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CA Title 24
Request for Equal Status

13.3 NRCA-MCHA-04-A Air Distribution Systems Acceptance

13.61 Test Procedure: NA7.5.3 Air Distribution Systems Acceptance

INTRODUCTION

Form NRCA-MCH-04-H Duct Leakage is the only Certificate of Acceptance that names a verifier other than the Acceptance Test Technician who is certified to sign forms NRCA-MCH-02-03 and NRCA-MCH-05 thru 18. In keeping with the spirit of the Standard to qualify experienced and knowledgeable Acceptance Test Technicians this document intends to show competence of the United Association HVAC Technician, who becomes certified as an Acceptance Test Technician in compliance with the 2013 Building Energy Efficiency Standards, to sign NRCA-MCHA-04-A. Furthermore, the intention of this request is provide evidence of proper training and testing that will qualify the UA Acceptance Test Technician as an equal to the HERS rater. This request, if approved, will accelerate the execution of the Certificate of Acceptance for Duct Leakage where applicable.

REFERENCES

- Attachment One
  Appendix NA2-Nonresidential Field Verification & Diagnostic Test Procedures

- Attachment Two
  HERS Rater Certification

- Energy Auditing Practices - A Guide to Benchmarking, Auditing, and Retrofitting Residential, Commercial and Industrial Buildings
  Attachment Three - Pre-class worksheet
  Attachment Four – Lab for Envelope and Duct Leakage Assessment
  Attachment Five – Energy Auditor Certification Quality Manual

CREDENTIAL REVIEW

The Residential Energy Services Network or RESNET is a recognized national standards-making body for building energy efficiency rating and certification systems in the United States. RESNET created the Certified Home Energy (HERS) Rater to inspect and evaluate a home's energy features, prepare a home energy rating and make recommendations for improvements that will save the homeowner energy and money. The United Association created the Certified Energy Auditor to benchmark, audit, and retrofit residential, commercial, and industrial buildings.

The table that follows compares and contrasts the curriculum covered by both RESNET and the UA certified energy audit programs. In addition, the table also defines the pre-requisites for candidates for each program along with requirements for attendance before taking the certification exam.

Both of the organizations require a written or computer evaluation and a hands-on lab for certification. RESNET allows the lab procedures to be reviewed in the field under varying circumstances determined by each candidate and the respective agent. On the other hand, the UA provides a reliable and repeatable process programmed into the certification process. Attachment Four outlines the required lab for the student. There are two mandatory opportunities to demonstrate measurement and verification proficiency to the instructor:
- Hampden House – mock up setting for envelope, duct, and mechanical system testing
- Child Care Center – 5,000 sq. ft. building that is audited for the purpose of creating reports and presenting the finding to the class.

Completion of the audit and presentation are part of the grading and certification structure for the United Association (Attachment Five).

Category	HERS Rater	UA Certified Energy Auditor (CEA)	
Pre-requisite	None	1. Five year Apprenticeship, Mechanical Equipment Service (MES) Training, or Equal 2. Pass the HVAC STAR Mastery Exam	
Attend Class	Not required	Mandatory	
Subjects Covered	Basic principles of building science	Apprentice/MES	Related Science Manual
	Thermal resistance of insulation materials	Apprentice/MES	HVACR Manual
	Blower door testing procedures	CEA	Energy Audit Manual
	Duct leakage testing procedures	CEA	Energy Audit Manual
	Variations in construction types	CEA	Energy Audit Manual
	Types and efficiencies of windows	CEA	Energy Audit Manual
	Types and efficiencies of heating, cooling, water heating, and lighting systems	CEA	Energy Audit Manual
	Characteristics of space conditioning and hot water distribution systems	Apprentice/MES	HVACR Manual Hydronic Manual
	Types of thermostatic controls	Apprentice/MES	HVACR Manual
	Determination of air leakage	CEA	Energy Audit Manual
	Determination of fuels used by major appliances	CEA	Energy Audit Manual
	Utility rate structures	CEA	Energy Audit Manual
	On-site inspection procedures	CEA	Energy Audit Manual
	Producing a scaled and dimensional drawing of a house	Apprentice/MES	Drawing Interpretation & Plan Reading Manual
	Calculating the area of rectangles, triangles, circles, ovals, and combinations of these shapes	Apprentice/MES	Related Math Manual
	Calculating the volume of boxes, pyramids, spheres, and other geometric shapes	Apprentice/MES	Related Math Manual
	Completing a home energy rating checklist or entering data into a home energy rating software program	CEA	Energy Audit Manual EPA Portfolio Manager
	Completing a home energy improvement analysis	CEA	Energy Audit Manual
	Basic knowledge of financial incentive programs and energy efficient mortgages	CEA	Energy Audit Manual
	Communicating the benefits of energy saving measures and practices to the consumer	CEA	Energy Audit Manual
Quality Assurance	1% annually	NITC Quality Assurance	10% Annually

ADDED VALUE BY THE UA TECHNICIAN

The HERS Rater is not in compliance with EPA Section 608 and therefore does not carry a CFC license. Every UA HVACR Technician earns the appropriate level of CFC licensing for execution of their daily work. UA HVACR Technicians work within the EPA guidelines to start-up, charge, commission, evaluate and measure the performance of all mechanical systems.

CONCLUSION

Approval of this request for equal status will positively impact the budget and schedule of the project since the UA Acceptance Test Technician can complete the Certificate of Acceptance absent the cost of a third-party vendor.

The Certified Energy Auditor Program administrated by the United Association and verified by NITC meets and exceeds the Nonresidential Field Verification and Diagnostic Test Procedures outlined in Appendix NA2.

Nonresidential Appendix NA2

Appendix NA2 – Nonresidential Field Verification and Diagnostic Test Procedures

NA2.1 Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems

NA2.1.1 Purpose and Scope

1. NA2.1 contains procedures for field verification and diagnostic testing for air leakage in single zone, constant volume, nonresidential air distribution systems serving zones with 5000 ft² of conditioned floor area or less as required by Standards section 140.4(l).
2. NA2.1 procedures are applicable to new space conditioning systems in newly constructed buildings and to new or altered space conditioning systems in existing buildings.
3. NA2.1 procedures shall be used by installers, HERS Raters, and others who perform field verification of air distribution systems as required by Standards Section 140.4(l).
4. Table NA2.1-1 provides a summary of the duct leakage verification and diagnostic test protocols included in Section NA2.1, and the compliance criteria.

NA2.1.2 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

NA2.1.2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of plus or minus 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes, Dwyer A303 or equivalent.

NA2.1.2.2 Duct Leakage Measurements

All measurements of duct leakage airflow shall have an accuracy of plus or minus 3 percent of measured airflow or better using digital gauges.

NA2.1.2.3 Calibration

All instrumentation used for duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the accuracy requirement specified in Section NA2.1.2.

NA2.1.3 Diagnostic Apparatus

NA2.1.3.1 Apparatus for Duct Pressurization and Leakage Flow Measurement

The apparatus for duct system pressurization and duct system leakage measurements shall consist of a duct system pressurization and leakage airflow measurement device meeting the specifications in Section NA2.1.2.

NA2.1.3.2 Apparatus for Smoke-Test of Accessible-Duct Sealing (Existing Duct Systems)

The apparatus for determining leakage in and verifying sealing of all accessible leaks in existing duct systems provide means for introducing controllable amounts of non-toxic visual or theatrical smoke into the duct pressurization apparatus for identifying leaks in accessible portions of the duct system. The means for generating smoke shall have sufficient capacity to ensure that any accessible leaks will emit visibly identifiable smoke.

NA2.1.4 Verification and Diagnostic Procedures

NA2.1.4.1 Nominal Air Handler Airflow

The nominal air handler airflow used to determine the target leakage rate for compliance for an air conditioner or heat pump shall be 400 cfm per rated ton of cooling capacity. Nominal air handler airflow for heating-only system furnaces shall be based on 21.7 cfm per kBtu/hr of rated heating output capacity.

NA2.1.4.2 Diagnostic Duct Leakage

Diagnostic duct leakage measurement shall be used by installers and HERS Raters to verify that duct leakage meets the compliance criteria for sealed duct systems for which field verification and diagnostic testing is required. Table NA2.1-1 summarizes the leakage criteria and the diagnostic test procedures that shall be used to demonstrate compliance.

Table NA2.1-1 – Duct Leakage Verification and Diagnostic Test Protocols and Compliance Criteria

Case	User and Application	Leakage Compliance Criteria, (% of Nominal Air Handler Airflow)	Procedure(s)
Sealed and tested new duct systems	Installer Testing HERS Rater Testing	6%	NA2.1.4.2.1
Sealed and tested altered existing duct systems	Installer Testing HERS Rater Testing	15%	NA2.1.4.2.1
Sealed and tested altered existing duct systems	Installer Testing and Inspection HERS Rater Testing and Verification	Fails Leakage Test but All Accessible Ducts are Sealed Inspection and Smoke Test with 100% Verification	NA2.1.4.2.2 NA2.1.4.2.3 NA2.1.4.2.4

NA2.1.4.2.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

The objective of this procedure is for an installer to determine and a HERS Rater to verify the leakage of a new or altered duct system. The duct leakage shall be determined by pressurizing the entire duct system ducts to 25 Pa (0.1 inches water) with respect to outside. The following procedure shall be used for the fan pressurization tests:

(a) Verify that the air handler, supply and return plenums and all the connectors, transition pieces, duct boots, and registers are installed, and ensure the following locations have been sealed:

1. Connections to plenums and other connections to the air-handling unit.

2. Refrigerant line and other penetrations into the air-handling unit.
3. Air handler access door or panel (do not use permanent sealing material, metal tape is acceptable).

The entire duct system including the air- handler shall be included in the test.

(b) For newly installed or altered ducts, verify that cloth backed rubber adhesive duct tape has not been used.

(c) Temporarily seal all the supply registers and return grilles, except for one large centrally located return grille or the air handler cabinet access door or panel. Verify that all outside air dampers and/or economizers are sealed prior to pressurizing the system.

(d) Attach the fan flowmeter device to the duct system at the unsealed return grille or the air handler cabinet access door or panel.

(e) Install a static pressure probe at a supply register located close to the air handler, or at the supply plenum.

(f) Adjust the fan flowmeter to produce a positive 25 Pa (0.1 inches water) pressure at the supply register or the supply plenum with respect to the outside or with respect to the building space with the entry door open to the outside.

(g) Record the flow through the flowmeter, this is the duct leakage flow at 25 Pa (0.1 inches water).

(h) Divide the duct leakage flow by the nominal air handler airflow determined by the procedure in Section NA2.1.4.1 and convert to a percentage. If the duct leakage flow percentage is equal to or less than the target compliance criterion from Table NA2.1-1, the system passes.

NA2.1.4.2.2 Sealing of All Accessible Leaks

For altered existing duct systems that are unable to pass the leakage test in Section NA2.1.4.2.1, the objective of this test is to verify that all accessible leaks are sealed. The following procedure shall be used:

(a) Complete the leakage test specified in Section NA2.1.4.2.1.

(b) Seal all accessible ducts.

(c) After sealing is complete, again use the procedure in NA2.1.4.2.1 to measure the leakage after duct sealing.

(d) Complete the Smoke Test as specified in NA2.1.4.2.3.

(e) Complete the Visual Inspection as specified in NA2.1.4.2.4.

All duct systems that fail to pass the leakage test specified in Section NA2.1.4.2.1 shall be tested and inspected by a HERS Rater to verify that all accessible ducts have been sealed and damaged ducts have been replaced. Compliance with HERS verification requirements shall not utilize group sampling procedures when the installer used the Sealing of All Accessible Leaks procedure in Section NA2.1.4.2.2.

NA2.1.4.2.3 Smoke-Test of Accessible-Duct Sealing

For altered existing ducts that fail the leakage tests, the objective of the smoke test is to confirm that all accessible leaks have been sealed. The following procedure shall be used:

(a) Inject either theatrical or other non-toxic smoke into a fan pressurization device that is maintaining a duct pressure difference of 25 Pa (0.1 inches water) relative to the duct surroundings, with all grilles and registers in the duct system sealed.

(b) Visually inspect all accessible portions of the duct system during smoke injection.

(c) The system shall pass the test if one of the following conditions is met:

1. No visible smoke exits the accessible portions of the duct system.

2. Smoke only emanates from the furnace cabinet which is gasketed and sealed by the manufacturer and no visible smoke exits from the accessible portions of the duct system.

NA2.1.4.2.4 Visual Inspection of Accessible Duct Sealing

For altered existing duct systems that are unable to pass the leakage test in Section NA2.1.4.2.1, the objective of this inspection in conjunction with the smoke test (Section NA2.1.4.2.3) is to confirm that all accessible leaks have been sealed. Visually inspect to verify that the following locations have been sealed:

(a) Connections to plenums and other connections to the air-handling unit.

(b) Refrigerant line and other penetrations into the air-handling unit.

(c) Air handler access door or panel (do not use permanent sealing material, metal tape is acceptable).

(d) Register boots sealed to surrounding material.

(e) Connections between lengths of duct, as well as connections to takeoffs, wyes, tees, and splitter boxes.

HERS Rater

Certification Requirements

A certified home energy rater must successfully complete training by a RESNET Accredited Rater Training Provider and must be certified by a RESNET Accredited Rating Provider.

A rater must successfully complete training by a RESNET accredited rater training organization. The training is conducted in accordance with a syllabus developed by RESNET. The training addresses:

- Basic principles of building science (i.e., viewing the home as a system)
- Thermal resistance of insulation materials
- The minimum rated features for buildings
- Blower door testing procedures
- Duct leakage testing procedures
- Variations in construction types and their ramifications
- Types and efficiencies of windows
- Types and efficiencies of heating, cooling, water heating, and lighting systems
- Types and characteristics of space conditioning and domestic hot water distribution systems
- Types of thermostatic controls
- Determination of air leakage
- Determination of fuels used by major appliances
- Utility rate structures
- On-site inspection procedures
- Producing a scaled and dimensioned drawing of a home
- Calculating the area of rectangles, triangles, circles, ovals and combinations of these shapes

- Calculating the volume of boxes, pyramids, spheres, and other geometric shapes
- Completing a home energy rating checklist or entering data into a home energy rating software program
- Completing a home energy improvement analysis or entering data into a home energy rating software program that performs improvements analysis
- Basic knowledge of financial incentive programs and energy efficient mortgages
- Communicating the benefits of energy saving measures and practices to the consumer
- Quality assurance

ATTACHMENT THREE

UAT 410 Energy Audit Certification
Pre-class Worksheet

NAME:______________________________ LOCAL:_____________

1. If 1400 cfm of air passes through a furnace rated at 80% AFUE and the temperature of the air increases 60 deg F, how much heat in BTU will be transferred to the air?

   BTU = CFM x 1.08 x TD

   Determine the bonnet capacity if: INPUT = BTUH / AFUE

2. Water pipes with a surface temperature of 50 deg F are running through an area maintained at 70 deg F. What is the maximum relative humidity that can be maintained without condensation on the pipe surface? (use the attached psychrometric chart)

3. The manufacturer’s data sheet states that the pressure drop through the chiller is 10 ft. at a flow rate of 100 gpm. What would the pressure drop be at a 120 gpm flow rate?

4. Heat input can be measured by clocking the gas meter to determine the rate of gas flow, in cubic feet per hour, then converting the result to heat input by multiplying the rate of gas flow in cfh by the heat content. What are the steps in the procedure for determining rate of gas flow in a residence?

5. Given the following thermal resistance (R value) for a particular wall construction:
   a) outside surface coefficient..........0.17
   b) brick, 4” thick.............................0.40
   c) air space filled with insulation....5.30
   d) gypsum wallboard......................0.45
   e) inside surface coefficient............0.68

   What is the “U” value for this wall?

$$U = 1 / R_T$$

$$R_T = R_1 + R_2 + R_3, \text{ etc.}$$

6. A substance has the following properties:
Specific heat when in solid state..................=0.40
Specific heat when in liquid state...............=0.90
Specific heat when in vapor state...............=0.30
Latent heat of fusion..................................=120 Btu/pound
Latent heat of vaporization........................=800 Btu/pound
Melting point...=40 degF
Boiling point..=120 degF

Calculate the TOTAL amount of heat which will be absorbed when 15 pounds of the solid substance at a temperature of 30 degF is changed to a vapor at a temperature of 130 degF.

SH = Weight x Specific Heat x TD
LH = Weight x Constant
TH = SH + LH

7. Tests of an air conditioning system made while the refrigeration sub-system was operating at full capacity show the supply fan motor to be drawing exactly rated current of 25.4 amperes. If the refrigeration system is turned off, the motor will

a) draw more amps

b) draw less amps

c) draw the same amps

d) be overloaded

8. A hot water terminal unit has a specified capacity of 120,000 BTUH when supplied with 20 GPM of 180 deg F water. Detemine the leaving water temperature (LAT).

BTUH = 500 x GPM x TD

9. Given the following cooling coil conditions:

3,000 CFM of standard air
EAT: 82F DB, 71F WB
LAT: 62F DB, 58F WB

BTUH = CFM x 1.08 x TD

The sensible heat removal is approximately:

a) 6,400 BTUH
b) 33,000 BTUH
c) 65,000 BTUH
d) 133,000 BTUH

$$BTUH = 4.5 \times CFM \times (H_1 - H_2)$$

The total heat removal is approximately:

a) 13,000 BTUH
b) 66,000 BTUH
c) 133,000 BTUH
d) 260,000 BTUH

10. A motor is rated at 1 HP 120 volts and 15 amps full load current. During a test, measured actual voltage at motor is 105 volts and measured current is 12 amps. Without considering the no-load current, the motor under test conditions is producing approximately __________ HP.

ATTACHMENT FOUR

UAT 410

Hampden House Energy Audit

Practical Examination Lab

Great Lakes Training Center, Ann Arbor, MI

ATTACHMENT FOUR

Example Blank Form

Building Airtightness Test Form

Customer Information:

Name: ______________________________

Address: ______________________________

City: ______________________________

State/Zip: ______________________________

Phone: ______________________________

Email: ______________________________

Building Address: (if different from above)

Street: ______________________________

City/State: ______________________________

Building and Test Conditions:

Date: __________

Time: __________

Indoor Temperature (F): __________

Outdoor Temperature (F): __________

Volume (ft^3): __________

Floor Area (ft^2): __________

Surface Area (ft^2): __________

Bedrooms: __________

Occupants: __________

Wind Shielding: __________

Comments:

____

____

____

____

Test #1

Depress ______ Press ______

Pre-test Baseline Pressure: ______ (Pa)

Bdlg Press. (Pa)	Flow Ring Installed	Fan Press (Pa)	Flow (cfm)

Post-test Baseline Pressure: ______ (Pa)
Fan Model/SN: ______________________________

Results:

CFM50: __________

ACH50: __________

CFM50/ft^2: __________

Mpls Leakage Ratio: __________

Test #2

Depress ______ Press ______

Pre-test Baseline Pressure: ______ (Pa)

Bdlg Press. (Pa)	Flow Ring Installed	Fan Press (Pa)	Flow (cfm)

Post-test Baseline Pressure: ______ (Pa)
Fan Model/SN: ______________________________

Results:

CFM50: __________

ACH50: __________

CFM50/ft^2: __________

Mpls Leakage Ratio: __________

Appendix E Home Energy Article *

Infiltration: Just ACH50 Divided by 20?

by Alan Meier
Alan Meier is executive editor of ***Home Energy Magazine****.*

This* Home Energy *classic, originally printed in 1986, explains a simple way to take one air infiltration measurement and determine a home's average air infiltration rate.

Many researchers have sought to develop a correlation between a one-time pressurization test and an annual infiltration rate. Translating blower door measurements into an average infiltration rate has bedeviled the retrofitter and researcher alike. The rate of air infiltration constantly varies, yet the pressurization test is typically a single measurement. Nevertheless, many researchers have sought to develop a correlation between a one-time pressurization test and an annual infiltration rate.

ACH Divided by 20

In the late 1970s, a simple relation between a one-time pressurization test and an average infiltration rate grew out of experimentation at Princeton University. For a few years, the correlation remained "Princeton folklore" because no real research supported the relationship. In 1982, J. Kronvall and Andrew Persily compared pressurization tests to infiltration rates measured with tracer-gas for groups of houses in New Jersey and Sweden. They focused on pressurization tests at 50 Pascals because this pressure was already used by the Swedes and Canadians in their building standards. (This measurement is typically called "ACH50.") Other countries and groups within the United States have also adopted ACH as a measure of house tightness. Persily (now at the National Institute of Science and Technology) obtained a reasonably good estimate of average infiltration rates by dividing the air change rates at 50 Pascals by 20, that is:

$$\text{average infiltration rate (ACH)} = \frac{\text{ACH50}}{20} \quad (1)$$

In this formula, ACH50 denotes the hourly air change rate at a pressure difference of 50 Pascals between inside and outside. Thus, for a house with 15 ACH at 50 Pascals (ACH50 = 15), one would predict an average air change rate of (15/20 =) 0.75 ACH.

This simple formula yields surprisingly reasonable average infiltration estimates, even though it ignores many details of the infiltration process. These "details" are described below:

* Printed by Permission of Home Energy Magazine.

- ***Stack effect.*** Rising warm air induces a pressure difference, or "stack effect," that causes exfiltration through the ceiling and infiltration at (or below) ground level. The stack effect depends on both the outside temperature and the height of the building. A colder outside temperature will cause a stronger stack effect. Thus, given two identically tall buildings, the one located in a cold climate will have more stack-induced infiltration. A taller building will also have a larger stack effect. Even though outside temperature and building height affect average infiltration rates, neither is measured by the pressure test. During the summer, stack effects disappear because the inside air is usually cooler (especially when the air conditioner is operating). Wind-induced pressure therefore becomes the dominant infiltration path.

- ***Windiness and wind shielding.*** Wind is usually the major driving force in infiltration, so it is only reasonable to expect higher infiltration rates in windy areas. Thus, given two identical buildings, the one located in a windy location will have more wind-induced infiltration. Nevertheless, a correlation such as ACH50/20 does not include any adjustment for windiness at the house's location. Trees, shrubs, neighboring houses, and other materials also shield a house from the wind's full force. Since a brisk wind can easily develop 10 Pascals on a windward wall, the extent of shielding can significantly influence total infiltration. A pressurization test does not directly measure the extent of shielding (although a house with good shielding may yield more accurate measurements since it is less affected by wind).

- ***Type of leaks.*** The leakage behavior of a hole in the building envelope varies with the shape of the hole. A long thin crack, for example, responds less to variations in air pressure than a round hole does. The pressure/air change curve (determined with a calibrated blower door) often gives clues to the types of leaks in a house.

A person conducting pressurization tests on a particular house can collect considerable information about these details. For example, it is easy to measure a house's height and estimate the wind exposure. The kinds of cracks can often be judged through careful inspection of the building construction. Climate data, including windiness and temperature, can be obtained from local weather stations. Ideally, this additional information should be applied to the formula in order to get a correlation factor more accurate for that house. Unfortunately, the formula was developed from data in just a few houses in New Jersey and Sweden, and it cannot be easily adjusted to other locations and circumstances. Should a retrofitter in Texas also use ACH50/20, or is dividing by 15 more appropriate for the Texas climate and house construction types?

The LBL Infiltration Model

Researchers at Lawrence Berkeley Laboratory developed a model to convert a series of fan pressurization measurements into an "equivalent leakage area." (See HE, "Blower Doors: Infiltration Is Where the Action Is," Mar/Apr. '86, p.6. and the ASHRAE Book of Fundamentals chapter on ventilation and infiltration.) The equivalent leakage area roughly corresponds to the combined area of all the house's leaks.

A second formula converts the equivalent leakage area into an average infiltration rate in air changes per hour. This formula combines the physical principles causing infiltration with a few subjective estimates of building characteristics, to create relatively robust estimates of infiltration. ASHRAE has approved the technique and describes the formulae in ASHRAE Fundamentals. The LBL infiltration model is now the most commonly accepted procedure for estimating infiltration rates.

Max Sherman at LBL used this model to derive the theoretical correlation between pressure tests at 50 Pascals and annual average infiltration rates.[1] His major contribution was to create a climate factor to reflect the influence of outside temperature (which determines the stack effect) and windiness. Sherman estimated the climate factor using climate data for North America and plotted it (see Figure 1). Since the factor reflects both temperature and seasonal windiness, a cold, calm location could have the same climate factor as a warm, windy location. The map also reflects summer infiltration characteristics. Note how Texas and Vermont have the same climate factors.

Sherman found that the correlation factor in the revised formula could be expressed as the product of several factors:

$$\text{correlation factor, } N = C * H * S * L \quad (2)$$

where:

C = climate factor, a function of annual temperatures and wind (see Figure 1)

H = height correction factor (see Table 1)

S = wind shielding correction factor (see Table 2)

L = leakiness correction factor (see Table 3)

Values for each of the factors can be selected by consulting Figure 1 and Tables 1-3. An estimate of the average annual infiltration rate is thus given by

$$\text{average air changes per hour} = \frac{ACH50}{N} \quad (3)$$

This formula provides a more customized "rule-of-thumb" than the original ACH50/20 , when additional information about the house is available.

An Example

The application of the climate correction is best shown in an example. Suppose you are pressure testing a new, low-energy house in Rapid City, South Dakota. It is a two-story house, on an exposed site, with no surrounding vegetation or nearby houses to protect it from the wind.

1. At 50 Pascals, you determine that the ACH50 is 14.
2. You consult Figure 1, and determine that the house has a climate factor, "C," of 14-17. Since Rapid City is near a higher contour line, select 17.
3. The house is two stories tall, so the appropriate height correction factor, "H" (from Table 1), is 0.8.
4. The house is very exposed to wind, and there are no neighboring houses or nearby trees and shrubs. The appropriate wind shielding correction factor, "S" (from Table 2), is 0.9.
5. The house is new, and presumably well-built. The appropriate leakiness factor, "L" (from Table 3), is 1.4.

6. Calculate N:

$$N = 17 * 0.8 * 0.9 * 1.4$$

$$= 17$$

Calculate the average annual infiltration rate:

$$ACH = \frac{ACH50}{17}$$

$$= \frac{14}{17}$$

$$= 0.82$$

The difference in this case (between dividing by 20 and 17) is not great--only 17%--but it demonstrates how the building conditions and location can affect the interpretation of pressurization tests.

Sherman compared his results to those reported by Persily. Sherman noted that he obtained a correlation factor (N) of about 20 for a typical house in the New Jersey area. Thus, Sherman's theoretically derived correlation factor yields results similar to Persily's empirically derived correlation factor.

The range of adjustment can be quite large. In extreme cases, the correlation factor, N, can be as small as 6, and as large as 40. In other words, the ACH50/20 rule of thumb could overestimate infiltration by a factor of two, or underestimate it by a factor of about three.
This formula is still only a theory; it has not been validated with field measurements. Moreover, there is considerable controversy regarding the physical interpretation of the climate factor. For example, the formula yields a year-round average infiltration rate, rather than just for the heating season. Such a result is useful for houses with both space heating and cooling, but it may be misleading for some areas.

Recommendations

There is no simple way to accurately convert a single pressure-test of a building to an average infiltration rate, because many building and climate-dependent factors affect true infiltration. Long-term tracer gas measurements are the only reliable way to obtain average infiltration rates. However, tracer gas measurements are impractical for retrofitters, and even most conservation researchers. A simplified rule of thumb to let the retrofitter quickly translate a pressure-test to an infiltration rate is clearly attractive.

Persily and Kronvall developed a crude conversion technique, ACH50/20, that provides reasonable results. On the other hand, it was impossible to customize the relationship of ACH50/20 to local conditions. What are the components of the magic number, 20?

Now Sherman has created a similar conversion factor that can be modified to reflect local building and climate conditions. This correlation factor accounts for windiness, climate, stack effect, and construction quality. Some judgement is needed to select the appropriate correction factors, but the blower-door user can now understand the quantitative impact of local conditions on infiltration. For example, a three-story house will have significantly more infiltration than a ranch house--even though the pressure tests are identical--due to a greater stack effect. (Clearly an infiltration standard should take these factors into account.)

Of course, Sherman's correlation factor still cannot account for occupant behavior or perversities in the building's construction. Nor is it a substitute for tracer-gas measurements. Field measurements must also be conducted to validate the formula. Still, it puts a scientific foundation behind what was previously an empirically derived relationship. It is a modest step forward in the efficient and accurate use of the blower door.

Table 1. Height Correction Factor

Select the most appropriate value and insert in Equation 2.

Number of stories	1	1.5	2	3
Correction factor "H"	1.0	0.9	0.8	0.7

Table 2. Wind Shielding Correction Factor

Select the most appropriate value and insert in Equation 2.

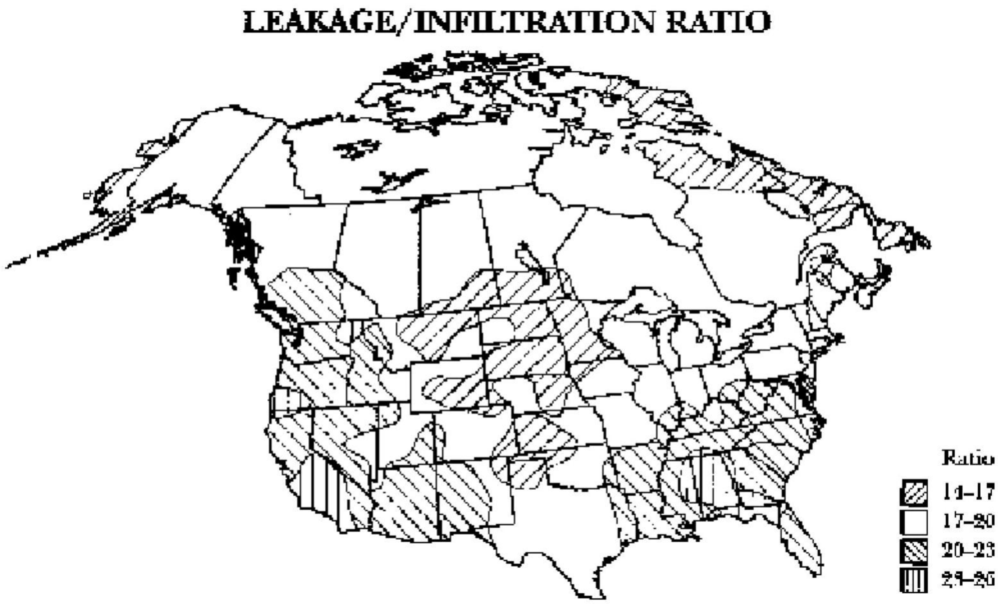
Extent of shielding	well-shielded	normal	exposed
Correction factor "S"	1.2	1.0	0.9

Table 3. Leakiness Correction Factor

Select the most appropriate value and insert in Equation 2.

Type of holes	small cracks (tight)	normal	large holes (loose)
Correction factor "L"	1.4	1.0	0.7

Figure 1: LEAKAGE/INFILTRATION RATIO



Climate correction factor, "C," for calculating average infiltration rates in North America. Note that the climate correction factor depends on both average temperatures and windiness. It also includes possible air infiltration during the cooling season. For these reasons, locations in greatly dissimilar climates, such as Texas and Vermont, can have equal factors. Select the value nearest to the house's location and insert it in Equation 2. This map is based on data from 250 weather stations.

Appendix F Calculating a Design Air Infiltration Rate

The following procedure can be used to calculate a design air infiltration rate for a house from a single or multi-point blower door airtightness test. Calculated design air infiltration rates can be used in ACCA Manual J load calculations in lieu of the estimation procedures listed in Manual J. The calculation procedure presented below is based on the Lawrence Berkeley Laboratory (LBL) infiltration model. More information on this procedure can be found in the 1997 ASHRAE Fundamentals Handbook, Section 25.34.

Note: This calculation procedure is contained in the TECTITE test analysis software.

- Determine the 4 Pascal Effective Leakage Area (ELA) of the house in square inches from the Blower Door test data. This can be done in 2 ways:

  1. Perform a multi-point Blower Door test of the house and determine the ELA using the TECTITE software, or

  2. Perform a single-point 50 Pa Blower Door test to determine house CFM50. Multiply CFM50 by 0.055 to estimate the ELA of the house in square inches. This procedure assumes the "House Leakage Curve" has a slope (or "N" value) of 0.65. Research has shown that N = 0.65 is a reasonable assumption for a large sample of houses.

- Determine the ***Stack Coefficient (A)*** and the ***Wind Coefficient (B)*** for the house from the Tables below:

Stack Coefficient (A)

House Height (Stories)		
One	Two	Three
0.0156	0.0313	0.0471

Wind Coefficient (B)

Shielding Class	House Height (Stories)		
	One	Two	Three
1	0.0119	0.0157	0.0184
2	0.0092	0.0121	0.0143
3	0.0065	0.0086	0.0101
4	0.0039	0.0051	0.0060
5	0.0012	0.0016	0.0018

Shielding Class Description

1. No obstructions or local shielding.
2. Light local shielding, few obstructions, a few trees or small shed.
3. Moderate local shielding; some obstructions within two house heights, thick hedge, solid fence or one neighboring house.
4. Heavy shielding; obstructions around most of perimeter, building or trees within 30 feet in most directions; typical suburban shielding.
5. Very heavy shielding; large obstructions surrounding perimeter within two house heights; typical downtown shielding.

- Determine the air flow rate due to infiltration from the following equation:

$$Q = L \times ((A \times T) + (B \times V^2))^{1/2}$$

where:

Q = airflow rate in cubic feet per minute (CFM).
L = Effective Leakage Area (ELA) in square inches.
A = Stack Coefficient.
T = Design indoor-outdoor temperature difference (F).
B = Wind Coefficient.
V = Design wind speed (MPH - measured at a local weather station).

Frequency data for mean hourly wind speeds within the United States can be found in a summarized printed pamphlet from the National Climatic Center in Asheville, North Carolina, and from the Atmospheric Environment Service in Downsview, Ontario for Canadian sites.

- Convert airflow rate in CFM to Air Changes per Hour (ACH).

ACH = (Q x 60) / Volume of House in Cubic Feet

Example Calculation

Estimate the winter-time design infiltration rate for a 2 story, 30,000 cubic foot house in Minneapolis with suburban wind shielding. Use a design wind speed of 20 MPH and a design temperature difference of 82 degrees F. A single-point Blower Door test of the house measured an airtightness rate of 2,350 CFM50.

Estimated ELA in square inches = 2,350 x 0.055 = 129.25

$$Q = 129.25 \times ((0.0313 \times 82) + (0.0051 \times 20^2))^{1/2}$$

= 277.4 CFM

ACH = (277.4 x 60) / 30,000 = 0.55 ACH

ATTACHMENT FOUR

Minneapolis Duct Blaster ®

Operation Manual

(Series B Systems)

The Energy Conservatory
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ATTACHMENT FOUR

ATTACHMENT FOUR

Manual Edition: July 2014

ENERGY CONSERVATORY WARRANTY

EXPRESS LIMITED WARRANTY:

Seller warrants that this product, under normal use and service as described in the operator's manual, shall be free from defects in workmanship and material for a period of 24 months, or such shorter length of time as may be specified in the operator's manual, from the date of shipment to the Customer.

LIMITATION OF WARRANTY AND LIABILITY:

This limited warranty set forth above is subject to the following exclusions:

a) With respect to any repair services rendered, Seller warrants that the parts repaired or replaced will be free from defects in workmanship and material, under normal use, for a period of 90 days from the date of shipment to the Purchaser.

b) Seller does not provide any warranty on finished goods manufactured by others. Only the original manufacturer's warranty applies.

c) Unless specifically authorized in a separate writing, Seller makes no warranty with respect to, and shall have no liability in connection with, any goods which are incorporated into other products or equipment by the Purchaser.

d) All products returned under warranty shall be at the Purchaser's risk of loss. The Purchaser is responsible for all shipping charges to return the product to The Energy Conservatory. The Energy Conservatory will be responsible for return standard ground shipping charges. The Customer may request and pay for the added cost of expedited return shipping.

The foregoing warranty is in lieu of all other warranties and is subject to the conditions and limitations stated herein. No other express or implied warranty IS PROVIDED, AND THE SELLER DISCLAIMS ANY IMPLIED WARRANTY OF FITNESS for particular purpose or merchantability.

The exclusive remedy of the purchaser FOR ANY BREACH OF WARRANTY shall be the return of the product to the factory or designated location for repair or replacement, or, at the option of The Energy Conservatory, refund of the purchase price.

The Energy Conservatory's maximum liability for any and all losses, injuries or damages (regardless of whether such claims are based on contract, negligence, strict liability or other tort) shall be the purchase price paid for the products. In no event shall the Seller be liable for any special, incidental or consequential damages. The Energy Conservatory shall not be responsible for installation, dismantling, reassembly or reinstallation costs or charges. No action, regardless of form, may be brought against the Seller more than one year after the cause of action has accrued.

The Customer is deemed to have accepted the terms of this Limitation of Warranty and Liability, which contains the complete and exclusive limited warranty of the Seller. This Limitation of Warranty and Liability may not be amended or modified, nor may any of its terms be waived except by a writing signed by an authorized representative of the Seller.

TO ARRANGE A REPAIR: Please call The Energy Conservatory at 612-827-1117 before sending any product back for repair or to inquire about warranty coverage. All products returned for repair should include the reason for repair, a return shipping address, name and phone number of a contact person concerning this repair, and the purchase date of the equipment.

ATTACHMENT FOUR

ATTACHMENT FOUR

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ATTACHMENT FOUR

Safety Information

Equipment Safety Instructions ⚠

1. The Duct Blaster® fan should only be connected to a properly installed and tested power supply. In case of emergencies, disconnect the power cord from the AC power mains outlet. During installation, use the nearest readily accessible power outlet and keep all objects away from interfering with access to the outlet.
2. The Duct Blaster fan is a very powerful and potentially dangerous piece of equipment if not used and maintained properly. Carefully examine the fan before each use. If the fan housing, fan guards, blade, controller or cords become damaged, do not operate the fan until repairs have been made. Repairs should only be made by qualified repair personnel.
3. Disconnect the power plug from the Duct Blaster fan receptacle before making any adjustments to the fan motor, blades or electrical components.
4. Keep people and pets away from the Duct Blaster fan when it is operating.
5. Do not operate the Duct Blaster fan unattended. The operator should wear hearing protection when in close proximity to the fan operating at high speed.
6. Do not use ungrounded outlets or adapter plugs. Never remove or modify the grounding prong.
7. Before connecting the speed controller to the fan, be sure the toggle switch of the controller is at zero and that the control knob is turned completely to the left (counterclockwise).
8. Do not operate the Duct Blaster fan if the motor, controller or any of the electrical connections are wet. Recommended for indoor use only.
9. The Duct Blaster fan motor is <u>not</u> a continuous duty motor and should <u>not</u> be run for extended periods of time (more than 2 hours at one time).
10. If using a theatrical fogger with the Duct Blaster system, inject the fog stream toward the edge of the fan housing and not directly into the Duct Blaster fan motor. In addition, clean off any theatrical fog residue from the Duct Blaster fan motor and fan housing following the test procedure. Use only non-corrosive fog.
11. Be sure to remove all temporary register seals after completing the test procedure.
12. When making repairs to the duct system with mastic or other curing sealants, allow the sealant to properly cure before conducting a duct leakage test to determine the effectiveness of your sealing efforts. Refer to sealant installation instructions for proper curing times.
13. Adjust all mechanical equipment (including the air handler fan) so that it does not turn on during the test.
14. Be sure you have returned the mechanical equipment controls back to their original position before leaving the building.
15. Sealing leaks in a duct system should always be part of a larger total system diagnostic procedure which includes examining total system air flow, system charge, airflow balancing and operation of vented combustion appliances. In addition, sealing air leaks (including duct leaks) in existing buildings can reduce the ventilation rate in those buildings. Existing ventilation rates and sources of indoor air pollutants should be considered by technicians before large changes in ventilation rates are undertaken. Because of these complicated systemic interactions between air sealing activities and occupant health and safety issues, it is highly recommended that technicians familiarize themselves with the Pressure Balancing/System Performance and Combustion Safety test procedures listed in Chapters 14 and 15 before attempting to seal leaks in a duct system.
16. Equipment safety measures may be compromised if the Duct Blaster fan is used in a manner other than recommended in this document and the system operation manual.

Chapter 1 Introduction to the Minneapolis Duct Blaster®

Air leakage in forced air duct systems is now recognized as a major source of energy waste in both new and existing houses and commercial buildings. Research conducted by the Florida Solar Energy Center (FSEC), Advanced Energy Corporation (AEC), Proctor Engineering, Ecotope and other nationally recognized research organizations has shown that testing and sealing leaky distribution systems is one of the most cost-effective energy improvements available in many houses and light commercial buildings

The Minneapolis Duct Blaster® is a calibrated air flow measurement system designed to test and document the airtightness of forced air duct systems. Airtightness measurements of duct systems are used for a variety of purposes including:

- Documenting and certifying compliance with building code or other construction standards requiring airtight duct systems.
- Troubleshooting comfort and performance complaints from building owners.
- Measuring and documenting the effectiveness of duct sealing activities.
- Estimating annual HVAC system losses from duct leakage.

This manual describes how to measure duct airtightness using the Minneapolis Duct Blaster. Duct airtightness is determined by measuring the leakage rate of the duct system when it is subjected to a uniform test pressure by the Duct Blaster fan. Duct airtightness test results are typically expressed in terms of cubic feet per minute (cfm) of leakage at a corresponding test pressure (e.g. 155 cfm at 25 Pascals). Duct airtightness test results can also be expressed in terms of leakage areas (e.g. square inches of hole) or normalized leakage rates (e.g. measured duct leakage rate as a percent of total system air flow).

A duct airtightness test is performed by first connecting the Duct Blaster system to the ductwork at either a central return grille or at the air handler cabinet. After temporarily sealing off all intentional openings in the duct system (e.g. supply and return registers, and combustion or ventilation air inlets which are connected to the duct system), the Duct Blaster fan is used to pressurize or depressurize the entire duct system to a standard test pressure. For residential duct systems, 25 Pascals (0.10 inches w.c.) is the most commonly used test pressure. This test pressure has been adopted by most duct testing programs because research has shown that 25 Pascals represents a typical operating pressure in many residential systems. The air flow needed from the Duct Blaster fan to generate the test pressure in the duct system is the measured leakage rate. Both the duct system pressure and the Duct Blaster fan air flow are measured by a calibrated digital pressure gauge.

In addition to measuring duct airtightness, the Minneapolis Duct Blaster can be used as a powered flow hood to accurately measure total air flow through the air handler, supply and return registers, exhaust fans and other air flow devices. The Duct Blaster can also be used as a small Blower Door to test the airtightness of small or tightly built houses.

Note: The leakage rate of a duct system determined using the airtightness test procedures listed in this manual may differ from the leakage rates occurring in the duct system under actual operating conditions. When conducting an airtightness test, all leaks in the ductwork are subjected to approximately the same pressure (i.e. the test pressure). Under actual operating conditions, pressures within the duct system vary considerably with the highest pressure present near the air handler, and the lowest pressures present near the registers. Researchers are working on developing additional test procedures which will provide duct leakage measurements under actual operating conditions.

Chapter 2 Duct Leakage Basics

2.1 Why Is Duct Leakage Important?

Studies indicate that duct leakage can account for as much as 25% of total house energy loss, and in many cases has a greater impact on energy use than air infiltration through the building shell. In many light commercial buildings, duct leakage is often the single largest cause of performance and comfort problems.
Here are just a few of the problems resulting from duct leakage:

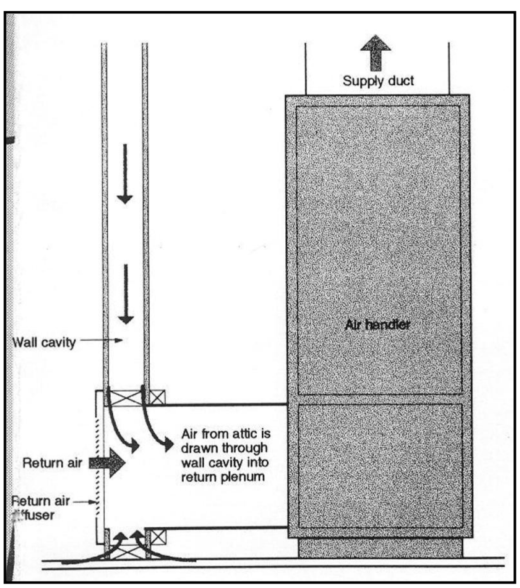
- Leaks in the supply ductwork cause expensive conditioned air to be dumped directly outside or in the attic or crawlspace rather than delivered to the building.
- Leaks in the return ductwork pull unconditioned air directly into the HVAC system reducing both efficiency and capacity. For example, if 10 percent of the return air for an air conditioning system is pulled from a hot attic, system efficiency and capacity are often reduced by as much as 30 percent.
- In humid climates, moist air being drawn into return leaks can overwhelm the dehumidification capacity of air conditioning system causing buildings to feel clammy even when the system is operating.
- Duct leakage greatly increases the use of electric strip heaters in heat pumps during the heating season.
- Leaks in return ductwork draw air into the building from crawlspaces, garages and attics bringing with it dust, mold spores, insulation fibers and other contaminants.

2.2 Where Does Duct Leakage Occur?

Because the air leaking from ductwork is invisible, most duct leaks go unnoticed by homeowners and HVAC contractors. In addition, ducts are often installed in difficult to reach spots like attics and crawlspaces, or are "buried" inside building cavities making them even more difficult to find. And the hard to find leaks are usually the most important leaks to fix, because they are connected to a hot attic or humid crawlspace.

Common Duct Leakage Problems

Return Leak Through Wall Cavity



Supply Leak at Take-Off Connection

Duct leaks can be caused by a variety of installation and equipment failures including:

- Poorly fitting joints and seams in the ductwork.
- Disconnected or partially disconnected boot connections.
- Holes in duct runs.
- Use of improperly sealed building cavities for supply or return ducts.
- "Platform" return plenums which are connected to unsealed building cavities.
- Poor connections between room registers and register boots.
- Poorly fitting air handler doors, filter doors and air handler cabinets.
- Failed taped joints.

The impact on a particular building will depend on the size of the duct leak, the location of the duct leak and whether or not the leak is connected to the outside.

2.3 How Much Can Energy Bills Be Reduced By Sealing Duct Leaks?

Numerous studies conducted by nationally recognized research organizations has shown that testing and sealing leaky distribution systems is one of the most cost-effective energy improvements available in many houses. A summary of 19 separate duct leakage studies indicates that the average annual energy savings potential in a typical home is around 17 percent.[1]

A 1991 study in Florida found:[2]

- Air conditioner use was decreased by an average of 17.2% in a sample of 46 houses where comprehensive duct leakage diagnostics and sealing were performed.
- These houses saved an average of $110 per year on cooling bills at a cost of approximately $200 for repairs.

Duct leaks also waste energy in heating climates. A study of 18 houses in Arkansas showed that a duct leakage repair service saved 21.8% on heating bills by eliminating three-quarters of the duct leakage in the study houses.[3] In addition to the energy savings, duct leakage repair improves homeowner comfort and reduces callbacks by allowing the HVAC system to work as designed.

2.4 Duct Leakage to the Outside

Duct leakage to the outside has the largest impact on HVAC system performance. Duct leakage to the outside commonly results from leaky ductwork running through unconditioned zones (attics, crawlspaces or garages). Most of the duct leakage research studies referenced in this manual have been performed on houses which contain significant portions of the duct system in unconditioned zones. However, significant leakage to the outside can also occur when all ductwork is located within the building envelope. In these cases, leaky ducts

1 Neme, Chris et. al. 1999, "Energy Savings Potential From Addressing Residential Air Conditioner and Heat Pump Installation Problems".

2 Cummings, James et. al. 1991, "Investigation of Air Distribution System Leakage and its Impacts in Central Florida Homes".

3 Davis, Bruce 1991, "The Impact of Air Distribution System Leakage on Heating Energy Consumption in Arkansas Homes".

passing through wall or floor cavities (or the cavities themselves may be used as supply or return ducts) create a pressure differential between the cavity containing the ductwork and other building cavities indirectly connected to the outside. Air can be forced through these leaks whenever the air handler fan is operating.

2.5 Duct Leakage to the Inside

Much less is known about the energy and system efficiency impacts of duct leakage inside the house. A study of new houses in Minnesota has shown that the duct systems are very leaky, but that very little of that leakage was connected directly or indirectly to the outside.[4] One of the primary causes of duct leakage in Minnesota houses was found to be very leaky basement return systems which use panned under floor joists as return ductwork. Because most of the duct leakage was occurring within the conditioned space of the house, the energy efficiency penalty from this leakage is thought to be much less significant. **Note**: In Minnesota, basements are typically considered heated space.

However, the Minnesota study did find that leaky return systems can cause the basement (where the furnace and water heater are typically located) to depressurize to the point where combustion products from the water heater or furnace would spill into the house. Negative pressures from return leaks can also contribute to increased moisture and radon entry into houses. In addition, summertime comfort problems were often experienced due to supply duct leaks in the basement delivering cool air to the basement even though the basements have little or no cooling loads. These problems all suggest that controlling duct leakage to the inside may, in some cases, be just as important as leakage to the outside.

4 Nelson, Gary et. al. 1993, "Measured Duct Leakage, Mechanical System Induced Pressures and Infiltration in Eight Randomly Selected New Minnesota Houses".

Chapter 3 System Components

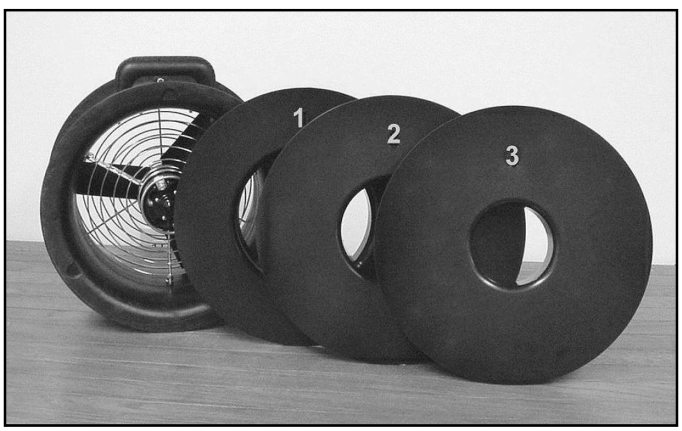
The Series B Minneapolis Duct Blaster System consists of the following components:

- Series B Duct Blaster Fan
- Test Instrumentation (DG-700 Digital Pressure Gauge) and Fan Speed Controller
- Flexible Extension Duct
- Duct Blaster Carrying Case

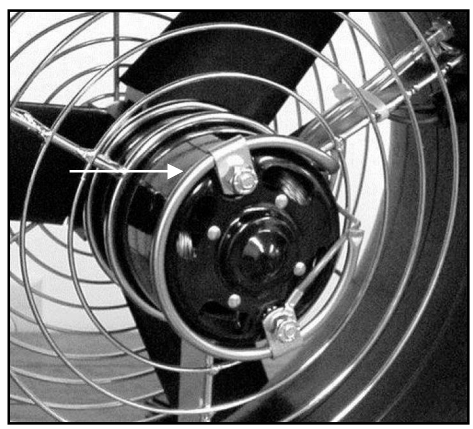
3.1 Duct Blaster Fan

The Series B Duct Blaster fan consists of a molded fan housing with a variable speed motor. The Duct Blaster fan will move up to 1,500 cubic feet of air per minute (CFM) at zero back pressure (i.e. free air), and approximately 1,350 CFM against 50 Pascals (0.2 inches w.c.) of back pressure. With the flexible extension duct attached, the fan will move 1,250 CFM (free air) and 1,000 CFM against 50 Pascals of back pressure. Fan flow is determined by measuring the slight vacuum created by the air flowing over the flow sensor attached to the end of the motor. The Duct Blaster fan can accurately measure flows between 2.4 and 1,500 CFM using a series of four calibrated Flow Rings which are attached to the fan inlet (see **Appendix A** for issues affecting fan calibration and accuracy). The Duct Blaster fan motor is not reversible, however the fan can be installed to either pressurize or depressurize the duct system.

Duct Blaster Fan with 3 Standard Flow Rings



Flow Sensor on Duct Blaster Fan



The Duct Blaster fan meets the flow calibration specifications of the following standards: CGSB 149.10-M86, ASTM E779, ASTM E1827, ASHRAE 152, EN 13829, ATTMA TS1, NFPA 2001, RESNET and USACE. The Minneapolis Duct Blaster has a fan flow accuracy of +/- 3 percent when using the DG-700 Digital Pressure Gauge. These calibration specifications include inaccuracies due to production tolerances of the fan and calibration error of the gauge.

3.1.a Determining Fan Flow and Using the Flow Rings:

Fan pressure readings from the flow sensor are easily converted to fan flow readings by reading flow directly from the digital pressure gauge, using a Flow Conversion Table (see Appendix B), or through use of the TEC software programs and apps. The Duct Blaster fan has 5 different flow capacity ranges depending on the configuration of Flow Rings on the fan inlet. Table 1 below shows the approximate flow range of the Duct Blaster fan under each of the 5 Flow Ring configurations. The greatest accuracy in fan flow readings will always be achieved by installing the Flow Ring with the smallest opening area, while still providing the necessary fan flow to pressurize the duct system to the test pressure. **Note:** When taking Duct Blaster measurements, stand at least 12 inches from the side of the fan inlet. Standing directly in front of the fan may affect the flow readings and result in erroneous measurements. Also refer to Appendix A, Section A.2.c for information on the maximum allowable backpressures to ensure the flow calibration accuracy of the fan.

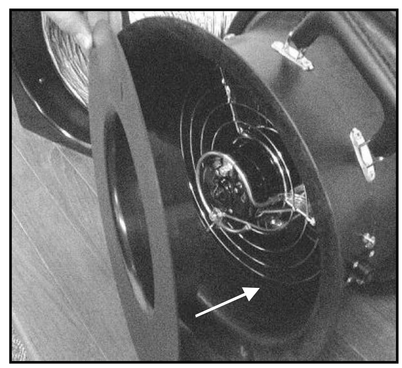
Table 1: Fan Flow Ranges

Flow Ring Configuration	Flow Range (CFM)	Minimum Fan Pressure (Pa)
Open (no Flow Ring) *	1,500 – 600	25 Pa
Ring 1	800 – 225	25 Pa
Ring 2	300 – 90	25 Pa
Ring 3	125 – 10	3 Pa
Ring 4 (Optional)	25 – 2.4	5 Pa

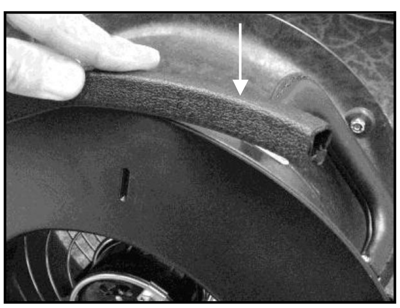
* The "Open" configuration can only be used when using the Duct Blaster fan to pressurize the duct system, not when depressurizing the duct system (see Chapters 9-11 for more information on depressurization testing).

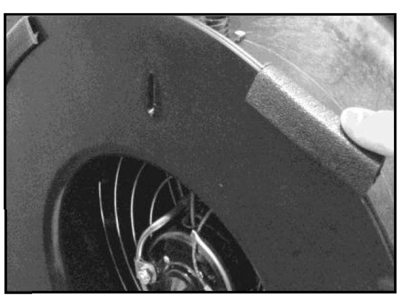
Flow Ring Installation:

To install any of the Flow Rings, place the ring against the inlet of the fan so that the outer edges of the ring roughly line up with the outer edge of the inlet flange on the fan. Be sure the nozzle located in the middle of the ring is pointing inward toward the fan motor.



Secure the outer edge of the Flow Ring and the fan flange together by pushing the black connecting trim over both edges all the way around the fan flange.

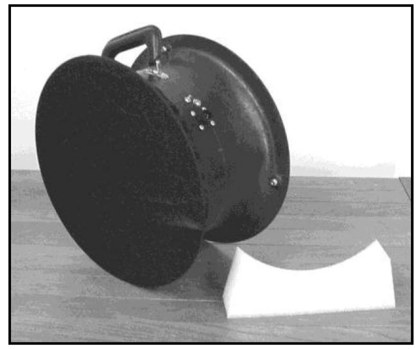




Note: You can also attach the Flow Rings using the four 2 inch long pieces of connecting trim found in the plastic parts bag stored in the accessory case.

TEC
The Energy Conservatory

In addition to the 3 Flow Rings, the Duct Blaster fan comes with a nylon fan cap to cover the inlet of fan, and a foam foot which can be used to stabilize the fan housing during fan operation.



Note: Installation and use of optional Ring 4 is discussed in Appendix F.

3.2 Test Instrumentation (DG-700 Pressure and Fan Flow Gauge)

The DG-700 is a differential pressure gauge which measures the pressure difference between either of its ***Input*** pressure taps and its corresponding bottom ***Reference*** pressure tap. The DG-700 gauge has two separate measurement channels which allows you to simultaneously monitor and display the duct system pressure and the flow through the Duct Blaster fan during the duct airtightness test. The digital gauge is shipped in a separate padded case which is stored in the Duct Blaster accessory case. Also included is a black mounting board to which the digital gauge can be attached using the Velcro strips found on the back of the gauge.

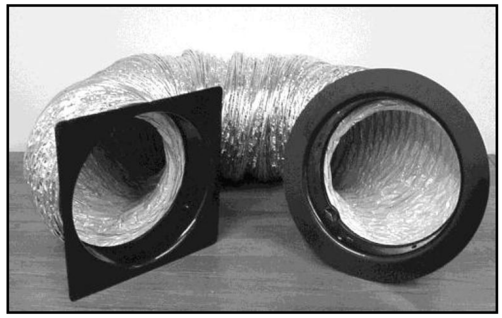
DG-700 Pressure Gauge

3.3 Fan Speed Controller

The Duct Blaster fan is controlled by a variable fan speed controller. Fan speed can be manually adjusted using the adjustment knob on the face of the speed controller. The speed controller is clipped onto the black mounting board supplied with your Duct Blaster system. The Duct Blaster fan controller can be removed from the mounting board by sliding the controller clip off the board.

Newer Duct Blaster fan speed controllers also contain a fan control communication jack on the side of the device which can be used for cruise control or computerized fan control.

3.4 Flexible Extension Duct



The flexible extension duct consists of a 12 foot long section of 10" round flexible duct with one square and one round black plastic transition piece attached at either end. The flexible extension duct is used to connect the Duct Blaster fan to the duct system. The round transition piece connects to either the fan exhaust flange (pressurization testing) or the fan inlet flange (depressurization testing), while the square transition piece can be attached directly to a large return register, or installed at the air handler cabinet. The extension duct allows the Duct Blaster fan air flow to be easily directed to the duct system while leaving the fan on the floor or on a table.

The flexible extension duct is connected to the fan flange using black connecting trim. To connect the round transition piece to the Duct Blaster fan, first place the round transition piece against the fan flange so that the outer edges of the transition piece line up with the outer edge of the fan flange. Secure the outer edge of the transition piece and the fan flange together by pushing the black connecting trim over both edges all the way around the fan (similar to how Flow Rings are attached to the fan).

3.5 The Flow Conditioner

<u>The flow conditioner is used whenever the flexible extension duct is connected to the inlet side (i.e. the side with the flow sensor) of the Duct Blaster fan.</u>

The two primary applications which require use of the flow conditioner are:

- conducting a duct leakage test in the <u>**depressurization**</u> mode (i.e. pulling air out of the duct system (see Chapter 9).
- using the Duct Blaster as a powered flow hood to measure flows through <u>supply</u> registers (see Chapter 13).

The flow conditioner consists of a round one-inch wide perforated foam disk which is stored in the Duct Blaster accessory case. The flow conditioner is inserted into the round transition piece (part of the flexible extension duct) before the round transition piece is connected to the inlet flange of the Duct Blaster fan. The flow conditioner conditions the air flow upstream of the fan flow sensor to provide an accurate fan flow reading when the flex duct is connected to the inlet side of the fan.

To install the flow conditioner, first line up the crescent shaped key slot on the outside of the foam disk with the key indentation inside the round transition piece. Insert the flow conditioner all the way into the round transition piece until it is pushed beyond the three small round indentations located on the inside of the transition piece, and up tightly against the ridge stop. When fully engaged, the three round indentations will hold the flow conditioner in place during fan operation.

3.6 Duct Blaster Carrying Case

The Duct Blaster system is stored in the lightweight fabric carrying case. A shoulder strap on the carrying case provides an easy method for carrying the system to and from testing locations. Inside the carrying case you will also find the Operation Manual, laminated flow table, extra tubing and a static pressure probe.

3.7 TECBLAST Duct Airtightness Test Software (Optional)

TECBLAST is a duct airtightness test analysis program for Windows computers. The TECBLAST program can be used to calculate and display test results from a Duct Blaster airtightness test. In addition, TECBLAST's choice of professional looking reports makes it simple to present the results of the test to your customers.

3.7.a TECBLAST Features:

- Designed specifically for use with Minneapolis Duct Blaster Systems.
- Easy entry of all test data.
- Calculation and display of test results including leakage rate in cubic feet per minute (CFM), leakage area in square inches, leakage as a percent of system air flow, and estimated annual system efficiency loss from the measured leakage rate.
- Built-in report generator and file storage features.
- TECBLAST lets you print your company logo directly on the reports.
- On-line Help.
- Compatible with all Windows computers.

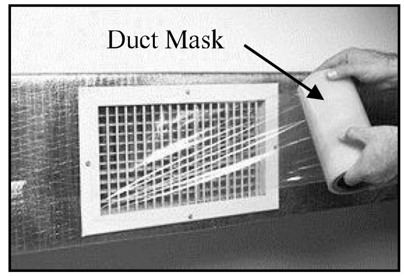
Note: A 30 day demonstration copy of TECBLAST is available from The Energy Conservatory's website at *www.energyconservatory.com*.

Chapter 4 Prepare the Duct System and Building for Testing

In order to conduct a duct airtightness test, you will need to prepare both the duct system and building. This typically includes temporarily sealing off intentional openings in the duct system (e.g. registers), and adjusting HVAC controls. The following setup procedures are recommended by The Energy Conservatory. If you are conducting the airtightness test according to a specific program guideline, the program guidelines may require you to set up the duct system and building differently than described below.

- Adjust the HVAC system controls so that the air handler fan does not turn on during the test.

- Temporarily seal off all supply and return registers (except any central return register being used to connect the Duct Blaster system to the duct system - see Chapter 5). A quick and easy way to temporarily seal registers is to use ***Duct Mask™*** temporary register sealing material. A sample roll of ***Duct Mask*** is provided with your Duct Blaster system and additional rolls can be purchased from The Energy Conservatory. It is also possible to tape directly over the register with high quality painter's masking tape and masking paper. Most local hardware stores carry both painter's masking tape and hand-held dispensers of masking paper.



  Note: Be sure to read the instructions provided with the ***Duct Mask*** before applying to registers. Importantly, it is best not to extend ***Duct Mask*** beyond the register because of the risk of damaging paint or wall paper. While in most applications it would be ideal to seal any leakage between the register and the wall (or ceiling, floor), there is often too great a risk of damage. Also, ***Duct Mask*** should not be applied to registers that have been painted (i.e. not the original factory finish).

- Temporarily seal off all combustion air and ventilation air inlets which are directly connected to the duct system. This is usually done by sealing the inlet opening on the outside of the building, but can also be done by temporarily removing the inlet from the ductwork and taping off the opening.

- Turn off all exhaust fans, vented dryers, and room air conditioners.

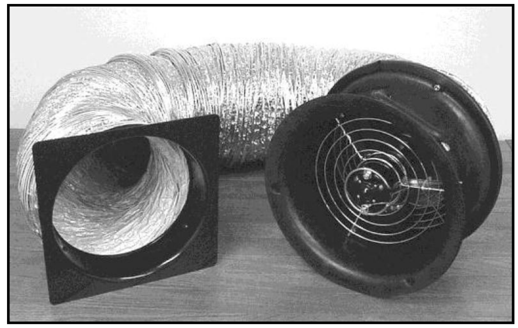
- Turn off all vented combustion appliances if there is a possibility that the space containing the appliance will be depressurized during the test procedure.

- Remove all filters from the duct system and air handler cabinet. If the Duct Blaster is installed at a central return grille, also remove the filter from that grille.

- If ducts run through unconditioned spaces such as attics, garages or crawlspaces, open vents, access panels, or doors between those spaces and the outside to eliminate pressure changes during the test procedure. This should also be done if the Duct Blaster fan will be installed in an unconditioned space (e.g. connected to an air handler located in a garage or crawlspace). Pressure changes during the test in spaces containing ductwork or the Duct Blaster fan can bias the test results.

Chapter 5 Setting Up the Duct Blaster for Pressurization Testing

The following instructions are for conducting a duct airtightness **pressurization** test. Pressurization testing involves blowing air into the duct system with the Duct Blaster fan and measuring the duct system's leakage rate when it is subjected to a uniform test pressure. When conducting a pressurization test of the duct system, the **inlet** side of the Duct Blaster fan will be open to the room where the Duct Blaster is installed, and the exhaust side of the fan will be connected to the duct system, typically using the flexible extension duct. In this configuration, the fan housing rests on the floor or on a table while the square transition piece is connected to a central return grille, or the air handler cabinet access panel.



Note: During pressurization testing, the flow conditioner should **not** be installed in the round transition piece.

Information on how to conduct a duct airtightness **depressurization** test (i.e. pulling air out of the duct system) is discussed in Chapters 9 - 11. Both pressurization and depressurization tests typically provide similar test results. Use of one procedure over the other is primarily a matter of personal choice. If you are conducting the leakage test according to a specific program guideline, the program guidelines may specify which procedure to use.

5.1 Where to Install the Duct Blaster System?

For most duct testing applications, the Duct Blaster System will be connected to the duct system at a large central return, or at the air handler cabinet. In single, double or triple returned systems, the largest and closest return to the air handler is often the best choice. Large return grilles typically make a good choice because they provide the least resistance to air flow from the Duct Blaster fan. In addition, with this type of duct system, it is common to find the air handler in a location which is difficult to access such as an attic or crawlspace.

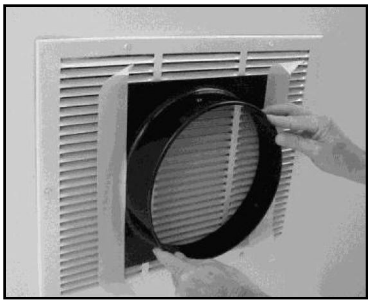
In multi-return systems (a return in every room), installing the Duct Blaster at the air handler cabinet is often the best choice. Return ductwork in multi-return systems is typically small in size, and as a result, can provide significant restriction to air flow. This restriction in air flow can reduce the maximum operating capacity of the Duct Blaster fan, can create large backpressures which can possibly degrade the fan calibration and can contribute to unequal pressures throughout the duct system. In addition, air handlers in these type of houses are commonly found in basements or air handler closets making them easy to access.

5.2 Connecting the Duct Blaster to the Duct System

The Duct Blaster System can be connected to the duct system at either a central return, or at the air handler cabinet (i.e. blower compartment access panel).

5.2.a Installing at a Central Return:

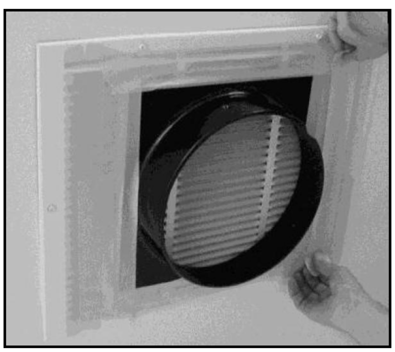
- **Option 1: Using the Flexible Extension Duct**

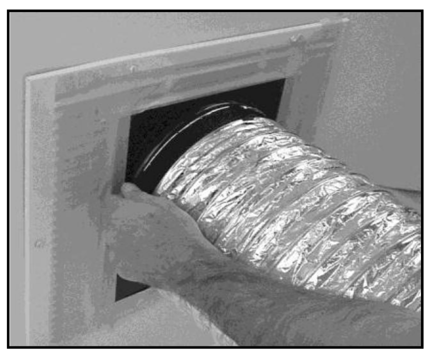


The first step is to connect the square transition piece (from the flexible extension duct) to the return grille. The square transition piece is usually installed with the flex duct disconnected. **Note:** Be sure the filter has been removed from the grille filter rack before attaching the transition piece).

Place the square transition piece up against the middle of the grille and seal the transition piece to the grille with tape. We recommend using high quality painter's masking tape. You may also use the two 10" bungee cords provided with your Duct Blaster to hold the transition piece in place before using tape to make a final seal.

Once the square transition piece is in place, seal off the remaining opening of the return grille with tape. Now slide the flex duct fully over the round flange of the square transition piece, and tightly secure the flex duct using the black Velcro strap attached to the end of the flex duct. Always position the Duct Blaster fan to minimize very large bends in the flex duct (e.g. over 90 degree bend), particularly where the flex duct is attached to the fan.





- **Option 2: Using the Optional Filter Grille Attachment Panel**

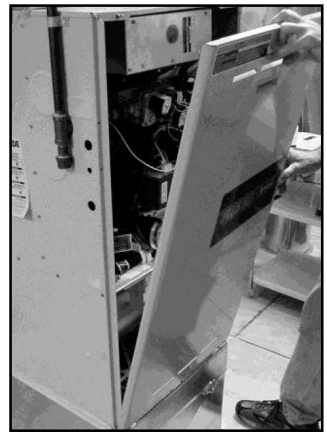
An optional 20"x20" filter grille attachment panel is available from TEC to provide for quick attachment of the Duct Blaster fan to the filter slot of a central return. To use the attachment panel, first open the filter grille door, remove the existing filter, and push the attachment panel into the open filter slot. The H-channel gasket on the edges of the attachment panel should provide an airtight seal between the panel and the filter slot, and should hold the panel in place. You may now secure the Duct Blaster fan directly to the attachment panel using the 4 clips mounted on the panel. The clips are pushed down onto the exhaust flange of the Duct Blaster fan.

Note: This attachment method is very useful if you will be using the Duct Blaster system to also measure total air handler flow (see Chapter 13) on a single return duct system, and the return ductwork is substantially airtight. In addition, this method provides greater fan flow by reducing restrictions caused by the flex duct.

5.2.b Installing at the Air Handler Cabinet:

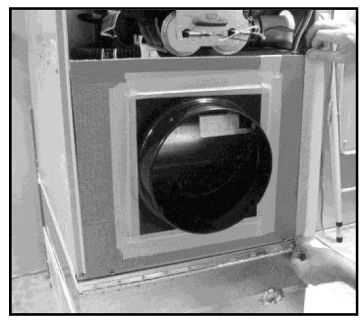
- **Option 1: Using the Flexible Extension Duct**

You will need a piece of cardboard (at least the size of the access panel), a box cutter, and masking tape.



First remove the access panel to the blower compartment. Cut a piece of cardboard approximately the same size as the blower compartment opening. Now cut a square hole in the center of the cardboard which is approximately one inch smaller than the outer flange on the square transition piece. It is helpful to pencil an outline of the transition piece onto the cardboard before cutting. Center the square transition piece over the hole in the cardboard and tape the transition piece to the cardboard using tape.

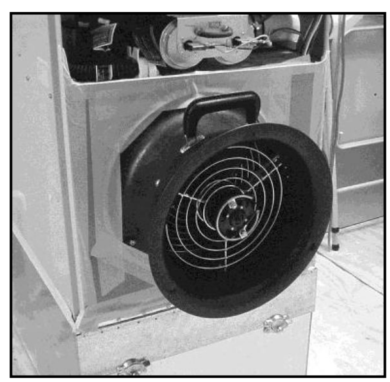
Now insert the cardboard into the access opening of the blower compartment (with the square transition piece remaining outside of the air handler cabinet). Tape the cardboard to the air handler cabinet making sure to you have made an airtight seal on all sides.



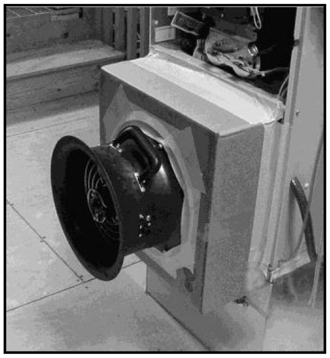
Slide the flex duct fully over the round flange of the square transition piece, and tightly secure the flex duct using the black Velcro strap attached to the flex duct. Always position the Duct Blaster fan to minimize very large bends in the flex duct (e.g. over 90 degree bend), particularly where the flex duct is attached to the fan.

- **Option 2: Connecting the Fan Without the Flexible Extension Duct**

The Duct Blaster fan can be connected directly to the air handler cabinet without the flexible extension duct attached. The easiest way to install the fan without the extension duct is to tape the exhaust flange of the fan to a piece of cardboard which has a round hole cut out which is slightly smaller than the outside diameter of the exhaust flange. The cardboard can then be sealed in place of the blower compartment access panel. The fan is light enough (7 pounds) so that masking tape will hold the fan to the cardboard without additional support. Attaching the Duct Blaster in this way provides greater fan flow by reducing restrictions caused by the flex duct.



TEC
The Energy Conservatory



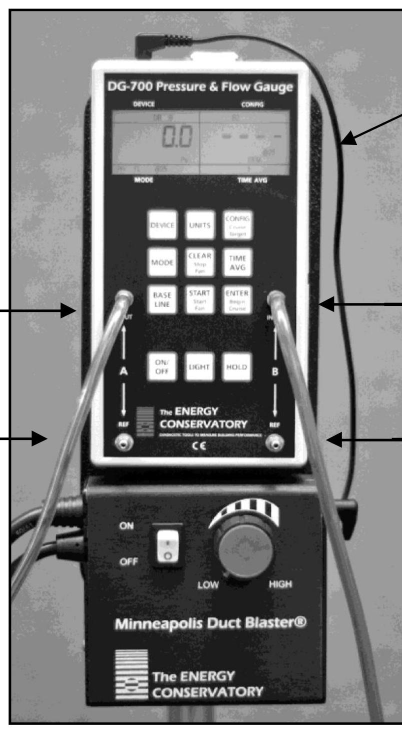
Note: If the air flow exiting from the Duct Blaster is severely obstructed by the air handler fan or other air handler components, this may significantly reduce the total flow capacity of the Duct Blaster. If this is a problem, try attaching the Duct Blaster fan to the blower compartment access opening using a small cardboard box rather than a flat piece of cardboard. This will tend to increase the Duct Blaster fan flow by providing less restriction to air flow as it enters the air handler blower compartment.

5.3 The Gauge Mounting Board

The black mounting board for the DG-700 digital pressure gauge and fan speed controller can be attached to any door or vertical surface using the C-clamp connected to the back of the board. The mounting board can also be attached to a horizontal surface by rotating the clamp 90 degrees. The gauge mounting board can also be placed on the floor near the Duct Blaster fan.

5.4 Gauge Tubing Connections for Pressurization Testing

The Duct Blaster comes with 2 pieces of color coded tubing - a 15 foot length of green tubing for measuring duct system pressure, and a 10 foot length of red tubing to measure fan pressure and flow. Connect the tubing to the DG-700 gauge as shown below:



Optional fan control cable (for Cruise Control).

Connect the **Green** (or Clear) tubing to the **Chan A Input** tap. The other end of the **Green** tubing should be connected to the duct system (see Section 5.5.a).

Connect the **Red** tubing to the **Chan B Input** tap. The other end of the **Red** tubing should be connected to the brass tap in the middle of the DB fan housing.

Connect the **Chan A Ref** tap to inside of building (if gauge is located in the building, leave this tap open).

Connect the **Chan B Ref** tap to space where the fan is installed (if fan and gauge are in the same space, leave this tap open).

5.5 Selecting a Location to Measure Duct System Pressure

During the airtightness test we will need to measure the pressure in the duct system created by the Duct Blaster fan. The duct pressure will be measured using the tubing connected to **Channel A Input** tap on the digital gauge. Choose one of the following three most common locations to measure duct pressure:

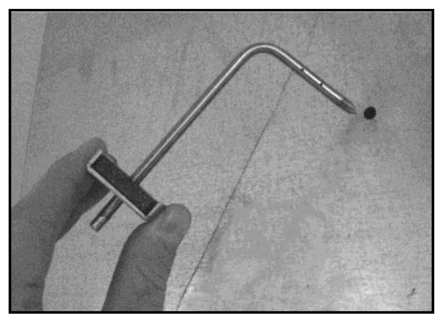
- A main supply trunkline makes a very good choice due to its location approximately midway between the Duct Blaster fan and the supply registers.
- The supply plenum can be used if the Duct Blaster fan is installed at a central return.
- A supply register can also be used.

Note: If the duct system is relatively airtight (e.g. less than 200 cfm of leakage at 25 Pascals), the pressure in the duct system will tend to be quite uniform during the test and any of the 3 locations above will provide very consistent results. If the duct system is very leaky (e.g. more than 500 cfm of leakage at 25 Pascals), there may be large pressure differences from one part of the duct system to another during the test. In this case, the choice of pressure measurement locations may effect the test results.

For example in a very leaky duct system, using the farthest supply register from the air handler will tend to result in a higher leakage rate than would occur from using a supply trunkline, the supply plenum or a register close to the air handler. In the case of very leaky systems, the operator may wish to conduct 2 separate tests (one with the pressure measurement location farthest from the air handler and one with a location close to the air handler) and average the 2 test results. For many duct testing programs, the choice of pressure measurement location is predetermined by the program guidelines.

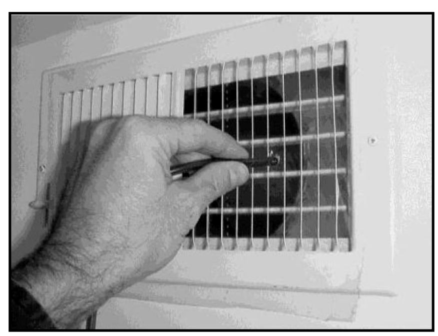
5.5.a Insert the Pressure Probe:

- **When Using a Supply Trunkline or Supply Plenum:**



Drill a small (1/4" to 3/8" OD) hole into the plenum to allow a static pressure probe to be installed (a static pressure probe is provided with the Duct Blaster system). Insert the static pressure probe into the hole and be sure the static pressure probe is pointed into the air stream that will be generated by the Duct Blaster fan. Connect the remaining end of the **Green** tubing to the static pressure probe. If you need additional tubing, connect the extra 30' of clear tubing stored in the accessory case to the **Green** tubing using one of the plastic tubing connectors.

- **When Using a Supply Register:**

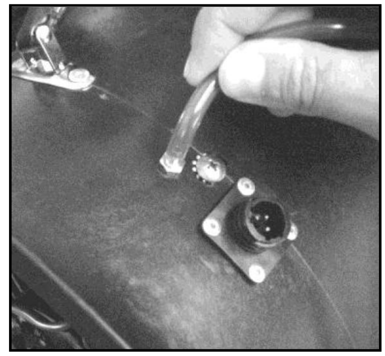


When using a supply register to measure duct pressure, insert the remaining end of the **Green** tubing through the Duct Mask or tape covering the register. When measuring duct pressure at a supply register, use of a static pressure probe is not necessary.

5.6 Tubing and Electrical Connections to the Fan

5.6.a Connect Red Tubing to the Fan:

The remaining end of the **Red** tubing should be connected to the brass pressure tap on the Duct Blaster fan housing.



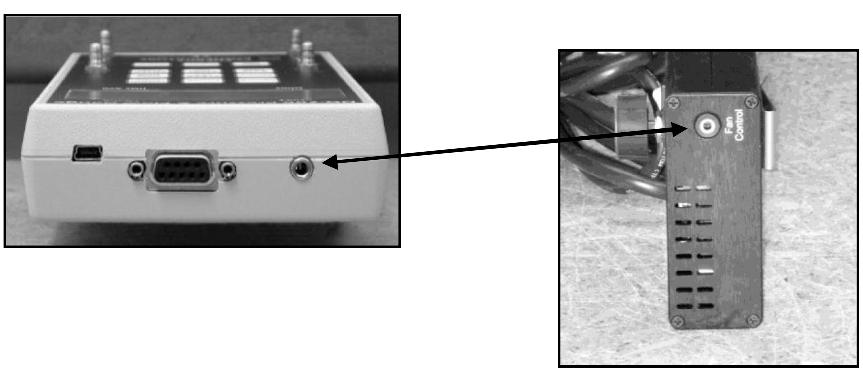
5.6.b Electrical Connections:

Connect the female plug from the fan speed controller to the male power receptacle on the fan housing. To connect the female plug, line up the plug with the three metal pins on the fan receptacle and push the plug completely onto the pins. Now secure the plug to the fan by pushing the locking ring from the plug against the fan and turning the ring clockwise until it locks in place. The remaining cord (power cord) should be plugged into a power outlet that is compatible with the voltage specifications of the fan controller and motor (be sure the fan controller knob is turned all the way counter clockwise and the power switch is turned to the "off" position before plugging into the power outlet). The standard Duct Blaster System sold in the United States is compatible with 110V AC power.

Note: The Duct Blaster fan motor is not reversible

5.7 Fan Control Cable for Cruise Control

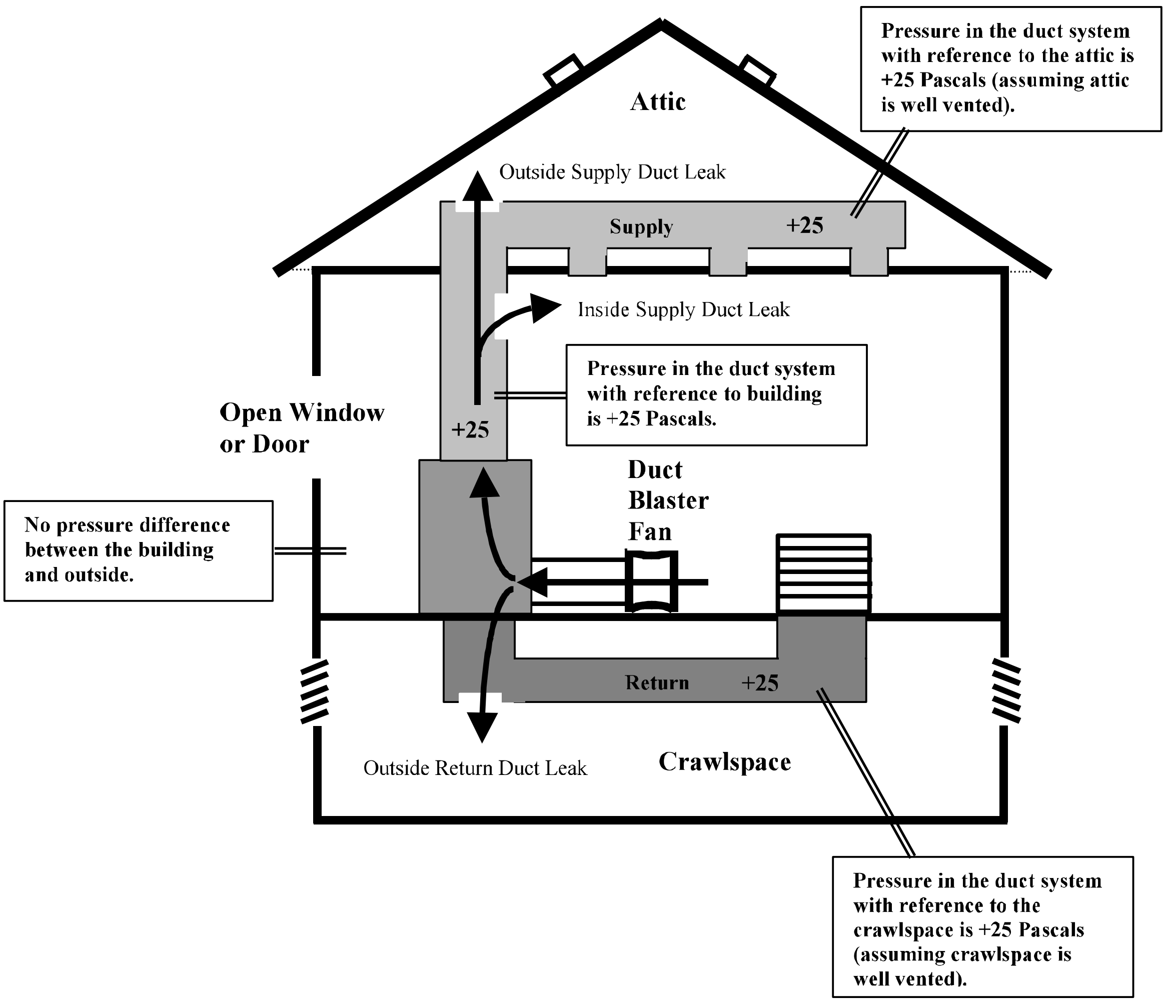
Beginning June 2011, Duct Blaster fan speed controllers contain a fan control communication jack on the side of the device which can be used along with the DG-700's Cruise Control feature to automatically control the Duct Blaster fan to maintain a constant duct pressure. To use Cruise Control, you must install a fan control cable between the fan control jack on the top of the DG-700 and the communication jack on the side of the speed controller.



Chapter 6 Conducting a Total Leakage Pressurization Test

This chapter covers the test procedures for conducting a **Total Leakage Pressurization Test**. The Total Leakage Pressurization Test is used to measure the duct leakage rate in the entire duct system (including leaks in the air handler cabinet), when the duct system is subjected to a uniform test pressure. The Total Leakage Pressurization Test measures both duct leakage to the outside of the building (e.g. leaks to attics, crawlspaces, garages and other zones that are open to the outside), and duct leakage to the inside of the building. This test procedure requires use of a Duct Blaster system only.

Figure 1: Illustration of Total Leakage Pressurization Test
(at a Test Pressure of 25 Pascals)
with Duct Blaster Fan Installed at Air Handler



<u>The air flow through the Duct Blaster fan required to pressurize the duct system to the test pressure is the measured total duct leakage rate.</u>

The following instructions assume you have set up the Duct Blaster system for a pressurization test as outlined in Chapter 5 above. Information on how to conduct a Total Leakage **<u>Depressurization</u>** Test (i.e. pulling air out of the duct system) is discussed in Chapters 9 and 10.

Note: It is possible to separately measure total supply and return duct leaks by installing a temporary barrier in either the supply or return opening to the air handler cabinet. With a temporary barrier in place, each side of the duct system can be tested independently. It is also possible to separately measure supply and return leakage before the air handler or furnace unit has been installed.

6.1 Final Preparations (Open a Door or Window to the Outside)

Open a door or window between the building and outside to prevent changes in building pressure when the Duct Blaster fan is running. We want to prevent changes in building pressures because the pressure difference across duct leaks will be different for leaks to the inside of the building compared with leaks to the outside. Changes in building pressure could be caused by:

⇒ If the Duct Blaster is installed inside the building and there are large leaks between the duct system and outside, pressurizing the duct system with building air may depressurize the building relative to outside.

⇒ If the Duct Blaster is installed in an unconditioned space (attic, garage or crawlspace air handler), pressuring the duct system with outside air may pressurize the building relative to outside.

6.2 Choosing the Test Pressure and Number of Test Readings

6.2.a Test Pressure:

For residential duct systems, we generally recommend that 25 Pascals (0.10 inches w.c.) be used as the test pressure. This pressure has been adopted by the majority of residential duct testing programs in the U.S. because 25 Pascals represents a typical operating pressure seen in many residential systems. In cases where 25 Pascals is not a representative pressure in the duct system being tested, it may be appropriate to use a different test pressure. For example, in small commercial HVAC systems which typically operate at higher duct pressures than residential systems, it may be appropriate to use a test pressure greater than 25 Pascals. In extremely leaky duct systems, such as duct systems found in many basement style houses, typical operating pressures in the duct system may be significantly less than 25 Pascals. In this case it may be appropriate to use a test pressure lower than 25 Pascals.

6.2.b Number of Test Readings:

The most common test procedure is to conduct a ***One-Point Test*** to measure duct airtightness. The ***One-Point Test*** utilizes a single measurement of Duct Blaster fan flow needed to produce the test pressure in the duct system. The ***One-Point Test*** provides a quick and simple way to measure duct leakage without the need to have a computer to analyze the test data (although a computer program like TECBLAST can still be useful to generate reports and store data).

The ***Multi-Point Test*** procedure involves testing the duct system over a range of test pressures and analyzing the data using a duct airtightness test computer program (e.g. TECBLAST). A typical ***Multi-Point Test*** of a residential duct system includes taking measurements at 5 different test pressures including 35 Pascals, 30, 25, 20 and 15 Pascals. Making multiple measurements allows some of the errors introduced by fluctuating pressures and operator error to be averaged out over several measurements, typically increasing test accuracy.

6.3 Total Leakage Test Procedures Using the DG-700

The following test procedures cover use of the DG-700 for both *One-Point Tests* and *Multi-Point Tests*. These procedures assume that a test pressure of 25 Pascals is being used.

a) Turn on the DG-700 and place it in the proper Mode:

- *DG-700: One-Point Test*

Turn on the gauge by pressing the **ON/OFF** button. Press the **MODE** button three times to put the gauge into the **PR/ FL @25** mode. In this specialized test mode, **Channel A** is used to measure duct system pressure while **Channel B** is used to display estimated total duct leakage at a test pressure of 25 Pascals (CFM25 Total). The leakage estimate shown on **Channel B** is determined by mathematically adjusting the actual air flow from the Duct Blaster fan to a test pressure of 25 Pascals, using the real-time **Channel A** duct system pressure reading and a Can't Reach Pressure (CRP) factor. CRP factors are discussed later in this Chapter.

- *DG-700: Multi-Point Test*

Turn on the gauge by pressing the **ON/OFF** button. Press the **MODE** button once to put the gauge into the **PR/ FL** mode. The **PR/ FL** mode is a multi-purpose mode used to measure a test pressure on **Channel A** while simultaneously measuring air flow from the Duct Blaster fan on **Channel B**.

b) Optional measurement of baseline duct pressure (same for both *One-Point* and *Multi-Point Tests*).

When conducting a total leakage test, we want to measure the change in duct system pressure caused by air flowing through the Duct Blaster fan. In order to measure this change accurately, we sometimes need to account for any existing pressures on the duct system caused by stack, wind and other driving forces. This existing duct system pressure is called the "baseline duct pressure".

In many cases, the baseline duct pressure will be very small or zero, and this section of the test procedure can be omitted. For example, during mild weather conditions (e.g. little wind and less than 20 degrees temperature difference between inside and outside the building), the baseline duct pressure will typically be less than 1 Pascal and omitting baseline pressure measurements will have little or no effect on the final test results.

If it is very windy or there are very large temperature differences between inside and outside, and the ducts are located in unconditioned zones (e.g. attics, crawlspaces or garages), baseline duct pressures may be greater than 1 Pascal and should be measured. The DG-700 has a built-in baseline measurement procedure which allows the user to quickly measure and record the baseline pressure on **Channel A**, and then display the baseline adjusted pressure. This feature makes it possible to "zero out" the baseline duct pressure on **Channel A**, and display the actual change in duct pressure caused by the Duct Blaster fan.

With the fan sealed off, begin a baseline duct pressure reading from **Channel A** by pressing the **BASELINE** button. The word "BASELINE" will begin to flash in the **Channel A** display indicating that the baseline feature has been initiated. Press **START** to start the baseline measurement. During a baseline measurement, **Channel A** will display a long-term average baseline pressure reading while **Channel B** is used as a timer in seconds to show the elapsed measurement time. When you are satisfied with the baseline measurement, press the **ENTER** button to accept and enter the baseline reading into the gauge. The **Channel A** display will now show an **ADJ** icon to indicate that it is displaying a baseline adjusted duct pressure value.

c) Choose a Flow Ring for the Duct Blaster fan (same for both *One-Point* and *Multi-Point Tests*).

Fan Configuration	Flow Range (cfm) for Series B DB fan
Open (no Flow Ring)	1,500 - 600
Ring 1	800 - 225
Ring 2	300 - 90
Ring 3	125 - 10

Install the Flow Ring which you think best matches the needed fan flow. Installation of Flow Rings will depend on the tightness level of the duct system being tested. For example, for relatively leaky duct systems (greater than 600 CFM25), you will want to start the test using the Open Fan configuration (i.e. no Flow Rings installed). As you test tighter duct systems, you will need to install Flow Rings 1, 2, or 3. Refer to the Table to the right for approximate flow ranges of the fan using the various Flow Rings configurations. Don't worry if you guess wrong and start the test with the incorrect Flow Ring - you can change the Fan Configuration during the test procedure.

d) Enter the selected Flow Ring into the Gauge (same for both *One-Point* and *Multi-Point Tests*).

In order for the DG-700 to properly display fan flow, you need to input the Duct Blaster fan model and selected Flow Ring into the gauge. Check, and adjust if necessary, the selected test Device (i.e. fan) and Configuration (i.e. Flow Ring) shown in the upper part of the gauge display to match the fan and Flow Ring being used in the test.

Press the **DEVICE** button to change the selected Duct Blaster fan.

Device Icon

DB A	Series A Duct Blaster fan	**DB B**	Series B Duct Blaster fan

Once the fan is selected, the configuration of the fan can be selected by pressing the **CONFIG** button. The currently selected Flow Ring configuration is shown in the Config section of the gauge display.

Config Icon

OPEN	No Flow Ring	**B2**	Ring 2
A1	Ring 1	**C3**	Ring3

Also be sure that **Channel B** is showing the proper air flow units for your test (this should typically be set to **CFM**). Units can be changed by pressing the **UNITS** button.

e) Turn on and adjust the Duct Blaster fan:

- *DG-700: One-Point Test*

If Manually Controlling Fan:

Turn on the Duct Blaster fan controller and slowly turn the fan controller knob clockwise. As the fan speed increases, the duct pressurization displayed on **Channel A** should also increase. Continue to increase the fan speed until the duct pressurization shown on **Channel A** is between 20 and 30 Pascals. Do not waste time adjusting and re-adjusting the fan speed control to achieve a test pressure of exactly 25 Pascals. As long you are using the **PR/ FL @25** mode and the test pressure displayed on **Channel A** is within 5 Pascals of the 25 Pascal target pressure, any errors introduced by estimating the leakage on **Channel B** will typically be very small (less than 1%).

If Using Cruise Control:

Turn the Duct Blaster speed controller to the “just on” position (i.e. turn the controller knob all the way down counter-clockwise and flip the on/off switch to “ON” – the fan will not be turning). Now press the **Begin Cruise (Enter)** button. The **Channel A** display will now show the number 25 (your target Cruise pressure). Press the **Start Fan (Start)** button. The Duct Blaster fan will now slowly increase speed until the duct pressurization displayed on Channel A is approximately 25 Pascals.

Channel B will now display the *One-Point* CFM25 total leakage estimate. If the total leakage estimate is fluctuating more than desired, try changing the Time Averaging setting on the gauge by pressing the **TIME AVG** button and choosing the ***5*** or ***10*** second or ***Long-term*** averaging period. Record the CFM25 total leakage estimate.

Turn off the fan. If you are using Cruise Control, this is done by pressing the **Stop Fan (Clear)** button.

(If "**------**" or "LO" appear on **Channel B**, see below).

Whenever "**-----**" or "**LO**" appears on **Channel B** in the **PR/ FL @ 25** Mode, the DG-700 can not calculate a reliable leakage estimate. The messages "**-----**" and "**LO**" appear on **Channel B** under the following three conditions:

- "**-----**" is continuously displayed when the duct test pressure from **Channel A** is below a minimum value of 5 Pascals. Estimating duct leakage results when the test pressure is below this value may result in unacceptably large errors. If possible, install a larger Flow Ring or remove the Flow Rings to generate more fan flow.
- "**LO**" is continuously displayed when there is negligible air flow through the test device.
- "**LO**" alternates with a flow reading when the air flow reading through the device is unreliable (i.e. you are trying to measure a flow outside of the calibrated range of the test device in its current configuration). If possible, you should change the test device configuration to match the flow rate being measured (e.g. install a Flow Ring or a smaller Flow Ring).

Note: If you change the Flow Rings on the fan, be sure to change the Configuration setting on the gauge to match the installed Ring.

- *DG-700: Multi-Point Test*

Turn on the Duct Blaster fan controller and manually increase the fan speed. As the fan speed increases, the duct pressure displayed on **Channel A** should also increase. Increase the fan speed until you achieve the highest target duct pressure (e.g. +35 Pascals) on **Channel A**. The fan flow needed to create this duct pressure can be read directly from **Channel B**. Record the test readings (duct pressure and fan flow). Now reduce the fan speed until the duct pressure equals the next target pressure (e.g. +30 Pa). Once again record the test readings. Continue this procedure for each of the remaining target pressures. Turn off the fan when the final set of readings are completed.

Enter the test readings into the TECBLAST software to generate the CFM25 total leakage estimate. **Note:** Always enter a baseline pressure value of 0 into the TECBLAST Manual Data Entry Screen (because you either "zeroed out" the baseline pressure using the DG-700's built-in baseline feature, or you skipped the optional baseline procedure).

(If "LO" appears on **Channel B**, see below).

Whenever "**LO**" appears on **Channel B** in the **PR/ FL** Mode, the DG-700 can not display a reliable fan flow reading. The message "**LO**" appears on **Channel B** under the following two conditions:

- "LO" is continuously displayed when there is negligible air flow through the test device.
- "LO" alternates with a flow reading when the air flow reading through the device is unreliable (i.e. you are trying to measure a flow outside of the calibrated range of the test device in its current configuration). If possible, you should change the test device configuration to match the flow rate being measured (e.g. install a Flow Ring or a smaller Flow Ring).

Note: If you change the Flow Rings on the fan, be sure to change the Configuration setting on the gauge to match the installed Ring.

6.4 Using the Can't Reach Pressure Factors (*One-Point Tests*)

If you were performing a *One-Point Test* and the Duct Blaster fan was unable to pressurize the duct system by 25 Pascals because one of the Flow Rings was installed, remove the Flow Ring and repeat the test (removing the Flow Ring will increase the maximum air flow available from the fan). If you were not able to pressurize the duct system by 25 Pascals (with the "Open Fan" running at full speed) because the duct system is extremely leaky, use the following instructions:

- *For DG-700 Users:*

No adjustments to the test procedure above are necessary other than to make sure the gauge was in the **PR/ FL @25** mode during the *One-Point Test*. If you can not achieve the target test pressure of approximately 25 Pascals because the duct system is extremely leaky, a CFM25 total leakage estimate will automatically be displayed on **Channel B**. The leakage estimate shown on **Channel B** is determined by continuously adjusting the measured air flow from the Duct Blaster fan to a test pressure of 25 Pascals, using the real-time **Channel A** duct pressure reading and the Can't Reach Pressure Factors shown in Table 2 below.

Table 2: Can't Reach Pressure Factors (25 Pa Target)

Duct Pressure (Pa)	CRP Factor	Duct Pressure (Pa)	CRP Factor
24	1.02	14	1.42
23	1.05	13	1.48
22	1.08	12	1.55
21	1.11	11	1.64
20	1.14	10	1.73
19	1.18	9	1.85
18	1.22	8	1.98
17	1.26	7	2.15
16	1.31	6	2.35
15	1.36	5	2.63

Example: *With no Flow Ring installed and the fan running full speed, you are able to achieve a duct system test pressure of 14 Pascals with a measured fan flow of 1,200 cfm. The corresponding CRP Factor for a duct pressure of 14 Pascals is 1.42. The estimated total duct leakage at a test pressure of 25 Pascals is 1,200 x 1.42 = 1,704 cfm.*

$$\text{Can't Reach Pressure Factor} = \left\{ \frac{25}{\text{Current Test Pressure (Pa) (Channel A)}} \right\}^{0.60}$$

Note: The TECBLAST program automatically applies the CRP Factors to *One-Point Test* data.

6.4.a Potential Errors In One-Point CFM25 Estimate from Using the CRP Factors:

Table 3 below show the potential errors in the *One-Point* CFM25 total leakage estimates from using the CRP factors. There are two main sources of error:

- The actual test pressure (**Channel A**) not being equal to the target pressure of 25 Pascals.
- The actual exponent of the leaks being measured differing from the assumed exponent of 0.60.

Table 3: Error in One-Point Leakage Estimate from CRP Factor

		Actual exponent "n"					
		0.5	**0.55**	**0.6**	**0.65**	**0.7**	**0.75**
Test Pressure in Pa (Channel A)	**5**	14.9%	7.7%	0.0%	-8.4%	-17.5%	-27.3%
	10	8.8%	4.5%	0.0%	-4.7%	-9.6%	-14.7%
	15	5.0%	2.5%	0.0%	-2.6%	-5.2%	-8.0%
	20	2.2%	1.1%	0.0%	-1.1%	-2.3%	-3.4%
	25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	30	-1.8%	-0.9%	0.0%	0.9%	1.8%	2.7%
	35	-3.4%	-1.7%	0.0%	1.7%	3.3%	4.9%
	40	-4.8%	-2.4%	0.0%	2.3%	4.6%	6.8%

For example, Table 3 shows that for a *One-Point* 25 Pa duct airtightness test, a 4.5% error would be introduced if the leakage estimate was determined at an actual test pressure of 10 Pa (**Channel A**), and the actual exponent of the leaks was 0.55 rather than the assumed value of 0.60.

6.5 Unable to Reach a Target Building Pressure During a Multi-Point Test?

If the Duct Blaster fan was unable to achieve the highest target duct pressure (e.g. 35 Pascals) because one of the Flow Rings was installed, remove the Flow Ring and repeat the test. If you were not able to reach the highest target pressure with the "Open Fan" running at full speed because the duct system is extremely leaky, take your first set of test readings the highest achievable duct pressure. Continue your test by using the remaining target pressures which are less than the highest achievable pressure. Enter these test values into the TECBLAST program to generate your total leakage estimate.

6.6 Before Leaving the Building

Be sure you have returned the building to its original condition before leaving. This includes removing any temporary register seals, turning HVAC controls to their original settings and closing access doors or vents opened during the test. In addition, it is highly recommended that the test procedures outlined in Chapters 14 and 15 be performed before leaving the building.

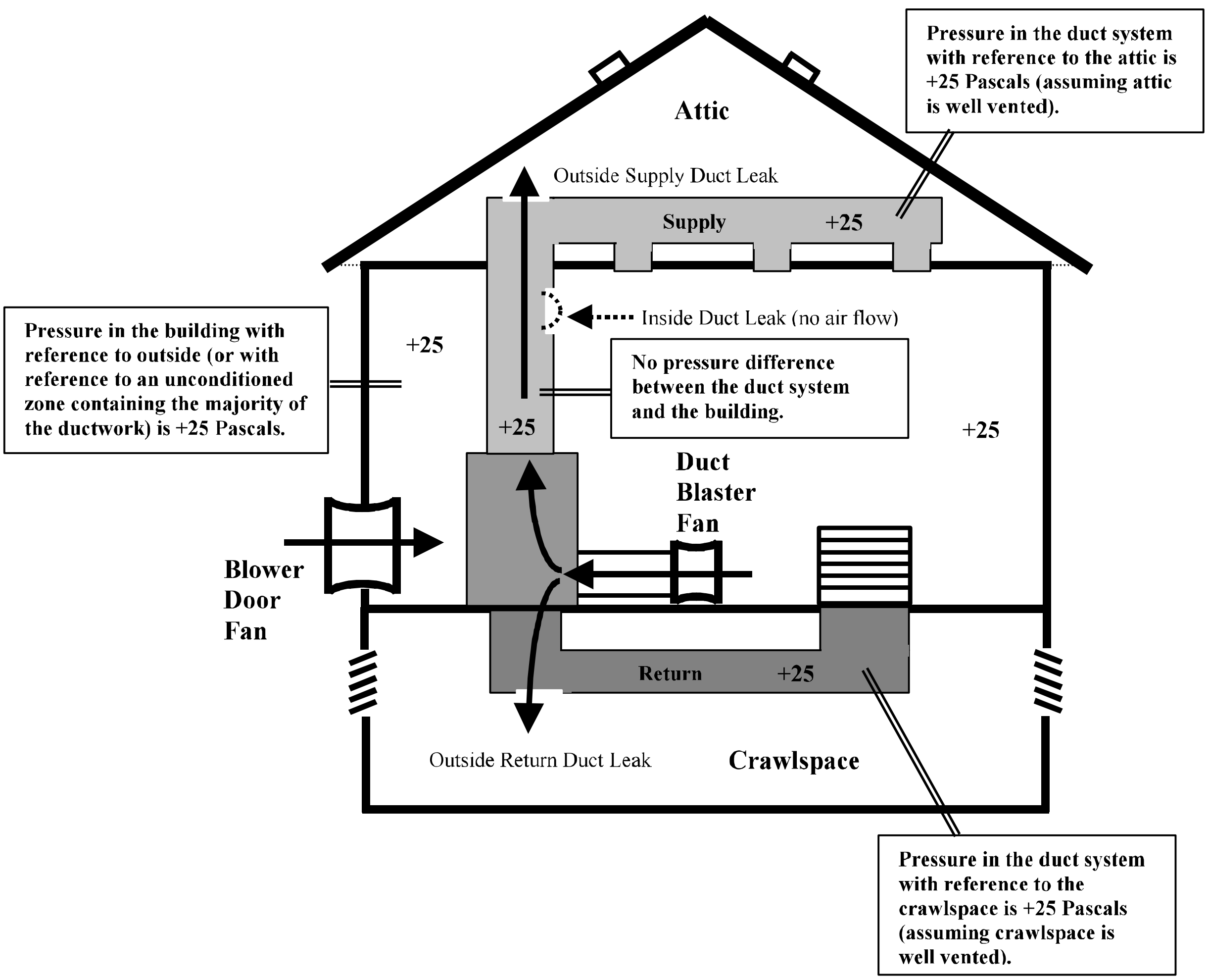
ATTACHMENT FOUR

Chapter 7 Conducting a Leakage to Outside Pressurization Test

This chapter covers the test procedures for conducting a **Leakage to Outside Pressurization Test**. The Leakage to Outside Test is used to measure the duct leakage rate to the outside of the building only, when the duct system is subjected to a uniform test pressure. This test procedure requires simultaneous use of both a Duct Blaster and Blower Door system.

During this procedure, a Blower Door fan will be used to pressurize the building to the test pressure, while the Duct Blaster system is used to pressurize the duct system to the same pressure as the building. Because the duct system and the building are at the same pressure, there will be little or no leakage between the ducts and the building during the leakage rate measurement.

Figure 2: Illustration of Leakage to Outside Pressurization Test
(at a Test Pressure of 25 Pascals)
with Duct Blaster Fan Installed at Air Handler



<u>The air flow through the Duct Blaster fan required to pressurize the duct system to the same pressure as the building (while the Blower Door is pressurizing the building to the test pressure) is the measured duct leakage rate to the outside</u>.

The following instructions assume you have set up the Duct Blaster system for a pressurization test as outlined in Chapter 5 above. Information on how to conduct a Leakage to Outside **Depressurization** Test (i.e. pulling air out of the duct system) is discussed in Chapter 11.

Note: It is possible to separately measure supply and return duct leaks by installing a temporary barrier in either the supply or return opening to the air handler cabinet. With a temporary barrier in place, each side of the duct system can be tested independently. It is also possible to separately measure supply and return leakage before the air handler or furnace unit has been installed.

7.1 Final Preparations (Set Up Blower Door in Building)

Install the Blower Door system in a centrally located exterior door, including a gauge to measure building pressure. You will need to prepare the building for a Blower Door test as described in the Blower Door Operation Manual including closing all exterior doors and windows, opening all interior doors, and adjusting combustion appliances to remain off during the test. The Blower Door fan should be set up to pressurize (or blow air into) the building. Importantly, we will not be measuring air flow through the Blower Door fan during this test procedure. Refer to your Blower Door manual for complete instructions on Blower Door system installation.

7.1.a Building Pressure Measurements:

During the test, you will need to monitor the change in building pressure caused by the Blower Door system. Typically the Blower Door building pressure gauge will be setup to measure building pressure with reference to the outside (this is the typical set up for a Blower Door test).

However, if you are testing a duct system that is located primarily in one unconditioned zone (e.g. a single attic or single crawlspace), you have the option of setting up the building pressure gauge to measure building pressure with reference to that zone, rather than with reference to outside. The purpose of making this change is to ensure that the duct leaks located in that zone are subjected to the full test pressure.

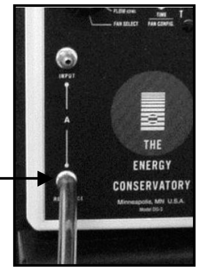
For example, it is possible that a crawlspace containing most of the ductwork may be significantly pressurized by air being forced into that zone from the Blower Door fan (through air leaks between the building and the crawlspace). In this case, you may underestimate the duct leakage rate if you are measuring building pressure with respect to outside during your test because the leaks in the crawlspace ductwork will not be subjected to the full test pressure (i.e. they will be subjected to the test pressure minus the crawlspace pressurization caused by the Blower Door fan). Changing the reference tap on the Blower Door building pressure gauge from outside to the crawlspace would eliminate the underestimation problem in this building.

ATTACHMENT FOUR

- *Using a Digital Gauge to Monitor Building Pressure:*

If you are using a separate DG-700 or DG-3 gauge to monitor building pressure, connect the outside building pressure tubing to the **CHANNEL A Reference** tap.

Connect the outside building pressure tubing to the Blower Door **CHANNEL A Reference** tap. The other end of this tubing should either be run to the outside, or to the unconditioned zone which contains the majority of the ductwork.



7.2 Choose the Test Pressure

For the Leakage to Outside Pressurization Test, we will be simultaneously pressuring the duct system and the building to the same test pressure. For residential duct systems, we generally recommend that 25 Pascals (0.10 inches w.c.) be used as the test pressure. This pressure has been adopted by the majority of residential duct testing programs in the U.S. because 25 Pascals represents a typical operating pressure seen in many residential systems. In cases where 25 Pascals is not a representative pressure in the duct system being tested, it may be appropriate to use a different test pressure. For example, in small commercial HVAC systems which typically operate at higher duct pressures than residential systems, it may be appropriate to use a test pressure greater than 25 Pascals. In extremely leaky duct systems (e.g. more than 600 cfm of leakage at 25 Pascals), such as duct systems found in many basement style houses, the typical operating pressures in the duct system may be significantly less than 25 Pascals. In this case it may be appropriate to use a test pressure lower than 25 Pascals.

7.3 Leakage to Outside Test Procedures Using the DG-700

The following test procedure covers use of the DG-700 for the Leakage to Outside Test procedure. This procedure assumes that a test pressure of 25 Pascals is being used.

a) Turn on the building pressure gauge and pressurize the building to 25 Pascals.

Turn on the Blower Door building pressure gauge and set it to measure pressure on **Channel A**. Slowly turn on the Blower Door fan and begin to pressurize the building. Increase the Blower Door fan speed until the building is pressurized to the test pressure of 25 Pascals, as measured on the building pressure gauge. In leaky buildings, you may need to remove all Flow Rings from the Blower Door fan in order pressurize the building to the test pressure. Leave the Blower Door fan running.

Note: If the Blower Door pressure gauge and Blower Door fan speed controller are compatible with Cruise Control, use the Cruise Control function to maintain the 25 Pa building pressurization.

b) Turn on the Duct Blaster DG-700 and put it in the proper Mode.

Turn on the gauge by pressing the **ON/OFF** button. Press the **MODE** button once to put the Duct Blaster gauge into the **PR/ FL** mode. The **PR/ FL** mode is a multi-purpose mode used to measure a test pressure on **Channel A** while simultaneously measuring air flow from the Duct Blaster fan on **Channel B**.

c) Choose a Flow Ring for the Duct Blaster fan.

Fan Configuration	Flow Range (cfm) for Series B DB fan
Open (no Flow Ring)	1,500 - 600
Ring 1	800 - 225
Ring 2	300 - 90
Ring 3	125 - 10

Install the Flow Ring which you think best matches the needed fan flow. Installation of Flow Rings will depend on the tightness level of the duct system being tested. For example, for relatively leaky duct systems (greater than 600 CFM25), you will want to start the test using the Open Fan configuration (i.e. no Flow Rings installed). As you test tighter duct systems, you will need to install Flow Rings 1, 2, or 3. Refer to the Table to the right for approximate flow ranges of the fan using the various Flow Rings configurations. Don't worry if you guess wrong and start the test with the incorrect Flow Ring - you can change the Fan Configuration during the test procedure.

d) Enter the selected Flow Ring into the Gauge.

In order for the DG-700 to properly display fan flow, you need to input the Duct Blaster fan model and selected Flow Ring into the gauge. Check, and adjust if necessary, the selected test Device (i.e. fan) and Configuration (i.e. Flow Ring) shown in the upper part of the gauge display to match the fan and Flow Ring being used in the test.

Press the **DEVICE** button to change the selected Duct Blaster fan.

<u>Device Icon</u>

DB A Series A Duct Blaster fan　　**DB B** Series B Duct Blaster fan

Once the fan is selected, the configuration of the fan can be selected by pressing the **CONFIG** button. The currently selected Flow Ring configuration is shown in the Config section of the gauge display.

<u>Config Icon</u>

OPEN	No Flow Ring	**B2**	Ring 2
A1	Ring 1	**C3**	Ring3

Also be sure that **Channel B** is showing the proper air flow units for your test (this should typically be set to **CFM**). Units can be changed by pressing the **UNITS** button.

e) With the Blower Door fan continuing to run, turn on and adjust the Duct Blaster fan.

If Manually Controlling the Duct Blaster Fan:

Turn on the Duct Blaster fan controller and slowly turn the fan controller knob clockwise. Increase the fan speed until the pressure between the duct system and the building (displayed on **Channel A**) reads <u>zero</u>.

If Using Cruise Control for the Duct Blaster Fan:

Turn the Duct Blaster speed controller to the "just on" position (i.e. turn the controller knob all the way down counter-clockwise and flip the on/off switch to "ON" – the fan will not be turning). Now press the **Begin Cruise (Enter)** button. The **Channel A** display will now show the number 50 (the default target Cruise pressure). Press the **Cruise Target (Config)** button <u>twice</u> to change the target Cruise pressure to +0. Press the **Start Fan (Start)** button. The Duct Blaster fan will now slowly increase speed until the pressure between the duct system and the building (displayed on **Channel A**) reads <u>zero</u>.

f) Re-check the building pressure.

Re-check the building pressure gauge and if necessary, re-adjust the Blower Door fan speed to maintain a test building pressure of 25 Pascals. **Note:** If the Blower Door fan is being controlled by Cruise Control, skip to step **g)** below,

g) Re-check the duct pressure.

If you are manually controlling the Duct Blaster fan, re-check the Duct Blaster system and if necessary, re-adjust the Duct Blaster fan until the pressure between the duct system and the building reads zero (**Channel A** on the Duct Blaster DG-700).

Channel B on the Duct Blaster DG-700 will now display the CFM25 leakage to outside estimate. If the leakage estimate is fluctuating more than desired, try changing the Time Averaging setting on the gauge by pressing the **TIME AVG** button and choosing the ***5*** or ***10*** second or ***Long-term averaging*** period. Record the CFM25 leakage to outside estimate and turn off both the Blower Door and Duct Blaster fans.

(If "LO" appears on **Channel B**, see below).

Whenever "**LO**" appears on **Channel B** in the **PR/ FL** Mode, the DG-700 can not display a reliable fan flow reading. The message "**LO**" appears on **Channel B** under the following two conditions:

- "LO" is continuously displayed when there is negligible air flow through the test device.
- "LO" alternates with a flow reading when the air flow reading through the device is unreliable (i.e. you are trying to measure a flow outside of the calibrated range of the test device in its current configuration). If possible, you should change the test device configuration to match the flow rate being measured (e.g. install a Flow Ring or a smaller Flow Ring).

Note: If you change the Flow Rings on the fan, be sure to change the Configuration setting on the gauge to match the installed Ring.

7.4 What If You Can Not Pressurize the Building to the Test Pressure with the Blower Door Fan?

If the Blower Door system is unable to pressurize the building to the test pressure because one of the Flow Rings was installed on the Blower Door fan, remove the Flow Ring and repeat the test. If you are not able to pressurize the building to the test pressure because the building is too leaky, then you will need to conduct the test at the highest achievable building pressure and use the Can't Reach Pressure Factors in Table 4 below to estimate the final duct leakage rate.

Table 4: Can't Reach Pressure Factors (25 Pa Target)

Duct Pressure (Pa)	CRP Factor	Duct Pressure (Pa)	CRP Factor
24	1.02	14	1.42
23	1.05	13	1.48
22	1.08	12	1.55
21	1.11	11	1.64
20	1.14	10	1.73
19	1.18	9	1.85
18	1.22	8	1.98
17	1.26	7	2.15
16	1.31	6	2.35
15	1.36	5	2.63

Example: *With the Blower Door fan running at full speed (& no Flow Rings attached), you are only able to pressurize the building to 18 Pascals. While the Blower Door is pressurizing the building to 18 Pascals, adjust the Duct Blaster fan to create zero pressure between the duct system and the building. At this point the measured Duct Blaster fan flow is 450 cfm. The corresponding CRP Factor for a building pressure of 18 Pascals is 1.22. The estimated duct leakage to outside at a test pressure of 25 Pascals is 450 x 1.22 = 549 cfm.*

$$\textbf{Can't Reach Pressure Factor} = \left\{ \frac{\textbf{25}}{\textbf{Current Test Pressure (Pa) (Channel A)}} \right\}^{\textbf{0.60}}$$

Note: The TECBLAST program automatically applies the CRP Factors to test data.

7.5 What If You Can Not Pressurize the Duct System to the Same Pressure as the Building with the Duct Blaster Fan?

If the Duct Blaster fan was unable to create a pressure difference of zero between the duct system and the building (while the Blower Door is pressurizing the building to the test pressure) because one of the Flow Rings was installed, remove the Flow Ring from the Duct Blaster fan and repeat the test. If you were not able to create a pressure difference of zero because the duct system is extremely leaky to the outside, then the test will need to be performed at a lower building pressure and the Can't Reach Pressure Factors (Table 4) used to estimate the final duct leakage rate.

> *Example:* *Because you were unable to create a pressure difference of zero between the duct system and the building, re-adjust the Blower Door to pressurize the building to a lower pressure (e.g. 20 Pascals). While the Blower Door is running, adjust the Duct Blaster fan to create a pressure difference of zero between the duct system and the building. If you are still unable to create a pressure difference of zero, repeat the test at an even lower building pressure (e.g. 15 Pascals). Finally, multiply the flow through the Duct Blaster fan needed to create a pressure difference of zero by the appropriate CRP factor.*

For example, with the Blower Door pressurizing the building to 15 Pascals, the flow through the Duct Blaster fan needed to create a pressure difference of zero (between the duct system and the building) is 1,200 cfm. The corresponding CRP Factor for a building pressure of 15 Pascals is 1.36. The estimated duct leakage to outside at a test pressure of 25 Pascals is 1200 x 1.36 = 1,632 cfm.

Note: The TECBLAST program will automatically apply the CRP Factors to test data.

7.6 Before Leaving the Building

Be sure you have returned the building to its original condition before leaving. This includes removing any temporary register seals, turning HVAC controls to their original settings and closing access doors or vents opened during the test. In addition, it is highly recommended that the test procedures outlined in Chapters 14 and 15 be performed before leaving the building.

Chapter 8 Test Results

Basic test results from a duct airtightness test can be manually calculated to provide a quick assessment of the leakage rate of the duct system. For more complicated calculation procedures including analysis of Multi-Point Test data and estimated annual system efficiency losses from duct leakage, we recommend that you use the TECBLAST program.

8.1 Basic Duct Airtightness Test Results

Duct airtightness test results can be presented in a number of standardized formats.

8.1.a Duct Leakage at 25 Pascals:

- *Total Leakage at 25 Pascals:*

Total Duct Leakage at 25 Pascals is a measurement of the duct leakage rate (in cubic feet per minute) which occurs when the entire duct system is subjected to a uniform test pressure of 25 Pascals (0.1 inches of water column). The air flow through the Duct Blaster fan required to pressurize (or depressurize) the duct system to the test pressure is the measured total duct leakage rate. Total duct leakage includes both duct leakage to the outside of the building (e.g. leaks to attics, crawlspaces, garages and other zones that are open to the outside), and duct leakage to the inside of the building.

- *Leakage to Outside at 25 Pascals:*

Leakage to Outside at 25 Pascals is a measurement of the duct leakage rate (in cubic feet per minute) to the outside of the building only, when the duct system is subjected to a uniform test pressure of 25 Pascals (0.1 inches of water column). The air flow through the Duct Blaster fan required to pressurize (or depressurize) the duct system to the same pressure as the building, while a Blower Door is pressurizing (or depressurizing) the building to the test pressure, is the measured duct leakage rate. Duct leakage to the outside of a building typically has a much larger impact on HVAC system performance than does duct leakage to the inside of a building.

Note: A test pressure of 25 Pascals has been adopted by the majority of residential duct testing programs in the U.S. because 25 Pascals represents a typical operating pressure seen in many residential systems. In cases where 25 Pascals is not a representative duct system pressure, it may be appropriate to use a different test pressure.

Duct leakage rates for houses can vary dramatically based on the construction style and age of the building. Below are duct leakage test results from a few field tests of new and existing homes around the United States.

	Average Total Leakage at 25 Pa
28 New Houses in Arizona (1996)	310 cfm
40 New Houses in Pacific Northwest (1995)	166 cfm
56 New Houses in California (1997)	144 cfm
8 New Houses in Minnesota (1993)	1,463 cfm
21 Existing Houses in Pacific Northwest	379 cfm
121 Existing Houses in California	220 cfm

	Average Leakage to Outside at 25 Pa
28 New Houses in Arizona (1996)	193 cfm
40 New Houses in Pacific Northwest (1995)	65 cfm
32 New Manufactured Houses in US (1996)	120 cfm
8 Existing Manufactured Houses in Pacific Northwest	242 cfm
22 Existing Houses in Pacific Northwest	221 cfm
18 Existing Houses in Arkansas	410 cfm

8.1.b Normalizing Duct Leakage for the Size of the HVAC System and Building:

In order to compare the leakage rate of various duct systems, it is useful to adjust (or normalize) the leakage test results for the size of the HVAC system and the building. This allows easy comparison of duct airtightness tests conducted on various size buildings or HVAC systems with each other, or with program standards. The two most common variables used to normalize are the total HVAC system air flow rate, and the floor area of the building.

- *Duct Leakage as a % of Total System Airflow:*

One way to compare the leakage rate of various duct systems is to express the leakage rate as a percent of total airflow through the air handler. Duct Leakage as a Percentage of Total System Airflow is calculated by dividing the duct leakage rate by the air handler flow rate. Air handler flow rates can be estimated using the temperature rise method, or by directly measuring the airflow using a TrueFlow™ Air Handler Flow Meter or the Duct Blaster pressure matching method (see Chapter 13). For multiple speed air handler fans, the lowest fan speed is typically used.

$$\text{Duct Leakage as a \% of Total System Airflow} = \frac{\text{Duct Leakage at 25 Pa (cfm)}}{\text{Total System Airflow (cfm)}} \times 100$$

California's recently revised Title 24 Energy Code requires that all new houses have a measured total duct leakage rate of less than 6% of total system airflow.

- *Duct Leakage as a Percent of Floor Area:*

Another useful way to compare the leakage rate in different duct systems is to compare the measured duct leakage rate to the conditioned floor area of the building. *Duct Leakage as a Percent of Floor Area* is calculated by dividing the duct leakage rate by the conditioned floor area of the building.

$$\text{Duct Leakage as a \% of Floor Area} = \frac{\text{Duct Leakage at 25 Pa (cfm)}}{\text{Floor Area (square feet)}} \times 100$$

Over the past decade, a number of residential new construction programs have specified a maximum duct leakage target using *Duct Leakage as a Percentage of Floor Area*. These programs have typically specified maximum target leakage rates ranging from 3% to 6%.

8.1.c Leakage Areas:

Once you have performed an airtightness test on the duct system and have quantified the leakage rate, it is possible to calculate a Leakage Area of the duct system in square inches. The Leakage Area estimate can be a useful way to visualize the physical size of all cumulative leaks in the duct system. The Leakage Area is defined in this manual as the size of a sharp edged hole (i.e. orifice) which would leak at the same flow rate as the measured duct system leakage, if the hole was subjected to the test pressure.

To calculate the Leakage Area, you first need to know the leakage rate of the duct system in cubic feet per minute (cfm), and the test pressure at which the leakage test was conducted (e.g. 25 Pa). Knowing these two variables, we can use the following equation to calculate the Equivalent Orifice Leakage Area (EOLA):

$$\text{EOLA (sq. in.)} = \frac{\text{Duct System Leakage Rate (cfm)}}{1.06 \times \sqrt{\text{test pressure (Pa)}}}$$

Note: Leakage Area calculations are performed automatically in the TECBLAST program.

Table 5: Example Leakage Area Calculations:

Duct Leakage Rate	Equiv. Orifice Leakage Area (test pressure at 25 Pa)	Equiv. Orifice Leakage Area (test pressure at 50 Pa)
50 CFM	9.4 sq. in.	6.7 sq. in.
100 CFM	18.9	13.3
150 CFM	28.3	20.0
200 CFM	37.7	26.7
250 CFM	47.2	33.4
300 CFM	56.6	40.0
350 CFM	66.0	46.7

8.2 Additional Test Result Options (requires use of TECBLAST software)

8.2.a Estimated System Efficiency Losses:

The TECBLAST program contains a simple method for estimating HVAC system losses from field measurements of duct leakage. This method uses a duct leakage measurement along with a number of assumptions about the HVAC and duct system (including system airflow, average operating pressure in the ductwork, the breakdown of leakage between supply and return side, and the energy loss penalty from supply and return leaks) to estimate an energy loss penalty for heating or cooling. Information on the model used in the TECBLAST program can be found in Appendix E.

Note: Because duct leakage loss calculations are extremely complex, the estimation technique in TECBLAST should be used with caution and should be viewed only as a rough estimate of the magnitude of losses possible. The leakage rate of a duct system determined using the airtightness test procedures listed in this manual may differ from the leakage rates occurring in the duct system under actual operating conditions. In addition, the duct leakage loss estimates do not include many important but complex impacts on system efficiency including latent load impacts, heat pump strip heating impacts, conduction losses, increases in infiltration from dominant duct leakage, or interactions of leakage on mechanical operating efficiencies, all of which can be significant depending on the type and location of the system being tested. We do not recommend that this simple model be used for research purposes, program design studies or impact evaluations. More sophisticated duct leakage loss models are available and better suited to these needs. Listed below are three references to other duct leakage loss models:

ASHRAE Standard 152-2004, Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems, ASHRAE, Atlanta GA, 2004.

Development of a Practical Method for Estimating the Thermal Efficiency of Residential Forced Air Distribution Systems, EPRI, Palo Alto CA, January 1997.

Improvements to ASHRAE Standard 152P, Paul Francisco and Larry Palmer, Ecotope, Seattle WA, June 1999.

8.2.b Duct Leakage Curve:

Once the duct leakage test data has been collected and entered into the TECBLAST program, it is plotted on a Test Graph and a "best-fit" regression line (called the Duct Leakage Curve) is drawn through the plotted data. The Duct Leakage Curve can be used to estimate the leakage rate of the duct system at any pressure. If you conduct a single point test, TECBLAST assumes an exponent (n) of 0.60 in its calculation procedures.

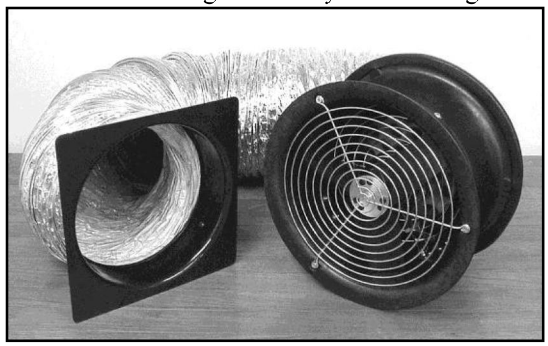
The Duct Leakage Curve is defined by the variables Coefficient (C) and Exponent (n) in the following equation:

$$Q = C \times P^{\wedge n}$$

where:
Q is leakage into (or out of) the duct system (in CFM).
C is the Coefficient.
P is the pressure difference between inside and outside of the duct system (in Pascals).
n is the Exponent.

Chapter 9 Setting Up the Duct Blaster for Depressurization Testing

The following instructions are for conducting a duct leakage **depressurization** test. Depressurization testing involves pulling air out of the duct system with the Duct Blaster fan and measuring the duct system's leakage rate when it is subjected to a uniform test pressure. When conducting a depressurization test of the duct system, the **exhaust** side of the Duct Blaster fan will be open to the room where the Duct Blaster is installed, and the inlet side of the fan will be connected to the flexible extension duct. In this configuration, the fan housing typically rests on the floor or on a table while the square transition piece is connected to a central return register, or the air handler cabinet access panel.

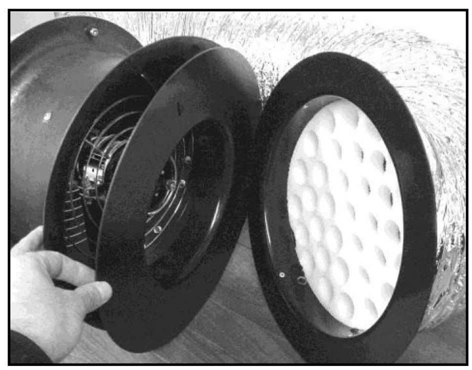


Note: During depressurization testing, the flow conditioner should **always** be installed in the round transition piece (see Section 9.1 below).

Information on how to conduct a duct leakage **pressurization** test (i.e. pushing air into the duct system) is discussed in Chapters 5 - 7. Both pressurization and depressurization tests typically provide similar leakage results. Use of one procedure over the other is primarily a matter of personal choice. If you are conducting the leakage test according to a specific program guideline, the program guidelines may specify which procedure to use.

9.1 Installing the Flow Conditioner and Flow Ring

When conducting a duct leakage depressurization test, the flow conditioner and one of the Flow Rings must always be installed. The flow conditioner consists of a round one-inch wide perforated foam disk which is stored in the Duct Blaster accessory case. The flow conditioner is inserted into the round transition piece by lining up the crescent shaped key slot on the outside of the foam disk with the key indentation inside the round transition piece, and pushing the disk tightly into the transition piece and up against the ridge stop.



Before attaching the round transition piece (with flow conditioner installed) to the inlet side of the Duct Blaster fan, first place one of the Flow Rings against the fan inlet. Use the Flow Ring which you think will provide the appropriate air flow range for the test. Don't worry if you install the wrong Flow Ring, they can be changed during the test procedure.

Fan Flow Ranges

Flow Ring Configuration *	Flow Range (CFM)
Ring 1	800 – 225
Ring 2	300 – 90
Ring 3	125 – 10

* A Flow Ring must always be installed when depressurization testing

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Secure both the Flow Ring and round transition piece to the fan inlet flange using the black connecting trim. Because the flexible extension duct and one of the Flow Rings must always be used when using the Duct Blaster to conduct a depressurization test, the maximum air flow achievable during a depressurization test is approximately 800 cfm.

9.2 Where to Install the Duct Blaster System?

See **Section 5.1** - this section is the same for both pressurization and depressurization testing.

9.3 Connecting the Duct Blaster to the Duct System

See **Sections 5.2.a (Option 1)** and **5.2.b (Option 1)**.

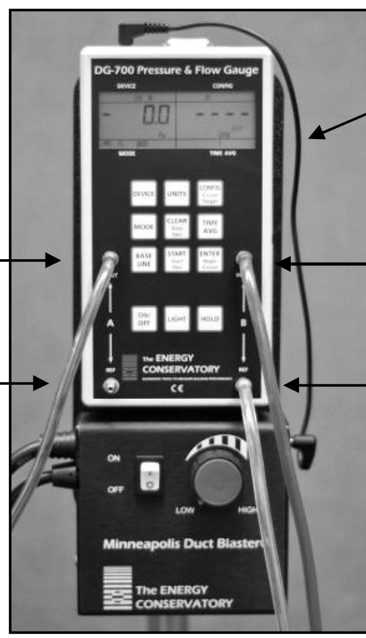
Note: When conducting a depressurization test, the flexible extension duct must always be used to connect the Duct Blaster to the duct system. In addition, once the flexible extension duct has been connected to the duct system (at either a central return or the air handler cabinet), the flex duct should be stretched relatively straight for about 4 feet in front of the Duct Blaster fan.

9.4 Gauge Tubing Connections for Depressurization Testing

The DG-700 Digital Pressure Gauge comes with 2 pieces of color coded tubing - a 15 foot length of green tubing for measuring duct system pressure, and a 10 foot length of red tubing to measure fan pressure and flow. In addition, a 30 foot length of clear hose is stored in the Duct Blaster carrying case. Connect the tubing to the gauge(s) as shown below:

Connect the **Green** tubing to the **Chan A Input** tap. The other end of the **Green** tubing should be connected to the duct system (see section 9.5).

Connect **Chan A Ref** tap to inside of building (if gauge is located in the building, leave this tap open).



Optional fan control cable (for Cruise Control).

Connect the **Red** tubing to the **Chan B Input** tap. The other end of the **Red** tubing should be connected to the brass tap in the middle of the DB fan housing (section 9.6.a).

Connect the **Clear** tubing from the **Chan B Ref** tap to the plastic tap on the Round Transition Piece (section 9.6.b).

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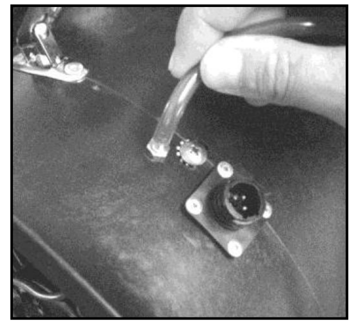
9.5 Selecting a Location to Measure Duct System Pressure

See **Section 5.5 -** this section is the same for both pressurization and depressurization testing.

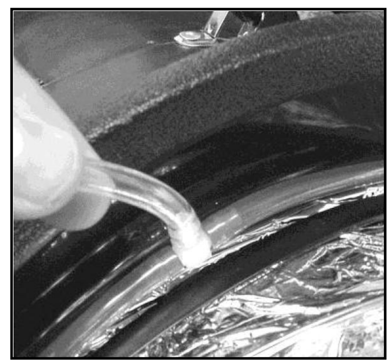
9.6 Tubing and Electrical Connections to the Fan



9.6.a Connect Red Tubing to the Fan:

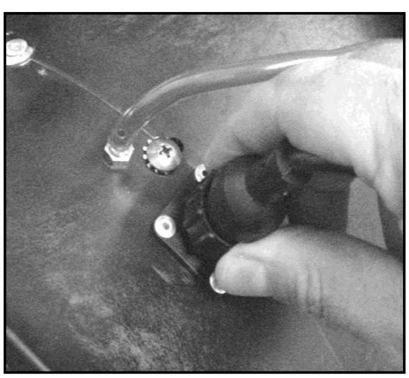
The remaining end of the **Red** tubing should be connected to the brass pressure tap on the Duct Blaster fan housing.

9.6.b Connect Clear Tubing to the Round Transition Piece:



The remaining end of the **Clear** tubing should be connected to the plastic pressure tap on the round transition piece (which is installed on the inlet of the Duct Blaster fan).

9.6.c Electrical Connections:



Connect the female plug from the fan speed controller to the male power receptacle on the fan housing. To connect the female plug, line up the plug with the three metal pins on the fan receptacle and push the plug completely onto the pins. Now secure the plug to the fan by pushing the locking ring from the plug against the fan and turning the ring clockwise until it locks in place. The remaining cord (power cord) should be plugged into a power outlet that is compatible with the voltage specifications of the fan controller and motor (be sure the fan controller knob is turned all the way counter clockwise and the power switch is turned to the "off" position before plugging into the power outlet). The standard Duct Blaster System sold in the United States is compatible with 110V AC power.

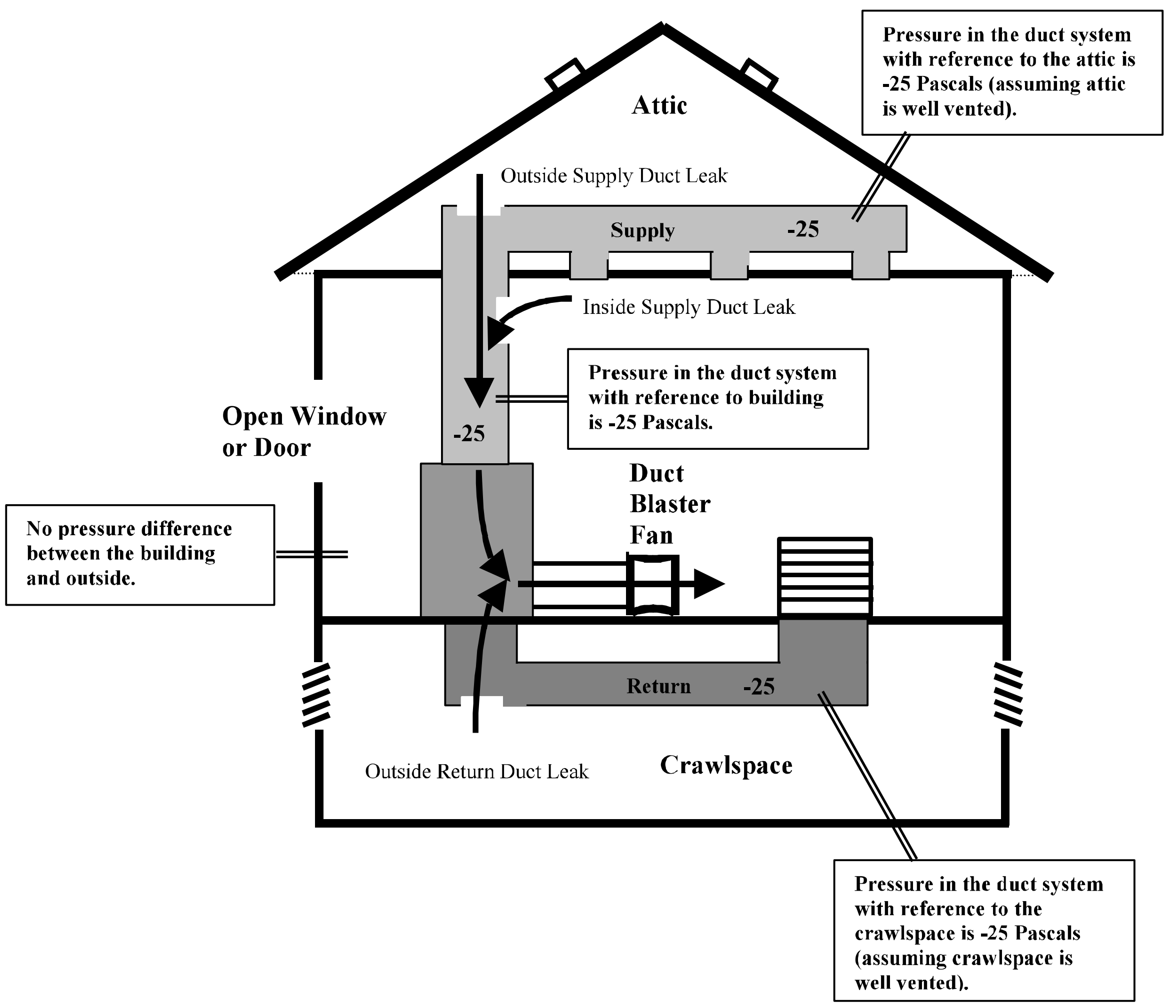
Note: The Duct Blaster fan motor is not reversible.

ATTACHMENT FOUR

Chapter 10 Conducting a Total Leakage Depressurization Test

This chapter covers the test procedures for conducting a **Total Leakage Depressurization Test**. The Total Leakage Depressurization Test is used to measure the duct leakage rate in the entire duct system (including leaks in the air handler cabinet) when the duct system is subjected to a uniform test pressure. The Total Leakage Depressurization Test measures both leakage to the outside of the building (e.g. leaks to attics, crawlspaces, garages and other zones that are open to the outside), and leakage to the inside of the building. This test procedure requires use of a Duct Blaster system only.

Figure 3: Illustration of Total Leakage Depressurization Test
(at a Test Pressure of 25 Pascals)
with Duct Blaster Fan Installed at Air Handler



<u>The air flow through the Duct Blaster fan required to depressurize the duct system to the test pressure is the measured total duct leakage rate.</u>

The following instructions assume you have set up the Duct Blaster system for a depressurization test as outlined in Chapter 9 above. Information on how to conduct a Total Leakage **<u>Pressurization</u>** Test (i.e. blowing air into the duct system) is discussed in Chapter 6.

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Note: It is possible to separately measure total supply and return duct leaks by installing a temporary barrier in either the supply or return opening to the air handler cabinet. With a temporary barrier in place, each side of the duct system can be tested independently. It is also possible to separately measure supply and return leakage before the air handler or furnace unit has been installed.

10.1 Final Preparations (Open a Door or Window to the Outside)

- Open a door or window between the building and outside to prevent changes in building pressure when the Duct Blaster fan is running. We want to prevent changes in building pressures because the pressure difference across duct leaks will be different for leaks to the inside of the building compared with leaks to the outside. Changes in building pressure could be caused by:

  ⇒ If the Duct Blaster is installed inside the building and there are large leaks between the duct system and outside, depressurizing the duct system may pressurize the building relative to outside.

  ⇒ If the Duct Blaster is installed in an unconditioned space (attic, garage or crawlspace air handler), depressurizing the duct system may depressurize the building relative to outside.

10.2 Choosing the Test Pressure and Number of Test Readings

10.2.a Test Pressure:

For residential duct systems, we generally recommend that -25 Pascals (-0.10 inches w.c.) be used as the test pressure. This pressure has been adopted by the majority of residential duct testing programs in the U.S. because 25 Pascals represents a typical operating pressure seen in many residential systems. In cases where 25 Pascals is not a representative pressure in the duct system being tested, it may be appropriate to use a different test pressure. For example, in small commercial HVAC systems which typically operate at higher duct pressures than residential systems, it may be appropriate to use a test pressure greater than 25 Pascals. In extremely leaky duct systems, such as duct systems found in many basement style houses, typical operating pressures in the duct system may be significantly less than 25 Pascals. In this case it may be appropriate to use a test pressure lower than 25 Pascals.

10.2.b Number of Test Readings:

The most common test procedure is to conduct a ***One-Point Test*** to assess duct airtightness. The ***One-Point Test*** utilizes a single measurement of Duct Blaster fan flow needed to produce the test pressure in the duct system. The ***One-Point Test*** provides a quick and simple way to measure duct leakage without the need to have a computer to analyze the test data (although a computer program like TECBLAST can still be useful to generate reports and store data).

The ***Multi-Point Test*** procedure involves testing the duct system over a range of test pressures and analyzing the data using a duct airtightness test computer program (e.g. TECBLAST). For example, a typical ***Multi-Point Test*** of a residential duct system includes taking measurements at 5 different test pressures including -35 Pascals, -30, -25, -20 and -15 Pascals. Making multiple measurements allows some of the errors introduced by fluctuating pressures and operator error to be averaged out over several measurements, typically increasing test accuracy.

10.3 Total Leakage Test Procedures Using the DG-700

The following test procedures cover use of the DG-700 for both *One-Point Tests* and *Multi-Point Tests*. These procedures assume that a test pressure of -25 Pascals is being used.

a) Turn on the DG-700 and place it in the proper Mode:

- *DG-700: One-Point Test*

Turn on the gauge by pressing the **ON/OFF** button. Press the **MODE** button three times to put the gauge into the **PR/ FL @25** mode. In this specialized test mode, **Channel A** is used to measure duct system pressure while **Channel B** is used to display estimated total duct leakage at a test pressure of -25 Pascals (CFM25 Total). The leakage estimate shown on **Channel B** is determined by mathematically adjusting the actual air flow from the Duct Blaster fan to a test pressure of -25 Pascals, using the real-time **Channel A** duct system pressure reading and a Can't Reach Pressure (CRP) factor. CRP factors are discussed later in this Chapter.

- *DG-700: Multi-Point Test*

Turn on the gauge by pressing the **ON/OFF** button. Press the **MODE** button once to put the gauge into the **PR/ FL** mode. The **PR/ FL** mode is a multi-purpose mode used to measure a test pressure on **Channel A** while simultaneously measuring air flow from the Duct Blaster fan on **Channel B**.

b) Optional measurement of baseline duct pressure (same for both *One-Point* and *Multi-Point Tests*).

When conducting a total leakage test, we want to measure the change in duct system pressure caused by air flowing through the Duct Blaster fan. In order to measure this change accurately, we sometimes need to account for any existing pressures on the duct system caused by stack, wind and other driving forces. This existing duct system pressure is called the "baseline duct pressure".

In many cases, the baseline duct pressure will be very small or zero, and this section of the test procedure can be omitted. For example, during mild weather conditions (e.g. little wind and less than 20 degrees temperature difference between inside and outside the building), the baseline duct pressure will typically be less than 1 Pascal and omitting baseline pressure measurements will have little or no effect on the final test results.

If it is very windy or there are very large temperature differences between inside and outside, and the ducts are located in unconditioned zones (e.g. attics, crawlspaces or garages), baseline duct pressures may be greater than 1 Pascal and should be measured. The DG-700 has a built-in baseline measurement procedure which allows the user to quickly measure and record the baseline pressure on **Channel A**, and then display the baseline adjusted pressure. This feature makes it possible to "zero out" the baseline duct pressure on **Channel A**, and display the actual change in duct pressure caused by the Duct Blaster fan.

With the fan sealed off, begin a baseline duct pressure reading from **Channel A** by pressing the **BASELINE** button. The word "BASELINE" will begin to flash in the **Channel A** display indicating that the baseline feature has been initiated. Press **START** to start the baseline measurement. During a baseline measurement, **Channel A** will display a long-term average baseline pressure reading while **Channel B** is used as a timer in seconds to show the elapsed measurement time. When you are satisfied with the baseline measurement, press the **ENTER** button to accept and enter the baseline reading into the gauge. The **Channel A** display will now show an **ADJ** icon to indicate that it is displaying a baseline adjusted duct pressure value.

c) Choose a Flow Ring for the Duct Blaster fan (same for both *One-Point* and *Multi-Point Tests*).

Fan Configuration	Flow Range (cfm) for Series B DB fan
Ring 1	800 - 225
Ring 2	300 - 90
Ring 3	125 - 10

Install the Flow Ring which you think best matches the needed fan flow. Installation of Flow Rings will depend on the tightness level of the duct system being tested. For example, for relatively leaky duct systems (greater than 500 CFM25), you will want to start the test using the Ring 1 configuration. As you test tighter duct systems, you will need to install Flow Rings 2 or 3. Refer to the Table to the right for approximate flow ranges of the fan using the various Flow Rings configurations. Don't worry if you guess wrong and start the test with the incorrect Flow Ring - you can change the Fan Configuration during the test procedure.

d) Enter the selected Flow Ring into the Gauge (same for both *One-Point* and *Multi-Point Tests*).

In order for the DG-700 to properly display fan flow, you need to input the Duct Blaster fan model and selected Flow Ring into the gauge. Check, and adjust if necessary, the selected test Device (i.e. fan) and Configuration (i.e. Flow Ring) shown in the upper part of the gauge display to match the fan and Flow Ring being used in the test.

Press the **DEVICE** button to change the selected Duct Blaster fan.

<u>Device Icon</u>

DB A Series A Duct Blaster fan **DB B** Series B Duct Blaster fan

Once the fan is selected, the configuration of the fan can be selected by pressing the **CONFIG** button. The currently selected Flow Ring configuration is shown in the Config section of the gauge display.

<u>Config Icon</u>

OPEN No Flow Ring (**Note:** When depressurizing, a Flow Ring must be installed).
A1 Ring 1
B2 Ring 2
C3 Ring3

Also be sure that **Channel B** is showing the proper air flow units for your test (this should typically be set to **CFM**). Units can be changed by pressing the **UNITS** button.

e) Turn on and adjust the Duct Blaster fan:

- *DG-700: One-Point Test*

If Manually Controlling Fan:

Turn on the Duct Blaster fan controller and slowly turn the fan controller knob clockwise. As the fan speed increases, the duct depressurization displayed on **Channel A** should also increase. Continue to increase the fan speed until the duct depressurization shown on **Channel A** is between -20 and -30 Pascals. Do not waste time adjusting and re-adjusting the fan speed control to achieve a test pressure of exactly -25 Pascals. As long you are using the **PR/ FL @25** mode and the test pressure displayed on **Channel A** is within 5 Pascals of the 25 Pascal target pressure, any errors introduced by estimating the leakage on **Channel B** will typically be very small (less than 1%).

If Using Cruise Control:

Turn the Duct Blaster speed controller to the "just on" position (i.e. turn the controller knob all the way down counter-clockwise and flip the on/off switch to "ON" – the fan will not be turning). Now press the **Begin Cruise (Enter)** button. The **Channel A** display will now show the number 25 (your target Cruise pressure). Press the **Start Fan (Start)** button. The Duct Blaster fan will now slowly increase speed until the duct depressurization displayed on Channel A is approximately -25 Pascals.

Channel B will now display the *One-Point* CFM25 total leakage estimate. If the total leakage estimate is fluctuating more than desired, try changing the Time Averaging setting on the gauge by pressing the **TIME AVG** button and choosing the 5 or 10 second or Long-term averaging period. Record the CFM25 total leakage estimate.

Turn off the fan. If you are using Cruise Control, this is done by pressing the **Stop Fan (Clear)** button.

(If "**------**" or "LO" appear on **Channel B**, see below).

Whenever "**-----**" or "**LO**" appears on **Channel B** in the **PR/ FL @ 25** Mode, the DG-700 can not calculate a reliable leakage estimate. The messages "**-----**" and "**LO**" appear on **Channel B** under the following three conditions:

- "**-----**" is continuously displayed when the duct test pressure from **Channel A** is below a minimum value of 5 Pascals. Estimating duct leakage results when the test pressure is below this value may result in unacceptably large errors. If possible, install a larger Flow Ring or remove the Flow Rings to generate more fan flow.
- "**LO**" is continuously displayed when there is negligible air flow through the test device.
- "**LO**" alternates with a flow reading when the air flow reading through the device is unreliable (i.e. you are trying to measure a flow outside of the calibrated range of the test device in its current configuration). If possible, you should change the test device configuration to match the flow rate being measured (e.g. install a Flow Ring or a smaller Flow Ring).

Note: If you change the Flow Rings on the fan, be sure to change the Configuration setting on the gauge to match the installed Ring.

- *DG-700: Multi-Point Test*

Turn on the Duct Blaster fan by slowly turning the fan controller clockwise. The fan should be pulling air out of the duct system. As the fan speed increases, the duct pressure displayed on **Channel A** should also increase. Increase the fan speed until you achieve the highest target duct pressure (e.g. -35 Pascals) on **Channel A**. The fan flow needed to create this duct pressure can be read directly from **Channel B**. Record the test readings (duct pressure and fan flow). Now reduce the fan speed until the duct pressure equals the next target pressure (e.g. -30 Pa). Once again record the test readings. Continue this procedure for each of the remaining target pressures. Turn off the fan when the final set of readings are completed.

Enter the test readings into the TECBLAST software to generate the CFM25 total leakage estimate. **Note:** Always enter a baseline pressure value of 0 into the TECBLAST Manual Data Entry Screen (because you either "zeroed out" the baseline pressure using the DG-700's built-in baseline feature, or you skipped the optional baseline procedure).

(If "LO" appears on **Channel B**, see below).

Whenever "**LO**" appears on **Channel B** in the **PR/ FL** Mode, the DG-700 can not display a reliable fan flow reading. The message "**LO**" appears on **Channel B** under the following two conditions:

- "LO" is continuously displayed when there is negligible air flow through the test device.
- "LO" alternates with a flow reading when the air flow reading through the device is unreliable (i.e. you are trying to measure a flow outside of the calibrated range of the test device in its current configuration). If possible, you should change the test device configuration to match the flow rate being measured (e.g. install a Flow Ring or a smaller Flow Ring).

Note: If you change the Flow Rings on the fan, be sure to change the Configuration setting on the gauge to match the installed Ring.

10.4 Using the Can't Reach Pressure Factors (*One-Point Tests*)

If you were performing a *One-Point Test* and the Duct Blaster fan was unable to depressurize the duct system by -25 Pascals because one of the smallest Flow Rings was installed (e.g. Ring 2 or 3), replace the Flow Ring with a larger Flow Ring (e.g. Ring 1) to increase the maximum air flow available from the fan. If you were not able to depressurize the duct system by –25 Pascals because the duct system is extremely leaky, use the following instructions:

- *For DG-700 Users:*

No adjustments to the test procedure above are necessary other than to make sure the gauge was in the **PR/ FL @25** mode during the *One-Point Test*. If you can not achieve the target test pressure of approximately -25 Pascals because the duct system is extremely leaky, a CFM25 total leakage estimate will automatically be displayed on **Channel B**. The leakage estimate shown on **Channel B** is determined by continuously adjusting the measured air flow from the Duct Blaster fan to a test pressure of -25 Pascals, using the real-time **Channel A** duct pressure reading and the Can't Reach Pressure Factors shown in Table 6 below.

Table 6: Can't Reach Pressure Factors (-25 Pa Target)

Duct Pressure (Pa)	CRP Factor	Duct Pressure (Pa)	CRP Factor
-24	1.02	-14	1.42
-23	1.05	-13	1.48
-22	1.08	-12	1.55
-21	1.11	-11	1.64
-20	1.14	-10	1.73
-19	1.18	-9	1.85
-18	1.22	-8	1.98
-17	1.26	-7	2.15
-16	1.31	-6	2.35
-15	1.36	-5	2.63

Example: With Ring 1 installed and the fan running full speed, you are able to achieve a duct system test pressure of -14 Pascals with a measured fan flow of 700 cfm. The corresponding CRP Factor for a duct pressure of -14 Pascals is 1.42. The estimated total duct leakage at a test pressure of -25 Pascals is 700 x 1.42 = 994 cfm.

$$\text{Can't Reach Pressure Factor} = \left\{ \frac{25}{\text{Current Test Pressure (Pa) (Channel A)}} \right\}^{0.60}$$

Note: The TECBLAST program automatically applies the CRP Factors to *One-Point Test* data.

10.4.a Potential Errors In One-Point CFM25 Estimate from Using the CRP Factors:

Table 7 below show the potential errors in the *One-Point* CFM25 total leakage estimates from using the CRP factors. There are two main sources of error:

- The actual test pressure (**Channel A**) not being equal to the target pressure of -25 Pascals.
- The actual exponent of the leaks being measured differing from the assumed exponent of 0.60.

Table 7: Error in One-Point Leakage Estimate from CRP Factor

		Actual exponent "n"					
		0.5	**0.55**	**0.6**	**0.65**	**0.7**	**0.75**
Test Pressure in Pa (Channel A)	**-5**	14.9%	7.7%	0.0%	-8.4%	-17.5%	-27.3%
	-10	8.8%	4.5%	0.0%	-4.7%	-9.6%	-14.7%
	-15	5.0%	2.5%	0.0%	-2.6%	-5.2%	-8.0%
	-20	2.2%	1.1%	0.0%	-1.1%	-2.3%	-3.4%
	-25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	-30	-1.8%	-0.9%	0.0%	0.9%	1.8%	2.7%
	-35	-3.4%	-1.7%	0.0%	1.7%	3.3%	4.9%
	-40	-4.8%	-2.4%	0.0%	2.3%	4.6%	6.8%

For example, Table 7 shows that for a *One-Point* 25 Pa duct airtightness test, a 4.5% error would be introduced if the leakage estimate was determined at an actual test pressure of -10 Pa (**Channel A**), and the actual exponent of the leaks was 0.55 rather than the assumed value of 0.60.

10.5 Unable to Reach a Target Building Pressure During a Multi-Point Test?

If the Duct Blaster fan was unable to achieve the highest target duct pressure (e.g. -35 Pascals) because one of the smallest Flow Rings was installed (e.g. Ring 2 or Ring 3), replace the Flow Ring with a Larger Flow Ring (e.g. Ring 1) and repeat the test. If you were not able to reach the highest target pressure because the duct system is extremely leaky, take your first set of test readings the highest achievable duct pressure. Continue your test by using the remaining target pressures which are less than the highest achievable pressure. Enter these test values into the TECBLAST program to generate your total leakage estimate.

10.6 Before Leaving the Building

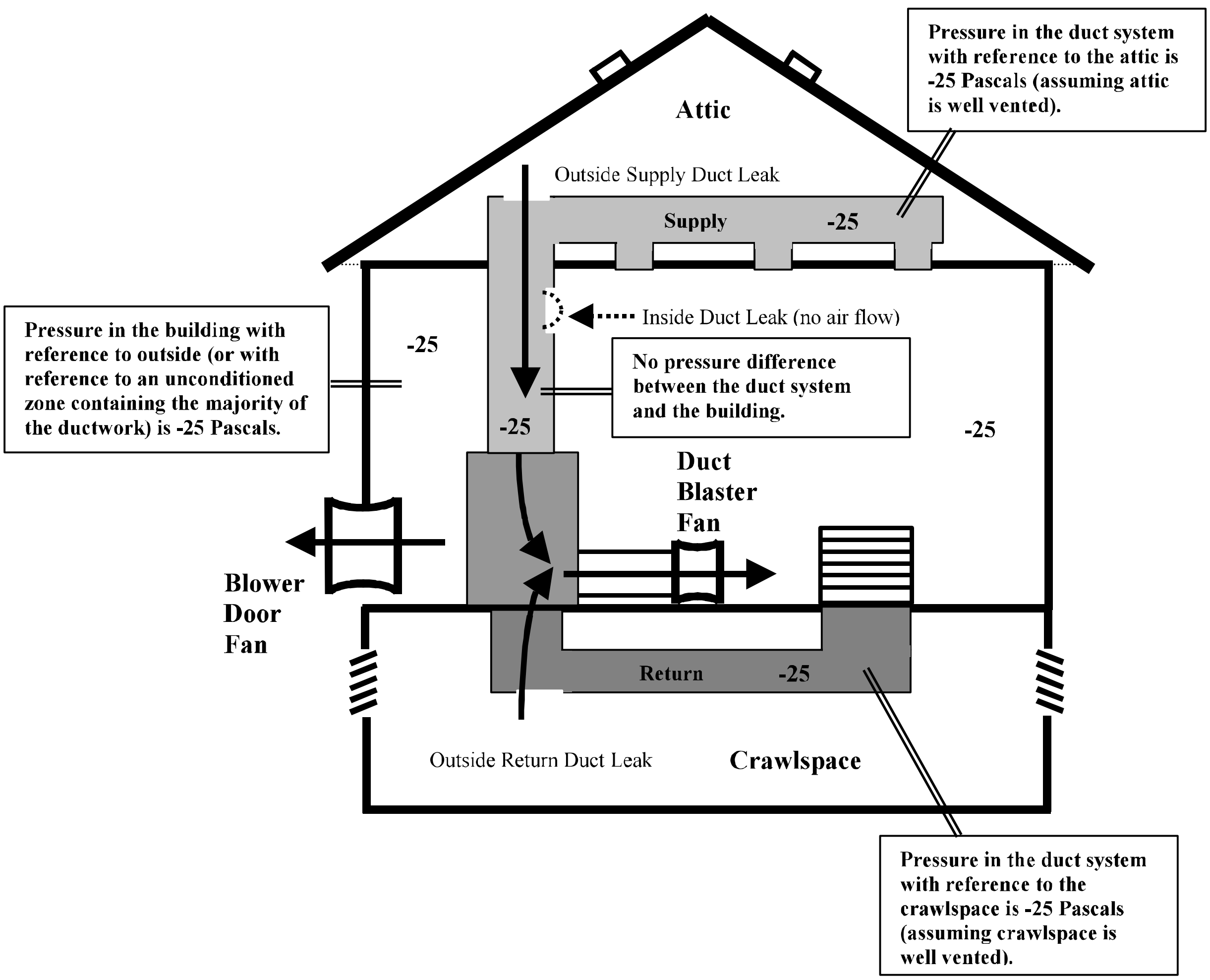
Be sure you have returned the building to its original condition before leaving. This includes removing any temporary register seals, turning HVAC controls to their original settings and closing access doors or vents opened during the test. In addition, it is highly recommended that the test procedures outlined in Chapters 14 and 15 be performed before leaving the building.

Chapter 11 Conducting a Leakage to Outside Depressurization Test

This chapter covers the test procedures for conducting a **Leakage to Outside Depressurization Test**. The Leakage to Outside Test is used to measure the duct leakage rate to the outside of the building only, when the duct system is subjected to a uniform pressure. This test procedure requires simultaneous use of both a Duct Blaster and Blower Door system.

During this test procedure a Blower Door fan will be used to depressurize the building to the test pressure, while the Duct Blaster system is used to depressurize the duct system to the same pressure as the building. Because the duct system and the building are at the same pressure, there will be no leakage between the ducts and building during the leakage rate measurement.

Figure 4: Illustration of Leakage to Outside Depressurization Test
(at a Test Pressure of -25 Pascals)
with Duct Blaster Fan Installed at Air Handler



<u>The air flow through the Duct Blaster fan required to depressurize the duct system to the same pressure as the building (while the Blower Door is depressurizing the building to the test pressure) is the measured duct leakage rate to the outside</u>.

The following instructions assume you have set up the Duct Blaster system for a depressurization test as outlined in Chapter 9 above. Information on how to conduct a Leakage to Outside **Pressurization** Test (i.e. blowing air into the duct system) is discussed in Chapter 7.

Note: It is possible to separately measure supply and return duct leaks by installing a temporary barrier in either the supply or return opening to the air handler cabinet. With a temporary barrier in place, each side of the duct system can be tested independently. It is also possible to separately measure supply and return leakage before the air handler or furnace unit have been installed.

11.1 Final Preparations (Set Up Blower Door in Building)

Install the Blower Door system in a centrally located exterior door, including a gauge to measure building pressure. You will need to prepare the building for a Blower Door test as described in the Blower Door Operation Manual including closing all exterior doors and windows, opening all interior doors, and adjusting combustion appliances to remain off during the test. The Blower Door fan should be set up to depressurize (or blow air out of) the building. Importantly, we will not be measuring air flow through the Blower Door fan during this test procedure. Refer to your Blower Door manual for complete instructions on Blower Door system installation.

11.1.a Building Pressure Measurements:

During the test, you will need to monitor the change in building pressure caused by the Blower Door system. Typically the Blower Door building pressure gauge will be setup to measure building pressure with reference to the outside (this is the typical set up for a Blower Door test).

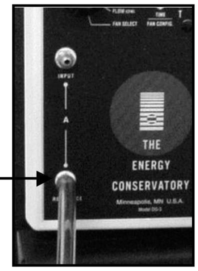
However, if you are testing a duct system that is located primarily in one unconditioned zone (e.g. a single attic or single crawlspace), you have the option of setting up the gauge to measure building pressure with reference to that zone, rather than with reference to outside. The purpose of making this change is to ensure that the duct leaks located in that zone are subjected to the full test pressure.

For example, it is possible that a crawlspace containing most of the ductwork may be significantly depressurized by air being pulled out of that zone from the Blower Door fan (through air leaks between the building and the crawlspace). In this case, you may underestimate the duct leakage rate if you are measuring building pressure with respect to outside during your test because the leaks in the crawlspace ductwork will not be subjected to the full test pressure (i.e. they will be subjected to the test pressure minus the crawlspace depressurization caused by the Blower Door fan). Changing the reference tap on the Blower Door building pressure gauge from outside to the crawlspace would eliminate the underestimation problem in this building.

- *Using a Digital Gauge to Monitor Building Pressure:*

If you are using a separate DG-700 or DG-3 gauge to monitor building pressure, connect the outside building pressure tubing to the **CHANNEL A Reference** tap.

Connect the outside building pressure tubing to the Blower Door **CHANNEL A Reference** tap. The other end of this tubing should either be run to the outside, or to the unconditioned zone which contains the majority of the ductwork.



11.2 Choose the Test Pressure

For the Leakage to Outside Depressurization Test, we will be simultaneously depressurizing the duct system and the building to the same test pressure. For residential duct systems, we generally recommend that -25 Pascals (-0.10 inches w.c.) be used as the test pressure. This pressure has been adopted by the majority of residential duct testing programs in the U.S. because 25 Pascals represents a typical operating pressure seen in many residential systems. In cases where 25 Pascals is not a representative pressure in the duct system being tested, it may be appropriate to use a different test pressure. For example, in small commercial HVAC systems which typically operate at higher duct pressures than residential systems, it may be appropriate to use a test pressure greater than 25 Pascals. In extremely leaky duct systems (e.g. more than 600 cfm of leakage at 25 Pascals), such as duct systems found in many basement style houses, the typical operating pressures in the duct system may be significantly less than 25 Pascals. In this case it may be appropriate to use a test pressure lower than 25 Pascals.

11.3 Leakage to Outside Test Procedures Using the DG-700

The following test procedure covers use of the DG-700 for the Leakage to Outside Test procedure. This procedure assumes that a test pressure of -25 Pascals is being used.

a) Turn on the building pressure gauge and depressurize the building to 25 Pascals.

Turn on the Blower Door building pressure gauge and set it to measure pressure on **Channel A**. Slowly turn on the Blower Door fan and begin to depressurize the building. Increase the Blower Door fan speed until the building is depressurized to the test pressure of -25 Pascals, as measured on the building pressure gauge. In leaky buildings, you may need to remove all Flow Rings from the Blower Door fan in order depressurize the building to the test pressure. Leave the Blower Door fan running.

Note: If the Blower Door pressure gauge and Blower Door fan speed controller are compatible with Cruise Control, use the Cruise Control function to maintain the -25 Pa building depressurization.

b) Turn on the Duct Blaster DG-700 and put it in the proper Mode.

Turn on the gauge by pressing the **ON/OFF** button. Press the **MODE** button once to put the Duct Blaster gauge into the **PR/ FL** mode. The **PR/ FL** mode is a multi-purpose mode used to measure a test pressure on **Channel A** while simultaneously measuring air flow from the Duct Blaster fan on **Channel B**.

c) Choose a Flow Ring for the Duct Blaster fan.

Fan Configuration	Flow Range (cfm) for Series B DB fan
Ring 1	800 - 225
Ring 2	300 - 90
Ring 3	125 - 10

Install the Flow Ring which you think best matches the needed fan flow. Installation of Flow Rings will depend on the tightness level of the duct system being tested. For example, for relatively leaky duct systems (greater than 500 CFM25), you will want to start the test using the Ring 1 configuration. As you test tighter duct systems, you will need to install Flow Rings 2 or 3. Refer to the Table to the right for approximate flow ranges of the fan using the various Flow Rings configurations. Don't worry if you guess wrong and start the test with the incorrect Flow Ring - you can change the Fan Configuration during the test procedure.

d) Enter the selected Flow Ring into the Gauge.

In order for the DG-700 to properly display fan flow, you need to input the Duct Blaster fan model and selected Flow Ring into the gauge. Check, and adjust if necessary, the selected test Device (i.e. fan) and Configuration (i.e. Flow Ring) shown in the upper part of the gauge display to match the fan and Flow Ring being used in the test.

Press the **DEVICE** button to change the selected Duct Blaster fan.

Device Icon

DB A Series A Duct Blaster fan **DB B** Series B Duct Blaster fan

Once the fan is selected, the configuration of the fan can be selected by pressing the **CONFIG** button. The currently selected Flow Ring configuration is shown in the Config section of the gauge display.

Config Icon

OPEN No Flow Ring (**Note:** When depressurizing, a Flow Ring must be installed.)
A1 Ring 1
B2 Ring 2
C3 Ring3

Also be sure that **Channel B** is showing the proper air flow units for your test (this should typically be set to **CFM**). Units can be changed by pressing the **UNITS** button.

e) With the Blower Door fan continuing to run, turn on and adjust the Duct Blaster fan.

If Manually Controlling the Duct Blaster Fan:

Turn on the Duct Blaster fan controller and slowly turn the fan controller knob clockwise. Increase the fan speed until the pressure between the duct system and the building (displayed on **Channel A**) reads zero.

If Using Cruise Control for the Duct Blaster Fan:

Turn the Duct Blaster speed controller to the "just on" position (i.e. turn the controller knob all the way down counter-clockwise and flip the on/off switch to "ON" – the fan will not be turning). Now press the **Begin Cruise (Enter)** button. The **Channel A** display will now show the number 50 (the default target Cruise pressure). Press the **Cruise Target (Config)** button three times to change the target Cruise pressure to -0. Press the **Start Fan (Start)** button. The Duct Blaster fan will now slowly increase speed until the pressure between the duct system and the building (displayed on **Channel A**) reads zero.

f) Re-check the building pressure.

Re-check the building pressure gauge and if necessary, re-adjust the Blower Door fan speed to maintain a test building pressure of -25 Pascals. **Note:** If the Blower Door fan is being controlled by Cruise Control, skip to step **g)** below.

g) Re-check the duct pressure.

If you are manually controlling the Duct Blaster fan, re-check the Duct Blaster system and if necessary, re-adjust the Duct Blaster fan until the pressure between the duct system and the building reads zero (**Channel A** on the Duct Blaster DG-700).

Channel B on the Duct Blaster DG-700 will now display the CFM25 leakage to outside estimate. If the leakage estimate is fluctuating more than desired, try changing the Time Averaging setting on the gauge by pressing the **TIME AVG** button and choosing the ***5*** or ***10*** second or ***Long-term averaging*** period. Record the CFM25 leakage to outside estimate and turn off both the Blower Door and Duct Blaster fans.

(If "LO" appears on **Channel B**, see below).

Whenever "**LO**" appears on **Channel B** in the **PR/ FL** Mode, the DG-700 can not display a reliable fan flow reading. The message "**LO**" appears on **Channel B** under the following two conditions:

- "LO" is continuously displayed when there is negligible air flow through the test device.
- "LO" alternates with a flow reading when the air flow reading through the device is unreliable (i.e. you are trying to measure a flow outside of the calibrated range of the test device in its current configuration). If possible, you should change the test device configuration to match the flow rate being measured (e.g. install a Flow Ring or a smaller Flow Ring).

Note: If you change the Flow Rings on the fan, be sure to change the Configuration setting on the gauge to match the installed Ring.

11.4 What If You Can Not Depressurize the Building to the Test Pressure with the Blower Door Fan?

If the Blower Door system is unable to depressurize the building to the test pressure because one of the Flow Rings was installed on the Blower Door fan, remove the Flow Ring and repeat the test. If you are not able to depressurize the building to the test pressure because the building is too leaky, then you will need to conduct the test at the highest achievable building pressure and use the Can't Reach Pressure Factors below to estimate the final duct leakage rate.

Table 8: Can't Reach Pressure Factors (-25 Pa Target)

Duct Pressure (Pa)	CRP Factor	Duct Pressure (Pa)	CRP Factor
-24	1.02	-14	1.42
-23	1.05	-13	1.48
-22	1.08	-12	1.55
-21	1.11	-11	1.64
-20	1.14	-10	1.73
-19	1.18	-9	1.85
-18	1.22	-8	1.98
-17	1.26	-7	2.15
-16	1.31	-6	2.35
-15	1.36	-5	2.63

<u>Example:</u> With the Blower Door fan running at full speed (& no Flow Rings attached), you are only able to depressurize the building to 18 Pascals. While the Blower Door is depressurizing the building to 18 Pascals, adjust the Duct Blaster fan to create zero pressure between the duct system and the building. At this point the measured Duct Blaster fan flow is 450 cfm. The corresponding CRP Factor for a building pressure of 18 Pascals is 1.22. The estimated duct leakage to outside at a test pressure of -25 Pascals is 450 x 1.22 = 549 cfm.

$$\text{Can't Reach Pressure Factor} = \left\{ \frac{25}{\text{Current Test Pressure (Pa) (Channel A)}} \right\}^{0.60}$$

Note: The TECBLAST program automatically applies the CRP Factors to test data.

<u>11.5 What If You Can Not Depressurize the Duct System to the Same Pressure as the Building with the Duct Blaster Fan?</u>

If the Duct Blaster fan was unable to create a pressure difference of zero between the duct system and the building (while the Blower Door is depressurizing the building to the test pressure) because one of the smallest Flow Rings was installed (e.g. Ring 2 or Ring 3), install Ring 1 and repeat the test. If you were not able to create a pressure difference of zero because the duct system is extremely leaky to the outside, then the test will need to be performed at a lower building pressure and the Can't Reach Pressure Factors (Table 8) used to estimate the final duct leakage rate.

> *<u>Example:</u> Because you were unable to create a pressure difference of zero between the duct system and the building, re-adjust the Blower Door to depressurize the building to a lower pressure (e.g. -20 Pascals). While the Blower Door is running, adjust the Duct Blaster fan to create a pressure difference of zero between the duct system and the building. If you are still unable to create a pressure difference of zero, repeat the test at an even lower building pressure (e.g. -15 Pascals). Finally, multiply the flow through the Duct Blaster fan needed to create a pressure difference of zero by the appropriate CRP factor.*

For example, with the Blower Door depressurizing the building to -15 Pascals, the flow through the Duct Blaster fan needed to create a pressure difference of zero (between the duct system and the building) is 600 cfm. The corresponding CRP Factor for a building pressure of -15 Pascals is 1.36. The estimated duct leakage to outside at a test pressure of -25 Pascals is 600 x 1.36 = 816 cfm.

Note: The TECBLAST program will automatically apply the CRP Factors to test data.

11.6 Before Leaving the Building

Be sure you have returned the building to its original condition before leaving. This includes removing any temporary register seals, turning HVAC controls to their original settings and closing access doors or vents opened during the test. In addition, it is highly recommended that the test procedures outlined in Chapters 14 and 15 be performed before leaving the building.

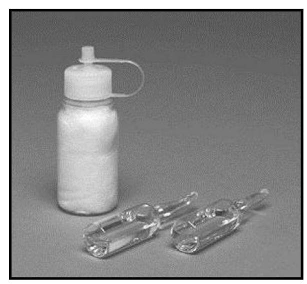
Chapter 12 Finding Duct Leaks

12.1 Using a Theatrical Fog Machine

One of the most effective ways to find leaks in a duct system is to use a theatrical fog machine while **pressurizing** the duct system with the Duct Blaster fan. With the registers and grilles temporarily sealed off, the fog machine is used to inject a non-toxic theatrical fog through the Duct Blaster fan and into the duct work. The theatrical fog is pushed out of the leakage sites in the duct system visually demonstrating the location and extent of the duct leakage problem. Use of the fogger helps crews find hidden leakage sites in attic and crawlspace ducts, as well as makes a fantastic presentation for homeowners and builders. Theatrical fog machines are available from many local theatre supply and electronics outlets.

Note: Typically only a small amount of smoke is needed to create a good presentation. When using a theatrical fogger, inject the fog stream toward the edge of the fan housing and not directly into the Duct Blaster fan motor. In addition, always clean off any theatrical fog residue from the Duct Blaster flow sensor, fan motor and fan housing after using a fog machine. **Importantly, use only non-corrosive glycol/water based fog fluid products with the Duct Blaster fan. Use of corrosive fog fluid or smoke bomb products will damage the fan and void your warranty.**

12.2 Using a Handheld Smoke Puffer



The use of a handheld smoke puffer is often helpful in finding duct leaks. With the building air handler running, squirt small puffs of smoke toward suspected leakage sites and watch to see if the smoke gets sucked into the leak (return leak) or pushed away from the leak (supply leak). With a piece of tubing attached to the smoke puffer, you can often reach deep into corners or in hard to reach spots. Handheld smoke puffers are available from The Energy Conservatory.

Note: Smoke from the chemical puffer is very corrosive. Do not inject smoke from this product into the Duct Blaster fan, or store the puffer in a closed container with other items, especially tools or gauges.

Chapter 13 Using the Duct Blaster as a Powered Capture Hood

In addition to measuring duct airtightness, the Minneapolis Duct Blaster can be used as a powered capture hood to measure total air handler flow, as well as air flows through supply and return registers, exhaust fans and other air flow devices.

13.1 Measuring Total System Air Flow (Pressure Matching Method)

This procedure is used to measure total air flow through an air handler. **Note:** If you are using a DG-700, the gauge has a built-in mode (**PR/ AH**) which can be used for making measurements of total air handler flow with a Duct Blaster fan. Refer to the DG-700 manual for specific operating instructions.

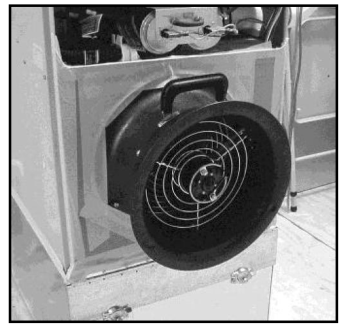
Part 1: Measure the Normal System Operating Pressure (NSOP)

- Turn off the air handler fan.
- Open a window or door between the building and outside to prevent pressure changes in the building during the test.
- If the air handler fan is installed in an unconditioned zone (e.g. crawlspace, attic), open any vents or access doors connecting that zone to the outside (or to the building) to prevent pressure changes in the zone during the test.
- Make sure all supply and return registers are open and untapped. Replace filters if they are dirty (or keep dirty filters in place if you want to measure flow in a "as found" condition).
- Insert a static pressure probe into the supply plenum, or in a main supply trunk line a few feet away from the supply plenum. Make sure the static pressure probe is pointing into the air flow created by the air handler fan.
- Connect a piece of tubing to the static pressure probe. Connect the other end of the tubing to the **Channel A Input** tap on the digital pressure gauge.
- The **Channel A Reference** tap should be connected to the inside of the building, or it can be connected to an unconditioned zone containing the air handler provided that the zone remains at the same pressure as the building during the test.
- Turn on the air handler and measure the Normal System Operating Pressure (**NSOP**) in the duct system using **Channel A**. If the **NSOP** is fluctuating too much to determine the reading, try using the ***5*** or ***10*** second or ***L***ong-term time average setting on the gauge. Record the **NSOP** and turn off the air handler. Do not move the static pressure probe because you will need to use it in Part 3 of this test.

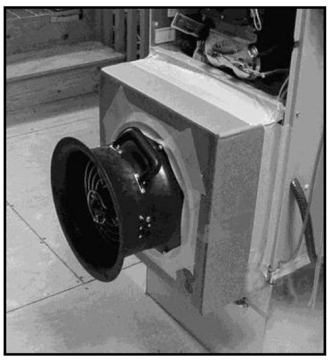
Part 2: Connect the Duct Blaster Fan to the Duct System

The Duct Blaster fan is typically installed at the air handler cabinet. However, if this test is being performed on a single return duct system, and the return ductwork is substantially airtight, the Duct Blaster fan may be installed at the single return.

Option 1: Installing at the Air Handler Cabinet



- Open the air handler cabinet access panel. Seal off the return opening in the cabinet from the air handler fan using tape and cardboard.
- Now install the Duct Blaster in place of the air handler cabinet access door as described in ***Section 5.2.b Option 2***. In this configuration, all return air flow will be moving through the Duct Blaster fan, with the return ductwork effectively sealed off from the supply system.
- Connect a piece of tubing to the brass pressure tap on the Duct Blaster fan housing. Connect the other end of the tubing to the **Channel B Input** tap.
- The **Channel B Reference** tap should be connected to the space where the Duct Blaster fan is installed. If the Duct Blaster fan and gauge are located in the same space, leave the **Channel B Reference** tap open.



Note: If the air flow exiting from the Duct Blaster is severely obstructed by the air handler fan or other air handler components, this may significantly reduce the total flow capacity of the Duct Blaster. If this is a problem, try attaching the Duct Blaster fan to the blower compartment access opening using a small cardboard box rather than a flat piece of cardboard. This will tend to increase the Duct Blaster fan flow by providing less restriction to air flow as it enters the air handler blower compartment.

Option 2: Installing at the Single Central Return

- An optional 20" x 20" filter grille attachment panel is available from TEC to provide for quick attachment of the Duct Blaster fan to the filter slot of a single return.
- To use the attachment panel, first open the filter grille door, remove the existing filter, and push the attachment panel into the open filter slot. The H-channel gasket on the edges of the attachment panel should provide an airtight seal between the panel and the filter slot, and should hold the panel in place.
- You may now secure the Duct Blaster fan directly to the attachment panel using the 4 clips mounted on the panel. The clips are pushed down onto the exhaust flange of the Duct Blaster fan.

Note: The Duct Blaster fan can also be attached to the filter slot using cardboard and tape.

Part 3: Match the Normal System Operating Pressure (NSOP)

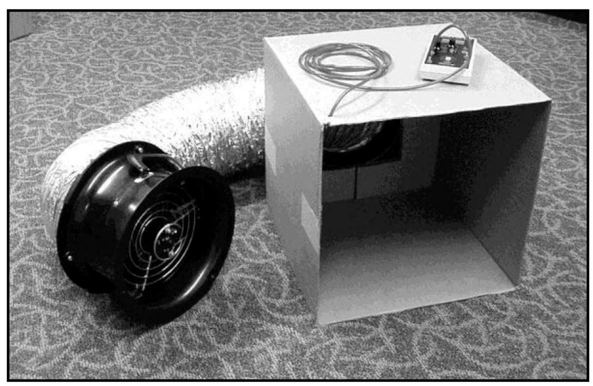
- Turn the air handler fan back on and re-measure the operating duct pressure using **Channel A** (be sure the static pressure probe has not been moved from **Part 1** above). Now turn on the Duct Blaster fan and adjust the fan speed until the operating duct pressure on **Channel A** equals the normal operating duct pressure (**NSOP**) measured in **Part 1** above. Once adjusted in this way, determine the air flow through the Duct Blaster fan by measuring the fan pressure on **Channel B** and using the flow table, or by using the digital gauge's fan flow feature.
- The measured Duct Blaster fan flow is your estimate of the total system air flow including flow through return registers, plus return duct leakage, plus leakage at the air handler access panel. The only component of total system airflow that is not included in this measurement is any leakage on the return side of the air handler cabinet (other than the air handler access panel).

13.2 Measuring Return Register and Exhaust Fan Flows

The first step is to construct a flow box to seal around the return register (or exhaust fan) where you want to make your measurement. One easy option is to use a cardboard box, but the hood from a commercial flow capture hood may also work well. The open end of the flow box or hood should have rough dimensions which are at least 2 times the register dimensions, and the depth of the box should be at least the average of the two opening dimensions.

Part 1: Construct a Flow Box and Make Tubing Connections

- Cut a square hole in the back side of cardboard flow box which is approximately one inch smaller than the dimensions of the square transition piece. Tape and seal the square transition piece over the hole you cut in the box.
- Attach the open side of the round transition piece to the exhaust flange of the Duct Blaster. Connect the open end of the flex duct to the square transition piece on the flow box.
- Install the Flow Ring (on the fan inlet) which you think will provide the proper flow range for the test.
- Punch a small hole (1/4") in one of the corners of the open end of the box and insert a piece of tubing into the hole. Connect the other end of the tubing to the **Channel A Input** tap. The **Channel A Reference** tap should be left open to the room where the register or exhaust fan is located.



- Connect a piece of tubing to the brass pressure tap on the Duct Blaster fan housing. Connect the other end of the tubing to the **Channel B Input** tap.
- The **Channel B Reference** tap should be connected to the space where the Duct Blaster fan is installed. If the Duct Blaster fan and gauge are located in the same space, leave the **Channel B Reference** tap open.

Part 2: Install Flow Box and Zero Out the Box Pressure

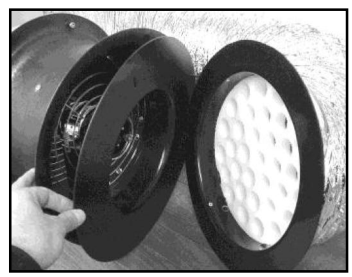
- Turn on the air handler fan (or exhaust fan), and place the flow box tightly over the return register (or exhaust fan grill). If the wall or ceiling surface is very uneven, you may want to attach a piece of gasket to the open end of the flow box to make a tighter seal - The Energy Conservatory has gasket available.
- Now turn on the Duct Blaster fan and slowly adjust the fan speed until the pressure on **Channel A** (the pressure difference between the flow box and the room) equals zero. Once adjusted in this way, determine the flow through the Duct Blaster fan by measuring the fan pressure on **Channel B** and using the flow table, or by using the digital pressure gauge's fan flow feature.
- The Duct Blaster fan flow at this point is your estimate of air flow through the return register (or exhaust fan) tested.

Note: The Energy Conservatory manufactures an Exhaust Fan Flow Meter which will measure exhaust fan flow rates up to 120 cfm with an accuracy of 10%.

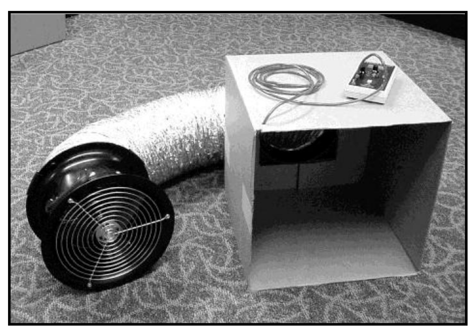
13.3 Measuring Supply Register Flows

As in measuring return register flows, you will need to construct a flow measuring box for this method. One easy option is to use a cardboard box, but a hood from a commercial flow capture hood may also work well. The open end of the flow box or hood should have rough dimensions which are at least 2 times the register dimensions, and the depth of the box should be at least the average of the two opening dimensions.

Part 1: Construct a Flow Box and Make Tubing Connections



- Cut a square hole in the back side of cardboard flow box which is approximately one inch smaller than the dimensions of the square transition piece. Tape and seal the square transition piece over the hole you cut in the box.
- Insert the white foam flow conditioner into the round transition piece. Attach the open side of the round transition piece, along with one of the Flow Rings, to the inlet flange of the Duct Blaster fan. Use the Flow Ring which you think will provide the correct flow range. Connect the open end of the flex duct to the square transition piece on the flow box.



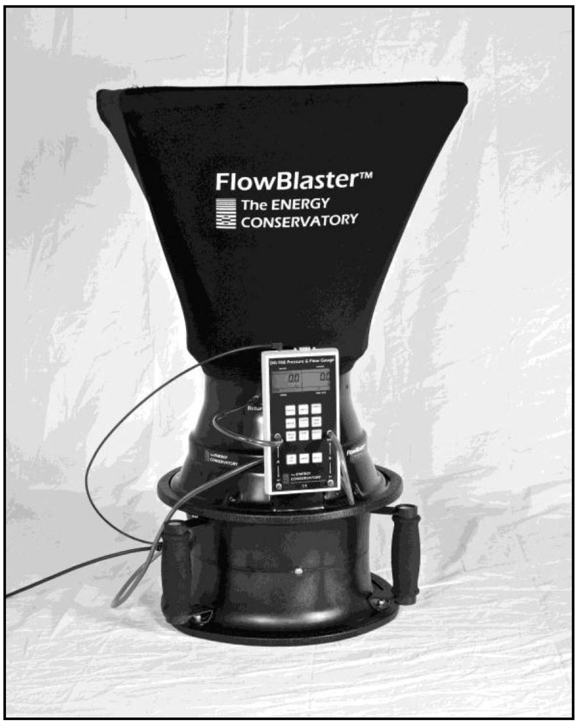
- Punch a small hole (1/4") in one of the corners of the open end of the box and insert a piece of tubing into the hole. Connect the other end of the tubing to the **Channel A Input** tap. The **Channel A Reference** tap should be left open to the room where the register or exhaust fan is located.
- Connect a piece of tubing to the brass pressure tap on the Duct Blaster fan housing. Connect the other end of the tubing to the **Channel B Input** tap.
- The **Channel B Reference** tap should be connected to the plastic pressure tap on the round transition piece using an additional piece of tubing.

Part 2: Install Flow Box and Zero Out the Box Pressure

- Turn on the air handler fan and place the flow box tightly over the supply register. If the wall or ceiling surface is very uneven, you may want to attach a piece of gasket to the open end of the flow box to make a tighter seal **-** The Energy Conservatory has gasket available.
- Make sure that flex duct is stretched relatively straight (for about 4 feet) where the flex duct is connected to the Duct Blaster fan.
- Now turn on the Duct Blaster fan and slowly adjust the fan speed until the pressure on **Channel A** (the pressure difference between the flow box and the room) equals zero. Once adjusted in this way, determine the flow through the Duct Blaster fan by measuring the fan pressure on **Channel B** and using the flow table, or by using the digital gauge's fan flow feature.
- The Duct Blaster fan flow at this point is your estimate of air flow through the supply register tested.

13.4 The FlowBlaster™ Capture Hood Accessory

Beginning January 2012, the FlowBlaster Capture Hood Accessory is available to accurately measure supply, return and exhaust flows from 10 to 300 CFM. The FlowBlaster works by adding necessary flow conditioning and then precisely adjusting the speed of the Duct Blaster fan to compensate for the pressure loss through the conditioners. The FlowBlaster uses your existing Duct Blaster fan and DG-700 gauge, along with a new combination fan speed controller and rechargeable Lithium-Ion battery. Set the DG-700 to Cruise, place the FlowBlaster over the register/grille and the fan will automatically adjust to read the correct value. Contact TEC for more information on the FlowBlaster Capture Hood Accessory.



Chapter 14 Pressure Balancing and System Performance Testing

14.1 Testing for Pressure Imbalances Caused By Forced Air System Flows

Air handler fans commonly move 500 to 2,000 cubic feet of air per minute (CFM). Pressure imbalances within the building can be caused by air hander fan operation if supply and return air flows to each part of the building are not in balance. Pressure imbalances within the building can significantly increase infiltration rates, contribute to radon and moisture entry, create durability problems, and cause potential combustion appliance spillage and backdrafting. In addition, research on combustion appliances has found that very small negative pressures (as low as 2 Pascals) can cause spillage and backdrafting in natural draft appliances.

Building pressure imbalances can also be caused by duct leakage to the outside. If either the supply or return air ductwork has leaks to the outside, air will be forced through these leaks when the air handler fan is operating. If the leaks are in the supply ducts, building air will be exhausted to the outside through the leaks and this will tend to depressurize the building. If the leaks are in the return system, outside air will be sucked into the leaks and the building will tend to be pressurized. If there are equal amounts of leakage in both the supply and return, no change in building pressure will occur, even though large energy losses may result.

Below are a set of test procedures used to help identify pressure imbalances caused by leaks between the duct system and the outside, and by imbalanced supply and return air flows throughout a building. These tests are very sensitive to wind effects, and on windy days it can be very difficult to get accurate results.

14.1.a Dominant Duct Leak Test:

This test measures whole building pressurization or depressurization caused by duct leakage to the outside during operation of the air handler fan. A pressure change due to duct leakage can cause safety, durability, comfort, and efficiency problems.

- Be sure all exterior doors and windows in the building are closed. Replace all HVAC filters (be sure they are clean). Open all interior doors and check that all exhaust fans and the air handler fan are off.
- Set up the digital pressure gauge to measure the building pressure With Respect To (WRT) outside. Connect tubing from the bottom (Reference) pressure tap on **Channel A** to the outside. The **Channel A** input tap should remain open to the building. Set up the gauge to measure pressures.
- Turn on the air handler fan and record the change in building pressure caused by operation of the fan. **Note:** The DG-700 gauge has a built-in "Baseline" feature which makes it easy to zero out the existing building baseline pressure and display the actual change in building pressure caused by turning on the air handler fan. See the DG-700 manual for specific operating instructions.
- Repeat this test several times by turning the air handler on and off for better certainty.

- Greater leakage on the return side of the duct system will cause the building to become pressurized since the return ductwork is drawing outside air into the ductwork. In this case, there will be a positive reading on pressure gauge. The size of the pressure change will depend on both the amount of imbalanced duct leakage and the tightness of the building being tested (see Figure 5 in Chapter 15).

- Greater leakage on the supply side of the system will cause the building to become depressurized since the supply ductwork is exhausting building air to the outside, just like an exhaust fan. In this case, there will be a negative reading on the pressure gauge. The size of the pressure change will depend on both the amount of imbalanced duct leakage and the tightness of the building being tested (see Figure 5 in Chapter 15).

In cold climates, pressurizing a building to even 1 Pascal could lead to moisture problems caused by forcing warm, moist air into the walls and attic where it can condense on cold surfaces. In warm humid climates, depressurization by 1 Pa can also cause severe moisture problems from warm moist outside air being drawn into the walls where it can condense on the backside of cooled gypsum board. If there are natural draft combustion appliances, or if radon is a problem, depressurizing a building by as little as 2 Pascals may also be a problem.

If there is no change in building pressure, this means that there is either equal supply and return leakage to the outside, no leaks to the outside, or the building itself is too leaky for the imbalanced duct leakage to create a measurable pressure change.

Note: For APT users, a prototype software program called ONOFF is available to help precisely measure small changes in building or room pressures. The program uses a signal averaging technique which significantly reduces noise, particularly in windy weather, allowing for precise measurement of small pressure changes. Contact The Energy Conservatory for more information.

14.1.b Master Suite Door Closure:

This test measures the effect of closing the master suite door on the pressure in the main body of the building. The master bedroom is often the largest room in a building and can contain multiple supply registers while having no returns. Closing of bedroom doors can restrict the supply air pathway back to the air handler, causing bedrooms to become pressurized while other parts of the building may become depressurized. Repeat this test for other building areas that contain large numbers of registers and can be closed off from the main body of the building with one door (e.g. a basement door when the basement has supply registers).

- Keep the gauge set up to measure the pressure between the main body of the building WRT outside.
- With air handler still running, close the master suite door.
- Record the pressure change caused by closing the master suite door. (Large impacts from Master Suite Door Closure are most common in single and double return houses.)
- Consider pressure relief if the Master Suite door is frequently closed and causes the pressure in the main body of the building to change by 1 Pascal or more in either direction.

14.1.c All Interior Doors Closed:

This test measures the added effect of closing all interior doors on the pressure in the main body of the building.

- Keep the gauge set up to measure the pressure between the main body of the building WRT outside.
- With the air handler still running, close all interior doors.
- Record the pressure change caused by closing all interior doors.
- Consider pressure relief if closing all the doors causes the pressure in the main body of the building to change by 2 Pascals or more in either direction.

14.1.d Room to Room Pressures:

This test measures the pressure difference between each room in the building and the main body, with the air handler operating. Excessive pressurization in rooms can create durability problems by driving moisture into walls, ceilings and floors. Excessive depressurization in rooms can pull outside moisture into building components in humid climates. Pressure imbalances can also lead to large increases in building infiltration rates.

- Close all interior doors and walk around the building with the digital pressure gauge.
- Connect a piece of tubing to the **Channel A** Input tap and leave the **Channel A** Reference tap open to the room.
- While standing in the main body of the building, place the open end of the tubing under each door (including the combustion appliance room and/or basement).
- Record the pressure difference from each room WRT the main body.
- Consider pressure relief for any rooms pressurized or depressurized by 3 Pa or more with respect to the main body of the building.

Note: If there are combustion appliances in a depressurized area (i.e. fireplaces, furnace or water heater), their ability to draft properly may be affected. Try to eliminate all depressurization in combustion appliance zones by finding and sealing leaks in the return ducts, plenum, filter access door and air handler cabinet, or by providing pressure relief. See Chapter 15 for more information on Combustion Safety Testing procedures.

14.2 System Performance Testing

Although not covered in this manual, other important test procedures should be performed whenever repairs and changes are made to the duct system.

14.2 a Total System Air Flow:

The air flow rate through air handlers is a very important variable in estimating and optimizing the performance of heat pumps, air conditioners and furnaces. Many studies of residential systems have shown low air flow to be a common problem. **In addition, sealing duct leaks will commonly result in reduced total system air flow, especially if the duct system is sized improperly.**

There are a number of methods to measure total system air flow including the Duct Blaster® pressure matching method (see Chapter 13), the temperature rise method, system static pressure and fan curve, as well as a new direct flow measuring tool (TrueFlow™ Air Handler Flow Meter) available from TEC. If the duct system is substantially airtight, directly measuring supply or return air flows with a calibrated flow capture hood may also be used to estimate total system airflow.

Note: Research has shown that in most cases, the temperature rise, fan curve and flow capture hood methods are much less accurate than either the Duct Blaster or TrueFlow methods.

14.2.b System Charge:

Having the proper amount of refrigerant installed in a heat pump or air conditioning system is another critical variable in determining system efficiency, as well the longevity of the system compressor. Numerous studies have shown the incorrect amount of system charge to be a common installation problem.

14.2.c Airflow Balancing:

Verification that proper air flow is being delivered to each room in a building is another important component of a complete system assessment. Air flow rates are commonly measured using a calibrated flow capture hood.

Chapter 15 Combustion Safety Testing

15.1 Overview

Buildings with natural draft combustion appliances should be routinely tested to ensure that the spillage of combustion products into the building is unlikely. Combustion safety testing is critical because of the potential for severe health effects from improperly venting appliances, including carbon monoxide poisoning.

Spillage of combustion products into the building can be caused by a variety of conditions including:

- Blocked or partially blocked chimneys, vents, or vent connectors.
- Improper equipment installation.
- Cracked heat exchangers.
- Leaks in the venting system (disconnected flue pipes, open cleanest door etc.).
- Low vent temperatures.
- Combustion appliance zone depressurization. As buildings are made tighter, it becomes easier for exhaust fans and forced air system imbalances to create potentially hazardous depressurization conditions.

Many cases of improperly venting combustion appliances have been related to depressurization (or negative pressures) in the room that contains the combustion appliance. Depressurization can be caused by exhaust fans, dryers, imbalanced forced air distribution systems, and forced air system duct leakage. As buildings (or combustion appliance rooms) are made tighter, these problems can be made worse, although very leaky buildings can also have venting problems related to depressurization. Figure 5 below estimates the amount of depressurization that can be caused by various exhaust fan flows. For example, from Figure 5 we can see that a 400 cfm exhaust fan will depressurize a 2,500 CFM50 building (or room) to approximately 3 Pascals. That same 400 cfm fan would produce over 10 Pascals of depressurization in a 1,000 CFM50 building.

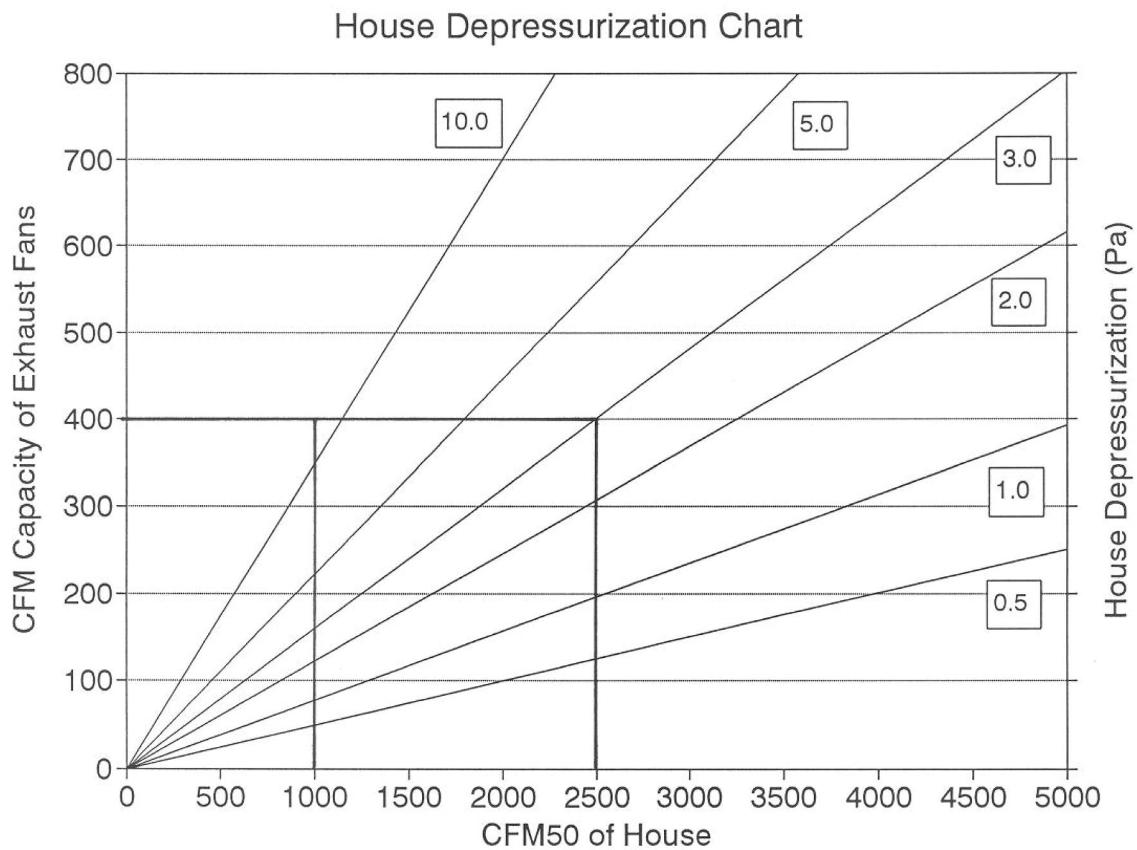
The presence of code approved combustion air intakes does not ensure that venting problems will not occur. Significant combustion room depressurization is frequently found even after code approved combustion air intakes have been installed. Passive combustion room air intakes typically do not provide sufficient airflow to relieve negative pressures caused by distribution imbalances, duct leakage, or large exhaust appliances. For example, a typical 6" passive inlet can at best supply only about 50 cfm at a 5 Pa negative building pressure. And because passive air intakes are often poorly installed (i.e. many sharp bends, long runs), they typically provide much lower flows than designed. Building codes typically give little or no guidance on how one would design a combustion air opening when competing exhaust appliances are present (the 2000 Minnesota Energy Code is the only code we are aware of to give such guidance).

The only way to be reasonably sure that venting problems will not occur in a building is to perform combustion safety tests. Described below is a test procedure designed to locate existing or potential combustion safety problems in buildings. **These procedures are offered only as an example of what other organizations in North America typically recommend for testing. The Energy Conservatory assumes no liability for their use, and contractors should have a working knowledge of local codes and practices before attempting to use the procedures outlined below.**

If combustion safety problems are found, tenants and building owners should be notified immediately and steps taken to correct the problem including notifying a professional heating contractor if basic remedial actions are not available. Remember, the presence of elevated levels of carbon monoxide in ambient building air or in combustion products is a potentially life threatening situation. **Building or duct sealing work should not be undertaken until existing combustion safety problems are resolved, or unless air sealing is itself being used as a remedial action.**

ATTACHMENT FOUR

Figure 5



This chart can be used to estimate the amount of house depressurization caused by operating exhaust fans. To use the chart, find the intersection between the airtightness (CFM50) of the house and the cfm capacity of the exhaust fans in question. The amount of depressurization caused by the fan(s) is read off the diagonal house depressurization lines. For example, a 400 cfm kitchen range hood operating in a house with an airtightness level of 2,500 CFM50 would depressurize the house by approximately 3 Pa relative to the outside. This same fan operating in a 1,000 CFM50 house would produce over 10 Pa of depressurization.

Note: This chart was generated by assuming that all houses have a "House Leakage Curve" with an exponent (or slope) of n = 0.65,

15.2 Test Procedures

This procedure is not intended to cover all circumstances you will find in the field. A basic understanding of the dynamic interactions between building pressures, air flow and mechanical system operation is required to fully utilize the procedures presented below.

15.2.a Measure Ambient CO Level in Building:

- Zero your digital CO tester outside before entering the building. CO tester should have 1 PPM resolution.
- Measure the ambient CO level in all occupied areas of the building. Be sure to measure ambient CO levels in kitchens and in combustion appliance rooms.
- Investigate any ambient CO levels above 2 ppm. **Note:** Areas close to very busy streets may have ambient CO levels above 2 ppm.
- Maximum CO concentration guidelines:
  9 ppm for 8 hour exposure (EPA)
  35 ppm for 1 hour exposure (EPA)
  200 ppm single exposure (OSHA)

<u>CO concentrations at or above these levels requires immediate remedial action.</u>

15.2.b Survey of Combustion Appliances:

- Walk through the building and survey all combustion appliances including furnaces, water heaters, fireplaces, woodstove and auxiliary heating units, dryers and cooking stoves.
- Write down the following information on a survey form:

  - Location, type and input of combustion appliances.
  - Signs of visible deterioration and leaks in flue pipes and connections.
  - Presence of gas leaks, signs of spillage or flame roll-out.
  - Location, size and operable condition of combustion air supply(s).
  - Evidence of rusted interior surfaces of heat exchangers.

<u>Gas or fuel leaks are a very serious safety problem requiring immediate remedial action.</u>

15.2.c Survey of Exhaust Fans:

- Walk through building and note the location and rated capacity (or estimated capacity) of all exhaust fans including kitchen and stove fans, bath fans, dryers, whole house vacuum systems, attic vent fans (not including whole house ventilation fans) etc.

15.2.d Measure Worst Case Fan Depressurization:

With this test procedure, the goal is to measure worst case depressurization in all combustion rooms with natural draft appliances and fireplaces. This measurement gives us an indication of the likelihood of exhaust and air handler fans causing the combustion appliances to backdraft and spill. The procedures below measure worst case depressurization under 3 separate operating conditions; running exhaust fans only, running exhaust and air handler fans, and running the air handler fan only. These tests are very sensitive to wind effects, and on windy days it can be very difficult to get accurate results.

Initial Preparation

Close all exterior windows and doors and be sure furnace, water heater and other vented combustion appliances are off. Close all interior doors. Set up the digital gauge to measure the pressure difference of the combustion appliance zone (CAZ) with reference to (WRT) outside. Record the existing baseline building pressure. **Note:** The DG-700 gauge has a built-in "Baseline" feature which makes it easy to zero out the existing building baseline pressure and display the actual change in building pressure caused by fan operation. See the DG-700 manual for specific operating instructions.

1. Exhaust Fans Only

Turn on all exhaust fans found in the survey above (for dryer, clean out lint filter before turning on). Now determine the worst case position of interior doors with the smoke test below:

> ***Smoke Test:*** While standing in the main body of the building, squirt smoke under each door containing an exhaust fan (except the CAZ currently being tested). If the smoke goes into the room, open the door. If the smoke comes back into the main body of the building, keep the door closed. Now squirt smoke under the CAZ door (while continuing to stand in the main body). If smoke goes into the CAZ, leave the CAZ door shut. If smoke comes back into the main body of the building, open the door.

Measure the depressurization of the CAZ WRT outside caused by turning on the exhaust fans (i.e. the change in building pressure from the baseline condition). Depressurization should not exceed the appropriate House Depressurization Limits (HDL) listed in Table 9 below. If it is windy, it is often necessary to turn fans off and on several times to obtain good pressure readings.

> ***Fireplace Zones:*** For Fireplace Zones, repeat the same procedure and measure and record depressurization of fireplace zone WRT outside from exhaust fan operation. Depressurization should not exceed the appropriate HDL listed below.

2. Air Handler and Exhaust Fans

With exhaust fans continuing to run, turn on the air handler fan (note: air handler fan only, do not turn on burner) and close any supply registers in combustion appliance room. For both CAZ and Fireplace Zone tests, re-determine worst case position of all interior doors with the smoke test described above. If cooling is available, be sure air handler fan is running at high speed. Repeat worst case depressurization measurements.

3. Air Handler Fan Only

Turn off all exhaust fans and leave air handler operating (if cooling is available, be sure air handler is running at high speed). For both CAZ and Fireplace Zone tests, re-determine worst case position of all interior doors with the smoke test described above. Repeat worst case depressurization measurements.

> ***If the HDL are exceeded for any of the worst case depressurization tests above, pressure relief is needed***. Pressure relief could include duct system repair, undercutting of doors, installation of transfer grills, eliminating or reducing exhaust fan capacity, or instructing homeowner on safe exhaust fan operation. If negative pressures in the combustion appliance zone (or basement) are a function of return leaks in that area, check for leaks in the return ductwork, plenum, filter access door and air handler cabinet. Pay particular attention to panned under floor joists (used as returns) as they typically have many leaks.

Note: For APT users, a prototype software program called ONOFF is available to help precisely measure small changes in building or room pressures. The program uses a signal averaging technique which significantly reduces noise, particularly in windy weather, allowing for precise measurement of small pressure changes. Contact The Energy Conservatory for more information.

Table 9: House Depressurization Limits (HDL)

Appliance Type	Depressurization Limit
Individual natural draft water heater (WH)	2 Pascals
Natural draft WH and natural draft furnace/boiler	3 Pascals
Natural draft WH and Induced Draft (ID) furnace/boiler	5 Pascals
Individual natural draft furnace/boiler	5 Pascals
Individual ID furnace/boiler	15 Pascals
Power vented and sealed combustion appliances	>25 Pascals

Source: *CEE Appliance Safety Test Methods, MAC Part 150 Residential Sound Insulation Program, Mpls, MN.*

15.2.e Spillage Test (natural draft and induced draft appliances):

This test identifies actual spillage of combustion byproducts into the living space under worst case depressurization conditions.

- With building set up in worst case depressurization mode (as specified above), fire up each combustion appliance.
- If appliances are common vented, conduct test on smallest input appliance first, then test with both appliances running.
- When burner lights, check for flame rollout (stand away from burner).
- Check for spillage (using chemical smoke) at the end of the spillage test period (see Table 10 below). For natural draft appliances, spillage is tested at the draft diverter. When an induced draft heating system is vented in common with a natural draft water heater, spillage is checked at the water heater draft diverter. For a single induced draft appliance, spillage is checked at the base of the chimney liner or flue, typically using the drip tee at the bottom of the liner.

Table 10: Spillage Test Period

Appliance Type	Spillage Test Period (minutes)
Water heater, gravity furnace and boiler	3.0 minutes
Space heater	2.0 minutes
Furnace	1.0 minutes

Source: *CEE Appliance Safety Test Methods, MAC Part 150 Residential Sound Insulation Program, Mpls, MN.*

- If spillage continues beyond the spillage test period, remove the negative pressure in combustion room by turning off fans and/or opening an exterior window or door.
- Re-check for spillage. If spillage stops, there is a pressure induced spillage problem. If spillage continues, check flue and chimney for obstructions, and check compatibility of appliance BTU input with chimney size.

> ***Spillage of combustion products beyond the spillage test period is a health and safety concern.*** If the problem is a blocked flue or chimney, or inadequately sized flue or chimney, consult a professional heating contractor. If the problem is pressure induced, provide pressure relief. Re-check for spillage following attempt to provide pressure relief. If spillage continues, contact a professional heating contractor to investigate the problem.

15.2.f Draft Test (natural draft appliances):

This test measures flue draft pressure in the venting systems of all natural draft combustion appliances under worst case depressurization (not to be done for sealed combustion or induced draft appliances).

- Drill a small hole in the vent pipe approx. 2 feet downstream of the draft diverter or barometric damper. Insert a static pressure probe.
- Measure draft pressure (vent WRT combustion room) with Magnehelic or digital pressure gauge after 5 minutes of operation.
- Compare measured draft with minimum draft pressures below:

Table 9: Minimum Draft Pressures

Outside Temp	*Draft Pressure*
Below 10 F	*-2.50 Pa*
20 F	*-2.25 Pa*
40 F	*-1.75 Pa*
60 F	*-1.25 Pa*
80 F	*-0.75 Pa*
Above 90 F	*-0.50 Pa*

Source: *CEE Appliance Safety Test Methods, MAC Part 150 Residential Sound Insulation Program, Mpls, MN.*

If measured draft is below the minimum draft pressure above, check for flue or chimney obstructions, disconnected vents, open chimney cleanout doors etc.. Also remove sources depressurization (e.g. turn off exhaust fans) and test again to determine if CAZ depressurization is contributing to poor draft.

15.2.g Carbon Monoxide Test:

This test measures carbon monoxide levels in all operating combustion appliances.

- After 5 minutes of appliance operation, measure the CO level in the flue products of all combustion appliances.
- CO should be measured before appliance draft diverter, or barometric damper.
- CO levels should be below 100 ppm in all flues.
- For gas stoves, measure CO from oven exhaust port and 3 feet above burners with all burners running. CO level should be below 50 ppm.
- If CO found in gas stove, re-measure ambient kitchen CO after 10 minutes of stove operation.

The presence of CO and spillage requires immediate remedial action.

15.2.h Heat Exchanger Integrity Test (Forced Air Only):

This test is used to determine if a crack or hole is present in the furnace heat exchanger. A crack or hole could allow products of combustion into the building, and/or promote carbon monoxide production through flame distortion and impingement. There are 3 main types of tests which can be performed:

1. Flame Distortion Test

This test involves watching the furnace flame when the furnace air handler first turns on. Any distortion of the flame indicates a hole or crack in the heat exchanger. This test can be done in conjunction with the flame rollout component of the spillage test. Another method for conducting a flame distortion test is to slowly extend a match up and down into each combustion chamber with the burner off and the air handler fan on, and watch for movement of the flame head.

2. Blocked Flue Test

With the furnace off, block the flue ports leading from the combustion chamber to the draft diverter or barometric damper. Squirt smoke into the combustion chamber. Turn on the furnace fan and watch to see if the smoke is disturbed when the fan comes on. Smoke movement indicates a hole or crack in the heat exchanger.

3. Tracer Gas Test

A number of testing procedures exist for injecting a tracer gas into the combustion chamber (usually with the furnace fan off) and then measuring or detecting the tracer gas on the warm air side of the heat exchanger.

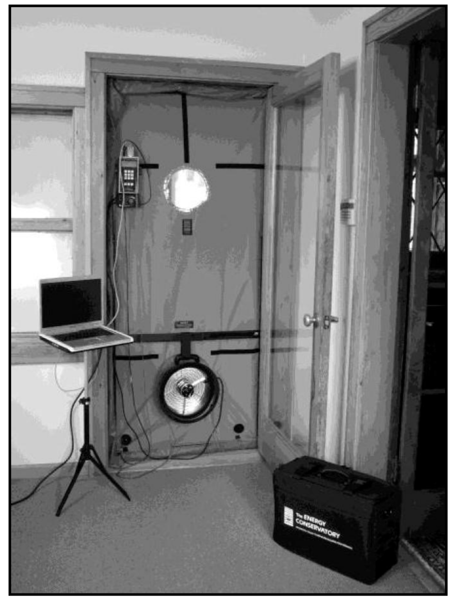
> ***If any of the above heat exchanger tests provides a positive indication for a cracked heat exchanger, immediate action should be taken to notify the residents of the potential danger, and a professional heating contractor should be contacted to investigate the problem.***

Turn off fans and return appliance controls to their original settings once the test procedures have been completed.

Special thanks to Advanced Energy, Sun Power and the Center for Energy and Environment (CEE) for their work in developing and refining the combustion safety test procedures above.

Chapter 16 Using the Duct Blaster as a Blower Door

The Duct Blaster fan can be easily used as a Blower Door fan to test and measure the airtightness of buildings, as well as a diagnostic tool to find air leakage paths. The maximum Duct Blaster fan flow capacity of 1,500 CFM (1,350 at 50 Pa) will enable the fan to conduct complete airtightness testing procedures on many new houses which have been built to energy efficient airtightness standards. For example, a new 4,000 ft2 house built to a 1.5 Air Change per Hour at 50 Pa (ACH50) standard will require only about 800 CFM of fan capacity to perform a complete airtightness test.



The Energy Conservatory (manufacturer of the Minneapolis Blower Door) sells a nylon door panel which allows the Duct Blaster fan to be sealed into a door opening when used with the Minneapolis Blower Door adjustable aluminum door frame. The nylon panel has a smaller hole opening to accommodate the smaller diameter Duct Blaster fan. The Duct Blaster fan is supported by the middle cross bar on the aluminum frame. Because of its light weight, the Duct Blaster fan can also be easily sealed into a window opening using tape and cardboard.

When used as a Blower Door, the Duct Blaster fan will typically be operated <u>without</u> the flexible extension duct or the flow conditioner installed. To conduct a house depressurization test, install the Duct Blaster fan with the exhaust side of the fan on the outside of the house and the inlet side of the fan inside the house. Fan flow can be measured directly from the DG-700 gauge or TECTITE software.

More information on Blower Door testing can be obtained from The Minneapolis Blower Door Operation Manual which is available from TEC.

Appendix A Calibration and Maintenance

A.1 Fan Calibration

Series B Duct Blaster Fan Calibration Parameters (Updated January 2007):

Fan Configuration	Calibration Parameters
Open Fan	Flow (cfm) = **108.7** x (Fan Pressure in Pa)$^{.5032}$
Ring 1 Installed	Flow (cfm) = **40.50** x (Fan Pressure in Pa)$^{.5038}$
Ring 2 Installed	Flow (cfm) = **15.27** x (Fan Pressure in Pa)$^{.5064}$
Ring 3 Installed	Flow (cfm) = **5.840** x (Fan Pressure in Pa)$^{.5140}$

Note: All fan flows indicated on Energy Conservatory gauges or flow tables are corrected to a standard air density of 0.075 lbs/cubic foot, and are not the actual volumetric flow going through the fan. The indicated flows are corrected to standard air density according to the CGSB Standard CAN/CG-SB-149.10-M86. The correction is done in such a way that, for particular types of leaks (where the viscosity of air is negligible and the flow exponent "n" equals 0.5), the indicated flow is independent of barometric pressure. For this type of leak, the indicated flow is the flow that would have been going through the fan if the test had been conducted at standard barometric pressure, and air temperatures were unchanged.

If the actual volumetric flow rate going through the fan is desired, multiply the flow indicated from the formula above by:

$$\sqrt{\frac{0.075}{\text{actual air density*}}} \qquad \text{(where air density is in lb/ft3)}$$

or

$$\sqrt{\frac{1.204}{\text{actual air density*}}} \qquad \text{(where air density is in Kg/m3)}$$

* Use the density of air flowing through the fan.

Flow Ranges and Minimum Fan Pressures (Pa)

Flow Ring Configuration	Flow Range (CFM)	Minimum Fan Pressure (Pa)
Open Fan	1,500 – 600	25 Pa
Ring 1	800 – 225	25 Pa
Ring 2	300 – 90	25 Pa
Ring 3	125 – 10	3 Pa

Note: Open Fan configuration may only be used in Pressurization mode.

ATTACHMENT FOUR

A.2 Issues Affecting Fan Calibration

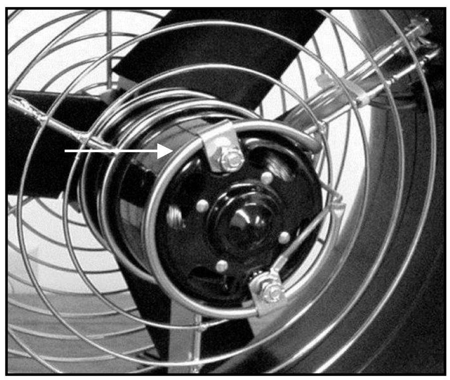
A.2.a Fan Flow Sensor and Motor Position:

Duct Blaster fans maintain their calibration unless physical damage occurs. Conditions which could cause the fan calibration to change are primarily damaged flow sensors, movement of the motor and blades relative to the fan housing, and leaks in the sensor or tubing running from the flow sensor to the fan pressure tap. These conditions are easily detected and should be tested for on a regular basis.

Damaged Duct Blaster Flow Sensor

The Duct Blaster uses a flow sensor manufactured out of thin stainless steel tubing. The flow sensor is permanently attached to the end of the fan motor opposite the fan blades.

Duct Blaster Fan Flow Sensor



First visually confirm that the sensor is not broken or deformed due to impact. Check that the sensor is firmly attached to the motor. Next, perform a test for leaks in the sensor or the tubing connecting the sensor to the fan pressure tap.

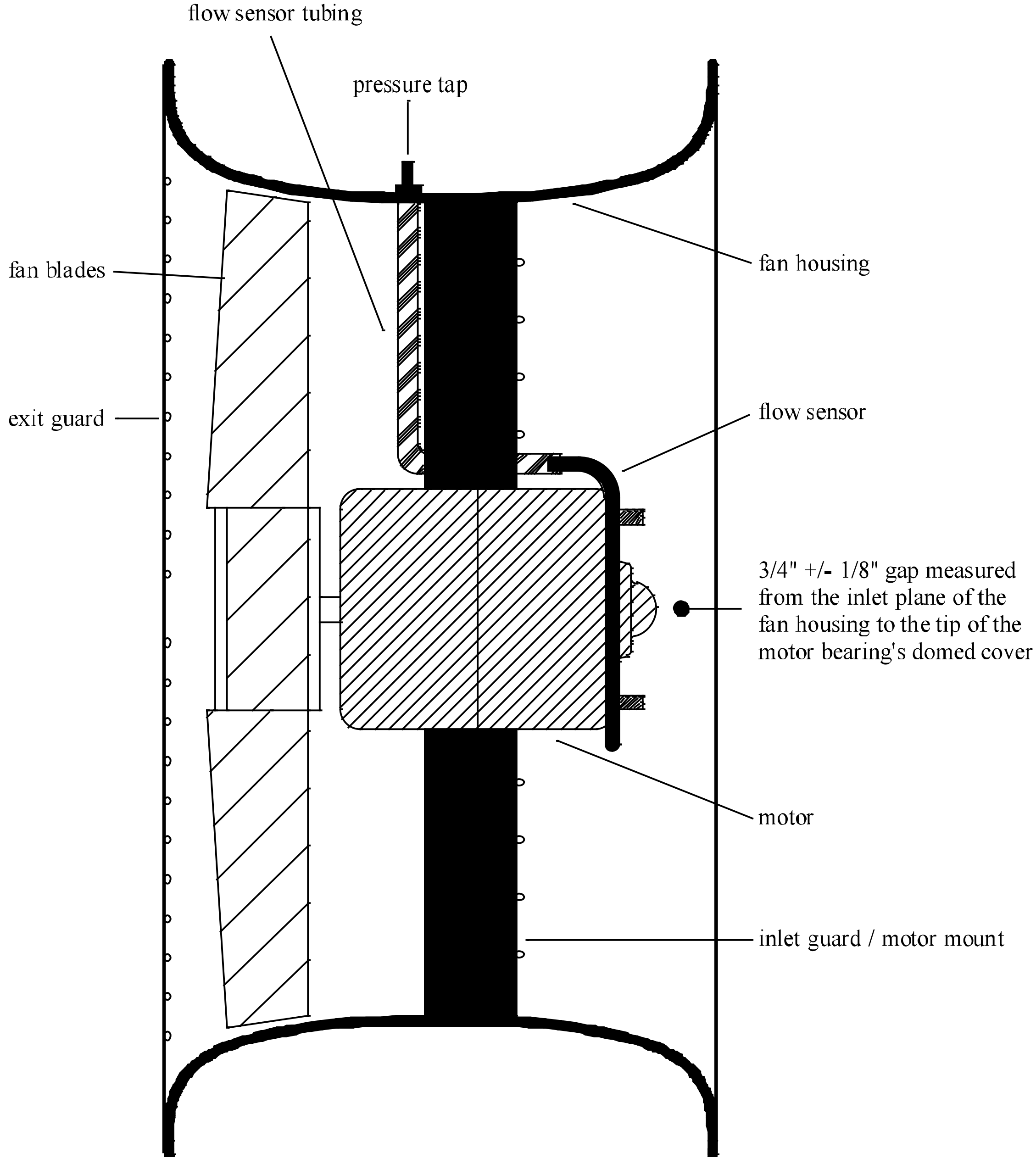
Attach a piece of tubing to the brass pressure tap on the Duct Blaster fan housing. Leave the other end of the tubing open. Find the 3 intentional sensing holes in the flow sensor - they are evenly spaced on the back side of the sensor. Temporarily seal the 3 holes by covering them with masking tape. Next, create a vacuum in the fan pressure tubing by sucking on the open end. A vacuum in the tubing assures that the flow sensor does not leak. There is a vacuum, if by placing your tongue over the end of the tubing, the tubing sticks to your tongue. Make sure that the vacuum persists for at least 5 seconds. If a vacuum can not be created, contact The Energy Conservatory to further diagnose the sensor leakage problem.

Duct Blaster Motor Position

If a fan has been dropped, the motor may have shifted from its proper position in the motor mount. This can degrade the fan calibration. To test the motor position, lay the fan on its side with the flow sensor facing up and all Flow Rings removed. Place a straightedge (such as a heavy yardstick on edge) across the inlet of the fan. Use a ruler to measure the following distance and compare this measurement to the appropriate specification.

> ***Duct Blaster Fan:*** Measure the distance from the bottom of the straightedge to the tip of the motor bearing's domed cover. This distance should be in the range of 5/8th to 7/8th of an inch (see schematic below). If the motor is not in the proper position, call The Energy Conservatory for further instructions.

Figure 6: Schematic of Series B Duct Blaster



A.2.b Upstream Air Flow Conditions:

- When using the Duct Blaster fan to conduct a duct leakage depressurization test (i.e. the flex duct is connected to the inlet side of the fan), always position the fan so that the flex duct is stretched relatively straight for about 4 feet in front of the fan.
- When the fan inlet is open to the room, try to install the fan so that there is not a large obstruction within 2 feet in front of the fan.

A.2.c Operating Under High Backpressure Conditions:

Note: For most testing applications, backpressure is not a concern and can be ignored.

The term "backpressure" is used to describe the pressure that the Duct Blaster fan is working against when it is running. Backpressure is determined by measuring the static pressure difference between the air directly upstream of the fan, and the air directly exiting the fan. High backpressures are typically caused by a large restriction between the Duct Blaster fan and the location where the test pressure is being made.

Although the Duct Blaster's flow sensor was carefully designed to be affected as little as possible by variations in backpressure, under certain very high backpressure operating conditions (described below) the calibration of the fan can degrade.

High Backpressure Conditions

Series B Duct Blaster fans can be used in most testing applications with backpressures up to 100 Pascals with no significant effect on calibration accuracy (except as noted below). This is true for all fan flow configurations (Open through Ring 3), provided that the fan is operated within the accepted flow range for each configuration. The only exception to this rule is for flow measurements below 20 CFM (Ring 3 will measure down to 10 CFM). When measuring flows between 20 and 10 CFM using Ring 3, backpressures should be kept below 40 Pascals. Backpressures above these values can diminish the accuracy of the fan calibration and should be avoided.

One example of an application that could cause high backpressure is when the flexible extension duct is connected to a small, high resistance register. The high resistance register can cause the pressure in the flex duct to be very high (i.e. over 150 Pascals) even if the test pressure in the duct system is only 25 Pascals. Operating the Duct Blaster fan under these operating conditions is not advised. To avoid this problem:

- Always try to avoid connecting the Duct Blaster fan to the duct system using a relatively high resistance connection (such as a small supply register).
- If you are using a high resistance connection and suspect a high backpressure condition, try to measure the backpressure. If the measured backpressure is less than the values listed above, then there should not be a problem. If the flexible extension duct is being used, the backpressure can be easily determined by measuring the pressure difference between the room where the Duct Blaster fan is installed and pressure inside the flex duct (measured from the plastic tap on the round transition piece).

A.3 Duct Blaster Fan Maintenance and Safety

There are several maintenance tips and procedures to ensure the proper operation of the Duct Blaster fan and to avoid any safety risks.

A.3.a Maintenance Checks:

- Examine the motor cooling holes for excessive dust and dirt build-up. Use a vacuum with a brush attachment to remove dust, or blow out the dust with compressed air.
- Inspect housing, blades and guards. Especially note clearance of blade tips relative to the fan housing. There should be about 1/4 to 1/8 inch of clearance.
- Inspect electrical wiring and electrical connections on the fan and the fan speed controller.

A.3.b General Operational Notes and Tips:

- The Duct Blaster fan motor is not a continuous duty motor and should not be run for extended periods of time (more than 2 hours at one time).
- The fan should not be left running unattended.
- Do not use ungrounded outlets or adapter plugs.
- Do not operate if the motor, controller or any of the electrical connections are wet.
- Keep people and pets away from the fan when it is operating.

The Duct Blaster fan is a very powerful and potentially dangerous piece of equipment if not used and maintained properly. Carefully examine the fan before each use. If the fan housing, fan guards, blade, controller or cords become damaged, do not operate the fan until repairs have been made. Contact The Energy Conservatory if there are any unusual noises or vibrations while the fan is running.

A.4 Calibration and Maintenance of Digital Pressure Gauges

A.4.a Digital Gauge Calibration:

Re-calibration of digital pressure gauges is recommended every 12 months. Gauges should be sent back to The Energy Conservatory for re-calibration. It is also a good idea to perform gauge comparisons between calibrations, especially when damage is suspected (e.g. when a gauge has been dropped).

Digital Gauge Comparison

This technique is used to compare the readings of two digital gauges when they are both connected to the same pressure source. When two gauges are being compared, you should expect them to agree within their specifications:

DG-3 Accuracy Specifications:

Low Range:	+/- 1% of reading or 0.2 Pa, whichever is larger (0-200.0 Pa)
High Range:	+/- 1% of reading or 2 Pa, whichever is larger (0-800 Pa)
	+/- 2% of reading (800-1,000 Pa)

DG-700 Accuracy Specifications:

+/- 1% of reading or 0.15 Pa, whichever is greater (0-1,250 Pa)

Parts Needed for Comparison

- 2 digital gauges
- one Magnehelic gauge
- 2 "T" fittings
- one syringe
- five 1 foot sections of tubing

Comparison Procedure

Using the two T fittings and short sections of hose, hook up the gauges and syringe as shown in Figure 7 below. Turn on the digital gauges, (if DG-3's, set on High Range). They should both be reading 0 Pa. Pull out on the syringe slowly until the desired test pressure on the digital gauges is achieved. Record your results and compare with the specifications above.

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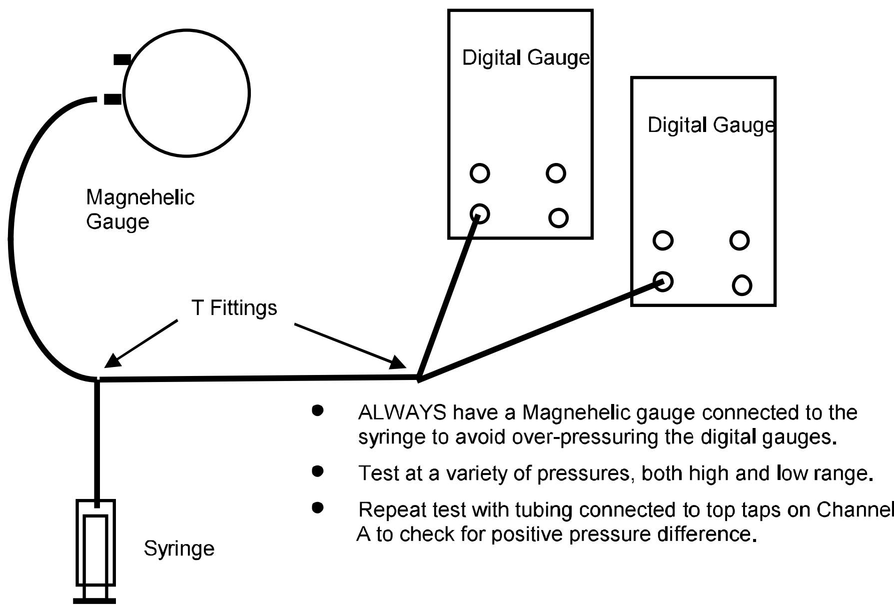
Figure 7: Comparison Setup



A.4.b Digital Gauge Maintenance:

- Operating temperature range: 32 °F to 120 °F.
- Storage temperatures 5 °F to 160 °F (best to keep it warm during cold weather).
- Avoid conditions where condensation could occur, for example taking a gauge from a cool environment into a hot humid environment.
- Do not store gauge in the same container as chemical smoke. The smoke can and does cause corrosion.
- Do not ignore low battery indicator (readings can start being in error almost immediately).
- Avoid exposing the gauge to excessive pressures, such as caused by tubing slammed in a door.

A.5 Checking for Leaky Tubing

It does not happen very often, but leaky tubing can seriously degrade the accuracy of duct leakage tests. These leaks can be small enough to go undetected for years but large enough to affect fan calibration.

- Before starting, inspect both ends of the tubing to make sure they are not stretched out to the point where they will not make a good seal when attached to a gauge.
- Seal off one end of the tubing by doubling it over on itself near the end.
- Create a vacuum in the tubing by sucking on the open end (make sure the hose is clean first!). Let the end of the tubing stick to your tongue due to the vacuum.
- The tubing should stick to your tongue indefinitely if there are no leaks. Waiting for 5 seconds or so is a good enough test.
- If the tubing has a leak, it should be replaced immediately.
- The ends of the tubing will sometimes get stretched out or torn after many uses. Periodically trim 1/4" off the ends of the tubing to remove the damaged end.

ATTACHMENT FOUR

Appendix B Flow Conversion Table

Series B Duct Blaster (110V and 230V)

Flow (cfm)

Fan Pressure	Open Fan	Ring 1	Ring 2	Ring 3
(Pascals)				
4				12
6				15
8				17
10				19
12				21
14				23
16				24
18				26
20				27
22				29
24				30
26	560	209	80	31
28	581	217	83	32
30	602	225	85	34
32	622	232	88	35
34	641	239	91	36
36	660	246	94	37
38	678	253	96	38
40	696	260	99	39
42	713	266	101	40
44	730	273	104	41
46	746	279	106	42
48	762	285	108	43
50	778	291	111	44
52	794	296	113	45
54	809	302	115	45
56	824	308	117	46
58	839	313	119	47
60	853	319	121	48
62	867	324	123	49
64	881	329	125	50
66	895	334	127	50
68	909	339	129	51
70	922	344	131	52
72	935	349	133	53
74	948	354	135	53
76	961	359	137	54
78	973	364	139	55
80	986	368	140	56
82	998	373	142	56
84	1010	377	144	57
86	1023	382	146	58
88	1034	386	147	58
90	1046	391	149	59
92	1058	395	151	60
94	1069	400	152	60
96	1081	404	154	61
98	1092	408	156	62
100	1103	412	157	62
102	1114	416	159	63
104	1125	420	160	64
106	1136	424	162	64
108	1147	428	164	65
110	1157	432	165	65
112	1168	436	167	66
114	1178	440	168	67
116	1189	444	170	67
118	1199	448	171	68
120	1209	452	172	68

Flow (cfm)

Fan Pressure	Open Fan	Ring 1	Ring 2	Ring 3
122	1219	456	174	69
124	1229	459	175	70
126	1239	463	177	70
128	1249	467	178	71
130	1259	470	180	71
132	1269	474	181	72
134	1278	478	182	72
136	1288	481	184	73
138	1297	485	185	74
140	1307	488	186	74
142	1316	492	188	75
144	1325	495	189	75
146	1335	499	190	76
148	1344	502	192	76
150	1353	506	193	77
152	1362	509	194	77
154	1371	512	196	78
156	1380	516	197	78
158	1389	519	198	79
160	1397	522	200	79
162	1406	526	201	80
164	1415	529	202	80
166	1424	532	203	81
168	1432	535	205	81
170	1441	538	206	82
172	1449	542	207	82
174	1458	545	208	83
176	1466	548	209	83
178	1474	551	211	84
180	1483	554	212	84
182	1491	557	213	85
184	1499	560	214	85
186	1507	563	215	86
188	1516	566	217	86
190	1524	569	218	87
192	1532	573	219	87
194	1540	576	220	88
196	1548	578	221	88
198	1556	581	222	88
200	1564	584	223	89
202	1571	587	225	89
204	1579	590	226	90
206	1587	593	227	90
208	1595	596	228	91
210	1602	599	229	91
212	1610	602	230	92
214	1618	605	231	92
216	1625	608	232	93
218	1633	610	233	93
220	1640	613	234	93
222	1648	616	236	94
224	1655	619	237	94
226	1663	622	238	95
228	1670	624	239	95
230	1677	627	240	96
232	1685	630	241	96
234	1692	633	242	96
236	1699	635	243	97
238	1707	638	244	97
240	1714	641	245	98

Series B (110V & 230V)

Flow (cfm)

Fan Pressure	Open Fan	Ring 1	Ring 2	Ring 3
242	1721	643	246	98
244	1728	646	247	99
246	1735	649	248	99
248	1742	651	249	99
250	1749	654	250	100
252	1756	657	251	100
254	1763	659	252	101
256	1770	662	253	101
258	1777	664	254	101
260	1784	667	255	102
262	1791	670	256	102
264	1798	672	257	103
266	1805	675	258	103
268	1812	677	259	103
270	1818	680	260	104
272		682	261	104
274		685	262	105
276		687	263	105
278		690	264	105
280		692	265	106
282		695	266	106
284		697	267	107
286		700	268	107
288		702	269	107
290		705	270	108
292		707	271	108
294		710	272	108
296		712	272	109
298		714	273	109
300		717	274	110
302		719	275	110
304		722	276	110
306		724	277	111
308		726	278	111
310		729	279	111
312		731	280	112
314		734	281	112
316		736	282	113
318		738	283	113
320		741	283	113
322		743	284	114
324		745	285	114
326		748	286	114
328		750	287	115
330		752	288	115
332		754	289	115
334		757	290	116
336		759	291	116
338		761	291	116
340		764	292	117
342		766	293	117
344		768	294	118
346		770	295	118
348		773	296	118
350		775	297	119
352		777	297	119
354		779	298	119
356		781	299	120
358		784	300	120
360		786	301	120
362		788	302	121
364		790	303	121
366		792	303	121
368		795	304	122
370		797	305	122

Flow (cfm)

Fan Pressure	Open Fan	Ring 1	Ring 2	Ring 3
372		799	306	122
374		801	307	123
376		803	308	123
378		805	308	123
380		808	309	124
382		810	310	124
384		812	311	124
386		814	312	125
388		816	312	125
390		818	313	125
392		820	314	126
394		822	315	126
396		824	316	126
398		827	317	127
400		829	317	127
402		831	318	127
404		833	319	128
406		835	320	128
408		837	321	128
410		839	321	129
412		841	322	129
414		843	323	129
416		845	324	130
418		847	324	130
420		849	325	130
422		851	326	131
424		853	327	131
426		855	328	131
428		857	328	132
430		859	329	132
432		861	330	132
434		863	331	132
436		865	331	133
438		867	332	133
440		869	333	133
442		871	334	134
444		873	335	134
446		875	335	134
448		877	336	135
450		879	337	135
452		881	338	135
454		883	338	136
456		885	339	136
458		887	340	136
460		889	341	136
462		891	341	137
464		893	342	137
466		895	343	137
468		897	344	138
470		899	344	138
472		901	345	138
474		903	346	139
476		905	347	139
478		906	347	139
480		908	348	139
482		910	349	140
484		912	349	140
486		914	350	140
488		916	351	141
490		918	352	141
492		920	352	141
494		922	353	142
496		924	354	142
498		925	355	142
500		927	355	142

ATTACHMENT FOUR

Appendix C Sample Test Form

Example Completed Form

Duct Leakage Test Form

Customer Information:

Name: Tom Jones
Address: 2345 First Ave.
City: Phoenix
State/Zip: AZ, 86777
Phone: 333-333-3333
Email: tjones@wildworld.com

Building Address: (if different from above)

Street: ____________
City/State: ____________

Test Conditions:

Date:	May 23, 2001
Time:	8:00 AM
Indoor Temperature (F):	78 F
Outdoor Temperature (F):	84 F
Floor Area (ft^2):	2,500
System Airflow (cfm):	1,625
Cooling Size (tons):	4
Heating Size (btu):	60,000
Primary Location of Supply Ductwork:	Attic
Primary Location of Return Ductwork:	Garage

Comments:

Platform return in garage. Platform open to wall cavity. Single return.
Flex duct in attic.

Total Leakage Test

Depress ______ Press x

Test Pressure: 25 (Pa)

Baseline Duct Pressure (optional): N/A (Pa)

Duct Press. (Pa)	Flow Ring Installed	Fan Press (Pa)	Flow (cfm)
25	Ring 2	370	304

Fan Model/SN: # 1056

Results:

Total Leakage (cfm): 304
Total Leakage as % System Airflow: 18.7%
Total Leakage as % Floor Area: 12.1%

Outside Leakage Test

Depress ______ Press x

Test Pressure: 25 (Pa)

Duct Press. (Pa)	Flow Ring Installed	Fan Press (Pa)	Flow (cfm)
25	Ring 2	242	246

Fan Model/SN: #1056

Results:

Outside Leakage (cfm): 246
Outside Leakage as % System Airflow: 15.1%
Outside Leakage as % Floor Area: 9.8%

TEC The Energy Conservatory

Example Blank Form

Duct Leakage Test Form

Customer Information:

Name: ______________________

Address: ______________________

City: ______________________

State/Zip: ______________________

Phone: ______________________

Email: ______________________

Building Address: (if different from above)

Street: ______________________

City/State: ______________________

Test Conditions:

Date: __________

Time: __________

Indoor Temperature (F): __________

Outdoor Temperature (F): __________

Floor Area (ft^2): __________

System Airflow (cfm): __________

Cooling Size (tons): __________

Heating Size (btu): __________

Primary Location of Supply Ductwork: __________

Primary Location of Return Ductwork: __________

Comments:

____

____

____

____

____

____

Total Leakage Test

Depress ______ Press ______

Test Pressure: ______ (Pa)

Baseline Duct Pressure (optional): ______ (Pa)

Duct Press. (Pa)	Flow Ring Installed	Fan Press (Pa)	Flow (cfm)

Fan Model/SN: ______________________

Results:

Total Leakage (cfm): __________

Total Leakage as % System Airflow: __________

Total Leakage as % Floor Area: __________

Outside Leakage Test

Depress ______ Press ______

Test Pressure: ______ (Pa)

Duct Press. (Pa)	Flow Ring Installed	Fan Press (Pa)	Flow (cfm)

Fan Model/SN: ______________________

Results:

Outside Leakage (cfm): __________

Outside Leakage as % System Airflow: __________

Outside Leakage as % Floor Area: __________

Appendix D Technical Specifications

D.1 Specifications

	(without flex duct)	(w/ flex duct installed)
Maximum Flow:	- 1,500 CFM @ 0 Pa - 1,350 CFM @ 50 Pa	- 1,250 CFM @ 0 Pa - 1,000 CFM @ 50 Pa

Flow Range: - 1,500 - 10 Cubic Feet per Minute (cfm)

Flow Measurement System:
- Integral flow measuring nozzles.
- Flow calibration meets the following standards: CGSB 149.10-M86, ASTM E779, ASTM E1827, ASHRAE 152, EN 13829, ATTMA TS1, NFPA 2001, RESNET and USACE.
- Flow calibration accuracy: +/- 3% or 1 CFM, whichever is greater (using DG-700 digital gauge).

Pressure Gauge: - DG-700.

Dimensions:
- Fan: 10" diameter, 8" long.
- Flexible Extension Duct: 12 feet long w/ 10" flex duct.
- Digital Gauge: 7 1/2" long, 4" wide, 1 1/4" deep.

Weight:
- Fan: 7 lbs (8.5 lbs with 3 flow nozzles).
- Flexible Extension Duct: 5 lbs.
- Digital Gauge: 1 lbs.
- Total System Shipping Weight: 27 lbs.

Fan Controller: - Variable Speed Solid State DC (maximum controller output is 60 Volts DC nominal). Maximum 4 amp current draw (110V AC input).

Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements

Appendix E contains a simple method for estimating HVAC system losses from field measurements of duct airtightness. This method uses a duct airtightness measurement along with a number of assumptions about the HVAC and duct system (including system airflow, average operating pressure in the ductwork, the breakdown of leakage between supply and return side, and the energy loss penalty from supply and return leaks) to estimate an annual energy loss for heating or cooling. The model shown below is used in the TECBLAST duct leakage test software to estimate annual system losses.

Note: Because duct leakage loss calculations are extremely complex, this estimation technique should be used with caution and should be viewed only as a rough estimate of the magnitude of losses possible. The leakage rate of a duct system determined using the airtightness test procedures listed in this manual may differ from the leakage rates occurring in the duct system under actual operating conditions. In addition, the duct leakage loss estimates do not include many important but complex impacts on system efficiency including latent load impacts, heat pump strip heating impacts, conduction losses, increases in infiltration from dominant duct leakage, or interactions of leakage on mechanical operating efficiencies, all of which can be significant depending on the type and location of the system being tested. We do not recommend that this simple model be used for research purposes, program design studies or impact evaluations. More sophisticated duct leakage loss models are available and better suited to these needs.

How to Use this Method:

The equation for this estimation procedure is located in section 5 below. Follow procedures 1-4 to determine reasonable values to use in Section 5.

1. Conduct a Duct Leakage Test

Set up your duct testing equipment to measure **Duct Leakage to the Outside** (in CFM). For consistency in reporting and comparison between duct systems, we recommend that you conduct your duct airtightness test at a test pressure of 25 Pa. This pressure has become the most commonly used test pressure for residential duct airtightness testing. (see Section 2 below for adjustments to the CFM25 leakage reading due to variations in duct operating pressures). Record the CFM25 of duct leakage to the outside.

2. Determine the CFM25 Multiplier for Average Operating Pressure:

Because we tested the duct system at a test pressure of 25 Pascals, we have implicitly assumed that 25 Pascals is a representative pressure seen by the leaks in the duct system under normal operating conditions. While this appears to be a reasonable assumption for many residential duct systems, it can be modified if you have evidence to suggest that a different operating pressure better represents the pressure seen by the predominant duct leaks during normal operation. Table 10 below can be used to adjust the measured CFM25 for different average operating pressures. This adjustment can be made separately for the supply leakage and the return leakage in the duct system. **Note:** During normal operation, pressures in the duct system vary greatly, while during a duct leakage test, pressures are much more uniform.

For example, if the majority of leaks in the duct system are at supply boot connections, it might be reasonable to assume that the average operating pressure for the supply leaks is less than 25 Pascals (e.g. 10 or 15 Pascals). If the majority of leaks are located at a high pressure location such as a supply or return plenum, then it might be reasonable to assume that the average pressure seen by the leaks is larger than 25 Pascals. Table 10 shows example multipliers. Write down separate multipliers for the return and supply duct systems, as appropriate.

Note: When possible, it is always best to measure actual operating pressure during normal operation to determine the appropriate multiplier to use from Table 10.

Table 10 Multiplier for CFM25

Average Operating Pressure in the Duct System	Multiplier for CFM25
5 Pa	0.38
10 Pa	0.58
15 Pa	0.74
20 Pa	0.87
25 Pa	1.00
30 Pa	1.12
35 Pa	1.22
40 Pa	1.33
45 Pa	1.42
50 Pa	1.52

$$\text{Multiplier} = (\text{Avg. Operating Pressure}/25)^{0.60}$$

3. Calculate a Loss Factor For Supply and Return Leaks:

Calculate and write down the Loss Factors for both sides of the system:

A. Supply Loss Factor = (SLS x SLP x SPM)

where:

SLS = Supply Leakage Split (Default Value = 0.5)
SLP = Supply Leakage Penalty (Default Value = 1.0)
SPM = Supply Pressure Multiplier (Default Value = 1.0)

Using the default values, the Supply Loss Factor = (0.5 x 1.0 x 1.0) = 0.5

- **Supply Leakage Split** is the percentage of the measured leakage which is located in the supply side of the system. The default value of 0.5 means that 50% of the measured leakage in the system is located in the supply side. If you have measured the supply leakage directly, or have other evidence that more or less of the measured leakage is in the supply side, then adjust the default value accordingly.

- **Supply Leakage Penalty** represents the effective annual energy penalty to the HVAC system for each percent loss in delivered system air flow due to supply side leakage. In other words, the default value of 1.0 means that a measured supply leakage rate of 1 percent (i.e. 1 percent of system airflow) contributes to a 1 percent annual loss to the HVAC system. The default SLP of 1.0 assumes that supply side leaks are direct losses to the outside and are not recaptured back to the house. The SLP can be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the energy lost from supply leaks in a crawlspace will probably be regained back to the house (sometimes 1/2 or more may be regained). In this case, a SLP of less than 1.0 might be appropriate.

- **Supply Pressure Multiplier** is the appropriate CFM25 multiplier for supply leaks from Table 10 above. The default value of 1.0 assumes that 25 Pa is representative of the pressures seen by supply duct leaks during normal operation.

B. Return Loss Factor = (RLS x RLP x RPM)

where:

RLS = Return Leakage Split (Default Value = 0.5)
RLP = Return Leakage Penalty (Default Value = 0.5)
RPM = Return Pressure Multiplier (Default Value = 1.0)

Using the default values, the Loss Factor for Return Leaks = (0.5 x 0.5 x 1.0) = 0.25

- **Return Leakage Split** is the percentage of the measured leakage which is located in the return side of the system. The default value of 0.5 means that 50% of the measured leakage in the system is located in the return side. If you have measured the return leakage directly, or have other evidence that more or less of the measured leakage is in the return side, then adjust the default value accordingly. (**Note:** The SLS and the RLS, when added together, should always equal 1.0.)

- **Return Leak Penalty** represents the effective annual energy penalty to the HVAC system for each percent of return air flow that is drawn from the outside. In other words, the default value of 0.5 means that a measured return leakage rate of 1 percent (i.e. 1 percent of system airflow) contributes to a 0.5 percent annual loss to the HVAC system. The default value of 0.5 for the RLP suggests that on average, return leaks contribute less to energy losses than do supply leaks (default SLP of 1.0). The RLP value can be adjusted upward from the default value if you have reason to suspect that the measured return leaks contribute significantly more energy loss than "average" (e.g. pulling return air from a super heated attic), or can be adjusted downward to represent significantly less energy loss (e.g. pulling return air from a moderate temperature crawl space) .

- **Return Pressure Multiplier** is the appropriate CFM25 multiplier for return leaks from Table 10 above. The default value of 1.0 assumes that 25 Pa is representative of the pressures seen by return duct leaks during normal operation

Note: When in doubt, we recommend that you use the default values for Loss Factors.

4. Estimate the HVAC System Airflow:

Estimate the total system airflow (in CFM) from either the system nameplate, measured static pressure and fan curve, or by measuring the system airflow using a reasonable flow measuring technique (e.g. temperature rise method, flow hood, Duct Blaster pressure matching method, or the TrueFlow Air Handler Flow Meter. Write down the estimated/measured total system airflow.

5. Calculate Percent HVAC System Loss:

Percent HVAC System Loss =

$$\frac{\text{CFM25 Leakage to Outside x (Supply Loss Factor + Return Loss Factor)}}{\text{Estimated System Airflow (in CFM)}}$$

Example 1:

We conduct a duct leakage to outside test on a 3 ton, 11 SEER heat pump system (supplies located in the attic and returns in the crawlspace). The owners report a $1,500 a year cooling bill and a $500 a year heating bill. Using 25 Pascals as our duct testing pressure, we measure 355 CFM25 of duct leakage to the outside. We measure a total system airflow of 1,275 CFM using the TrueFlow Air Handler Flow Meter. We will use the default values for the Supply and Return Loss Factors.

Percent HVAC System Loss =

$$\frac{355 \text{ CFM25} \times (0.5 \text{ (Supply Loss Factor)} + 0.25 \text{ (Return Loss Factor)})}{1{,}275 \text{ CFM (system airflow)}}$$

= 266.3 / 1275 = **.209 or 20.9%**

This loss estimate (.209) can be used to estimate:

annual cooling loss: .209 x $1,500 = $314
annual heating loss: .209 x $ 500 = $105
annual capacity loss: .209 x 3 ton = 0.6 tons
annual operating SEER: (1 - .209) x 11 SEER = 8.7 SEER

Example 2:

For the same house used in Example 1, we separately measure the leakage in the supply and return side of the duct system and determine that the majority of the leakage (300 CFM) is in the supply side, and is located at a high pressure plenum takeoff. Because the majority of the leaks in this system are at a plenum takeoff, we assume that the average operating pressure for the supply leaks is closer to 40 Pascals, instead of 25 Pascals. For the return side of the duct system, we will use the default operating pressure of 25 Pascals.

First, we determine the CFM25 Multipliers from Table 10.

For the supply side, we will use a SPMultiplier of 1.33 (average operating pressure of 40 Pascals)

For the return side, we will use a RPMultiplier of 1.0 (default value)

Now we calculate Leakage Splits for both sides of the system:

Supply Leakage Split (SLS) = 300 CFM25 / 355 CFM25 = 0.845

Return Leakage Split (RLS) = 55 CFM25 / 355 CFM25 = 0.155

Next, we calculate the Loss Factors for both sides of the system:

Supply Loss Factor = (0.845 (SLS) x 1.0 (default SLP) x 1.33 (SPMultiplier)) = **1.12**

Return Loss Factor = (0.155 (RLS) x 0.5 (default RLP) x 1.0 (RPMultiplier)) = **0.08**

Percent HVAC System Loss =

$$\frac{355 \text{ CFM25} \times (1.12 \text{ (Supply Loss Factor)} + 0.08 \text{ (Return Loss Factor)})}{1{,}275 \text{ CFM (system airflow)}}$$

= 426.0 / 1275 = **.334 or 33.4%**

This loss estimate (.334) can be used to estimate:

annual cooling loss: .334 x $1,500 = $501
annual heating loss: .334 x $ 500 = $167
annual capacity loss: .334 x 3 tons = 1.0 tons
annual operating SEER: (1 - .334) x 11 SEER = 7.3 SEER

Appendix F Using Optional Ring 4

Ring 4 is an optional Flow Ring for the Series B Duct Blaster fan used to measure very low air flows. Ring 4 has a flow range of approximately 2.4 to 25.0 cfm. To install Ring 4, place the flat side of the ring against the inlet of the fan so that the outer edges of ring roughly line up with outer edge of the inlet flange on the fan. Secure the outer edge of the ring and the fan flange together by pushing the black connecting trim over both edges all the way around the fan.

** When using Ring 4, always use the pressure tap mounted on Ring 4 to connect the fan to the Channel B Input tap on your gauge (rather than the pressure tap on the fan housing).

Determining Ring 4 Flow Rates

Flow rates can be displayed directly using various TEC software/apps including our iTEC-700 mobile app, and TECTITE and TECLOG3 programs. In addition, flow rates can be manually determined by measuring the fan pressure signal from Ring 4 and using the flow table below.

Fan Pressure (Pa)	Flow (cfm)	Fan Pressure (Pa)	Flow (cfm)	Fan Pressure (Pa)	Flow (cfm)	Fan Pressure (Pa)	Flow (cfm)	Fan Pressure (Pa)	Flow (cfm)
5	2.4	105	11.0	205	15.4	305	18.8	405	21.7
10	3.4	110	11.3	210	15.6	310	18.9	410	21.8
15	4.1	115	11.5	215	15.8	315	19.1	415	21.9
20	4.8	120	11.8	220	16.0	320	19.3	420	22.1
25	5.4	125	12.0	225	16.1	325	19.4	425	22.2
30	5.9	130	12.3	230	16.3	330	19.6	430	22.3
35	6.3	135	12.5	235	16.5	335	19.7	435	22.5
40	6.8	140	12.7	240	16.7	340	19.8	440	22.6
45	7.2	145	12.9	245	16.8	345	20.0	445	22.7
50	7.6	150	13.2	250	17.0	350	20.1	450	22.8
55	8.0	155	13.4	255	17.2	355	20.3	455	23.0
60	8.3	160	13.6	260	17.3	360	20.4	460	23.1
65	8.7	165	13.8	265	17.5	365	20.6	465	23.2
70	9.0	170	14.0	270	17.7	370	20.7	470	23.4
75	9.3	175	14.2	275	17.8	375	20.8	475	23.5
80	9.6	180	14.4	280	18.0	380	21.0	480	23.6
85	9.9	185	14.6	285	18.2	385	21.1	485	23.7
90	10.2	190	14.8	290	18.3	390	21.3	490	23.8
95	10.5	195	15.0	295	18.5	395	21.4	495	24.0
100	10.7	200	15.2	300	18.6	400	21.5	500	24.1

Calibration Parameters

Fan Configuration	Calibration Parameters
Ring 4 Installed	Flow (cfm) = **1.064** x (Fan Pressure in Pa)$^{0.502}$

Flow Range: 2.4 CFM to 25.0 CFM
Minimum Fan Pressure: 5 Pascals
Maximum Back Pressure: 100 Pascals
Accuracy: +/- 1 CFM

ATTACHMENT FIVE

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ENERGY AUDITOR

CERTIFICATION PROGRAM

PLUMBERS • UNION • PIPEFITTERS • SERVICE TECHS • STEAMFITTERS • SPRINKLERFITTERS •

QUALITY SYSTEM MANUAL

FORWARD

In the ever-changing business and environmental climate that we are in, energy efficiency has emerged as a critical factor in many construction and maintenance issues today. Whether existing policies are changed or new energy efficiency standards are implemented, how efficiently something operates has come to the forefront of this movement.

In keeping with providing a highly skilled and sought after workforce, the United Association (UA) has developed a program to assist with the identifying deficiencies in building operations. The UA Energy Auditor Certification provides additional knowledge and training to make certain that skilled UA craft persons are prepared to perform an Energy Audit on a building or facility.

The UA has designed the UA Energy Auditor Certification to encompass residential, commercial and industrial buildings. The program covers all of these individual components with a uniform standard; however, it also enables the program to be modified if a need to cover a specific area in more detail due to regulatory or geographical needs arises.

The United Association's Director of Training, a team of UA Training Specialists, Instructors and the UA Director of Sustainable Technologies, has established an examination/qualification program that provides an outstanding tool for determining an individual's capabilities and competences and ensures their on-going training needs are provided for and validated in a structured environment. The UA Energy Auditor Certification Program provides an assurance to industry that UA members have the necessary skills not only to do the job right but also to do the job right the first time.

It is our goal to provide highly trained UA journey workers with detailed knowledge and experience that will improve their job performance and contribute to lower building operating costs.

Without a doubt, the United Association boasts the premier training program available in the pipe trades industry today. For more than a century, we have been training apprentices and journey workers to the highest standards possible. There are approximately 330,000 highly skilled United Association members, of which 40,000 are apprentices, who belong to 309 individual local unions across North America. The UA maintains approximately 340 training centers in the United States and Canada. The UA's joint union-management training programs are now valued at a half billion dollars in equipment and real estate, moreover, about $200 million is spent annually in operation of these programs.

For a contractor or building owner, choosing Certified Energy Auditor from the United Association is an assurance that the quality of craftsmanship is the highest you can find in industry today.

UA STANDARD FOR EXCELLENCE

The UA Energy Auditor Certification Program has no parallel in industry today. Developed under the leadership of the United Association's General President William P. Hite, the program is designed to help meet the growing need for trained and qualified energy auditors. The program provides trained, experienced, certified and immediately available energy auditor throughout the United States and Canada, at no cost to contractors or their clients (owners and users). The United Association underwrites the cost of training and qualifying its Energy Auditors and provides for the use of Certified Energy Audit Instructors and other third parties involved in the program's success.

OBJECTIVES OF THE PROGRAM

- ✯ Promote uniform administration and enforcement of UA Energy Auditor qualifications and certifications.
- ✯ Promote a level of qualification standard, which will support safety, quality, and economical green systems installation activities.
- ✯ Provide industry with a qualification that is complete, accurate, consistent, reliable and current to comply with the required applications.
- ✯ Commit each UA Energy Auditor to performance that includes quality, safety and cost effectiveness for the required work.
- ✯ Enable all UA Energy Auditor to recognize their individual commitment to the integrity of the UA Energy Auditor Certification Program.
- ✯ Provide all UA Energy Auditors the opportunity to enhance the quality of their work and life and to emanate goodwill among the United Association, its members, the employing contractors and their clients (owners and users).

"The UA Standard for Excellence policy is a Labor-Management commitment to uphold the highest industry standards in the workplace and ensure customer satisfaction. The energy auditor certification program is designed to promote UA members' world class skills and safe, efficient work practices on the jobs performed by our signatory contractors for their customers while providing for a sustainable future for all."

Confirmation Signature: William P. Hite

William P. Hite - United Association General President

UA STAFF AND COMMITTEE PERSONNEL

UA GENERAL ADMINISTRATION

William P. Hite
General President

Christopher A. Haslinger
Director of Training

Phillip F. Martin
Administrator of Certification Programs

ENERGY AUDITOR TECHNICAL COMMITTEE

Richard Benkowski
Local Union 47

Charles Pelkey
Local Union 250

Paul Chapello
Local Union 597

THE UA ACKNOWLEDGES THE COOPERATION OF THE FOLLOWING ORGANIZATIONS:

HVAC Excellence

Green Mechanical Council

UA QUALITY SYSTEM MANUAL

The Administrator of Certification Programs is responsible for maintaining this Quality System Manual. The Manual shall be revised when necessary to improve existing procedures, when work methods or organizational changes occur, or to keep the Manual current with industry requirements. The Administrator of Certification Programs shall approve new or revised parts of the Manual; his approval is indicated on the Table of Contents Page by signature and date.

The UA Energy Auditor Certification Program Quality System Manual is maintained at the UA Certification Program Department, UA Building, UA Building, Three Park Place, Annapolis, MD 21401

Upon approval by the Administrator of Certification Programs, the Quality System Manual and its subsequent revisions are posted on UANet.org. The electronic version of the Manual is considered the only controlled version of the Quality System Manual and as such is password protected with only the Administrator of Certification Programs and designated UA Administrative Staff having editing capabilities. Printed out pages of the Manual are considered uncontrolled and are for informational purposes only. All UA Local Union Training Facilities are provided access to UANet.org.

Uncontrolled printed copies of the Manual may be issued to others upon request to the Administrator of Certification Programs. Uncontrolled copies are current at time of issue only and will not be issued to UA personnel.

Revisions to the Manual are made by Manual Section; however, when there are significant revisions throughout the entire Manual, a new Edition may be issued. The Revision dates and Edition number are identified on the Table of Contents page and the applicable revision date is shown on the bottom right-hand corner of each page of the Manual. The Summary of Changes page of the Manual describes the revisions made to the quality program. Each approved revision is issued with revised Table of Contents and Summary of Changes pages. Manual revisions become mandatory ninety (90) days after the revision date indicted on the Table of Contents page.

This Quality System Manual contains mandatory requirements and non-mandatory guidance for energy audit certification activities. The Manual does not address all aspects of these activities and those aspects that are not specifically addressed should not be considered prohibited. It is the responsibility of the Administrator of Certification Programs and members of the Technical Committee using sound technical judgment to provide guidance and a course of action in such matters.

All recipients of this Quality System Manual and related documents are trusted for their physical condition, intended use and maintenance. Violations of this trust, brought to the attention of the Administrator of Certification Programs, would support the withdrawal of all such documents.

SUMMARY OF CHANGES

Second Edition: January 2012

TABLE OF CONTENTS

Second Edition

Approval Signature: ________________________________

Phillip E. Martin, Administrator of Certification Programs

SECTION 1: ORGANIZATIONAL LEADERSHIP

1.1 Scope

a) The objective of the United Association Energy Auditor Certification Program is to provide highly qualified workers to fulfill the quality and workmanship requirements governing energy audit activities.

b) The implementation and maintenance of this certification program is conducted in accordance with this Quality System Manual.

1.2 UA General Administration Responsibilities and Authority

a) **General President -** has the authority and responsibility for the overall operations of the United Association and ensures that sufficient funding and personnel are available to properly administer the program.

b) **Director of Training -** has the authority and responsibility for the UA training program for all members, including journeymen, apprentices and instructors, along with seminars conducted for personnel throughout the UA.

c) **Administrator of Certification Programs -** has the authority and responsibility for all UA certification programs.

d) **Energy Audit Examination Administrator –** an individual who has satisfactorily completed the UA Energy Audit Training Course, who is responsible for proctoring and maintaining the integrity & security of the UA Energy Auditor Certification Examination.

e) **Energy Audit Instructor -** responsible for execution of the Local Union Energy Auditor Training Program, (Instructors are required to complete the UA Energy Auditor Training Course).

1.3 Program Resources

a) The resources for support of the Energy Auditor Certification Program consist of the following:

- The UA's International Training Fund underwrites funding for this Energy Auditor Certification Program.
- The development of the Energy Auditor Certification Program, including development, maintenance and control of the UA Quality System Manual and training material.
- The efforts of the UA Representatives to promote acceptance throughout the industry.
- The execution of the Energy Auditor Certification Program Examinations.
- Control of documents and records, including document issue, maintenance and storage.

SECTION 2: ENERGY AUDITOR TRAINING PROGRAM

2.1 Responsibilities

a) The Local Union Management is responsible for: ensuring that training materials are up to date, scheduling classes, providing Certified Instructors, and maintaining records of the training classes they provide.

b) Each training facility is responsible for arranging to have the necessary equipment, tools and materials available for use during Energy Auditor training classes.

2.2 Training

a) The UA Energy Auditor Certification Program may be instructed utilizing two different formats. Individuals who currently have the UA Green Systems Awareness Certification and the UA HVACR Star Certification can participate in the UA Energy Auditor course in a 40-hour instructional format. Individuals who do not currently have the UA Green Systems Awareness Certification and the UA HVACR Star Certification will be required to attend the UA Energy Auditor course in a minimum 80-hour instructional format.

b) Copies of the Energy Audit Training Manual are available from the IPT Bookstore for individuals use during the Energy Auditor training programs.

c) Other training materials that may be used to further class instruction are available via Blackboard through the UA Intranet. Only the Administrator of Certification Programs with technical approval from the Energy Audit Technical Committee may authorize materials that will reside on this website. Only Certified Energy Audit Instructors may access and utilize this website

2.3 Trainees Testing and Evaluation

a) Following completion of the training program a computerized only UA Certification Examination is provided. ***It is not recommended*** that individuals take the UA Energy Auditor Certification Examination without fully completing the training course.

- To schedule an examination the Local Energy Auditor Certification Program Administrator must fill out and submit the Exam Request Form from the NITC website a minimum of two (2) weeks before the examination date to schedule the exam.

b) As an alternative to the above, individuals who can provide documented evidence that shows extensive work experience performing energy audit type of work in residential, commercial and industrial buildings, may take the UA Energy Auditor Certification Examination without completing the 40-hour training program. This documentation shall be submitted at the time of making application for the exam to be reviewed by the Administrator of Certification Programs for approval.

c) The UA Energy Auditor Certification Examination consists of a 100 question multiple choice, open book, computer only examination. A score of 80% or above on the examination is required to attain certification.

d) The UA Energy Auditor Certification Examination additionally consists of hands-on practical skill set evaluation utilizing equipment while performing an actual or simulated energy audit on a structure. The guidelines for the completion of this portion of the exam are provided to instructors completing the UA Energy Auditor "Train the Trainer" course.

2.4 Training Records

a) A record package for each training session is maintained at the Local Union Training Facility and shall include a Training Group Summary Sheet for each training group completing the training program and an Individual Training Record for each person completing the program.

SECTION 3: ENERGY AUDITOR CERTIFICATION

3.1 Responsibilities

a) The Administrator of Certification Programs is responsible for the evaluation of UA Energy Auditor candidates. Upon completion of a satisfactory evaluation of the candidate's qualifications and examination results, the Administrator of Certification Programs issues the individual UA Energy Auditor credentials.

3.2 Initial Qualification Requirements

a) Individuals shall have started the fifth year of their apprenticeship before starting the UA Energy Auditor Certification Program.

b) Individuals shall have successfully completed and currently hold the UA Green Systems Awareness Certification Program before starting the UA Energy Auditor Certification Program.

c) Individuals shall have successfully completed and currently hold the UA HVACR Star certification before starting the UA Energy Auditor Certification Program.

d) As an alternative to the above, individuals who can provide evidence that shows extensive work experience in previously performing energy audits, will also be considered as meeting the prerequisites for participating in the UA Energy Auditor Certification Program.

e) Individuals who are participating in the UA Energy Audit Instructors Course shall currently hold the UA Green Systems Awareness Certification and the UA HVACR Star Certification.

3.3 Energy Auditor Certification

a) Upon satisfactory completion of all required classroom sessions, the Energy Audit Instructor reviews each individual's records of training for completeness and correctness.

b) Upon receiving a passing grade of 80% or above on the UA Energy Auditor Certification Examination the Administrator of Certification Programs shall issue the individual UA Energy Auditor credentials.

- Should an individual score less than 80% on the written (computerized test) examination, a retake of the exam may only be taken once. Should the individual score less than 80% on the retaken examination, the Energy Audit training course and full examination must be administered again.
- Should an individual score less than 80% on the practical skill set examination, a retake of the exam may only be taken once on the same day. Should the individual score less than 80% on the retaken examination, the Energy Audit training course and full examination must be administered again.
- UA Energy Auditor Certification is valid for a three-year period. Before expiration of the three-year certification, individuals are required to recertify per paragraph 3.4 below.

3.4 Recertification

a) Recertification training is provided to each individual holding UA Energy Auditor Certification on a three-year basis before the expiration of his or her certification. This UA update training is to maintain the proficiency of the skills and knowledge required for the UA Energy Auditor Certification, acceptable performance and to adopt new industry standards on performing energy audit type of work.

b) The recertification process is as follows:

- Before the expiration of their certification, individuals must take the 4-hour UA Energy Auditor Recertification Course. The course must have been attended before the certification expires and evidence of attending provided to the Energy Audit Examination Administrator.
- Complete a 50 question recertification exam from NITC and obtain a score of 80% or higher on the exam.

SECTION 4: SAMPLE FORMS

SAMPLE FORM NAME

- UA ENERGY AUDITOR TRAINING GROUP SUMMARY SHEET
- UA ENERGY AUDITOR INDIVIDUAL TRAINING RECORD

UA ENERGY AUDITOR TRAINING GROUP SUMMARY SHEET

Program Title: UA Energy Auditor Training

Local Union No. ___________

Program Start Date: ________________ **End Date:** _______________ **Total Hours:** ________

Instructor (s): ___________________________________ ___________________________________

Program Attendees (print names)	Sat/Unsat	Green Awareness	HVACR Star

____ ____________________

Instructor Signature Date

UA ENERGY AUDITOR - INDIVIDUAL TRAINING RECORD

Program Title: UA Energy Auditor Training

Name: ________________________________ **Union Card No.** ______________________

Home Local #: __________

Training Local #: _________ **City:** ______________________________ **State:** ____

Total Number of Classroom Hours Attended: ________

Hands-on Lab Practical Exercises	
Lab Guide	**Date Completed**
Blower Door Operation (Building Tightness)	
HVAC Equipment Efficiency	
Pitot Tube Test & Report	
Air Apparatus Test & Report	
Pump Test & Report	
Compressor/Condenser Test & Report	

Appraisals	Satisfactory or Unsatisfactory
U to R Calculation Exercise	
Blower Door Calculation Exercise	
Energy Audit Data Collection Form	
Electrical & Gas Consumption Exercise	
Final Examination	
Overall Course Average	

By completing a review of the individuals training records and by signing below I certify that the above named person has met all requirements of the UA Energy Auditor Training Program.

______________________________________ ______________________

Instructor Signature Date

____

Instructor Printed Name