Blower Doors: Infiltration Is Where the Action Is

In spite of their usefulness, blower doors remain one of the least understood house-doctoring tools. This article describes blower door design and use. An article in the May issue will discuss the growth of the blower door industry and the different types of blower door users. A third article will explore methods of using blower doors and the reliability of blower door measurements.

Infiltration Heat Loss

The two most important heat loss pathways in a home are conduction and infiltration. Many retrofits (e.g. insulation) reduce only the conduction losses. As conductive losses are reduced, heat loss from infiltration may increase to as much as 60 percent of the total heat loss. A blower door enables the retrofitter to make the home more efficient by pinpointing the air leakage sites, sealing them effectively and directly measuring the improvement.

Pinpointing the Leaks

A blower door is a door- or window-mounted, variable speed fan that blows air into (pressurizes) or sucks air out of (depressurizes) a house. A generic blower door is shown in Figure 1. The size and complexity of the fan varies, but all blower doors have adjustable frames around the fan so that they can fit snugly into most doorways. Its primary function is to assist in locating leaks in the building envelope. This can be done by either pressurizing or depressurizing the house. Each method has its advantages; however performing *both* pressurization and depressurization tests guards against factors such as wind pressure which can distort the measurements.

During a depressurization test, air is sucked into the house at leaky spots such as windows, doors, baseboards, or wall-ceiling joints. These air leaks can then be detected using a smokestick or a wet hand.[1] Yet many retrofitters prefer to pressurize the home because it is easier to detect leaks with a smokestick in a pressurized home; the smoke visibly snakes out of the house through any cracks. A note of caution: the blower door is designed to find *unintentional* leaks in the building envelope; therefore, all vents and the fireplace damper should be closed before conducting the test. Some first-time house doctors have made the mistake of forgetting to remove ashes from the fireplace before the test—resulting in a filthy living room, an embarrassed retrofitter and a distressed homeowner.

The infrared (IR) camera is a diagnostic tool often used with the blower door. In a depressurized home, the camera takes thermographs which can reveal pathways of incoming cool air. In a pressurized home, thermographs are taken from the attic to locate hard-to-find thermal bypasses through the wall cavities. Some retrofitters take exterior thermographs to detect warm air leaking out of the house. In either case, an IR camera can only be used at certain times of the year, i.e., when there is at least a 15°F temperature difference between inside and outside. [2]

Measuring Air Leakage

There is no general agreement among retrofitters on how to use a blower door—let alone on what type of model to use. The "quick and dirty" technique employs a fire evacuation fan, or even an attic fan, to suck air out of and depressur-

[1] A smokestick is a thin glass tube filled with the chemical titanium tetrachloride, or sulfur trioxide treated crystals, which produce dilute chemical vapors when exposed to air. The retrofitter squeezes a rubber bulb to force a small stream of smoke out of the tube.

[2] See "Practical Techniques for Residential Thermography," EA&R, Jan/Feb '86.)

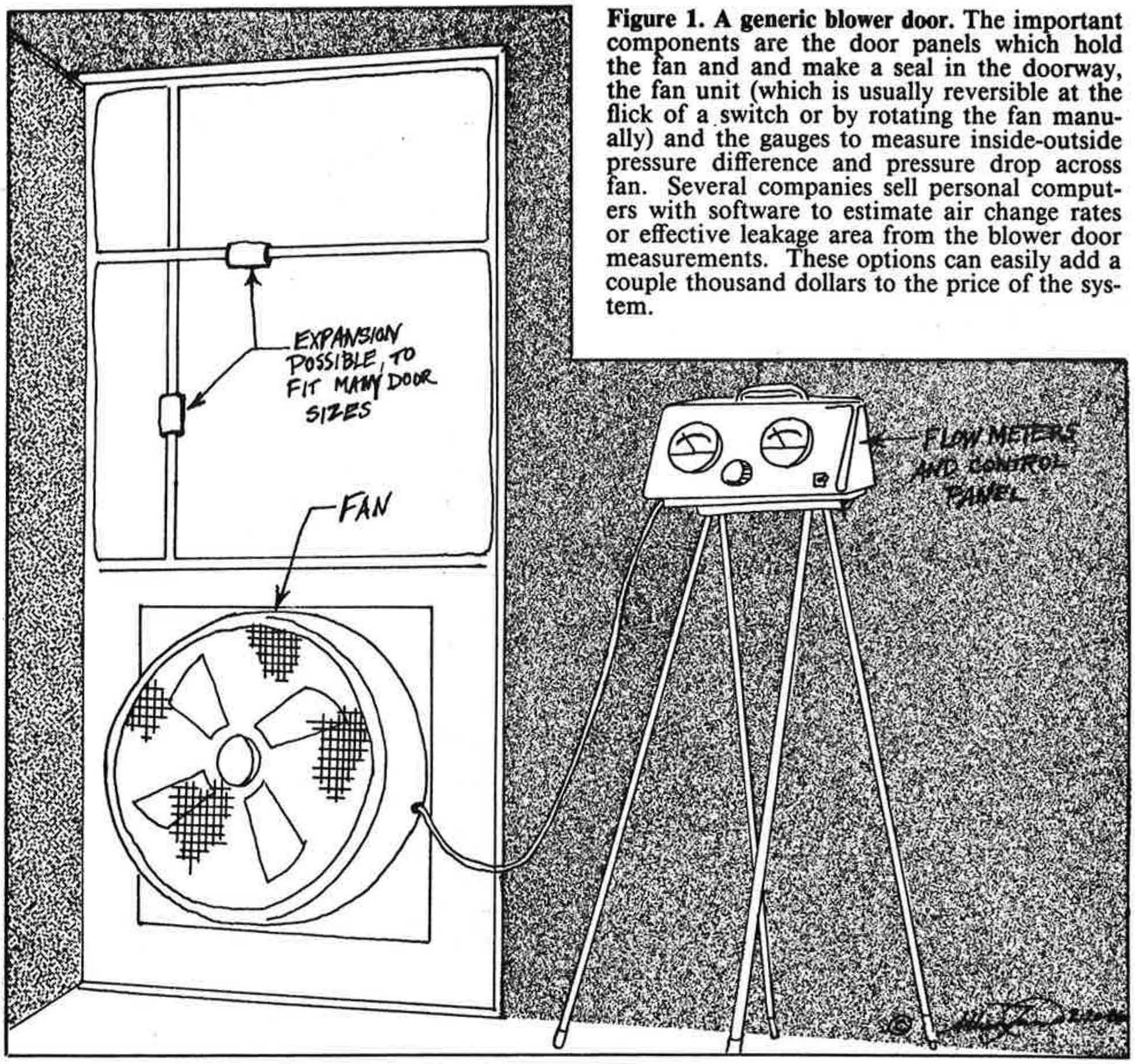


Figure 1. A generic blower door. The important components are the door panels which hold the fan and and make a seal in the doorway, the fan unit (which is usually reversible at the flick of a switch or by rotating the fan manually) and the gauges to measure inside-outside pressure difference and pressure drop across fan. Several companies sell personal computers with software to estimate air change rates or effective leakage area from the blower door measurements. These options can easily add a couple thousand dollars to the price of the system.

ize the house [3]. At the other end of the scale there is the calibrated blower door, which enables the user to quantify whole-house leakage before and after the retrofit. The average test takes between one and two hours, depending on the comprehensiveness of the test, required preparation time, and experience of the blower door user.

There are two kinds of blower doors—calibrated and uncalibrated. An uncalibrated blower door is a low-cost tool the retrofitter can use to pinpoint leakage sources and cut heat loss in old, leaky homes. However, the retrofitter can only determine how effective the treatment is in reducing air leakage and heat loss with a more expensive, calibrated door.

Most blower doors have two sets of pressure sensors. One set measures the pressure difference created between indoors and outdoors, while the other measures the air flow through the fan-necessary to sustain this inside-outside pressure difference. One can intuitively understand the relationship between these two measurements: the leakier the home, the greater the flow rate required to maintain a given inside-outside pressure difference. Without these measurements it is not possible to calibrate the door (see box on calibration and accuracy). There are two common ways to translate these readings into natural leakage estimates[4]:

[3] Depressurizing the house with a window or attic fan to locate and seal leaks is a measure recommended by the Department of Energy's 50/50 low-cost weatherization program.

[4] "Standards for Contractors Performance of Airtightness Measurement in Residential Structure," Prepared by J.A. Poole, David Saum and Richard Catlin for the City of Austin Resource Management Department, May 1985. This report discusses the pros and cons of the ACH, ELA and other calculation methods currently in use.

- *Air changes per hour (ACH)* at 50 pascals of indoor-outdoor pressure difference [5]. This high-pressure reading can partially mask the natural pressure effects of wind and temperature.
- *Effective Leakage Area (ELA).* The ELA is the combined area in square inches of all the leaks and cracks in the house.

A future article will discuss different techniques used to calculate rates of air leakage.

Why Buy a Calibrated Door?

The question of whether or not to use calibrated doors has generated an enormous amount of controversy among blower door designers and users. The reason is the trade-off between performance and price. A $100 fire evacuation fan can identify infiltration sources, but cannot be used to calculate the leakage area or air-change rate of a building. The $7,000 computer-linked "Cadillac" system, on the other hand, automatically measures air flow and generates ELA measurements. The air leakage data is then used by a built-in computer to perform more sophisticated building energy-use analysis.

[5] A pascal is 1 Newton/meter^2. A home under normal conditions is typically at about 4 Pa pressure above the outdoor pressure, caused by air infiltration and temperature differences. During a blower door test, air flow measurements are taken at several pressures, typically in the 10 to 70 pascal range.

The Uncalibrated School

The "simple" school of thought is that accurate measurements are often unnecessary. Bill French, of *Your Energy Services* who manufactures an inexpensive, uncalibrated unit, has firm ideas about what's important in selecting a blower door:

> *"The first Princeton blower door must have been built with military money. It took two people twenty minutes to get the door up and running. It had government written all over it. No State agency would ever buy my door [because it's not glamorous] . . . This is a Blue Collar blower door, not a White Coat one. It's simple, rugged, and a chimp can use it—maybe even more successfully than some researchers."*

Bill claims that his powerful 3/4 horsepower fan provides the client with a dramatic demonstration of how drafty the house is. He finds that the economics of repair often mean that you can't over-weatherize a house—after five years in business he's never had a complaint about making a

Calibration and Accuracy

By using a calibrated blower door, the retrofitter can measure the air change rate (ACH at 50 pascals) and effective leakage area (ELA) of a house. Blower doors are calibrated by testing a building with known leakage area. Researchers have developed equations to predict the ELA and ACH of a building as a function of air velocity through the fan and inside-outside pressure difference. Computers commonly offered for sale by door manufacturers will compute the ELA from measurements made during field tests. The accuracy of these readings is normally published with sales literature (see Table 1).

Air flow through the fan is calculated in two ways for two different types of doors. The most common type is a pressure door, where the air flow through the fan is a function of the pressure drop across the fan. An equation is then used to relate air flow to the pressure difference across the fan for that door. Some blower doors—referred to as RPM doors—rely instead on fan speed measurements. Readings are taken at various fan speeds (each produces a different house pressure) and the resulting family of curves is plotted versus air flow. An equation is developed to relate air flow (RPM) through the fan to the inside-outside pressure difference and the RPM of the fan. For pressure doors, recalibration becomes necessary if the nozzle opening size is accidentally misshapen. For RPM doors, recalibration may be required if the fan blades are damaged or the fan opening modified so that airflow is restricted or increased. Pressure or fan speed gauges are more susceptible to damage than orifice openings. It may appear that a door needs recalibration, i.e., the user has difficulty reproducing the same test results on the original building when, in fact, the problem is caused by differences in climatic conditions (wind speed) or changes in the building envelope (e.g., swelling of the window frames during high-humidity periods can temporarily seal certain cracks) between the first and second test dates.

house too tight—so why worry about 5 percent measurement accuracy? "People don't want to buy a certain leakage area . . . It doesn't matter to them. They want a more comfortable house that is relatively less leaky. That's all."

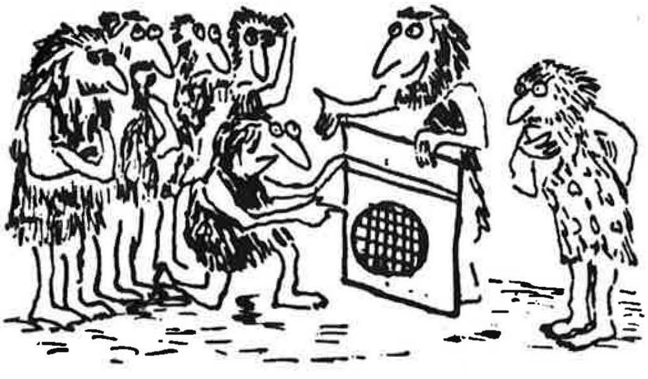
Mike Eder of *Eder Energy*, who sells both a calibrated and an uncalibrated model, says of the problem of over-tightening homes,

> *"Contractors have to use common sense. The people buying my uncalibrated doors are not working in super-tight, efficient houses. They're working in sieves, and with the Reagan budget, low-income weatherization contractors can't afford a $5,000 blower door."*

The Calibrated School

The "precision" school argues that calibrated doors are necessary to prevent retrofitters from over-tightening houses and sealing in pollutants. Ken Gadsby of *Gadzco* believes that, especially in smaller homes, the leakage diagnosis and sealing technique alone can put the occupants in jeopardy by possibly lowering the air change rate to unhealthy levels. "There should be a law against uncalibrated blower doors," says Gadsby. The people at *Retrotec* apparently agree. According to Gavin Conway of *Retrotec*, "We stopped manufacturing our model 630 because we didn't think it was responsible for a blower door manufacturer to produce an uncalibrated door."

Another argument for calibrated doors is that, by accurately determining the leakage area of the house before and after weatherization, the retrofitter knows what percentage of the infiltration sources have been sealed, and can then give a client information on the dollar savings expected from the weatherization job (although the calculation may be difficult to do accurately). Firms promising a certain level of leakage reduction must use calibrated doors if they intend to provide evidence of the savings for the client. Accuracy requirements may also appear in future testing protocols and standards (see box on test standards and user certification).



It's called a blower door.
It makes great banana smoothies.

Equipment Specifications

EA&R contacted 11 manufacturers and have listed important characteristics of 16 currently available blower doors. Specifications such as weight, air flow range (cubic feet per minute), reversibility (pressurization/depressurization at the flick of a switch), price, warranty period, and the range of doorway openings the blower door will fit are shown in Table 1. List prices for the basic residential unit range from $870 to $3400 (not including extra costs for computer equipment to analyze the data). Manufacturers report that all-time sales of blower doors total 1300, with 390 sold last year alone. A major trend seems to be towards lighter, lower cost and more attractive equipment. Manufacturers are also concentrating more on computerized data analysis tools—from programmable hand calculators to microcomputers.

Each blower door has special features. Not all doors can fit mobile homes, for example. Although the concern is usually that the doorway will be too narrow, **EA&R** recently tested a double-wide trailer with a *Retrotec* door, and a couple of two-by-fours had to be installed to fully seal the 39" door opening. Another important feature, computer analysis, can speed up a blower door test and make it more impressive, but costs more. There are two types of data analysis for blower door measurements: 1) automatic analysis by a computer hooked up to the blower door (*AQL* and *Enercorp*, among others); and 2) manual analysis, (most blower doors have this) with the use of a hand-held computer to calculate ELA, and ACH at 50 pascals. The high-priced *AQL* door, for example, is controlled by a computer that automatically runs a series of tests at incremental pressure differences, and provides digital readouts to reduce human error. These devices speed up the analysis process by taking the blower door readings and generating graphs and diagnostic data. The *AQL* computer feeds the leakage area results into a program that calculates whole-building energy use and selects the most cost-effective retrofits.

There are a number of important questions to ask when selecting a blower door:

1. Is the door calibrated, and where can it be recalibrated?

2. Is the motor AC or DC? DC motors are more reliable and less likely to overheat.
3. Is the air flow direction of the fan reversible? Some doors have a reversible fan motor; for others it is necessary to lift and rotate the entire fan unit.
4. How are the door panels constructed? The Minneapolis doors, for example, are made of fabric and are therefore easy to transport and install. Steel door panels can be very heavy.
5. What are the minimum/maximum door opening sizes? Will they fit in mobile homes (small doorways) or commercial buildings (large doorways)? The range of door widths in Table 1 is 24"-48", and the range of door heights is 48"-94".
6. How heavy is the door? The heaviest element is normally the fan, and one person should be able to carry it. The weight range (shown in Table 1) is 55-160 pounds for the entire door and 18-117 pounds for the fans alone.
7. What is the flow range? Blower doors designed for use in superinsulated homes can have relatively low-power fans. Very leaky buildings may not be able to be brought up to full pressure with these small fans. The maximum flow of the surveyed units is from 1,800 to 5,500 cfm for installed fans at a pressure drop of 50 pascals.
8. Are the fan air flow measurements based on pressure or revolutions per minute (RPM)? RPM measurements can be disturbed by wind conditions.
9. How are the calculations performed? Without a computer you will have to use graphs and/or equations to determine leakage areas or air change rates.
10. Does the blower door comply with existing or anticipated standards for new and existing homes? If not, you may have to buy another in the near future.

Blower Door Test Standards and User Certification

A 1986 Lawrence Berkeley Laboratory report summarizes the status of blower door standards in the U.S. and abroad: "In recent years at least four measurement standards have been introduced to provide a standard method for determining airtightness in buildings. These standards have been introduced in Canada (CGSB, 1985), Norway (NBR, 1981), Sweden (SIS 021551, 1980), and the United States (ASTM, 1981). Both the proposed Canadian standard and the ASTM standard incorporate air temperature and atmospheric pressure corrections for airflow measurements, while the Norwegian standard requires only an air temperature correction of airflows. With regard to wind speed at the time of the measurement, the Norwegian standard *requires* that the measurement not be performed when the wind speed is greater than 6.0 m/s [13.4 miles/hour]. The proposed Canadian standard *recommends* that the measurement not be performed when the wind speed exceeds 5.5 m/s [12.3 mph], while the ASTM standard *recommends* that the measurements not be performed when the wind speed exceeds 4.5 m/s [10.1 mph]. In the *draft* ASTM standard E779-85, the maximum wind speed criteria for calculating the effective leakage area at 4 Pa has been reduced to 2.0 m/s." *

Don Stevens, of the Energy Business Association (EBA) of Washington State, is working with Puget Power and Light to develop a voluntary blower door certification and standards package for the Pacific Northwest that combines the best features of the various standards and research. Their primary goal is to make it easier for utilities and regulatory bodies to endorse blower door testing by providing a certification of quality and reliability and to thereby expand the blower door market.

The EBA certification is based on a written test and field-trial. The written test currently consists of 25 questions about blower door operation procedures. In the field-trial, the door user tests a building that has an opening of known size. The aperture is then reduced and the house retested. The door user must determine the change in opening size within a certain accuracy. Of eight doors tested so far, five predicted the actual leakage area within 17 percent. Homemade doors performed very poorly, even some claiming to be calibrated. For more information on the EBA project, contact Don Stevens, Energy Business Association, 911 Western Ave., #300 A, Seattle, WA 98104. tel: (206) 622-7171.

* J.B. Dickinson and H.E. Feustel, *Seasonal Variation in Effective Leakage Area*, January, 1984. Lawrence Berkeley Laboratory, LBL Report #19337.

Table 1. BLOWER DOOR SPECIFICATIONS*

Manufacturer & Model	Type P/T	Opening Size (inches)	Weight All/fan (lbs)	Flow Range (cfm)	Accur-acy	Motor Type (AC/DC)	List Price	War-ranty (months)
AQL/CARE II	T	29x78-37x86	50/39	25-4200	5%	DC,R	$3400	12
C.M.S.	P	–	88/40	0-2500	–	DC,R	$4075	12
Eder/CFM	T	24x72-37x84	60/45	0-3600†	not tested	AC,R	$1695	1
Eder/S-2	na	24x72-37x84	55/40	0-3000†	not calib.	AC	$869	1
Heatnapper	T	28x78-38x83	160/56	95-5,200	7%	DC,R	$3000	12
Gadzco/104	T	28x77-37x83	75/38	100-4500	5%	R,DC	$2500	12
Gadzco/105	T	30x77-37x83	110/80	300-5000	5%	R,DC	$3000	12
Infiltec/R-1	P	28x78-36x88	74/39	545-4750	5%	var. AC	$3250	3
Infiltec/E1	na	28x78-36x88	80/45	0-3400	non calib.	AC,R	$1750	3
Infiltec/E2	na	28x78-36x88	83/45	500-3400	semi calib.	AC,R	1750	3
Mekankonsult Lifa	P	35-82	40/18	50-1800	5%	AC	$1000	12
Minneapolis	P	24x48-40x94	55/34	50-5,500	10%††	var. AC,R	$1250	12
Retrotec/610	P	29.5x78-36x86	120/38	30-5500†	5%	DC,R	$5825**	12
Retrotec/620	P	29.5x78-36x86	91/38	15-4500†	5%	AC,R	$3250	12
Retrotec/650‡	P	(see manuf'r)	152/117	13,500†	5%	AC	$8950**	12
Y.E.S. Door	na	30x73-48x84	90/70	0-8,500†	non calib.	var. AC,R	$2400	12
Enercorp/1-panel‡‡	P	30x80-36x84	150/75	53-1700	5%	AC	$1800	12
Enercorp/3-panel‡‡	P	30x80-36x84	125/25	38-1800	5%	AC	$2800	12
Enercorp/microproc'r‡‡	P	30x80-36x84	150/20	47/4800	7%	AC,R	$6200	12
Energy Doctor‡‡	T	32x80-36x84	135/	–	–	–,R	–	–
Harmax‡‡	T	32x72-42x82	100/	0-4000	–	DC,R	$5500	none

Legend to Table 1.

* Data collected from manufacturers' literature and telephone correspondence.
** AQL and Retrotec doors have a computer built in.
† Flow measurents taken under free flow conditions, rather than at 50 pascals.
†† Can be custom calibrated to within 5% for an extra $200.
‡ Commercial Size blower door: Consists of three fans.
‡‡ Firm no longer manufactures blower doors.

Type: (How the flow rate across the fan is measured.) P=Pressure reading; T=Tachometer (rpm reading).
Opening Size: Minimum and Maximum door heights and widths.
Weight: Entire system weight/fan weight.
Flow Range: Minimum-Maximum flow in cubic feet per minute at a pressure drop of 50 pascals unless otherwise reported.
Accuracy: Test error for output readings
Motor: AC or DC; Var.=variable speed; R=Reversible
Readout: Output readings -- Press. = pressure drop across the fan;
RPM=speed across fan;
ELA=effective leakage area; ACH=air changes per hour.
Price: Current List Price.
Warranty: Warranty period on fan, in months

Note: We have contacted two Swedish manufacturers of blower doors: Mekankonsult Lifa and Veab Elocmicro. We were not able to obtain specifications for the latter blower door.

BLOWER DOOR MANUFACTURERS

CURRENTLY MANUFACTURING BLOWER DOORS

Air Quality Labs, Inc.
The CARE-II Blower Door
Larry Eddington
5805 East Sharp
Spokane, WA 99206
(509) 534-6932

Conservation Management Services
The CMS Blower Door
Mike McKeever
761 SW Vista #207
Portland, OR 97205
(503) 796-7222, 227-0400

Eder Energy
The Detecdoor CFM, S-2
Mike Eder
7535 Halstead Dr.
Mound, MN 55364
(612) 446-1559

The Energy Conservatory
Minneapolis Blower Door
Gary Anderson, Gary Nelson
920 West 53rd Street
Minneapolis, MN 55419
(612) 827-1117, 929-6949

Heatnapper
The Draft Arrester
Dick Weiss
3035 Saratoga Street
Omaha, NE 68111
(800) 228-7256

Infiltec
Infiltec R-1, E-1, E-2
Dave Saum
PO Box 1533
Falls Church, VA 22041
(703) 820-7696

Mekankonsult Lifa
Juergen Lindgren
Jukragen 13
352-42 Vaxjo
Sweden
Tel: 46-470-22956

Princeton Energy Partners, Inc.
The Gadzco Blower Door
Ken Gadsby
PO Box 1221
Princeton, NJ 08540
(609) 586-6747

Retrotec
Retrotec Door Fan
Brendan Reid, Colin Genge
PO Box 939
Ogdensburg, NY 13669
(800) 267-3861

Veab Elocmicro AB
Box 22
S-360 50 Lessebo
Sweden
Tel: 0478 11376
or 46-478-11376

Y.E.S. Door
Your Energy Services
Bill French
PO Box 90034
Nashville, TN 37209
(615) 383-9546

NO LONGER MANUFACTURING BLOWER DOORS

Enercorp
Infiltrometer
Peter Giesbrick
Suite 206-435 Berry St.
Winnipeg, Canada R3J-1N6
(204) 888-9612

Energy Conservation Systems
TWV Enterprises
4216 50th Street
Suite F
Lubbock, TX 79413
(806) 794-4459

The Energy Doctor
Energy Door
Jeff Tucker
P.O. Box 180609
Austin, TX 78718
(Unable to locate)

Harmax Corporation
Harmax Blower Door
Max Sherman
6224 Orange Street
Los Angeles, CA 90048
(213) 936-2673

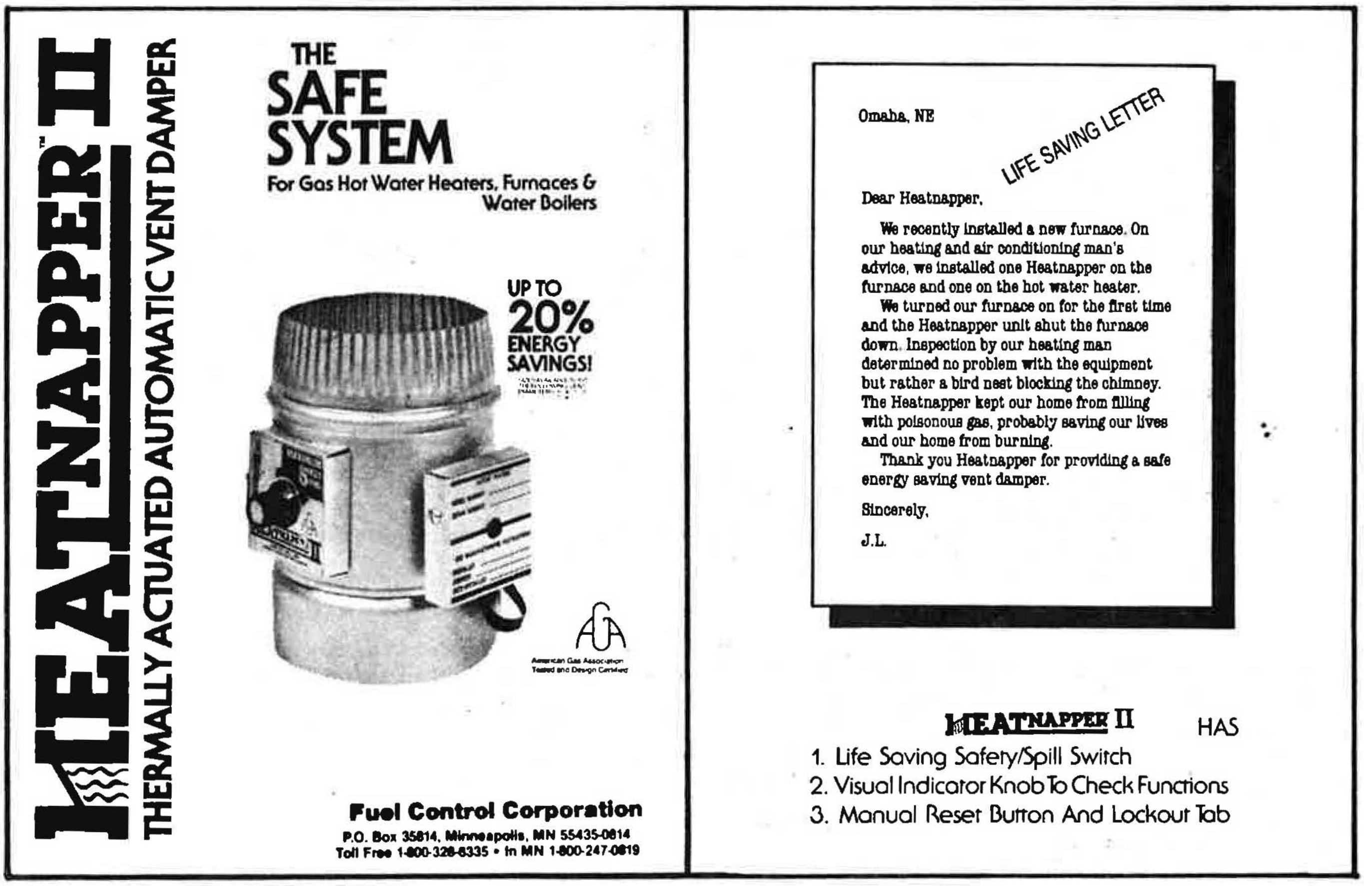


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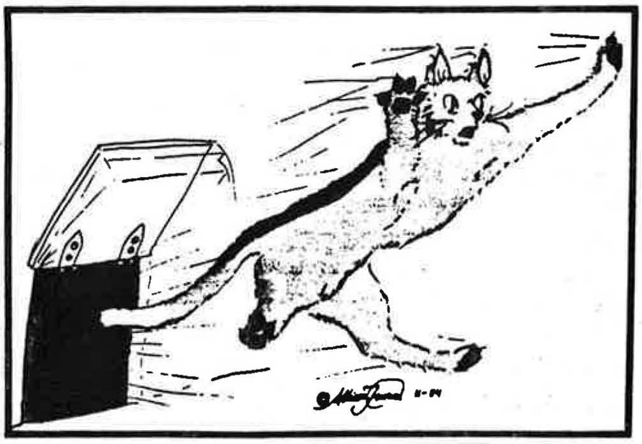
Table 1 provides a starting place for those in the market for a blower door. Contact the manufacturers directly for more details—many new blower doors are on the drawing boards.

Blower Doors in the 90s

Blower doors have made it beyond the strict research environment into successful commercial use. The outlook is favorable but the blower door industry will have to resolve a number of technical issues.

- *Environment:* What effect do wind, temperature, and humidity have on the measurement results?
- *Testing procedures:* Is depressurization superior to pressurization or should one conduct both tests for accurate leakage measurements?
- *Repeatability:* How accurate are different tests taken on the same house? Before and after tests can be skewed by environmental conditions: the building envelope itself can change (e.g., higher humidity may cause wood to temporarily swell and close cracks); or different auditors may perform their tests differently.
- *Quality Control:* How does the industry insure customers of the accuracy and honesty of readings?
- *Certification:* Should blower doors and users be certified? If so, how and by whom?
- *Accuracy:* How can the industry validate the various calculation methods being used? How accurate are translations of ELA to natural ACH or to the cost of infiltration heat loss?



When using the blower door in an occupied house, make sure you've carefully explained the procedures to *all* the occupants.

Recommendations

The blower door can be an invaluable tool for the house doctor, whether it be for simple leak detection and sealing or for sophisticated analysis of the home's leakage characteristics. The eleven manufacturers we surveyed offer a broad range of options. The prospective blower door buyer must assess her current and future needs before deciding on the appropriate door type. The important challenges facing the potential user are:

- Choosing between cheap "leak finders" and expensive "precision doors".
- Deciding whether to do pressurization tests, depressurization tests, or both.
- Deciding whether to invest in the costly, but useful technology of IR scanning.
- Keeping abreast of research in the field of infiltration and insuring an accurate and honest leak detection service.

-Evan Mills

Hearty thanks to Bruce Dickinson of Morgan Systems Corp., in Berkeley, CA, and Helmut Feustel, of the Lawrence Berkeley Laboratory for their thoughtful review of this article.