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WSEO

Home Conservation

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Wise Use of Resources Through Education

Reducing Home Air Leakage

Anyone living in the Northwest has probably experienced the discomfort delivered by drafts of cold winter air leaking into a home. Uncomfortable and often unhealthy, this leakage can also have a chilling effect on one's energy bills. Twenty to thirty percent of a typical home's heating cost is the result of air leaks. In this pamphlet we'll learn what air leakage is, how it takes place, and how it effects comfort, health, and energy costs. We'll also explore how one can effectively reduce air leakage in the home by utilizing a systematic and comprehensive process called air sealing or house tightening.

What Is Air Leakage?

There are two types of air exchange that take place between a heated building and the unheated environment: ventilation and air leakage. Ventilation is the controlled air exchange – via exhaust fans, openable windows, etc. With a properly designed and installed ventilation system, one can control when air exchange takes place and how much air exchange occurs. A common example is the bathroom exhaust fan which is usually controlled by a switch. Air leakage, on the other hand, is the uncontrolled air exchange that takes place as air exits and enters the building via cracks, holes, plumbing and electrical penetrations, and around doors and windows, etc.

It is important to recognize that there are also two types of air leakage: infiltration and exfiltration. Infiltration is the leakage of air into a building. In winter, infiltration brings in cold and relatively dry air. Cold infiltrating air can filter through insulation and "wash" the warmth out of it by replacing the warmed dead air spaces with cold air. Infiltration also causes cold drafts and contributes to cold interior surfaces. You can often detect infiltration by wetting your hand and placing it near suspected spots. In summer, infiltrating air carries hot air into the cooler home. It also carries in dust and pollen.

Exfiltration is the leakage of air out of a building. Exfiltrating air carries out heat in two forms: the warm air itself and heat contained in the water vapor that is in this air. Exfiltration also delivers this water vapor to the wall cavity, and, under the right conditions, the water vapor can condense into liquid form, thereby reducing the effectiveness of the insulation, and potentially causing mildew and rot problems if adequate moisture accumulation occurs. You cannot detect exfiltration by feeling with your hand.

Dynamics Of Air Leakage

Air leakage results from pressure differences that occur between the inside and outside of a building as the result of temperature differences, wind, and the use of appliances that consume air (such as dryers and combustion furnaces).

Some air leakage is driven by temperature differences between the inside and outside of a building. In winter, the warmer air inside the house is much more buoyant than the colder, denser outside air and so it "bubbles" up through building cracks, flues, and chimneys. Chimney or furnace flue stack pressures can result in significant air exchange because they are even warmer. Stack pressures are also affected by the building height: the greater the height, the greater the stack pressure. If one could "see" air leakage due to the stack effect it would be visually similar to the effect of drilling holes in the bottom of a bucket, then turning it upside down and immersing it in water in order to see the buoyant bubbles streaming upward.

Wind pressures vary all the time and are very significant when the wind is blowing. They cause infiltration on the windward side and exfiltration of the leeward side.

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The exhaust of air that is caused by operation of bath and kitchen fans, fireplaces, furnaces, dryers, etc., is called induced exhaust. When these appliances are operating, they will draw air from the home forcefully enough to depressurize the home relative to the outside, and consequently outdoor air will be drawn in (infiltration) to replace the removed air.

Often these pressures occur simultaneously and the result is a complex and constantly changing pattern of infiltration and exfiltration. Generally speaking though, the upper portions of the building experience exfiltration and the lower portions experience infiltration.

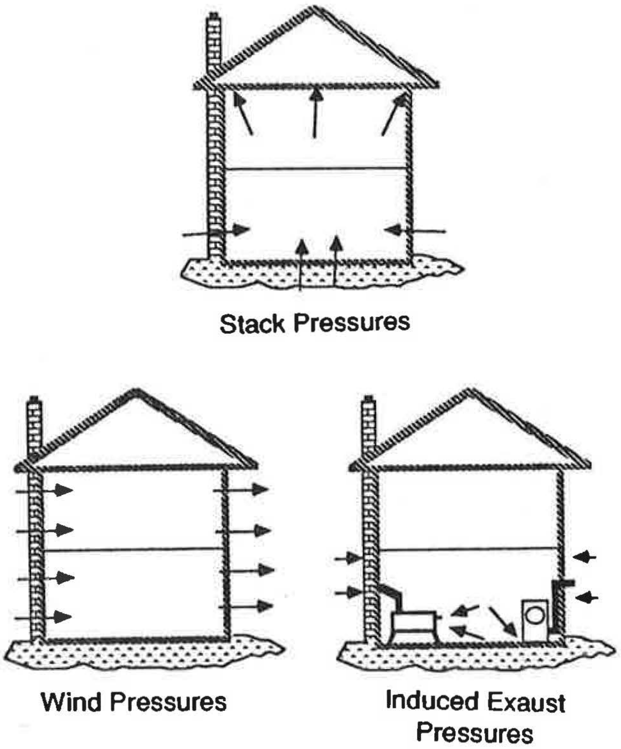
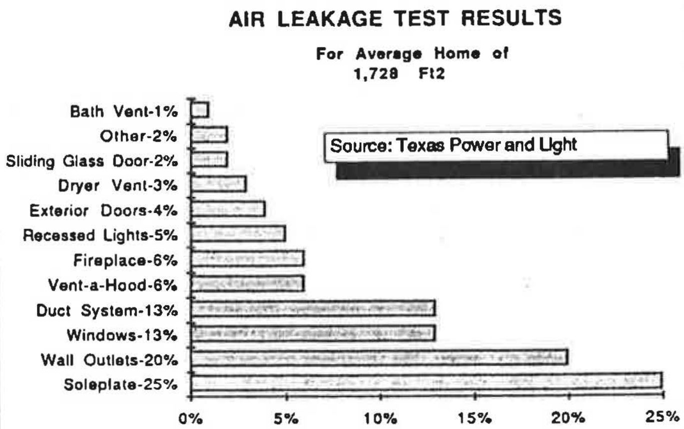


Figure 1. Causes of Air Leakage

That portion of the building that provides the boundary between the heated and unheated environment is often called the building envelope, and air leakage occurs through a great number of different locations in this envelope. Figure 2 depicts a partial list of likely leakage sites and indicates the percentage of total leakage for each site. The results of Figure 2 may not represent homes in Washington. Also, the percentages as well as specific leakage sites will vary considerably from house to house. However, it is certainly clear that the sources of air leakage are significantly more than the cracks around windows and doors. Other common locations include attic hatches, plumbing pipe penetrations, electrical service panels, kitchen cabinets, and even interior partition walls (think of all the holes the electrician drilled in order to run wires to interior wall outlets). One other important source of air leakage warrants special mention: the entry of air from the soil through cracks, joints, and penetrations in the basement wall (one study determined that 5 to 20 percent of the infiltrating air came from porous soils around certain homes).

The amount of air leakage that occurs in a home can be measured, and is often stated in air changes per hour (ACH). One ACH equals one house volume of air exchanged in one hour. The quantity of air (ft^3) involved in one ACH, then, varies with the volume of the house. For example, a 16,000 ft^3 house would have one half the air (and heat) involved in one ACH than the 32,000 ft^3 house next door. The national average of tested homes is about one ACH. Most homes test between .4 and 1 ACH. It is important to realize that leakage air change rates will vary considerably from home to home and are difficult to predict.

Figure 2. Test Results From One Study



It's also important to realize that leakage air change rates will vary considerably within a given home, depending on the interaction of wind, stack, and induced pressures. They will typically result in too many air changes in winter and not enough during certain spring and fall periods when the inside and outside temperatures are nearly equal and there's no wind. So uncontrolled leakage can be costly in winter yet may not help reduce indoor air quality problems in spring and fall.

A Bit Of Context

During the seventies, a great number of buildings were insulated (insulation does not stop air leakage, though it may significantly reduce it) and their resultant thermal performance was monitored. Consistent failure of these buildings to perform as predicted led to the realization that "air leakage" contributed more to thermal losses than had been thought. Instead of causing 10 to 15 percent of the building thermal losses, leakage of air was found to be responsible for 20 to 35 percent, sometimes 50 percent, of the energy lost. Since then considerable effort has been directed toward the issue of air leakage and methods for greatly reducing air leakage in both new and existing homes have evolved. It is now widely realized that the process of optimizing the energy efficiency of a home is considerably more than simply placing insulation in the attic. It is a complex process involving assessment of appropriate levels of investment in three major areas:

- Air sealing to reduce air leakage;
- Addition of insulation to walls, ceilings, and floors, and upgrading windows and doors; and
- Heating system improvements (including solar retrofit).

Each house is unique and the best mix of investments will vary from house to house, but in most cases, air sealing will be an important component of a comprehensive approach to a home's energy efficiency.

When the building air leakage is known, the thermal losses due to this convection can be calculated for the particular climate. Then, by integrating this information with conduction losses (obtained by determining "R values" of windows, walls, doors, floor, ceiling, etc.), a "whole house picture" of thermal performance can be obtained. The relative efficiencies and costs of various options can then be compared and a "menu" of improvements selected that best fits the building owner's investment priorities. The best approach to air sealing, as with any energy efficiency measure, lies in seeing it in context with all other possible measures. How cost effective is air sealing in relation to upgrading windows; adding insulation to walls, ceiling, or floor; etc. One can prioritize these measures and develop an overall plan to be accomplished over time as budget capabilities allow.

What Is Air Sealing?

Air sealing is a systematic approach to plugging the leaks that allow air to infiltrate or exfiltrate a building. It is not possible to completely seal an entire house, but by proper application of the right materials one can significantly reduce a home's air leakage. The sealing is accomplished by systematically locating leakage points and applying various sealants, foams, weatherstrippings, plastics, and rigid materials in order to seal them shut. Sealing is primarily done from the inside – the heated side – of the structure, as this allows a more effective seal to be attained and reduces the delivery of moisture into the building shell.

Some leaks can be located by visual inspection but most cannot. Even experienced sealing contractors who have developed a sense of where leaks commonly occur in a given house are often surprised. It is possible to seal all suspected leak locations and effectively reduce air leakage, but it is also possible to miss major leakage sites. Through use of a door fan, or even a powerful window fan that can be rented or purchased inexpensively, one can blow air into a building and exaggerate the air flow through cracks and holes. The leaks can then be found by using a smoke stick or gun (instruments which emit a highly visible smoke via chemical reaction rather than burning). The smoke can be seen wisking through holes and cracks in the building envelope.

A wide variety of sealing materials are required in air sealing. Sometimes sealants must bond to dissimilar materials, such as masonry and wood or metal and wood. Other factors influencing the selection of sealing materials include the size of openings to be sealed, the amount of movement due to thermal expansion of building components, and the temperature of certain components (metal furnace flues).

What Are The Benefits Of Air Sealing?

Better comfort and health through reduced drafts, less dust and pollen, and improved humidity levels.

Both air temperature and the speed of air flow adjacent to our bodies affect comfort. Cold drafts are double jeopardy, and their elimination or reduction will considerably improve comfort. Persons sensitive to dust and pollen can benefit from air sealing, as the effectiveness for air cleaning devices will be enhanced. Cold infiltrating air is relatively dry in comparison to indoor air, so it absorbs water vapor as it warms up, thereby reducing overall indoor humidity levels. Winter humidity levels are often too low in leaky homes, and this leads to higher rates of evaporation from the body, a cooling effect that reduces thermal comfort. It also causes static electricity as well as respiratory discomfort. Air sealing will raise humidity levels. In some cases, high levels of air sealing could lead to excessive humidity levels which must be corrected by source reduction and/or ventilation.

Cost-effective reduction of heating and cooling costs.

Annual space heating costs vary widely and the percentage of space heating costs due to air leakage also vary widely, so costs are difficult to predict. Also, the difficulty of sealing a particular house will vary. For example, a very leaky house with large, easy-to-access leaks may allow leakage reduction to .5 ACH with a 2-3 year payback; while a house with numerous small and difficult-to-access leaks (e.g., basement with leaks through rim joists concealed by finished ceiling) may be impossible to seal to .5 ACH within a 7 year payback.

The air leakage reduction potential for a house could range from 20 to 90 percent, depending on skill and time invested as well as the features of the house; but a 30 to 40 percent leakage reduction, costing between $200 and $1,200 and yielding a 10 to 15 percent reduction in heating costs would be more typical.

The following is offered as a general example. If your annual space heating bill is $1,000 and air leakage is responsible for 30 percent of it, then you pay $300 a year to heat the infiltrating air. If air sealing could cut the leakage in half and you were willing to accept a five year simple payback, you could allocate $750 to an air sealing investment.

If a 10 year payback was acceptable, you could allocate $1,500. There is some risk in the investment because the effectiveness of the sealing cannot always be predicted in advance. Also, as a house is made progressively tight, it will ultimately reach a point where the air exchange is too low to maintain sufficient indoor air quality. If pollutant source strengths cannot be reduced, improvements to the ventilation system will be necessary and will add to the investment.

Increased effectiveness of ventilation, the controlled air exchange.

Ventilation strategies meant to control humidity and outdoor pollutants, such as dust and pollen, are less effective when air leakage is a large percentage of the air exchange. They become increasingly effective as the percentage of air leakage is reduced.

Prevention or elimination of mildew, paint blistering, and possible structural deterioration in the building shell due to moisture problems.

Water exists in gas form as water vapor and is always in the air to some degree. However, a pound of cold air cannot hold nearly as much water vapor as a pound of warm air. In winter, the air in our homes is quite warm relative to the outdoor air. We are also constantly generating moisture in the home, and there may often be one-half of a gallon of water in the air. If the warm, moisture laden air exfiltrates through the wall cavity it will get progressively colder until it reaches the outdoor air temperature. At some point the air may no longer be able to hold as much water vapor and some of the water vapor will condense into liquid form. As air continues to exfiltrate from the building, the water in walls and ceilings can accumulate, soaking insulation, discoloring walls, blistering exterior paint, creating odors and mildew, and possibly leading to deterioration of structural members. To the extent that air sealing reduces the exfiltration of moisture laden air, it reduces the potential of moisture problems.

It is wise to seal before increasing insulation levels, especially in the attic. When insulation levels are increased, the cold side of the attic or wall cavity will be at a lower temperature, and the condensation risk will increase. Insulation before sealing may, in some cases, wet the insulation, thereby defeating its purpose and exposing components of the envelope to moisture problems.

What Are The Health And Safety Concerns?

Maintaining or improving indoor air quality.

Poor indoor air quality occurs when the concentration of a substance is great enough to be a health hazard, a source of discomfort, or a threat to the structure itself (e.g., moisture). Indoor air quality is a complex issue and all the factors affecting it are not yet well understood. The concentration of a given pollutant in a home depends upon both the rate at which it is delivered into the home's air and the rate at which it is removed. This is obvious enough, but the difficulty lies in the factors determining the rates of entry and removal.

Pollutants either enter the home from outside or are generated indoors. Those that enter from the outside include dust, pollen, auto exhaust fumes, industrial emissions, formaldehyde in exterior wall cavities, and radon gas in the soil. They may be reduced by appropriate air sealing but not necessarily. While air sealing might reduce the rate of entry of a given pollutant, it may also reduce the rate of removal.

Those pollutants generated in the home include moisture (potentially a pollutant), carbon dioxide, formaldehyde in furniture or cabinets, combustion by-products, organic chemicals from solvents and cleansers, odors, etc. The concentration of these pollutants will generally increase as a result of air sealing and may result in an indoor air quality problem.

The first step toward improving indoor air quality is the removal of the pollutant source. If that is impossible, reduce the source strength as much as possible. The second step is to improve the quality of ventilation. For further information see the WEES pamphlet on indoor air quality.

Ensuring adequate air supply for combustion appliances.

Combustion furnaces and water heaters, fireplaces, and woodstoves typically consume indoor air during operation. There must be adequate air supply for both combustion and for carrying the combustion by-products up and out the flue or chimney. It is possible to tighten a house to the point where, under certain conditions, the gases will be pulled back into the home. A worst-case situation occurs when all air consuming appliances are on and competing for air at the same time and resultant negative pressures in the home could cause backdrafting. The amount of air required varies, but an adequate supply must be available in order to prevent serious health effects and possibly death from the backdrafting of combustion by-products such as carbon monoxide, sulphur dioxide, and nitrogen oxides into the home. It is possible to have a home tested by a registered heating contractor once it has been sealed. In well sealed, energy-efficient homes, outdoor air is directly ducted to the combustion air intake of such appliances so that they no longer draw their air from indoors. This can be an excellent solution for an existing home as well. Unvented combustion appliances, such as free standing heaters, are not recommended in highly sealed homes.

Avoiding fire hazards from improper use of materials.

Proper sealing around chimneys, furnace flues, and electrical outlets/fixtures requires specific materials and attention to local codes. The lives and safety of future occupants depends upon proper installation and use of appropriate materials, especially in these locations.

Avoiding hazards to those installing the sealing measures.

Asbestos may be encountered while sealing an older home. One should wear a proper respirator and learn how to correctly deal with asbestos. Use of a good respirator (not disposable paper "face masks") is advised in crawlspaces, attics, and other dusty situations. Caution regarding electrical shock is warranted when sealing around electrical outlets, fixtures, and service panels.

How Do I Do It?

The safe and successful sealing of a home will require more information than is offered in this pamphlet, and a study of the referenced literature is recommended.

New Buildings

It is much easier and more cost effective to seal a building during the construction process. A much tighter seal can be obtained as well. Consequently cost-effective strategies for reducing air leakage currently vary for new construction and existing homes. A current strategy in new, tight, energy-efficient houses is to nearly eliminate the uncontrolled air leakage, then provide the air exchange necessary for healthy indoor air quality by using a variety of ventilation strategies. Suggested Reading #7 provides a good introduction to the principles and methods of air sealing in new energy-efficient construction.

Existing buildings: hiring a contractor

Air sealing is a growing industry in Washington, and you may be able to locate air sealing contractors in your area. These contractors have specialized equipment, as well as knowledge of appropriate materials and methods. The key tool utilized is the door fan. The door fan allows the contractor to obtain a reasonably accurate measurement of the rate of air leakage through the building envelope. As well, it allows the contractor to pinpoint specific locations of air leakage (via use of a smoke gun or smoke pencil) and seal them. Once specific leaks have been identified and sealed, the effective reduction in air leakage can be reduced to a specified level: a level that both minimizes thermal losses and prevents the accidental "over-tightening" that could lead to problems of indoor air quality. Door fan testing is currently offered by private sector contractors who provide both testing and computerized "whole building" analysis. They will also contract to perform the required air sealing work. Reference #5 can provide information about utilizing air sealing contractors.

Existing buildings: Doing it yourself

It is possible to do your own air sealing work. Reference #4 is a manual intended for use by weatherization contractors and homeowners who wish to perform air sealing without specialized equipment or knowledge. Reference #1 is also recommended for a good discussion of health and safety issues as well as the technical issues. Reference #3 discusses the use of a window fan and smoke sticks to detect leaks.

Written by: Mike Nuess

Suggested Reading

1. *Air Sealing Homes for Energy Conservation,* Buildings Energy Technology Transfer Program, Energy, Mines and Resources, 460 O'Connor St., Ottawa, Ontario, K1S 5H3.

This is a very comprehensive manual with well over 300 pages of text, drawings, and step-by-step instructions.

2. *Energy Sense: Air Sealing*, 1/2" VHS video tape available from WEES.
3. *Find Those Air Leaks*, Terry Brennan, Progressive Builder, June 1987, p. 39.

   This is a good introduction of how to use a fan and smoke sticks to locate leaks. It is oriented to new construction but very applicable to existing homes.
4. *House Tightening Manual for Homeowners and Weatherization Contractors*, Bonneville Power Administration Office of Conservation, P.O. Box 3621, Portland, OR 97208, 1986.

   This is oriented to homeowners of existing homes. It has excellent drawings of many leakage locations as well as details on what to use and how to use it.
5. Indoor Air Council of the Energy Business Association, 911 Western Ave. #420, Seattle, WA 98104, 1-800-732-1228.
6. *Indoor Air Quality* and *Building Energy Efficient Homes*, Bonneville Administration Office of Conservation, P.O. Box 3621, Portland, OR 97208.

   This organization develops standards for air leakage testing with the door fan, and provides training and certification for contractors.
7. *Super Good Cents Technical Reference and Construction Manuals*, Bonneville Power Administration Office of Conservation, P.O. Box 3621, Portland, OR 97208, 1986.

   This set of two notebooks provides both a practical guide to and technical specifications for a particular new energy-efficient home construction program. It also contains a good discussion of the principles of ventilation, air quality, and air sealing.

WEES Publications:

Indoor Air Quality (WAOENG-89-20)
Reducing Air Leakage With A Door Fan (FS-1105)

Washington Energy Extension Service

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