Building Science Primer

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I.

The House as a System

To ensure good performance, it is critical to think of a house as a system comprised of the building structure, the mechanical systems, and the residents. These three elements are interactive and interconnected—an action meant to influence one can unintentionally impact another. Although homes built today take advantage of many advances in building technology, recent evidence indicates that they are less forgiving. In other words, they perform well only within a more narrow range of conditions. On the other hand, a forgiving house is one that can perform well over a wide range of conditions.

We have long recognized that good envelope design and construction are important to achieving rigorous structural, energy, and durability requirements. And increased interest and advancements in residential mechanical systems are on the rise. However, we are just beginning to fully understand the importance of mechanical systems to the overall energy efficiency and durability of the building envelope. Lack of properly designed and installed ventilation causes excess moisture in many homes. And improper installation of forced-air ductwork causes large pressure differentials that can lead to increased moisture and indoor air quality concerns.

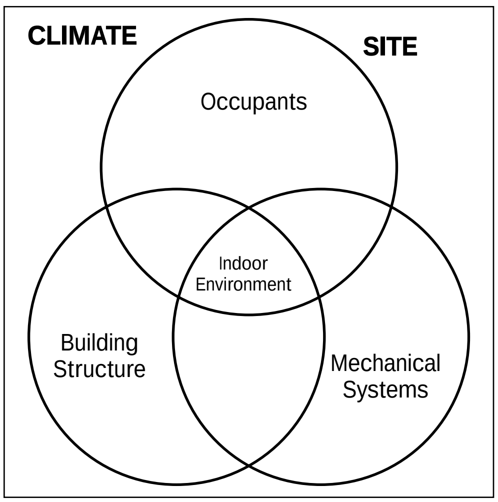


Figure 1. The House System

The house system also is dynamic. Climate conditions and interior activities change the demands placed on the building envelope and mechanical systems. This becomes especially challenging when we also consider the occupant's actions. Because of the wide range of occupant lifestyles, habits, and maintenance activities, the same house can work for one family yet fail for another. The result: increased callbacks and customer service problems for builders and material suppliers, and frustration and lower satisfaction levels for new homeowners.

Building Physics: Every Action has an Equal and Opposite Reaction

Perhaps the best way to describe the system concept is with an example. Although the following illustration is hypothetical, numerous site visits and recent building research document all of the situations described.

A builder builds a home with quality materials and careful installation and, as a result, achieves an air-exchange rate lower than that of previous homes. The drying of building materials and the resident's lifestyle generate more moisture than the house and ventilation system can handle. At this point, the homeowner complains of ongoing window condensation. After some examination, it is decided that the existing ventilation fans are inadequate to properly exhaust excess moisture. A larger and more powerful fan is installed (or the existing fan is reconfigured and operated for a longer period). However, because the home is fairly tight, the improved exhaust-fan system puts the house under a sizable negative pressure. In other words, the fan exhausts air faster than air can enter. The chimney for the furnace and/or water heater is the easiest route for air to enter. This causes the fossil-fuel combustion appliances to backdraft combustion gases back into the home. If this persists for a long period or if the combustion appliance is not working properly backdrafting can become a dangerous situation for the occupants.

The backdrafting indicates that the home needs additional outdoor air for combustion. Therefore, a duct is brought into the home from the outside and is connected directly to the return side of the forced-air furnace. This will pressurize the home while the furnace is running and guarantees successful drafting of combustion products up the chimney. However, this can cause another problem: structural moisture. It's important to remember that if outside air is brought into the home, an equal amount of air must go out of the home. If air is brought in faster than it is removed, a positive pressure will develop in the home relative to the outdoors. Unfortunately, this pressure can force warm, moist air out of the building through any remaining small holes and cracks in the building envelope. This quickly leads to severe attic moisture problems. Over the long run, serious wall cavity moisture problems can cause siding and paint failure or even structural decay.

Several steps can be taken to resolve this final problem. The first solution, which may seem the least likely, is to increase the tightness of the building envelope with improved construction procedures and materials. An airtight envelope helps prevent warm, moisture-ladened air from entering the structural cavities. The second step is to bring fresh air into the home in a way that will minimize the potential for positive pressure. This can be done by bringing the fresh air in freely—without connection to the furnace—and ensuring that the occupants can't close the duct off in winter. If a direct connection is desired, be sure the incoming air duct is carefully sized and the exhaust fan runs during furnace operation. Or, better yet, install a ventilation system that has carefully balanced exhaust and supply airflows, such as an air-to-air exchanger.

BACKDRAFTING

Within the building industry, we're hearing more and more about "backdrafting."

What is it? During backdrafting, a reverse flow of gases in the chimney causes exhaust fumes from a combustion appliance to come back into the home rather than up the chimney.

Why is backdrafting more common today than in the past? There are three important reasons. First, builders build tighter houses. Intentionally-or unintentionally in some cases-new homes and weatherized existing homes have less natural air infiltration and lower air-exchange rates. Second, the newer, mid-efficiency heating systems (not sealed or induced draft) have lower flue temperatures. That means there is less natural buoyancy to push combustion gases up the chimney. Third, and perhaps the most important, today's homes contain more exhausting equipment including bath and kitchen ventilation fans, clothes dryers, and central vacuum systems.

Can backdrafting be prevented? It is possible to reduce the incidence of backdrafting of conventional combustion appliances. This can be achieved by providing sufficient amounts of combustion air for the furnace, water heater, or fireplace and by providing adequate make-up (replacement) air for the exhausting appliances. However, the only way to eliminate backdrafting concerns is with sealed or closed combustion appliances.

II.

The Ins and Outs of Building Science: Energy Basics

In recent years there has been increasing attention to the energy performance of our homes. To better understand the full impact of more insulation and improved airtightening, it is important to review the basics of energy (or heat) flows through the building

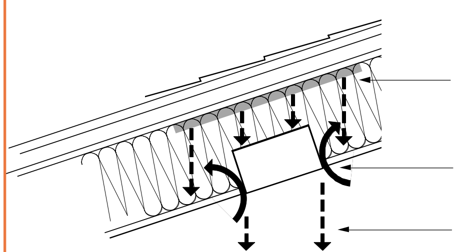


Figure 2: Heat Loss Through the Building Envelope (winter conditions)

envelope. This discussion will concentrate on the performance of the opaque or insulated portions of the building envelope.

There are two basic ways that heat energy moves through a wall, roof or floor system: transmission and air infiltration/exfiltration. Transmission heat loss is the transfer of heat energy by conduction, convection, and radiation through building materials. The amount of heat lost by transmission is reduced by increasing the R-value of the wall, ceilings, floors, windows and doors. And the amount of heat loss by air infiltration, which can be 30 to 40 percent of the total heat loss, is reduced by sealing all air leakage paths between the conditioned—heated or cooled—space and the outdoors. [Note: Technically, air infiltration is air moving into the building and air exfiltration is air moving out of the building. However, the term "air infiltration" commonly includes both.]

It is important to note that moisture will also move through the building envelope by airflow. In fact, recent research has shown that moisture movement by airflow is a key aspect of building performance in our climate.

The bottom line is clear—airflow is a critical issue in building envelope design and construction. There are four types of airflow that must be controlled:

1) airflow through the wall or roof assembly,
2) airflow that enters the structural cavities from the outside and returns to the outside [This is commonly called windwashing, because the wind "washes" through the insulation and reduces its effectiveness],
3) airflow that enters the cavity from the inside and returns to the inside, and
4) convective airflow within the structural or insulation cavity.

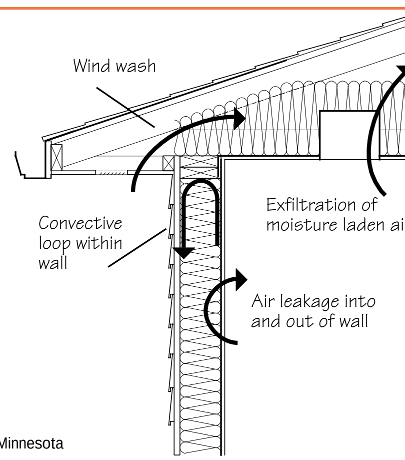


Figure 3: Four Types of Airflows in the Building Envelope

To have air flow from one area to another, there must be a pressure differential across the air leakage path. These pressure differences can be caused by natural forces such as the wind and temperature difference (stack or chimney effect) or by mechanical means such as exhaust fans, combustion equipment using house air, leaky or improperly balanced ductwork, clothes dryer, etc.

Key Components of the Building Envelope

So how can we control these heat flows in residential buildings? The following four key components will do the job. Please note the descriptive terms used with each feature-they are critical to the overall performance of that component as well as the entire "house system."

1. Full coverage, optimum thermal insulation.

The first key component is continuous, optimum thermal insulation. Although we all know the importance of good insulation, we often underestimate the importance of details. Full coverage simply means that the insulation system should completely surround the conditioned space. Framing materials or other thermal bridges are "breaks" in the thermal insulation system. They degrade the overall energy performance and can lead to cold spots where condensation and mold or mildew can occur. The insulation system can be made "continuous" by removing unnecessary framing members. Optimum Value Engineering* (O.V.E.) and Advanced Framing techniques are two approaches that can be used to improve the overall thermal envelope. Optimum implies that adequate insulation levels are used to minimize life cycle costs and that the insulation is installed properly (without voids, gaps and open channels) to reduce the potential for convective airflow within the insulation or wall cavity. Higher density insulation is also less prone to convective air flow.

2. Full coverage, interior-side vapor retarder.

As the amount of cavity insulation increases the temperature of exterior surfaces and sheathing decreases in the winter. Therefore it is critical that a full coverage, interior-side vapor retarder-the second key component-is installed to slow vapor diffusion to these cold surfaces. The vapor retarder must have a low permeability or low perm rating. In Minnesota the perm rating of the interior-side vapor retarder must be less than 1.0. Full coverage means that the vapor retarder must cover all exterior insulation systems, including rim joist assemblies.

3. Continuous air barrier .

Perhaps the most important key component is the continuous air barrier. This should be placed on the inside of the entire building envelope to prevent house moisture from entering the insulated cavities. Although the exact details vary, two systems are being used currently for air barriers in cold climates. The first is carefully installed, continuous polyethylene placed inside of all exterior wall and ceiling insulation [Note: This membrane also can serve as the full coverage interior-side vapor retarder.] An upgraded, more durable polyethylene is recommended and special details, techniques, and/or products must be used to provide a continuous air barrier at electrical and plumbing penetrations, interior wall partitions, rim joist assemblies, and window/door openings. A second system, commonly called the airtight drywall approach (ADA), uses drywall with gaskets to create an interior air barrier. A vapor retarder such as foil-backed drywall or polyethylene is still required. Clearly a home with a carefully installed continuous air barrier will require attention to providing adequate natural or mechanical ventilation

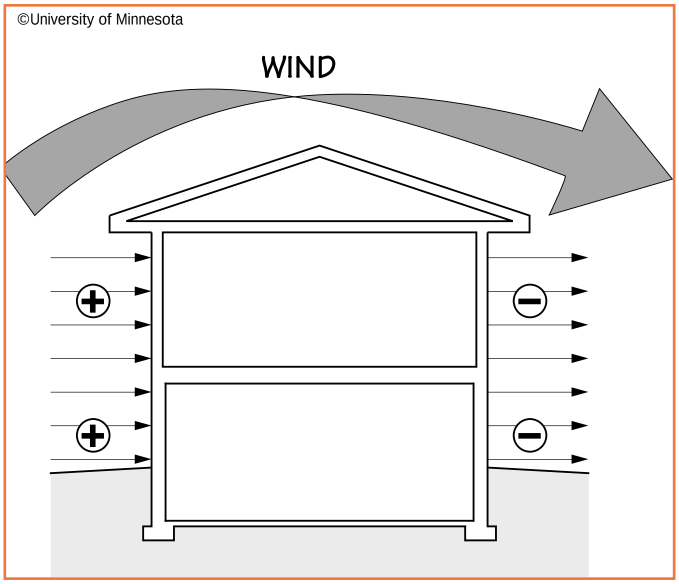
4. Continuous, exterior-side weather barrier.

Another key component is a continuous, exterior-side weather barrier. This component- or inmany cases a series of components including sheathing and cladding or roofing materials—is intended to keep wind and water out of the building envelope and insulation system. This can be achieved in a number of ways. Today, house "infiltration" wraps are common for wall assemblies. The weather barrier can also be achieved with tightly fitting and/or taped building sheathings that are impervious to water and air. Foam-plastic insulative sheathing or plywood and waferboard products are examples. Wood products, however, should be protected from bulk water with a building paper. A weather barrier is especially critical at the top plate/roof overhang and cantilever floors to prevent airflow (windwash) through the insulation system.

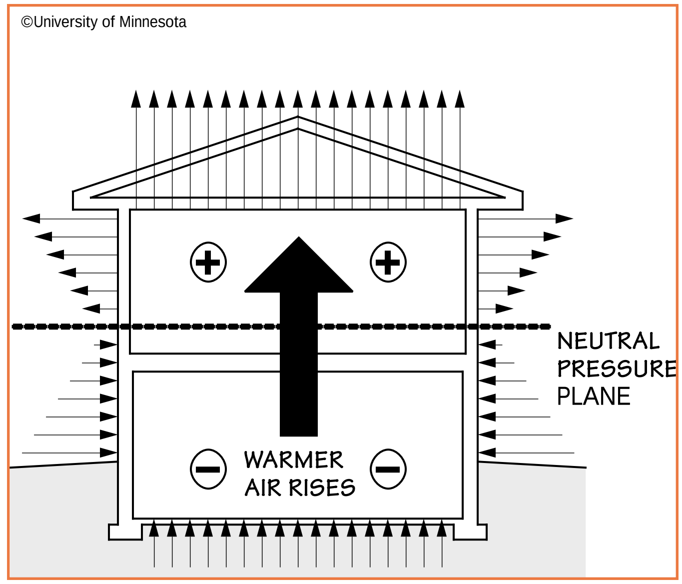
The Bottom Line

Although much of the previous discussion focused on energy and to a lesser extent moisture, these key components also can play an important role in indoor air quality. For instance, the interior-side air barrier and vapor retarder keep exterior and building cavity pollutants from entering the home. They also ensure that the mechanical ventilation systems will be effective and efficient in removing indoor air pollutants by preventing the ventilation from being short-circuited by uncontrolled infiltration.

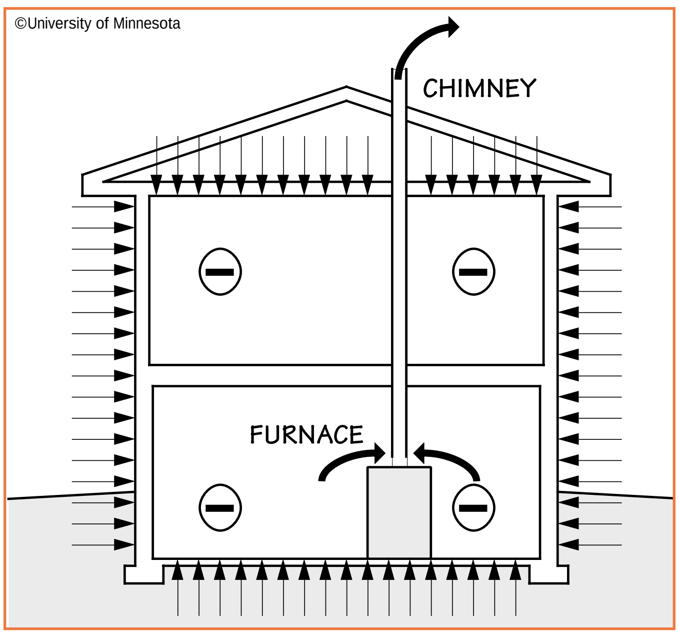
* See **Advanced Framing Techniques: Optimum Value Engineering (OVE),** National Association of Home Builders, January 1999



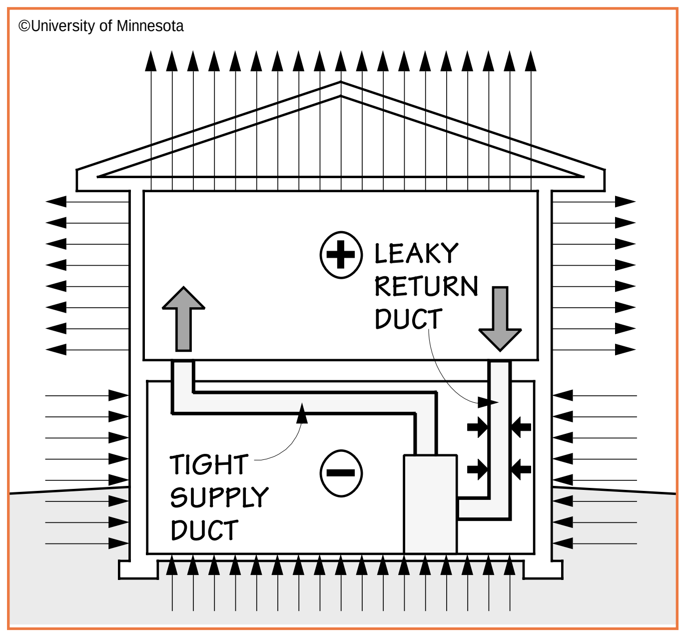
Wind effect



Stack effect



Chimney flue/exhaust effect



Imbalanced/leaky ductwork

Figure 4. What Causes a Pressure Difference

3.

Design for Performance

Specific building components must be present and work together to ensure good performance in our homes. In fact, many of the common problems we see in homes today can be eliminated through good design choices and careful specification. Let's begin with a review of the ten key components that should be incorporated into every performance-built home.

The Ten Key Components

These ten components do not simply refer to a particular product, but instead describe a function that is performed through careful design and installation of a combination of materials or devices. Remember, the house will perform properly when each part is carefully integrated with the rest of the system. It also is important to note that each of these components address a combination of energy, moisture, and indoor air quality concerns (see Figure 5). The ranking of importance is based on a qualitative review of current research results and local construction practice.

1. Full coverage, optimal thermal insulation .

This insulation wrap is usually a combination of materials installed to minimize thermal defects, insulation gaps, bridges, and convective looping.

2. Continuous, warm-side air barrier .

This barrier is essential to keep warm, moist air from entering structural cavities and condensing on building components. It is generally achieved by using one of two approaches: a) a carefully sealed, durable polyethylene system or b) a series of airtight materials (eg. drywall and sheet goods) and gaskets.

3. Full-coverage, warm-side vapor retarder.

A vapor retarder is required on the warm side of the insulation to slow vapor diffusion and keep the insulation and structural cavities dry.

4. Continuous, exterior-side weather barrier.

This barrier is needed to prevent water and wind intrusion into the structural cavities and insulation. This is generally achieved by using a carefully installed air- and water- impermeable sheathing or a sealed house wrap.

5. Energy-efficient and condensation-resistant windows.

Low U-value windows with warm edge designs will improve energy performance and reduce winter condensation.

6. Effective ground moisture/soil gas control.

This is a below-grade system designed to deal with the first four above-grade components listed above. It will require good drainage and capillary breaks to control liquid water and an air barrier and vapor retarder to control soil gases, especially water vapor and radon.

7. Managed mechanical ventilation.

A carefully designed and installed mechanical ventilation system is absolutely critical to good moisture control

8. Safe and efficient space heating and cooling.

It is essential that heating and cooling systems be carefully designed and installed to be highly efficient and not susceptible to backdrafting of combustion products into the home. This is most easily achieved by installing power-vented or sealed combustion appliances.

9. Low-toxicity building materials, finishes, and furnishings.

The best strategy for good indoor air quality is source reduction by selecting materials and finishes that will not off-gas harmful pollutants.

10. Efficient and safe appliances and lighting .

Appliances and lighting must also be carefully selected to complement the efficiency, comfort, and healthy indoor environment provided by the rest of the package.

KEY COMPONENTS OF A COLD CLIMATE HOUSE

	Energy Saving	Moisture Control	Improving Air Quality
Continuous, warm-side air barrier	Secondary Benefit	Primary Benefit of Measure	Minor Effect
Full-coverage, warm-side vapor retarder	Secondary Benefit	Primary Benefit of Measure	Minor Effect
Full-coverage, optimal thermal insulation	Primary Benefit of Measure	Secondary Benefit	Minor Effect
Continuous, exterior-side weather barrier	Secondary Benefit	Primary Benefit of Measure	Minor Effect
Energy-efficient & condensation-resistant windows	Primary Benefit of Measure	Secondary Benefit	Minor Effect
Effective ground-moisture / soil gas control	Minor Effect	Primary Benefit of Measure	Secondary Benefit
Safe, efficient space heating & cooling	Primary Benefit of Measure	Minor Effect	Primary Benefit of Measure
Managed mechanical ventilation	Minor Effect	Primary Benefit of Measure	Primary Benefit of Measure
Low-toxicity materials, finishes & furnishings	Secondary Benefit	Minor Effect	Primary Benefit of Measure
Efficient & safe appliances & lighting	Primary Benefit of Measure	Minor Effect	Secondary Benefit

Primary Benefit of Measure   Secondary Benefit   Minor Effect

Figure 5. Ten Key Components

Eliminate Potential Problem Areas Through Design

Now that we have identified the key building components, let's discuss several critical design decisions that can make a big difference.

• **Cantilevered floors**—While the use of a cantilevered upper floor can increase floor area, maximize the structural properties of the floor system, and add to the architectural character of the house at a small initial cost, it has several inherent drawbacks in our climate. It can be hard to insulate properly and makes it especially difficult to incorporate a continuous interior air barrier. This makes this area of the home very susceptible to both excessive heat loss and condensation problems. Blocking or rigid insulation must be added to serve as an air barrier (see Figure 6.). A weather barrier and rigid insulated sheathing is recommended below the floor system to improve comfort and reduce the condensation potential. It is critical that plumbing and ductwork be eliminated in the cantilevered area.

• **Rooms over garages**—Like cantilevered floors, rooms over the garage can be extremely difficult to air seal and insulate. In addition to the moisture and energy concerns, the garage can be filled with air pollutants that must not be drawn into the rooms above. Because the floor system will probably have plumbing and duct runs, a different insulation and air barrier approach will be needed. The subfloor can serve as the air barrier if it is carefully seal at all joints and penetrations. A blown-in or spray insulation can provide improved thermal performance and comfort. It is important to provide a carefully sealed weather barrier beneath the insulation system.

• **Exterior tubs and showers**—Because exterior tubs and showers are set in place before the walls are insulated and air sealed, it is critical that procedures be developed to ensure a continuous air barrier and full coverage insulation behind the unit. Make sure the appropriate materials are on the job site before the plumber arrives and develop special framing details so the job can be successfully completed by the insulator. One of the most troublesome design problems is a whirlpool tub unit located over a cantilevered floor- this should be avoided.

• **Dropped soffits**—There can be huge air leaks where soffits or lowered ceilings meet exterior walls and ceilings. It is important that all framing be done to accommodate a continuous air barrier. In most cases, it is easiest to install the air barrier before the soffit is framed .

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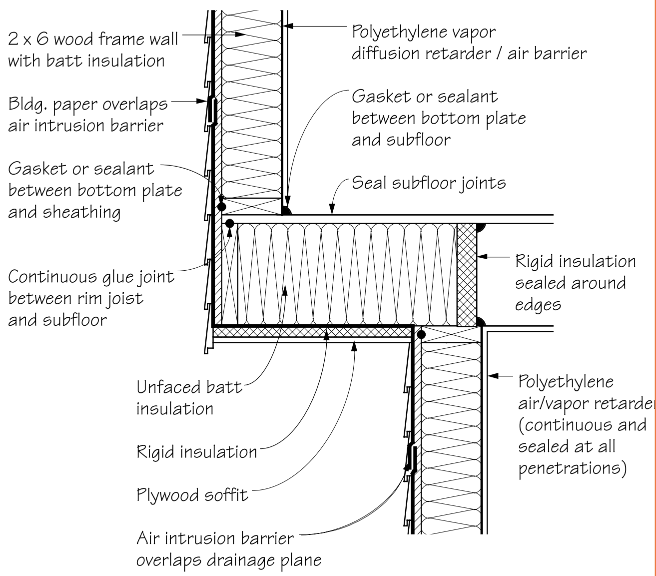


Figure 6. Blocking at Cantlivered Floor

•**Ductwork—**All ductwork should be locate inside the insulated envelope. Provide sufficient vertical chases to keep both supplies and returns on inside walls. If ductwork must run up an outside wall, install rigid insulation into the cavity and seal it to the studs and plates before the duct goes in. Ductwork in the attic is not recommended.

•**Fireplaces and chimneys—**Exterior fireplaces can be extremely difficult to properly insulate and airtighten. An exterior chimney will tend to run cold making it difficult to establish a good draft and prone to creosote buildup. All chimneys should be inside the insulated envelope of the home and should penetrate the highest ceiling location to improve draft and minimize the chance for backdrafting of combustion pollutants. Also, by eliminating exterior masonry chimneys you will reduce chimney odor complaints, which can be common during mild weather conditions. Do not use unvented (or "vent free") hearth products or space heating devices due to high moisture production and the potential for indoor air quality concerns.

Critical Specifications

Below are a number of items that can dramatically improve overall performance if they are properly specified.

•**Mechanical ventilation—**Specifying the mechanical ventilation system may be the single most important item for good overall house performance. You should have a minimum of 15 cubic feet per minute (cfm) per bedroom plus an additional 15 cfm of mechanical ventilation that is designed and installed for continuous operation. The total ventilation capacity should be at least 0.35 air changes per hour [or 0.05 cfm per square foot]. If exhaust fans are used they must be adequately sized and the ductwork must be carefully installed to ensure proper air flow rates. A balanced ventilation system is recommended to provide a more controlled airflow and to reduce the negative pressure potential in the home. Heat recovery ventilation systems can provide several advantages, most noteably energy savings, tempered fresh air, and ease of installation.

•**Combustion equipment—**The furnace and water heater should be power-vented or sealed combustion equipment to maximize efficiency and reduce backdrafting concerns.

•**Kitchen range vent—**It is important to vent cooking pollutants and odors directly to the outside. However, oversized range vents can produce large negative pressures and cause a serious backdrafting potential in the home. Using a range hood with a large front and side baffles will maximize the capture of cooking vapors with a smaller air flow. Specify equipment that will need less than 250 cfm of house air. Larger airflows will require a make-up air duct to replace exhuasted air.

•**Windows—**All windows should have a "total unit" U-value of 0.33 or less and preferably include a warm edge design or low conductivity edge spacer.

•**Floor slab—**The floor slab should be placed over a minimum of 4 inches of large (3/4" to 1") washed aggregate and a durable polyethylene vapor barrier. The footing drainage system should be connected to an airtight sump basket. This could be used for future radon mitigation, if necessary.

•**Recessed lights—**All recessed lights in exterior ceilings must be sealed airtight. This includes lights over bow and bay windows. The current Minnesota Energy Code requires an airtight fixture or the installation of a special airtight box over a conventional fixture.

•**Fireplaces—**A direct-vent, sealed gas fireplace unit is recommended in order to minimize the potential for backdraft conditions in the home. If a wood burning unit is preferred, specify a factory-built, "high tech" system designed with airtight doors and a combustion air supply. These systems are designed to use only 20 to 35 cfm of air for operation compared to 400 to 600 cfm for traditional masonry or factory-built fireplaces.

• **Ductwork—**All ductwork should be sealed with a high quality duct mastic or long-life tape listed as meeting UL Standard 181. Returns should be hard-ducted. If panning is used it must be sealed to the joists and at all transitions, end-panning, and penetrations.

• **Separation of grade and wood—**The grade should be a minimum of 6 to 8 inches below the sill plate and 4 to 6 inches below the bottom of any wood or wood-based siding or trim.

• **Low toxic materials and finishes—**Where possible, specify wood products, adhesives, sealants, paints, varnishes, carpets, and wall coverings that have low emission rates of volatile organic compounds.

Summary

In conclusion,remember that these design recommendations, key components, and specifications only deal with two parts of the house system: the building envelope and mechanical equipment. Although this article has carefully prescribed certain design and construction features for the physical building elements, it is critical that the occupant be an informed and responsible operator of the system. At a minimum the occupants must be provided with user-friendly controls and instructions for heating, cooling, ventilation, and moisture control. If the system requires significant occupant interaction, it is important to provide an operator's manual to help them maximize the performance of the system that has been designed and constructed. This last step assures your client an energy efficient, durable, and healthy home and at the same time reduces your callbacks and potential liability.

4.

Balancing Energy, Moisture, & Indoor Air Quality

Today's home must carefully balance high energy efficiency, positive moisture control and good indoor air quality, while at the same time maintaining housing affordability. Because of all the critical connections between energy, moisture and indoor air quality, the design and construction of a high-performance house can be like solving a giant puzzle. However, the solution to the puzzle can be simplified by looking at each performance objective individually and then by finding creative ways to combine them. Below is a summary of the key ingredients necessary to ensure good performance in each area.

Energy Efficiency

We still find energy efficiency near the top of the list for new home buyers. In Minnesota, most new homes incorporate many, if not all, of the following keys to superior energy efficiency:

- Optimal insulation with careful installation to minimize heat loss,
- High-efficient windows to reduce heat loss and improve comfort,
- High-efficiency heating and cooling systems to provide more comfort and reduce bills,
- Efficient water heating, lighting and appliances to help stretch energy dollars.

Moisture Control and Enhanced Building Durability

In the past decade the number of moisture-related complaints and call backs has been on the rise. Below is a list of the keys to effective moisture control.

- Airtight construction to keep interior moisture from condensing in wall and ceiling cavities,
- High R-value windows with warm-edge designs to reduce window condensation, and
- Mechanical house ventilation to control interior moisture levels.

Indoor Air Quality

Consumers and builders alike are struggling with the concern for a healthy indoor environment. While it can be a controversial subject and, in many cases a very confusing issue because of the lack of definitive studies, it is a real concern for many new home buyers. The general keys to good indoor air quality are listed below:

- Eliminate or remove pollutant sources, especially radon and combustion bases,
- Use filtration to remove larger particulates from the indoor air, and
- Incorporate mechanical house ventilation to dilute gaseous indoor pollutants.

An Industry in Transition

Increasing concerns for energy efficiency, building durability, and indoor air quality have moved residential design and construction into a new era.

- Consumer demands and performance expectations have escalated.
- More stringent building and energy codes have been adopted.
- Many new building products and advances have been introduced.

The bottom line is simple. Residential buildings are becoming increasingly complex and the range of building performance concerns for manufacturers, builders, and subcontractors continues to expand.

- Evidence of moisture and building durability problems is on the rise.
- Reports of indoor air quality and health concerns are increasing.
- There is a growing interest in resource efficient and environmentally-sensitive building materials.

For builders to be successful today, a good understanding of the materials they use and how they are put together is imperative. To address the broad range of issues facing the building industry, this initiative takes an integrated look at the design, construction, and operation of homes for cold climates.

As you review these lists you will see several common ingredients. Airtight construction will reduce structural moisture concerns and increase energy efficiency. Highly efficient windows can improve energy performance and reduce interior moisture condensation, especially those with the warm edge designs. Mechanical house ventilation is essential to reduce both interior moisture build-up and indoor air quality problems. Highly efficient heating and water heating equipment will improve energy efficiency and is less susceptible to combustion backdrafting and indoor air quality concerns.

The challenge for the builder is not "what should I do?" but instead "how can I do it and keep it affordable?". Following is a simplified list of construction features that will improve energy, moisture and indoor air quality performance. Two different levels are provided to help address various market segments and affordability concerns. this list can help you put together a "performance-built" package for your future home buyers.

A PERFORMANCE-BUILT HOUSE IN 10 EASY STEPS

BETTER	BEST
Ceiling	
R-44 high density blown-in insulation Foam/caulk bypasses Seal electrical boxes	Same with raised heel trusses Continuous poly air-vapor barrier Seal top plates
Walls	
2x6 walls w/high density batts (or blown-in) Seal window/door openings and electrical boxes Gasketed/sealed rim joist assembly Same with interior air/vapor barrier	Advanced framing Add insulating sheathing Continuous poly air/vapor barrier Seal partition walls
Windows	
Low-emissivity w/argon or krypton gas	Same with warm edge designs Consider triple low-e
Foundation	
R-10 insulation; damp proofing and drainage Poly and gravel under slab; sealed sump	R-15 insulation; waterproofing and drainage Seal poly; add radon vent to sump
Mechanical	
Balanced mechanical ventilation system Power-vented furnace and water heater	Same with energy recovery Sealed combustion furnace and water heater

5.

Moisture Control for Houses

Moisture is a fact of life and is present everywhere. However, the presence of excess moisture in a house can cause a number of problems ranging from mold and mildew, condensation on walls and windows, poor indoor air quality, decreased insulating value of the insulation, siding and paint failure, deterioration of building materials, and even structural damage. Current studies suggest that moisture damage represents over 90% of all building and building material failures. A recent report by ASTM states that, except for structural errors, moisture damage is the leading cause of problems in buildings in the United States costing owners billions of dollars annually. Moisture-related problems led the list of top callbacks for Minnesota builders in a 1994 survey by the Builders Association of Minnesota and the University of Minnesota.

Basics Of Moisture Movement

With the exception of high indoor humidity being capable of providing a suitable environment for mold growth, almost all moisture problems are a result of liquid water. This could be as bulk water movement or as condensation of water vapor. We will review the key moisture movement mechanisms for water both as a liquid and as a gas (water vapor).

Movement Mechanisms for Liquid Water

Liquid water flow is potentially the most devastating to building performance and, therefore, must remain as the primary concern in new home construction. The three key mechanisms for liquid flow are gravity, fluid pressure, and capillary action.

Gravity—This mechanism is primarily responsible for the entry of bulk water into the home through leaks in the roof, walls, windows, and below grade components. This is controlled by shingles, cladding systems, and foundation drainage systems. Common problems include poor flashing details for roof and wall penetrations and poor site drainage.

Fluid Pressure—This type of moisture movement is caused by a pressure, such as wind-driven rain, or hydrostatic pressure on a below grade wall or slab. Wind pressures can be controlled with a vented rain screen behind the cladding and hydrostatic pressure can be relieved with a foundation drainage system. If the pressure is not control, a weather barrier, such as a building paper or house wrap, must be used above grade and a waterproofing membrane must be employed below grade. Common problems include the improper application of building paper, house wrap, and flashing and inadequate foundation drainage.

Capillary Action—The flow of liquid moisture through small interconnected pores or spaces due to adhesion and surface tension- commonly referred to as “wicking”. This is a very powerful mechanism and depending on pore size and available water the moisture can rise many feet against the force of gravity. Capillarity can be controlled by sealing the pores or making the pores very large, such as washed aggregate. Common problems include capillary rise from the footing into the foundation wall and capillary suction of water behind siding.

Movement Mechanisms For Water Vapor

Before discussing water vapor movement, it is important to briefly review psychrometrics or the study of air, water, and temperature relationships. The bottom line of psychrometrics is fairly simple- warm air can hold more water vapor than cold air can hold. This also can help us understand the term relative humidity, which is the amount of moisture in the air compared to the amount of moisture it is capable of holding. So given a fixed amount of water vapor in a given volume of air its relative humidity will be higher at a cold temperature and lower at a warm temperature. Another way of looking at this is that as cold air is heated its relative humidity goes down and as warm air is cooled its relative humidity goes up.

The critical point is when the water vapor is high and the air cools sufficiently that the air reaches 100% relative humidity- the dew point- and the water vapor will begin to condense into liquid water. This can lead to significant moisture accumulation inside the building envelope in cold climates by two distinct movement mechanisms: vapor diffusion and air flow.

Diffusion—Similar to heat which travels from hot to cold, water vapor will move from an area of high water vapor concentration to an area of low water vapor concentration. In the winter the outdoor air has less water vapor than the house air. Therefore, in the winter there is a constant pressure for indoor water vapor to move towards the outdoors. If this movement is not carefully controlled the water vapor may condense as it reaches a cold surface during its migration. This movement by diffusion can be easily controlled by a vapor retarder installed on the warm side (interior) of the wall and ceiling insulation. Common trouble spots are rim joists and cantilevered floors.

Air Flow—Warm air moving from indoors to outdoors in the winter carries with it not only heat, but also water vapor that can condense inside the cooler ceiling and wall cavities. In a typical home, this moisture movement mechanism can move 10 to 100 times more water vapor than diffusion. For this type of moisture flow to occur it is necessary to have moisture in the house air, a hole in the building envelope, and a pressure difference pushing air to the outside. Because it is important to have some moisture in the house air and because the pressures are very difficult to manage due to varying outside conditions, the primary means to control this airflow is a continuous air barrier in the exterior wall and ceiling assemblies. Common problem areas are ceiling bypasses (including chimneys, plumbing vents, fireplace chases, dropped soffits, and recessed lights) electrical boxes, rough openings for windows and doors, rim joists, and interior partition walls at the exterior walls and ceiling.

Sources Of Moisture

When evaluating moisture control in buildings, it is critical to identify whether the moisture is coming from external or internal sources. Below is a list of potential moisture contributors.

External Moisture Contributors

Above the grade, exterior moisture generally moves into the home as a liquid or bulk water. It is also possible for snow to be blown into the attic or roof system. However, below the grade water vapor can be a significant movement mechanism for ground moisture to enter the home through the foundation walls, floor slab, or crawl space.

Above grade—The greatest concern for above grade components is the leakage of bulk water. A second concern is capillary action of water under the shingles, roof drip edge, and siding systems. Brick, masonry, concrete, and stucco not only support capillary action, but can also absorb large quantities of bulk water. In the summer this water can be evaporated by the sun and driven into the wall system as water vapor. This is one area of concern for summer moisture movement because the water vapor can condense inside the wall, especially if the house is air-conditioned. Another critical issue for above grade components is “splashback”, where rain or roof water hits the ground or other surfaces near the house and splashes back up onto the foundation or wall cladding. Lawn sprinklers can cause similar problems.

Below grade—This is perhaps the most underrated moisture source in new homes. In addition to bulk water penetration, moisture can also move into the house by capillary action, diffusion and air flow into the home. Capillary action can wick moisture from the soil into the footing and up into the foundation wall to subsequently evaporate into the home. Moisture movement by diffusion is quite different below grade. If the soil is saturated the flow of moisture will be inward toward the house, even in the winter, and in most homes there is a very large surface area exposed to the soil. Last, but not least, is air flow. If the basement is drawing air in from the outside—which is frequently the case due to the stack effect, exhaust fans, and return duct leakage—moisture-laden soil gas can be pulled into the home. Even small amounts of airflow could contribute large amounts of water vapor into the home.

Internal Moisture Contributors

There are a number of internal sources for moisture. Unless there is a plumbing leak or an overflow of a fixture or appliance, this moisture generally moves throughout the house as water vapor.

Building materials—Many building materials will pick up moisture during high humidity conditions (summer) and release this moisture during low humidity conditions (winter). This seasonal fluctuation can represent a large moisture load for the home in late fall and early winter. The moisture released by building materials following construction can be very significant. This new construction related moisture release could be a gallon or more per day for the first 12 to 18 months.

Occupants—Clearly occupants can generate substantial amounts of moisture in the home. This can be directly from the occupants themselves through respiration and perspiration and indirectly through bathing, cooking, cleaning, and washing. There are many other lifestyle factors like house plants, indoor firewood storage, aquariums, refrigerator defrost, and pets. Of particular concern would be humidifiers and moisture resulting from improper venting of combustion gases.

A typical home will generate three to four gallons of water per day. A house with good site drainage and dry foundation construction and low occupant contributions might only generate one to two gallons. However, a house with inadequate below grade moisture control and high internal contributions might be as high as five or six gallons per day.

Strategies for Moisture Control

Above Grade Control Moisture

Air Barrier—A continuous air barrier toward the interior of the thermal envelope is needed to retard air transported moisture movement into the wall and ceiling assemblies. This is usually achieved with a durable, polyethylene membrane that is sealed at all openings, penetrations, and seams.

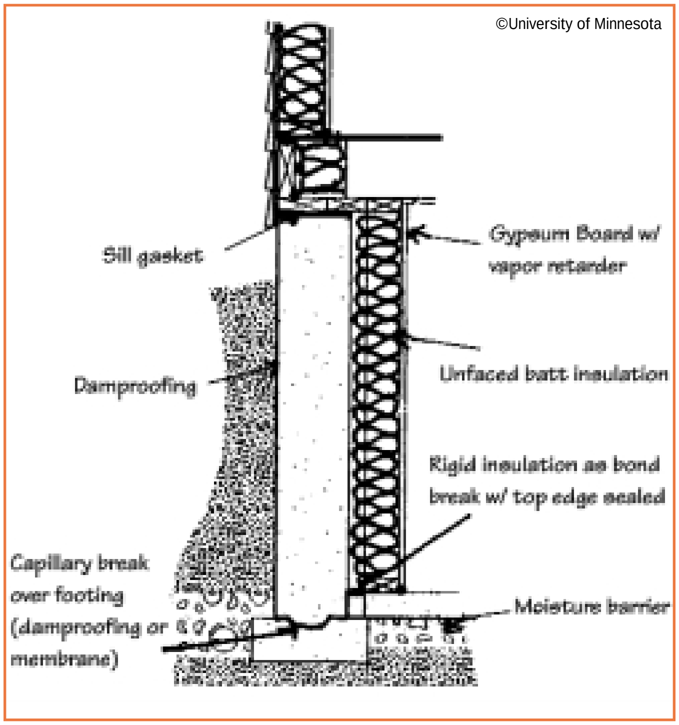
Vapor Diffusion Retarder—To slow diffusion, simply use a material with a low perm rating on the interior side of the thermal insulation. This could be polyethylene, kraft paper facing, foil back drywall, or vapor retarder paint.

Weather Barrier—A combination of sheathing and building paper or house wrap to prevent wind-driven rain and capillary water from getting into the wall system or onto moisture susceptible sheathings. Also, long overhangs can reduce capillarity by protecting the wall cladding from frequent wetting.

Rain Screen—A vented airspace between the cladding and sheathing will equalize air pressures preventing wind-driven rain entry and will provide a "drop" zone and drying capability for capillary water.

Capillary Break—The key areas for capillary breaks are at the roof drip edge and flashing for wall openings, trim boards, or adjacent roof areas. The siding should be held up a minimum of 3/4" from the horizontal surface of the flashing and a minimum of 3" from a roof surface. Siding should also be a minimum of 6 inches from the ground or any horizontal surface. The end grain of all exposed wood trim, siding, and decking must be sealed to prevent capillary suction.

Figure 7. This illustrates a typical concrete basement wall with interior insulation. The recommended practices are shown to ensure effective protection from water and moisture problems in the foundation area.



Below Grade Moisture Control

Site Drainage—Bulk water must be directed away from the home with gutters, downspouts, and careful site grading.

Dry Foundation Construction—Foundation waterproofing or dampproofing with a foundation drainage system should be used to control ground moisture.

Capillary Break—To prevent capillary rise up the foundation use a dampproofing material or sheet of durable polyethylene on top of the footing before the foundation wall is poured or the block is laid.

Dry Slab Construction—To control moisture under the slab, install 4 inches of large washed aggregate as a drainage layer and capillary break and place a strong, durable polyethylene membrane below the slab to control diffusion. All penetrations should be sealed to retard soil gas entry.

Remove Moisture Sources

The second important indoor moisture control strategy is to reduce moisture generation within the home. A direct vent should be provided for the clothes dryer, firewood should not be stored indoors, and moisture released from cooking and cleaning should be minimized. Do not install a humidifier!

Ventilate or Dehumidify

The last moisture control strategy is to remove and dilute indoor moisture. In the winter, ventilation - exhausting moist indoor air and bringing in dry outdoor air-is the easiest way to reduce indoor moisture levels. A mechanical ventilation system should be installed to immediately remove moisture from baths, kitchen, laundry room and any other point sources. General house ventilation may also be needed to remove moisture from disperse sources, such as people, plants, and pets. In the summer, ventilation is not as effective and it may be necessary to use a dehumidifier to keep interior moisture levels under control.

6.

Energy and Moisture Performance of Windows

Windows are one of the most important components of the building envelope. In addition to providing view, egress and aesthetics, they play a critical role in the overall comfort, energy efficiency, moisture control, and indoor air quality in the home. Energy and moisture are two key performance issues of window systems.

Energy Performance

In cold climates, window heat loss can be 25 to 40 percent of the home's total heat loss. However, from an energy perspective, windows are much more complex than wall and ceiling insulation systems, because they can simultaneously allow solar energy- both heat and light- into the home.

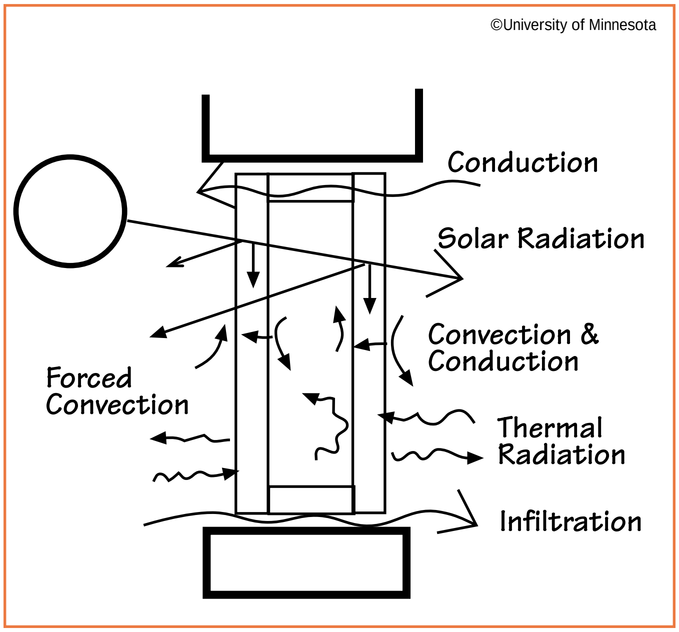
Winter Heat Loss and Summer Heat Gain

Just like insulation, windows allow heat loss in the winter and heat gain in summer. Heat always flows from warm to cold and can be transferred through windows in two ways: transmission and infiltration. The transmission losses result from the transfer of heat energy by convection, conduction, and radiation heat flow to and through the glass and frame components. The infiltration losses result from air flow around or through the unit.

Transmission heat loss is reduced by selecting windows with a low U-value. The insulative value of a windows is commonly listed as the U-value, which is essentially the mathematical inverse of the overall window R-value. For example, a window with a 0.33 U-value has an overall R-value of 3.0.

Windows have three distinct components that contribute to overall transmission heat flow: the center of glass, edge of glass (approximately two and one-half inches around the glass perimeter), and the structural components, including frame, sash, and dividers. The

Figure 8. Heat transfer through a window.



low-emissivity coatings and gas-filled air spaces being used in many windows today have cut heat loss through the center of glass area in half. However, edge of glass and frame heat loss are still similar to windows of the past. Several window manufacturers have introduced low-conductivity edge spacers and new frame technologies to reduce heat transfer at the edge and improve overall U-Values. For instance, a good quality, wood-frame window with low-emissivity, gas-filled glass unit using a conventional, aluminum spacer will have a center of glass U-value of 0.25 (R-value of 4.0), but an overall window unit U-value of 0.34 (R-value of 2.9). This same window with a low-conductivity spacer would have an overall window U-value of 0.31 (R-value of 3.2).

These changes have resulted in a need for the window industry to standardize the U-Value calculation, testing, and reporting. The National Fenestration Ratings Council has completed NFRC 100-91: Procedure for

Determining Fenestration Product Thermal Properties. When comparing window U-Values be sure the number has been determined using this NFRC procedure. Ask your window manufacturer for a NFRC Certified Products Directory that compares the U-values for all the window products that have been rated.

The second type of heat transfer is air infiltration. Most windows today have very tight-fitting weatherstripping and hardware. Despite popular belief that windows are the primary source of air leakage in a home, recent research suggest that they account for less than 20 percent of the total air infiltration in a typical home. Air infiltration testing and reporting has not yet been standardized by the NFRC.

Winter Solar Gain

In the winter, solar energy can penetrate windows and offset all or a portion of the heat loss. In our region, the most important factor in the solar performance of the window is orientation. Provided there is no exterior shade, south windows will receive solar energy throughout the day. East and west windows only benefit from direct solar heat gain for half of the day and north windows will receive indirect solar energy only. A second important factor is the shading coefficient of the window. The shading coefficient is the ability of a window to transmit solar heat relative to a standard single-pane glass. For best winter solar heat gain the window should have a high shading coefficient.

Summer Solar Gain

Summer solar heat gain can contribute to sizeable cooling loads and energy bills. Just as in the winter, the orientation and exterior shading are absolutely critical. Primary concern for summer solar heat gains is the east and west facing windows where the sun angle is low and can penetrate into the home. On the south side the sun angle is much higher and the suns rays can be intercepted with a small overhang. Most NFRC labels now list products' solar heat gain coefficient (SHGC). In the summer it would desirable to have a much lower SHGC, especially for west windows, to reduce undesirable solar heat gain.

Moisture Performance

Windows in cold climates have long been associated with winter condensation. In recently years window condensation problems have been on the rise, primarily as a result of higher indoor relative humidities. For new homes there are two important contributors to the increased window condensation. First, builders and insulating contractors are continuing to do a better job of airtightening. While an airtight shell is an important component of a performance-built house, it can lead to excessive moisture build-up if mechanical ventilation is left out, improperly installed, or undersized. A second contributor for homes built this past summer is the large amount of moisture that has been stored in the building materials. It may take all winter to bring the moisture content of some of these materials to a normal level. Under the construction conditions that we had this summer, it is especially important to provide mechanical ventilation with a boost capacity to help dry the house out during its first winter season.

While window condensation is quite simple to understand, it often is very challenging to prevent. You really only have two options to reduce troublesome condensation (fogging, dripping, or frosting) on the windows: reduce the indoor humidity or increase the window surface temperature.

Reducing Indoor Relative Humidity

In most cases, reducing the indoor humidity should be the first step in condensation control. First, attempt to decrease the moisture generation within and into the home. Try to limit moisture sources that release water vapor into the house air. Reduce moisture entry into the home, especially from below grade sources by implementing good drainage practices and installing moisture barriers on all below-grade walls, slabs, and crawl spaces. A second approach is to remove moisture from the house air. In the winter, this is most commonly achieved by increasing the ventilation rate, or the removal of warm, moist air and the introduction of cold, dry outdoor air into the home. Although this can be accomplished by simply opening the window, a more desirable approach is to incorporate a mechanical ventilation system into the home. This ventilation would run on a continuous basis during cold weather and when house humidities are high. This can be extremely important during the first winter as the house components release large quantities of construction moisture. For summer moisture removal a dehumidifier or air conditioner will be required. In some cases, localized areas of high relative humidity can be temporarily improved with better air circulation throughout the house.

Increasing the Glass Surface Temperature

A second method to control window condensation is to increase the temperature of the interior window surface. Higher window surface temperatures can best be achieved by increasing the R-value of the glazing system. This can be done through window replacement or simply upgrading with additional layers of glass or plastic glazings. This option has the additional benefits of reducing energy consumption and improving comfort in the home. If you are selecting new windows be sure to use a high R-value window with a warm edge design. This type of window uses special materials and construction techniques to improve the edge R-values and provide a warmer interior glass temperature.

Other Factors in Window Condensation

It is important to mention that there are many other factors that can contribute to excessive window condensation. Interior window treatments can have a profound impact on the window's energy and moisture performance. Many window coverings can improve the comfort and overall energy performance of the window. However, many of these same products will lead to increased incidence of moisture condensation, frost, and ice on the window unit. Window coverings such as drapes, blinds, and shades have the tendency to reduce heat flow to the window surface and lowers the inside glass temperature. And because most of these coverings are not tightly sealed, moisture in the indoor air can still travel to the cooler window surface. Therefore, during periods of cold exterior conditions or high indoor humidity, condensation will likely increase when the window coverings are drawn.

A few other subtle contributors to window condensation problems include interior screens and deep window sills. An interior screen retards the flow of warm room air across the window surface and increases the potential for condensation problems. Large or deep window sills also retard the flow of warm air across the bottom of the window unit. This, along with the convective air flow within the air space between glass panes, results in a much cooler glass temperature at the bottom of the window. For most windows, the bottom will be the first location for condensation. This can be an early warning sign to employ a moisture management strategy to prevent heavy condensation, frost, or ice buildup if exterior temperatures remain cold.

Summary

When planning a new home, keep in mind that proper window location can significantly improve both winter and summer energy efficiency and thermal comfort with little or no cost. And when selecting a window unit, remember that the increased cost will almost always be offset by the long-term savings of energy and reduced maintenance. Don't forget that you also can reduce heating and cooling equipment costs with the high efficiency windows.

Low U-values will reduce transmission heat loss, increase thermal comfort, and reduce condensation. For our climate a U-value of 0.35 (the value qualifying for an EPA Energy Star label) or lower is recommended. The 2000 Minnesota Energy Code requires windows in the house to have an average value of 0.37 or less. Improved airtightness will reduce infiltration heat loss and improve thermal comfort. A high shading coefficient is desirable for south windows and is especially important for passive solar designs. For large west windows, consider shading devices and glazing options with low shading coefficients. And last, proper placement of operable window units can provide ventilation and valuable natural cooling. The bottom line is simple - good window planning and energy efficient windows can increase comfort and reduce cost.

EXAMPLE

At 0 degrees outside and 70 degrees inside, a standard double-glazed window would normally be able to tolerate 40% relative humidity without significant condensation at the center of the window. However, condensation at the perimeter would occur at approximately 25% relative humidity. Under the same temperature conditions a high R-value window with a low emissivity coating and argon gas would be able to tolerate an indoor relative humidity of 60% at the center of the window and about 30% at the perimeter. If the improved window also incorporated a "warm edge" design the perimeter could handle an indoor humidity level of 35% or more.

7.

Healthy Indoor Air Quality

The quality of the air in our indoor environment has become a key concern for many home buyers. And this concern for healthy indoor air continues to grow. In 1994 the Environmental Protection Agency's Region 5 Office, which includes the north central states, developed a list ranking the health impacts of 26 top environmental problems, including hazardous waste sites, lead, outdoor and indoor air pollution, ground water contamination, chemical storage facilities, radiation, and ozone depletion. The concern having the highest potential negative health impact in this region was indoor air pollution (not including radon). The number two ranking was indoor radon.

Indoor air quality is clearly an up and coming issue for the home building industry. There are two important facts that seem to reinforce this conclusion. First, indoor air quality has been demonstrated to be many times worse than outdoor air quality, even in large metropolitan areas. Second, people spend more than 90 percent of their day indoors and 65 percent of that is in their homes. There are three basic aspects of indoor air quality that will be covered in this article—the sources of indoor air pollution, the health affects of common pollutants, and how to provide healthy indoor air.

Pollutant Sources

There are literally thousands of potential pollutants in a home. This article will focus on several main categories of indoor air pollution.

Volatile Organic Compounds

The largest and most difficult group of pollutants are organic chemicals and compounds that can release gases under typical indoor temperature and humidity conditions. These frequently come from a variety of building and household products including: paints, solvents, sealants, adhesives, pesticides, preservatives, cleaners and disinfectants, air fresheners, stored fuels, hobby supplies, and dry-cleaned clothing.

These compounds can cause eye, nose, and throat irritation; headaches, loss of coordination, nausea; and damage to the liver, kidneys, and central nervous system. Several of these organic compounds are known carcinogens.

As a builder it is important to gather as much pollutant information for your building products as possible, so you can help your customer select materials and finishes that will not emit gas and harmful pollutants.

Combustion Products—The process of burning any hydrocarbon fuel, which includes gas, oil, wood, etc., will result in carbon dioxide, water vapor, nitrogen oxides and several other potential pollutants depending on the type of fuel and equipment that is being used. Some of the other pollutants are carbon monoxide, respirable particles, sulfur dioxide, and aldehydes. With properly vented equipment, these pollutants are directed to the outdoors. However, with unvented equipment, improperly installed equipment, or equipment that is being challenged by a strong indoor negative pressure, some or all of the combustion gases can come into the home. This obviously could be a potentially hazardous or even life-threatening situation.

These byproducts of combustion can cause eye, nose and throat irritation, impair lung function and increase respiratory infections. Carbon monoxide can cause fatigue and chest pain at low concentrations, and at higher concentrations, impaired vision and coordination, headaches, dizziness, confusion, and nausea. At very high concentrations it can be fatal.

It is critical that all combustion equipment be properly installed and vented to the outdoors. If the furnace or water heater is gas or oil-fired, it must be able to operate against the house pressures that might be exerted on it without backdrafting combustion products into the home. This can be easily achieved with power vented or sealed combustion appliances. All fireplaces and wood-burning equipment must have sufficient outdoor air and tight-fitting doors. In addition, all ranges, cooktops, and ovens, especially gas units, should have exhausts that vent directly to the outdoors. [Note: Don't forget to provide adequate make-up air for these exhaust fans to prevent excess negative pressure in the home.] Have a qualified contractor encapsulate or remove asbestos or lead-containing materials.

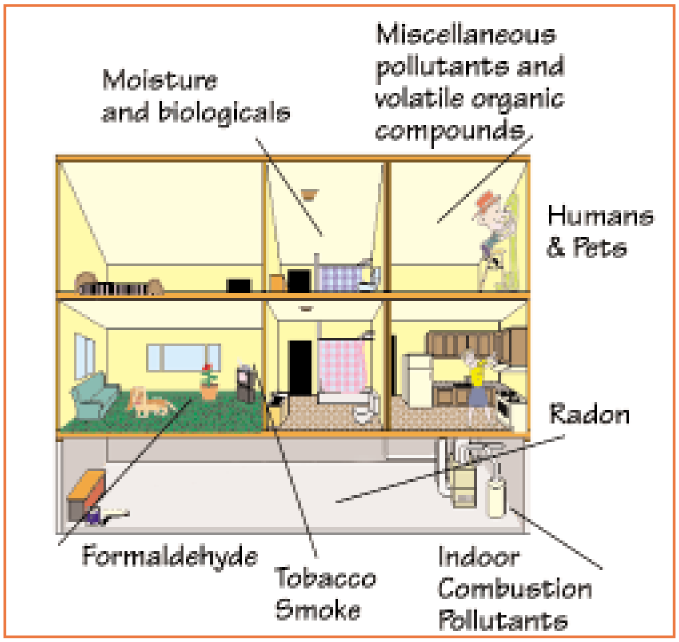


Figure 9. Sources of Indoor pollution exist in every home.

Radon—Radon is a colorless, odorless, radioactive gas that is released as uranium when radium radioactively decays. In Minnesota, the rocks and glacial soils contain uranium and radium. When radon or its radioactive decay products are inhaled, they can cause irreversible cell damage in lung tissue that could lead to lung cancer.

Builders should follow the new radon-resistant construction standards to minimize the change of elevated radon levels in their new homes. In general, this would include a number of below-grade sealing techniques, an aggregate layer beneath the floor slab, a sealed sump basket, and a vent pipe and electrical service to the attic for a future active sub-slab mitigation system.

Biologicals—This is one of the newest and may be one of the biggest indoor air pollution concerns. This category includes mold, dustmites, bacteria, pollen, and viruses. By controlling the relative humidity, many of these biological contaminants can be minimized. For instance, house dustmites, which are the source of one of the most potent allergens, will only grow in a warm and damp environment.

Respirable Particulates—This is a broad class of solid pollutants that can be inhaled deeply into the airways and lungs. These particles are frequently attributable to combustion, smoking, and biologicals. The health effects include eye, nose, and throat irritation; respiratory infections and bronchitis; and lung cancer.

These particles can be minimized by using a high-efficiency air filtration unit on forced-air heating and cooling systems. Remind the home buyer to replace filters and to maintain the system. If any wood-burning equipment is going to installed, the doors must fit tightly.

Environmental Tobacco Smoke—The health concerns for smoking and even "secondhand smoke" continue to build. Tobacco smoke includes a complex variety of pollutants, many of which are known carcinogens. Of course, smoking is a personal choice and beyond the control of the builder. However, if you know that a smoker will be buying your home, you may want to discuss ventilation strategies that would quickly and efficiently remove pollutants from areas that might be used for smoking.

Asbestos and Lead—In the past decade we have heard a lot about asbestos and lead. Asbestos exposure can induce abdominal cancers and lung disease, and high lead exposures can impair mental and physical development. However, for newer homes, asbestos and lead are usually not an issue. Lead and asbestos have virtually been eliminated from common building products. For existing homes, it may be necessary to have a qualified contractor encapsulate or remove asbestos or lead-containing materials.

Maintaining Healthy Indoor Air

There are four basic strategies to reduce indoor air pollution. The most effective way to minimize indoor air pollutants is to eliminate the source. It does not make sense to bring large quantities of a pollutant into the home and then try to remove it or dilute it. Radon, ground moisture, and other soil gases would be a good example of this approach. The most effective solution is to retard their entry into the building. The second strategy is to control the pollutant source through sealing or encapsulation to prevent the potential pollutant from being released into the home. This can be an effective approach for formaldehyde products or existing lead and asbestos. The next strategy is to contain and exhaust pollutants at or near the place where they are generated, such as cooking or bathing. And, as a last resort, dispersed pollutants such as respiration, body odors, and off-gassing from building materials, must be diluted by general or house ventilation.

As a builder, you have varying levels of control over each of these strategies. It is important to note that even though ventilation is an essential component for a healthy indoor environment, it cannot guarantee good indoor air quality by itself. The ventilation rate may not be enough to dilute strong pollutant sources or the ventilation system may not be properly maintained or operated by the occupant. Therefore, it is critical that you use building materials and finishes that will not produce or allow large quantities of indoor pollutants to be generated.

Homeowner education is equally important to reduce the pollutants that they will bring into the home with furnishings, household cleaners, and hobbies, and to ensure that they will use and maintain the ventilation system that you have provided.

8

The New Energy Code & Residential Mechanical Ventilation Requirements

The latest revision of the Minnesota Energy Code goes into effect on April 15, 2000. The new energy code has several unique features. First, the code was totally reformatted and rewritten to make it easier to read and follow. Second, the code has attempted to address moisture control and indoor air quality concerns by requiring adequate ventilation of the living space and incorporating specific measures to protect the thermal insulation from moisture intrusion. Third, to facilitate an orderly transition, since 1994 the code has allowed for two categories of construction and compliance-Category 1 and Category 2.

Perhaps one of the most significant changes in the 2000 Minnesota Energy Code is the specific exclusion of natural air infiltration as a means to satisfy the house ventilation requirement.

Recognizing that mechanical ventilation would be a key part of the Category 1 homes in the 1994 Minnesota Energy Code, the Residential Ventilation Standards Task Force was formed. This group came together with a common concern that the mechanical ventilation systems must be properly designed and installed to ensure good overall performance and minimize potential problems and callbacks for the industry.

Both prescriptive and performance paths are provided in the code. The code is based on the premise that adequate combustion air has been provided for all combustion equipment per state mechanical code.

Mandated ventilation rates are based on ASHRAE Standard 62-89, and the 1993 Ontario Ventilation Code, which was used as a model by the RVS Task Force. This report recommended a dual ventilation rate with a minimum of 15 cubic feet per minute (cfm) per person that is intended to be operated on a continuous basis and a total ventilation capacity of a least 0.35 air changes per hour that could be used continuously, if needed.

Perhaps one of the most critical and difficult ventilation issues is house depressurization by the ventilation system and other large exhaust fans or exhausting devices, such as a clothes dryer or central vacuum. The code has established allowable limits for various types of combustion equipment. Once you have determined the type of combustion and exhaust equipment you will be using, you can select an appropriate mechanical ventilation system and make-up air supply, if required. Another area of concern is making sure the fresh outdoor air is being delivered to all habitable rooms as prescribed by the code. This fresh air distribution can easily be accommodated by the forced-air heating system or central air conditioning ductwork. However, additional ductwork may be required for homes using hydronic heating and no central air conditioning system.

In general, the prescriptive paths will allow a variety of equipment designs. But here is a quick summary of what will likely be needed for those who choose to follow this voluntary standard. [Note: In some cases alternative designs can be used to meet specific requirements.]

1. If your home has all sealed vent combustion equipment and no solid fuel-fired (wood burning) equipment, you may use an exhaust only ventilation system. You will generally not be required to provide make-up air for the clothes dryer or kitchen range vent.

2. If your home has power direct vented combustion equipment and no solid fuel-fired equipment, you must a) provide proper combustion and dilution air and b) use either a balanced or exhaust only ventilation system. In almost all cases you will need to provide make-up air for any large fans or exhaust devices.

3. If your home has any natural draft combustion equipment or any solid fuel-fired equipment, you must a) pro-

vide proper combustion and dilution air, b) use a balanced ventilation system, and c) provide adequate make-up air for the clothes dryer and any large fans or exhaust devices. The code includes tables to properly size the make-up openings and ducts. With natural draft combustion equipment or solid fuel-fired equipment it may be necessary to have one or more large make-up air opening(s) and powerd make-up air supplies to keep the house depressurization below the appropriate limits.

For new homes mechanical ventilation is now required. It is a great way to ensure that your new homes will be more comfortable, energy efficient, and durable and provide a healthier indoor environment for your customers.

Using the fundamental philosophy that the “house is a system” the industry has formulated a proactive response to the complex and interconnected issues of energy conservation, house air sealing, combustion safety, premature structural deterioration, and indoor air quality. Mechanical ventilation has become a concern that is common to all of these issues. It seems increasingly clear that properly designed and installed mechanical ventilation needed to become an integral component of new homes in Minnesota.

For copies of the code, contact the Department of Commerce Energy Information Center at 651-296-5175 or 1-800-657-3710. You also can find it at the Commerce Department web site: www.commerce.state.mn.us

Additional Resources

New Homes Energy Guide
http://www.dpsv.state.mn.us/docs/infocntr/houswarm/housmain.htm)

Written for persons building or thinking about building a new home, this guide discusses a wide range of options for increasing energy efficiency beyond the normal code requirements. Subjects include insulation, ventilation, air/vapor controls, furnaces, windows, doors and appliances, as well as common design pitfalls.

Health House
http://www.healthhouse.org/

The American Lung Association developed the Health House Project in 1993 because in home construction what you can't see ...may hurt you. Today, Health House is nationally recognized for raising the standards of residential air quality and energy efficiency. The Health House Advantage™ Program is an educational program for builders and consumers to test and certify that a house has met the Health House performance standards.

Building America Program
http://www.eren.doe.gov/buildings/building_america/

The U.S. Department of Energy's Building America Program.

Building America works with members of the home building industry to produce quality homes that use up to 50% less energy without costing more to build. Includes a listing of Minnesota builders participating in the Building America Program.

The Residential Energy Efficiency Database
http://www.its-canada.com/reed/reed.htm

Designed as a guide to understanding residential energy efficiency, REED provides users with a wide range of usable information on energy efficient housing. Includes detailed drawings of energy efficient construction.

Energy Efficient Building Association
http://www.eeba.org/

A source for builders and persons involved in the home building industry. Provides information concerning efficient buildings and training opportunities.

Energy Star® Homes
http://inotes.icfkaiser.com/epa/estar/eshaware.nsf

U.S. Environmental Protection Agency energy efficient homes program that protects the environment and saves you money. Includes a listing of Minnesota builders who have joined the Energy Star Homes program.

Fort Collens Builders' Guide
http://www.light-power.org/builders_guide/index.htm

The city of Fort Collens Colorado Builders' Guide to Energy Efficient Home construction. Detailed drawings of airtight drywall (not using polyethylene) approach to energy efficient construction.

Are Your Houses Too Tight?
http://www.energyconservatory.com/article2.html#1

After more than two decades of sealing up houses to make them more energy efficient, many people are wondering whether we've gone too far. The answer may be that we haven't gone far enough. This excellent article explains why houses are being built so tight.

Efficient Windows
http://www.efficientwindows.org/

The Efficient Windows web site is sponsored by the Efficient Windows Collaborative with support from the U.S. Department of Energy's Windows and Glazings Program and the participation of industry members. This web site provides unbiased information on the benefits of energy-efficient windows, descriptions of how they work, and recommendations for their selection and use.

Foundation Wall Research
http://www.research.cala.umn.edu/BuildFound/default.htm

This site is devoted to describing research undertaken at the University of Minnesota pertaining to building foundations. The research described has been carried out over a period of more than 19 years, firstly at the Underground Space Center, then at the Minnesota Building Research Center and, finally, at the College of Architecture and Landscape Architecture.

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This information will be made available, upon request, in alternative formats such as large print, Braille, cassette tape, CD-ROM.

This publication was produced with funds from a U.S. Department of Energy State Energy Program grant. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author and do not necessarily reflect the views of the Department of Energy.

Minnesota Department of Commerce

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Minnesota Home Energy Guides

The Department of Commerce publishes a series of booklets designed to help Minnesotans save energy in their homes. You may find them useful for your clients. Copies of the titles listed below are available by calling or contacting the Minnesota Department of Commerce.

CD-ROM contains all of the Home Energy Guides An added bonus on the disk is a Guide on Ice Dams.

Appliances advises consumers on what to look for in energy efficient appliances and includes information on efficient operation and maintenance of refrigerators, freezers, washers, dryers, dishwashers, cooktops, ovens, and home office equipment.

Attic Bypasses explains how to find those “hidden air passageways” and fix them to prevent costly heat loss and damage to roofs, ceilings, walls, and insulation.

Basement Insulation discusses the pros and cons of interior vs. exterior insulation and provides detailed how-to instructions.

Caulking and Weatherstripping describes how to identify sources of air leaks, lists various types of caulk and weatherstripping, and provides illustrated how-to-apply instructions.

Combustion Air describes the causes of dangerous combustion air problems and tells how to install an outside combustion air supply. It also tells how to test your home for combustion air problems.

Energy Saving Landscapes describes how to use trees and shrubs for long-term energy savings, and lists trees appropriate for energy-savings.

Home Cooling tells you how to cool without air conditioning, and provides information on buying and operating energy efficient air conditioners.

Home Heating describes proper maintenance techniques and helps you become an educated shopper if you are buying a new heating system.

Home Insulation helps the homeowner evaluate the benefit of added insulation, providing information on buying and installing insulation.

Home Lighting looks at new technologies for residential lighting, identifying four basic strategies and providing examples for putting them into practice.

Home Moisture describes symptoms of moisture problems, lists common indoor and outdoor causes, and discusses preventive and corrective measures.

Indoor Ventilation describes the types of home mechanical ventilation systems that are available, the amount of ventilation air needed, and how best to operate and maintain the system.

Low Cost/No Cost addresses the often overlooked energy saving tips for all areas of your home.

New Homes discusses a wide range of options for increasing energy efficiency beyond the normal building code requirements. Subjects covered include insulation, ventilation, air-vapor controls, heating and cooling, windows, doors, and appliances.

Water Heaters helps you determine whether to buy a new water heater or improve the old one. It explains the efficiency of different types of water heaters and provides installation tips.

Windows and Doors helps you decide whether to replace or repair windows or doors and gives a good summary of energy efficient replacement options.

Wood Heat offers advice on purchasing and installing a wood stove, with special emphasis on safety.