#3888

REDUCING HOME AIR LEAKAGE WITH A DOOR FAN

FACTSHEET

WASHINGTON ENERGY EXTENSION SERVICE

April 1988

INTRODUCTION

There are two types of air exchange between a heated building and the unheated environment: Ventilation is the controlled air exchange - via exhaust fans, openable windows, etc. Air leakage is the uncontrolled air exchange - via cracks, plumbing and electrical penetrations, etc. There are two types of air leakage: infiltration and exfiltration. This discussion focuses on a method for systematically measuring, locating, and sealing the uncontrolled air exchange in order to reduce the associated thermal losses.

The key tool utilized is the door fan, or blower door. It consists of a relatively powerful fan constructed and calibrated to be capable of measuring a range of pressure differences corresponding to different rates of air flow through it, and a mounting panel or frame. The door and its panel can then be sealed into an existing exterior doorway, so the air must pass through the calibrated fan. When turned on the fan will depressurize or pressurize the house, overriding the pressures that occur naturally on a day-to-day basis.

BACKGROUND

Though somewhat effective, the air sealing of buildings was much more of a hit and miss prospect before the development of the door fan. "Eyeball" estimates were necessary and they were much less reliable; possibly ±200 percent accuracy. During the seventies a great number of buildings were insulated (insulation does not necessarily stop air leakage) 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 10-15 percent of the building's thermal losses, leakage of air was found to be responsible for 20-35 percent, sometimes 50 percent, of the energy lost. Cost-effective methods for measuring and reducing air leakage gained in importance.

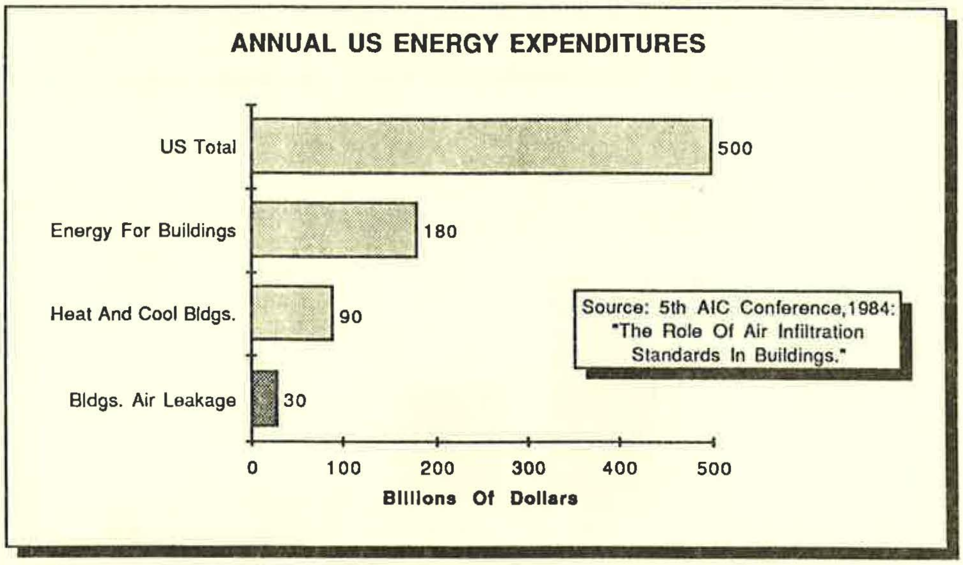

Figure 1. Cost Impact of Building Air Leakage

WISE USE OF RESOURCES THROUGH EDUCATION

SEATTLE UNIVERSITY
SEATTLE, WA 98122
(206) 296-5640

W. 808 SPOKANE FALLS BLVD., RM. 627
SPOKANE, WA 99201
(509) 624-4180

The door fan is a relatively new tool that is well equipped to address the issue of air leakage. It was developed in Sweden about fifteen years ago where it has been used on a commercial basis for about 10 years. It underwent testing at Lawrence Berkeley Labs and Princeton University in the US during the middle seventies and is just now becoming commercially available here.

WHAT IT DOES

The door fan allows us to cost effectively obtain a reasonable estimate of the rate of air leakage through the building envelope. As well, it allows us to pinpoint specific locations of air leakage and seal them. Once specific leaks have been identified (via use of a smoke gun, smoke pencil, or even a wetted hand) and sealed, the effective reduction in air leakage can be estimated with the door fan. In this manner the building's air leakage can be reduced to a level intended to both minimize thermal losses and prevent the accidental "overtightening" that could lead to problems of indoor air quality.

When the door fan is turned on the airflow through the cracks and holes is greatly increased, and smoke can be readily seen as it is wisked through these openings. The smoke gun is a lightweight instrument that produces a highly viscuous smoke at the same temperature as the surrounding air. The smoke just floats where squirted but readily moves if there is any air movement. Smoke guns use hydrochloric acid and titanium tetrachloride to generate smoke. They are refillable. The smoke produced is about as toxic as auto exhaust so one should avoid direct inhalation. Many contractors report that they seldom use smoke guns as most leaks can also be readily felt with the hand.

Measurement of a home's rate of air leakage is expressed in terms of air changes per hour(ACH). One ACH equals one house volume of air replaced by outside air in one hour. For example a 16,000 FT^3 house with a 0.5 ACH will exchange 8,000 FT^3 of air each hour. The quantity of air (cubic feet)involved in one ACH varies with the volume of the house. For example this 16,000 FT^3 house would have on half the air (and heat) involved in one ACH than the 32,000 FT^3 house next door.

The term ACH is often applied to different situations, and one must understand the intended meaning for a particular application. It may refer to the rate of air leakage in a home that will occur under natural day-to-day conditions over the course of the heating season. If so, it is often called the natural ACH. It may also refer to the rate of total air exchange (air leakage plus ventilation) in a home.

The national average tested natural air leakage rate for homes is about 1 ACH. Most homes test between 0.4 and 1 ACH, though the range is from .02 ACH in very draft-free energy efficient homes to more than 2 ACH in older, drafty homes. It is important to realize that natural air change rates will vary considerably from day-to-day, depending on the interaction of wind and stack pressures (In winter the warmer air inside the house is much more buoyant than the colder, denser outside air and so it flows up through building cracks, flues, and chimneys as a result of "stack" pressures.) Typically the result is too many air changes in winter, maybe 4-6 ACH on cold days, 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 air leakage can be costly in winter yet may contribute to indoor air quality problems in spring and fall.

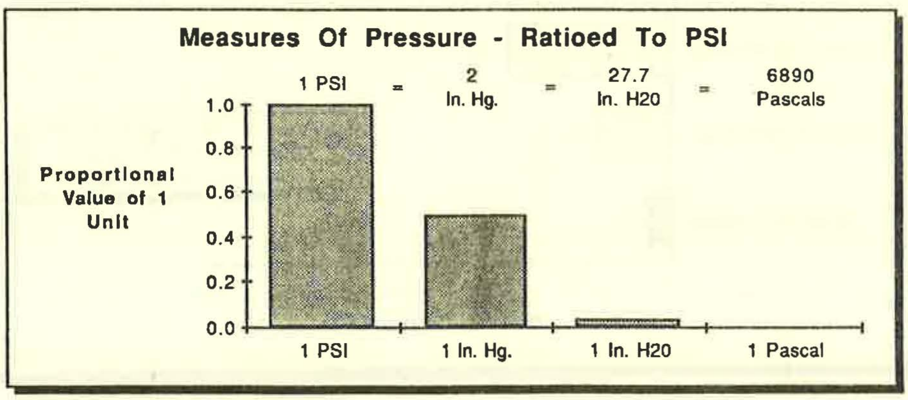

Figure 2. The Pascal is measure of a very small pressure

The Pascal is the measure of pressure that is most often used in door fan testing. It takes about 6,890 Pascals to equal one pound per square inch. It is relatively small in comparison to the more familiar units of pressure, so small that is doesn't even show up on the chart in Figure 2, which ratios various measures of pressure to PSI (lbs./in^2). A pressure of 50 Pascals has been said to be the pressure equivalent of about a thirty mph wind acting on all sides of a building at once. It is a great enough pressure to overcome influences such as stack pressures and the pressure of a light wind. Stack pressures inside the home are usually less than 10 Pascals and typically about 3 - 5 Pascals.

Often the air leakage of a building is expressed as the number of ACH that occur when the house is under a door fan induced pressure of 50 pascals, because this value is attainable by direct measurement. By measuring the induced pressure differences that occur through the fan under a corresponding range of air flow rates, it is possible to estimate the leakage that will occur under natural conditions. Current Canadian and Swedish energy efficient home standards require leakage rates of 1.5 ACH or less at 50 Pascals which roughly corresponds to about 0.075 ACH of air leakage under natural conditions.

Two other terms used to express the air leakage of a door fan tested home are the Equivalent Leakage Area (ELA) and the Leakage Ratio. The ELA is the area that is equal to the sum of the areas of all the individual leaks. For example a house may have an ELA of 576 in^2, the equivalent of a square hole 24 inches on a side. The Leakage Ratio is the number of in^2 of leakage area per 100 FT^2 of envelope area. It is useful for comparing the leakiness of buildings of different sizes. Leakage Ratio = [ELA/envelope area] x 100.

The actual air leakage that takes place under natural conditions depends on the leakage distribution -- the particular pattern of leaks in a building. Leak distribution significantly affects the natural air change rate but doesn't affect the leakage rate as determined by the door fan. Here is an example: Two houses have the same ELA but all the leaks of house A occur along the first floor rim joists and the leaks of house B are evenly split; half in the ceiling and half the first floor rim joist. Under natural conditions house A will have no stack pressure leakage while house B will have considerable leakage due to stack pressure. However, with the door fan both houses would test the same. While this condition may seldom occur (except perhaps as the consequence of a poor sealing job), it serves to show an important limit of the door fan method. The door fan only measures the tightness of the building shell. It does not measure the actual air exchange rate. (Air infiltration measurement systems utilizing a tracer gas can be used to provide additional information about the leakage characteristics of a building.)

Once the building air leakage is known, the thermal losses due to this can be calculated for the particular climate. By integrating this information with conduction losses (obtained by determining "R values" of windows, walls, doors, floor, ceiling, etc.), we can obtain a "whole house picture" of thermal performance. 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 air sealing in context with all other possible measures. How cost effective is the air sealing potential in relation to upgrading windows, adding insulation to walls, ceiling, or floor? One can attempt to prioritize these measures and develop an overall plan to be accomplished over time as budget capabilities allow.

There are additional interrelationships that come into play when determining the best overall plan. For example, one might find that the addition of attic insulation will result in greater savings and shorter payback than air sealing. However, typically 30 percent of air leakage is into the attic and much air sealing work has to be done there. Sealing the attic after the insulation has been installed will require considerable extra work to rake aside the insulation, clean, seal, then replace the insulation. The net effect is that the sealing will cost more. Also, installation of attic insulation without sealing could reduce the insulation's effectiveness because leaking air can carry moisture into the insulation and reduce its R value. Hence attic insulation and air sealing would comprise a better package; but if both are not immediately affordable, air sealing might be the better first choice.

AIR SEALING CONTRACTORS

Door fan testing is currently offered by private contractors, who often provide both testing and computerized "whole building" analysis. Currently testing costs range from $100 - $200. They will also contract to perform the required air sealing work. (They often provide related services, such as the installation of a ventilation system or testing for radon, formaldehyde, or excessive moisture.) The cost of air sealing varies considerably and cannot be predicted for a specific house until the house has been examined and tested. Cost savings and payback depend on the amount, locations, and distribution pattern of a particular building's air leakage. For example, a very leaky house with large, accessible leaks may allow leakage reduction to 0.5 ACH with a 2-3 year payback; while a house with numerous small and difficult-to-access leaks (eg. basement with leaks through rim joists concealed by finished ceiling) may be impossible to seal to 0.5 ACH within a 7 year payback.

As in construction, both short and long term quality of performance depends on the contractors knowledge and integrity. It is advisable to be informed about proper air sealing procedures and materials, check references, and monitor results. The reduction in energy bills can be predicted from pre- and post- sealing tests with the door fan, provided that occupant lifestyle changes and seasonal climatic variations are taken into consideration.

The Indoor Air Council of the Energy Business Association has a Door Fan Contractor Certification Program to help consumers select a contractor who is certified. See Reference #3.

DO-IT-YOURSELF AIR SEALING

Do-it-yourself air sealing, with or without a doorfan, is certainly possible. It should be viewed as a major task that will require careful attention to detail in order to competently address health and safety issues -- as will as attain the desired performance. Air sealing manuals are available (see References) and one should become thoroughly acquainted with the issues involved. An understanding of air sealing methods, materials, and health/safety issues is essential.

AIR SEALING NEW BUILDINGS

The door fan can be used during construction to detect leaks that remain unsealed and seal them before they become difficult to access. It also allows the building to be progressively tightened until the desired level of tightness is achieved. It is much easier and more cost effective to seal a home or other building during the construction process, and a much tighter seal can be obtained as well. Consequently cost-effective levels of tightness are often different for new construction and existing homes.

One current strategy in new, tight energy-efficient houses is to nearly eliminate the uncontrolled air leakage, and then provide the air exchange necessary for healthy indoor air quality with ventilation (remember ventilation is the controlled air exchange).

Additionally, since one of the original reasons for reducing air leakage is to reduce energy losses, and since the exhausted ventilation air would still carry away significant (though much less) heat, these new houses often employ heat recovery ventilation systems that recover some of the heat from the exhaust and return it to the building.

LIMITS

First we want to eliminate the leakage in order to:

- reduce heat loss, and
- gain control over the rate of air exchange.

Then we can minimize the air exchange by both automatic and manual adjustment of the home's ventilation system. But how much air exchange is enough?

We need some level of air exchange to sustain indoor air quality. Many different pollutants are typically generated within a home or building and we know that we must remove them at a rate at least equal to that at which they are generated. There isn't a simple answer. Indoor air quality is a complex issue, and standards have been difficult to come by.

One great difficulty with regard to setting standards is that the generation of pollutants can vary tremendously from building to building. Occupant lifestyle habits, building size and location, and the concentration of pollutant sources all affect a particular building's requirements for fresh air supply. Another difficulty is that relatively little is known about how different concentrations of some pollutants affect human health. Also different people have different sensitivities.

Guidelines have been developed and the current most often stated guidelines range from 0.35 to 0.5 ACH (air leakage plus ventilation) as a reasonably safe lower limit.

Written by Mike Nuess.

REFERENCES

1. Terry Brennan, "Find Those Air Leaks", Progressive Builder, June 1987, p.39.
   Good introduction regarding how to use a fan and smoke sticks to locate leaks. Oriented to new construction but very applicable to existing homes.

2. 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 a both 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.

3. Indoor Air Council of the Energy Business Association; 911 Western Ave. #420, Seattle, WA 98104; 1-800-732-1228.
   An organization endeavoring to develop standards for air leakage testing with the door fan, and provide training and certification for contractors.

4. Reducing Home Air Leakage, WEES Factsheet (FS-1101).

5. 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.

6. 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.

7. Indoor Air Quality, WEES Factsheet (FS-1801).

8. Indoor Air Quality and Building Energy Efficient Homes; Bonneville Power Administration Office of Conservation; P.O. Box 3621; Portland, Or 97208.

9. AIC Literature List; Air Infiltration Centre; Old Bracknell Lane West; Bracknell; Berkshire; Great Britain RG12 4AH; Tel 034453123
   Worldwide index to technical research related to air leakage.

Washington Energy Extension Service, a Seattle University and Washington State Energy Office program, is funded by the Bonneville Power Administration and the U.S. Department of Energy.

You can obtain free copies of this and other fact sheets by contacting a WEES office listed on page one of this document, or: Energy Librarian; Washington State Energy Office; 809 Legion Way S.E., FA-11; Olympia, WA 98504-1211.

FS-1105 (4/88)