes. The technology and products used in past construction were not as advanced as they are today, so air leakage is typical.

Weather-stripping around doors may help to reduce drafts, as will caulking and sealing at window openings. In addition, there are window and door units available with better seals between glazing units and around frames. If you are planning to install new windows where the client has complained about leakage, you should focus on products with good air-leakage ratings.

Many windows include a label that indicates the air-leakage performance of the unit. Ask the window manufacturer for details.

A well-sealed window with poor thermal resistance can also produce discomfort for a person near it. The cold feeling is caused by radiative heat loss from the body to the window and should not be confused with drafts. A smoke pencil, lit candle or incense stick can be used to determine if air is leaking in through a window or door opening. Dust and dirt around the window are also clues to leaking air. As air leaks by the window, it deposits the dust and dirt it carries, leaving telltale signs.

### **Structural Support**

As a home shifts and settles, signs can appear around windows and doors. In some instances, when a house settles, the lintel over a door or window, or a partition wall, can end up carrying extra loads. These movements can appear as a number of symptoms.

Small cracks in the wall finishes at the corners of window and door frames, as well as sticking doors or windows, are typical signs that the house has moved. Cracked glass panes, cracked caulking, warped or out-of-plumb doors are other symptoms that indicate settlement or movement.

### **Other Problems**

Maintenance of a building ultimately determines the life span of its different components. Windows and doors are some of the many items that require regular maintenance. There are a number of specific maintenance items related to them that should be checked when assessing the house.

Are the materials selected for the doors and windows appropriate to the location of the opening? Wooden doors are susceptible to deterioration if exposed for a long time to driven rain on the windward side of the house. The plastic panels on exterior doors can deform after a storm door is installed as a result of heat build-up between the two from solar gains. You should also ensure that the warranty requirements of the doors you install are not contravened.

Doors and windows need properly maintained weather stripping and caulking to resist air and

moisture penetration. The door threshold should be clear of debris and properly designed to help stop water from making its way into the house.

Most modern windows and doors come with a comprehensive warranty. The warranty is generally valid only for windows and doors that have been installed according to the manufacturer's instructions.

## RENOVATION IMPLICATIONS

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This part of the chapter discusses some common consequences of altering windows or doors. It is important to recall that changes to seemingly small parts, such as windows and doors, of the house can greatly affect the performance of other components and systems.

### *New or Altered Openings*

When incorporating a new or altered opening into an existing wall system, there are a number of issues that must be addressed. The structural system, hidden services in the wall, and circulation paths within the house can all be affected.

When installing new interior or exterior doors, it is important to predict how changes may affect circulation patterns within the house. The direction of the door swing, as well as the location of the opening, will affect the way a room is used. Refer to Figure 5-1.

Window locations can also affect the layout of a room. Furniture may need to be located near or away from windows, depending on the style and opening direction of the window. Windows can also cause glare that can limit furniture arrangements.

To ensure that the house will be functional and efficient after the renovation, you may want to discuss traffic flows and furniture arrangements with the home-owners before making changes.

When deciding to add or change the size of window or door openings in a building, building code requirements will need to be addressed. The minimum and maximum sizes of windows are among the most notable concerns. Depending on the location of the opening with respect to the property lines, limits to size may

exist in order to stop fire from spreading to adjacent buildings.

Maximum window opening sizes are also related to structural support (the ability to span and support the wall and roof structure above the opening). Minimum sizes are necessary for light, ventilation and for escape during an emergency. Other requirements, such as the maximum height of the window sill and the type of glazing used in the window, can also be found in building codes.

When adding a skylight during a renovation, there may be alterations to the existing roof framing. The members surrounding the skylight may have to be doubled to carry and transfer the loads of the roof above.

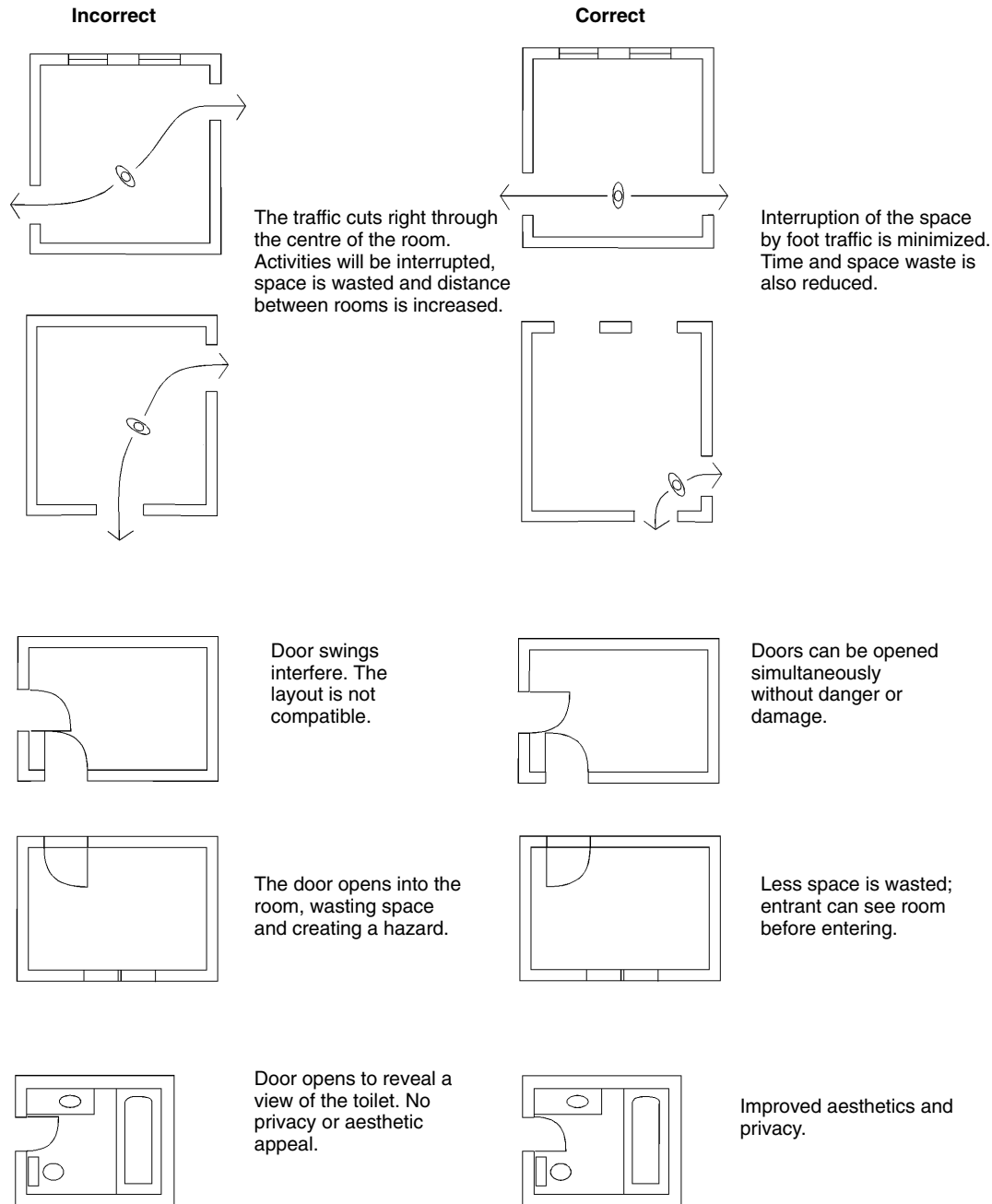
Large skylights may be difficult or impossible to install in a roof framed with trusses. An alternative to installing skylights is installing dormer windows or a light pipe. Dormer windows also need additional framing but can increase the volume of an interior space while adding natural light. A light pipe brings additional light into the room without requiring structural modifications. If alterations to the trusses are required to install a skylight, an engineer or a truss manufacturer must be consulted before proceeding.

The structural support provided by the walls of the house can be seriously compromised by a new, improperly designed opening. Poorly designed framing around the opening may not be able to carry the loads from walls and roofs above. This could lead to sagging roof lines or damage to the window or wall. Refer to Figure 5-2.

Bracing the structure during the renovation will help to prevent any settling, racking, sagging or deflection caused by the temporary loss of support. See Figure 5-3.

You should also ensure that the new opening is capable of supporting the imposed loads after the renovation. Cripple studs, jack studs and other measures are required to ensure proper support. Lintels need to be carefully selected as these are major structural elements. Local building codes will prescribe requirements that apply to the framing.

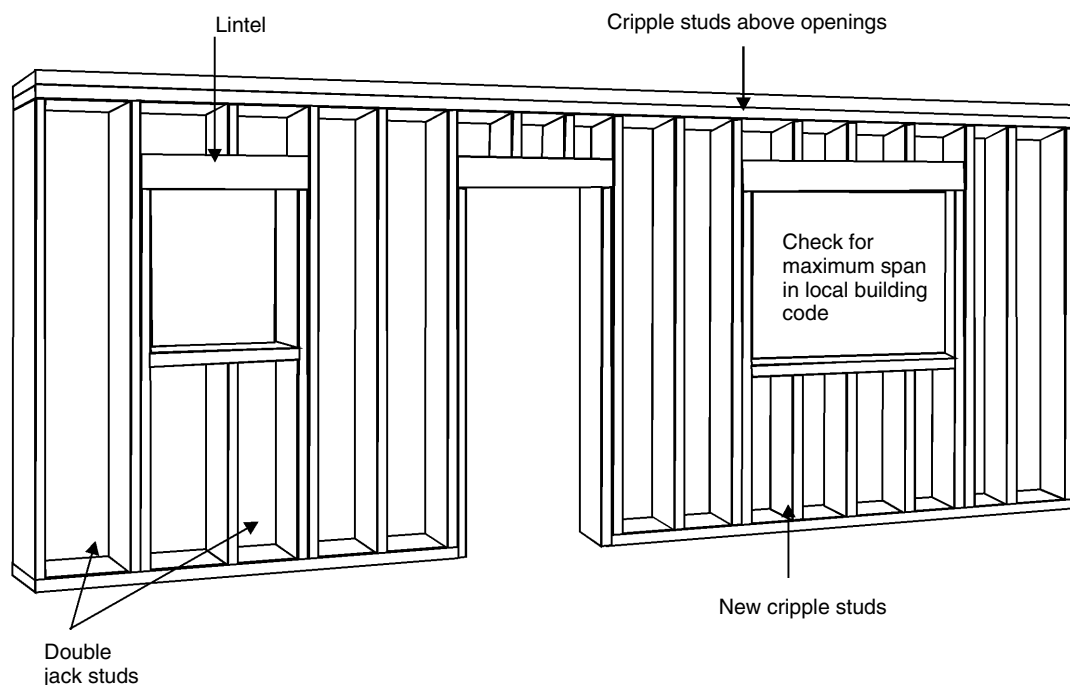
Adding a greenhouse or solarium to a building is a way of increasing natural light that does not require a lot of structural alterations. Many

**Figure 5-1: Traffic Patterns**

greenhouse models are available that are premanufactured. Structural requirements are normally provided by the manufacturers. Be warned that like other large areas of glazing, solariums can cause overheating, increase the

incidence of condensation and affect air infiltration into the house.

When altering a wall, particularly an interior wall, you may find that hidden services run

**Figure 5-2: Framing Around New Openings in a Load-bearing Wall**

through the space where you were planning to put an opening. If this occurs, you will need to reroute the services. Look at this as an opportunity to improve or upgrade the existing services. Additional outlets or switches are typical improvements that add value to the renovation. Refer to Figure 5-4.

A problem may occur where plumbing or ducting must remain in place to retain a proper slope or other requirement. In this situation, the only option may be to find another place to cut the opening.

When cutting into a wall to create a new opening, it is important not to disturb the services that may be located inside. Try to remove the interior finish without penetrating too far into the wall. Interfering with existing services can create extra work and can be dangerous.

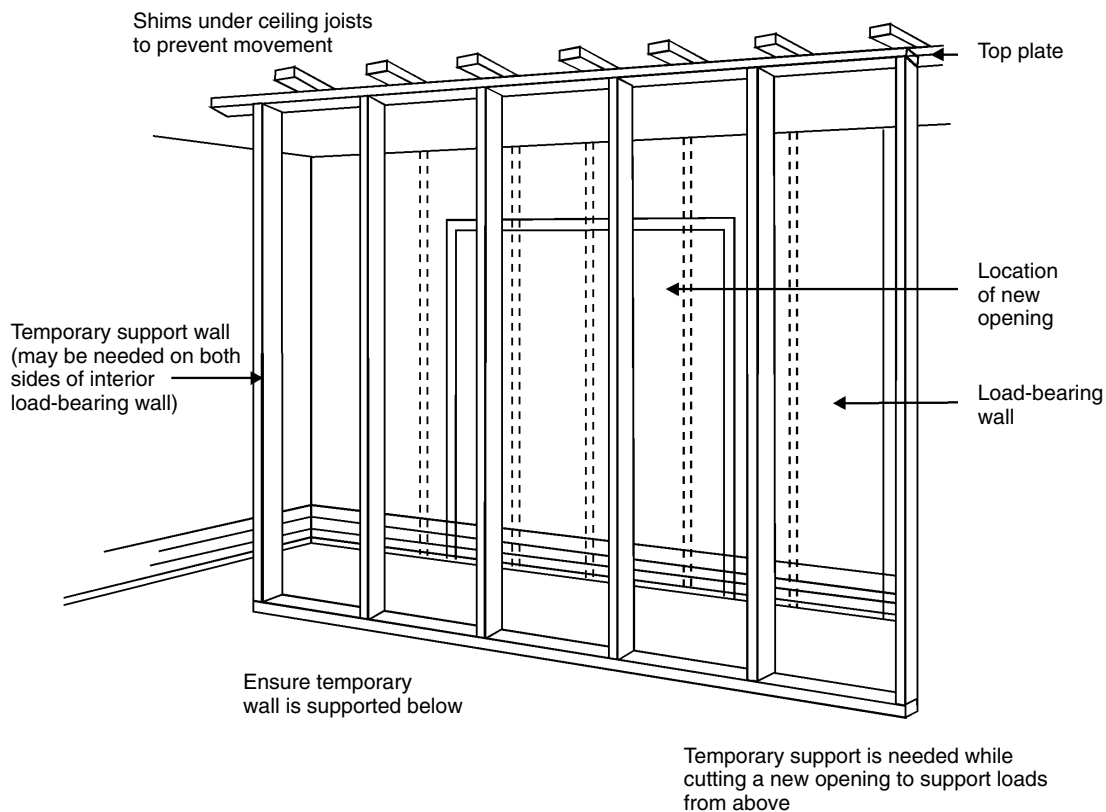
### **Selecting a New Product**

When choosing or suggesting a new product to replace an old window or door, there are a number of factors to be considered. Thermal performance, air leakage, rain and wind

infiltration, as well as security, should be as important as aesthetic appeal. There are many different types of window and door systems available, making it possible to find a fit to almost every renovation need. Windows are often tested under the Canadian Standard Association's A-440 window standard. These windows have been subjected to a performance test to determine their air leakage, watertightness and wind resistance characteristics. Look for the (CSA) label on products.

The thermal resistance of window and door units has improved greatly over the last few years, and continues to improve. Better seals, high-quality weather stripping, insulating materials and fabrication technologies have all improved.

When selecting a model, it is important to read the manufacturers' literature about the characteristics of their products. Ask them for the results of tests performed by certifying agencies. This information may show air-leakage rates, energy rating, fire resistance, flame-spread ratings, noise transmissions and other important information.

**Figure 5-3: Temporary Supports**

Other factors that may influence your decision about a product can include ease of cleaning, direction and method of operation, construction materials and general appearance. Cost and availability are often determining factors in the selection of a product as well. Selecting a product with a long-term warranty will ensure that any problems can be easily dealt with later. It also demonstrates a company's confidence in the quality of its product.

Choosing good quality materials for the hidden parts of the assembly (like framing, fasteners, and so on) will also improve the successful installation of a window or door. Do your homework and investigate different product lines and manufacturers.

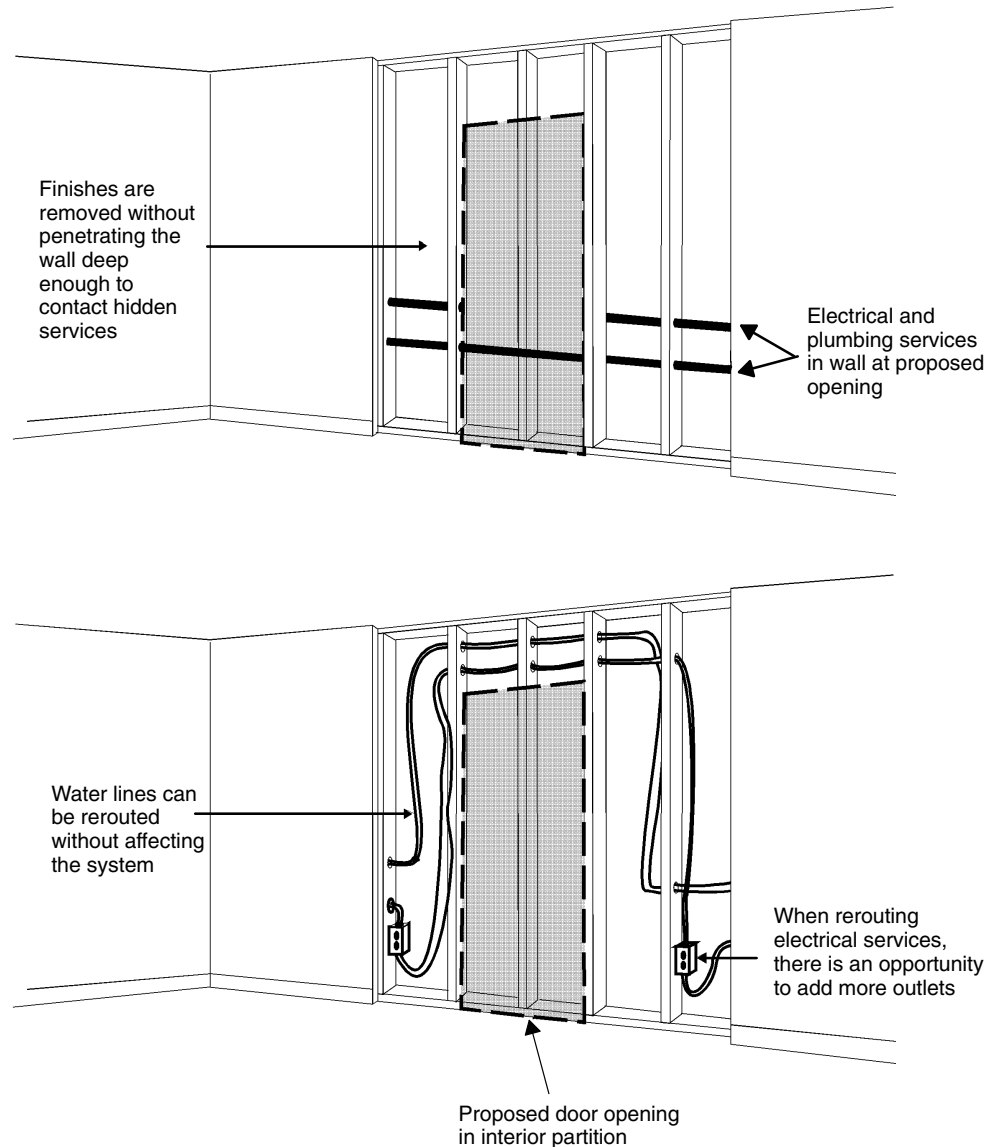
### **Natural Light**

Natural light is desirable inside the home for many reasons. If not provided, it would need to be artificially supplied, increasing electricity costs. Sunlight also improves the health and moods of the occupants and can be used to grow

plants or improve the aesthetics of the inside spaces.

Windows and other forms of glazing can be used to allow light into a space. See Figure 5-5. Doors can allow light to enter through transoms, sidelights and glazing units in the door slab itself. Skylights and sloped glazing are very effective at bringing natural light into a space, especially to the interior of a building. Skylights are often located over staircases or in hallways to give additional light. As long as a roof space is accessible for installation, skylights can be used. Where a transparent finish is undesirable, glass block and other alternative types of glazing can also provide light.

When locating and placing windows, be aware of east and west light and low sun during the winter. These orientations may cause overbrightness, overheating and glare. Windows oriented in these directions are difficult to shade with overhangs and must often rely on window coverings to provide control.

**Figure 5-4: Hidden Services in a Wall**

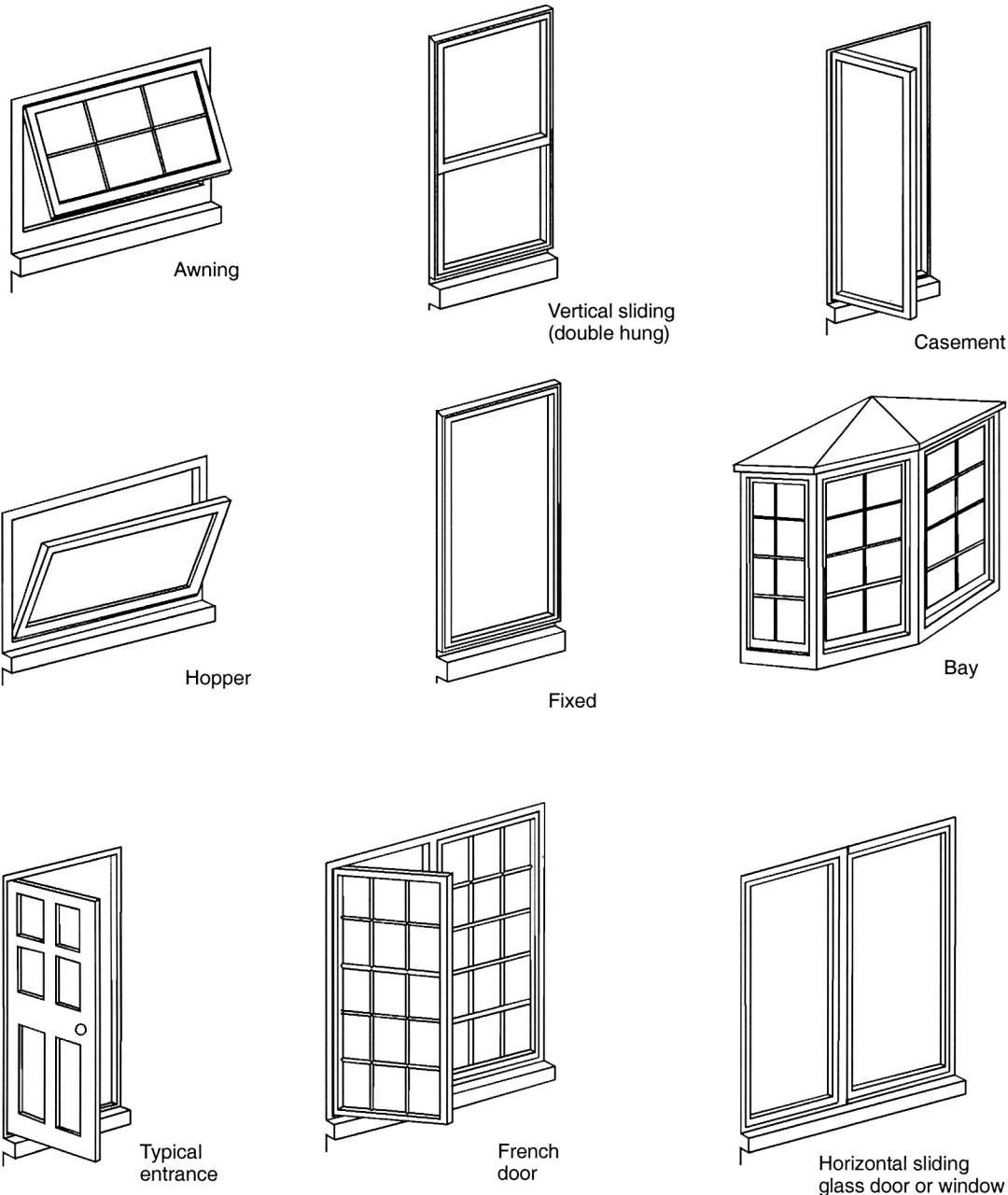
It is also important to locate large windows in rooms where the light will not disturb normal household activities. Large windows on an east wall in a bedroom do not work well for someone who works shifts and has odd sleeping hours.

Skylights located on bright sides of roofs may also need some form of light control. Some models come with built-in or attachable blinds or other covering devices. Coatings on the

surface of the skylight also reduce light penetration.

Skylights located in sloped roofs or truss roofs may require an insulated light shaft to allow the light to penetrate into the room. Flaring the shaft will allow even more light penetration into the room. Refer to Figure 5-6.

When designing window openings or altering them significantly, it is important to account for

*Figure 5-5: Types of Window and Door Units*

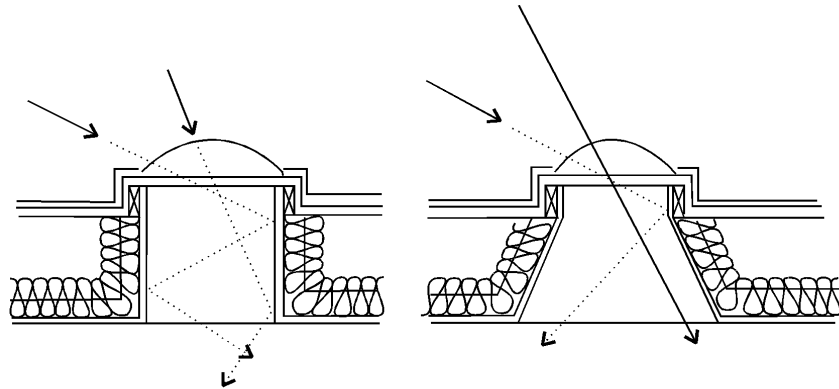
the changes that will occur inside the home. Levels of light can affect the suitability of a space as well as occupant comfort.

### **Solar Gains and Heat Loss**

Windows are usually one of the largest sources of heat loss in a home. This tendency to lose heat is related to the low thermal resistance and

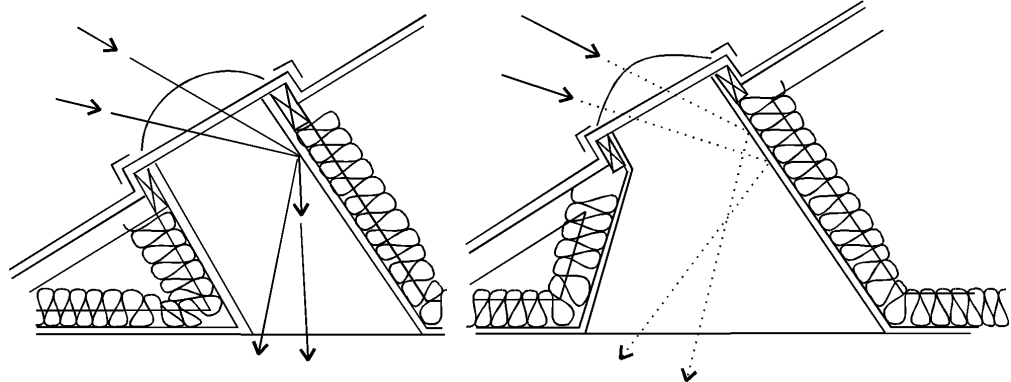
air-leaking characteristics of most older windows. New high-performance windows can help to reduce heat loss. If windows are located where they are subjected to many hours of solar radiation during a day, they can even gain some usable heat for the house in winter. A high-performance window located on the south side of a house may gain more heat than it loses in winter. Whether a window loses or gains heat



**Figure 5-6: Controlling Light Penetration and Diffusion**

A straight lightwell  
allows little direct  
sunlight into the space

A tapered lightwell  
emits more direct light



Paint vertical surfaces white  
to reflect light into the room

The light well of the skylight  
can be used to control  
light penetration and diffusion

for a house will be influenced by a number of factors.

If the house is surrounded by tall trees or buildings, it may be shaded from the sun for much of the day. Tall deciduous trees may be helpful in shading the house in summer while allowing sunlight to penetrate in winter. In this case, south-facing windows will not gain any heat from solar radiation.

South-facing glazing can cause overheating in summer and even during the winter. However,

by providing a way to store and distribute the heat that enters through the windows, overheating can be reduced and heating bills lowered. A heavy material, such as concrete or thick ceramic tiles used for walls or floors inside a well-glazed room helps absorb radiated heat that can be released back into the space after the sun has set. Air distribution systems normally incorporate large return air grilles in the room that circulate passive solar heat to other areas of the house.

Canada Mortgage and Housing Corporation has produced a number of useful publications on passive solar design. Contact your nearest CMHC office for a list of publications.

Improved energy-efficient replacement windows can decrease heat loss and heat gains in the house. These may have an effect on the heating, air conditioning or ventilating needs of the space. Chapter 10 discusses heating systems in more detail and should be referred to for further information.

### ***Airtightness and Mechanicals***

As discussed throughout this guide, air-tightening a home will affect the indoor air quality. When making improvements to windows and doors through air sealing, weather stripping or installing more advanced units, the amount of air leaking into or out of the house will decrease.

When air leakage is reduced, humidity and contaminant levels in the home can rise. The moisture and contaminants that were able to find a way out through the envelope before can now become trapped inside a tighter house. High humidity can cause condensation to form on the new windows or in other areas of the house. Increased contaminant levels may appear as stuffiness and result in headaches, nausea or other health symptoms in the occupants. Humidity and contaminant levels may both increase as the new materials used during the renovation dry out and off-gas.

Air-tightening of the home and its related effects can create or increase a need for mechanical ventilation. If a mechanical ventilator exists, it should be checked to ensure it is working efficiently. An old ventilator may not be large enough or in proper working order for the new needs of the house.

The new windows should not be relied on for ventilation. During calm, mild days with no wind or stack effect, even open windows will provide little ventilation air. In winter, open windows will cause discomfort and waste energy. A mechanical ventilation system is much more reliable and can condition and filter the air that is entering much more effectively than open windows.

Mechanical systems, particularly ventilation systems, may be affected by any air-tightening that occurs during a renovation. Heating costs may be reduced, as less cold air is entering the building and less hot air is escaping. However, ventilation requirements may be increased, as the tighter envelope will not allow as much fresh air to enter. It is important that the mechanical systems in the home not be over- or under-sized after the renovation. If you are unsure of the effects of your renovation, consult a heating or ventilation system professional. Refer to Insight 4 — Airtightness, Depressurization and Combustion Appliances — for further discussion of this important issue.

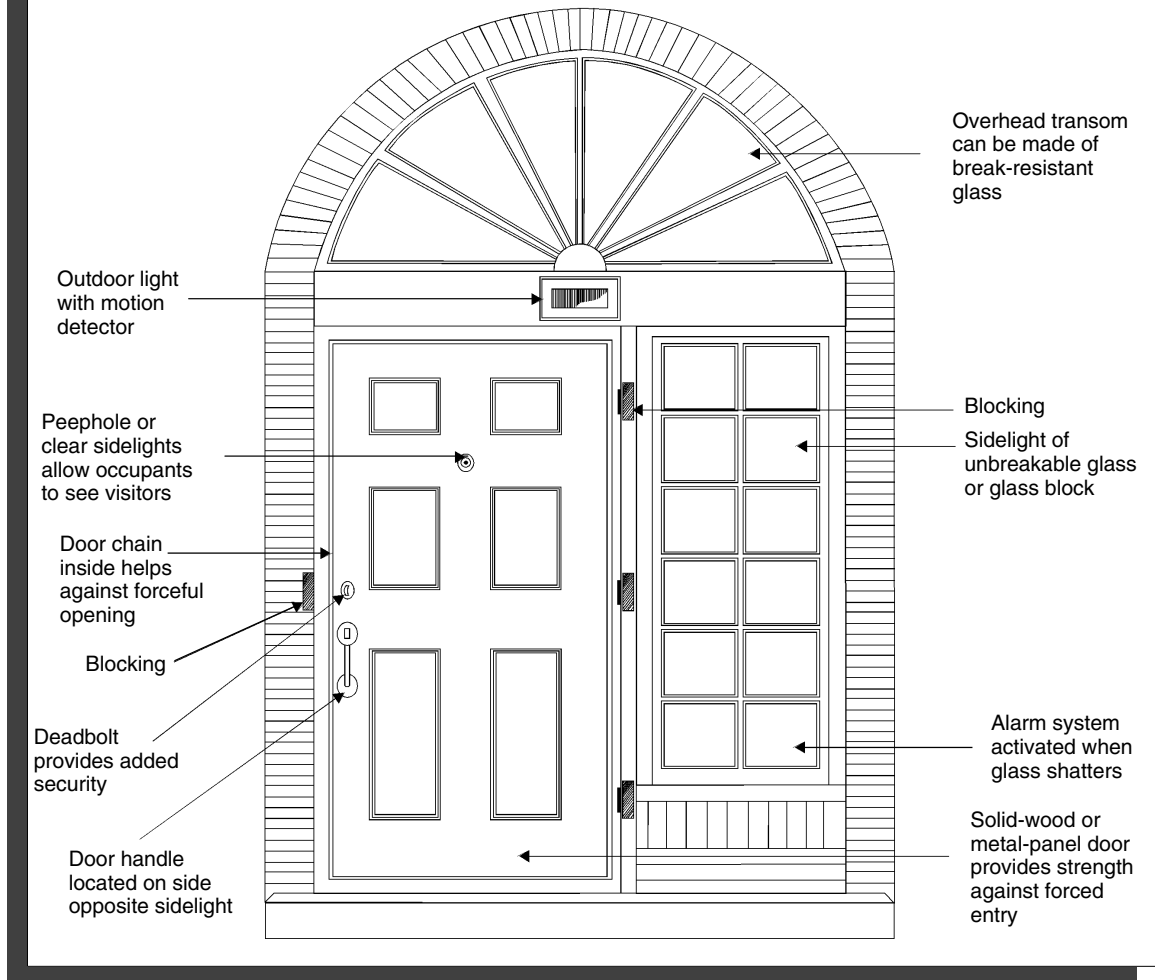
Chapter 10 discusses mechanical ventilation systems in greater detail. The impacts of air-tightening a house are also expanded upon in Chapter 2.

### ***Security***

Security is necessary to protect a home's occupants and contents from intruders. Windows and doors are usually the weakest point of the building envelope for security purposes. If an intruder attempts to enter the building, the attempt will likely be made through a door or window. Skylights in accessible locations can also be a risk.

A number of measures can be taken to improve the security of the home. Security strike plates, vertical-drop deadbolts, escutcheon plates and other types of security hardware, properly installed, are some of the easiest and most cost-effective modifications that can be made to the home. See Figure 5-7. When selecting new windows or doors, specify strong locks that are difficult to open from the outside. Deadbolt locks are much more difficult to bypass than regular lock-in-handle types. Some locks are especially difficult to open because of the design of the catch. Check local hardware stores or locksmiths to see what is available in your area. Peepholes can add security for occupants inside the home by allowing them to determine who is outside without opening the door. Exercising good judgment will help the home-owner decide what precautions will suit them.

Some types of doors and windows are more difficult to gain entry through. Casement, awning and hopper style windows usually have strong locking devices. Often a burglar has to

**Figure 5-7: Security Features of New Doors**

break the window or sash to enter. Metal and solid-wood doors usually provide enough strength that they cannot be broken apart without considerable noise and effort. Some cheaper, thin-panelled, hollow wood doors can be kicked in or punched through with very little force. In many regions of Canada, local building codes do not permit the use of these products in new housing.

The location of a door lock in relation to a sidelight may also affect the security of the door. A solid door and lock can easily be breached by reaching through a broken sidelight and opening the door from the inside. Sidelights should be break-resistant or made of glass block, 200 mm (8 in.) or less in width and located on the hinge side of the door.

Door locks that require a key to open from the inside prevent arms from reaching in but could pose a very serious hazard during a fire. Even if the key is kept near the door, it could be lost or forgotten in a panic. In Canada, these are not permitted in new houses. Unbreakable glass or polycarbonate glazing are better alternatives.

Some types of glazing can improve the security of the house. Tempered glass and glass block make more noise when broken and may be a good way to deter an intruder. Wire glass will hold together when broken, providing extra resistance to entry.

Security grilles, alarm systems and other features that can be added to doors, windows, skylights or other parts of the home can also improve security. Additional lighting, fewer

fences, visibility between neighbours and other features can all help to deter potential intruders. Refer to CMHC's publication *How to Lock Out Crime: Protecting Your Home Against Burglary* 61124 for more information.

To prevent rodents, insects and other pests from entering the home through windows or doors, proper screening is required.

A pet door can be installed in many door types. Screen door panels with pet entrances are even available. When installing a pet door, or selecting a door that has one, it is important to ensure that the door is well-fitted to the animal. Too large a pet door may provide entry to intruders or other unwanted pests. A good seal can help to prevent any problems and will reduce air leakage and heat loss.

### **Safety**

Specialty glass, such as tempered or laminated glass, can reduce injury caused by broken glass. This glazing is used in doors, skylights, sidelights, and other applications where safety is especially important. Mirrored glass in doors is of particular concern since people tend to walk into it.

### **Controlling Noise and Fire**

Noise and fire control has three general objectives: preventing fire and noise from entering the home from outside; preventing inside noise or fire from spreading to adjacent homes; and preventing passage between spaces within the home.

Spreading fire to a neighbouring building is a concern when introducing new openings near a property line. Unprotected openings may not be permitted, depending on the distance of the opening to the property line. Fixed wired glass in steel frames, fire-rated glass or fire shutters may, in some cases, be used where glazing is desired in these locations. Refer to your local building code.

In a noisy neighbourhood, the home-owner may want improved sound resistance of exterior windows and doors. Living near train tracks or an airport can be less noisy if the sound is blocked from entering the house.

When worried about fire and noise passing between interior spaces, a number of measures

can be taken. Solid wood or metal doors are often available with fire ratings and can be used to separate spaces from fire or noise. Usually, a material with a high fire rating also has a high resistance to noise transmission. The manufacturer or retailer should be a good source of advice when selecting an interior door to meet these needs. Local building codes will dictate whether there are any special requirements for the doors within a home.

### **Garage Doors**

The garage is a separate space from the living areas of the house but is often attached by a shared wall and door. The toxic fumes and substances that may be stored or emitted in the garage must be isolated from the house. When making changes to either space, or to the wall in between, it is important to remember the need for proper gas-barrier separation.

Doors between living spaces and garages must be airtight and equipped with an automatic closer. For increased safety, these doors should be fire-resistant as many of the items stored in garages are combustible. They should also reduce the noise transmission if the garage is used as a workshop. Doors between a garage and house should be fitted with a lock to prevent people from entering.

Overhead garage doors should also be designed for security. The doors used in garages are typically less substantial than those that directly access the home. They should also have a secure locking system, and panels should not be thin enough to kick through easily. Garage security will be more important to those with expensive cars, tools or other items stored inside.

## **HEALTHY HOUSING WINDOWS AND DOORS**

Upgrading the windows and doors in a building can also contribute to improving the healthiness of the home. New windows can improve daylighting in the space and reduce drafts, thereby adding to the comfort and health of the occupants. The benefits of free passive solar heating must not be overlooked in reducing heating loads when the orientation of the house is right.

Energy efficiency can be improved by the air-tightening and improved thermal resistance

that high performance windows and doors can offer. Reduced heating and cooling needs after the renovation will help to offset the cost of new doors and windows.

## **FLEXHOUSING WINDOWS AND DOORS**

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All doors must provide a minimum clear opening of 810 mm (32 in.), which can be achieved with a swing door 865 mm (34 in.) wide. Exterior sliding doors must usually be at least 1800 mm (72 in.) wide to provide the 810 mm (32 in.) opening. Thresholds should be avoided where possible, but where required, should be beveled and have a maximum height of 19 mm (3/4 in.) at exterior doors, and 13 mm (1/2 in.) at interior doors. Hardware should be easy to grasp and use ( e.g., lever handles, D-shaped pull handles).

### ***Design Considerations***

- Clear door width:
  - Manoeuvring space
  - Thresholds

- Dwelling unit doors:
  - House entrance
  - Apartment entrance
  - Doors in living area
  - Balconies/Patios
- Common area doors in apartment buildings:
  - Main entrance
  - Secondary entrance
  - Corridors and vestibules
  - Communal facilities
  - In apartment buildings automatic door openers on entrance and vestibule doors

Windows should be located to allow occupants to enjoy outdoor views from a seated position. This requires that sills be not more than 750 mm (30 in.) above floor level.

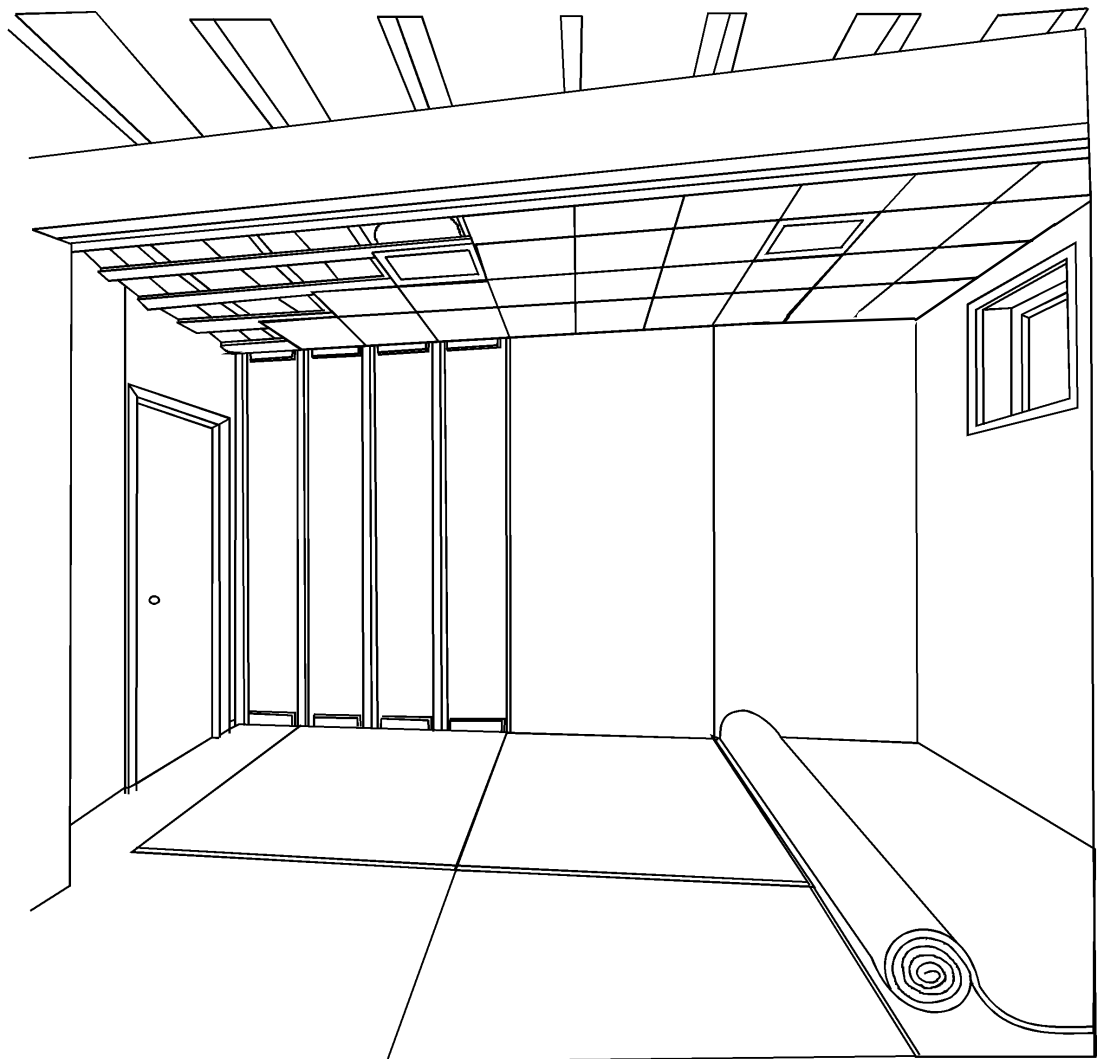
### ***Design Considerations***

- Type of windows which permit ease of use
- Opening mechanisms that are easy to grasp and operate
- Locking mechanisms that are easy to operate



## Renovating Interior Finishes

**T**his chapter presents those factors that affect the interior finishes in the house. Drawing on information about the overall function of the house from earlier chapters, it introduces you to problems you might encounter, and shows how damage to finishes often reflects underlying problems with the structure or indoor environment. It also discusses things to look out for in any renovation of interior finishes that could affect the future performance of the house. This information will help you to assess existing damage and offer suitable, lasting solutions.



## INTRODUCTION

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Assessing the condition of the existing finishes inside a house provides valuable information for identifying what kinds of hidden problems may be present in the building envelope and structure. This chapter addresses the signs you should look for when evaluating the condition of a house. It offers suggestions about how you might tackle and remedy common problems in both the building envelope and structure that affect the performance of interior finishes. Finally, it discusses the effect of environmental conditions surrounding interior finishes.

A visible defect of the interior finish can be related to any number of problems, including movement and deflection of the structure, uncontrolled shrinkage or expansion of the building or unusual indoor conditions. A hairline crack in the corner of a third-storey bedroom on the outside wall of a house might be the result of a settling foundation. The source of a problematic crack above the kitchen doorway on the first floor may be high up in the attic. An ugly brown stain on a stipple ceiling may be caused by condensation forming on a pipe, rather than the broken pipe it was thought to be.

The remedies for interior finish problems are often simple. The most difficult part of finding a solution can be determining the real cause of the problem. In many cases, the existing finishes must be removed to find the source of the problem. Whether a problem source is easy or difficult to detect, your ability to accurately diagnose symptoms is a valuable tool on the job-site.

While you plan the renovation project, consider the materials you will use. The interior finish materials can have a profound affect on the quality of the indoor air. Materials that off-gas formaldehyde or other organic compounds can adversely affect the occupants. This chapter provides you with some guidance on dealing with these issues.

## EXISTING CONDITIONS

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Interior finish problems in a house can be related to the finish materials and their installation, or to other causes unrelated to the

finish. Using materials that are not as durable as they should be, or not following the manufacturer's installation instructions may cause unsightly finish problems. Water damage and inadequate structural support are common causes of defects to interior finishes that have little to do with the actual finish.

The assessment checklist and the discussions that follow can be used to help you diagnose and remedy problems you detect as you walk through the house. Remember that providing relief to the symptom of a problem won't guarantee a long-lasting cure.

As you set about to renovate the interior finishes of the building, remember that house systems are interrelated and that a finish problem may have its root cause in another, seemingly unrelated, system. Consider the entire house when you renovate the building's interior.

## ASSESSMENT CHECKLIST

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The assessment checklist for renovating interior finishes includes symptoms that should be checked when evaluating existing interior finishes. These issues are explained in detail on the referenced pages.

### **Water Damage**

Water can enter a building in a variety of ways, causing numerous problems with interior finishes. This damage is caused by one of the three water-movement mechanisms: vapour diffusion, capillary, or bulk water flow. Remember from Chapter 2 that water in a gaseous form is called vapour. Vapour can condense when it comes into contact with a cool material. Capillary water moves directly through the pores of one material, often affecting other materials that are in direct contact. Bulk water flow, including precipitation entry and water leaks from plumbing components, is an obvious cause of damage to interior finishes. Each type of water movement needs to be managed and controlled in both new and existing houses.

Refer to Chapter 4 for the common problems you can encounter in kitchens and bathrooms. Both of these rooms accommodate many activities that generate water that can damage interior finishes. Countertops, bathtub surrounds and shower stalls can show a number of problems related to how these rooms are used.



## Checklist

### WATER DAMAGE (page 110)

- ☐ lifting or flaking paint
- ☐ blistering paint
- ☐ water stains on upper-floor ceilings
- ☐ blackened or swollen hardwood floors
- ☐ dusting on interior finishes
- ☐ shadowing at stud or truss locations
- ☐ swelling of floor underlay
- ☐ moldy carpets and other finishes
- ☐ water staining on walls, window trim or window frame
- ☐ soft, rotten or bulging drywall or plaster

### STRUCTURAL SUPPORT (page 116)

- ☐ cracks in wall, ceiling or floor finishes
- ☐ warped or squeaking floors

### CONSTRUCTION TECHNIQUES (page 118)

- ☐ squeaking, sagging, warped or crowning floors
- ☐ nail pops
- ☐ cracking of tile floors
- ☐ resilient floor finish shows dents and joints of underlay below
- ☐ swelling of floor underlay
- ☐ ripples or bubbling of carpets
- ☐ telegraphing of floor finishes

### DURABILITY OF MATERIALS (page 121)

- ☐ faded or peeling paint and wallpaper
- ☐ carpeting stained, dampened or rotting
- ☐ lifting of sheet vinyl or vinyl tile
- ☐ panelling
- ☐ worn resilient or vinyl flooring
- ☐ resilient-floor discolouration

The greatest risk posed by water vapour is its susceptibility to condensation. While this is a relatively easy condition to spot when it occurs on cold walls and windows, it is not so easy to see when it forms within the wall assembly. The slow process of inner wall condensation can

take years to show itself as a problem on interior finishes.

Paint defects are one type of interior finishing problem that is typically related to vapour diffusion or condensation. There are a number

of problems that can appear on painted interior surfaces. Two such conditions indicate current or past moisture problems in the wall:

- lifting or flaking which occurs when paint has been applied to a damp or powdery surface; and
- blistering, which occurs when moisture is trapped beneath the paint film and is drawn out by the heated interior of the building.

Problems with paint that are caused by moisture are discussed in detail in Insight 6 — What Can Go Wrong With Paint? — in this chapter. Refer to it for more information if these or other paint defects are detected.

When inside air has a lower moisture content than the outside air (typically in summer), moisture travels inward by diffusing through the wall system. Heat from the sun shining on the wet surface of the building can drive water vapour through the building envelope towards the building interior. Water vapour will diffuse as far as a vapour retarder will allow. If there is no vapour retarder to restrict the movement of moisture, vapour may infiltrate through the entire assembly, causing blistering paint and other interior finish problems.

It is never safe to assume water stains on top-floor ceilings are caused by leaks from the attic. Condensation may be the culprit, particularly in kitchens and bathrooms. As the moisture moves upwards, it can condense on a cool ceiling surface. If the condensation problem is ongoing, similar stains to those caused by leaks can occur. The problem should be investigated carefully before selecting a remedy.

Newly installed insulation in a ceiling without an adequate air barrier or vapour retarder protection can also result in moisture damage that can appear on interior finishes. Vapour moving into the space by diffusion, and especially by air leakage, can cause condensation in the roof space that can damage the interior finish. Always ensure that air and vapour barriers are in place when surveying and diagnosing moisture problems.

Materials that absorb vapour from the air can experience swelling, shrinking or rotting. In some cases, damage to finishes can be

permanent. It is next to impossible to keep moisture out of absorptive materials when relative humidity within the building is high. Problems with high indoor air moisture content are often seen as symptoms in subfloors, floor underlay and hardwood floors.

Floor underlay can swell from moisture it absorbs before, during or after installation. Before being installed, underlay can absorb moisture from outdoor snow, or rain, or other materials with which it is stored. During installation, the underlay can absorb water if spills occur or if it comes into contact with other moisture. After installation, underlay can be exposed to capillary moisture that wicks from adjacent construction material or through bulk water that enters through unsealed joints.

Replacement is often the only cure for swollen underlay. To prevent reoccurrence after replacement, seal any joints in finished flooring. Check for possible sources of water infiltration and seal against them. Common entry points include under toilets and along the side of bathtubs. Installing the underlay over a poly or wax sheet can prevent moisture penetration from below. Selecting a type of material that is appropriate to the location will help avoid problems with swelling of underlay. Some finish flooring products are more water-resistant than others. Spend time getting to know what products are available in your area and their history of performance.

Wood is susceptible to swelling and shrinkage when large moisture changes occur. The floor can swell if the moisture content of the wood increases or shrink if moisture leaves the wood. If wood strip flooring does not have room to expand under swelling conditions, the strips push against each other causing warping and uplift. If strips shrink excessively in a dry period, gaps will be visible between them and squeaking may be heard. To prevent these problems, wood floors are usually treated with a protective coating. Warped or buckling strips may be evident in older buildings where the finish has worn off and significant moisture activity is present. Refer to Figure 6-1.

Many building materials will rot under prolonged exposure to moisture. Wood rot or mold growth usually indicates that a material has been wet for some time. Mold and mildew

**Insight 6 — What Can Go Wrong With Paint?**

Most paint problems are avoidable. Paint problems most often occur as a result of poor construction practices and years of exposure to weather and severe indoor conditions.

Some common paint defects and their most frequent causes include:

- Lifting and flaking — occurs if paint is applied over a surface that is damp or powdery.
- Cracking — caused when paint is applied over a previous coat that was not completely dry.
- Blistering — develops on almost any surface. Caused by vapour or liquid trapped under the paint and expanding while the paint is still flexible. Blisters can also form from steam or standing water.
- Cratering — results from rain or condensation droplets falling onto the wet paint surface.
- Running, sagging or curtaining — occurs when paint is applied too thickly on vertical surfaces.
- Wrinkling or shrivelling — can result on horizontal surfaces if paint is applied too thickly.
- Corrosion — rust that bleeds through from metal surfaces.
- Mold — can affect paint as the surface becomes discoloured.
- Abrasion
- Chipping
- Erosion
- Alligatoring — develops if the top-coat is fast-drying and the undercoat is not dry. The defect resembles an alligator hide.
- Smoke stains and odour — use shellac to seal odour and stop bleeding of stains.

Painting over areas that show signs of failure requires thought. While every painter is aware of the necessity and value of preparing all surfaces to be painted, special care must be taken when refinishing any damaged part of the interior or exterior. Of course, if the problems have not been fixed, they will most likely recur or make painting very difficult.

Aside from the quality of the paint used, the proper preparation of the surface is among the most important aspects of a defect-free job. A poorly prepared surface that is wet or damp prior to painting will create lifting and flaking problems after the job is completed. A powdery or wet surface will not accept paint properly. If

the paint is unable to bond with the material it is being applied to, lifting and flaking typically result. In these cases, proper preparation before applying new paint will probably help keep the problem from reoccurring.

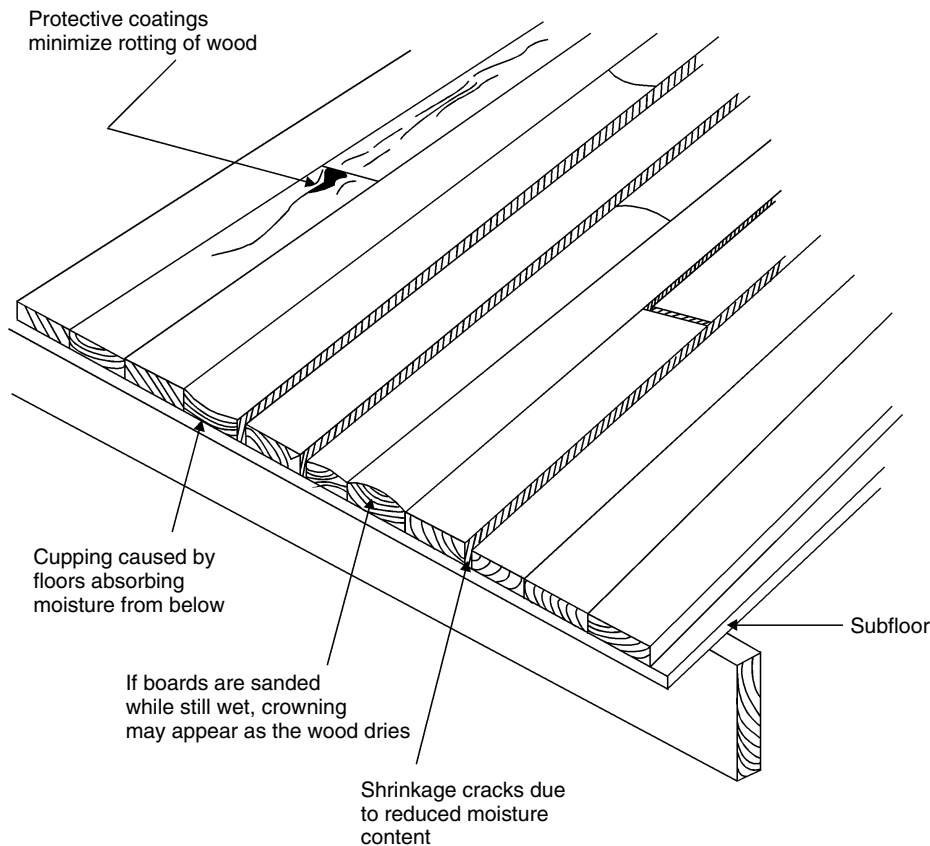
Problems with painted surfaces in bathrooms and kitchens often relate to the high moisture content in these spaces. The installation of ventilation and the application of a higher-quality, more durable paint are some quick and simple remedies. In some cases, the replacement of regular drywall with special water-resistant backing board, or a sheet rock product may also be necessary.

The most common cause of paint peeling on the exterior of a building or home is moisture that gets under the paint's surface from either the interior of the house or underside of the painted cladding. In essence, the paint is pushed off by moisture trying to escape to the outside. Caulking along joints, at window and door frames, along roof lines and under eaves, and so on, prevents the penetration of water and consequent peeling.

If a specific area of a ceiling or wall surface is exhibiting blistering, there is likely a problem with localized moisture entry. A hole in an air-barrier material or a poor seal around plumbing or electrical penetrations are typical sources of localized entry. If the problem is a skylight that needs reflashing or a glazing seal that has broken, it will need to be repaired. When blistering on the wall or ceiling surface is not restricted to one area, a faulty, poorly placed, or non-existent air-vapour barrier is likely the problem.

When warm inside air has a lower moisture content than that of outside air, moisture will travel inward by diffusing through the wall system. Water vapour will diffuse as far as a vapour retarder will allow. If there is no vapour barrier to stop the moisture, or if the barrier has been significantly damaged, the vapour may infiltrate through the entire assembly. If the vapour works its way inside the building, it may lift paint from the interior face of the wall surface. This lifted paint will appear as blisters on the wall or ceiling surface. These types of problems normally require a detailed investigation if they are to be permanently remedied.

A defective paint surface can turn an otherwise successful renovation into a failure in the eyes of the home-owner. Such problems can be easily avoided by following some simple preventative measures.

**Figure 6-1: Moisture-related Problems that Can Occur on Hardwood Floors**

are discussed further in Insight 3 — Health Hazards and Mold.

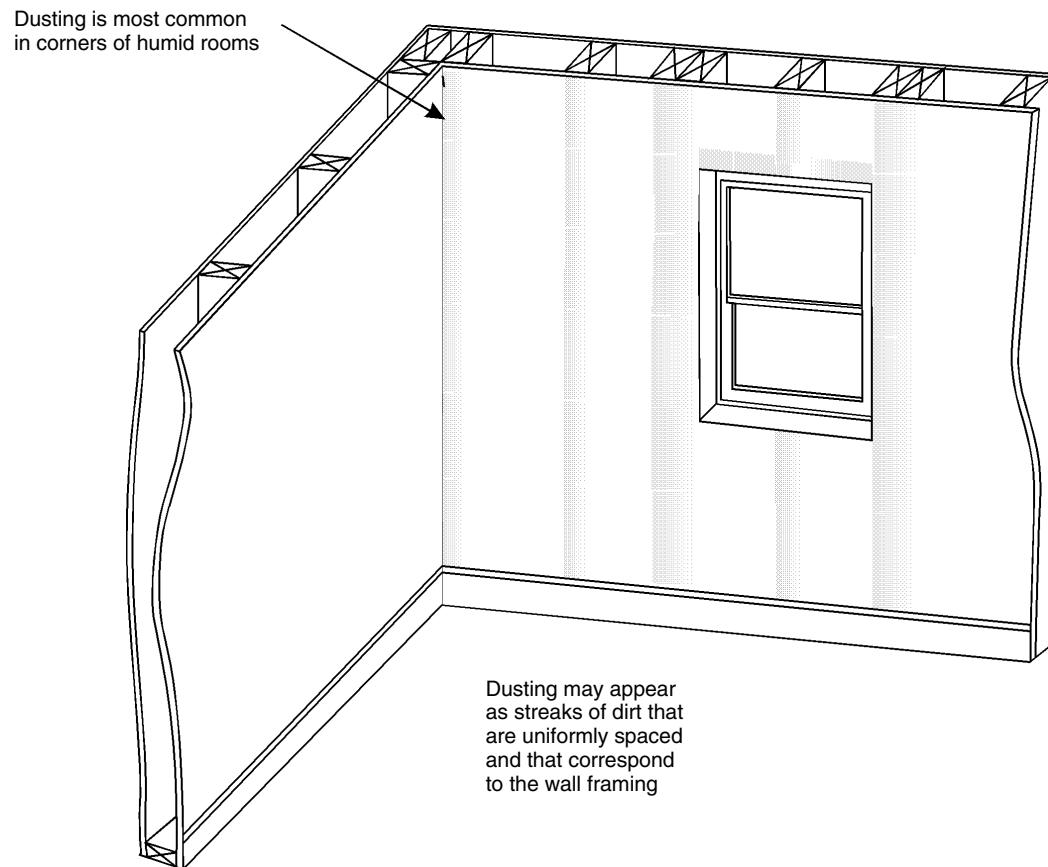
Dusting on interior surfaces of exterior walls often appear as uniformly spaced streaks of dirt that correspond to the spacing of the wall or ceiling framing members. Refer to Figure 6-2.

The cause of dusting is thermal bridging through framing members and the resulting cooler interior surface. The temperature of the portion of wall with the studs behind is cooler than the portion of the wall with the cavity behind. The cooler surface over each framing member can attract airborne dust. The dusting phenomena is often most pronounced at corners in humid rooms. Adding insulated sheathings to eliminate the thermal bridge is a technique used often in new construction. Reducing humidity levels is another effective remedy for this problem. Providing adequate ventilation in these rooms

by using whole house ventilation systems or by using good-quality exhaust fans controlled by humidistats can also help eliminate the dusting effect.

Capillary water moving from material to material in the building can cause similar problems with interior finishes. Materials that are especially susceptible to capillary water movement are masonry, concrete, gypsum board, wood and other porous materials. Any of these materials that, for whatever reason, come in contact with moisture, can pass that moisture to interior finish materials. Interior wood framing in direct contact with foundation walls or slabs can transfer moisture to drywall, damaging paint, wallpaper and other finishes. It can also lead to dry rot and mold.

To prevent moisture-wicking, a capillary break is needed to stop water from wicking into the

**Figure 6-2: Thermal Bridging and Dusting of Walls**

wood framing. Refer to Chapter 3 for a complete discussion of this effect.

Capillary water activity can affect the state of the floor as well. When finished floors and subfloors are constructed over a concrete slab on ground, a good dampproofing layer, such as polyethylene sheeting, is required between the slab and wood with which it comes in contact. Without a capillary break, moisture wicked up through the slab and into the subfloor can swell finished flooring causing it to buckle, heave or warp.

A painted wall or ceiling surface can show signs of hidden capillary activity behind the finish surface. When drywall or plaster has been in contact with moisture for prolonged periods, it becomes soft and crumbly. In this state, it does not take paint well, resulting in the lifting or flaking of the paint finish. Prolonged exposure

to moisture can also encourage mold and growth on or behind the layers of paint. CMHC produces a useful publication on mold entitled *Clean-Up Procedures for Mold in Houses*, 61091.

Three things must be present for rain to penetrate through a wall: water available on the wall; openings that permit its passage; and forces that drive or draw it inwards. Water penetration can be prevented by eliminating any one of these. The forces that can draw or push moisture into a house are gravity, capillary action, wind and air-pressure differences. These forces are explained in Chapter 2. After reading that chapter, you will be better prepared to understand and fix the problem.

Leaking water can also come from within the house. The plumbing or hydronic heating systems can leak. Pipes are most likely to leak at

poorly connected joints, but cracks and holes can also occur. Cracks and holes in pipes can be caused by exposure to freezing temperatures. If water in the pipe freezes, it will expand and may cause the pipe to burst.

Leaks in plumbing or hydronic heating pipes should be repaired immediately to prevent further deterioration of any finishes or other materials. If the leak is caused by something other than age or poor workmanship, that problem should also be remedied to prevent the leak from reoccurring.

Water running off pipes or collecting on a pipe surface could be due to causes other than a leak. If the pipe carries cold water, or is located in a humid space, condensation may be occurring on its surface. Pipe insulation or reduced humidity are quick answers to this type of problem.

Blistering and peeling paint might indicate a bulk water problem in either a ceiling or a wall. If this condition appears on the interior side of an outside wall, possible failure of the exterior cladding or flashing should be considered. Chapter 7 discusses this issue in detail.

Water damage around exterior doors and windows most likely relates to the condition of the opening itself. Broken seals, imperfect fit and poor frames (often resulting in excessive condensation or leakage) can all cause damage to interior finishes. A decision about whether to repair or replace the problematic door or window should be made after reading Chapter 5.

In the case of insulated ceilings, plaster work or drywall can begin to sag or bulge. This may indicate that water has been sitting, or is still sitting, in the ceiling. If water is still sitting there, look for the source. A leak in the flashing around a skylight or chimney, or a hole in the roof, may be visible. A build-up of condensation, or melted snow that has entered through a vent or from an ice dam, can also be the culprit. You can be sure the finish material, which is not designed to support much weight, is prone to collapse. If the damage was caused by water, the bulge is usually accompanied by a brown stain and will be soft to the touch. The wet insulation will normally have to be replaced, in addition to repairing the exterior defect.

### ***Structural Support***

Small cracks may or may not indicate big problems. You should be aware that the source of a small crack can be high in the attic or deep under the footings. Foundation settlement and truss uplift are the two major causes of cracks in the finished wall or ceiling. Cracks in floor finishes are usually linked to deflections resulting from poor support.

As the major elements of the structure shift and move under natural expansion and contraction, or as the building shifts in the soil, telltale signs can appear on the interior surfaces of the house. If the loading from the building is uneven, or if the soil does not have adequate bearing capacity, the foundation can settle unevenly. Known as differential settlement, this can place parts of the foundation under tension. The pressures often result in cracks in the structure, interior finishes or other elements.

A foundation that has settled in one of its corners, for instance, will cause the floor joists at that corner to sag, placing stress on any associated partition and load-bearing walls. As the wall structure contorts and deforms because of the sagging corner, the inflexible nature of plaster or joint compound results in visible cracks.

It is not uncommon for houses to shift over time. Even new houses can settle as the soil under them adjusts to the new load. It is also possible to experience cracking of interior finishes in new additions where differential movement occurs. Chapter 3 discusses foundation settlement problems in detail.

In general, repairs to finishes can take place once most or all of the settlement has taken place. Gauging the stability of the foundation cracks can be useful when making this determination (refer to Chapter 3). Permanent repairs to finishes where settlement is still occurring is not recommended. You may want to seek the advice of a foundation specialist where settlement is active and causing the building distress.

Truss uplift is a term that explains the natural movement of roof trusses as a result of temperature and moisture differences between the top and bottom chords.

The bottom and top chords of a truss are exposed to conditions that differ dramatically in

winter when the top is exposed to higher relative humidity. Because of the higher relative humidity, the top chord absorbs moisture and tends to lengthen, pulling up on the bottom chord through the web members. The bottom chord, embedded in the warm insulation, experiences a much lower relative humidity and tends to shrink. The differential expansion and contraction causes the bottom truss to bow upwards. As the bottom chord bows, it lifts the attached ceiling with it. The ceiling tugs at the finished corner of the interior partition wall, resulting in cracks.

The forces involved in truss uplift are tremendously strong. When an interior partition wall is fastened to the base of a truss, the whole partition can lift, resulting in separation at the base of the wall. Of all finishes, truss uplift most commonly affects drywall.

In almost all houses where trusses are used, uplift is an unavoidable condition that occurs with a varying degree of severity. Trusses with relatively low slopes are generally more susceptible to uplift, as are trusses made with juvenile wood. Simple methods that account for the uplift have been used by many builders and renovators. CMHC has produced a number of publications and videos that outline approaches for dealing with the problem at the design stage. Refer to the CMHC publication catalogue, available from your nearest CMHC office, for more details.

The success of these methods lies in the design of the building detail. At the interior corner, the edge of the finished ceiling can be attached to the partition instead of the truss. Tape, instead of a rigid fastener, can be used to secure the finish. This allows the wall and ceiling finishes to move or “float” independently of the truss. Where cornices are used, attaching them only to the ceiling allows for free movement along the wall surface, according to the activity of the truss. By allowing for movement of the truss, interior finishes can be prevented from reacting to the thermal expansion of the roof. Refer to Figure 6-3.

Cracked tiles, deflections and squeaks are usually caused by poor support in the subfloor. A subfloor with a lot of bounce will deflect when walked on. This deflection cannot be

absorbed by rigid floor finishes and cracking can occur.

Ceramic-tile floors are especially prone to cracking under these circumstances because the tiles are very rigid. Ceramic tile cracks are a common complaint by home-owners. Tile popping, although less common, is another complaint associated with this phenomenon. In the case of tiles detaching from the subfloor, the failure is often related to the adhesive. If the adhesive is stronger, cracking of the tile is more likely. See Figure 6-4.

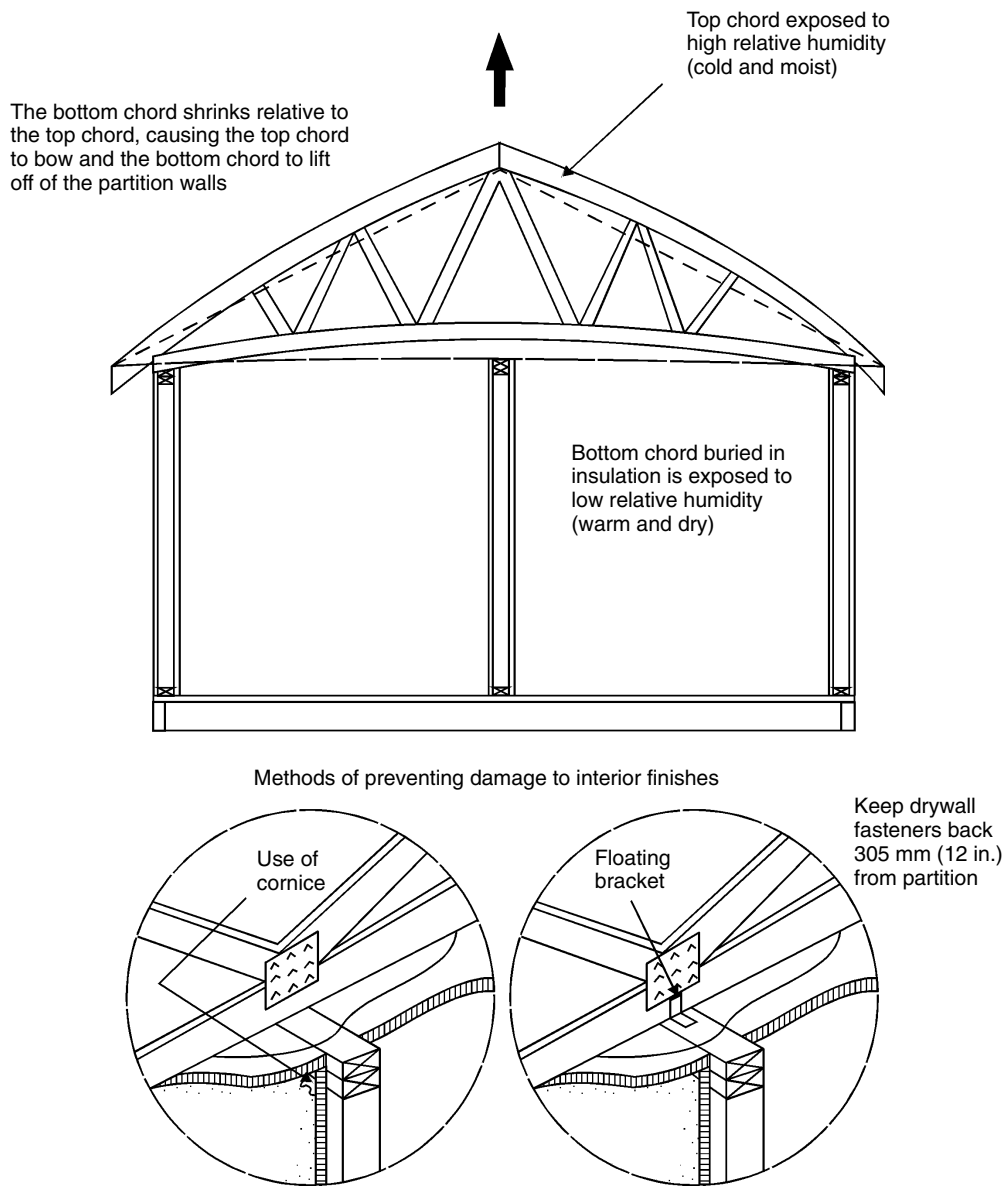
A cracked tile floor requires removal and replacement. You will often encounter difficulty in removing damaged tiles without affecting other tiles. The new tiles will also likely experience cracking if the underlying cause of the cracking is not dealt with. Refer to Figure 6-5.

To stiffen a bouncy floor, a number of steps are involved. The National Building Code of Canada requires that a panel-type subfloor, covered with ceramic tile, must be supported at its edges with tongue and groove plywood or 38 mm x 38 mm (2 x 2 in.) blocking nailed between framing members (below the joint in floor sheathing panels). Alternatively, the subfloor can be doubled up. Beyond this requirement, a few other practices will help to improve the stiffness of the subfloor system.

Floor deflection can also increase over large floor spans. If incorporating new floor spans, or removing structural members during a renovation, the floor might need to be braced for additional stiffness. Floors with an increased tendency to vibrate or deflect will not hold rigid finishes well.

During a major renovation, the structural layout of the building can affect the interior finishes. The longer the cantilever, the more the floor system supporting the cantilever will be susceptible to deflection. The result may be cracks in the floor finishes from the bending action. If planning to incorporate any new structural elements, advice from a structural designer may help to discover the potential effects of the change.

When installing a new flooring system, keeping traffic off of the finished surface for a few days can help to improve the settling of the product. Ceramic-tile floors and glued-down hardwood

**Figure 6-3: Truss Uplift**

should not be walked on until adhesives have had time to set.

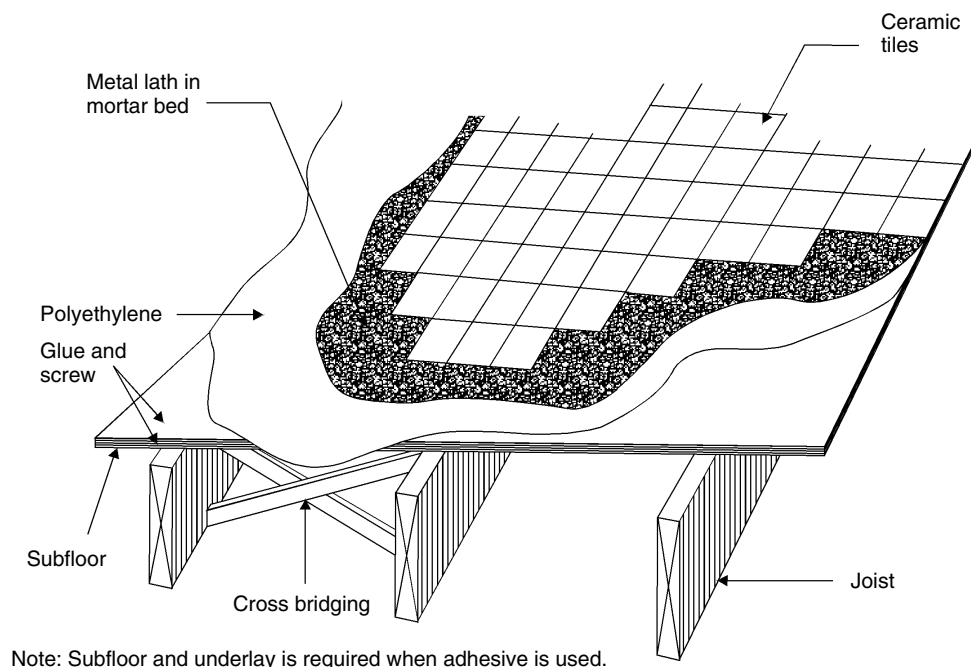
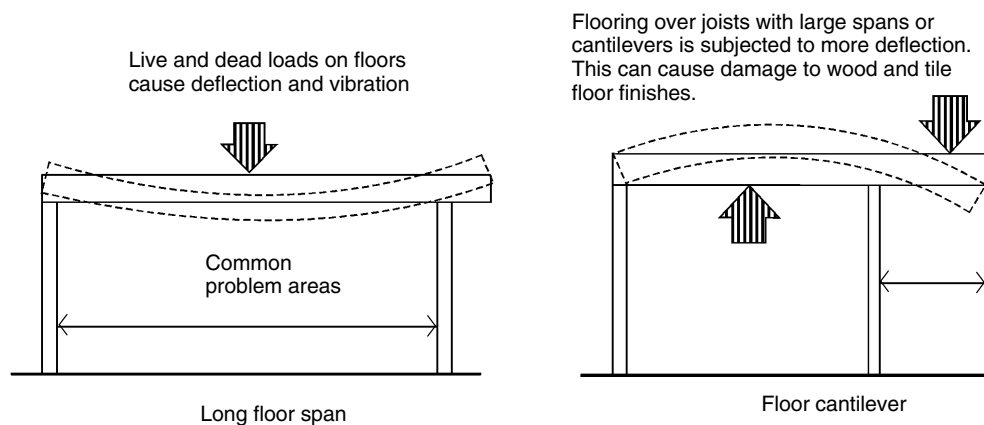
Choosing good quality materials for the hidden parts of the assembly will also improve the chances of installing a successful floor system. When selecting plywood for subfloors, check that the layers have not delaminated. When choosing joists for structure, pick the straightest boards available and install them with the crown up. The parts of the system that are not visible

can have a huge affect on the performance and appearance of the visible materials.

### **Construction Techniques**

Poor installation techniques during the original construction or a previous renovation is commonly the cause of interior finish problems. Flooring systems are especially susceptible to the effects of poor workmanship because of their exposure to repetitive and constant loading.



**Figure 6-4: Proper Installation of Ceramic-tile Floors****Figure 6-5: Floor Deflection**

Many defects in wood floors can be traced back to the original installation. Wood that was installed without proper drying or stored incorrectly on-site might have had a high moisture content when it was installed. Wood with a high moisture content tends to shrink after installation, causing a variety of problems. Typical problems include warped or cupping

boards, squeaking, cracking, crowning and gaps between the boards.

Dry, untreated wood stored in areas of high humidity can absorb moisture directly out of the air. It is now common practice to allow hardwood flooring and other wood finishing materials to be stored on-site for up to a week to

acclimatize it to the specific humidity conditions of the house before it is installed. This allows it to either shrink or swell as it reaches equilibrium with interior conditions. Keeping interior conditions stable during the lifetime of the materials also helps to prevent problems with swelling and shrinkage. The annoying sounds that often accompany an attractive wood floor can mean the floor was installed without allowing it to properly acclimatize to the building conditions. The process of absorbing moisture and then drying can cause swelling and shrinkage and cause deformation of the flooring after installation. Warped flooring can also be due to the installation of poor quality materials. In most cases, replacement of the finish is the only option. Although, in some cases, resurfacing may be possible. It is important to avoid making the same mistakes when installing the new flooring.

A squeaky floor might also be the result of flooring that has loosened or separated from the supporting joists because of shrinkage or deflection of the supporting joists. The space between the joist and the subfloor allows for movement under loads from above. These squeaks are easily repaired if the floor system is accessible from underneath. Installing a shim in the gap will prevent future movement. From above, the subfloor can be screwed or nailed more securely to the joist. This option is possible only when the floor finish is being replaced.

Telegraphing and discolouration are common problems with resilient flooring. Telegraphing describes the phenomena where any marks, dents or joints in the underlayment are visible in the finished floor surface. It usually occurs when the resilient flooring is fully glued to the underlay.

Discolouration of resilient floors is a more recent concern. Renovators, manufacturers and researchers are still working on the exact cause of the colour changes. It is clear, however, that a discoloured floor that is permanently marked must be replaced.

To prevent the discolouration of newly installed flooring, follow the manufacturer's instruction closely. Most manufacturers recommend underlayment, fillers and adhesives that are to be used with their product. Installation

procedures are also outlined by the manufacturer. Failing to follow these instructions explicitly can void the warranty.

Some flooring will also show bulges where underlay has swelled. Because swollen underlay cannot be repaired, the piece will have to be replaced, or the unsightly bulge accepted. The best prevention against bulges in the flooring from wet underlay is choosing a suitable underlay for the location and limiting contact with moisture by care and sealing during the installation.

Carpets may also show symptoms of poor construction below. A loose, thick carpet with substantial underpadding is less likely to show marks than an industrial or commercial carpet applied directly over the subfloor. Another common complaint about carpeting is loosening or buckling after the original installation.

Carpets are stretched during installation. If a carpet has not been stretched enough, it will become loose during wear. A loose carpet can be a tripping hazard and can be especially dangerous in a home with small children or seniors. A buckling carpet is easily stretched and can be done by carpet installers.

Squeaky or warped floors can have very little to do with the significant movement of the whole structure. The floors can have localized reactions to loads from people moving throughout a house, as well as stationary loads from furniture, construction materials and other objects. Loading on floors can cause squeaks to appear. Squeaks and deflection caused by stationary loads may not be evident until the load has been shifted. A stack of drywall stored on a floor, for example, may cause the floor to warp under its heavy mass. Remember this when storing heavy materials on finished floors, and don't leave them there for extended periods.

Squeaks caused by the deflection of supporting members over time, or by house settlement, do occur. However, squeaking floors are more commonly the result of poor installation and improper fastening.

Moisture in studs is the major culprit behind nail pops. When drying occurs in wet lumber as it is exposed to lower humidity or interior heating, the wood shrinks, forming a gap between the two materials; and the fasteners pop when the stud twists or the finish is pushed. Long, smooth

nails tend to pop more than short nails or screws. Nails showing their heads on a painted or wallpapered surface are a good indication that shrinkage of the framing has taken place. Repairing the damage is generally sufficient once the shrinkage is complete. Using dry lumber (i.e., moisture content less than 19 percent) is necessary to reduce this problem. Refer to Figure 6-6.

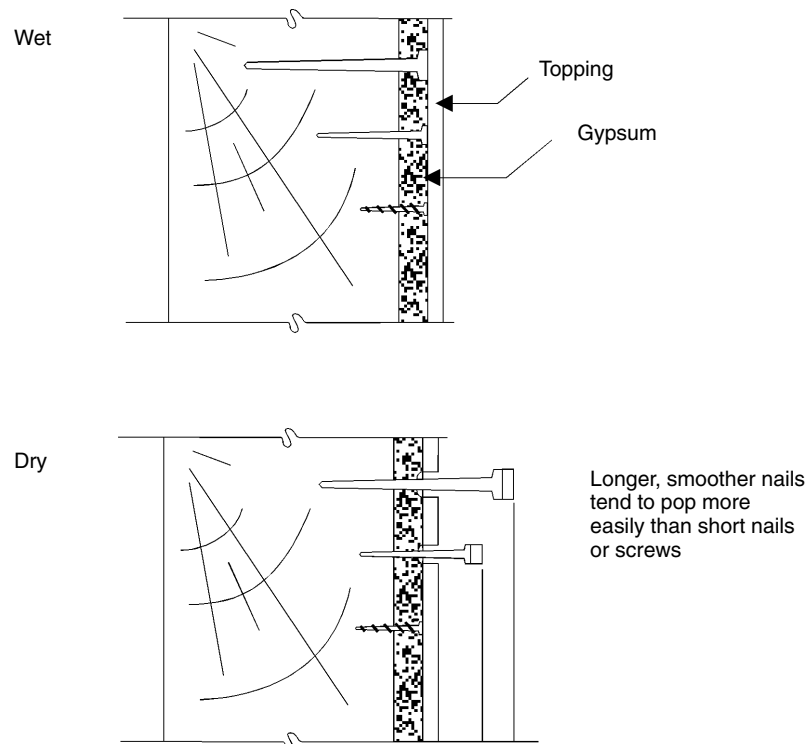
### ***Durability of Materials***

Materials selected for interior finishes are chosen based on a number of criteria. One important consideration is durability. Finishes with poor durability are common in homes and typically cause occupant dissatisfaction. Basing the selection of a product only on its initial cost can be a false economy, particularly if the product fails long before the higher-priced alternative, or if it involves significant maintenance costs.

Problems that can arise from poor durability of finishes include paint defects, peeling wallpaper, wallpaper that holds stains, panelling or carpet that fades quickly in areas exposed to sunlight, and carpeting that shows wear quickly in high-traffic areas. The lifting of sheet vinyl or vinyl tiles can be linked to the quality of the adhesives used rather than the quality of the flooring. Some flooring is secured only with staples along its perimeter. It is important to replace any worn finishes with quality durable materials.

Finding solutions to some of the problems mentioned in this section of the chapter is not an exact science. It requires patience and diligence. A solution that fits the needs of the renovation project and the home-owner is needed. Both factors will influence your decisions. Although some solutions are more time-consuming or costly than others, remember that your reputation depends on incorporating quality decisions in your work.

***Figure 6-6: Nail Popping***



Masking existing problems will not make them go away. A coat of paint over a water-damaged surface, or compound over a crack in the ceiling, will often prove to be superficial remedies. Unless the root of the problem is tended to, these symptoms can reoccur after a poor renovation or repair attempt.

### RENOVATION IMPLICATIONS

Where building defects have been diagnosed and corrected, or where no defects are evident, the renovation of interior finishes can have additional effects on the performance of the building.

This part of the chapter discusses some common and important implications to consider when planning changes to interior finishes. It is important to recall that changes to a small part of the house can greatly affect the function of other components and systems.

#### *Selecting New Finishes*

Material choices are often based on a compromise between many criteria. These might include:

- cost;
- availability;
- durability;
- moisture resistance;
- slip resistance;
- aesthetics;
- affect on indoor air quality;
- recycled content;
- environmental appropriateness; and
- safety.

While issues of cost and aesthetics depend on the client and the nature of a specific project, durability and safety should be significant concerns in any renovation decision. For example, ceramic tile is more expensive and time-consuming to install than resilient flooring but can generally hold its finish longer and may be more aesthetically pleasing. However, it can be very slippery when wet, depending on the finish. In any case, good judgment of the

specific situation is the key to the longevity of finishes.

Safety is an issue that can greatly influence a decision about specific finishes. For example, in a child's bedroom, hard finishes with sharp corners may not be desirable.

Materials with toxic finishes should also be avoided. Homes should have environmentally benign materials installed whenever possible.

Urea-formaldehyde-based particle boards, toxic adhesives and sealants and other manufactured products that off-gas should be avoided. Carpets also tend to contribute to poor indoor air and should be avoided. They can introduce both chemical contaminants (from off-gasing) and biological contaminants (molds and dust mites). CMHC has many publications that address these Healthy Housing concerns. Learning more about these important issues is recommended for today's professional renovator.

#### *Indoor Air Quality*

Although there is not enough room here for a comprehensive list of unhealthy materials to be aware of in old houses, you should be aware that quality standards are always improving in the housing industry as new discoveries are made. It follows that older materials found in homes may not have the same standards as the materials installed today. For example, old houses can contain materials with asbestos or other contaminants.

The removal of some materials or the alteration to existing (visible or covered up) finishes in older buildings may be cause for concern. Be especially wary when working with unfamiliar materials. Some materials to watch for include: existing paints and painted surfaces, resilient flooring, lining felts, some forms of insulation and asbestos tiles.

Old paints may appear harmless to the casual renovator. However, a painted surface may release lead or other contaminants when sanded or disturbed. Any paints containing lead or other unsafe ingredients should be carefully dealt with. Use appropriate equipment to protect yourself and others. Care must be taken in choosing and using a paint removal method. Ensure that the work space is well ventilated whenever you are using paint strippers. If young children or pregnant women are in the vicinity

of the renovated building, special care should be taken, as they are very susceptible to lead poisoning. Refer to the CMHC publication *Lead in Your Home 61941* for more information.

If an existing resilient floor, its backing or its lining felt must be removed, excessive movement, sanding and tearing should be avoided to minimize expelling fibres into the air. The fibres in older floor types may be hazardous. Slicing the flooring into strips and pulling the strips out individually may help to reduce exposure to contaminant particles.

When removing old materials, it is always important to use caution. Any hazardous or unidentified substances need to be dealt with as efficiently, quickly and carefully as possible. In a renovation where the building is occupied during the work, care is especially important. Contaminants stirred up or released during a renovation can take some time to be removed from the house after the work is finished.

Proper ventilation while renovating helps to protect the safety of anyone working on the project or occupying the building. Paint fumes, adhesive fumes, asbestos particles and other air contaminants should be exhausted away from any work spaces or occupied spaces. Ventilation of a renovated space may be necessary for some time after the renovation to assist in removing contaminants that have been released. Some of these contaminants will take longer to disperse than the duration of the project.

Many new materials used in interior finishes, such as adhesives, elastomers, plastics, rubber surface coatings, solvents, carpets and fabrics are a source of air contamination in newly renovated houses. Contaminants are released through off-gassing or chemical and physical reactions during and after installation. Many materials release contaminants when exposed to temperature extremes, humidity or light.

Some people experience adverse health symptoms when exposed to contaminants released during the renovation work. Health effects can result from existing contaminants that have been disturbed or from new contaminants that have been introduced. A

proper clean-up may help to eliminate a situation that is affecting the occupants.

Newly introduced contaminants can increase the need for mechanical ventilation. The house must have a constant supply of fresh air to dilute and replace any particles that contribute to poor air quality. In addition, air sealing or other tightening measures may have occurred during the renovation. These actions may have helped to reduce the amount of air that naturally flows into or out of the house, which further contributes to the need for mechanical ventilation systems.

If a mechanical ventilation system does exist, it may not be able to handle the new loads imposed on the system by changes during the renovation. Any existing systems should be checked for adequate capacity and proper operation during the renovation assessment. Ventilation system needs are discussed further in Chapter 10 — Renovations and Mechanical Systems.

### **Moisture Problems**

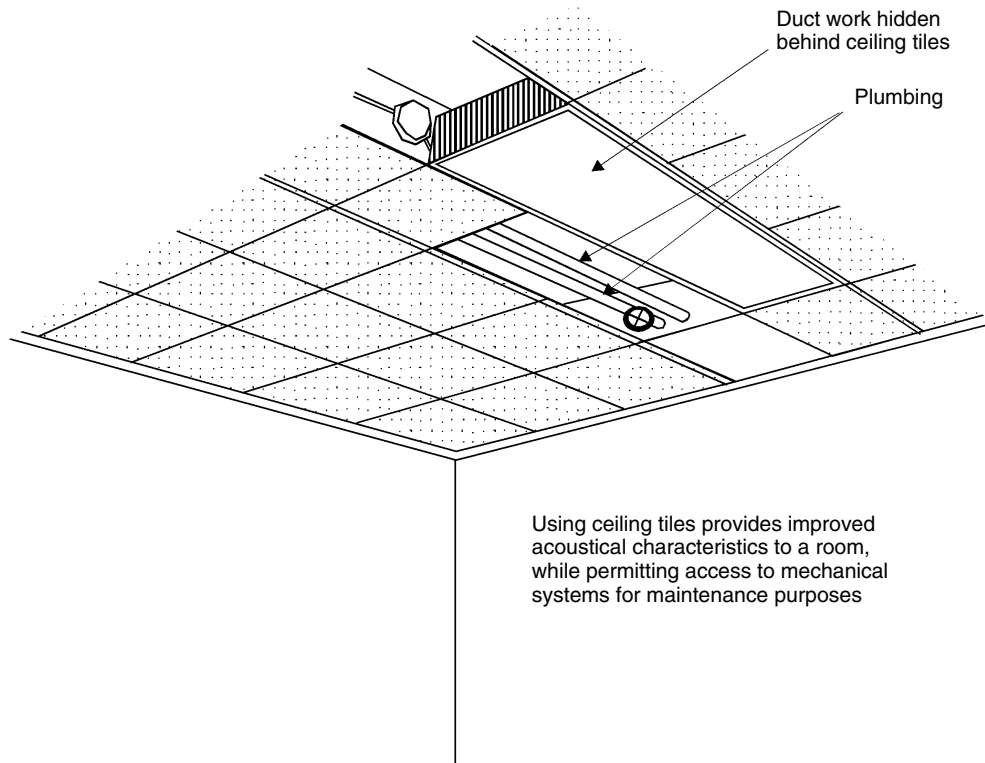
As discussed throughout this chapter, moisture concerns are important to the performance of interior finishes. When installing any new material, it is important to ensure that any existing moisture problems have been remedied.

Only materials that have been properly dried should be used in the new work. Paying extra for kiln-dried lumber may cost slightly more, but the cost of repairing damage from shrinkage can be much greater. A small investment up-front may save time and money later.

Materials that are affected by moisture conditions should be acclimatized to the conditions of the renovated space prior to being installed. A minimum of one week is recommended for this purpose. Of course, proper storing during this period is absolutely important.

### **Access to Mechanicals**

When installing new finishes, it is important to remember to leave access to mechanical and electrical elements in concealed spaces. Cleanouts in plumbing systems, electrical junction boxes and other elements require easy access. See Figure 6-7.

**Figure 6-7: Access to Mechanicals**

### **Opportunities for Energy Retrofitting**

During a renovation that involves removal or replacement of interior finishes, there may be opportunities to improve the energy efficiency of the house. While wall, ceiling or floor cavities are open, installing additional insulation or an air- and vapour-barrier system may be possible. Energy upgrades that are not possible without affecting interior finishes should be considered at this point, when it is most economical to do them. Chapter 11 discusses energy retrofit possibilities and procedures in greater detail.

### **Controlling Sound Transmission**

Sound transmission is a common problem in old homes. During a renovation of interior finishes, improvements in this aspect of the home can be easily accomplished.

Sound transmission improvements are common in bathrooms and other high-traffic areas of the home. Insulation installed in cavities between framing members, the arrangement of framing members and the method of attaching drywall or interior finishes to the framing can all affect sound transmission. Sealing of penetrations and joints can also help to stop the spread of noise through the home.

The selection of one finish material over another may be based on specific properties. The sound absorbing properties of some materials make them preferable in areas with special requirements. Lay-in ceiling tiles, for example, come in a variety of designs and materials. Some of these panels are specifically designed to reduce sound transmission. They may also have advantages in providing easy concealment of and access to mechanicals in the ceiling space.

## HEALTHY HOUSING INTERIORS

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When renovating the interior of a house, the five Healthy Housing principles — occupant health, energy efficiency, resource efficiency, environmental responsibility and affordability — should be considered. Occupant health is most directly affected by the emissions from interior finishes and furnishings. Most important, do not use materials intended for exterior use inside the house, particularly paints, caulking and sealants.

Energy efficiency can be improved when making changes to the interior by air sealing and adding insulation to the exterior envelope. By choosing renewable materials or those made from plentiful natural resources or recycled products, resources are used wisely. Minimizing and properly handling construction waste benefits the environment. Also, by selecting

durable materials and choosing to use chemical-free cleansers during the renovation process, we can reduce the pollution of our environment. Of course, the choices made here have to be affordable.

Some research into the advantages of different materials before selecting finishes will help you make good choices. Often, the cost differences in choosing healthy products are not extreme and shopping around before buying can further reduce added expense.

The renovation of the building's interior is always carefully scrutinized by the home-owner. Make sure you take the time to diagnose accurately the defects you observe, and that you carefully choose long-lasting solutions. Patchwork renovations often fail and are soon noticed by the client. By focussing on the details, your client will be more than happy to recommend your good work to others.





# Repairing and Replacing Exterior Finishes

**T**he exterior shell of any house provides an important function, especially in northern climates. This chapter discusses the role of cladding and roofing finishes in sheltering the building interior from the elements. It also discusses the relationship between the exterior finish and other building systems, including those that control air and moisture. The effects of the local site, weather and indoor environment on the building's shell are also addressed.

This chapter also focusses on the condition of exterior finishes like paint, siding, roofing and eavestroughing. It develops an understanding of the causes, both direct and indirect, of exterior finish problems and addresses common concerns about the shell of existing houses as well as problems to avoid during renovations.



### INTRODUCTION

The role of the building's shell in the overall performance of the building should not be underestimated, particularly in cold climates. The exterior shell and its finishes fulfil a number of important functions. Exterior finish defects can often indicate underlying problems with the shell of the house or its supporting substructure.

The shell of the house is expected to provide protection of the house interior from the elements — wind, heat, sunlight, rain, snow and other forms of precipitation. The shell must be securely attached to its supporting structure to withstand pressures from wind gusts and, in some locations, from earthquakes. It must be durable enough to resist normal movement caused by expansion and contraction due to changes in temperature. At the same time, exposure to sunlight should not cause finishes to deteriorate. The building's shell needs to shed rain and snow and keep them from penetrating into the building. In addition, the shell of a house needs to be able to withstand minor impacts from people and objects that can occur during everyday activities.

The failure of the building shell or exterior finish to fulfil the above functions can mean that rain or snow can make its way into the building. It can also mean that the finish blisters, peels, cracks or fades, that wind gusts blow parts of the cladding from the house or that impact from normal activity produces an unsightly appearance. Failures often result from defective materials or poor installation. Sometimes, the exterior finish can be well installed, with quality materials, yet still exhibit evidence of distress. In these cases, the cause of the defect is indirect and can be attributed to the failure of another of the building's systems. For instance, cracked brick veneer can result from foundation settlement or from uplift caused by adfreezing of an unheated garage foundation. Blistering paint can be caused by a defective air or vapour barrier inside the wall. Wavy shingles can be the result of inadequate or improperly installed roof sheathing.

Indirect causes of failure can be far more difficult to diagnose than direct ones. The underlying source of these problems may challenge you as you attempt to remedy them.

Remember to always follow these important steps to avoid repeating problems — observe, diagnose, formulate solutions, remedy and then renovate.

### EXISTING CONDITIONS

This section discusses damage that appears on the exterior of the house. It explains possible findings to help the renovator understand the caused and effects of some common symptoms.

The part entitled “Renovation Implications” looks at possible future effects of alterations to a building's exterior finish. It deals with issues that are related both directly and indirectly to the exterior finishes of the house.

Most often, problems with exterior finishes relate to the failure of one of the elements of the building's rain-shedding system. The building's above-grade rain-shedding elements that might be defective include:

- roof covering;
- flashing of roof elements (at roof and ridge vents, chimney and other roof penetrations);
- eave protection;
- eavestroughing;
- fascia;
- exterior wall cladding and its finish;
- flashing over windows and doors;
- wall sheathing and housewrap;
- sheathing paper;
- caulking at through-wall and roof penetrations
- weep holes in brick veneer;
- flashing at base of wall;
- separation of finish from grade;
- rain screen; and
- grade not sloped away from house.

A defective rain-shedding system can cause damage in parts of the house that appear unrelated to the house shell. Water spilling from a clogged, overflowing eavestrough can move inward through the building's protective cladding, through its insulated cavity and appear

a number of storeys below as damage to the building's interior finish. The effects of a defective rain-shedding system seldom go unnoticed. While signs of distress are obvious, linking their cause to the rain-shedding system is often more difficult, particularly when other causes of moisture damage are also present.

A thorough assessment of the existing condition of the house's exterior finish is the first step to uncovering causal relationships. Typical problems you can encounter with roofs and walls are discussed below.

Checking the installation and quality of the materials of each of these components is an essential part of the renovation process. Solutions that are proposed to any evident problem must address the underlying cause of the problem and not just provide relief from its symptoms. For instance, cleaning a rain-worn or stained wall provides only temporary relief, unless the wetting patterns of the wall are changed and the rainwater is redirected.

Indirect causes of problems are often difficult to determine from the symptoms observed. Problems can relate to improper fastening to, or support from, the underlying substructure. Uncontrolled movement of the building from frost action or settlement can also cause damage to the house exterior. In some cases, repairing the damage eliminates and cures the defective finish, while in others, the defect reappears. Every attempt must be made to diagnose the cause of the distress and devise a strategy to provide a lasting solution.

Some indirect water problems can also result from the uncontrolled movement of interior moisture as it moves through to the outdoors, or from water that wicks up through the wall's cladding from below grade. A range of outward signs, including blistering paint, efflorescence and brick spalling, are evidence of these types of uncontrolled water movement.

Other defective aspects of the house exterior relate to the choice of materials used in the building envelope. For example, materials might not be appropriate for the conditions to which they are exposed. These could be normal or unusual exposure conditions. Materials intended for interior use but used on the exterior will often fail prematurely and allow damage. The use of interior-grade caulking is the most

obvious example. Some finishes are less resistant to the wear and tear they may be subjected to. Dents and dings from children playing, for instance, are more likely with some types of cladding than with others. Selection of appropriate materials is key to ensuring good, long-term performance.

Finally, a common source of problems relates to improper installation procedures. While installation procedures are not detailed in this guide, it is important to be able to identify whether work has been completed properly.

An assessment checklist has been provided to help you evaluate the condition of the exterior. The checklist provides a summary of problems you can encounter when doing the assessment. Some of these factors will be linked with information from previous chapters as it is important not to isolate any one problem without considering its overall impact.

## ASSESSMENT CHECKLIST

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The assessment checklist for repairing and replacing exterior finishes identifies common symptoms of problems to be checked when evaluating existing exteriors. These issues are discussed in detail on the referenced pages.

### ***Inadequate Rain-and-snow-shedding System on Roof***

The most important function the roof fulfils is to shed rain and snow and provide protection to the occupants and the contents of the house interior. As part of the house assessment, roofs should be checked, preferably during or shortly after a heavy rain, in order to best detect water-shedding problems.

Roof leaks are usually caused by loose, torn or missing shingles, defective flashing or inadequate eave protection. As well, rain-diversion systems, such as eavestroughs and downspouts, that are poorly designed or maintained can also cause rain to penetrate into the house.

Cracked, torn or missing shingles can cause water damage in the rooms below. Shingles perform best on roofs with a pitch of 1-in-3, or more. On low-slope roofs, shingles tend to stay wet longer and disintegrate faster. Although special low-slope products and installation

**Checklist****INADEQUATE RAIN-AND-SNOW-SHEDDING SYSTEM ON ROOF***(page 129)*

- ☐ asphalt shingles — warped, uneven, curled or missing surface granules
- ☐ wood shingles — ragged, rotting or broken
- ☐ built-up roofing — blistered, brittle or soft in spots
- ☐ damaged or corroded flashing at chimneys, plumbing stacks, valleys, dormers, and so on
- ☐ eavestroughs — overflowing, sagging, rusting, corroding or clogged with debris
- ☐ soil erosion around downspout
- ☐ shingle granules under downspout outlets
- ☐ moss growth on roofs and walls
- ☐ interior water damage (ice damming)

**INADEQUATE RAIN-AND-SNOW-SHEDDING SYSTEM ON WALLS***(page 136)*

- ☐ uneven staining on exterior finish
- ☐ open joints in siding
- ☐ stained or damaged window or door frames and sills
- ☐ decay under window sills
- ☐ interior water damage
- ☐ peeling or blistered paint
- ☐ clogged or plugged weepholes
- ☐ missing mortar

**INDIRECT CAUSES OF FINISH DISTRESS (page 137)****Structural or Attachment Deficiency**

- ☐ uneven shingles or roof finish
- ☐ missing shingles (wind)
- ☐ warped siding — compressible insulation
- ☐ buckled siding

**Adfreezing or Frost Heave**

- ☐ cracked exterior masonry veneer on unheated garages
- ☐ cracked or warped siding on unheated garages

**Inadequate Dampproofing or Rain-diversion System**

- ☐ efflorescence
- ☐ brick spalling

**Checklist (Cont'd)****Grading**

- ☐ damaged wood or other siding material at or near grade
- ☐ soiled brick at or near grade

**Other Deficiencies**

- ☐ melted shingles
- ☐ dented siding
- ☐ insect or pest damage

procedures are available for roofs with pitches as low as 1-in-6, special care should be taken to avoid premature failure.

Asphalt and wood shingles are common, readily available shingle products. Asphalt shingles tend to be less expensive than their wood counterparts. Their surface is coated with granulated minerals used to deflect the ultraviolet rays of the sun. The mineral granules wear off the shingle over time as a result of abrasion and erosion. Once the granules have worn away, the shingle degrades quickly.

Warped, curled or worn shingles are generally indicative of normal wear and tear, unless the problems are confined to localized areas of the roof. Roof-wetting patterns should be observed in these cases. Often only replacement with a more durable product, carefully following manufacturer's instructions, provides a suitable remedy.

Wood shingles are made either as a shingle or a shake. Wood shingles are normally sawn into a tapered shape, while shakes are split or rived from logs.

Wood shingles and shakes are more susceptible to decay and need to be kept clear of leaves and conifer needles. The major cause of damage is cracking and warping due to poor roof ventilation. Typically, they are more difficult to repair than asphalt shingles since it is time-consuming to lift and replace them one at a time.

Built-up roofs consisting of a multi-layer sandwich of roofing felt and either asphalt or coal-tar pitch is common in low-slope

applications. A roof that is blistering, brittle or contains soft spots can lead to rain penetration. Its condition should be carefully examined. Leaks can travel through felt layers and show up in other locations, making them difficult to trace.

Other deteriorated elements of the roof should be replaced at the same time, along with any other repairs or upgrades to the roofing materials.

Given the extremes of the Canadian climate, an efficient and well-maintained eavestroughing system is beneficial to the performance of exterior finishes. A missing, poorly installed or deteriorated gutter system can cause uneven staining of exterior finishes, as well as premature paint failure of walls and the deterioration of trim and window frames. It can also cause interior damage if water makes its way inside the building's shell. This happens primarily when uncontrolled water flows against the building.

A gutter system may also prove ineffective simply because the size and number of downspouts is insufficient to handle a rapid accumulation of water. Water penetrating into the roof, causing damage to roof insulation and potential rotting of the roof structure, can lead to unwanted problems. The size and number of downspouts is the primary consideration in getting rid of roof water. If there is less than 100 mm<sup>2</sup> (0.16 in<sup>2</sup>) of downspout area for every 3 m<sup>2</sup> (32.2 ft<sup>2</sup>) of roof area, this may be the source of the problem.

Overflow may cause damage to both the roof and wall covering. Sagging eavestrough is a

primary cause of overflow. Refer to Figure 7-1. This may be the result of poor installation or broken or rusty eavestrough hangers. Gutters should be sloped 19 mm in 6.1 m (3/4 in./20 ft.).

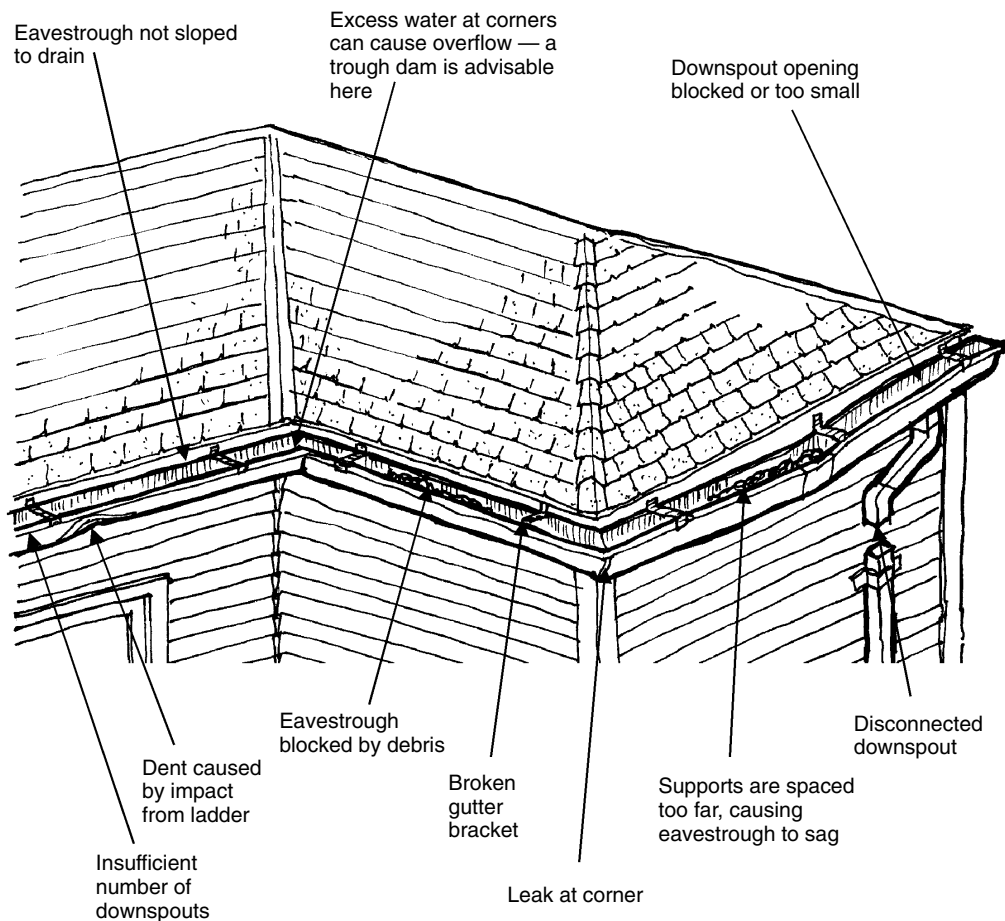
Gutters may also fill up with windblown dirt, leaves and the aggregate from worn asphalt shingles. Problems can result from the debris clogging the rain diversion system or from the added weight of the debris. Extra weight can put a strain on the hangers and, if the debris retains moisture, it can cause premature rusting of the galvanized eavestrough. Plastic gutters tend to be more resistant to corrosion.

Soil erosion around foundations immediately below downspouts can occur when run-off is too concentrated and improperly diverted away

from the foundation wall. The soil beneath the foundation can become saturated and, in extreme cases, promote differential settlement. Basement leakage, damage to finished interiors and localized foundation cracking are the most common symptoms of improper rainwater diversion.

Rainwater can be collected in a cistern that can be used for garden watering and car washing. The cistern reduces the need for municipal water and decreases the load on storm sewers and water treatment services. Many municipalities in Canada do not allow the direct connection of downspouts to storm sewers. Of course, downspouts should never be connected to the weeping tile system.

**Figure 7-1: Defects Typically Encountered with Eavestrough Systems**

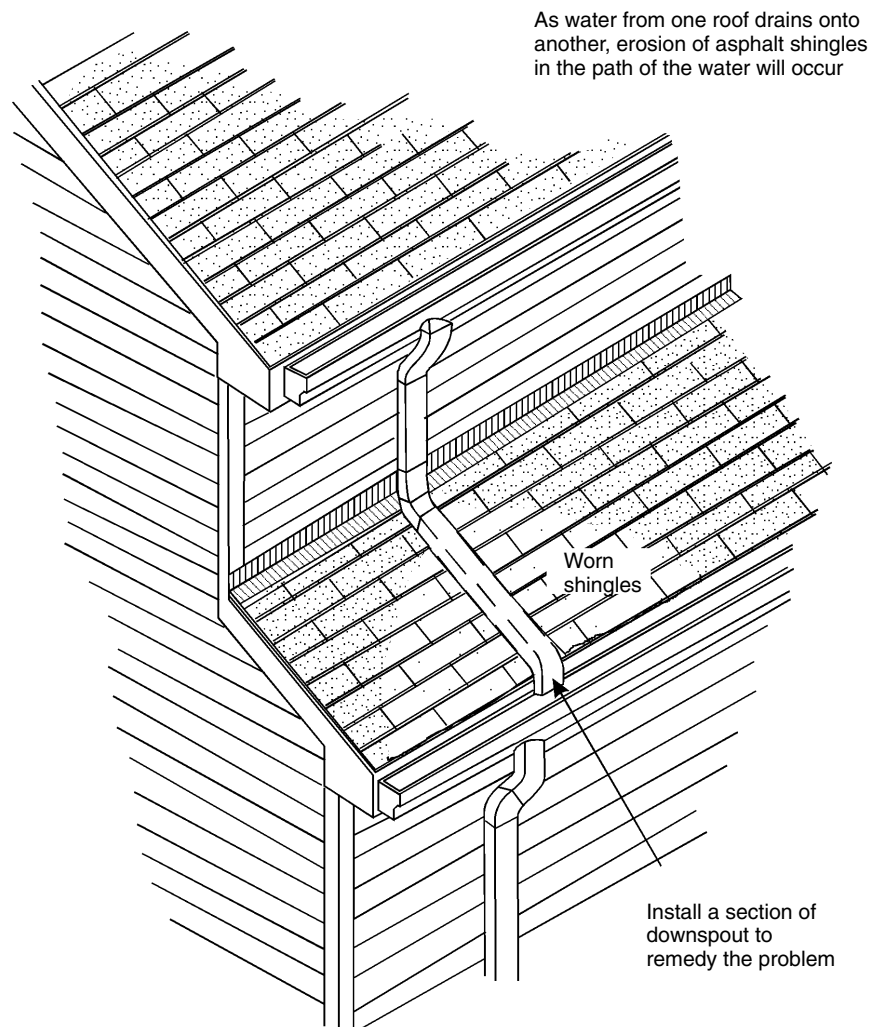


Another problem caused by the concentrated run-off from a downspout occurs when one roof's drainage system empties on to another roof below. The shingles below are subjected to excessive water wear and will deteriorate well before other parts of the roof. Repairing the roof without modifying the rainwater diversion system will only lead to a repeated premature failure. The use of an extension to connect the two drainage systems will avoid the problem. Alternatively, using an extended perforated pipe to dissipate the water evenly and in smaller amounts over the roof area will avoid the problem. Refer to Figure 7-2.

Flashing directs water away from the envelope, typically at joints between materials or components. Flashing is commonly located at:

- the bottom of the wall to direct water from the sheathing paper (acting as a weather barrier) away from the wall;
- the top of windows and doors;
- the intersection of roofs and walls;
- roof valleys or other changes in roof slope;
- chimney, vents and plumbing penetrations;
- the top of parapets as cap flashing; and

**Figure 7-2: Erosion of Asphalt Shingles**



- joints between dissimilar materials (e.g., siding and masonry).

Damaged or corroded flashing is a serious cause of rainwater penetration. All exposed flashing should be examined for defects if any telltale signs of water leakage are visible. Caulking should not be used as an alternative to flashing. Refer to Figure 7-3.

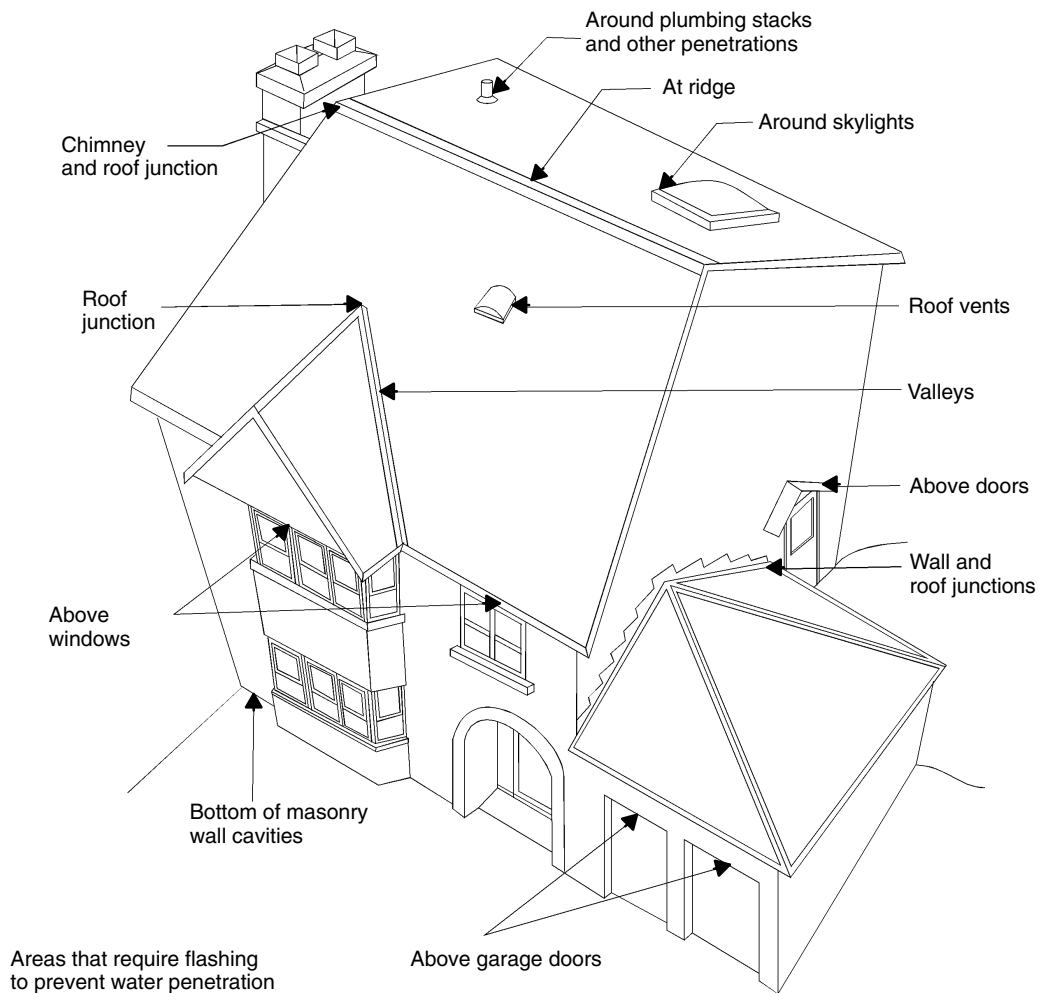
On sloped roofs, icicles can form at the eaves, causing water and structural damage and posing a threat to occupants and passers-by. Ice dams can also cause other problems, like sagging eavestroughs and peeling paint on fascia boards. They cause millions of dollars of damage each

year, and although the damage can be repaired, prevention is the best solution.

Leakage of water at the eaves is the most serious problem that ice damming causes. Water from melting snow can be prevented from running off the roof by the ice formation. In roofs with overlapping finishes, such as shingles, tiles or corrugated sheet metal, the backed-up water may leak under the roof finish into the roof and wall assembly to cause considerable damage.

The leakage can reveal itself as wet insulation and framing, decay in the wood, paint failure, efflorescence on masonry walls and damage to interior finishes. Figure 2-10 illustrates the process that creates ice dams.

**Figure 7-3: Location of Flashing**





Ice dams are the result of three combined conditions:

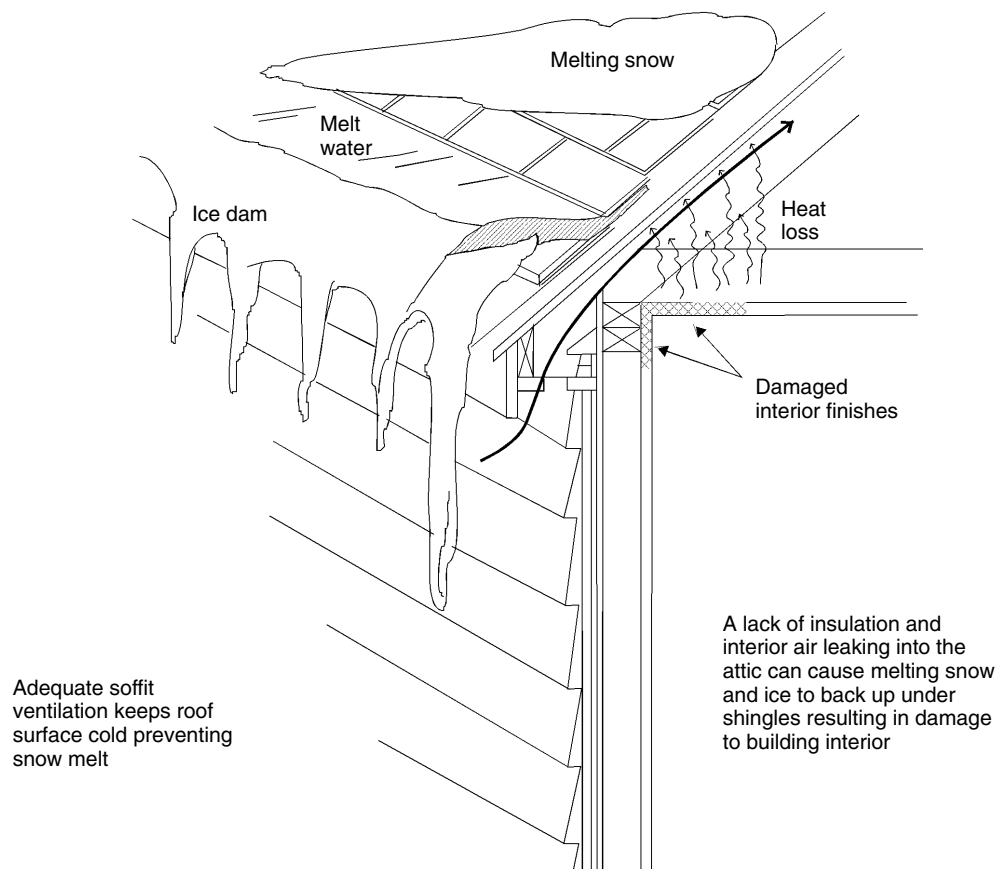
- snow on the roof;
- heat from the building melting the snow on the roof; and
- cold air temperature refreezing melted snow at the roof edge.

Water from the snow melts because of the heat from the building's interior and flows down the roof under the snow until it reaches the edge of the roof. As it drips over the edge, it is cooled by the outside air and refreezes. As the snow continues to melt, ice can accumulate at the edge of the roof or in the eavestroughing, where it

can form a dam that blocks the flow of water from the roof surface. Melted water can backup as a result of the dam and penetrate into the openings it encounters, including the spaces between overlapping shingles or other roofing units. Eventually, it will drain into the roof system and the building. When the outside temperature rises above freezing, the ice usually melts rapidly and slips or breaks away from the roof to create a falling ice hazard.

The mechanism for snow melting is the continuous heat loss from the house through the roof. Heat from the sun may also be a factor in melting the snow or in heating unvented attic spaces to cause melting. Heat loss through the

**Figure 7-4: Damage Caused by Ice Damming**



roof depends on the inside temperature conditions, the amount of insulation in the roof system, air leakage from inside the house and ventilation between the insulation and the roofing.

Ice damming damage is controlled by preventing water from entering the roof space and by keeping the roof surface cold. There are a number of ways to achieve this:

- installing eave protection as prescribed by local building codes;
- ensuring that ceiling insulation in the attic extends over the wall top plates, preferably to the same level as the rest of the ceiling;
- isolating the roof space from the living space by sealing all leaks between the house and the roof space.
- providing proper attic ventilation, particularly at the soffit, by installing the right amount of net free vent area, as prescribed by local building codes and ensuring that vents are not blocked by insulation; and
- choosing light-coloured roofing, particularly on roofs prone to ice dams.

Signs of algae, mold, mildew or moss can appear on surfaces of an exterior finish that have been subjected to wet or humid conditions. Surfaces that are continually damp will begin to host organic life. Signs of this will generally appear on walls and roofs as moss growth. As moss continues to grow, it can create a micro-environment that retains moisture, causing further damage. The presence of trees also encourages organic activity on walls and roofs. Trees not only shed organic debris that can end up in a fertile and rotting area of the roof but also prevent the penetration of sunlight and air circulation that could otherwise dry out the area. Insight 3 — Health Hazards from Mold — in Chapter 3 provides more information.

### ***Inadequate Rain-and-snow-shedding System on Walls***

Defective rain-shedding wall systems can lead to damage to both exterior and interior finishes. Exterior cladding that shows signs of decay, staining or uneven weathering points directly to a defect in this building system. Damage to

interior finishes may also be indicative of problems with this system, although many other causes may be at play.

Rain is directed away from the walls of the building first by the cladding, which in most cases does not provide an impervious barrier to weather but is merely a screen. It deters rain as it is driven into the house by absorbing the pressure exerted by wind and stops rain and snow from entering the wall system. Air and moisture are normally able to penetrate through the exterior cladding until they reach the main defence against weather — the weather barrier.

The weather barrier consists of multiple layers of sheathing paper, housewrap or a combination of sheathing and sheathing paper. These restrict the movement of rain and wind entering the wall cavity. They direct water that penetrates the cladding to the flashing at the bottom of the wall or over doors and windows. The flashing, with its drip edge, directs water away from the building. Houses clad with brick or masonry will be flashed and have weepholes to allow water to escape from the air space behind the brick. Of course, the mortar droppings must have been removed so as not to block the holes.

Weepholes should never be plugged, caulked or covered by soil. Home-owners should understand how important these are for a properly functioning wall assembly. They allow moisture that collects behind the wall an easy escape route. Damage to the interior and exterior finishes can result if these holes are plugged. Always check to ensure they are free of debris when assessing the house.

Staining on walls is sometimes the result of a previously removed fixture or from paint. Stains of this type can normally be removed without fear of reoccurrence. Other stains need to be considered more carefully.

Walls that are wetted by roof water diversion systems often appear stained, unsightly and unevenly weathered. Where possible, walls should always be uniformly wetted by rain. Your remedy to this staining problem should focus on changing the wall's wetting pattern rather than just cleaning the stains from the wall.

Staining of an exterior wood-clad wall along the bottom is often noticeable. This can occur where snow sits against the house during the winter. Ensure that home-owners understand the

importance of removing this snow as part of a regular home maintenance program.

Dirt on siding is often the result of splashing water. Splashed dirt left to sit on the wall for long periods can permanently stain the siding materials or finish. It is generally less damaging to non-wood sidings. Soiled brick cannot be wiped clean but will need to be washed with a hose and wire brush or a power spray.

Stained or damaged window or door frames are often related to improper or deteriorated flashing. In many cases, poorly sealed sills can also lead to water damage. The cause of the damage in these cases is often self-evident.

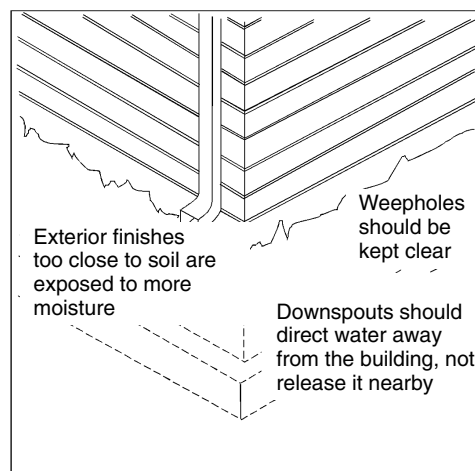
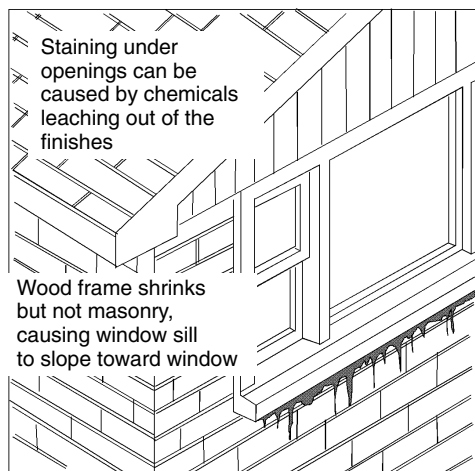
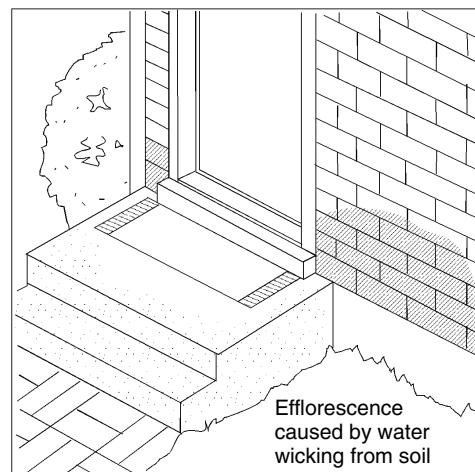
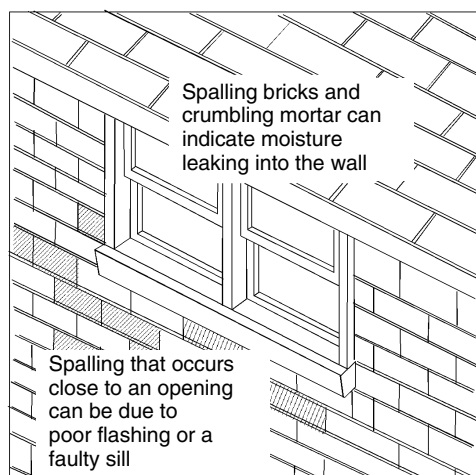
Repairing the flashing or resealing the sill often provides the required relief.

Interior damage from a defective wall rain-shedding system can be quite serious. Problems at the base of the wall or at the foundation can damage every component within the wall assembly. Structural and non-structural elements can be affected. Ensuring that rain is properly shed is among the most important aspects of any assessment that you perform. Refer to Figure 7-5.

### ***Indirect Causes of Finish Distress***

A number of indirect causes of distress to the exterior finish need to be considered as part of your assessment. Cracked or deformed roof and

***Figure 7-5: Problems Encountered with Exterior Masonry Finishes***



wall cladding, stained or spalled brickwork, or rotted wood siding can signify problems unrelated to the brick or siding.

Wavy shingles or roof finish can relate to inadequate structural support, with structural members spaced too widely apart or sheathing that is not thick enough. A regular wave in the roof finish is an indication that this is likely the problem.

Siding can appear wavy when it is improperly installed, especially over compressible sheathing, such as rigid glass fibreboard. Siding has also been known to buckle at the second-storey header of two-storey houses. Not allowing for the lumber shrinkage is the root of this problem. Siding should be hung from the structural members that support the sheathing. It should be nailed loosely, without deforming the sheathing or restricting movement due to expansion and contraction.

Cracked brick or masonry, or deformed siding, can be the result of processes deep in the soil. Adfreezing, particularly at exterior garage walls, has been known to lift foundation walls and cause cracking and deformation of the cladding. Chapters 2 and 3 discuss this issue in more detail. Installing a membrane that allows soil to slip against the foundation wall often prevents this problem. Polyethylene, exterior foundation insulations and air-gap membranes have been used successfully in the past. Alternatively, a backfill that is not susceptible to adfreezing can be used.

Other below-grade problems, like a missing or defective dampproofing system, can cause unsightly staining or spalling of above-grade masonry. Capillary water can bring salts to the surface of the brickwork as efflorescence and at times can be the underlying cause of brick spalling. Read Insight 7 — Efflorescence — for more details.

Inadequate grading can cause damage to wood sidings. Soil should never be allowed closer than 200 mm (8 in.) from any cladding that can be adversely affected by moisture. Replacing improperly installed, damaged siding in locations with insufficient clearance above grade provides only temporary relief if the underlying cause of the problem is not remedied.

Heat-deformed shingles are sometimes caused by improper installations, particularly over cathedral ceilings. Maintaining adequate roof ventilation will dissipate the buildup of heat within the roof cavity in summer. Inadequate roof venting can cause shingles to melt and deteriorate prematurely. Always install roof finishes according to manufacturer's installation instructions and always adhere to the requirements of local building codes.

Select materials that are appropriate to the application. Siding materials exposed to high-use areas need to be durable and impact-resistant. Children's activities, for instance, can dent and damage some siding materials. Always take special precautions when removing hazardous sidings, such as those made of asbestos. Wear proper protection and ensure proper disposal. Each project will place special demands on the materials used. Ensure that home-owners understand the importance of maintenance and the effects of neglect. Consider each application carefully.

## RENOVATION IMPLICATIONS

As already noted, the key to exterior finish renovations is the proper selection of materials for each specific application. This, together with proper installation procedures that carefully adhere to manufacturer's instructions, will help to avoid premature failure.

Because the exterior finish is exposed to rain, snow, wind and sun and experiences expansion and contraction, regular maintenance is necessary to ensure long-term performance. Remind home-owners that periodic recaulking, repainting and refinishing are important if walls and roofs are to continue to function properly.

### Roofing

The thoughtful selection of exterior finish materials should be based on your evaluation of the adverse conditions to which each material will be exposed. Roof materials, for example, should be chosen according to the performance needs of the house.

The most common types of roofing on pitched roofs in our climate are shingles made of asphalt, wood, mineral fibre or clay tile. Prefinished sheet-metal and new recycled

**Insight 7 — Efflorescence**

White powdery stains that appear on the surface of bricks, masonry, concrete and other surfaces can be brushed away or cleaned. But they often reoccur, indicating a deeper problem. This powdery staining is called efflorescence and is caused by water wicking through the materials.

A porous material can absorb, hold and wick moisture to other materials by capillarity. As the water inside the material moves, it dissolves salts present in the material. The water is drawn to the surface where it evaporates, leaving behind the salts which become white deposits.

Whether or not a material develops efflorescence depends on three factors:

- free salts;
- availability of water; and
- a material that can wick water.

The material must be partly composed of salts. Salts can come from within the masonry, grout, backing, or from the surrounding water that the material comes in contact with. The material must also contain water and be able to wick the water within it from one location to another. The water can come from the surrounding soil, wetting from precipitation or leakage into the assembly. Finally, there needs to be evaporation from the surface of the material. Without evaporation, surface salts would not appear.

There are a number of methods for dealing with efflorescence on building surfaces. Unfortunately, most of these address only the symptom, often resulting in reoccurrences. Efflorescence can be removed from the surface with a wire brush and a hydrochloric acid solution, but it is important to find the source of the moisture and eliminate or control it.

Soil water rising through concrete foundations to masonry walls requires some sort of capillary break. A drainage or dampproofing layer will usually accomplish this. A roof leak running into a masonry wall cavity can be dealt with by repairing the defect. Ground water can be directed away from the building, and other good rain-shedding practices can be followed.

Another practice that appears to deal with the problem but doesn't is silicone surface treatment. This prevents salts from reaching the surface. However, the salt may be deposited below the surface of the masonry, possibly resulting in spalling, flaking or the popping of brick faces.

The best method for dealing with efflorescence is by preventing it from occurring at all. Choose appropriate materials with no history of efflorescence problems. Most importantly, proper detailing to ensure that water is not permitted to contact or enter porous materials will prevent efflorescence and many other problems. Prevent the excessive wetting of walls by ensuring the rain-shedding system is properly designed and installed. To prevent problems, look for:

- properly installed flashing and dampproofing;
- grading that permits water to drain away from the house;
- good-quality air and vapour barriers; and
- brick veneer with proper air spaces and weep holes that are not plugged or clogged.

These are common elements that should be checked when efflorescence is noticeable.

polymer rubber roofing are becoming increasingly popular in residential applications. Flat roofs are commonly covered with single-ply roofing membranes or built-up roofing.

Asphalt shingles can degrade in sunlight in a way that other shingles do not. When exposed to sun and weather, the asphalt loses its suppleness, dries out and cracks. When the granules on the shingles wear away, they become brittle and degrade quickly.

Wood shingles are popular for their aesthetic contribution to homes and can be installed relatively easily on strapping or over spaced sheathing. This allows air to circulate around the shingles, keeping them dry and increasing their already long life span. Wood shingles deteriorate more quickly on shallow roofs, where they tend to stay wet longer. Cedar is among the most durable of wood shingles and the most widely available. The labour-intensive installation and the material cost can make this one of the more costly roofing options.

Slate shingles are one of most durable roofing materials. They can also be purchased used, making them an environmentally conscious choice. As their fasteners fail, slate tiles have been known to come loose. Once the slate cracks it is unrepairable and is often quite difficult to replace. Generally the flashing for this type of roof also fails before the slate does. Experienced slate roofers should be consulted for remedial work. High-quality installation is difficult for those with little experience. Although the quality of the roof is quite high, home-owners should know that proper maintenance is important and may be more expensive than a standard roof.

Architectural shingles are made from multiple overlapping layers laminated to form a heavier shingle with a textured appearance. They are long-lasting and come in a variety of colours and textures. They often attempt to imitate cedar or slate shingles, with varying degrees of success. They are often heavy and can be as expensive as the imitated material.

Clay tiles have an excellent fire rating and long life. However, they are very heavy and require a properly designed roof structure. Mineral-fibre shingles are also available as a lighter alternative to clay tile. These are made from Portland cement and reinforced with mineral fibre.

When replacing or repairing old mineral-fibre tiles, be aware that asbestos used to be the fibre of choice. The necessary precautions when handling and disposing of this material must be observed. With improved safety standards, new products contain no asbestos fibres.

Sheet-metal roofing, used traditionally on barns and outbuildings in Canada, is becoming increasingly popular as a residential roofing material. It comes in a variety of colours and styles. It is lightweight, making it an excellent choice for reroofing directly over damaged or worn roofs. In addition, most metal roof sheets have been manufactured from recycled materials, and the sheets themselves can be recycled even after years of use. The environmental benefits of this material may make it especially pleasing for some home-owners.

The type, and cost, of metal roofing varies widely from galvanized tin to copper (the most

expensive roofing material available on the market).

Built-up or tar-and-gravel roofing has traditionally been used to cover low-slope or flat roofs. It is composed of layers of roofing felt, alternated with mopped on layers of either bituminous asphalt or coal tar pitch. Single-ply roofing has, until recently, been used exclusively on large building projects but is becoming more common in residential applications. It is installed as a one-ply rubber membrane or modified bitumen (asphalt) membrane rather than as a layered process. This type of roof provides an excellent vapour barrier when installed correctly. For this reason, the installer must ensure that air is allowed to circulate between the membrane and the insulation in order to prevent moisture entrapment in the roof assembly.

New products, such as concrete tiles and fibreglass shingles, are entering the market all the time. Keep informed of product advancements. A new product might be just what you are looking for.

Also keep in mind that shingle or tile damage can result from wind pressures. Lower slopes on a pitched roof means that wind can exert more uplift pressures on the roofing than it can on a steeper-pitched roof.

The building's site, be it flat, suburban or urban is also an important consideration. Some roofing materials perform better than others in windy locations. Even self-tabbing shingles may need to be glued in windy locations. At the same time, securely attaching the roofing will be necessary when a building is greatly exposed.

### **Wall Cladding**

A range of wall cladding products are available for today's renovation projects. Siding, masonry and stone veneer, and stucco are among the most popular. Each brings with it advantages and disadvantages. The discussion below briefly outlines some of the implications of using each product.

Siding falls into three main categories: wood; wood-based composites; and manufactured materials. Many siding products are designed to look like wood. Cost, availability, ease of installation, maintenance, recyclability,

durability and attractiveness are all factors to be considered when choosing a siding.

Drop siding consists of tongue-and-groove horizontal boards installed without sheathing. It is primarily used on sheds and garages and is not completely watertight. You may encounter it in older houses where a covered porch or cold shed attached to the house has been converted to an interior room.

Board-and-batten siding is created by butting boards vertically and covering the joint with a thin vertical strip placed over top. This strip is the batten. Both drop siding and board-and-batten are long-lasting. However, longevity and cost will vary according to the quality of lumber used. Normally, this cladding requires painting.

Lap siding is the overlapping of horizontal wood boards applied over sheathing. The traditional Canadian clapboard house is an example of lap siding. The boards may be bevelled, and strips of plywood are sometimes used to reduce costs. It is durable and can require regular maintenance such as painting.

It is essential that manufacturer's installation instructions be carefully followed. Ensure you attend to all areas of the installation that need to be caulked or sealed. Remember the important rain- and snow-shedding function that the siding provides. Wood siding can develop rot, particularly at its joints. When installing it, ensure that water can easily drain out from behind. Some siding products must be installed over furring strips. This is particularly important in wet, coastal areas of the country. Use only the recommended nails. Nail heads normally keep overlapping boards apart and help prevent the wicking of water up behind them.

Where rot is suspected, damaged boards will need to be removed. Wood siding should never be placed in contact with soil or with surfaces that can collect water, such as the floor of balconies or the top of canopies. Also, wood siding should never be placed less than 200 mm (8 in.) from grade.

Vinyl siding is usually designed to simulate lap siding. It is inexpensive and requires little or no maintenance. Some grades of vinyl siding crack easily in cold weather and discolour in sunlight. In some instances, it can be damaged by impact or extreme heat. Ensure that it meets the

minimum product standards outlined in your building code.

Vinyl siding, if improperly ventilated or insufficiently spaced over old siding or sheathing, can act like a vapour barrier on the cold side of the wall. Follow the recommended installation procedures and refer to your local code.

Aluminum and other metal siding tends to be more costly than vinyl. Where new types of vinyl siding are relatively supple and durable, aluminum still tends to dent easily. Note carefully that inattentive finishing details at corners or poorly installed mouldings or trim around window and door openings can cause water penetration. At the same time, caulking and sealants should be applied only to areas identified by the manufacturer. This also applies to vinyl siding. Improper caulking or sealing can trap moisture in the wall that can damage susceptible materials.

Wood shingles used as siding are very long-lasting and usually applied with a double overlap versus a triple lap, for added weather protection. They are as labour-intensive to install as wood shakes or shingles.

Fibre-cement siding is manufactured from a composite of Portland cement and cellulose. It is installed like any lap siding. Companies will often guarantee these products for up to 50 years. Paint-on fibre-cement board will last up to 10 years. It is non-combustible, does not rot, dent, crack or attract termites. Fibre-cement board is becoming more and more popular in some parts of the world, though it has not yet made a huge impact in Canada. In some cases, it can cost about the same as vinyl siding.

Hardboard and other wood-based composites, like oriented strand board (OSB), are alternatives to wood siding. They resist water damage well, are inexpensive and can look like wood. However, they are prone to water absorption at the job-site, and care must be taken when they are installed. They are heavier than wood and require more than one person to lift and nail in place.

Brick and masonry cladding is popular in many regions of the country. While relatively maintenance-free, brick is one of the more expensive cladding alternatives that is available. Laying brick is best left to experienced trades.

Repointing of existing brickwork may be necessary, particularly at the corners of the building where erosion is accelerated by wind, rain and dripping water. The weather resistance of a brick-clad wall largely depends on the condition of the mortar joints. Refer to Figure 7-6.

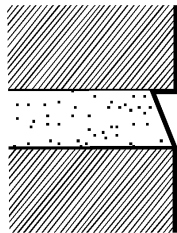
When repointing masonry that predates the Second World War, certain precautions should be observed. Severe, irreparable spalling and widespread cracking of the brick surface may result. The damage is usually linked to differential movement and expansion between the new mortar and old bricks.

The mortar used to repoint a masonry wall system should be compatible with the masonry units. Be aware that old mortar is not like new mortar in the same way that old brick differs from new brick. Previously, mortar was relatively soft, made from river sand and burned lime, and had a low compressive strength. Modern mortar, such as Portland cement, is designed to withstand extreme pressures and is hard and rigid. Using an appropriate and compatible mortar mix will ensure bonding between units.

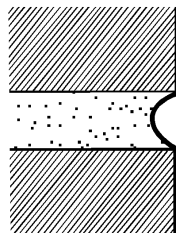
Stucco is a common renovation option for exterior finishes. It can add colour and

**Figure 7-6: Types of Mortar Joints**

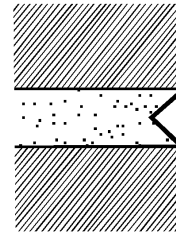
**GOOD TYPES OF JOINTS**



Weathered

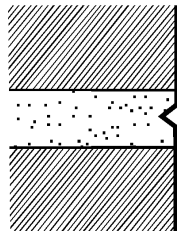


Concave or rodded

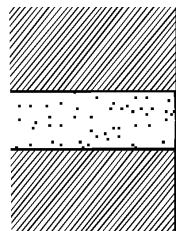


V-shaped

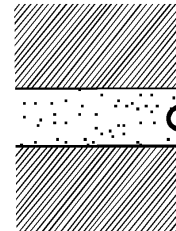
**FAIR TYPES OF JOINTS**



Ruled

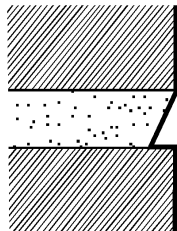


Flush or plain cut

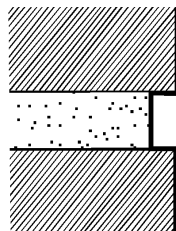


Flush and rodded

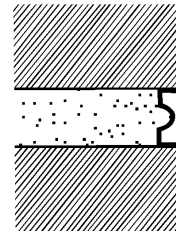
**POOR TYPES OF JOINTS**



Struck



Raked



Beaded

Certain types of mortar joints are more effective at weather-sealing a wall than others



rejuvenate a building. There are a number of stucco products on the market. These range in quality, price and durability. In general, it is important that you provide a sound substrate with the proper stucco lath to support the stucco. Consider expansion and contraction. Left to itself, most stucco finishes will crack if no crack control joints are provided. Follow the manufacturer's recommendations carefully if you are attempting the work yourself. Stucco substrates are readily available that specialize in the application of the product. Before you hire someone to do the job, however, look at some of their completed projects. Bad stucco jobs are very difficult to hide. The finished project becomes a good contractor's best reference.

### ***Air and Vapour Barriers***

When approaching any exterior work on the house, think of it as maintaining a continuous and delicate protective shell, rather than just working on a roof, wall or window. The relationship of the exterior finish to the air and vapour barriers is an important part of maintaining the shell's integrity. The shell has to work effectively as a unit if it is going to function properly and provide successful shelter from the elements.

Housewraps are becoming more popular as weather barriers and, in some cases, air barriers. Extending from the top of the wall to the bottom of the header, they help trim energy bills and, more importantly, help prevent moisture problems in the walls. Their use is recommended whenever the building is reclad.

As a weather barrier, the housewrap keeps wind and rain out of the wall assembly, preventing moisture damage and enhancing the effectiveness of the insulation.

As part of an air-barrier system, with seams and edges sealed, housewraps can control the infiltration and exfiltration of building air. Reducing the movement of air also reduces the movement of heat and moisture. Because of their effects on air infiltration, housewraps, like any other air barrier, need to be considered in light of indoor air quality and combustion appliance operation. Refer to Insight 4 — Airtightness, Depressurization and Combustion Appliances; and Insight 9 — Airtightness and Ventilation.

Most housewraps allow water vapour to move easily through them, while keeping liquid water and, of course, air out. They also allow for cold-weather handling.

Do not use a regular tape to seal the joints. Even though sheathing tapes are expensive, do not use duct or packing tapes as substitutes to seal seams. Sheathing tapes are designed to adhere to housewraps for the life of the building through a whole range of temperatures.

Housewraps are not all the same. Some have distinct inside and outside faces, while others do not. Installed with the wrong face out, some may do more harm than good.

It is acceptable to apply housewrap over existing felt sheathing if the felt is in good condition. The air-barrier membrane applied over the sheathing and beneath the finish siding is considered sound practice in the tightening up of any building structure. As these membranes prevent outside air from getting into the house, they make the control of internal humidity much easier than without them.

In cold climates, the lack of an effective vapour barrier on the warm side of the insulation can allow condensation to collect inside walls or on the back of low-permeability siding. This moisture can lead to paint failure or decay of the envelope's wooden components.

At times, sheathing or siding with low vapour permeability is used in the renovation of the house's exterior. Materials like aluminum, vinyl or foamed plastic insulation, installed on the outside of the wall, may trap water vapour inside the wall cavity. The trapped moisture can condense and cause damage. Placing vinyl over the old wood siding, for instance, can mask or accelerate water damage. The first step in avoiding problems of this type involves limiting the vapour that flows into the wall. This is achieved by ensuring that a material with very low vapour permeance is installed on the warm side of the insulation. Typically, 6 mil (0.15 mm) polyethylene provides this type of vapour control. It should always be in place when walls are reclad with vinyl or aluminum siding, or where foamed plastic insulating sheathing is added. Your local building code provides more details on this important requirement.

Exterior air and vapour barriers are generally not permitted in houses unless they are warm enough not to support condensation in winter design conditions. In practice, that means that joints in plywood, waferboard sheathings or sheathing made from low vapour-permeable foamed plastic must not be taped or caulked when installed on the outside of the building's envelope. This avoids trapping moisture-laden air that can cause condensation and water damage.

### HEALTHY HOUSING EXTERIORS

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Changes to the outside of the house can include choices that will make the renovation a healthy one. Occupant health can be improved by properly separating any exterior cladding or roofing materials that may off-gas into the inside of the house. Temporary ventilation during the renovation work, and proper ventilation after it is completed, will help to clear any fumes that entered the house during the renovation.

Resource-efficient exteriors use durable materials that will last under harsh weather

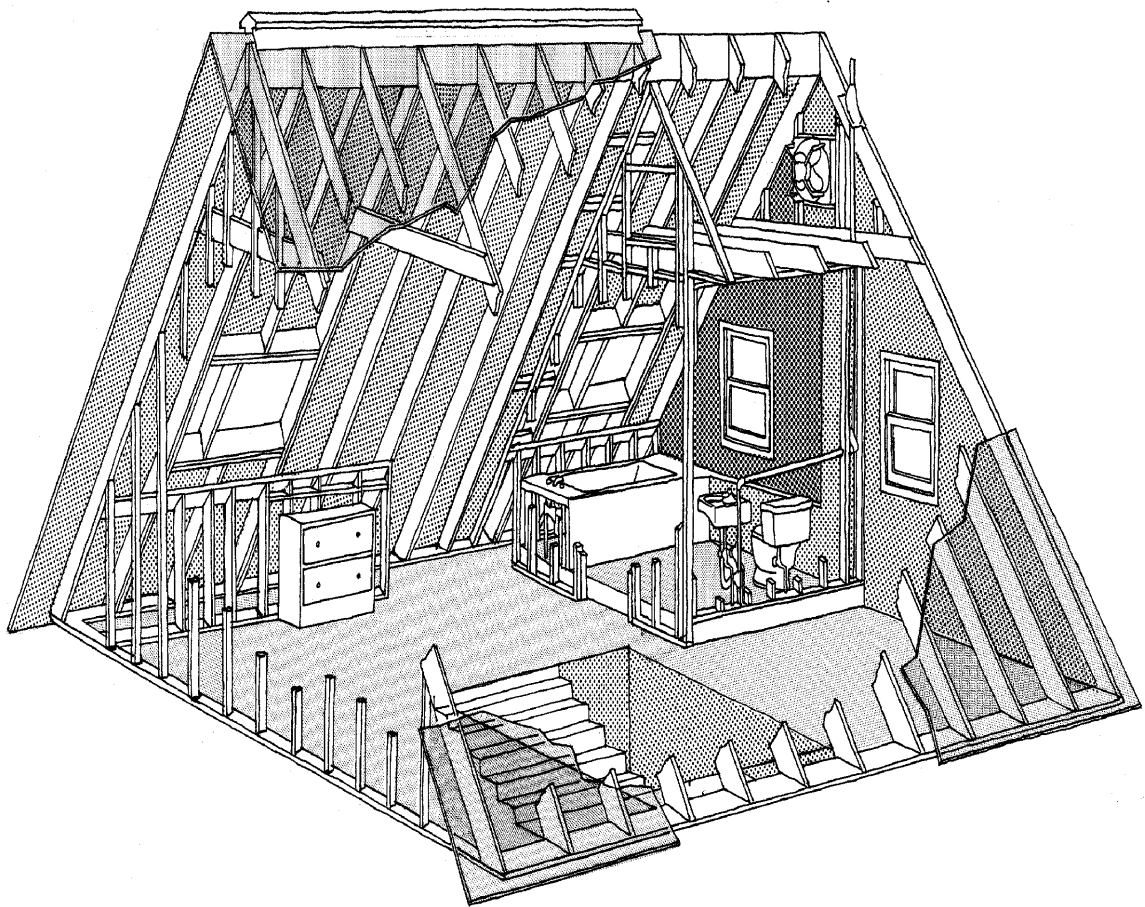
conditions. The materials chosen can be made from renewable or sustainable products. If they are produced locally, burdens on the transportation systems are reduced. Separating reusable or recyclable materials before sending wastes to the landfill site is another environmentally responsible practice. Disposing of hazardous wastes properly, particularly lead paints and coatings, and asbestos siding is essential. In addition, healthy homes will have improved performance characteristics, often reducing energy and other operating costs for the home-owner.

Before beginning new work on exterior finishes, try to remedy any existing problems. This ensures that problems will not reoccur and help new work to be problem free. When choosing an exterior finish, consider the effects it might have on other building systems. A finish should be appropriate for its location and take into account the loads that will be imposed on the wall system. Preventing potential problems will ensure customer satisfaction and prevent costly callbacks.

# Attic Conversions

**C**onverting an attic into a living space involves changes to the entire house. Many systems in the existing house affect the new living space. Poor structural support, inadequate mechanical services, a leaking roof and missing air barriers are just some of the conditions that might need to be fixed before the renovation can proceed. Many of these items may not pose a problem in the existing house but can adversely affect the performance of the new renovation.

The conversion of the attic will introduce new loads on the various systems, from structural to plumbing, of the existing building. The changes made during the renovation will need to be carefully considered. This chapter addresses the many issues involved in converting the attic.



### INTRODUCTION

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Depending on the type of roof design, the conversion of the attic can be achieved in an economical manner that enhances the liveability of the home. A need for additional living space, the desire to remain in a familiar neighbourhood and the desire to improve the resale value of the home may all motivate such conversions. Often, limits imposed by the site make building a new addition to the house difficult or impossible. This leaves the attic conversion as the only realistic alternative. In addition, converting an attic is often more economical than building a new addition or a new house.

Conventionally framed attics with rafters and ceiling joists are usually easier to convert to living space. Truss roof structures do not normally lend themselves to this type of renovation project. In other cases, the roof structure may be too weak to accommodate new superimposed loads.

The typical attic conversion can involve upgrading the roof structure, adding insulation, building kneewalls and partitions, adding dormers, stairs, windows or skylights, installing new plumbing and electrical wiring, and installing drywall and flooring. Many of these changes will have implications beyond the attic conversion that can affect the performance of the entire building.

The conversion of the attic, like other renovation projects, requires that the existing building be assessed to determine how well it is able to accommodate the renovation. House designs and roof forms vary, with some more suited to attic conversions than others.

The assessment may reveal problems with ventilation, damage from water or inadequate structure. Understanding these problems and how to remedy them are fundamental to successful attic conversions.

The design process normally begins with a review of existing zoning bylaws to determine whether increasing the floor area of the building into the attic is permitted. Measured drawings of the existing building can usually begin once initial planning issues are dealt with. Details of

the renovation can then be added to the drawings of the existing house both for construction and the building permit.

The impact of an attic conversion can be minimized by looking at the overall planning functions of the existing house layout. New functions should be organized to tie into the existing ones. You will need to resolve common problems like stair access, structural support and extension of services into the attic. Stair access, in particular, requires that you determine how to reach the upper level, the relationship to the existing stair system and other access alternatives that may be available.

The roof slope and height to the underside of the existing roof ridge will help to determine if the attic space is usable. The attic space must have sufficient headroom if it is to accommodate living space. You will also need to provide light, fresh air and a means of emergency escape. Together, these will make the space a proper extension of the home.

### EXISTING CONDITIONS

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A review of the existing state of the house is recommended prior to contemplating any new work. Make note of all existing and potential problem areas and bring these to the attention of your client.

The most common questions that arise in projects of this type will need to be resolved before the work begins. These questions often include:

1. Are the footings adequate to take the additional loading imposed by new living space?
2. Are the existing building structure, attic floor and load-bearing walls adequate for the loads to be imposed?
3. How can existing ceiling joists be reinforced to accommodate the new living space and the additional equipment?
4. Are the rafters able to accommodate adequate levels of insulation and still have sufficient space for roof ventilation?
5. Can a proper stair access to the attic be easily created?

6. Will special provisions for an emergency exit need to be provided for new third-floor spaces?
7. How will mechanical and electrical services be extended into the attic?
8. Is the condition of the existing roof covering adequate or will a new roofing finish be required?
9. Are there any existing problems to be corrected prior to starting the renovation project?

This last point will be considered further in the discussion that follows. You should also read the chapters on exterior finishes. Their condition is important because they protect the newly renovated attic.

Finally, remember the steps to providing renovations that perform well:

- Check the existing condition of the attic space;
- Determine the cause of any problems you observe;
- Formulate solutions and remedy the problems; and
- Renovate the attic according to plans.

## ASSESSMENT CHECKLIST

The assessment checklist for attic conversions identifies the condition of the attic prior to renovation. These issues are explained in detail on the referenced pages.

### ***Structural Damage and Foundation Support***

It's wise to assume that the foundation will not support the added loads that a new converted attic implies. The width and depth of footings for the house are normally based on the number of storeys they support, among other things. Converting the attic to new living space adds the live load of another full storey to the weight already supported by the footings. Check the width of the existing footing against what current building codes require for the given number of storeys.

The foundation should be solid with no cracks or crumbling that could indicate structural weakness. Consult a structural engineer or a competent structural designer if you observe any of these defects. Improper concrete placing and curing problems in some houses have left many foundations in older homes with defects. Chapter 3 discusses many more foundation problems that may be evident.

Check that the structure supporting the attic (including the exterior and interior walls, kneewalls and struts) is sound and not showing any signs of distress. Bowed walls and sagging floor and ceiling joists are an indication that the existing structure may not be able to support the type of renovation being contemplated. These symptoms will need to be investigated and corrected before you begin the new work.

Existing stairs that lead to the attic may be usable as part of the new renovation. You will have to check that these are structurally and functionally sound. Check for proper width, rise, run and headroom. Check for squeaking, loose or damaged boards, and that the stair structure is securely fastened. Insight 8 — Bearing Walls, Point Loads and Other Structural Concerns — provides additional information on this matter.

### ***Water Damage***

Problems found in the attic are often related to water, either in bulk form or as condensation. If you have not read Chapter 2, take this opportunity to review how the building envelope is expected to resist and manage the movement of water. Any water problems you notice should not be ignored. These will persist even after you renovate the attic and will undoubtedly continue to cause damage.

Roof leaks are among the most common water-related problem you will encounter in the attic. The problem may never have been serious enough to be noticed by the home-owner, but once inside the attic, telltale signs of the leak are evident. Dampness, mold and mildew or water stains are evidence of water leakage. Look for wet or water-swollen roof sheathing and wet or stained framing lumber or insulation. Examine the area around plumbing stacks and other roof penetrations. Look for water-damaged ceiling drywall or blistered, peeling paint. These are sure clues that a water problem exists in the attic. The attic may also show signs of leaks that

## Checklist

### STRUCTURAL DAMAGE AND FOUNDATION SUPPORT (page 147)

- ☐ inadequate footings
- ☐ weak foundation
- ☐ superstructure instability
- ☐ sagging ceiling or floor joists
- ☐ deflected floor joists

### WATER DAMAGE (page 147)

- ☐ peeling or blistering paint
- ☐ wet or damaged ceiling finish below attic
- ☐ leaky roof
- ☐ leaks around penetrations in the roof

### AIR AND VAPOUR PROTECTION (page 148)

- ☐ condensation problems
- ☐ hoar frost
- ☐ mold

### ATTIC VENTILATION (page 149)

- ☐ heat-deformed shingles
- ☐ inadequate soffit or roof venting

### SERVICES (page 149)

- ☐ inadequate heating of parts of the house
- ☐ deteriorated or substandard plumbing and electrical system

have already been repaired. Ask the home-owner about previous renovations that have taken place.

In addition to leaking flashing around roof penetrations, flashing at roof valleys and chimneys should also be checked. A worn or damaged roof covering can cause water to leak into the attic. As well, inadequate eave protection on a roof prone to ice damming may show water damage. All of these defects need to be repaired before embarking on the attic conversion.

Examine the condition of the roof covering. Signs of wear or deterioration should be noted

and remedial steps recommended to the home-owner. Review Chapter 7— Exterior Finishes — for more information.

### ***Air and Vapour Protection***

Condensation, visible frost on rafters or roof sheathing, and mold or wood rot are all possible signs of water vapour making its way into the attic and accumulating as bulk water. The first item you need to check is that the ventilation of the attic is adequate (as discussed below). Determine whether the attic was properly protected with a vapour barrier on the warm side of the insulation. Normally, polyethylene sheeting will be in place to limit the diffusion of

water vapour into the attic. In some attics, air-barrier protection will not be provided as required. The new renovation can make use of part of the existing insulation, air and vapour barriers. Where this is the case, make sure these are adequate. Check that ceiling fixtures, plumbing and mechanical penetrations into the attic are well sealed. All of these could lead to moisture problems.

Decaying wood members or sheathing should be removed before converting the attic. Depending on the nature of the renovation work, these may need to be replaced. Ensure that the structure that supports the renovation is sound and free of noticeable defects.

The new work will likely involve modifying the envelope system, including installing insulation, air and vapour barriers in new locations. Make sure the new work avoids any problems you have noted in the existing attic space. This is discussed in more detail in the Renovation Implications section of this chapter.

### ***Attic Ventilation***

Poor attic ventilation, due to inadequate vent areas or insulation-blocked vents, can lead to a number of observable problems. While moisture problems from condensation relate primarily to air and vapour protection, attic ventilation can reduce the incidence of these problems.

In general, the main benefit of attic ventilation is in providing a means to moderate the temperature of the roof. Keeping it cold in winter prevents snow from melting and causing ice damming; keeping it cool in summer prevents shingles from melting and deforming.

Ventilation of the attic roof is usually provided by continuous soffit vents and ridge, roof or gable vents. Regardless of how the attic space is renovated, the remaining attic and cathedral roof space must be suitably vented. Canadian building codes set minimum limits for ventilation of these areas. Refer to your local code for more details.

### ***Services***

Check the condition of services. Deteriorated or substandard plumbing and wiring should be replaced before new work begins. This topic is

discussed in more detail in Renovation Implications below.

## **RENOVATION IMPLICATIONS**

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When converting the attic to a usable space, there are a number of key aspects to be considered to ensure a properly performing renovation. First, a new supporting structure may need to be provided to handle the new live loads to be introduced. Second, a new envelope will need to be created that continues to resist weather and limit the movement of heat, air and water vapour. The new envelope should not be susceptible to moisture damage or damage from sun or ice. Attic ventilation will also need to be provided, even in difficult to ventilate spaces. In addition, the renovation of the attic will need to accommodate fire safety concerns, natural light and ventilation. It will also need to accommodate services from below, while not overloading existing heating, ventilation, air conditioning, plumbing and electrical systems. A good attic renovation also takes into account the transmission of sound to the spaces below. Finally, a good renovation incorporates Healthy Housing principles that enhance the value of the work.

As you consider these points and read the discussion that follows, remember that you will be selecting materials to perform as part of a component. They will substantially affect the overall performance of the renovation. Choose materials with a proven record of performance and durability. These will reduce callbacks, last longer and enhance your reputation with your clients.

### ***Structural Support***

Footings may need to be checked to ensure they are wide enough to support the additional storey of construction. You may need to refer to drawings that the home-owner or municipality has on file or excavate to determine the size of the footings.

The original floor of the attic space was not likely designed to accommodate its new use. You should recognize that the existing ceiling joists are often only sized to support the ceiling finish and are not designed to support live loads from people, furniture or equipment. Existing ceiling joists may need to be doubled, or a new,

**Insight 8 — Bearing Walls, Point Loads and Other Structural Concerns**

Always approach the alteration of a wall with care. Whether removing a wall, adding openings or cutting into existing structural members to accommodate new ducting or piping, it is important not to undermine the carrying capacity of the existing structural members.

The first step is to determine whether the wall is load bearing or not. A load-bearing wall will often have a double top plate, and usually runs perpendicular to the joists above and beneath it. It may also be located above or below other structural components, such as beams, posts or other walls. If the wall is load bearing, or if you are uncertain, you may want to seek the advice of a structural engineer, architect, or technologist.

When altering any wall, load-bearing or otherwise, remember to check for utility outlets, plumbing or ducting hidden inside. These should be shut off and rerouted before the wall is altered. The ceiling above should be supported with temporary supports before any work takes place. Even a brief period without support could result in disaster for some homes. Supports will also be useful in case a non-load-bearing wall has actually been supporting some loads.

If the wall to be altered is discovered to be a load-bearing wall, advise the home-owner of any changes or additional expense. The expense will be greater for removing parts of a structural wall than a non-structural one. Explain to the owner that lintels, beams, girders

and possibly posts may be required to carry the weight of the building. Unfortunately, the loads from floors and ceilings above do not disappear with the removal of the wall.

The size of any structural members will depend on a number of factors. These include the span of the element, the area of floor, roof or ceiling that it supports, and any special loads from tubs, jacuzzis or structural elements overhead. Consult applicable building codes when determining sizes. If a load-bearing wall supports another structural element, a professional should be brought in before any work is started.

Be sure to account for the support of the new structural elements. Have cut members been properly reinforced? How will the ends of a new beam be supported? If there are posts, how will the load be transferred to the foundation below? Will a new column footing be required? Does the post sit directly over a beam? Has the beam been designed to accommodate the loading from the post properly? Will lumber shrinkage have to be considered for matching-up old and new surfaces?

All structural elements need to be supported. For example, a post resting on floor sheathing between joists or beams could cause warping of the floor or could punch through the floor system. Remember that all structural loads must eventually be transferred to the ground. Consider any changes carefully before you start the renovation.

deeper floor system installed. Refer to your building code or see a structural designer for advice.

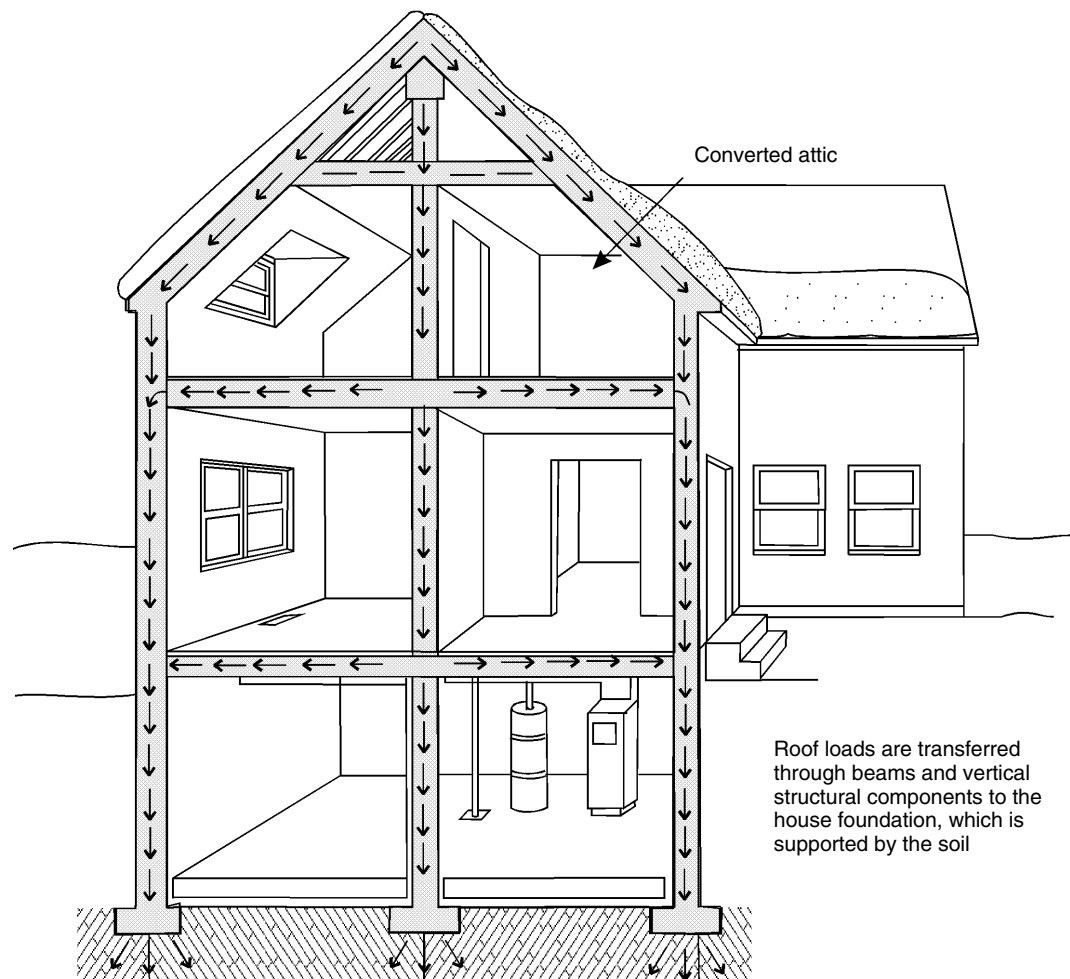
The roof of the house is subject to the most diverse loading conditions. The loads on a roof structure include the dead loads of the roof components themselves (the roof rafters, sheathing and roof covering materials); and live loads from snow, rain and wind. In the past, it was customary to design roofs with a steep pitch in order to shed snow, with the gable as the most common roof design. Refer to Figure 8-1.

In some roofs, you will notice a ridge beam with intermediate supports. The intermediate supports, such as posts or a kneewall, can obstruct the floor space of the attic. Removing

the intermediate supports will require a new ridge beam that spans the full length of the house. Alternatively, for roofs pitched 1-in-3 or greater, rafters and ceiling joists or wall ties can be connected as an A-frame to support the roof loads. In this case, the ridge beam serves no purpose and need not be supported in intermediate locations. The National Building Code of Canada can provide more details, or you can consult an engineer for help. Refer to Figure 8-2.

Collar ties are normally used as the ceiling of the new living space. Where existing collar ties are removed or relocated—for instance, to provide additional headroom—always check to ensure that the existing rafters are able to



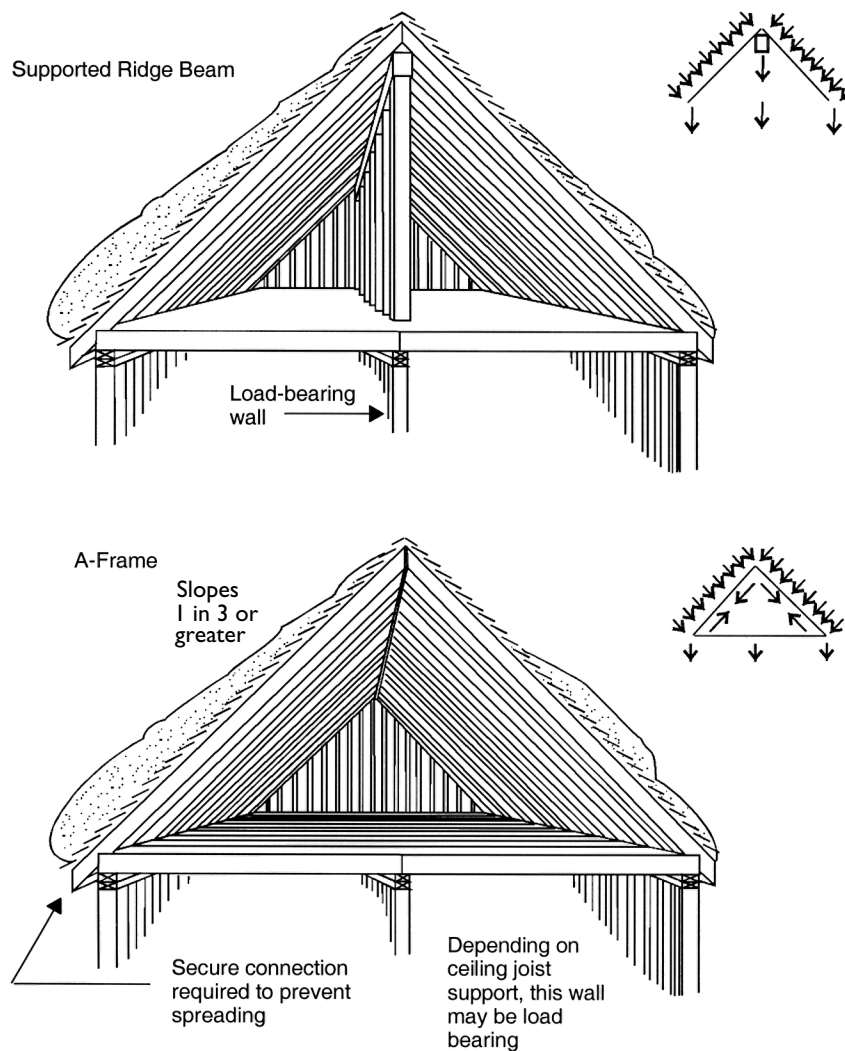
**Figure 8-1: Roof Loads at Work**

support the roof structure given their new span. You may need to double-up the rafters to continue to support the roof loads.

Dormers are often used to increase the headroom in a converted attic. In most designs, the ceiling joists of the dormer run at the same height and parallel to the collar ties. When building a new dormer, remember that whenever you cut into existing structural members, like rafters or collar ties, the existing structure needs to be braced. At the same time, make sure the new and existing structures are securely connected to each other. Refer to Figure 8-3.

Building stairs up to the new space can be a challenge, even for experienced renovators. The plan for the stair access to a converted attic should result from an analysis of the existing circulation patterns. Stairs function best if stacked one above the other as a vertical shaft, but this may not always be possible.

Stairs should be constructed so that they are suitably supported. Do not support stairs on the existing floor below without accounting for how the loads will be supported. You may need to add members, such as built-up beams in the supporting floor below, to transfer the loads to load-bearing vertical elements. Building codes

**Figure 8-2: Supported Ridges and A-frames**

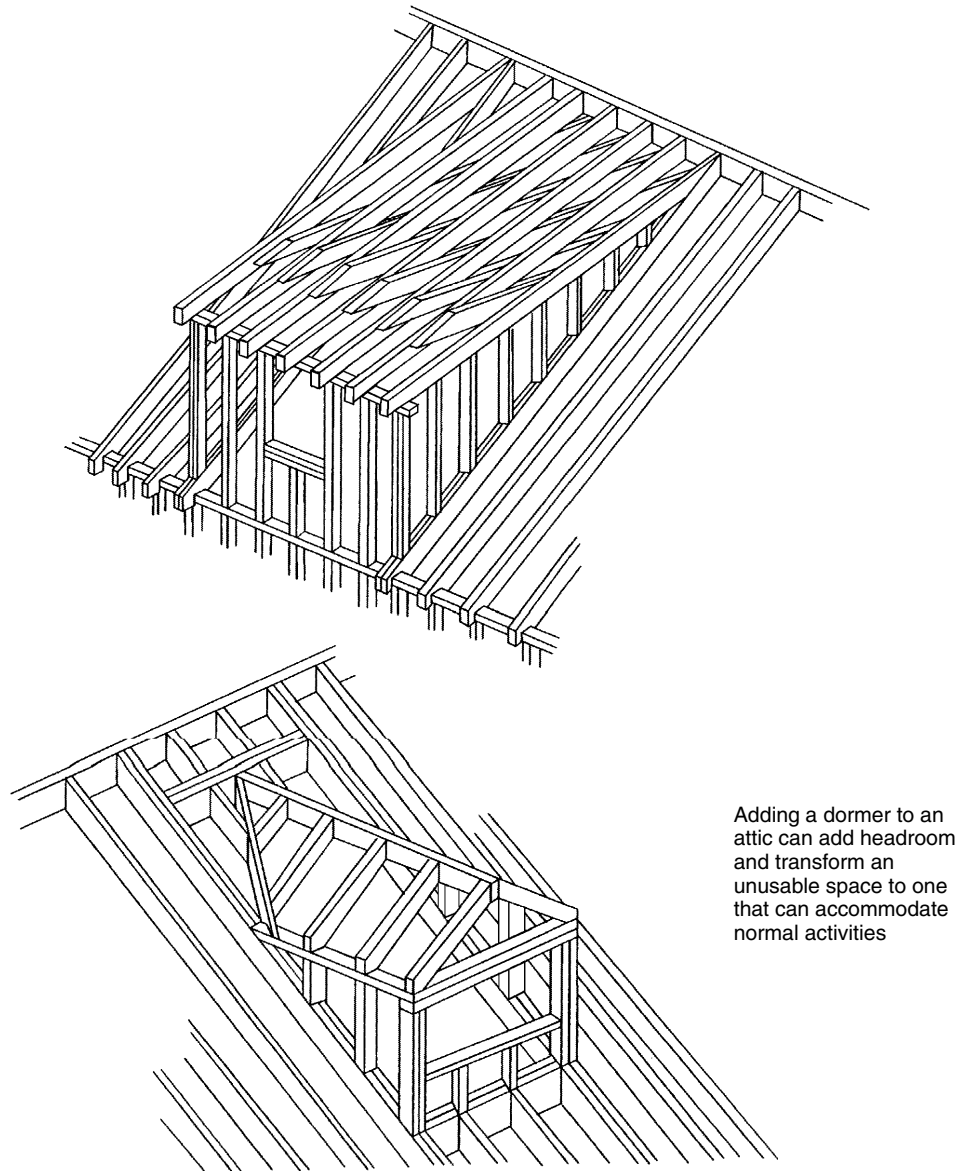
govern stair dimensions, specifying the rise and run of treads, the minimum headroom, the position of the handrail, the width of stair between handrails, and the spacing of the balustrade. Refer to your local requirements when designing the new staircase. See Figure 8-4.

### **Insulation, Air, Vapour and Weather Barriers**

Insulation for attic floors, walls and ceilings comes in a variety of forms. Insulating to at least the minimum levels of the current code is always recommended. It may, however, be difficult to accommodate these levels of

insulation in the existing envelope cavities. This is especially true of cathedral or sloped ceilings formed by rafters where attic ventilation must be taken into account. At least 63 mm (2.5 in.) of clear space must exist between the top of the insulation and the underside of the roof sheathing for proper ventilation of the roof space.

To accommodate any reasonable amount of insulation in the cathedral ceiling, the rafter needs to be very deep. In most houses, rafters will not be able to accommodate both the insulation and the ventilation space. One approach for increasing the cavity space to provide for both functions is to install strapping

**Figure 8-3: Building Dormers**

Adding a dormer to an attic can add headroom and transform an unusable space to one that can accommodate normal activities

on the underside of the rafters to accept additional insulation. Alternatively, rigid insulation can be used.

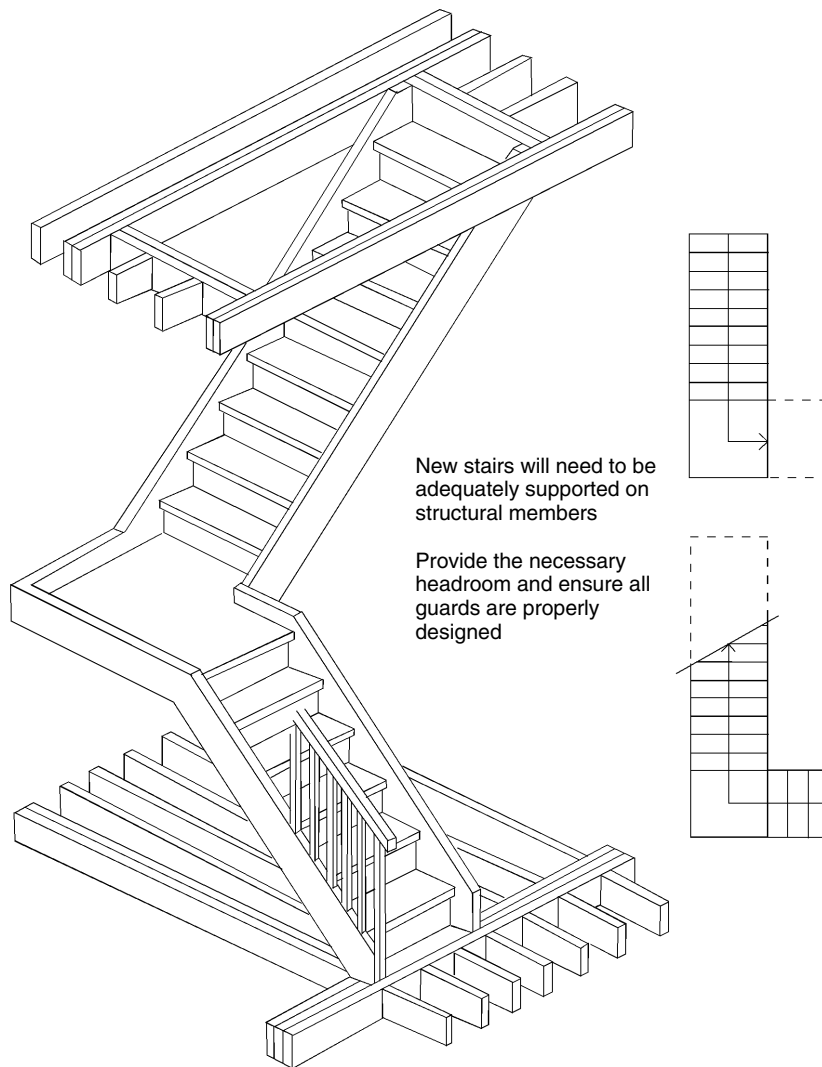
You will need to take care when installing the attic insulation to prevent it from blocking the soffit vents. (Attic ventilation is discussed in more detail in the section below.)

In older homes, be cautious of the effects of handling loose-fill or fibrous batt insulation. During the attic conversion, isolate the materials from the new space with polyethylene. Remove

the insulation carefully without scattering particles into the air unnecessarily. Whether you insulate the cathedral portion of the roof or a flat ceiling, the rules for air- and vapour-barrier protection still apply.

### **Attic Ventilation**

As already discussed, attic ventilation needs to be provided, regardless of the form of attic retrofit. Both attic and cathedral portions of the roof will need to be ventilated. This includes areas of the roof that are difficult to ventilate,

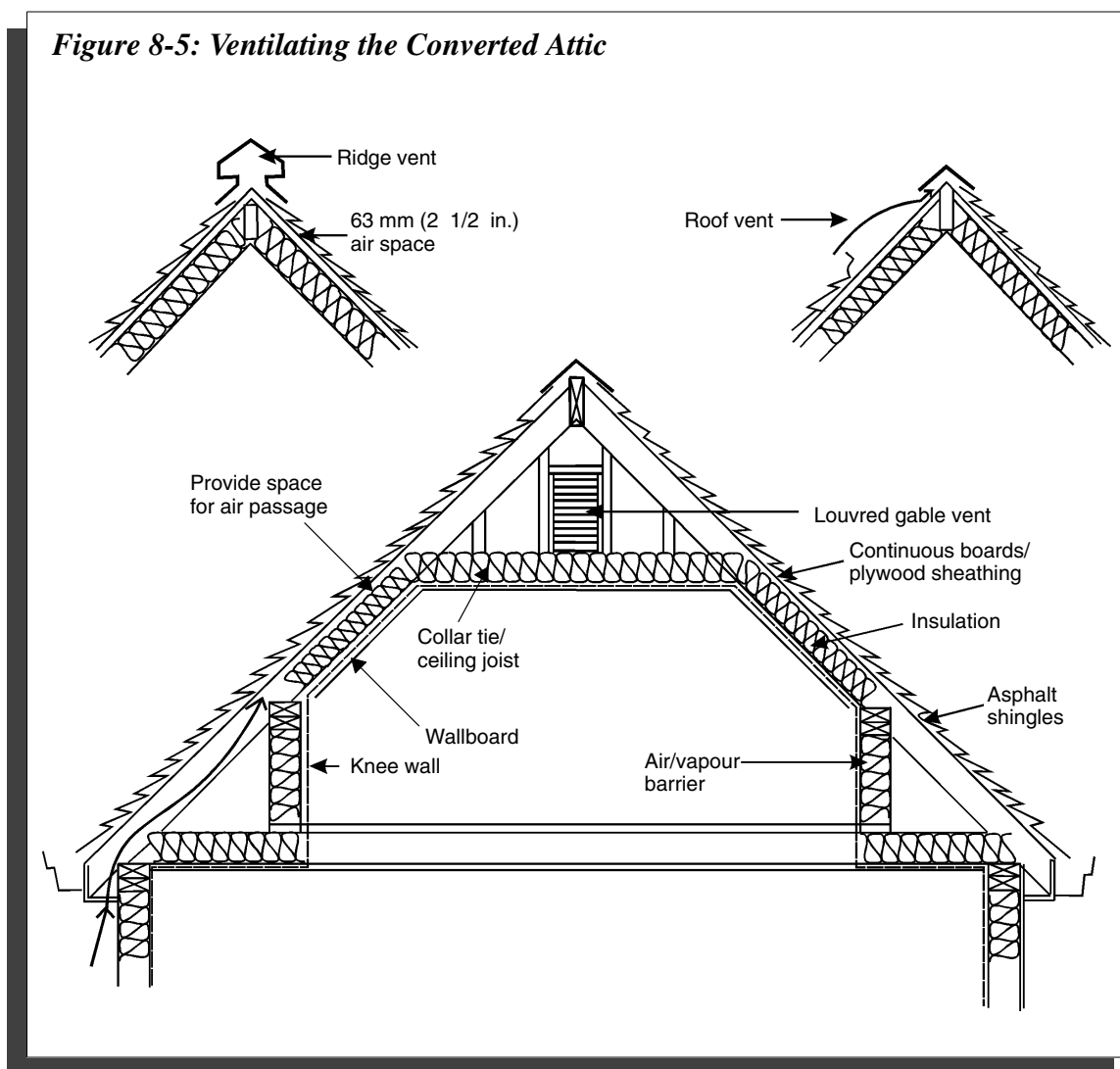
**Figure 8-4: Supporting Stairs**

such as on the roof below skylights. At the same time, the air that moves through the roof cavity should not be allowed to blow through the insulation. Figures 8-5 and 8-6 show various approaches to ventilating attics.

Air that blows through the attic insulation can reduce its effectiveness, increase heat loss, cool adjacent surfaces and possibly result in condensation. Baffles have been installed in many homes to prevent air and wind from moving through the insulation, while keeping the insulation from falling into the soffit vent spaces.

### **Fire Safety**

Fire-stopping is intended to prevent fire from spreading in walls, floors and other concealed spaces of the house. It is normally needed every 3 m (10 ft.) in walls and wherever one concealed space connects to another — for example, at a bulkhead in a kitchen or bathroom. The concealed space of the bulkhead connects to vertical wall cavities as well as to horizontal joist spaces. Normally, the bulkhead would need to be fire-stopped from both wall- and floor-joist spaces. For renovated attics, concealed spaces are often created by new walls and other

**Figure 8-5: Ventilating the Converted Attic**

assemblies. These will need to be fire-stopped from one another.

Attic conversions in two-storey houses also require that you provide an emergency exit. A window with an unobstructed opening of not less than 1 m (3 ft. 3 in.) in height and 0.55 m (1 ft. 10 in.) in width should be provided in the attic. It should be located so that the sill is not more than 1 m (3 ft. 3 in.) above the floor and not more than 7 m (23 ft.) above adjacent ground level. Alternatively, the converted attic space requires access to a balcony. Refer to the local building code for more details. See Figure 8-7.

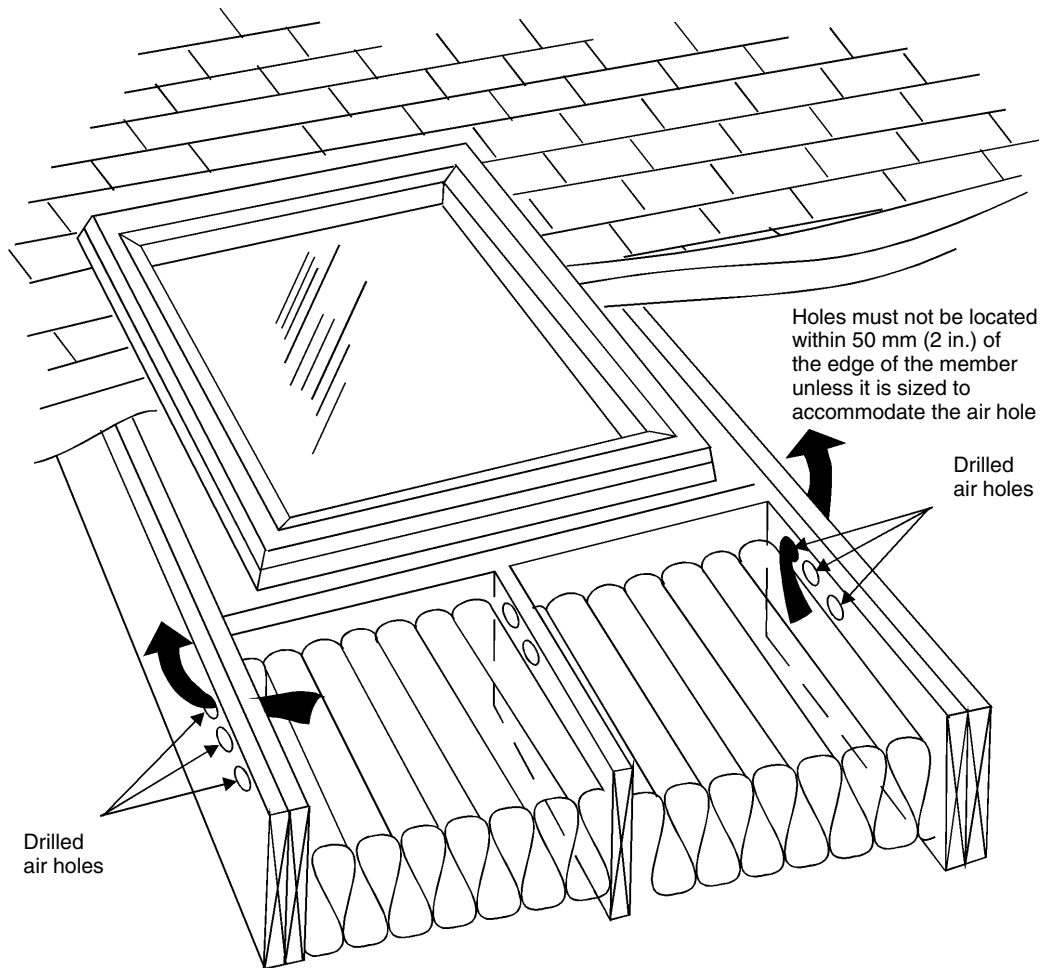
### **Noise Transmission**

Noise transmission is an area of concern when converting an attic into a room. If the new space

will not have a similar use to the floor below, you may wish to install sound-deadening isolation batts in the floor space or a new suspended ceiling on furring channels to the areas below. In some instances, providing rugs over sheet or hardwood flooring in the attic can reduce noise that can be heard on the floor below.

### **Natural Light and Fresh Air**

Providing natural light and fresh air to the new attic will considerably enhance the liveability of the space and will be required if the space is used as a bedroom, den or office. Adding windows or skylights, as detailed in Chapter 5, can provide natural light and ventilation. However, as Chapter 5 notes, there may be restrictions on the placement of windows

**Figure 8-6: Ventilating Below Skylights**

depending on the distance from the window to the building's property line.

Light fixtures should be installed without breaching the envelope's air barrier. The electrical box of the fixture should be sealed to the air barrier so that moisture-laden air does not leak into the cavity and cause damage.

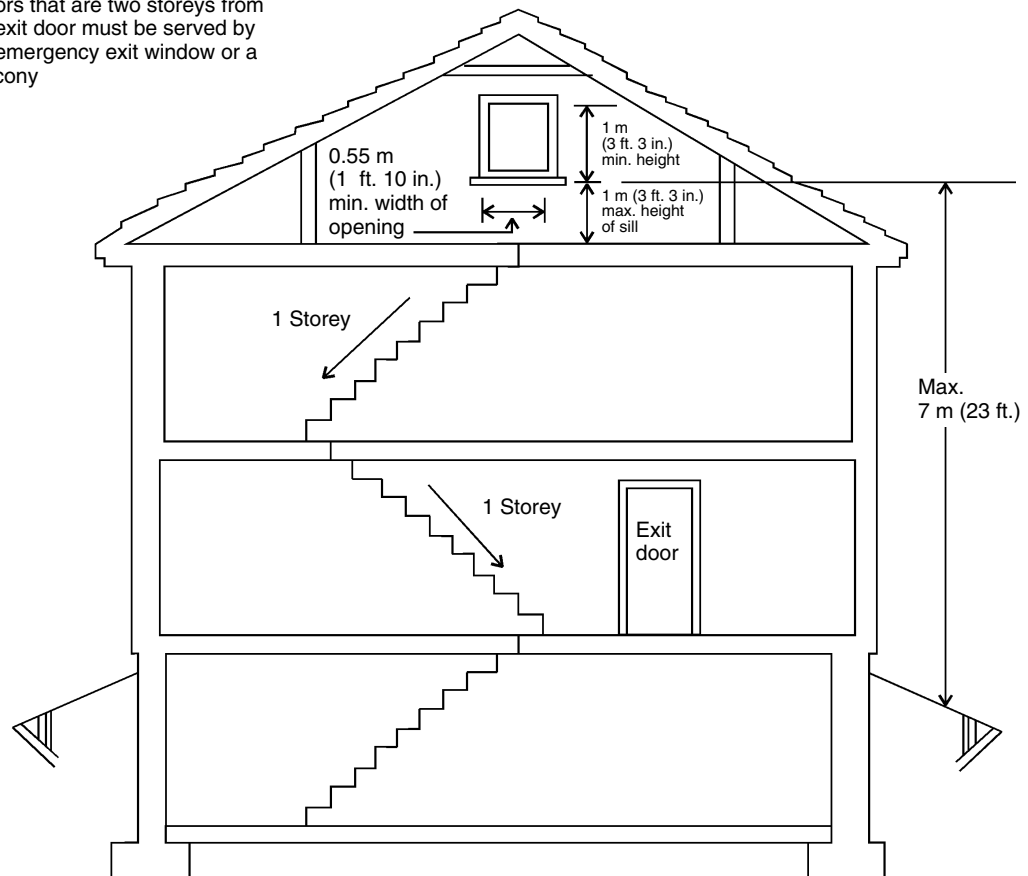
Ventilation, both natural and mechanical, should be considered carefully. This area of the house will tend to become a reservoir for warm air as it rises. Providing some means to redistribute the air to all the areas of the house can improve comfort and save money. At the same time, you will want to provide fresh air to the space.

A small heat recovery ventilator that serves the attic and possibly the rooms below is often the best choice if an existing ventilation system doesn't exist. The alternative is to install an exhaust fan, but it is much more expensive to operate. The advice of a ventilation-system designer or installer can widen the range of alternatives that might be available.

Changes to ventilation and other mechanical systems are discussed in Chapter 10. Chapter 9 discusses extending and adding a ventilation system to a new space. Review the discussion in these chapters.

**Figure 8-7: Refuge Window**

Floors that are two storeys from an exit door must be served by an emergency exit window or a balcony



### Services

One of the major concerns in attic-to-room conversions is the need to provide adequate heating, ventilating, air conditioning, plumbing and electrical services to the new space. Ensuring that the heating, plumbing and electrical systems have enough capacity to accommodate the new living space should be the first issue you resolve. The furnace, the air conditioner, the ventilation system, the electrical panel and the plumbing and septic systems should all be checked to see whether they can handle the additional loads of the new living space. When planning a new addition, the same questions exist. Refer to Chapter 9 — New Additions — for a more detailed discussion.

In houses with forced air heating systems, getting the duct work up to the attic may pose a number of problems. Routing runs up to the new space with few elbows and bends so that the

amount of heat supplied to the space is adequate, is always a challenge. Furring out ducts to minimize their impact on the space below can also pose problems and requires careful planning. New heating registers should be strategically placed to maximize comfort. Return air ducts are also strongly recommended to remove the rising warm air from the floors below. If the heating ducts provide cooling as well, consider how they will perform in summer. In many cases, electric heating is the only practical option for the converted attic space. The services of a heating contractor are often advisable in this type of project.

It is usually more economical and easier to connect new plumbing to the existing water supply, waste and vent pipes. If possible, locate a new attic bathroom above or near an existing one. Plumbing lines, especially uninsulated ones, need to be on interior walls as opposed to

exterior walls to prevent possible freezing during winter.

As today's lifestyles change, more people are considering a home office. Attics converted into home offices may require dedicated telephone lines, additional electrical lines and other services as an integral part of this new living space. Additional electrical outlets can often be handled by a subpanel with a separate feed from the main panel as an alternative to pulling wires from a basement panel box.

### HEALTHY HOUSING ATTIC RENOVATIONS

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Healthy attic renovations focus on good building practices that involve improved indoor air quality, resource efficiency, environmental responsibility and improved energy efficiency and affordability.

Installing low-emission materials and products will contribute to the good health of the occupants. Choose materials with low levels of volatile organic compounds. This could mean specifying water-based paints and adhesives. The need for natural light and fresh air has already been identified. All of these elements will contribute to a healthful indoor environment.

Choose products that have a high recycled content or are environmentally friendly. Manufactured wood products, finger-jointed studs, recycled drywall and batt or blown

insulation reduce the environmental impact of the renovation.

Environmental responsibility also extends to how the work is planned. The aim is to minimize construction wastes and manage the wastes that are produced. Many construction wastes can be recycled to reduce the burden on landfill sites and save on tipping fees.

The renovation of an attic provides opportunities to improve the energy efficiency of the house. This might involve upgrading insulation levels and improving the airtightness of the attic. High-performance windows and efficient lighting should also be considered.

Finally, consider the full life cycle of the materials and components you use. Choosing the least expensive item may be a false economy. Materials that demonstrate long-term performance and durability are often more cost-effective and more affordable when maintenance and replacement costs are included.

Finishing the attic space can present many challenges. It can involve new framing, installing ceilings, partitions and knee walls, adding dormers, new windows and skylights, running new plumbing and electrical wiring, and installing new wall and floor finishes. The work will affect many of the existing house systems, so consider the full implication of the changes you make. Make sure the new renovation does not affect the performance of the other systems in the house. Doing the job right, eliminates surprises, reduces costly callbacks and enhances your reputation as a renovator.



## New Additions

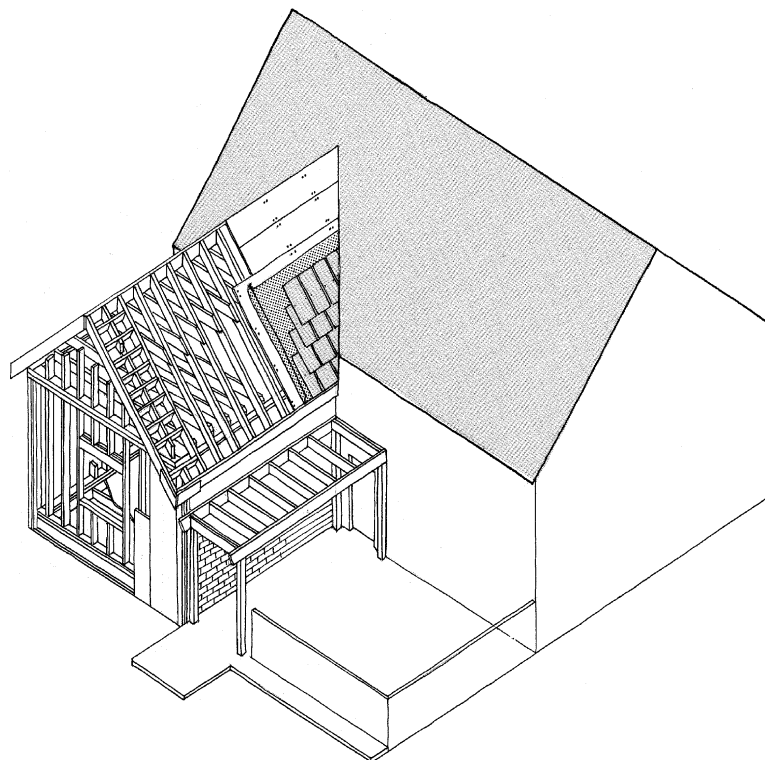
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**P**replanning is an essential part of preparing to build a new, trouble-free addition. The new addition will need to integrate the requirements of the user with the limitations imposed by building codes and local zoning by-laws.

*The home-owner may have all of the necessary approvals in hand prior to the renovator's involvement, or the renovator may be called on for assistance with the entire process. Regardless of the point at which the renovator becomes involved, an assessment of all the existing conditions will be required. This evaluation will review the state of the house as well as the conditions of the site and their ability to support the new addition.*

*The state of the house before the renovation will affect the new construction. Therefore, it is important to ensure that any problems with the existing building are remedied before changes take place. This chapter will look at existing conditions and making a proper assessment of the house for a specific addition project.*

*A new addition can affect many of the systems within the house. The new spaces, for example, could increase demands on the structural, mechanical and electrical systems, among others. This chapter considers the systems affected and looks at how to accommodate the new work.*



### INTRODUCTION

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A new addition to an existing house is often a solution to the home-owner's need for additional living space. The need for an extra bedroom, a new family room, an enlarged eat-in kitchen and any number of other types of spaces can call for a new addition.

The question is often whether it would be wiser to move to a larger house or build an addition. The answer, of course, depends on the home-owners and their circumstances. Almost always, the decision is based on an attachment to the house and the neighbourhood, and often on cost considerations.

An addition that meets the requirements for a new kitchen, bathroom, bedroom or family room can often be built with minimal disruption to the life of the residents. For the most part, work proceeds on the outside of the existing house. Only when it comes time to establish a connection between the two structures will the renovation work become potentially disruptive.

Scaled drawings of the existing house and its site are normally the first step of the planning and design process. This is usually carried out in parallel with an assessment of the existing condition of the house and its site.

The condition of the existing house and its systems can affect the performance of the new addition. As the new addition is built and operated, it can overwhelm the existing systems, particularly if there is little excess capacity for the new addition. The extra loads might not be able to be accommodated by the existing structural, HVAC, plumbing or electrical systems. In these situations, additional remedial work might be necessary to support the new addition.

This chapter focusses on additions attached to the existing house. Second-storey additions involve issues more closely related to attic conversions. Refer to Chapter 8 if you are considering this type of addition.

### EXISTING CONDITIONS

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It is important to consider carefully the extent of work to be done for the new addition, as well as its impact on the existing house.

A detailed design is a necessary first step, not only to obtain approvals and permits but also as a means of working through every aspect of construction. A proper design will take into consideration the conditions of the site and the house. The way the house and addition look and function together, including how the occupants will use both the new and existing space are important criteria. A proper design will detail the structural linkage between the new and old portions of the buildings. Finally, it will consider the affect of the new addition on heating, air conditioning, ventilation, electrical and plumbing services and whether they can handle the new loads. You will inevitably need to deal with some of these issues prior to construction as you consider the new addition and provide useful advice to the home-owner.

When carrying out the assessment of the house, work through the home systematically (e.g., from bottom up and from inside out). This will help to ensure that nothing is overlooked. Notice the condition of structural and non-structural elements. Look at the systems that provide weather protection. Review each system carefully as defects can cause problems with the new addition later.

An analysis of the existing house will assess the following issues:

- site conditions;
- footings and foundation;
- existing structural systems;
- building envelope;
- exterior cladding and finishes;
- interior floor and ceiling finishes; and
- mechanical and electrical systems.

At this preliminary stage, it is important to look at the house as a total system. Consider the effects of the proposed addition on the existing house with respect to site, access, internal and external circulation, structural systems and mechanical, electrical and plumbing services.

Many of these topics are discussed in the Renovation Implications section of this chapter.

A properly performed assessment will add value to the work you do. It tells home-owners that you have their best interests at heart and that you approach renovations holistically. They will appreciate the fact that you take time to ensure the entire house is performing adequately and are not just offering band-aid solutions.

Note the problems you encounter. Summarize them for the home-owner and indicate whether any of these will adversely affect the performance of the new addition.

If existing problems will affect the new addition, they should be resolved before work on the new addition begins. Consider what you will do if

the home-owner is not interested in remedying any of the existing problems before having the new work performed. Will you perform the renovation anyway? When making this decision, remember that your reputation will be affected by the outcome. Walking away before signing any contracts may be wise if you feel the quality of your renovation will be compromised by the poor condition of the building or the unrealistic expectations of the customer.

## ASSESSMENT CHECKLIST

The assessment checklist for new additions identifies some of the issues to consider as you assess the existing condition of the house and its ability to accommodate a new addition.

### Checklist

#### DESIGN, APPROVALS AND PERMITS (page 162)

- ☐ zoning bylaw review (site coverage, sideyard and setbacks)
- ☐ building code review (compliance and compliance alternatives)
- ☐ property survey (dimensions of property lines)
- ☐ interior and exterior traffic patterns
- ☐ site-use restrictions and limitations

#### SITE AND FOUNDATION CONDITIONS (page 162)

- ☐ surface water not diverted away from the building
- ☐ poor soil conditions

#### EXISTING STRUCTURAL CONDITIONS (page 163)

- ☐ foundation problems
- ☐ roof structure problems
- ☐ floor structure problems
- ☐ wall structure problems

#### SERVICES (page 165)

- ☐ inadequate capacity of existing heating system
- ☐ inadequate capacity of existing air conditioning system
- ☐ inadequate capacity of existing ventilation system
- ☐ inadequate capacity of existing plumbing and septic systems
- ☐ inadequate capacity of hydro panel and electrical system

**Design, Approvals and Permits**

Many factors will influence the planning of the addition, and information is available that can help you in the design and construction process. Understanding local regulations, zoning by-laws and local building codes, will speed up the approval process, allowing you to move onto the project more quickly.

Zoning bylaws provide information on a number of design aspects. A review of the zoning and building by-laws is critical in determining the feasibility of the addition in light of coverage, gross floor area permitted on the site, setbacks, sideyards and other restrictions particular to that municipality. A review of local zoning by-laws will determine if the site is large enough to permit the addition. It should also confirm the addition in terms of both total floor area and building footprint.

New work must meet the standards of local building codes. Understanding the requirements of the local building code is an important part of doing the job correctly. In most jurisdictions in Canada, new additions are considered new construction and fall within the scope of Part 9 of the building code. This is in contrast to the regulations regarding renovations that do not involve new floor area. In some parts of Canada, renovations are left unregulated, while in others, they must meet the requirements of other parts of the local building code. If in doubt, consult with a local municipal building official before you begin the project.

An updated property survey of the house is the first step in determining what changes have taken place over the years. The survey is a legal description of the property including boundary lines and bearings. It determines the location of the existing building on the site and provides information on front, side and rear setbacks. The survey notes the location of fences, outbuildings such as garages, easements on the property and the outline of adjacent buildings. Along with the deed, the survey describes the property, its location, street address, lot number, registered plan number, municipality and county.

You will need to locate all utilities, including electric, water, sewer, cable, gas and telephone lines. Be sure to contact the local utility

companies before you begin to excavate for the new addition.

Design drawings will aid in resolving problems that inevitably arise as part of construction. A new addition is essentially a miniature house with its own foundation, structure and finishes. Unlike a self-contained house, however, an addition is designed to be connected to another building. It is important that both the indoor and outdoor aspects of the addition are well integrated with the existing house. On the inside, consider the traffic patterns created by the new addition. On the outside, make sure the roof lines of the addition complement those of the main building. Aesthetically, integrating the new structure with the existing one is among the most challenging aspects of designing any addition. See Figure 9-1.

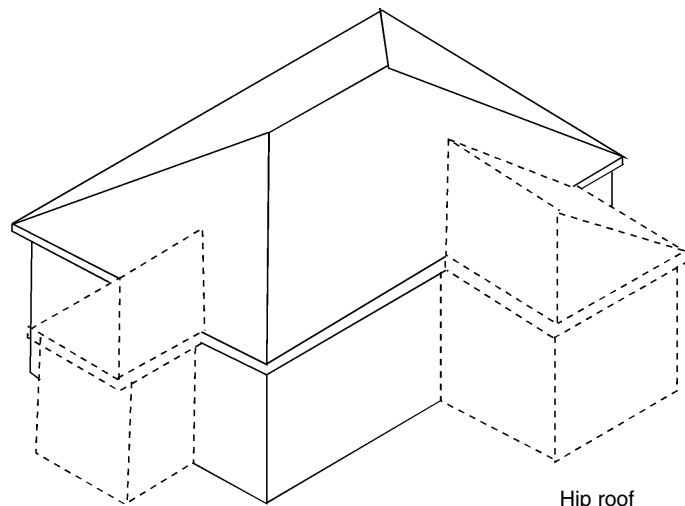
Conceptual design drawings reflect the extent of the proposed work. If the home-owner is satisfied with the design concept, detailed technical drawings and specifications normally follow. These documents are necessary for building permit applications and cost estimates.

**Site and Foundation Conditions**

The existing conditions of the site can adversely affect the performance of the renovation. Poor site drainage or improper grading are two of the most common problems that can lead to water infiltration and damage. Poor soil conditions can also affect the design of the new foundation system.

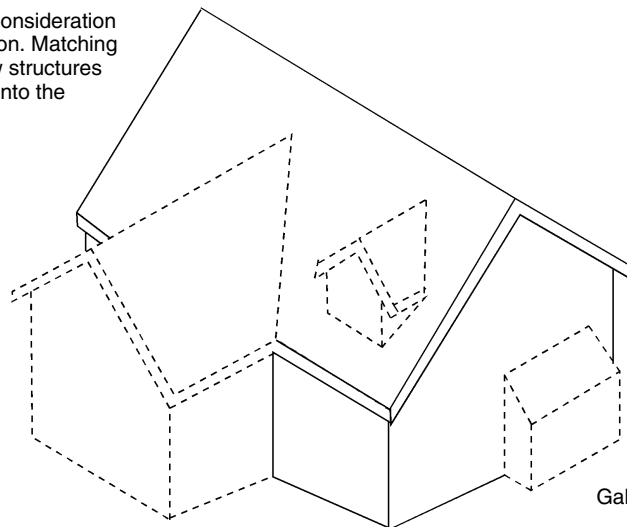
Assess the condition of the existing drainage system and observe the run-off patterns on-site. As shown in Figure 9-2, surface water should not drain towards the building. Poor drainage is often the cause of wet, damp basements. Efflorescence on concrete or masonry is another indicator of this problem. Try to remedy any drainage problems before adding onto the building. Refer to Chapter 2 for more details.

The new addition should not make a poor drainage situation worse by trapping water. Examine the conditions of the existing eavestroughs and downspouts. They should never discharge near the connection between the main building and the new addition. Check the house eavestroughing system to ensure it is not clogged. If it is clogged, determine the exact cause and clear, repair or replace the system before the addition is built.

**Figure 9-1: Roof Forms**

Hip roof

Aesthetics is an important consideration in designing any new addition. Matching the roofs of the old and new structures will help the addition blend into the existing building



Gable roof

You should also ensure the existing soil has the bearing capacity to support the new construction. Your local building code may help you to determine the bearing capacity of the soil.

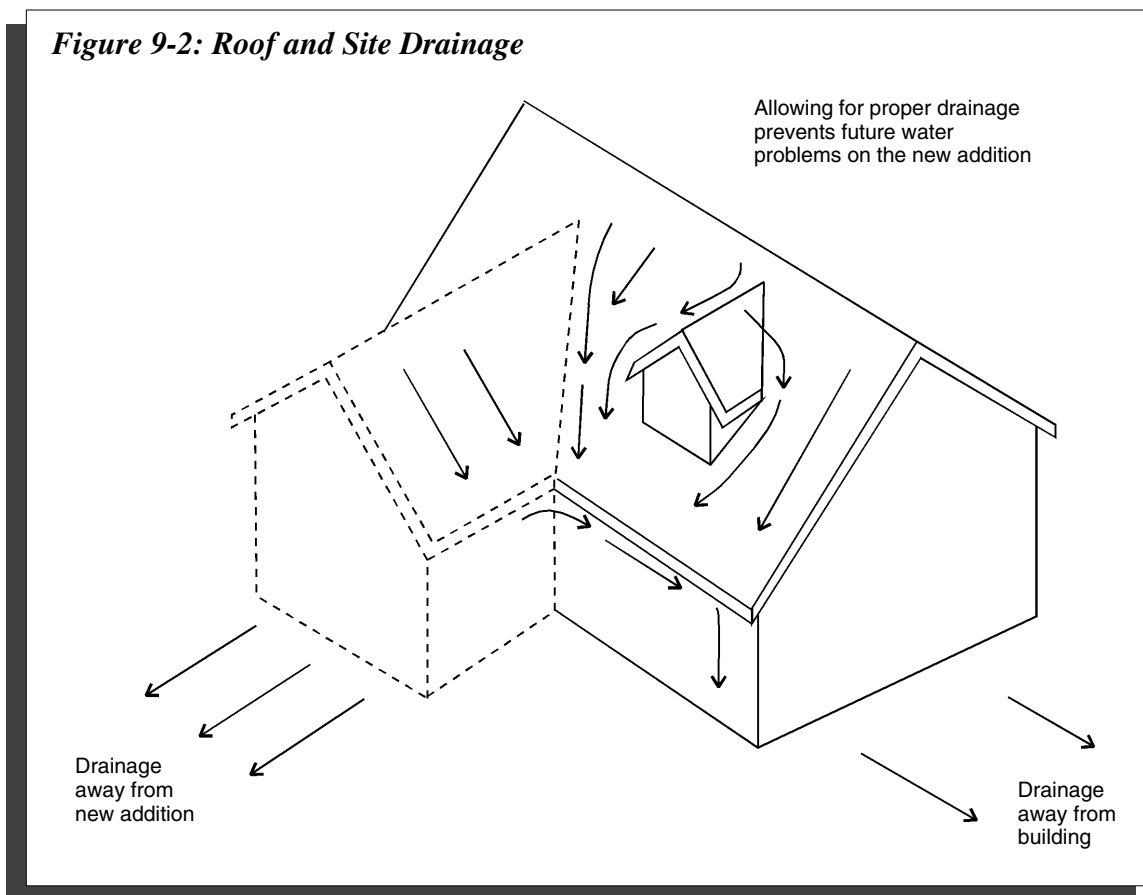
Note that an addition built on a site with loose or weak soil will likely settle at a different rate than the existing house, creating extra stress where the two structures are joined. If you suspect a problem, call in a soils engineer to evaluate the site and offer advice.

Examine the perimeter of the building for evidence of water damage or other signs of distress. Structural concerns to watch for include

wood decay, termites or carpenter ant infestation. Carefully evaluate any signs of structural weakness. See Figure 9-2.

### **Existing Structural Conditions**

Cracks caused by the movement of the different elements in the house can be signs of underlying structural problems. These normally do not pose significant risk to the existing structure, particularly if the cracking is stable and all settlement has taken place. However, adding a new addition can make a minor structural problem much worse as the addition adds its load to, perhaps, an already overloaded structural system. In most cases, a soils or

**Figure 9-2: Roof and Site Drainage**

structural engineer may be needed to review the existing condition. Cracks and other types of foundation problems are discussed in Chapter 3.

The roof structure can also show signs of deterioration; sagging roof lines or warped trusses are typical signs of structural problems. Roofs that have warped or deflected may be difficult to connect to the framing of the new renovation. It may be necessary to rebuild or repair part of the sagging roof before adding the addition. A sagging roof can also be caused by poor support from the walls below. If the sag occurs over a window or doorway, chances are that the opening was poorly framed with inadequate lintel or stud supports.

Check the framing members for water, termite and other forms of damage. These problems can weaken the ability of the structure to carry any new loads imposed by the addition. If the framing members are in very bad condition, they may have to be replaced during the renovation.

If the existing wall structure is used to support parts of the new addition, it will have to be checked to ensure that the studs are appropriately sized and spaced. If openings are to be created, ensure that the lintels and stud supports are adequately sized to local building code requirements.

When planning to move interior partition walls, ensure that the wall is not a load-bearing wall. Many homes have interior load-bearing walls, and any changes to these walls can seriously affect the stability of the whole house. If making changes to the load-bearing wall, be sure to provide proper support during and after the work.

In addition to making sure that the existing structure of the house is good, it is important to ensure that any new elements are properly connected. Take into account the shrinkage of new materials as you connect them to the existing materials. The proper attachment of the new foundation, roof, floors and walls to the existing house is necessary for a properly performing renovation. This issue is discussed

in more detail in the Renovation Implications section on the following page.

### **Services**

The heating, air conditioning, ventilation, plumbing and electrical systems were designed for the existing house. They conformed to code at the time the house was built. Each system has a certain capacity that was sized to fit the original house and household. However, the capacity of these services may be inadequate for extra demands of the new addition. An analysis of the services during the house assessment will be needed to determine their capabilities.

In some cases, the capacity of the existing furnace is not enough to heat the new addition. A heat loss calculation for the house and addition should be performed to verify the adequacy of the furnace. If you are unable to determine the new heat loss of the house and addition, a heating contractor will be able to perform the calculations.

The heating contractor will also be able to advise you about whether retrofitting the system may be possible to meet the new needs. A furnace retrofit can include installing a new burner or motor. The contractor will also advise you on the implications of extending the distribution system to the new addition.

In many cases, a separate heating source will be necessary, depending on the size of the addition. Unitary heaters, such as electric baseboards, are popular for their quick and easy installation. However, the cost of heating will normally be higher with these appliances.

An undersized air conditioner, although not recommended, is not as worrisome as an undersized furnace. An undersized air conditioner will usually need to run longer to maintain cooler temperatures. Generally, dehumidification of the air will not be affected and, in some cases, may actually improve.

A stand-alone air conditioner can be used in those rare instances where air conditioning needs are very important. A number of new systems are available as alternatives to the unsightly window variety of the past.

In addition, it may be possible to adjust an existing ventilation system to the new living

area of an addition. However, some existing ventilation systems might not be able to accommodate the new addition. This is especially true if more than one room is built. Refer to Insight 9 — Airtightness and Ventilation — for more discussion.

In situations where existing indoor air quality is marginal, adding new floor space can make things worse. To improve the indoor air quality in the home, consider the following improvements:

1. run the circulation fan of the furnace continuously at low speed;
2. install better kitchen and bathroom exhaust fans and operate them regularly; or
3. install new exhaust fans in the hall of the existing house or in the new addition; and
4. install a heat recovery ventilation system to serve the new addition or, if necessary, the whole house.

You should also remember to let the occupants know that ventilation is an important component of today's healthier houses, and that the systems should not be shut off to conserve energy.

When adding plumbing fixtures in the new addition, ensure that the system can handle the new loads. Both supply and waste water systems can be affected. The supply of water to other fixtures can be affected by changes to the water demand within the house. We have all experienced low water pressure in the shower when someone uses another fixture. Adding water-consuming fixtures in the new addition can increase this problem. In most cases, drawing the home-owners attention to the potential problem is all that is recommended. Increasing water pressure to the addition can be an expensive proposition. In some cases, temperature and pressure balancing valves can be installed on the new fixtures in the addition.

Waste water systems should also be checked to ensure they can accommodate the new addition. In the case of a septic system, the quantity of waste the system can handle should not be exceeded. Clogging, overflow and other problems can result. Using low-flow toilets and other water-conserving fixtures can help to reduce the load on the system. A septic system installer will have more information about specific options for your renovation project.

**Insight 9 — Airtightness and Ventilation**

Events in the last half of the twentieth century have led to tighter building construction. The changes have been most noticeable since the energy crisis of the 1970s. To prevent heat loss and high fuel costs, thermal resistance levels of building envelopes were increased.

The higher levels of insulation that resulted require better airtightness. Air can blow through or around an unprotected layer of insulation. That air can carry moisture that can condense in the insulation, and the insulative characteristics of materials are compromised when they absorb water. To maintain the thermal characteristics of insulation, it must be protected from air and water movement by air barriers and vapour retarders. Better windows, weather-stripped doors, and sealants and caulking around penetrations and openings are also needed to prevent air and moisture movement that can result in condensation and heat loss.

In addition to controlling moisture damage, a tighter building envelope offers other benefits. Decreased heat loss and fewer drafts will improve occupant comfort and reduce heating costs. A tight building envelope also allows for the mechanical ventilation system to function and be controlled more effectively, which is important for good indoor air.

Natural ventilation is inadequate for controlling indoor air quality. On a warm day with no breeze, little natural ventilation takes place, even through open windows. There is no natural air leakage without wind or stack pressure or if mechanical equipment is not drawing air out of the house. Every room in the house needs a constant supply of fresh outdoor air, and natural ventilation can not be relied on to provide this.

On the other hand, during cold winter months, strong winds or stack pressure can force too much air into the building, causing drafts and wasting heating fuel. Balanced mechanical ventilation systems provide predictability and control and ensure that the supply of fresh air to the house is constant. Airtightening helps to eliminate the uncontrolled portion of the total ventilation that's provided and allows the mechanical ventilation system to deliver just the right amount of air ventilation.

By airtightening and installing a mechanical ventilation system, indoor odours, excessive humidity, off-gassing from materials and other contaminants can be managed and controlled. Drafts, heat loss and, most importantly moisture damage can all be minimized.

The typical electrical panel found in older homes is 60 amps. In newer homes, the panel may be 100-amp or 200-amp service. In most cases, a 60-amp service will not be able to accommodate the electrical needs of a new addition (much less the existing house!)

You may want to ensure that the existing panel will be able to handle new outlets before making any changes. Refer the question to an electrician if you are unsure of the effects of your changes.

**RENOVATION IMPLICATIONS**

The effects of adding a new addition to an existing house are numerous. The possible impacts on the foundation, framing, exterior finishes, building envelope and services should be thought through before beginning any new work. Consider all the changes being contemplated. This might include changes to the way rainwater is diverted onto the existing roof, or the extra loads imposed on existing walls,

foundations and footings. Understand the effects of the new work on the old and you will prevent nasty surprises during or after the renovation.

Always consider the possible disruption to the occupants' lives during the renovation. Consider the timing of turning off water and electricity to lessen the effects on the occupants' lifestyle. Also, the noise from the renovation may irritate neighbours if it occurs too late or too early.

**Site and Foundations**

When considering the new addition, be aware of the location of the existing utilities and services. Before digging for footing placement, you must know where the water, sewer, electric, cable, gas and telephone lines are. You also want to avoid digging up sewer, septic or water pipes. Each utility company can give you information about where its services are located.

Chapter 3 — Foundations and Basement Renovations — provides some good background information, including a discussion of construction techniques, concrete curing,



concrete shrinkage and backfilling practices. Refer to it for more information.

As with all building foundations, potential water problems are always a concern. Your understanding of water in its three states (as discussed in Chapter 2) is important. Water vapour, capillary water and bulk water all act on the foundation. Consider how the new drainage systems will connect into the existing one. Can the new foundation drainage system tie into the existing weeping tile or will a sump pit and pump be necessary? These questions should be answered early in the renovation process to prevent incurring extra costs and redoing work.

When adding a basement that connects to the existing one by a doorway, check the available headroom for both. You may have to underpin the existing footings in order to connect the two basement spaces. This is often expensive and time-consuming.

### ***Framing***

When planning to add on to a house, understand that at least one wall will be shared by the new and old spaces. Shared walls support the loads from the existing building as well as new loads from the addition. In many cases, elements within those walls may be underdesigned to carry the extra weight. Lintels over door and window openings, wall studs and blocking may be inadequate for the new loads. The elements of the wall should be checked to ensure that they can support the new loads. If necessary, they should be reinforced or replaced with members able to support all loads.

Increased structural loading can also affect roofs and floors within the home. Suspending part of a new roof from the old roof is one example of new loads requiring support. Recognize that any new load imposed on the existing framing of the building can result in door and window operation problems, warped floors, sagging roofs, exterior or interior wall finish cracks and, in some cases, failure of one or more structural components. Avoid increasing loads unless all of the structural elements have been checked. Note that if the existing roof is a truss roof, the services of an engineer will be required to verify loads.

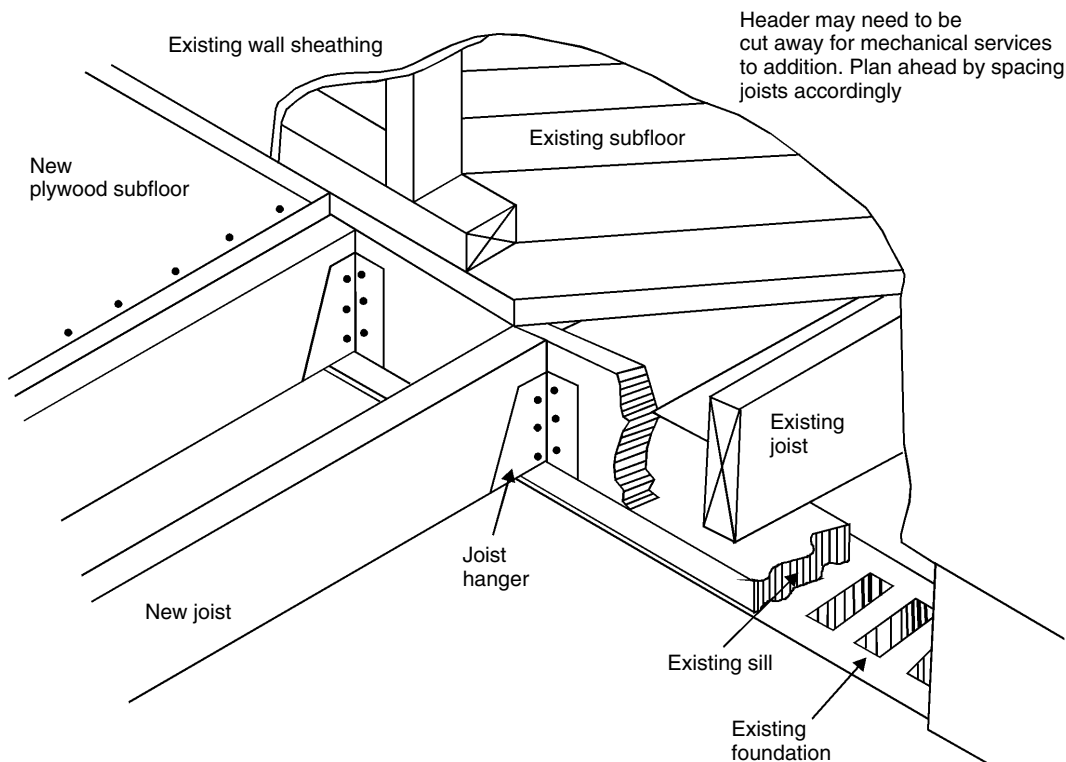
Additional framing may be required to support the loads of the new construction. New jack or hip rafters around a new roof, larger lintels or beams across openings between the spaces are common framing elements introduced when building an addition. You should also ensure that the loads from new structural elements are carried down to the footings through other structural elements. A new beam will need to be supported at each end by a column. Adding new framing can involve some major renovations and should always be approached with caution. Always check your building code for specific requirements. Securing the structural tie-in of the new work with the existing house is critical. New and old floor levels should be at the same plane. See Figure 9-3.

When tying in new roof framing, make sure the loads are properly shared by the old and new framing. (See Figure 9-4.) Wall framing should be properly tied so that the building will hold together during expansion and contraction cycles. The framing members that support it should act together as a complete system rather than separate pieces.

In older homes, you will notice that the dimensions of the framing lumber vary from those used today. You may need to account for this when connecting framing systems.

Temporary bracing of the existing structure may be necessary during the renovation. Cutting a new door opening in a load-bearing wall, for example, can result in temporary loss of support for the floor above. Although this might not seem serious, if the floor above is finished, extensive cracking can occur, even over a short time. In extreme cases, structural failure can occur. The need for temporary bracing will depend on the sizes of openings and the extent of work required to accommodate the new addition.

The common walls between the house and the addition will normally require further preparation to integrate them into the addition. The exterior finish needs to be removed and any necessary structural alterations made before the drywall or other interior finish material is installed. If an acceptable entry from the house to the new room already exists, structural work might not be required. The rough opening can simply be trimmed with the appropriate materials. One home-owner may prefer an

**Figure 9-3: Connecting Floor Systems**

exposed brick wall, while another may want it covered with gypsum and finished. What you should know is that if the exposed brick extends from the indoors to the outdoors, it can act as a very strong thermal bridge, drawing heat out of the house and cooling the interior in winter.

### **Exterior Finishes**

To make the building act as a system, allow for the different behaviours of dissimilar materials. In cases where dissimilar materials meet at a wall or roof, incorporate an expansion joint. An expansion joint allows each material to expand or contract without affecting the other. The joint between masonry veneer and wood cladding is an example of a connection where the materials should not be rigidly joined. If it is, the result could be the cracking or failure of one of the finish materials.

### **Envelope Improvements**

When adding space to an existing building, the construction techniques will often differ

between the new and old construction.

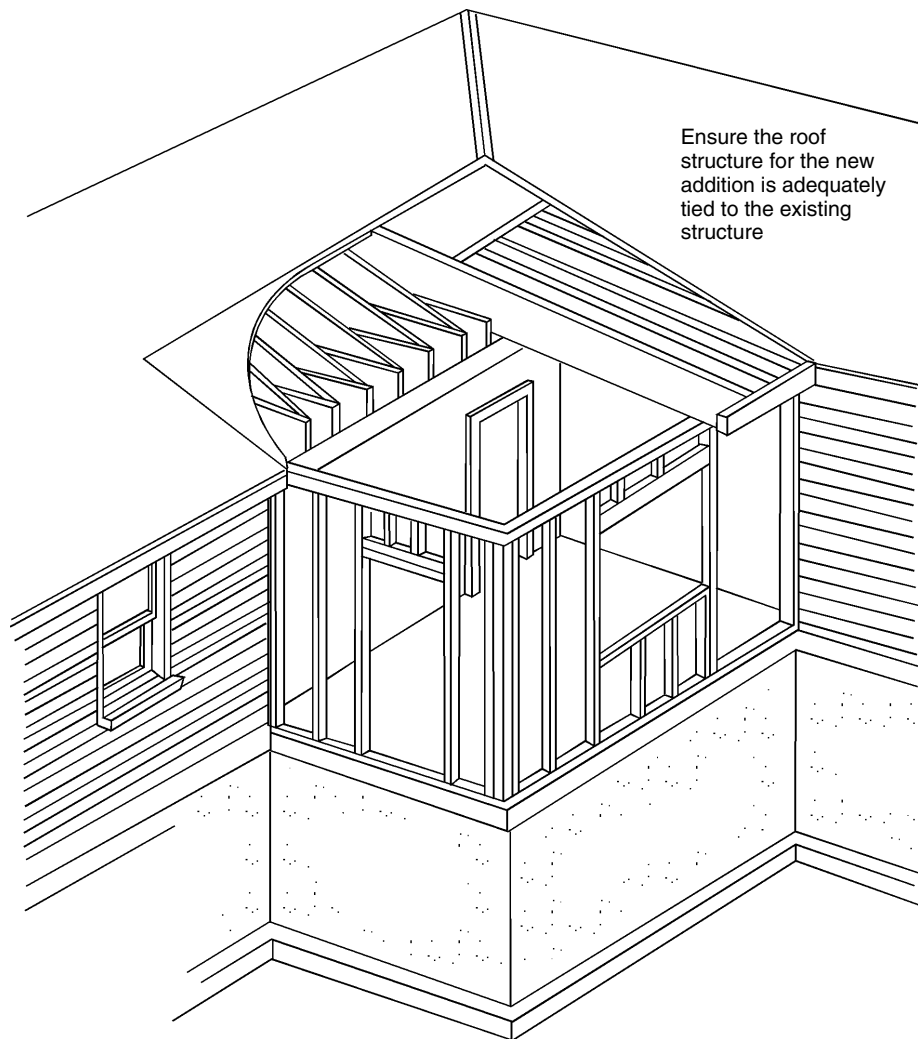
Insulation, air, vapour and weather barriers, as well as other components, may be included only in the new construction. You will need to link old and new together and include all of those necessary components in the new construction.

Insulating and airtightening are options the home-owner should be made aware of. Chapter 11 — Energy-efficient Upgrades — outlines some of the opportunities available. These should be considered as part of every renovation project.

### **Services**

The extension of existing services into the new addition may include water, sewage, gas, telephone or electricity. Integrating new services into existing ones without disruption or overloading should be the goal of the renovator.

Assess the existing systems and determine whether they can accommodate the new loads

**Figure 9-4: Connecting New Roofs**

imposed by the addition. If they do not appear to be able to meet the new demands, you may have to upgrade or replace them. Consult a professional who deals with a specific system if you are unsure about its capacity.

Central heating systems can often be retrofitted, or alternatively, unitary heaters can be used. With a central forced air heating system, correct extensions of duct runs can distribute heat to the new spaces. These upgrades are possible only if the central heating unit is properly sized and balanced to handle the increased heating loads. To determine this, do a heat loss calculation for the entire building. If the unit is undersized, there are upgrades available that will eliminate

the need to replace the system. In other cases, this could be a good opportunity to upgrade to a more efficient furnace.

In general, new, energy-efficient additions that have large glass areas with southern exposure can have good passive solar gains. This free heat should be circulated to the other parts of the house to provide a benefit in terms of energy savings and comfort.

Safety devices such as hard-wired smoke alarms and carbon monoxide detectors (where fireplaces and wood stoves are used) will need to be installed in the new addition as well.

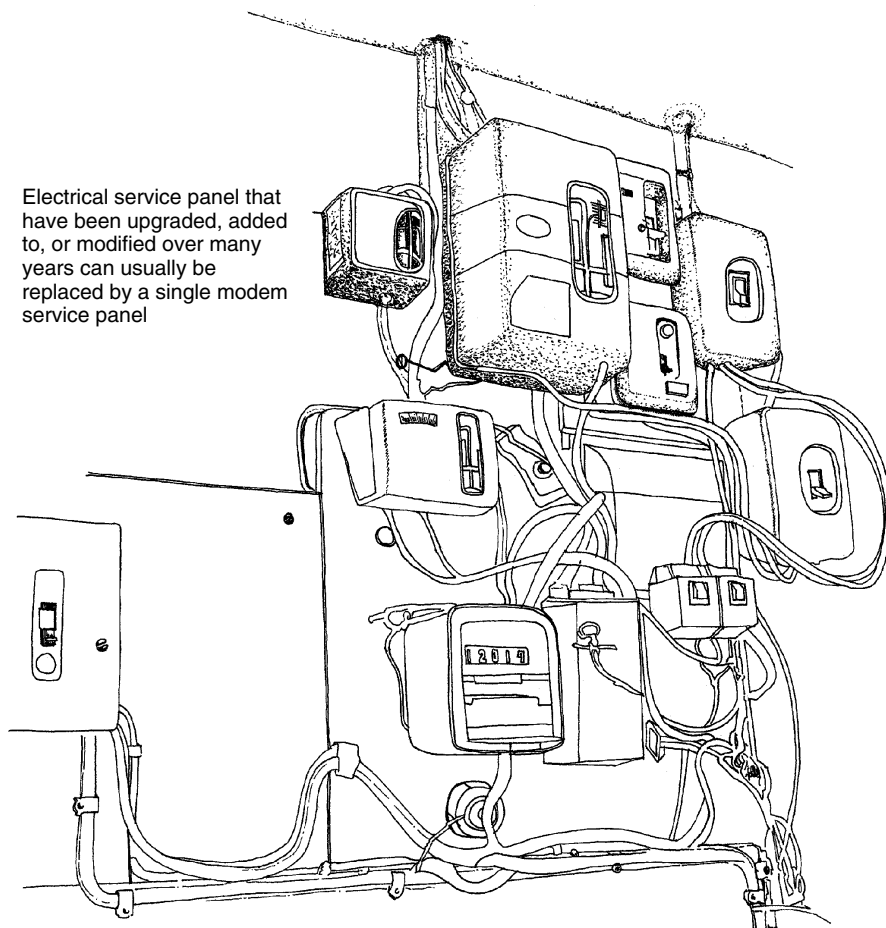
The addition of new electrical circuits or an upgrade of the existing service panel are

changes commonly made during a home renovation. (See Figure 9-5.) There can be a number of reasons for changes to the existing electrical system. Older homes often have faulty or unsafe wiring in need of replacement. The electrical system may be inadequate and ungrounded. Home-office equipment, new appliances and extra light fixtures in the new space can add to the demand on the existing system — something it may not be able to handle. In addition, new wiring may be needed for the smoke alarms required in the new construction to meet building code requirements.

Mechanical ventilation is normally required as part of the new addition, which is typically more airtight than the existing house. The amount of ventilation needed is related to the activities and functions carried out in the added space. New kitchens and bathrooms, for example, will require a high ventilation capacity to remove stale air, contaminants and moisture.

Mechanical systems are now available that can ventilate small spaces without inducing pressures that affect other parts of the house. Small heat recovery ventilators can efficiently ventilate the new addition with little added cost,

***Figure 9-5: Existing Electrical Services May Need to be Renovated***



regardless of the ventilation system that exists in the house. Ventilation system designers or installers can provide you with helpful advice when making the appropriate decisions.

You can lower plumbing costs for a new kitchen or bathroom by reducing pipe runs. This is often accomplished by locating the new fixtures on a wall that already holds the services. New soil and waste stacks that are placed away from existing ones will also incur extra costs. Sharing the existing ones can save the time and money involved in making the required connections and extending the stack and vent.

Many homes in rural areas obtain water from wells and discharge sewage through a septic system. Where a home is not attached to a municipal water supply system, there may be a limit to the amount of supply water available. The well might be unable to accommodate the demands of new fixtures. Always check the water capacity.

The building's new plumbing loads will also affect the septic system, which can only deal with a limited amount of sewage. If the waste water volume exceeds the capacity of the system, problems will occur. Call a professional when installing a new system, or if you are concerned about the size of an existing one.

## HEALTHY HOUSING ADDITIONS

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Always consider the five principles of Healthy Housing when adding on to a house: occupant health; energy efficiency; resource efficiency; environmental responsibility; and affordability.

Occupant health is of particular importance to many home-owners. To ensure occupant health after the renovation, protect against soil gases, use low-emission products in the construction, provide an effective air barrier and install an efficient ventilation system.

To improve energy efficiency, use high levels of insulation in the new work, whether increasing the existing levels of insulation or not. Use energy-efficient lighting in the new space.

Resource efficiency focusses on using manufactured wood products instead of old-growth forest lumber. Recycled or sustainably-harvested materials are now available in many areas. Other considerations related to environmental responsibility include efficient space planning, reduced construction wastes and the use of durable materials to reduce future maintenance and replacement costs. Good space planning, the use of quality construction techniques and durable materials improve energy efficiency and contribute to enhanced affordability for the owner.

In the process of putting on an addition to their residence, home-owners are making that affect not only the immediate addition but all areas of the existing home. We can see that changes to one area of the home affect systems elsewhere. Air circulation, indoor air quality, electrical and HVAC system demands, structural implications, building envelope, finishes and other items will all be affected by the addition. Be sure to take the effects on the whole house into account when planning or building an addition to a home.

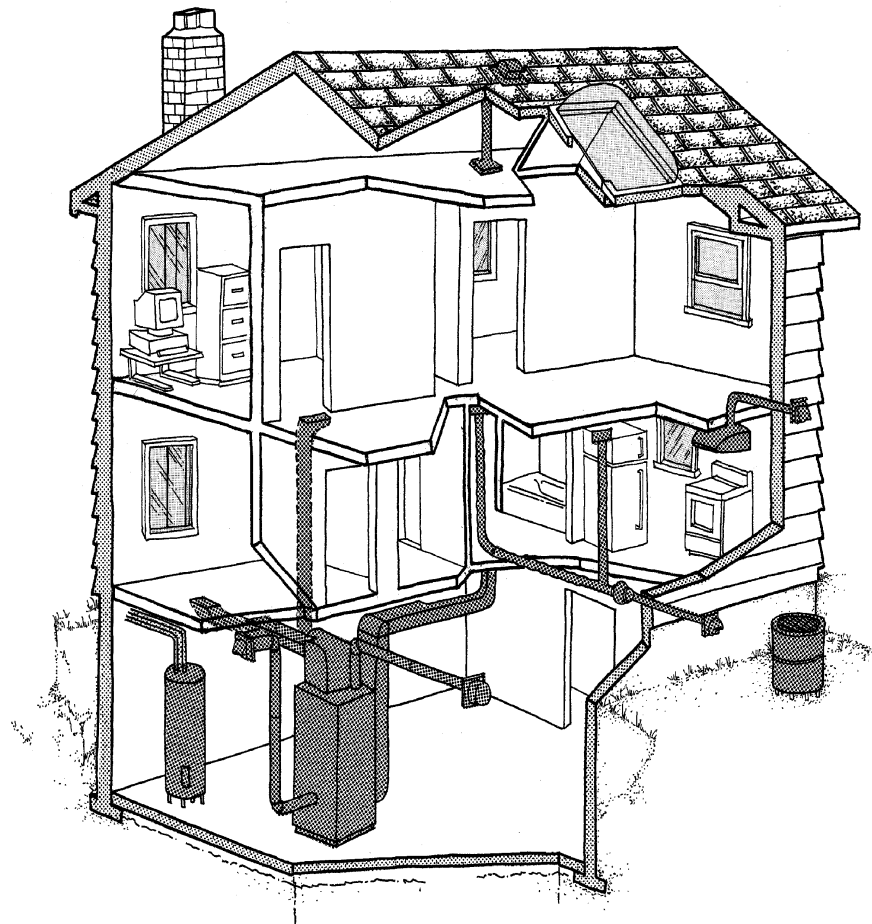


## Renovations and Mechanical Systems

**T**his chapter focusses on issues relating to mechanical systems. The mechanical systems in a home can include heating, cooling and ventilating equipment, as well as other appliances, such as carbon monoxide detectors, electronic air filters and humidifiers. Troubleshooting, fuel conversions and furnace upgrades are a few of the issues discussed.

The chapter begins by introducing different types of mechanical systems and equipment. It provides information on the influences of poor building envelope construction and poor maintenance. It also discusses inspection and problem correction for the different systems, furnace replacement, fuel switching and the effects of other building renovations. The impact of different equipment on the building is considered, as is the effect of the building on the proper functioning of that equipment.

In each renovation, the impacts of, and on, the mechanical systems need to be addressed. This chapter provides the renovator with the tools and information to predict and plan for those impacts.



## INTRODUCTION

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Mechanical systems perform a number of different functions in the building. Their primary role is to help moderate the indoor environment and provide comfort for the occupants. Typically, they are used to provide or remove heat and to ventilate, filter or humidify the air.

The mechanical systems in a house and the air leakage characteristics of the building envelope interact continuously because they perform many overlapping functions. Most systems will affect moisture, temperature and air movement. Mechanical systems also interact with the electrical and plumbing systems.

Many different types of heating systems are available. Heating systems can differ by heat source location, heat transfer media, type of distribution, fuel source and efficiency.

The heating appliance can be centrally located or placed in rooms as part of a unitary system. A central system with a furnace or boiler produces heat in one location and moves it to other areas through a distribution system.

Unitary systems generate heat within each space and are often used when it is impractical or impossible to use a central system. Typically, in older homes, these heaters are installed under or near windows on an outside wall to wash cold envelope surfaces with rising heat. In a well insulated house with energy-efficient windows, the location of unitary systems is not as critical for thermal comfort. Figure 10-1 illustrates air-washing techniques with unitary heaters.

The media used to transfer heat to the rooms and spaces varies with the type of system. Radiant heating systems use hot water, glycol or electrical elements to release heat to the building. Warm air systems use heated air pushed by fan or buoyancy pressure.

A warm air distribution system can use one of two methods to move air into other spaces: gravity or forced convection. With a gravity system, air is heated and rises naturally through ducts. This furnace is relatively large and is nicknamed an “octopus” furnace. These systems are generally effective in distributing heat and do not require extra energy for circulating it.

However, they occupy a lot of space, use large amounts of duct work and have to be located near the centre of the basement. Adding a central air conditioner to this system is usually not possible. With a forced air system, warm air is pushed through ducts by a circulating fan. A forced air system is more flexible and uses smaller diameter ducts.

Different types of heating systems use different sources of energy. Oil, gas and electricity are the most common sources of fuel for primary heating systems. Wood, propane, solar power, coal and pellet stoves are alternative heat sources that can be used in the home.

Air-to-air and ground-source heat pumps are also used to provide both heat and cooling. Typically, warm air systems include gas and oil furnaces, while radiant systems include baseboard electric heaters, electric radiant panels and hydronic systems (hot water radiators) with gas or oil boilers.

Heating systems can vary in efficiency. Different types of equipment require different amounts of fuel or energy to operate. In addition, they often have different outputs or heating capacities. Comparing the ratio of energy consumed to heat output gives the efficiency of a system. The typical efficiencies for different types of equipment are listed in Table 10-1.

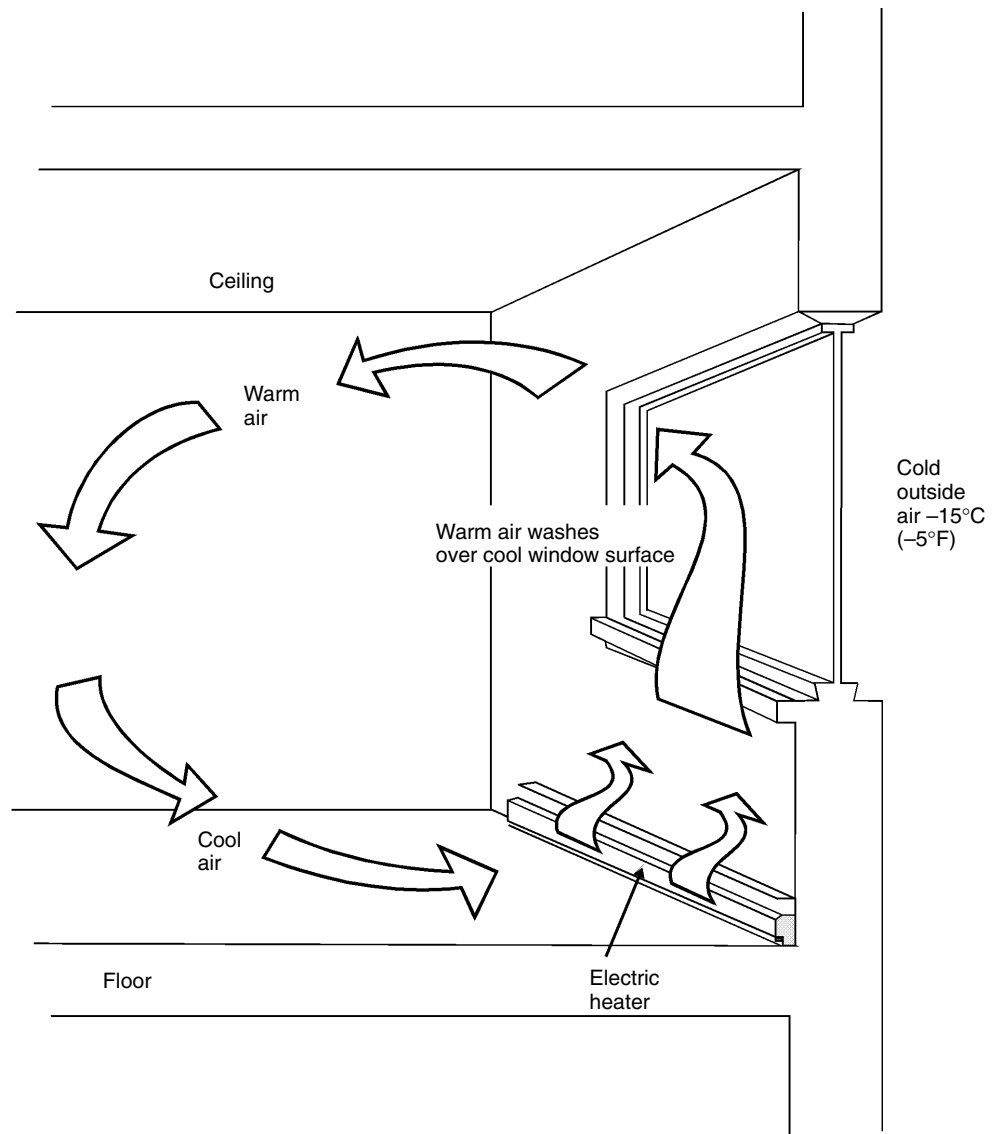
## EXISTING CONDITIONS

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When assessing a house for a renovation, there are a number of problems, thermal comfort issues, or other concerns with the indoor environment that can be found. These can be symptoms of inefficient mechanical systems, poor quality or poorly-installed materials, poor maintenance or faulty equipment. Of course, discomfort problems can also be associated with the building envelope.

The assessment checklist provides you with a list of the possible problems you might detect or the home-owner might report. Be sure that you refer the problem to a qualified mechanical contractor. The discussion that follows is intended to alert you to possible conditions that could exist and their relationship to the performance of the house and its systems. The information here should not be interpreted as



**Figure 10-1: Washing Cold Window and Wall Surfaces with Warm Air**

instructions for the repair and replacement of mechanical equipment. Only qualified personnel should engage in this type of work.

An inefficient mechanical system or building envelope can cause dissatisfaction with the heating system. To be effective, a heating system needs to be sized to the house in which it operates. If the heating plant is too small, it will not be able to meet the needs of the house, especially on very cold days, resulting in discomfort for the occupants. If the system is too large for the loads imposed by the building, it will cycle on and off frequently, reducing its efficiency and increasing the wear and tear on its parts.

Even if a heating system is properly sized, it might not provide enough heat for the building to be comfortable. There are two main reasons for this: poor distribution and excessive heat loss through the building envelope. The distribution of heat is important in ensuring that the building is heated efficiently and adequately. If the distribution system does not function properly, the heat will not be circulated throughout the house. If the building envelope is losing more heat than the system was originally designed to handle, the efficiency of the system could be adversely affected. Before replacing or repairing an existing furnace or heating system, you should fully assess the current

**Table 10-1: Space Heating Systems and their Steady-state Efficiencies**

Space Heating System	Efficiency
<b>Electric Space Heating</b>	
Baseboard, hydronic or plenum (duct)	100%
Forced air furnace	100%
Radiant floor or ceiling panels	100%
<b>Natural Gas or Propane Space Heating</b>	
Furnace or boiler with continuous pilot or spark ignition	60-78%
Induced draft fan furnace or boiler	78-83%
Condensing furnace or boiler	89-96%
<b>Oil Space Heating</b>	
Furnace or boiler	60-75%
Furnace or boiler with flame retention head	70-78%
Mid-efficiency furnace or boiler (no dilution air)	83-89%
Condensing furnace or boiler (no chimney)	85-95%
Direct vent, non-condensing	85-95%
<b>Wood Space Heating</b>	
Fireplace or wood stove	less than 50%
Advanced airtight wood stove	74%
Advanced airtight wood stove and catalytic converter	78%
Wood furnace	50%
<b>Heat Pumps</b>	<b>Coefficient of Performance</b>
Electric or gas fired (air, ground and water source)	1.7-5.0

*provided by Natural Resources Canada*

circumstances of the building and plan for any future changes.

## ASSESSMENT CHECKLIST

This assessment checklist for renovations and mechanical systems outlines typical problems found when inspecting mechanical systems. Each topic is discussed in detail on the referenced pages. A problem can have more than one cause, so it is important to investigate all symptoms carefully.

### Discomfort

Problems with the heat distribution system vary with the type of system and can be a cause of occupant discomfort. Some areas of the house

may be too warm or too cold. Distribution problems are usually found only in centralized systems that require a means of moving heat through the building. Forced air and steam- or water-heating systems are prone to different types of problems.

In forced air systems, problems with the ducts are common. Air flowing through ducts will always take the easiest path. Like liquids, air will simply increase its speed to get through a smaller opening. The speed at which air moves is directly related to the pressure that is moving it and the size of the hole it has to pass through. This is why ducts are sized according to the room that they have to heat. The size of the duct and the air flow determine how much warm air will pass into the room to counter the heat lost through the envelope.

**Checklist****DISCOMFORT (page 176)**

- ☐ discomfort in house — some areas too warm, other areas too cool
- ☐ house is too dry or too humid

**POOR ENVELOPE CONSTRUCTION (page 180)**

- ☐ poorly insulated or leaky envelope
- ☐ uncomfortable drafts
- ☐ cold wall surfaces with or without condensation

**HIGH HEATING BILLS (page 180)**

- ☐ faulty equipment
- ☐ inefficient building envelope
- ☐ inefficient heating or air conditioning system

**POOR MAINTENANCE (page 181)**

- ☐ dirty ducts, clogged filters
- ☐ dirt around air registers or vents
- ☐ smoky smell

**FAULTY EQUIPMENT (page 181)****Gas Furnaces**

- ☐ no heat or insufficient heat
- ☐ pilot light out
- ☐ delayed burner ignition
- ☐ woofing or exploding noise during start-up
- ☐ yellow burner flame

**Oil Furnaces**

- ☐ no heat or intermittent heat
- ☐ noticeable fuel odour
- ☐ woofing or exploding noise during start-up

**Hydronic Systems**

- ☐ no heat or too much heat
- ☐ heat in system but not in radiators or convectors
- ☐ water leaks
- ☐ cloudy water in the water gauge
- ☐ gurgling or hammering noise from convector or radiator

**Checklist (Cont'd)****FAULTY EQUIPMENT Cont'd (page 181)****Water Heaters**

- ☐ calcium or magnesium build-up
- ☐ pilot light out
- ☐ odour

**Heat Pumps**

- ☐ runs but does not heat or cool
- ☐ heats but does not cool, or cools but does not heat
- ☐ low air flow
- ☐ unusual noise

**Air Conditioners**

- ☐ compressor does not turn on
- ☐ system will run but does not cool
- ☐ visible leaking water
- ☐ unusually high operating costs
- ☐ noise
- ☐ leaking water

**VENTILATION (page 184)**

- ☐ too much noise
- ☐ insufficient air flow
- ☐ poor indoor air quality
- ☐ poor air distribution

**CHIMNEYS (page 184)**

- ☐ settlement cracking or spalling
- ☐ creosote build-up on chimney liner
- ☐ damaged chimney liner
- ☐ soot or blockage
- ☐ rusting
- ☐ leakage

In addition, the length of duct affects the amount of air that travels through it. Long ducts need more fan pressure to move a volume of air through them than short ducts. Bends and elbows also impede the flow of air as does flex duct. Typically, dampers are used to balance the amount of air that moves to rooms in the house. A closed damper is all it takes to limit the heat to a room.

If the ducts or vents are too small to carry heat to some rooms in the house, these rooms may not receive enough heat. Other problems that can prevent warm air from reaching its destination are leaks, holes and disconnected segments of duct work. Air will flow out through holes or gaps in the system, just as it flows out through vents. If ducts are blocked by debris or dirt, air can take an easier path out of the system, never reaching the intended rooms.

Ducts should be screwed together and sealed with aluminum tape. If the duct runs through unheated space, it also needs to be insulated. Duct work systems should be designed and installed by a licenced or competent person, in order to fit the individual house properly. Inspecting duct work for problems may solve mysteries about lost heat.

CMHC has developed an inexpensive test to measure the flow through heating registers in rooms. The equipment is easy to build, requiring only an open wire coat hanger and garbage bag. Bend the wire coat hanger until you have a rough rectangle. Tape the open end of a garbage bag around the wire. (The device should look like a big, green butterfly net.) Crush the bag up gently to deflate it and hold it over the supply duct. Time how long it takes to inflate the bag. It does not need to be fully inflated, just up and wrinkly. CMHC calibrated a standard garbage bag (Glad 26 x 36 inches, 66 x 91 cm). Use the following simple numbers to measure the flow (cfm is cubic feet per minute, L/s is litres per second):

- 50 cfm (25 L/s) takes about 3 seconds;
- 30 cfm (15 L/s) takes 5 seconds; and
- 10 cfm (5 L/s ) takes 12-13 seconds.

The test has limited accuracy, but it will indicate if a duct has air flowing out of it. A properly functioning supply duct should deliver 40-80 cfm (20-40 L/s). You can also test

bathroom and other exhaust fans by timing how long it takes a full bag to be emptied. A good bathroom fan should exhaust 40-80 cfm (20-40 L/s).

Water and steam systems also use distribution systems that can be subject to problems. The most common problem is air locks or water trapped inside the system. Fortunately, in older systems, this can be freed through the bleeder valves located on the heating units in individual rooms.

A common concern that applies to all heating systems is ducting or piping that runs through an unheated space. Unheated crawl spaces, attics and other similar spaces are unused and appear to be an ideal place to conceal duct work or piping. Unfortunately, any heating system element exposed to cold temperatures will lose the heat it is carrying. Energy will be wasted on heating unnecessary spaces. Moreover, pipes carrying water can even freeze if temperatures are cold enough, causing possible ruptures or cracks. The freeze and thaw cycles that these elements might be exposed to can also seriously reduce the lifespan of the materials by accelerating deterioration. Pipes and ducts are occasionally run through unheated spaces but are covered in insulation. Although this method works, it should be avoided if possible.

Problems in these areas are not only likely but are also difficult to detect before damage becomes extreme.

Older, leaky buildings often need humidification in winter. Complaints of dryness, cracked skin and electric shocks can be traced to a humidifier that is turned off, maladjusted or faulty. In some cases, humidifiers can become a health concern. Pads need to be cleaned regularly to prevent contaminants from being introduced into the house.

There are other approaches to humidification, including passive methods such as adding indoor plants or tightening the building envelope. Ensure that this aspect of the mechanical system is in proper working condition.

The location of the thermostat is also very important in establishing occupant comfort. For example, a thermostat on an exterior wall can be expected to deliver more heat than is required because it is influenced by the cold wall temperature. Thermostats placed on interior

walls hit by direct sunlight will turn the furnace down before the house is heated to the required temperature. A thermostat located near a local source of heat, a TV for instance, will behave similarly. Carefully review the location of the thermostat before you suggest major alterations to the heating system. Refer to Insight 10 — Measuring Humidity.

### ***Poor Envelope Construction***

The building envelope can have a major affect on the ability of a heating system to function properly. If the envelope is poorly constructed and leaky, wall surfaces will be cold and drafts may occur. Warm air will travel out through the building, and cold air will move in. A heating system will have to produce extra heat to make up for the heat that is being lost.

Inside wall and window surfaces of some older houses tend to be cold. This cold can be felt by a person near those walls or windows as his or her warm body radiates heat to the cold surface. More insulation in the walls or more efficient windows will prevent this discomfort and prevent home-owners from adjusting the thermostat to try to correct the problem. Adding insulation and improving windows can reduce the amount of heat needed. If these things are done, the home's existing heating system can become too large to handle the changed heating loads. If this occurs, the system can become

inefficient, with increased short-cycling and wear on the system.

Tightening the envelope to help prevent uncomfortable drafts will also reduce the amount of heat that the heating system needs to supply. Increased airtightness can also have consequences in terms of both combustion appliance venting and indoor air quality. Refer to Insight 4 — Airtightness Depressurization, and Combustion Appliances. It is important to check for any modifications to the building envelope when investigating problems with mechanical systems.

### ***High Heating Bills***

Regular, unusually high heating bills are often the result of a house that is not energy-efficient. The heating system may be undersized or oversized, or inefficient because of outdated technology, age or deterioration. The house envelope could be leaky or poorly insulated, resulting in excessive heat loss to the exterior. This causes the heating system to work harder and consume more fuel.

The lifestyle of the occupants can also have a large affect on heating costs. If the users regulate the temperature by lowering the thermostat at night or while out of the home, and keep the house at a moderate temperature, they will incur smaller heating costs. Sudden, drastic or irregular changes to the heating bill can be

### ***Insight 10 — Measuring Humidity***

The amount of moisture or water vapour in the air is known as humidity. It is an important part of our lives that helps create a comfortable, healthy environment to live in. But high or low indoor humidity levels can cause problems.

Knowing the humidity levels in the house makes it easier to control humidity and lets you know when you have reached acceptable levels. Humidity in the home can be controlled by changes in activities or habits or by installing new types of mechanical equipment such as exhaust fans or dehumidifiers. Controlling humidity in the home will create a better and healthier environment for the occupants.

A device that can be used to measure relative humidity levels is the hygrometer. (Also known as a relative humidity indicator or sensor.) The two types of hygrometers that are available for

household use are mechanical and electrical hygrometers. Prices vary, and the devices can be purchased in most hardware stores.

Take the hygrometer readings in the rooms that are used most often. It takes approximately two hours to acquire a stable reading in each location. The device must be left to adjust to different changes in relative humidity. To obtain accurate results, it is important that the hygrometer not be placed near areas that radiate direct heat.

The hygrometer will help you determine whether dampness or musty odours are the result of too much indoor humidity, whether surfaces are causing water to condense, or whether the source of moisture is outside the house. The hygrometer is an important piece of equipment in your diagnostic tool kit.

caused by an unusual activity or event. For example, in a semidetached or row house, if the neighbours turn down their heat while away on vacation, extra heat may be lost. If the wall between the units is uninsulated, heat will move into the neighbouring unit.

The most common solutions to heating problems usually involve upgrading or replacing the existing inefficient or poorly operating furnace. However, the furnace unit might not be the problem. When the building envelope is inefficient due to either air leakage or poor insulation, it is the envelope that needs to be improved to reduce the heating costs and improve comfort. Adding insulation or an air barrier will help to reduce these types of problems. If the lifestyle of the building's occupants is problematic, the measures just mentioned may be helpful. However, changing the habits of the occupants would probably cause the most substantial change in heating costs.

A central air conditioning system with high operating costs could indicate the same types of problems as high heating costs. If the problems occur only with the cooling system, they could indicate a problem either with the cooling equipment or the operation of the system. The problems might be a dirty condenser or a dirty or faulty blower fan. A faulty blower fan will need to be serviced. Regular maintenance and inspections will keep the unit in good, efficient working order.

### **Poor General Maintenance**

Irregular or poor maintenance can cause problems with heating and ventilating systems. Dirty ducts, clogged filters and other problems can appear as dirt around registers. The dirt patterns follow the path of the air leaving the register. Cleaning the ducts and inspecting any chimneys for buildup or disrepair will help prevent or remedy any problem. These measures can also improve the quality of the air being distributed in the house.

A smoky smell inside the house during or after the use of any chimney or other heating system can indicate venting failures or a cracked heat exchanger. These problems may also be due to clogged or blocked flues.

Smoky smells can also be caused by exhausted air being drawn back inside the house. For example, air that is exhausted too close to an open window or an intake vent may circulate back inside. To discover the cause of the smell, check the flue for blockage and check the clearances of the chimney above the roof and away from openings and the neighbour's homes.

### **Faulty Equipment**

It is important that the home-owner be encouraged to seek professional advice and service when enquiring about faulty equipment. Likewise, renovators who are unfamiliar with the equipment should not attempt to make any repairs without first contacting a qualified expert. The local gas, oil or electric company can provide additional information and answer any questions you may have.

If a gas furnace is not producing heat, either the power is off or the pilot light is out. If both of these are operating normally, there is likely a problem with the controls and they will require servicing. If the furnace is on but producing insufficient heat, the air intake could be blocked or the burner ports clogged. A delayed burner that fires with a noticeable woofing or exploding is a sign of clogged burner ports, crossovers or pilots. A yellow burner flame can indicate insufficient burning air or clogged burners.

When an oil furnace produces no heat, there are a number of possible causes. There may be no fuel or power source. When it provides only intermittent heat, the problem may be related to low fuel, dirty or clogged oil filters, fuel nozzles, photocells, stack heat sensors or an inoperative pump. If there is a noticeable fuel oil odour, the fuel nozzle or the pump may be leaking. In either case, refer the problem to a qualified heating contractor.

No heat in a steam or hot water system can indicate that no power is being supplied to the system, the water level is too low, the burners are malfunctioning or the thermostat or circulating pump is defective. If there is too much heat in the system, the aquastat or thermostat is likely faulty. If there is heat in the system but not in a radiator or convector, the inlet valve may be closed or air may be trapped inside. There could also be a problem with too much air in the hot water expansion tank or unbalanced air vents in a steam system.

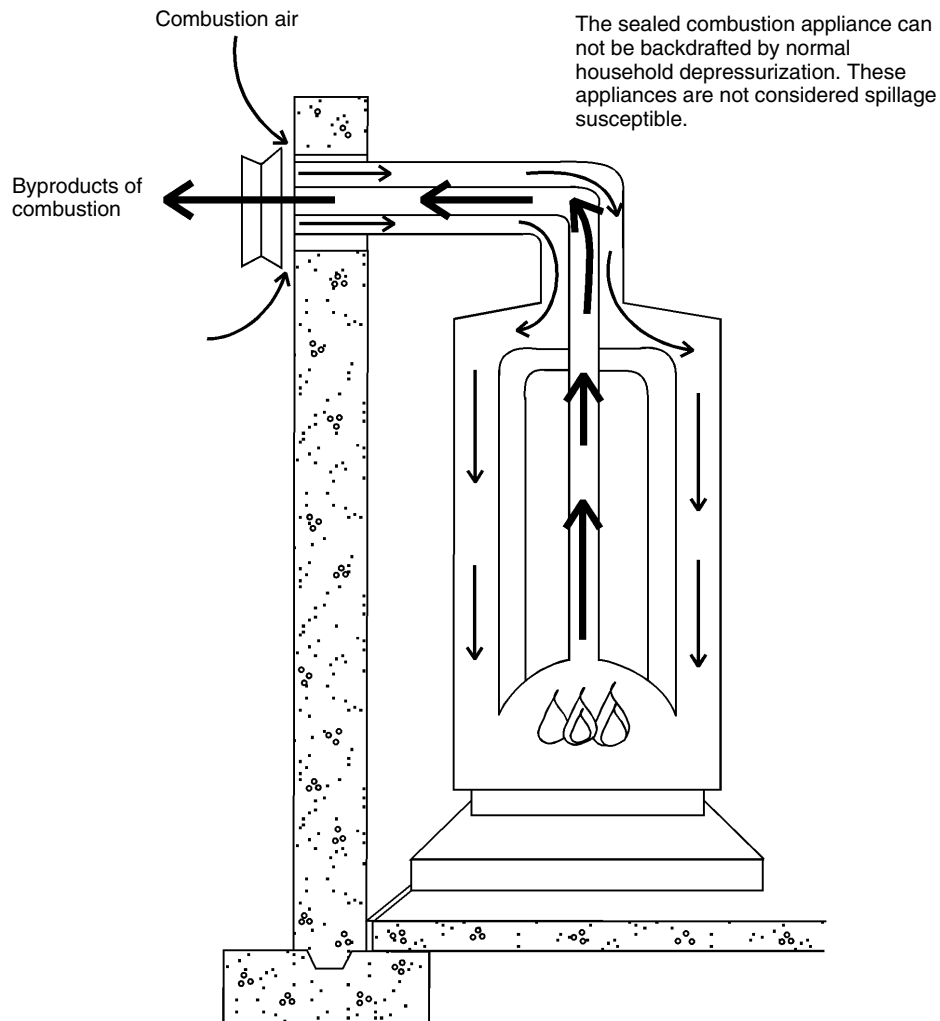
Leaks can occur in a number of places in a liquid-based heating system. A leaking radiator inlet valve is usually the result of worn stem packing that needs to be replaced and tightened. Leaking from the bleeder valve or stem trap indicates faulty equipment. A leaky pressure safety valve indicates that the valve needs to be replaced. If the circulating pump leaks, does not move water or is noisy, the system will require servicing to determine and remedy the problem.

Cloudy water visible in the water gauge of a steam system can indicate rust in the boiler. A gurgling or hammering noise from the convector or radiator can indicate trapped air in a hot water

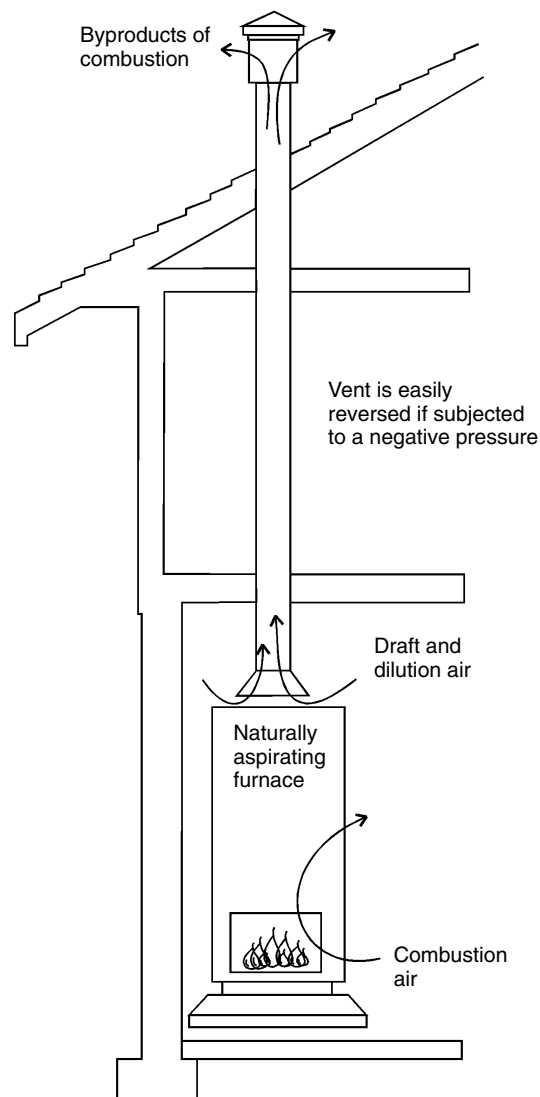
system or trapped water in a steam system. These noises could also indicate that the inlet valve is partly closed in a steam system.

If a heat pump runs but doesn't heat or cool, look for refrigerant leaks. If the heat pump heats but won't cool, the reversing valve may be stuck, heat relay points could be burned, the thermostat could be set too low or the manual control could be set on heat. If the pump cools but won't heat, check for adequate refrigerant levels, a stuck reversing valve, a thermostat set too high or a manual control set to cool. If the heat pump produces a low air flow, the air filter may be dirty, the return air duct could be

**Figure 10-2: Sealed-combustion Appliances**





**Figure 10-3: Natural Draft Combustion Appliances**

blocked or the motor could be on low speed. Noise in the system can indicate a loose pulley or dirty fan blade.

Air conditioners are similar in operation to heat pumps. If the air conditioner compressor does not turn on, there may be no power, the thermostat may be set at too high a temperature or the high-pressure switch or compressor may be faulty. In either of the two final scenarios, the equipment will need to be serviced. If the system turns on and runs but does not produce any cooling, the refrigerant level may be low, the condenser coil dirty, or the blower fan not operating properly.

When the compressor unit is noisy, the problem is often either bent fan blades or loose parts inside the unit. If water is leaking at the furnace, the drainpipe from the evaporator coil pan is probably clogged.

If the air conditioner compressor does not turn on, the problem may be that no power is being supplied to the unit. If the thermostat is not set to cool, the compressor may also not operate. Other common causes of this problem are a faulty high-pressure switch or compressor. In either case, you will need to call for service. If the system runs when turned on but doesn't cool, the refrigerant may be low or the blower

fan not operating. Both problems will require servicing. If the compressor unit is noisy, the fan blades could be bent, or components within the assembly could be loose.

If the system is operating inefficiently, the costs of operating the cooling system will be higher. Possible causes and solutions were discussed in the part of this chapter that dealt with high energy costs.

### **Ventilation**

The most common ventilation system problems include insufficient air flows, noise, poor air distribution and contamination of fresh air supply. Even ventilation equipment that is properly sized and installed might not provide adequate performance.

Blocked intakes and filters can cause the equipment to function poorly. (Intakes that are too close to the ground are easily blocked.) If the duct work is undersized, air flow will be limited. To maximize the system's performance, the ducting should incorporate as few elbows and as little flexible ducting as possible. Flexible ducting produces twice the flow resistance of straight ducting. Each 90° elbow is equivalent to about 10 feet of straight duct.

The grille and diffuser characteristics of the system can affect occupant comfort. The type of grille, its size and the mounting location are all important. They determine how much air is released into a space, and how quickly. Most importantly, it determines whether cool ventilation air is delivered in locations that can cause discomfort. Consult a qualified ventilation system installer for any problems that might exist.

Noise is a frequent complaint about ventilation systems. It is usually due to loose mountings or ducts or poor fan suspension. A vibration-absorbing mount can help to minimize operating noise. A flexible connection placed between the fan and the duct work can also help to minimize fan vibrations being carried into the duct work. The location of the fans can also affect operating noise. The closer the fans are to the mid span of joists, the more noise will be created. Locating fans closer to joist supports will reduce or prevent this problem.

Improper use of the ventilation system or furnace circulation fan can result in poor air distribution. Regular use will improve air distribution and should be encouraged. Exhaust-only ventilation strategies require circulation fan operation for best performance.

Diffusers should be located so that air is circulated throughout an entire room before being exhausted. Proper distribution is critical to adequate ventilation. Other concerns about ventilation systems are discussed in Chapter 2 and later in this chapter. Insight 4 — Airtightness, Depressurization and Combustion Appliances — and Insight 9 — Airtightness and Ventilation — may also provide useful information.

### **Chimneys**

If the materials used in the construction of the chimney or its attachments are unsuitable, a number of symptoms can appear during the house assessment. Problems with materials not lasting as long as expected can be related to the quality of the components or to poor workmanship during the original installation. All materials need to conform to local building code requirements.

Common chimney problems include loose joints, rust holes, corrosion on the flue pipe, dents in chimney pipes, a deteriorating clay chimney liner, wet chimneys, spalling brickwork around the chimney, leaking creosote or a collapsing chimney.

Materials that were improperly installed can contribute to water leakage, moisture infiltration or other water-related problems. Materials that contact water may also be subjected to freeze and thaw cycles. This action makes materials used in the assembly deteriorate faster. In heating systems, the chimney liner is susceptible to this problem. Liner problems also result from water condensing inside the chimney.

Cracks in masonry chimneys may result from settlement. The chimney foundation should be adequate to properly transfer the loads of the chimney to the soil below. If good foundation support is not provided, the chimney may settle unevenly, causing cracking and other problems. If chimney cracks are stable, they can be patched and filled. If they are unstable, they may indicate the need to replace the chimney.

Chimney linings have limitations in buildings, especially when used to vent wood stoves. Unless wood or other solid fuels are regularly burned at high temperatures, creosote can build up on the inside of the chimney liner. If the chimney is not cleaned regularly, the creosote can ignite during use of the chimney. The temperatures in a chimney fire can quickly reach over 982°C (1800°F). These extreme temperatures can cause the tile lining to crack. A stainless steel continuous replacement liner can be installed by someone who is qualified. If other questionable defects are observed in the chimney, they should also be repaired when possible. If repair is not an option, the chimney may have to be replaced.

Chimneys made of masonry or metal can conduct heat to adjacent materials that can burn when subjected to high temperatures. For this reason, your local building code gives minimum clearance distances for flammable materials around chimneys. Check the chimney being used in the renovated house to ensure it can operate safely.

## RENOVATION IMPLICATIONS

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Integrating mechanical systems into the new renovation and the house can be a challenge for the renovator. Although, you will probably not be installing the mechanical equipment yourself, you will need to understand how all of the systems work and how they are interrelated in order to explain it to your client and price your job. The discussion below deals with some of the more common mechanical system projects that can be part of the work.

### ***Fuel Switching and Furnace Replacement***

Converting to a gas heating system can reduce heating costs in areas where gas is available. In areas where gas is unavailable but expected to become available, home-owners might want to consider switching to propane as a transitional fuel. The conversion from a propane system to natural gas later is easy and inexpensive.

A gas domestic water-heating system has some advantages over an electric one. Cost is the obvious advantage. Gas water heaters generally cost more but have lower operating costs than

comparable electric units. The gas system also has a smaller tank due to its greater ability to heat water quickly. The temperature on the water heater thermostat should be set to at least 48°C (120°F) to prevent scaling and biological activity from occurring on the inside of the tank. Higher temperatures can result in scalding.

Installing an electric heating system can be the best choice for heating awkward spaces where ducting can not be installed or easily concealed, or for heating specific spaces, such as bathrooms. Electric systems can also be used in historic homes to discreetly add heat without destroying the historical nature of the building. Regardless of the reason for installing electric heating, it is important that the heating system be properly installed. Check that the service presently available in the house is adequate to meet the electricity needs of the new system. A 60- or 100-amp service is usually inadequate for electric heating needs.

Sizing the new heating system properly is important for achieving comfort and efficiency within the house. A furnace that is too small can result in a house that is uncomfortable during cold winter days. The furnace will struggle to maintain the temperature desired by the occupants and might not be able to generate enough heat. If the furnace is too large, it will cycle on and off frequently, reducing its efficiency and potentially reducing the life of the motor and other components. Oversizing of 25 percent compared to the design heating load is a good practice to allow for adequate heating during extremely cold weather. To ensure proper operation of the system, the furnace should not be oversized by more than 40 percent.

The heating output of the new furnace can be similar to that of the furnace being replaced, provided the previous furnace functioned satisfactorily and no upgrades were made to the building envelope during the renovation. (Before assuming that any problems with inadequate heating were caused by an improperly sized furnace, be sure to check that the distribution system is in proper working order.) If any upgrades were made to the building envelope, such as adding an air barrier, new windows or insulation, the heating load might have been significantly reduced. Before sizing a new, smaller furnace, a calculation of the expected building heat loss should be

performed by a qualified individual. The calculation will help you determine the appropriate size for the new furnace.

When installing a new system that uses duct work or piping, it is important to be aware of the implications of cutting into any structural or framing members to make room for the elements. Your local building code can provide you with more details. Refer to it before you cut into framing members.

A supply of air for combustion is important for combustion appliances and is required by equipment installation codes. Furnace installers generally make provisions for combustion air by providing a duct that supplies air near to the furnace, as required by code. This duct should not be blocked. Similarly, make-up air ducts that limit the depressurization of the house from air-exhausting appliances like central vacuums, downdraft cooktops or other fans should be kept clear. *Insight 4 — Airtightness, Depressurization and Combustion Appliances* — discusses make-up air requirements in more detail.

### ***Adding Air Conditioners***

Proper sizing is important when installing or replacing an air conditioning system. Oversized air conditioning systems will cause the house to feel cold and clammy. Undersized systems will result in dissatisfaction because of inadequate cooling. Get the right size for the individual house or room. Cooling calculations by qualified consultants can help you size the system properly.

Dehumidification is one of the most important functions the air conditioner provides. Proper sizing is most important to ensure dehumidification takes place.

Two types of air conditioners can be installed in a home. A central system cools the entire house, while room units cool only the space in which they are located. Small window units are usually fastened to the windowsill but can be installed into a sleeve in an exterior wall. Weather stripping will help prevent leaks around the joints where the unit is installed. If you are placing the unit in a bedroom or other quiet place, you may want to check noise and vibration levels prior to installing the system. Note that a special power supply may be

required for some appliances. Before making any decisions or purchases, the home-owners should consult a qualified installer.

Central systems are also available for renovation projects. New split systems on the market have compressors outdoors and condensers inside. This system minimizes noise and vibration within the house. The split system is the most energy-efficient system as well. The type of air conditioning unit selected will depend on the preference of the owners.

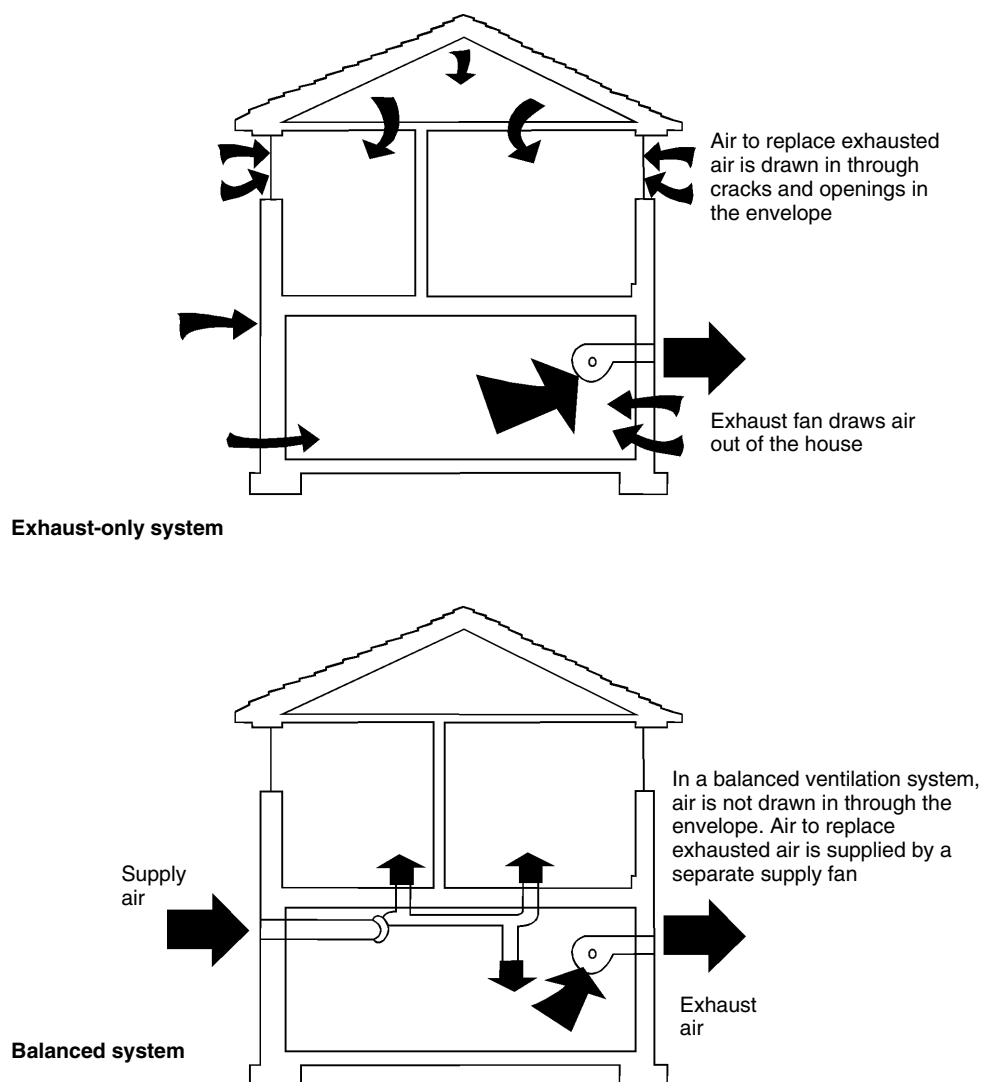
### ***Integrating Ventilation Systems***

Ventilation removes moisture and other contaminants from the interior spaces of the house. Mechanical ventilation systems remove contaminated air from the building and supply fresh air from the outdoors. Because these systems can affect many other aspects of house performance, professional advice is often called for. A ventilation expert can give design, sizing and installation advice to you or the home-owner.

As a renovator, it is important that you understand the basic principles of house ventilation. (Chapter 2 discusses these principles in more detail.) The discussion below is intended to alert you to important ventilation performance issues. It is not intended to make you a ventilation system installer. Only installers qualified by the Heating, Refrigerating and Air Conditioning Institute of Canada (HRAI) should install this equipment.

Mechanical ventilation systems can be broadly classified as either exhaust-only or balanced systems. With an exhaust-only system, fans exhaust contaminated air from the house, while replacement air is drawn into the house through make-up air openings or vents in the envelope. Exhaust-only systems create a pressure across the building envelope that draws outside air in.

A balanced ventilation system removes stale air from the house and replaces it with the same volume of fresh outdoor air. This system does not create a pressure across the envelope and causes little air to infiltrate through it. In addition, the balanced system often tempers the incoming ventilation air. See Figure 10-4. A heat recovery ventilator (HRV) installed as part of a balanced ventilation system will temper fresh outdoor air by using heat from exhausted stale air. An HRV system can be used during the

**Figure 10-4: Exhaust-only and Balanced Ventilation Systems**

cooling season as well, using the cool interior air being exhausted to lower the temperature of the supply air. Often, HRVs have incoming and outgoing air filters to further improve the quality of air being supplied. Heat recovery ventilators can often be easily retrofitted in houses with forced air heating systems. HRVs are available in smaller, less expensive units to ventilate rooms or additions.

Care needs to be taken when locating fresh air intakes to avoid contamination. Potential sources of contamination include exhaust grilles, gas meters, driveways and garbage cans. Air intakes should also be installed at least 450 mm

(18 in.) above grade to prevent blockage by snow in the winter. In some areas that are subject to large snow falls, this clearance needs to be increased to ensure proper operation.

Three rules of thumb should be followed when installing ventilation systems to ensure proper operation. First, locate the HRVs near outside walls to minimize the need for flexible piping and to keep the units away from floor joist mid-spans, where vibration noise will be maximized. Second, locate the exhaust ports serving the HRV, central vacuum and clothes dryer close together on the outside walls. This will provide a greater opportunity to locate

intakes away from exhausts and other sources of contamination. Finally, make the home-owners aware of maintenance and service requirements of their ventilation equipment. Ventilation systems, although not new technology, are still rather unfamiliar to the general public. Home-owners should be made aware of the basic functions and service needs of the equipment to prevent costly problems in the future.

### ***Installing Humidifiers and Dehumidifiers***

Dry air in the winter can cause occupant discomfort. A power humidifier added to the furnace can increase the moisture content of indoor air.

The inside of many humidifiers tends to become coated with mineral deposits, mold and bacteria if untended. Home-owners need to know that regular cleaning is critical. When the unit is shut off for the summer, it should be taken apart and cleaned to ensure maximum operating efficiency and safety during the following winter.

In the summer, there may be an excess of moisture in the indoor air. There are several methods of removing it. Dehumidifiers remove moisture from the air by condensing water vapour over cold coils in the appliance. Air conditioners normally provide this important function in summer. Ventilation can sometimes dehumidify during the summer as well.

### ***Fireplaces and Wood Stoves***

Solid fuel-burning fireplaces and wood stoves are often used as supplementary heat sources. When not in operation, they can provide an opening for air to escape from the building. There are a number of ways to improve the heating efficiency of the fireplace and prevent warm, heated air from being drawn up the chimney.

Check the wood stove doors regularly for defects and tight seals, and use tight-fitting doors to reduce air leakage. Inspect the chimney for any creosote buildup. The fire should burn hot to remove this material and prevent its buildup. Inspect the damper regularly to ensure a tight seal. A tight seal prevents warm air from escaping when the chimney is not in use. All of

these measures will help solid fuel appliances operate more efficiently.

When installing a new chimney, check the heating appliance and chimney manufacturer's installation instructions. They will describe safe and proper installation, and following them may be required under warranty. Local codes and standards give further requirements for fireplace and wood stove installation. The clearances described need to be maintained when placing combustible materials near the fireplace or stove. Combustion air provisions may also be discussed in these documents. It is important that the installation complies to all standards in order to reduce fire hazards and increase occupant safety. See Figure 10-5.

Gas fireplaces have become very popular. Their installation must conform to all local codes and standards. Gas fireplaces must never be vented to the interior of the house.

### ***Heat Pumps***

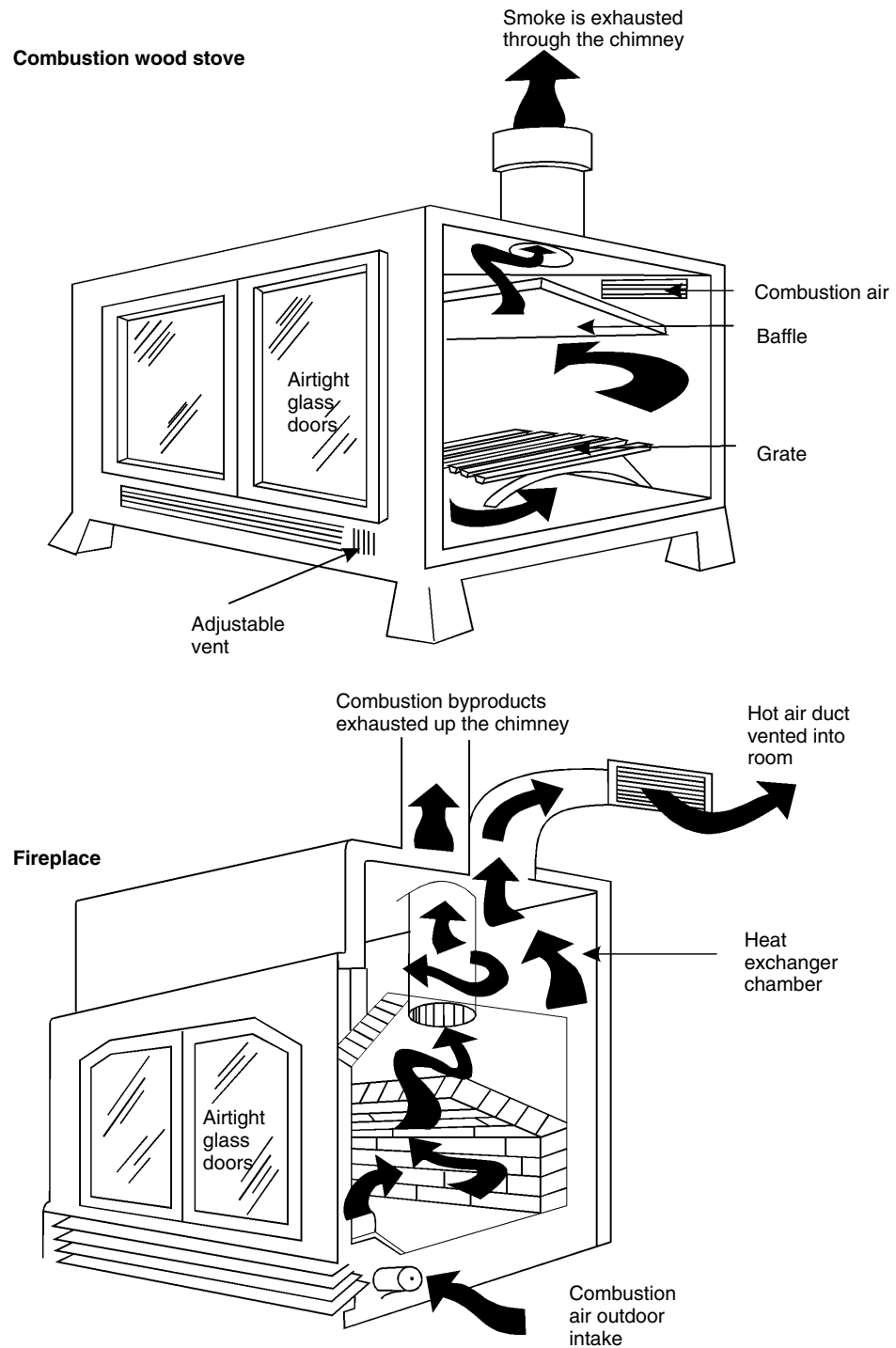
Heat pumps do not produce heat. They absorb it and move it to another place. This allows the pump to transfer heat into and out of a building. Heat pumps can provide both heating and cooling. It takes less energy to transfer heat than to generate it, making heat pump systems very efficient. Within certain limits, heat pumps can extract heat from ground, air or water sources. Air-source pumps do not extract heat during extremely cold temperatures, so a back-up system is required in areas that experience freezing temperatures in the winter. To protect against refrigerant leaks, it is important to properly install and maintain heat pumps. The furnace and air conditioner issues discussed earlier in the chapter also apply to heat pumps. Be sure to familiarize yourself with those issues when installing or inspecting a heat pump. Their installation should be left to a qualified contractor. See Figure 10-6.

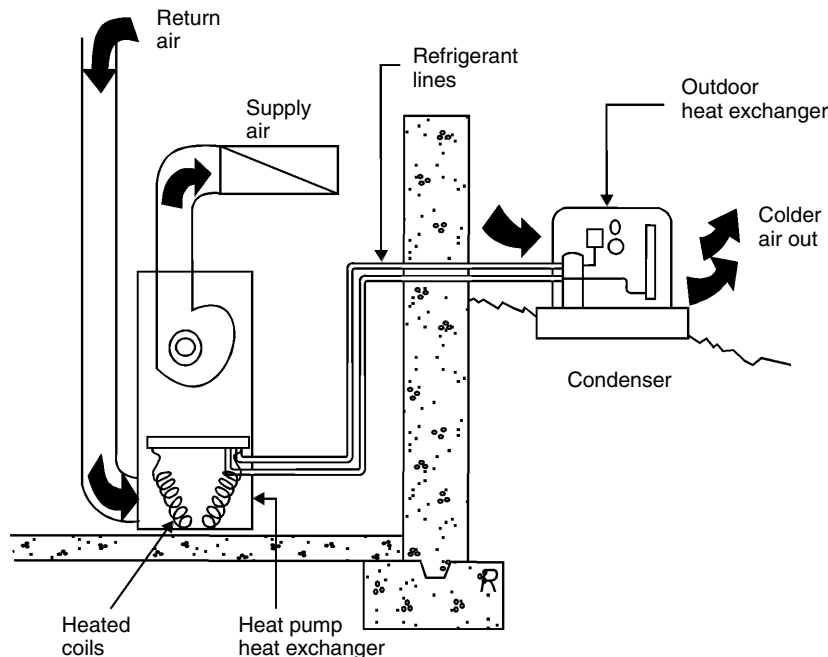
### ***Smoke Alarms and Carbon Monoxide Detectors***

Smoke alarms and carbon monoxide detectors are recommended for today's homes. Hard-wired smoke alarms should be placed on each floor level, in or near bedrooms and in corridors.

Carbon monoxide detectors are often recommended for houses with combustion

**Figure 10-5: Proper and Efficient Wood Stove and Fireplace Characteristics**



**Figure 10-6: Air-source Heat Pump System**

appliances. The detector can sense harmful levels of carbon monoxide resulting from combustion appliances, furnaces or infiltrating contaminants. They are required in some parts of the country when wood heating appliances are used.

## HEALTHY HOUSING MECHANICAL SYSTEMS

Improvements or upgrades to the mechanical systems in a house should also take Healthy Housing concerns into consideration. Occupant health can be improved by installing an energy-efficient ventilation system to keep indoor air fresh, and by checking combustion appliances for spillage and backdrafting into the house. Improving the filtering of air through forced air or ventilation systems will help to remove mold, dust, odours and other particles from the indoor air.

Ultimately, healthier choices that relate to mechanical systems tend to focus on improving the efficiency of the different systems and

finding alternative sources of energy. Higher-efficiency and better-performing mechanical systems can provide long-term energy and dollar savings to the home-owner. High-efficiency furnaces, heat pumps, air conditioners and other appliances can be installed to reduce fuel consumption. Insulating hot air ducts and hot water heaters and pipes will further improve energy efficiency. Using correctly sized equipment for the house will increase the operating efficiency of the mechanical systems and reduce energy and fuel consumption. Automatic controls for the mechanical systems can be used to lower temperatures at night and maintain the best heating levels in the home.

When inspecting an existing mechanical system or planning changes or installations, it is important to be familiar with the condition of the existing house. If there are problems with the heating or other systems, they need to be remedied before any upgrades take place. When working with mechanicals, it is also important to realize that changes in other parts of the house can strongly affect mechanical system



performance. Adding insulation and improving airtightness, for example, can affect system performance. Finally, it is important to be aware of any possible implications of changes to the

mechanical systems. This will help prevent client dissatisfaction and time-consuming callbacks.

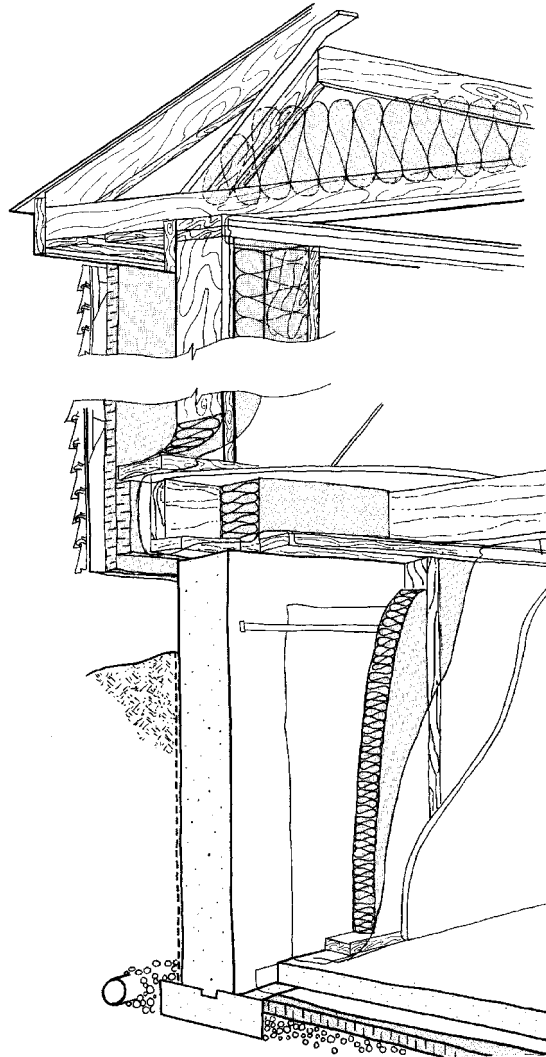


# Energy-efficient Retrofits

**T**his chapter discusses ways of incorporating energy efficiency in the renovation of a house. The benefits can include lower energy bills, increased occupant comfort and reduced environmental impact.

The primary focus will be the building envelope. The chapter reviews the need for assessing the existing house for improvement possibilities. It also applies the building science concepts introduced in Chapter 2 to energy conservation. Air leakage and insulation are examined in depth as the two main areas of energy efficiency upgrades. Other issues, including mechanical systems, lighting, controls, appliances and occupant lifestyles are also discussed, and their impact on energy efficiency is reviewed.

Each house presents a unique situation, so energy-efficient improvements must be carefully tailored to the house and the planned renovation. Remember to always consider the full impact of each renovation on all the systems of the house.



## INTRODUCTION

Energy efficiency in renovations implies using various techniques to reduce energy use within the building. This can involve reducing heat loss by improving the building envelope through such measures as adding insulation or installing better windows. It can also mean improving the mechanical systems, lighting and appliances, or changing the occupants' lifestyle. Energy-efficient buildings deliver high comfort levels to customers without high operating expenses or drastic lifestyle changes. The economic returns from energy efficiency can help justify the expense of many changes to the building.

In a typical home, heat loss occurs through all areas of the building envelope. Typically, it occurs according to the following distribution:

Overall air leakage	(30%)
Conductive heat loss	
- attics and ceilings	(10%)
- walls	(25%)
- windows and doors	(10%)
- basements	(25%)

Energy upgrades to the building envelope generally involve decreasing the level of uncontrolled air flow through a building and increasing the levels of insulation. But energy efficiency encompasses much more.

Air leakage and conductive heat losses are discussed in detail in the pages that follow. Energy, of course, is used for other purposes within the building, such as lights and appliances. These and other factors influencing energy use are discussed later in the chapter. For further information, refer to the *Builders' Manual* published by the Canadian Home Builders' Association (CHBA).

### **Advantages of Energy Efficiency**

As in new construction, there are many benefits to improving energy efficiency during a renovation. In fact, it is difficult to ignore energy efficiency in a renovation project. Both air sealing and adding insulation add little cost to the project but can significantly reduce operating costs and improve the occupant's comfort.

Energy efficiency should not be separate from basic, good renovation practices. A renovation will rarely create a warm, comfortable space without incorporating some aspects of energy efficiency. Energy efficiency opportunities need to be considered and integrated into every renovation project.

As a renovator, you often have the opportunity to encourage the home-owner to reduce the negative environmental impacts of building renovations. Many of these opportunities can also be justified economically. Therefore, improving the energy efficiency of a building being renovated is a triple-win situation — for the home-owner, the renovator and the environment.

Some potential benefits of energy efficiency measures taken during a renovation include:

- reduced energy costs for space heating and cooling;
- reduced water use;
- reduced noise;
- reduced dust levels;
- improved air quality;
- better quality construction;
- increased customer satisfaction and comfort;
- increased affordability of housing due to lower energy and water bills;
- increased function within the space;
- improved safety of the renovated space; and
- lowered environmental impacts from greenhouse gas emissions, urban smog, acid rain and energy generation and transmission.

### ***The Building Science Behind Energy Conservation***

Every house requires a specific amount of heat to keep it warm. Any heat lost from a house will have to be replaced to maintain its warmth. By reducing the amount of heat that is lost, you can reduce the amount of heat that has to be replaced. This will lower the heating costs and could allow for a smaller, more efficient heating system.

Although energy is used for other purposes, space heating usually accounts for a large

percentage of a home's energy consumption. One way to significantly reduce the energy used for space heating is to make the building envelope more energy-efficient. Improvements to the building envelope will also reduce the energy used for space cooling.

The first step toward improving the energy efficiency of the envelope involves reducing the amount of uncontrolled air leaking through it. Reducing air leakage can reduce the amount of heated air escaping and cold air entering the house. It can also reduce cold drafts in the house and help make the house feel more comfortable. Air leakage through the envelope can also reduce the likelihood of condensation damage within the building envelope.

In addition to the benefits of lower energy costs, improved occupant comfort and reduced potential for moisture damage, airtightening of the building envelope makes it possible to install efficient mechanical ventilation. Without envelope air tightening, any mechanical ventilation system must contend with the variable amount of air that leaks in and out of the house through the leaky envelope. This normally means overventilation in winter and underventilation in spring and fall.

The second step toward energy efficiency involves reducing conductive heat loss from the house. This means increasing the levels of insulation in the building envelope. As noted in Chapter 2, insulation slows down the rate of heat loss from the warm interior of the house to the colder exterior, and vice versa during the cooling season.

How much insulation is enough? The answer depends on a number of factors, including the location of the house, the climate, the cost of energy, the existing level of insulation and the nature of the retrofits being contemplated.

If the house is in a colder, northern community, more insulation is needed to keep the building comfortable and heating affordable. In southern or coastal locations, less insulation will provide acceptable levels of comfort and economy. Similarly, if the cost of electricity or space-heating fuel is high, more extensive energy retrofits might be cost effective.

Finally, the upfront cost of the energy retrofit compared to the cost of energy that can be saved

has an impact on the cost effectiveness of insulation. For example, upgrading above-grade wall insulation generally implies high upfront costs and can seldom be justified on the basis of energy savings alone. However, as part of a project where other work is planned, such as siding replacement, upgrading the wall insulation is often economical and normally recommended.

Use your local building code to determine the minimum level of insulation needed. The National Energy Code for Houses Model also provides recommended values for all climatic zones in Canada. It is a valuable reference tool and should be used for specific directions.

Renovators are often encouraged to improve upon minimum required levels of insulation in housing and can refer to a number of other valuable sources of information. Natural Resources Canada has produced a number of useful publications.

## ASSESSMENT CHECKLIST

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The assessment checklist for energy-efficient retrofits identifies energy-retrofit opportunities you can use to improve the house. Try to integrate as many of these energy efficiency measures as possible into each renovation project.

### *The Building Envelope*

The energy efficiency retrofit of the building envelope can involve a number of initiatives, from air sealing to adding insulation to replacing windows and doors. Each upgrade involves a host of decisions, triggering a number of implications. The discussion below outlines the most important issues that you and the home-owner will need to consider as you contemplate each renovation project.

### *Air Leakage*

When discussing improvements to energy efficiency in buildings, most people think only of adding more insulation. This is not the first, or even the easiest, step that can be taken to improve energy efficiency. A simple, economical improvement to consider is making the building more airtight. Heat prevented from leaving the envelope will not need to be replaced by the heating system.

**Checklist****BUILDING ENVELOPE (page 195)****Air Sealing**

- ☐ air seal floor headers and rim joists
- ☐ seal basement penetrations
- ☐ seal ceiling joints, attic and ceiling penetrations
- ☐ seal around all pipes and wires penetrating the air barrier
- ☐ seal electrical panels and electrical fixtures
- ☐ weather-strip or seal around doors, windows and skylights
- ☐ install draft stop and glass doors in fireplace
- ☐ caulk or seal gaps in exterior finishes

**Insulation**

- ☐ insulate attics
- ☐ insulate basement walls and slabs
- ☐ insulate floors over unheated spaces
- ☐ insulate exterior walls
- ☐ insulate window and door frames and wall joints
- ☐ insulate crawlspaces
- ☐ cover crawlspace floor with polyethylene vapour barrier

**Windows and Doors**

- ☐ replace glazing units
- ☐ install energy-efficient, low-E, gas-filled windows
- ☐ install energy-efficient sliding glass doors
- ☐ install energy-efficient double- or triple-glazed skylights
- ☐ install insulated entry doors
- ☐ install insulated overhead garage door
- ☐ replace weather stripping around windows and doors

**MECHANICAL SYSTEMS****Space Heating and Cooling Systems (page 210)**

- ☐ furnace tune-up and safety check
- ☐ install combustion air duct for heating appliances
- ☐ install multispeed furnace or fan motor
- ☐ fuel switch central or unitary heaters
- ☐ upgrade to energy-efficient furnace
- ☐ install programmable thermostat
- ☐ install energy-efficient gas fireplace

**Checklist (Cont'd)****Space Heating and Cooling Systems (cont'd)**

- ☐ install efficient wood-burning fireplace insert
- ☐ seal joints and seams on air plenums and ducts
- ☐ clean chimneys of wood-burning appliances
- ☐ upgrade oil-burning equipment
- ☐ install space heating in bathrooms and vestibules
- ☐ install a ground-, water- or air-source heat pump
- ☐ install or upgrade efficiency of window air conditioning units
- ☐ repair or upgrade existing central air conditioners

**Ventilation**

- ☐ install bathroom fans, dehumidistat controls and timers
- ☐ install kitchen range hoods to vent directly to outside
- ☐ install central or room unit heat recovery ventilators

**Domestic Hot Water Heating**

- ☐ fuel switch electric water heater to natural gas or oil, where cost effective
- ☐ insulate water heater and hot water pipes
- ☐ install toilet-flush water-saving devices, aerator faucets and showerheads
- ☐ replace existing toilet with ultralow-flush toilet
- ☐ replace washing machine with water-conserving type

**OTHER FACTORS (page 211)****Lighting**

- ☐ install energy-efficient light fixtures or bulbs (interior and exterior)

**Controls**

- ☐ install timers, dimmers and motion sensors
- ☐ install power saver cord on automobile

**Appliances**

- ☐ replace with energy-efficient models
- ☐ fuel switch — clothes dryers and stoves

**Lifestyle Choices**

- ☐ turn off lights in rooms when not in use
- ☐ reduce use of appliances and powered equipment
- ☐ reduce use of clothes washing and drying appliances
- ☐ improve daily home operation, such as drawing curtains in evenings

For other choices, see literature from provincial and local utilities and Natural Resources Canada.

**Table 11-1: Energy Retrofit Opportunities**

Renovation Work	Related Energy Retrofit Work	Implications
Repairing wet basement and installation of a new perimeter drainage	Placement of exterior foundation Insulation	Reduced heating and cooling costs Warmer and dryer basement Cost of insulation and above-grade protection Adjustment of heating system
Large-scale roof repair	Increased roof insulation by reconstructing roof or placing a new roof over existing one Installation of continuous air barrier	Reduced heating and cooling bills Lower possibility of ice damming on roof Higher framing and insulation costs
Upgrading of heating and cooling system	Higher-efficiency equipment Improvement to air distribution Balanced forced heating system	Lower heating and cooling costs Higher indoor air quality Higher comfort levels Increased cost of heating and cooling equipment
Recladding	Installation of new air barrier Installation of insulated sheathing	Lower heating and cooling costs Warmer and less drafty house Need for distributed ventilation system Higher humidity levels in the winter Reduced external noise
Interior renovations	Upgrading wall and ceiling insulation Installation of continuous air and vapour barrier Upgrading heating and ventilation systems	Lower heating and cooling costs Warmer and less drafty house Higher humidity levels in the winter Improved indoor air quality Added insulation and framing costs Reduced external noise
Window replacement	Placement of windows to benefit from solar gains High-performance windows Window sealing	Lower heating and cooling costs Reduced radiant heat losses and increased comfort Reduced possibility of condensation Fewer drafts and increased comfort Increased need for mechanical ventilation Reduced external noise
Finishing a basement	Increased basement insulation Installation of a sealed air barrier Placement of a vapour barrier	Lower heating bills, increased comfort Reduced potential for condensation formation on cold concrete basement walls Added insulation and framing costs
Convert attic space into a habitable space	Increased ceiling insulation Installation of air barrier Possible roof retrofit	Lower heating bills and increased comfort Added insulation and framing costs Reduced potential for condensation formation in the attic



A question commonly asked is whether a building can be made too airtight. The answer is no. If the ventilation system is properly installed, it will be effective. If the house is significantly tightened without adding a proper ventilation system, indoor air cannot be replaced regularly enough to provide good quality air. Combustion appliances can also be affected by airtightening. These issues are discussed in Insights 4 and 9.

Air sealing and weather-stripping a building will often produce the quickest reduction in energy consumption for the least cost. In some renovations, there is no practical or economical way of adding more insulation to existing walls. In such cases, air sealing might be the only practical way available to the home-owner or renovator of reducing heat loss. Of course, a house can be made airtight without adding insulation. But insulating without properly tightening may produce disastrous results. (Proper insulation installation is discussed later in this chapter.) A blower door test of the leakage characteristics of the envelope is a good diagnostic tool to use as part of your assessment. It will identify areas of the envelope that leak air and should be sealed. The test can focus your efforts and make the airtightening job easier and more effective.

When air sealing a building, you will want to create a continuous, fully sealed envelope to isolate the interior space. Try to eliminate openings where air can enter or leave the building. Remember that materials in the envelope act together as a system. Be careful when altering any part of the envelope that may be a part of the air-barrier system.

In renovations, sometimes the only practical approach to air sealing the building is to caulk around all door and window frames, along all baseboards and around wall penetrations and openings. This can provide a quick and noticeable difference in energy costs and comfort. In other instances, it may be possible to add a complete air-barrier system where none exists.

Common areas of the building that are prone to air leakage should be fully sealed. As noted in

Figure 11-1, these could include a number of different spaces within the building, such as:

- penetrations of the building envelope like electrical outlets and switches;
- fan openings to the outside or through an attic space;
- space around plumbing stacks and water pipes;
- mail slots and milk boxes; and
- attic hatches.

In some older buildings, it is also important to seal electrical, plumbing and baseboard openings on interior walls. This is because the interior walls often are connected to exterior walls and terminate in the attic where there are leaky wall to ceiling joints. Interior air can move into, and up through, interior partitions (which act like a chimney) and escape into the attic. This process is illustrated in Figure 11-2.

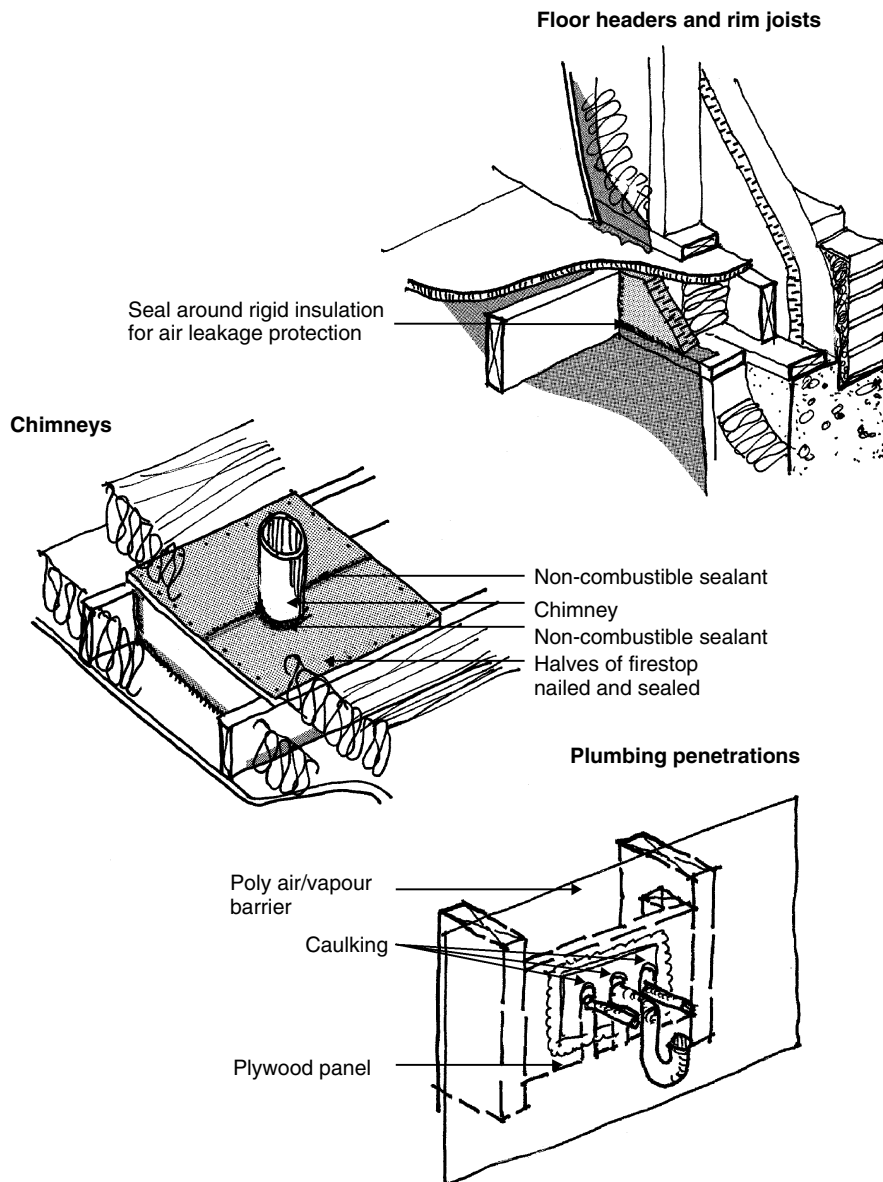
The most efficient and practical way of sealing the attic area is by working from above. This allows access to all partition walls and penetrating elements. Keep in mind when working around chimneys that all materials used should be non-combustible, and required clearances must be maintained.

Access and attic hatches located in a heated space should be properly insulated, weather-stripped and provided with latching mechanisms that can assure a good, airtight seal when closed.

Wherever floor header and joist areas are accessible, they should be sealed. These are notoriously leaky areas of the building envelope that are often overlooked. They must always be protected by vapour barriers if the area is insulated.

Window and door performance is significantly influenced by the quality of the installation and workmanship. Because replacement windows have to be installed in rough openings in walls there is usually a gap that must be insulated and made airtight around the window. Failing to make this gap airtight will undermine the energy improvements of new windows by allowing cold air to short-circuit the units.

The two most common ways of sealing a window are illustrated in Figure 11-3. They include caulking and sealing a one-component

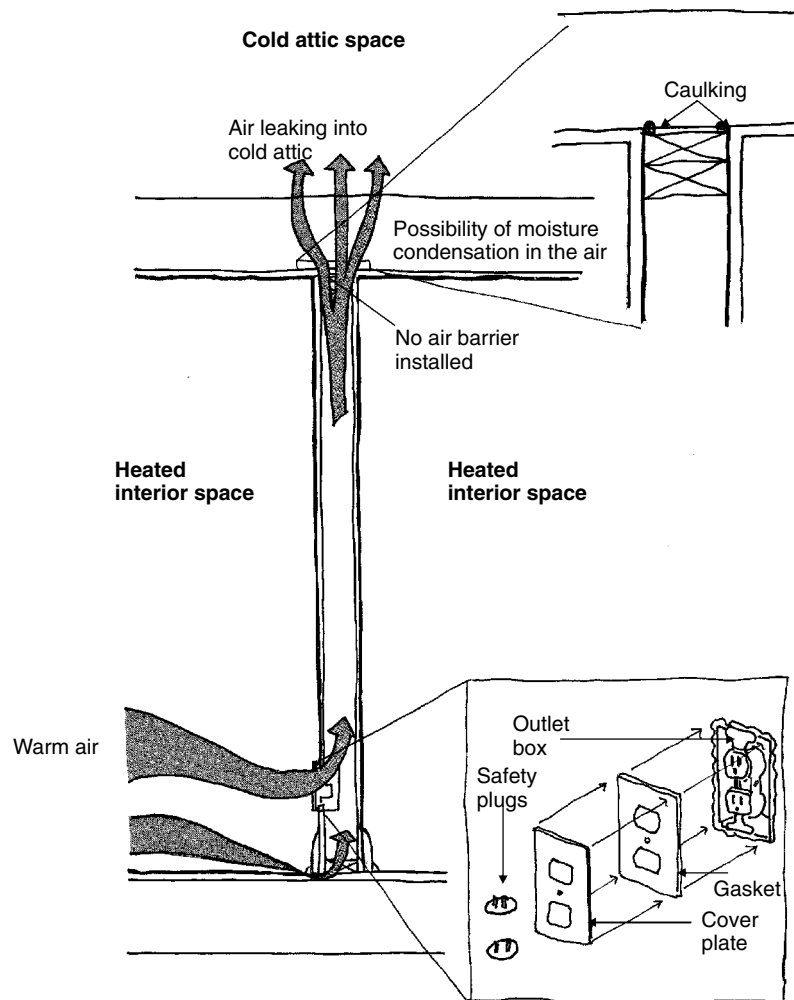
**Figure 11-1: Air Sealing Around the Building**

polyethylene sheet to the window unit and surrounding frame (with the gap around the window stuffed with fibreglass insulation), or using a polyurethane foam to fill and seal between the window and rough opening.

The polyurethane method is commonly used in renovations that do not involve refinishing the walls after installing new windows. When selecting a polyurethane foam for sealing around windows, choose one without too much expansion in order to avoid warping the window frame. Fibrous insulation is not an effective way

of sealing around windows. It is air permeable and no substitute for good caulking or polyurethane foam.

Weather stripping refers to the seal of joints which have to open and close. An example of weather stripping is the material along door frames and operable window frames. Weather stripping is subject to wear and needs periodic checking and replacing. Installing better-quality weather stripping pays for itself through longer life and better performance.

**Figure 11-2: Air Sealing Interior Partitions**

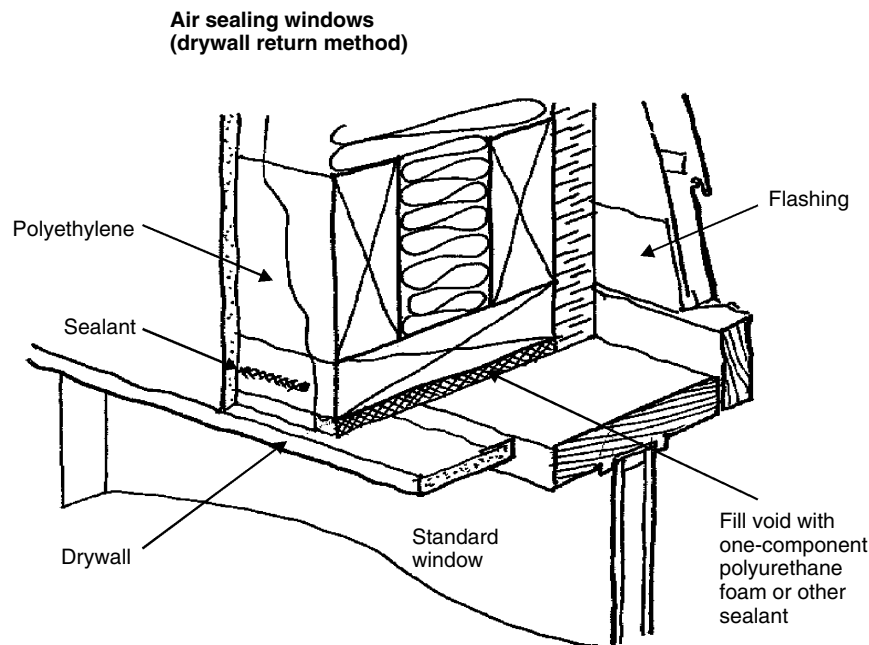
Different window and door designs are more or less effective in creating a quality seal. Testing of window designs shows that casement, awning and hopper windows, which have a positive compression clamping closure, usually perform best in resisting air penetration. Single-hung, double-hung and sliding windows typically have less resistance to air leakage. It is important to realize that most dissatisfaction with windows is from air leaks around the window frame and through the weather stripping.

Finally, air sealing is important in preventing air from bypassing insulation and from causing convection currents in wall and roof cavities. Sealing joints and penetrations through the

envelope will help to create a continuous seal. Always remember that air sealing can take place without adding insulation or any other energy-conservation measures.

For effective air sealing, follow the guidelines in the list below:

- select good quality low-emission materials, caulking and weather stripping;
- use only caulking products approved for use indoors in the location where they are being applied;
- properly prepare any sealant-receiving surfaces according to manufacturer's suggestions;

**Figure 11-3: Air Sealing Around Windows**

- seal from the inside of the house whenever possible;
- remember that top floor ceilings are most effectively sealed from the attic;
- note that insulation will not prove air-barrier protection;
- seal all penetrations into the attic, including plumbing stacks and exhaust vents;
- in older homes, interior walls and ceilings may require sealing;
- after tightening the envelope, check the operation of all mechanical ventilation systems and combustion appliances; and
- ensure adequate ventilation exists to meet occupant needs — effective bathroom and kitchen fans as a minimum are a must.

### **Insulation**

Energy-efficiency measures are one of the few aspects of renovation that can actually end up paying for themselves and returning cost

savings to the home-owner. How much insulation to add, and where to install it, depends on the situation and the home-owner's budget. In a basic analysis the energy savings should pay for all the insulation added to the building over the life of the renovation (about 15-30 years depending on the renovation). The National Energy Code for Houses has established guidelines for cost-effective insulation levels in new housing. They are a good starting point for your renovation.

You can combine two or more different materials to deliver the desired level of insulation. Insulation may be selected for economy or to fit the needs of a special application. Where there is a desire to keep the walls thin, for example, it may be necessary to use a more expensive high-thermal-resistance board to meet space restrictions. For exterior basement insulation, the choice of insulation is restricted to types that can tolerate direct contact with wet soil.

Prices may be higher for insulation that has properties that make it preferable for a specific

application. But installing the proper insulation at the beginning can prevent future expenses for repairs or changes.

Because of varying conditions and construction styles, the levels of wall insulation can range from no added insulation to R-2000 requirements or higher. During a renovation, it is wise to meet or exceed the existing insulation standards found in the local building code or the Model National Energy Code for Houses. Where changes are restricted by the type of work performed, the age or historical nature of the building, home-owner preferences or other factors, it is important to incorporate insulation levels that are as high as possible, both practically and economically. When completely gutting and rebuilding, an opportunity may exist to use updated or innovative construction techniques to insulate the walls.

It is important to assess how much insulation is present in the existing building. Sometimes it is possible to remove electrical wall plates and probe for the presence of insulation with a non-conducting probe. In wood-frame walls or ceilings, drilling small, exploratory holes in inconspicuous locations may reveal the level of insulation. Accessible attic spaces can be inspected easily. Knowing how much insulation exists will help you determine how much more to add. See Figure 11-4.

Before adding insulation to any part of a building, make sure that an air barrier and a vapour retarder have been installed and are in good condition. Air and vapour barriers can be separate or combined.

The air-barrier system needs to be continuous, able to withstand any wind to which it may be subjected, and made of air-impermeable materials. It can be placed anywhere in the building assembly, provided it does not also act as a vapour barrier.

Installing a continuous air barrier on the interior or warm side of insulation often involves installing a polyethylene sheet. A polyethylene air barrier also calls for sealing joints, penetrations and seams between sheets. Special attention must be paid to the details to make the upgrade effective. When renovating a building, make sure that any new air-barrier system is properly sealed to the existing one. The air

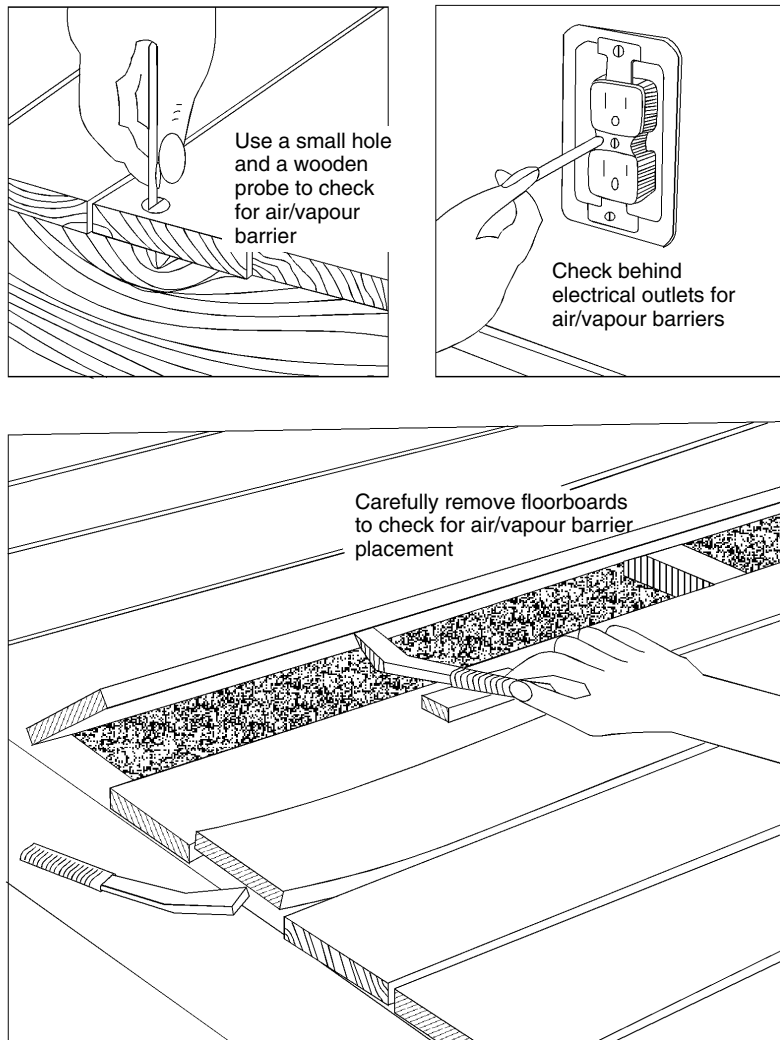
barrier will help to prevent air from short-circuiting the insulation, thereby reducing its effectiveness. More importantly, it will prevent air from carrying moisture into the insulation where it may condense or freeze and cause damage.

Other approaches to air-barrier protection involve rigid materials like framing, drywall and gasketing, caulking or sealants. Carefully sealing the edges of taped drywall at the bottom and top plates can provide a measure of air-barrier protection. Gasketing has also been successfully used to provide this seal. Sealing electrical outlets can be challenging when using drywall as the air barrier. When possible, these are often more easily accommodated on interior walls.

A vapour-retarder system must be installed on the warm side of the insulation and be resistant to vapour diffusion. (See Insight 2 — What is Dew Point?) It is needed on the warm side of the insulation to prevent moisture from moving into the wall assembly. If new insulation is added over an existing vapour retarder, keep the retarder within the warm side of the dew point. Remember, in moderate climates, the rule of thumb is to locate the vapour barrier within the first third of the insulation R-value, measured from inside. This changes to the first fifth in the Arctic. You can use a number of materials, such as polyethylene, special vapour-barrier paint or foamed-plastic insulation, to provide vapour-barrier protection.

A vapour retarder does not need to be continuous. A combined air- and vapour-barrier system (that is, one that meets the requirements of both) must be continuous, installed on the warm side of the dew point, impermeable to air and moisture movement and able to withstand any wind loads.

When insulating from the outside, pay careful attention to sealing holes and joints, so that air does not blow around the new insulation and into the house. The additional insulation should form as complete a blanket as possible. Holes and gaps will only decrease its effectiveness. A vapour-permeable, but continuous, air and weather barrier installed outside the insulation can help keep wind and weather out of the insulation to preserve its ability to resist heat loss.

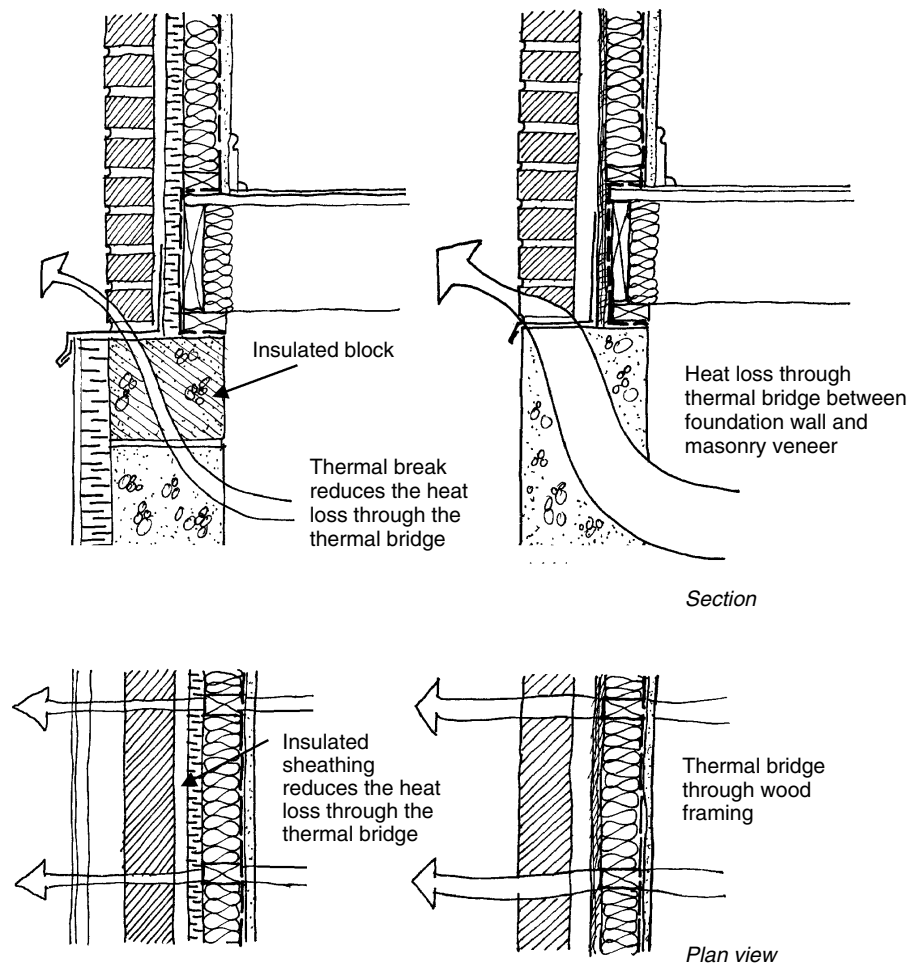
**Figure 11-4: Checking for Air and Vapour Barriers**

Elements that puncture the insulation act like a thermal bridge. They provide a path for heat through the insulation, just as a bridge provides a path over water. Brick ties, uninsulated lintels, or pipe penetrations can all act as thermal bridges. A thermal bridge can greatly increase heat loss through the building envelope and should be avoided whenever possible. See Figure 11-5.

A final issue to be addressed whenever adding insulation is ventilation. When adding insulation, you must add an air and vapour barrier to prevent condensation from occurring

within the envelope. As a consequence, the building's air leakage will decrease. This could mean that a poor indoor air quality situation will be made worse. Mechanical ventilation is normally used for moisture and odour control and to remove contaminated air by supplying fresh outside air.

After determining how much insulation to add and preparing the building to receive the new insulation, you will have to work with the home-owner to decide where to add it. Insulation can be added to a home in a number

**Figure 11-5: Thermal Bridges**

of different locations. Three common areas are attics, walls and basements.

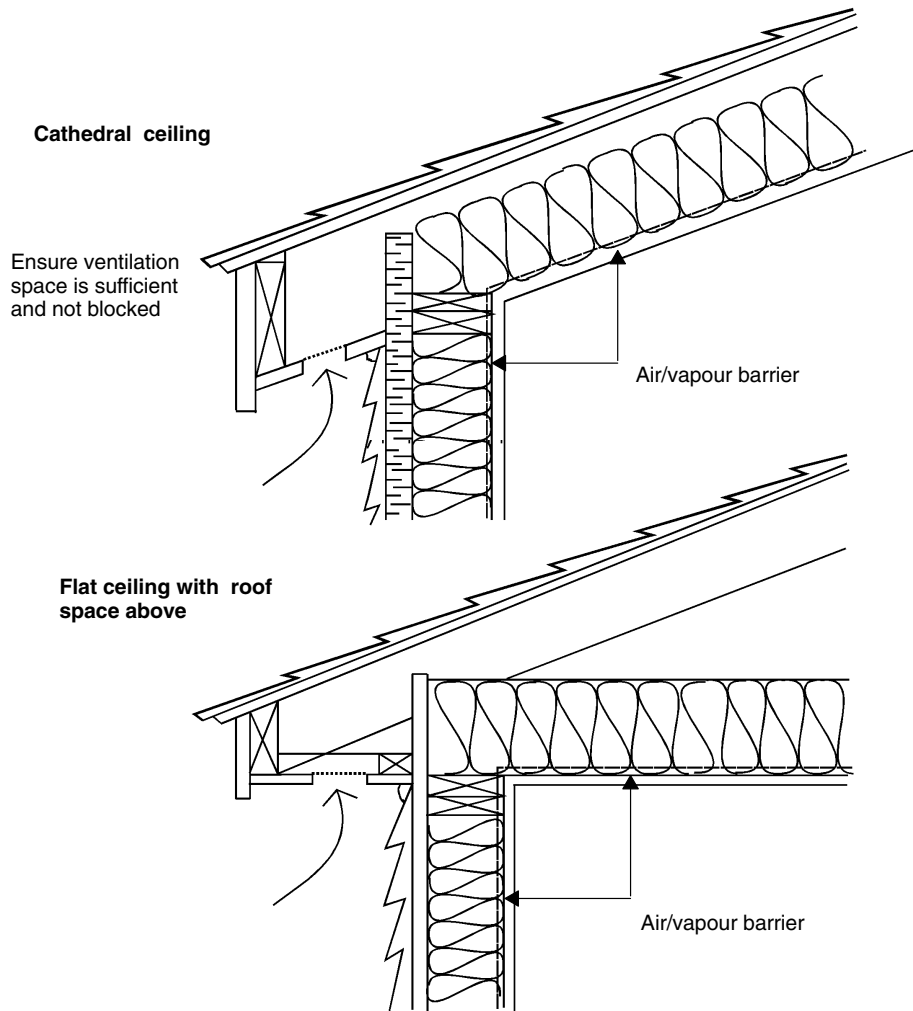
Each of these is discussed separately in this section.

When increasing insulation levels, the attic or roof is often the first area considered. There are two general types of attic or ceiling construction encountered in houses. Most common is a flat ceiling with an enclosed attic above. Cathedral ceilings, where the ceiling and roof finishes are secured to the same member, are also common. See Figure 11-6. During a renovation, either or both ceiling types can be encountered.

It is important to ensure that there are no moisture problems before installing new attic or ceiling insulation. Any existing moisture problems that are not resolved will usually be

made worse by the new insulation. Examine the existing insulation for wetness or staining. Check the rafters for any signs of decay or moisture damage, paying particular attention to areas near plumbing stacks, light fixtures or other penetrations in the attic. See Figure 11-7.

In buildings with flat ceilings and unfinished attic spaces, there is usually plenty of room to add insulation. Blown-in insulation, where available, is economical and easy to install. It also conforms to irregular spaces. This insulation can be made from chopped fibreglass, rock wool or cellulose. In other cases, batt insulation can be used. Be sure to cover the ceiling joists with an ample thickness of insulation to reduce thermal bridging. Check the integrity of the air and vapour barriers. Seal around all penetrations into the attic. Ensure

**Figure 11-6: Cathedral and Flat Roofs**

attic hatches are insulated, weather-stripped and can be latched tightly, as shown in Figure 11-8.

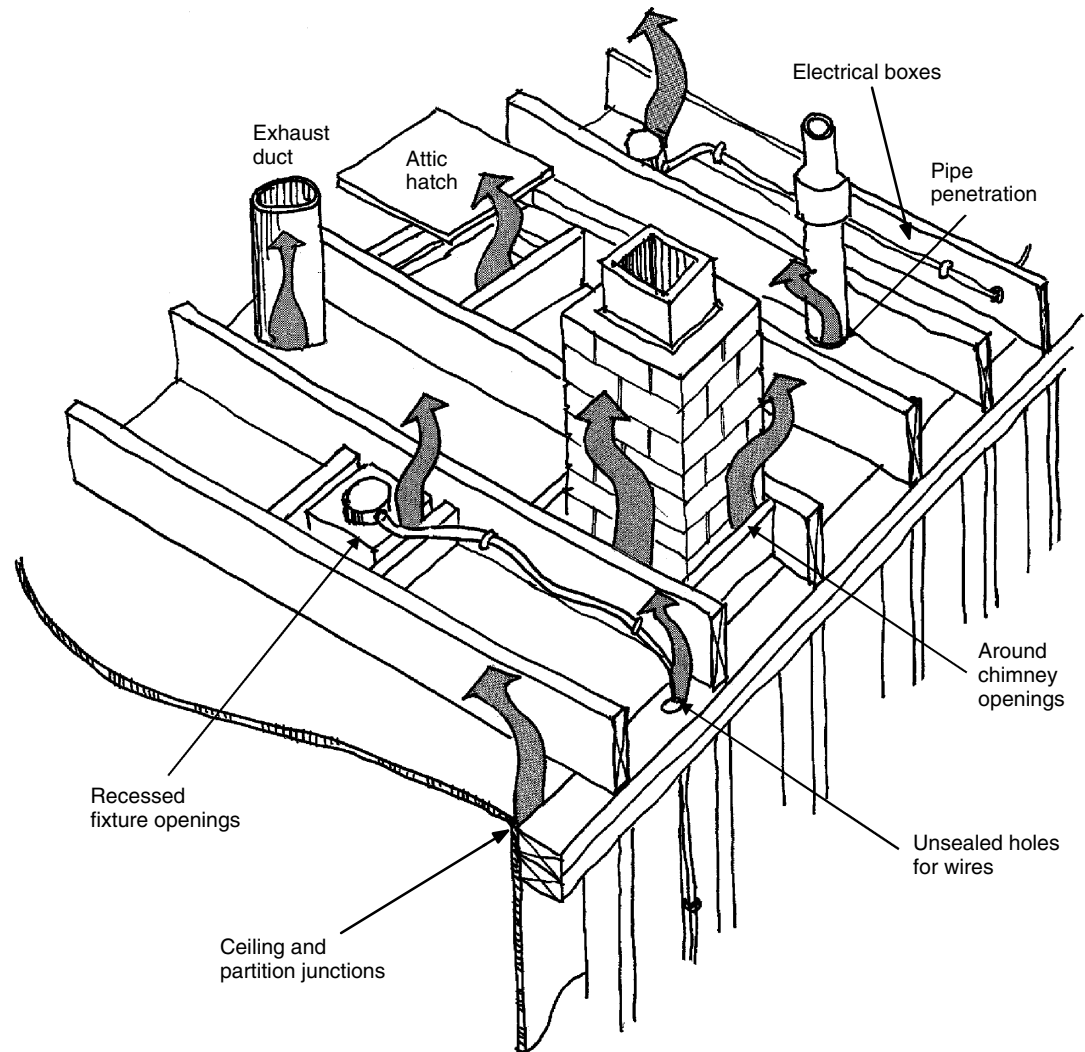
For cathedral ceilings or finished attics, you can add additional insulation on the inside or outside surfaces. Insulation is added to the inside either as a layer of strapping and batt insulation or as rigid insulation. Adding interior insulation almost always requires a new interior finish.

Cathedral ceilings can be insulated from the outside by adding rigid insulation to the roof, then resheathing and reroofing. Ensure that the existing vents are sealed and the ventilation space has been filled with insulation. Use sleepers on the existing roof to provide a ventilation space above the new rigid insulation.

Blown-in insulation is normally the easiest type to use for filling the old ventilation space. When adding insulation to a cathedral ceiling, make sure that any vapour barrier or combined air and vapour barrier is still located on the warm side of the dew point. When adding insulation to the inside surface, it may be advisable to install a new air and vapour barrier.

Ventilation is important for both types of roofs. In an unfinished attic space, proper ventilation moderates the roof temperature and can help to mitigate moisture problems. The most common vents for these spaces are soffit and roof vents, although gable and ridge vents are also available. Soffit vents must not be blocked with insulation. Baffles are often used to prevent this.



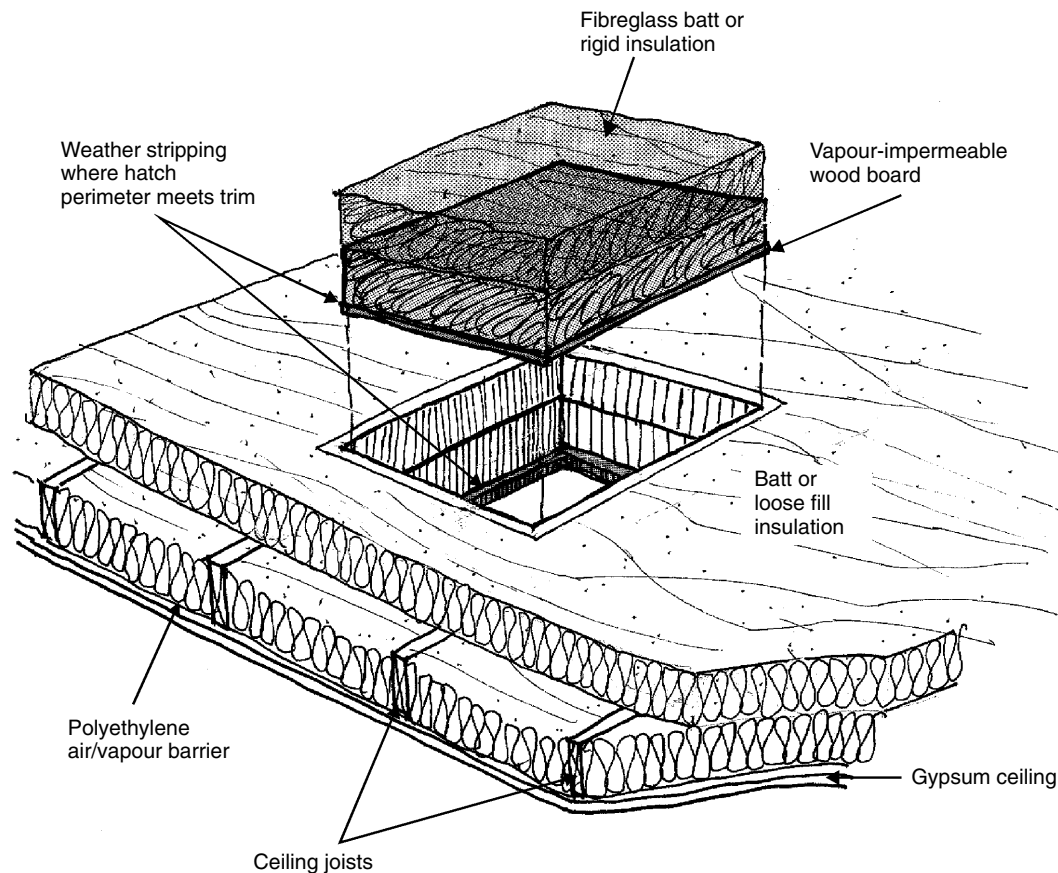
**Figure 11-7: Air Sealing Penetrations in the Attic**

In a cathedral ceiling, ventilation is sometimes more difficult to provide. An adequate amount of ventilation space needs to be maintained to ensure the roof system functions properly. Continuous soffit and ridge vents can be used in these roofs to promote air movement.

Interior attic renovations will also affect the insulation and ventilation of attic spaces. These issues are discussed in detail in Chapter 8 — Attic Renovations. Read that chapter before you make any major changes to the attic space.

Usually, the building component with the largest exposed area is the exterior wall. Walls provide a great opportunity for adding insulation when they are first built. Unfortunately, they can be quite difficult to upgrade, unless major modifications are contemplated.

In buildings with empty wall cavities, you can add blown-in insulation from inside or outside through small, drilled holes. Solid walls can be insulated on the interior or exterior surfaces by adding framing and batt insulation or spray foam. Alternatively, you can attach board

**Figure 11-8: Insulating and Weather-stripping Attic Hatches**

insulation to the surface of the wall directly. Both of these techniques will require a new wall finish and alterations to the electrical, and possibly the heat-distribution systems, after the insulation is added.

When the renovation proceeds from the exterior, an adequate weather barrier is sometimes a valuable component to add to the wall system. Adding insulation to the exterior of the house usually means that walls become thicker. As a result, the windows and doors will need to be built out over the new insulation and exterior finish.

When insulating from the inside, let the home-owner know if any space is going to be reduced. Additional framing and finishes used to support new insulation can subtract up to eight inches from the dimensions of a room. The home-owner will want to ensure that the interior spaces will still be functional if made smaller.

Homes often contain unfinished basements. Family expansion, changing needs and other factors can cause a family to choose to finish that space. To improve comfort within an unfinished (or even previously finished) basement, a common practice is to insulate the walls. The practice of insulating basement walls can extend beyond refinishing projects. Insulating the basement can significantly reduce the heat loss of a building. An uninsulated basement can be responsible for around one quarter of the total building heat loss.

Always check for moisture and potential mold problems before you renovate. Trapped moisture can cause many problems with the new work, while mold can have serious health effects. Read Chapter 3 for more details.

There are two approaches to renovating a basement for energy efficiency. The most common way of insulating an existing basement

is from the inside. This usually involves installing a dampproofing membrane against the foundation wall up to grade level, building a non-load-bearing wood or steel-frame wall, and adding insulation and a combined air and vapour barrier on the inside surface of the wall. If steel framing is used, beware of the strong thermal bridge through the material. A rigid insulation product separating the framing from the foundation wall is often the best solution. Insulating the basement from the outside involves attaching insulation to the outside after excavating and possibly dampproofing. The above-grade portion of the insulation normally needs to be protected from damage.

Each method of insulating basement walls has advantages and disadvantages. Insulating a basement from the interior will provide a warm, comfortable living room in the house, but it will decrease the floor area of the basement. The cost of interior insulation is relatively low, so higher levels of insulation can be added. The renovation can also be done at any time of the year. And interior insulation facilitates easy addition of wall finishes later.

Exterior basement insulation provides some distinct advantages over interior methods. Basement walls are protected from the natural elements, reducing the possibility of damage from the freeze-thaw cycle and adfreezing. If the basement is excavated when adding insulation, walls can be dampproofed, and drain tiles and drainage layers repaired or installed. In fact, some types of exterior foundation insulation provide drainage characteristics, keeping the basement dry while also insulating. The exterior insulation approach can also correct landscaping problems around the foundation. Moreover, the interior finishes, plumbing and electrical services are not disturbed, and no interior space is lost.

There are also disadvantages to each insulation placement option. Interior basement insulation coverage can be disrupted by electrical services, plumbing, stairs and partitions. (Plumbing should always be installed on the warm side of insulation.)

On the other hand, exterior insulation is much more expensive than interior insulation and has other disadvantages to be aware of. The most obvious is the need to excavate before

installation. Another disadvantage is that exterior installation is only practical during the warm months of the year.

Chapter 3 discusses the implications of basement insulation and basement moisture concerns in detail. Read it before you add any insulation to the basement.

When adding insulation to a building, remember the following important parts of the process:

- check the extent and condition of the existing insulation, air-barrier and vapour-barrier systems;
- consider the opportunity for energy-efficiency upgrades as part of each renovation project;
- determine whether any materials can be salvaged or reused;
- carefully plan the energy retrofit based on your preliminary findings; and
- proceed with upgrading the energy-efficiency aspects of the renovation.

### **Windows and Doors**

Window and door upgrades are popular among home-owners because they improve both the energy efficiency and appearance of the house. Windows and doors are often weak points in the building's thermal envelope. By upgrading old, leaky, single-pane windows to today's modern standards, you can easily cut in half the amount of energy lost through the windows.

Nonetheless, window and door upgrades rarely pay for themselves through energy savings alone. However, when comfort, aesthetics, value and customer satisfaction are considered, these upgrades can be a very worthwhile, energy-efficient improvement.

The thermal performance of windows has improved greatly in recent years with the use of low-emissivity coatings, insulating gases between panes, better quality seals, insulated frames and other features. Low-emission coatings, in particular, have been useful in preventing heat from entering or escaping from the building.

Many window products today are rated for their energy performance. Their energy rating (ER) measures the overall heating impact of the window in a typical house. The ER incorporates

the solar heat gain, the transmission heat loss and the infiltration heat loss of the window, calculated over the entire heating season for average winter conditions. The window's ER may be positive or negative. A positive ER indicates that, on average, the window gains energy over the heating season.

Doors too have been improved in a variety of ways. These include:

- better weather stripping, which prevents air leakage and drafts around its perimeter;
- lights with better thermal resistance often replace the single-paned elements;
- sandwiching a layer of insulation between hollow wood or steel panels; and
- substantially increased R-values.

Advances in windows and doors are ongoing. It is good practice to use the most advanced technology that is economical and available for the renovation.

Window and door replacements and upgrades are discussed in more detail in Chapter 5. That chapter deals exclusively with existing windows and doors, as well as the implications of possible improvements.

## MECHANICAL SYSTEMS

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Insulation upgrades can overshadow other types of energy retrofits, sometimes causing them to be ignored. The rest of this chapter discusses other aspects of energy efficiency within the home. Mechanical systems are one such aspect. The most common mechanical systems found in homes include heating, cooling, ventilation, and domestic hot water systems.

Mechanical equipment should be maintained regularly to ensure its efficient operation. Chapter 10 has already dealt with these important influences on house performance. If a system or piece of equipment is not functioning properly, or if it is dirty, efficiency can be greatly reduced. Furnaces, hot water heaters, heat recovery ventilators, air conditioners and other types of equipment all require regular maintenance for continued efficient operation. Some appliances, such as wood stoves and

chimneys, can pose health and safety problems if neglected.

### ***Heating and Cooling***

When adding insulation or reducing air leakage, the heat loss in a building can be substantially decreased. A new heat loss calculation may be required after any renovation to ensure that the existing furnace has not become substantially oversized.

A furnace or cooling system must be properly sized to meet the needs of the house in which it operates. A furnace that is too large or too small operates inefficiently. Furnace capacities that exceed the heat loss for the design by more than 40 percent can cause premature failure of the appliance as it cycles on and off more frequently. In a gas or oil system, a new orifice may eliminate the problem. Advice from a qualified furnace installer is normally recommended. Before installing any new heating, cooling or ventilating equipment, a calculation may also be necessary. Heating loads can be calculated by a qualified technician.

When installing a new heating or cooling system, choose the most efficient system that is economical for the home-owner. Having an efficient system may cost marginally more to purchase, but savings over the life of the system will offset any cost difference. A high-efficiency system also increases the resale value of the building, making energy-efficient furnaces even more economical.

### ***Ventilation***

When tightening a house to prevent air leakage, moisture movement or heat loss, additional ventilation may be required. This will rid the house of contaminants that were being diluted by infiltration and removed by exfiltration. Failure to properly ventilate a tightened space can lead to unacceptable levels of indoor pollutants, including moisture. This can affect the health and safety of the occupants. In a tightened house, air-exhausting appliances can induce enough pressure to backdraft conventional combustion appliances.

When installing ventilation, exhaust-only systems can be installed in kitchens as rangehoods and in bathrooms as exhaust fans. New, air-exhausting ventilation equipment must be quiet and efficient and should be checked for

any adverse effects on the venting of combustion equipment. Refer to Chapter 10 for a full discussion of the ventilation system options available. Insight 4 — Airtightness, Depressurization and Combustion Appliances — discusses these issues in more detail.

### ***Domestic Hot Water Heating***

Water-consuming fixtures are often overlooked when making energy-efficiency decisions. By reducing water consumption, the costs of supplying and heating water are also reduced. An additional benefit is reduced environmental impacts. Low-flow toilets, faucets and showerheads are currently available, as are appliances that use less water.

Reducing the water temperature of the domestic system will decrease the amount of electricity or fuel being used for water heating. Installing an insulating jacket around the water heater can prevent heat from being lost through the equipment. A heat trap will also provide energy-saving benefits. This will reduce the costs of keeping the water in the tank heated. Insulating the hot water pipes can result in hotter water being delivered to the fixtures, lower required water heater temperatures and energy cost savings. As environmental awareness increases, it is likely that other developments will become common.

Figures 11-9 and 11-10 illustrate methods of insulating elements of the mechanical systems in order to improve energy efficiency and reduce heat loss.

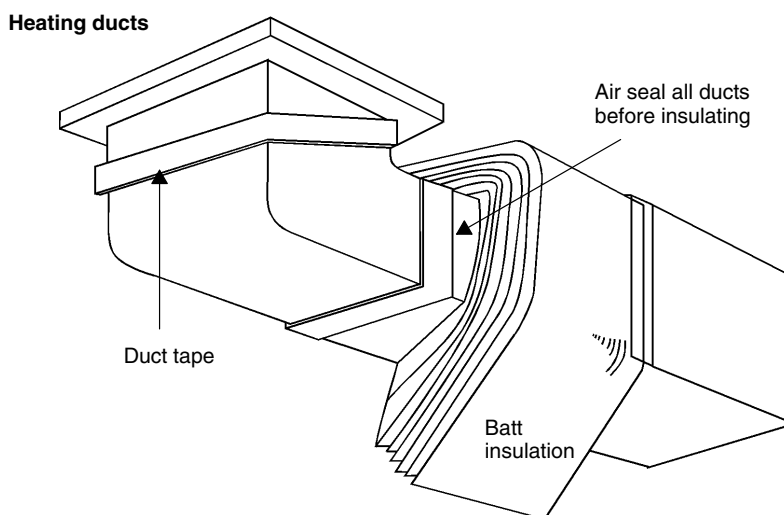
## **OTHER FACTORS INFLUENCING ENERGY CONSERVATION**

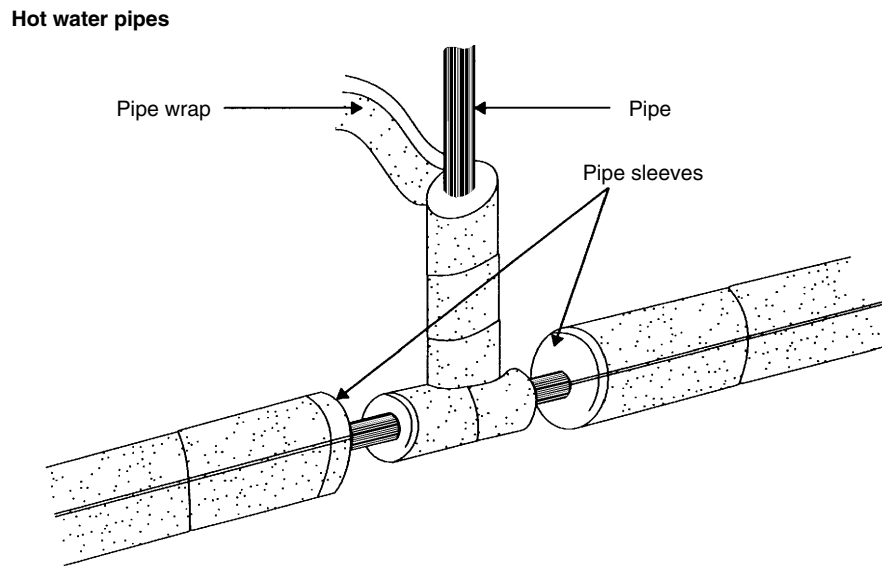
A number of other opportunities exist for energy efficiency in the home. Lighting, appliances and controls are aspects of the house that can provide savings for the home-owner. Providing the home-owner with helpful advice on energy-efficient lifestyle choices can add value to the services you provide as a renovator.

### ***Lighting***

Home-owners typically pay for energy for lighting and appliances. Simple lifestyle changes, such as turning off lights when rooms are not in use, or using task lighting to light spaces rather than an entire room can help reduce energy use. By selecting energy-efficient alternatives, costs can also be reduced. Energy-efficient light fixtures and bulbs are available. New bulbs that are more efficient than traditional types are readily available for almost every fixture, making this step toward energy efficiency an easy and convenient one.

***Figure 11-9: Insulating Mechanical Systems***



**Figure 11-10: Insulating Mechanical Systems**

Old incandescent fixtures can be fitted with specially designed, energy-efficient fluorescent bulbs. Fluorescent lighting uses less energy than incandescent and tends to produce less heat. (This can be an added bonus in the summer when cooling energy is an issue.) Replacement of incandescent bulbs with the more expensive fluorescent types should focus on high-use areas. Halls and kitchens, for example, often make for cost-effective replacement. Low-use areas generally do not warrant bulb replacement.

Some types of regular light fixtures also use less energy than others. Halogen lights are becoming popular as task and ambient lighting in residences. Incandescent bulbs that use less energy than conventional bulbs are now also available.

When selecting new lighting, such as task lights, it is important to locate the lighting where the activity is taking place. Two characteristics that affect the appropriateness of lighting are level and colour rendering. Not attending to these may result in low-energy use but dissatisfied home-owners.

A low lighting level may not be acceptable in a room where reading or other concentrated tasks are taking place. Lights that are too bright can cause headaches or a stark appearance in a

room, often washing colours out of walls, furnishings and people. Some types of bulbs affect colours in different ways. Cooking, applying make-up, painting and other colour-centred tasks often require full-spectrum fluorescent or halogen lighting as alternatives to incandescent. If colours are drastically affected by light, client dissatisfaction may follow.

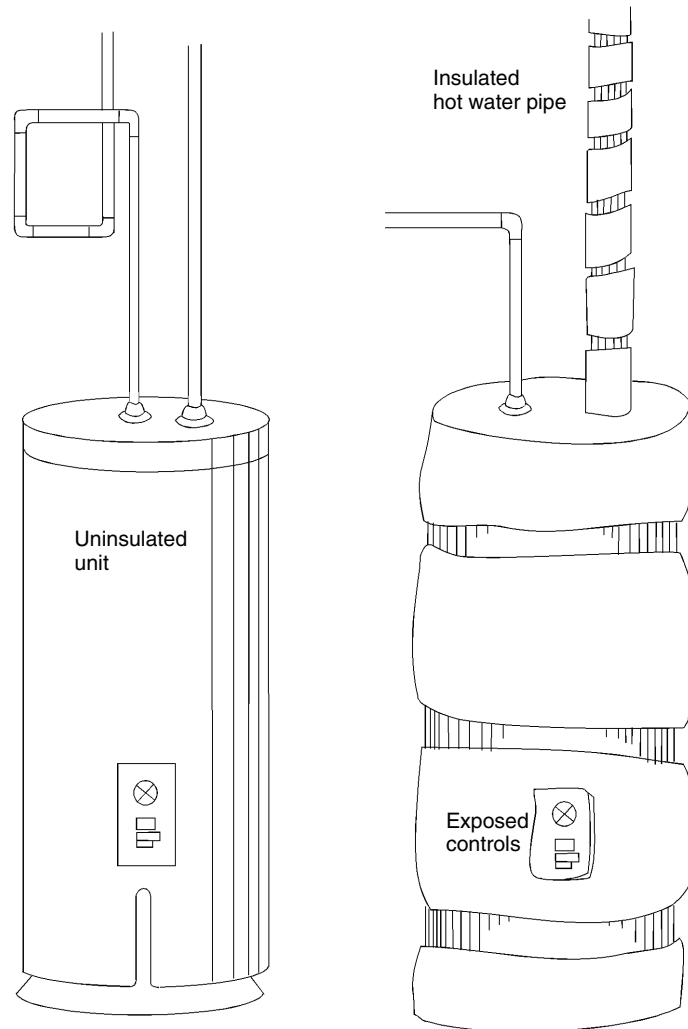
### **Controls**

Controls installed during the renovation can help conserve energy. Programmable-setback digital thermostats, zone controls for heating and cooling, dimmers for interior lighting and photosensors for exterior lighting are common and simple to install. Sophisticated digital controls for appliances in the house are also available and can be accessed from within the home or from remote locations.

### **Appliances**

Renovators often have a major influence on the appliances selected for a renovated building. The renovator is often asked to recommend appliances, such as space- and water-heating equipment.

An energy-efficient furnace or water heater will deliver the same amount of heat or hot water, but it uses less energy and is more economical in the long term. Choices of refrigerators,

**Figure 11-11: Insulating Mechanical Systems****Hot water heater**

dishwashers and kitchen ranges are often discussed with renovators because these decisions influence the design of a kitchen. Reminding customers to consider life-cycle energy costs when making these decisions can help in the selection of more efficient appliances. The Energuide label will provide useful information when making these choices.

### ***Lifestyle Choices***

In any house, the lifestyle of the occupants will affect how well the building performs. For example, issues like temperature preferences

will affect the amount of energy used to heat the house. There are many lifestyle choices that can help to improve energy efficiency within the home. However, the renovation should not rely on these lifestyle changes to provide energy savings. A well-designed or renovated house should accommodate differences in lifestyle and still function properly and efficiently. Some lifestyle elements can lead to the increased or decreased performance of a house. The renovator may need to make the home-owner aware of the effects of some lifestyle choices. The following discussion is a summary of a few of these effects.

Appliances and entertainment devices should be turned off when not in use. Refrigerators should be set at an efficient operating temperature. Ovens can be used to cook more than one item at a time, and the home-owner should avoid turning on an electric oven when a microwave or toaster oven can do a small task with less electricity. Clothes washing and drying uses a lot of purchased energy. Drying clothes on an outdoor clothesline will help to reduce this burden. Other energy-consuming tasks that can be done manually or naturally will also help to reduce energy loads.

Open windows are a bad way to ventilate the house. During the heating and cooling months, a heat recovery ventilator can provide fresh air. Not using the home's ventilation system increases the loads on the heating and cooling system. Although it would seem that the home-owner saves on the energy used to operate the system, the amount of heating energy saved by the system may be greater.

Drawing heavy blinds back during the day in winter will allow solar heat to enter the building. Closing window coverings after daylight hours will help prevent heat from escaping the

building through those same windows. It is also possible to buy insulated curtains that add to the thermal resistance of the window.

It is a good idea to encourage home-owners interested in substantially reducing their energy bills by changing their lifestyles to do so. These ideas are only a few of many possibilities. The home-owner should be told that more information on the topic is available from local utility companies and Natural Resources Canada.

If the issues discussed in this chapter are incorporated into renovation projects, customers can benefit from lower energy bills, improved comfort and safer houses. Improving the energy efficiency of a house is an important opportunity that should not be overlooked during the renovation. Adding value to the renovation by further enhancing energy efficiency can be an economically and environmentally rewarding venture for the home-owner. The effort means less acid rain, reduced greenhouse gas emissions and less consumption of natural resources. Energy-efficiency measures are easily incorporated into renovations and should be encouraged wherever possible.



# Checking Back

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**C**hapter 12 deals with issues and concerns to be addressed after the renovation work has been completed. It covers site clean-up, disposal of waste, final inspections and other issues. It also reviews a few important points to remember when renovating, including health hazards and the five steps to a good renovation. Finally, for those wanting more information, a number of information sources are listed. This chapter is intended to reinforce the concepts and issues addressed earlier in the book.

## INTRODUCTION

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Contrary to popular myth, today's new homes are generally better built than homes in the past. They are more comfortable and less expensive to operate. With all of their interacting systems, they represent years of research and development. Moreover, the science that describes their operation can now produce similar standards of performance in existing homes. Updating an older home to these standards requires that you understand how each of the building's systems affects the performance of the house.

By now, you will have read about the interrelationship of all the building's systems and how heat, moisture and air flows need to be controlled to prevent damage to the building and discomfort to the occupants.

The final stage of the renovation process should verify that the house is performing as expected. You must ensure that the renovation has not adversely affected any system within the house.

Do a final check through the building for last-minute items that may have been missed. Check for:

- drywall deficiencies;
- woodwork finish problems;
- paint problems (including droplets that have not been cleaned up);
- caulking and sealant deficiencies;
- the operation of the plumbing;
- the operation of the hot water heater and furnace;
- the operation of doors and windows;
- floor squeaks;
- the operation of all lights and electrical outlets, including the electrical panel; and
- the cleanliness of the project and site where you have worked.

The last item is of special concern. Some successful renovators use cleaning companies to clean the entire house after the project. This small expense leaves a lasting impression with the home-owner.

Check with the local building department for any deficiencies that inspectors may have noted during construction. Ensure you know about these before the project is completed.

Check for manufacturer's defects. Do not use products that are clearly defective. Manufacturers will normally warrant their products for premature failure in "normal use" conditions.

## QUALITY MATERIALS

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As you consider your next renovation project, remember that your choice of the materials and components used will affect long-term performance. Explain to the home-owner that the failure of a substandard material will cause its component, and ultimately its system, to underperform. Use a specific example, such as wet lumber used as framing, to describe the relationship. The wet lumber can warp and bend, causing the wall and finish to bulge and bow. Nail pops can also be expected. The poorly performing framing system, aside from not being able to function in its primary structural role, also affects other systems — in this case, interior finishes.

Be sure not to take the selection of materials for granted. If the home-owner insists on providing some, or all of the materials for the project, be sure to evaluate the selection and make suggestions before the material is delivered to the site. Your reputation may hinge on their quality. You should advise the home-owner that your warranty cannot cover the performance of materials supplied by him or her.

## REGULAR MAINTENANCE

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All houses require maintenance and you may have to remind the home-owner of its importance. Having put so much thought, time, effort and money into the renovation, the home-owner must know how to maintain the building so you won't be blamed for failure because of neglect.

Remind the home-owner of how important it is to attend to defects. A damp patch appearing on a wall should signal an immediate search for its cause. Inspecting the house from time to time

will help detect problems while they are still minor. Show the home-owner how to check the condition of:

- the roof and chimney using binoculars;
- gutters and downspouts, particularly when it's raining;
- walls, windows and doors, including signs of rot or rust; and
- interior finishes (especially in the basement).

A regular annual check-up is a good idea and should be discussed with the home-owner. During the fall, when the weather is still mild, a check-up will ensure the house is in top condition to withstand another Canadian winter.

## HEALTHY HOUSING CHOICES

Remember the principles of Healthy Housing and how they can add value to the renovation. Look for opportunities to enhance:

- occupant health;
- energy efficiency;
- the efficient use of materials and resources;
- environmental responsibility; and
- affordability.

Providing proper ventilation, with carefully selected low-toxicity materials, goes a long way towards improving the occupants' health. Enhancing the performance of the building envelope, including the windows and doors, as well as the mechanical systems will save the home-owner money while improving comfort. Saving energy also means reducing greenhouse gas emissions and helping to prevent global warming.

Low-volume toilets, showers, faucets and washing machines will, in many cases, also reduce costs — especially costs associated with building new infrastructure. Water-system efficiency reduces the demand for municipal water and the impact of water-treatment processes on the environment.

## Healthy Housing Landscaping

Landscape design should also consider the five principles of Healthy Housing.

The outdoor air can pollute the indoor air if the ventilation system draws in fumes from chemicals that have been spread across the site. Avoiding pesticide and herbicide use will prevent damage to the environment caused by harmful chemicals. As an alternative to pesticides, small trees, shrubs or housing for wildlife will attract creatures that feed on insects. Using a 4-inch layer of mulch in flower beds will reduce weed growth. Planting native grasses or wildflowers will reduce the need to use herbicides, and less water will be required to maintain the lawn.

Measures to improve energy efficiency can also be applied outdoors. Trees, depending on their location, can greatly affect the heating and cooling loads of a building. Reducing the area of lawn will cut down the energy required for maintenance and watering. Adding coniferous trees on the north side of the house will create a windbreak in winter; deciduous trees on the south side will give shade in summer. Exterior lighting can be provided by exterior-rated, compact fluorescent and sodium bulbs that reduce energy demand. Motion sensors enhance security by turning lights on only when required.

Efficient water use is one of the most important issues relating to Healthy Housing landscapes. Rainwater can be collected in a cistern or in barrels and used to irrigate gardens, shrubs, flowers and lawns during dry periods. Installing an efficient watering system, such as a subsurface drip system or in-ground sprinklers with automatic timers, further improves water efficiency.

The environmentally responsible landscape uses a composter to keep organic household wastes and lawn clippings out of landfills. A composter also creates fertilizer for the lawn and garden that is not chemically based. The Healthy Housing lawn uses naturally occurring and drought-resistant grasses that can survive without watering during periods of little rainfall. Finally, the responsibly-landscaped site minimizes surface runoff. It allows rainwater to penetrate into the earth and replenish ground-water supplies. Rainwater absorbed into

the earth also reduces the load on municipal water treatment facilities. Interlocking pavers used as an alternative to asphalt and concrete will help accomplish this as well.

The Healthy Housing landscape can reduce time, energy and the costs of maintenance. It can mean lower water and energy costs that become direct benefits for the home-owner.

### ***Disposal of On-site Materials***

Effective waste management is an important element of Healthy Housing. Accounting for waste as part of the design is likely the most effective step in a comprehensive waste-management strategy.

In addition to reducing materials, waste can be reduced by donating or selling reusable items. Doors, windows, drywall sheets, wood ends and plumbing or mechanical fixtures might be able to be reused on this project or another. In some areas, there are reuse centres that collect these items. Check to see what types of services are available. The local yellow pages may list facilities under “used building materials.” Activities that benefit the environment and community can only improve the home-owner’s and the community’s opinions of your company.

In addition, the costs of dumping can be reduced if substantial amounts of materials, such as cardboard, wood scraps, and drywall are recycled. Some municipalities have facilities for recycling glass and plastics used on site.

Another concern when disposing of site materials is the proper handling of hazardous products. Asbestos, lead paint and other products could be hazardous to you, the occupants and the environment. It is important that these materials be carefully removed and properly disposed of. The landfill can probably provide you with information on proper disposal methods. Don’t remove the materials until you know how to deal with them.

## **CHECKING BACK**

A good renovator’s business is built by satisfied customers who delight in discussing their renovation experience. Referrals are the foundation upon which a successful career is built, and they are very important to you.

Satisfied customers will be more than willing to discuss a positive experience and unsatisfied ones are always eager to talk about all that went wrong.

## **OTHER RESOURCES**

While it is not possible to cover every defect you might encounter in the house, this guide has highlighted those that are most common. There are a number of additional sources of information available that will help you to better understand how houses work.

CMHC has a variety of reports, pamphlets, brochures and other publications that give useful advice and information for renovators. The list below is comprehensive, but not complete. Contact CMHC for more information about available publications.

- *The Renovator’s Business Guide* 60944
- *Canadian Wood-Frame House Construction-Canada and Glossary of House Terms* 61833
- *Installation Guide for Residential Wood-I Joist floor systems* 63559
- *Building Solutions: A problem Solving Guide for builders and renovators* 60941
- *Investigating, Diagnosing and Treating Your Damp Basement* 61065

The Canadian Home Builders’ Association is another good source of information. You can visit their web-site at:

[www.chba.ca/products.htm](http://www.chba.ca/products.htm)

The offices of the association can be contacted at a national, provincial or local level.

Natural Resources Canada is yet another valuable source of information. This federal government department has published many documents dealing with home heating systems, home-energy use and ways to reduce energy costs while increasing comfort. They can be contacted by calling toll-free 1-800-387-2000 or

by visiting their internet site at:  
*<http://eeb-dee.nrcan.gc.ca>*

If you are looking for detailed information on specific topics, or if you are unsure about part of the renovation, seek the advice of a professional. Architects, engineers, heating-system specialists and other experts should be called upon as the need arises.

The final consultation on a renovation project may be an independent inspection. Performed by a recognized home inspector, the final inspection can alert you to minor problems you missed during your assessment. In addition, an independent assessment shows the home-owner that your work meets present standards. The fact that you are confident enough about your work to have someone else inspect it also improves your image with the client.

## LAST WORDS

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A house is the largest single purchase the average Canadian makes in a lifetime. So it only makes sense to make every effort to understand how the house works and to safeguard its proper operation. Understanding the nature of the problems you can encounter in the home, and developing the ability to remedy them without creating others, will help to prevent unexpected surprises. Remember the five steps to trouble-free renovations:

- observe;
- diagnose;
- formulate solutions;
- remedy; and
- renovate.

The extra time and effort you put in to providing a quality renovation enhances your reputation as a professional renovator. It is your reputation that guides your success, and it is up to you to do all you can to enhance it.



## Glossary

<b>above grade</b>	A term applied to any part of a structure or site feature that is above the adjacent finished ground level.
<b>accessible design</b>	A house or amenity/product design that allows easier access for people with disabilities. For example, accessible sink. (See barrier-free.)
<b>adfreezing</b>	The freezing of wet soil to below-grade materials, such as foundation walls or insulation, potentially causing those materials to move.
<b>air barrier</b>	Material incorporated into the house envelope to retard the movement of air. Called air-vapour barrier when it retards air and moisture.
<b>air conditioning</b>	The process of bringing air to a required state of temperature and humidity, and removing dust, pollen and other foreign matter. Generally refers to systems used to cool a building.
<b>air leakage</b>	The uncontrolled flow of air through a building envelope or component of a building envelope as a result of a pressure difference. See infiltration and exfiltration.
<b>air permeability</b>	A measurement of the degree to which a building component allows air to pass through it when it is subjected to a differential pressure.
<b>air pressure</b>	The force per unit of area exerted by the atmosphere. It can have two components: static pressure, which is caused by the weight of a column of atmosphere; and dynamic pressure, caused by air flow.
<b>airtightness</b>	The ability of the house envelope to resist infiltration and exfiltration of air.
<b>at grade</b>	A term applied to the part of a structure or site feature which is located at the same elevation as the adjacent ground level.
<b>attic</b>	The space between the upper floor ceiling and roof or between a dwarf partition and a sloping roof. Also called roof space.
<b>backdraft (flow reversal)</b>	The reverse flow of outdoor air into a building through the barometric damper, draft hood or burner unit as a result of chimney blockage or a pressure differential greater than can be drawn by the chimney. Backdrafting causes smell, smoke or toxic gases to escape into the interior of a building. "Cold" backdrafting occurs when the chimney is acting as an air inlet but there is no burner operation. "Hot" backdrafting occurs when the hot flue gas products are prevented from exhausting by flue reversal.
<b>backfill</b>	Material used after excavation for filling in a trench or the gap around a foundation well.
<b>backflow</b>	The flow of water or other liquids, mixtures, or substances into the distributing pipes of a potable supply of water, that may make the water in the pipe non-potable; may be produced by the differential pressure existing between two systems either or both of which are at pressures greater than atmospheric.
<b>baffle</b>	An object placed in an appliance to change the direction of, or retard the flow of air, gas-air mixtures or flue gases.

# Glossary

<b>barrier-free</b>	Housing designs that minimize or eliminate restrictions to occupant movement, usually included in homes for seniors or people with disabilities. Example: wider hallways, wider doorways, ramps.
<b>bearing capacity</b>	The applied load per unit area of surface of any structure or soil, which the structure or soil can support.
<b>below grade</b>	A term applied to any part of a structure or site feature that is below the adjacent finished ground level.
<b>capillary action</b>	The process of water movement through materials with tiny pores.
<b>capillary flow</b>	Or capillarity. The flow of liquid within small pore passages in a material. Also called wicking. The water transport mechanism is what allows a sponge to soak up water.
<b>cavity wall</b>	A masonry or concrete wall constructed of two separate thicknesses with a minimum 50 mm cavity between and tied together by metal ties or bonding units.
<b>cellulose fibre insulation</b>	Insulation made from shredded newsprint treated with chemicals that resist fire and fungal growth and inhibit corrosion.
<b>chalking</b>	A condition in which paint deteriorates by oxidation to form a chalk-like powder. Chalking may contaminate surrounding soil.
<b>chimney draft</b>	The available natural draft of the chimney, measured at or near the base of the chimney.
<b>concealed condensation</b>	Condensation occurring inside an exterior wall or roof. It can cause rapid deterioration of other building components. Also referred to as interstitial condensation.
<b>condensation</b>	The transformation of the vapour content of the air into water on cold surfaces.
<b>condensing furnace</b>	A furnace with an additional heat exchanger to condense some of the water vapour and regain latent heat.
<b>contractor</b>	A person or company hired for a particular job. In construction, a contractor may be hired to construct all elements of a building but subcontract other contractors, such as electricians and plumbers, to complete specific work within the building.
<b>controlled ventilation</b>	Ventilation brought about by mechanical means through pressure differentials induced by the operation of a fan.
<b>convection</b>	Transportation of heat by movement due to the ascension of air or liquid when heated and its descension when cooled. Certain types of heating systems, such as baseboard heaters, rely on convection for the distribution of heat.
<b>convector</b>	A heating device in which the air enters through an opening near the floor is heated as it passes through the heating element and enters the room through an upper opening.
<b>damper</b>	A valve or plate for regulating draft or the flow of flue gases.



<b>dampproof course</b>	A water-resistant material placed just above the ground level in a brick or stone wall to prevent ground moisture from seeping up through the structure.
<b>dampproofing</b>	(1) The process of coating the outside of a foundation wall with a special preparation to resist passage of moisture through the wall. (2) Material used to resist the passage of moisture through concrete floor slabs and from masonry to wood.
<b>dehumidify</b>	To reduce, by any process, the quantity of water vapour or moisture content in the air of a room.
<b>dehumidistat</b>	A device that senses the level of humidity in the home. If too high or low, the humidity is adjusted accordingly, using the supply of ventilation and air.
<b>depressurization</b>	The condition of a house or part of a house when air pressure inside is less than outdoor air pressure. It is commonly caused by kitchen and bathroom exhaust fans.
<b>dew point</b>	The temperature at which a given air and water vapour mixture is saturated with water vapour (i.e., 100% relative humidity). If air is in contact with a surface below this temperature, condensation will form on the surface.
<b>diffusion (water-vapour diffusion)</b>	The movement of water vapour through materials (including air) which is caused by a difference in vapour pressure. It is independent of air movement.
<b>down-draft</b>	A draft created in a chimney when air currents enter at the top and travel down; sometimes caused by not carrying the chimney high enough above the ridge of the roof.
<b>draft hood</b>	The constantly open air dilution device of a gas furnace.
<b>dry rot</b>	A decay of timber due to the attack of certain fungi.
<b>ER</b>	An energy rating system developed for windows and sliding doors which compares the amount of energy lost through air leakage and through the glass, spacers and frames with the amount of heat gained through solar gain. It is expressed in watts per square metre and can be a negative or positive number. A typical ER number for a single glazed window is -50, for double glazed -30 and for low-e argon filled between -12 and +4.
<b>eave</b>	The part of a roof which projects beyond the face of the wall.
<b>eave soffit</b>	The under surface of the eave.
<b>eavestrough</b>	A trough fixed to an eave to collect and carry away the run-off from the roof. Also called gutter.
<b>efflorescence</b>	Formation of a white crystalline deposit on the face of masonry walls.
<b>extruded polystyrene</b>	A foam plastic board with fine, closed cells containing a mixture of air and high-molecular weight gases (often fluorocarbons) used as an insulation material.
<b>fan depressurization</b>	A process by which a large fan is used to exhaust air from a building in order to create a pressure difference across the building envelope. An analysis of the flow rate through the fan at different pressure differences provides a measurement of airtightness.

# Glossary

<b>flashing</b>	Sheet metal or other material used in roof and wall construction to shed water.
<b>frost heaving</b>	The movement of soils caused by the phenomenon known as ice lensing or ice segregation. Water is drawn from the unfrozen soil to the freezing zone, where it attaches to form layers of ice, forcing soil particles apart and causing the soil surface to heave.
<b>HRV</b>	Acronym for Heat Recovery Ventilator. A ventilation system that provides fresh outdoor air to the house while extracting heat from the stale outgoing air. HRVs help keep indoor humidity levels under control, improve indoor air quality, and may keep heating costs down.
<b>HVAC</b>	A general term which means Heating, Ventilation and Air Conditioning. It is used to describe systems in the house which are used for space conditioning.
<b>healthy housing</b>	A term coined by Canada Mortgage and Housing Corporation to describe housing that is resource efficient, energy efficient, affordable, environmentally responsible and built to maximize occupant health.
<b>heat exchanger</b>	A device which transfers heat from a warm to a cooler medium, normally by conduction.
<b>heat pump</b>	A heating device which extracts usable heat from a medium like air or water by raising (pumping) its temperature. In its reverse mode, it can be used for cooling.
<b>heat recovery</b>	The process of extracting heat (usually from air or water) that would otherwise be wasted. Heat recovery in housing usually refers to the extraction of heat from exhausted air. (See HRV.)
<b>humidifier</b>	A device that may be portable or may be incorporated into the heating system's duct work and which increases the level of humidity in the house.
<b>humidistat</b>	A control mechanism that regulates the operation of a humidifier or dehumidifier, based on the amount of humidity in the house air.
<b>humidity</b>	A measure of the water vapour present in the air.
<b>IAQ</b>	Acronym for Indoor Air Quality. A general term relating to the presence of chemical and biological contaminants in the air within a building, and their potential health effects.
<b>induced draft flue system</b>	A type of heating system equipped with a fan downstream of the furnace. The fan pulls gases from the furnace and propels them to the outside, thereby eliminating the requirement for make-up air.
<b>infiltration</b>	The uncontrolled admittance of air through cracks and pores into a building.
<b>knee wall</b>	Partitions of varying length used to support roof rafters when the span is so great that additional support is required to stiffen them.
<b>latent heat</b>	The heat required to evaporate a liquid, or the heat produced by condensing a vapour to a liquid while the temperature remains constant.
<b>lateral thrust</b>	That component of a load which is exerted in the horizontal direction.

<b>leaching</b>	(a) Bringing soluble substances to the surface by the passage of water through a solid, such as brick or wood. In masonry, leaching often leaves a salty deposit on the surface. (b) The washing out of soluble nutrients and other elements from the soil by rainwater or irrigation, which alters the fertility and physical composition of the soil.
<b>lookout rafters</b>	Short wood members cantilevered over, or projecting from, a wall to support an overhanging portion of a roof.
<b>maintenance</b>	The process of sustaining the level of physical quality of an existing building and site. Usually involves a program of inspection, cleaning and repair activities.
<b>make-up air</b>	The air required by some combustion heating systems in order to isolate the furnace from outside pressure fluctuations and to maintain a constant chimney draft. Also referred to as dilution air.
<b>mechanical equipment</b>	In architectural and engineering practice, all equipment included under the general heading of plumbing, heating, air conditioning, gas fitting and electrical work.
<b>mechanical systems</b>	All the mechanical components of a building: plumbing, heating, ventilation, air conditioning and heat recovery.
<b>mildew</b>	A type of fungi that survives and grows on damp materials, including porous building materials, plants, paper, and so on.
<b>moisture barrier</b>	Any material used to retard the passage or flow of vapour or moisture into construction and thus prevent condensation. See also dampproof course, vapour barrier.
<b>moisture content</b>	The amount of water in a material such as wood, generally expressed as a percentage of oven-dry weight of the material.
<b>mold</b>	A fungus that grows on or in damp and decaying matter.
<b>negative pressure</b>	A pressure below atmospheric pressure. A negative pressure exists when the pressure inside the house envelope is less than the air pressure outside. Negative pressure will encourage infiltration and backdrafting.
<b>off-gassing</b>	The gradual release of volatile and often toxic substances from a wide range of construction materials. These rates generally decrease over time.
<b>polyethylene</b>	Very common plastic used in flexible tubing, vapour barriers, roof vents, and so on.
<b>polyurethane insulation</b>	A pale yellow insulation foam of closed cells containing refrigerant gases (fluorocarbons) that can also be used as an air barrier, but not a vapour barrier.
<b>positive pressure</b>	A pressure above atmospheric pressure. A positive pressure exists when the pressure inside the house envelope is greater than the air pressure outside. A positive pressure difference will encourage exfiltration.
<b>pressure difference</b>	The difference in pressure of the volume of air enclosed by the house envelope and the air surrounding the envelope.

# Glossary

<b>pressure equalized rainscreen</b>	A wall designed to prevent rain penetration by controlling the forces that drive water in a wall. Its major features are a compartmentalized cavity between the cladding and the backup wall, vents in the wall to allow moisture drainage and equalization of pressure on both sides of the cladding.
<b>R-2000</b>	A standard owned by Natural Resources Canada, a federal government department, which is available to home builders in Canada and around the world. R-2000 uses the latest techniques and products to make a home extra energy efficient, creating additional comfort and long-term energy bill savings.
<b>RSI</b>	Acronym for Resistance System International, a thermal resistance value provided in metric terms. This is a measurement of the ability of a material to resist heat transfer. It is often used to rate insulation materials.
<b>R value</b>	The overall coefficient of thermal resistance of a building material or assembly. An imperial measurement equivalent for RSI values. (See RSI.)
<b>radiant heating</b>	A heating system in which only the heat radiated from panels is effective in providing the heating requirements, so that only objects, not the air, are heated. This system can be installed in the ceiling, the floor or the walls.
<b>radon gas</b>	An odourless and colourless, naturally occurring radioactive gas formed by the disintegration of radium, which is found in most soils; it can enter a house from the soil beneath and around the house foundation or through the floor drain. It is carcinogenic with prolonged exposure.
<b>rain penetration</b>	The term used to describe rainwater that penetrates siding or other exterior veneer when openings are available, and when there are sufficient forces to move the water inward.
<b>range hood</b>	A formed canopy over a range. It usually contains an electric light and exhaust fan vented to the outside and is designed to evacuate smoke and fumes produced from cooking.
<b>renovation</b>	The act of restoring, changing or improving a structure or room.
<b>restoration</b>	The process of returning a building or site to its original appearance.
<b>retrofitting</b>	Upgrading an existing structure or system to increase performance. The term is often used to specify energy retrofitting, which is the upgrading of a house to improve its energy efficiency. This includes adding insulation, caulking, weather stripping, replacing windows and doors and improving the heating system.
<b>sealant</b>	A flexible material used on the inside (or outside) of a building to seal gaps in the building envelope in order to prevent uncontrolled air infiltration and exfiltration.
<b>sealant, acoustic</b>	A non-hardening sealant that does not adhere to paint but bonds to most surfaces, especially metal, concrete and gypsum board; it is particularly useful for sealing joints in polyethylene and vapour barriers.
<b>sheathing</b>	Lumber (usually matched) or other material used to cover the framework of buildings on the exterior.

<b>site drainage</b>	The removal of surface water from a site by natural run-off or through a storm sewer system.
<b>slab</b>	A thick, flat object: (1) a door without hardware and hinges; (2) the outside piece taken from a log in sawing it or (3) a concrete construction that is thick and flat.
<b>space heating</b>	The methods of heating individual rooms or living units by equipment located entirely within these rooms or living units. Such equipment consists of a single unit without ducts or piping.
<b>spalling</b>	The breaking off of the surface layer of concrete or brick work, usually caused by frost action.
<b>stack effect</b>	A phenomenon caused by gravity in which warm air rises in a house and exfiltrates through the upper half of the house, causing infiltration through the lower half of the house.
<b>stair lifts</b>	A chair or platform designed to glide up and down an extruded side riding rail or a monorail located near a staircase. It is used for people in wheelchairs or people with difficulty in moving.
<b>step flashing</b>	Overlapping rectangular or square pieces of flashing used at the junction of a shingled roof and walls. (Also called shingle flashing.)
<b>subdrain</b>	A drain that is at a lower level than the building drain and the building sewer.
<b>subflorescence</b>	A condition in masonry where mineral salts in crystalline form accumulate below the surface of masonry materials. The accumulation and expansion of these salts create pressures that can result in the loss of surface materials, exposing weaker materials on the interior.
<b>subsoil drainage pipe</b>	A perforated pipe installed underground to intercept and convey ground water.
<b>sump</b>	A watertight tank that receives the discharge of drainage water from a subdrain or a foundation drain and from which the discharge flows or is ejected into drainage piping by pumping.
<b>sump pump</b>	A pump, usually electrically operated, for removing water that collects in a sump.
<b>thermal break</b>	Materials of low conductivity used in a building assembly to reduce the flow of heat by conduction from one side of the assembly to the other. The term is often used to refer to materials used for this purpose in the frame of metal windows.
<b>thermal bridge</b>	A low thermal resistance path connecting two surfaces — for example, framing members in insulated frame walls or metal ties in cavity wall and panel construction.
<b>thermal envelope</b>	A term referring to the insulated envelope of a living unit (walls, ceiling or floors) that protect it from the exterior temperature variations.
<b>thermal resistance value</b>	Also, R-Value — a precise measurement of an insulation material's resistance to heat flow. The higher the resistance value, the slower the rate of heat transfer through the insulating material. Equivalent to the metric RSI.

# Glossary

<b>VOC</b>	Acronym for Volatile Organic Compound. One of a group of organic chemicals that can be a gas or vapour at indoor temperature and are found in a variety of common products such as oil-based paints and varnishes, caulking, glues, synthetic carpeting, vinyl flooring, and so on. They contribute to poor indoor air quality.
<b>vapour barrier</b>	Materials used in the house envelope to retard the passage of water vapour or moisture. The performance is rated in perms.
<b>vapour diffusion</b>	The movement of water vapour between two areas which is caused by a difference in vapour pressure, independent of air movement. The rate of diffusion is determined by: (1) the difference in vapour pressure; and (2) the permeability of the material to water vapour (hence the selection of materials of low permeability for use as a vapour diffusion retarders in buildings).
<b>ventilation</b>	The movement of outdoor air through a building's exterior envelope via leaks or intended openings, both inward and outward (infiltration and exfiltration). Ventilation is measured in air changes per hour.
<b>ventilation loss</b>	Heat loss by exfiltration through holes in a structure.
<b>venting system</b>	An assembly of pipes and fittings that connects a drainage system with the outside air to ensure circulation of air and the protection of trap seals in the drainage system by maintaining atmospheric pressure.
<b>waterproof membrane</b>	Sheet materials applied to a roof or wall surface to prevent the penetration of water, often in several layers or "plies."
<b>water vapour</b>	Water in a gaseous state which is present in the atmosphere in varying amounts.
<b>water-vapour permeance</b>	The rate at which water vapour diffuses through a sheet of any thickness of material (or assembly between parallel surfaces). It is the ratio of water vapour flow to the differences of the vapour pressures on the opposite surfaces. Permeance is measured in perms (ng/Pa_s_m <sup>2</sup> or grain/ft <sup>2</sup> hr (in_Hg)).
<b>water-vapour pressure</b>	The pressure exerted by water vapour in the air and proportional to the absolute amount of water in the air. Water vapour moves from an area of high pressure to an area of low pressure.
<b>weep hole</b>	A small hole, as at the bottom of a retaining wall or masonry veneer, to drain water to the exposed face.
<b>weeping tile</b>	Perforated pipes connected to a foundation drain below the surface of the ground to collect water from the foundation of a building.
<b>wind barrier</b>	A textile or fabric wrap located on the outside of a building envelope to protect insulation from the circulation of outside air. (See spunbonded olefin.)
<b>wind effect</b>	A condition that exists when wind blows against a house, and creates a high pressure area on the windward side, forcing air into the house. Simultaneously, a low-pressure area is present on the leeward and sometimes other sides of the house.

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