

# Using a Pressure Pan To Diagnose Duct Leakage



***Performance Testing Tools***

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# Using A Pressure Pan To Diagnose Duct Leakage

Manual Edition: April 2010

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Special thanks to John Tooley and Bruce Davis of Advanced Energy, Neil Moyer of Florida Solar Energy Center and Bruce Manclark of Delta T whose research and field work form the basis of the pressure pan procedures presented in this manual.

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## Chapter A Introduction to the Pressure Pan

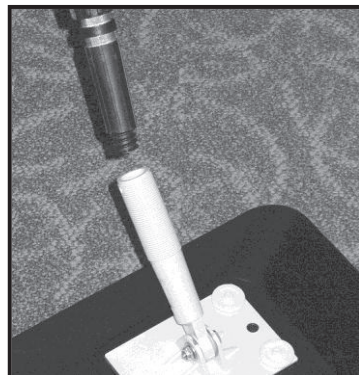
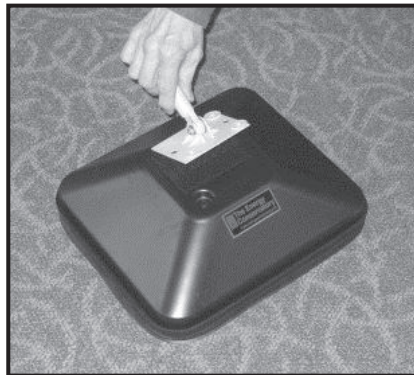
The pressure pan is a duct leakage diagnostic tool which is used along with a Blower Door to identify exterior air leaks in forced air duct systems. Pressure pans do not directly measure leakage rates. Rather, a pressure pan is used measure the pressure difference between the house and a duct run during a Blower Door test. This pressure reading can be used to estimate the degree to which a particular duct run is connected to the outside.

Pressure pan testing involves placing a gasketed pan over each register or grille, one at a time, with the air handler fan off and the Blower Door depressurizing (or pressurizing) the house to a standard reference pressure. The pattern of pressure pan readings often allows for quick identification of major leakage sites. Pressure pan readings can also be used as a quality control tool to tell technicians if they have done a good job of air sealing the duct system.

The essential feature of a pressure pan is the ability to provide a quick temporary seal over a register or grille. The Energy Conservatory manufactures two size pressure pans (10"x14"x4" and 22"x22"x4"), each made from molded plastic with an EPDM gasket attached to the lip of the pan, and a pressure tap mounted on the outside. The pressure pans are sized to fit completely over most typical residential registers and grilles. A short handle is provided which can be attached to the pan using Velcro strips. The handle is designed to allow a painters pole (not provided) to be threaded into the open end making it easier to access high wall or ceiling registers. A 10 foot length of coiled tubing is provided to connect the pressure tap on the pan to your pressure gauge.

**Note:** Sealing leaks in a duct system should always be part of a larger total system diagnostic procedure which includes examining total system air flow, airflow balancing, system charge, operation of combustion burners, house ventilation and leakage in the building envelope.

Pressure Pan Handle



## Chapter B How Does a Pressure Pan Work?

During a Blower Door test, the Blower Door fan creates a pressure difference between the inside of the house and the outdoors. A common Blower Door test procedure is to lower the pressure inside the house by 50 Pascals (or 0.2" w.c.) with respect to the outdoors. Under this condition, you can measure the pressure difference across any house exterior wall and find a pressure difference of approximately 50 Pascals (Pa).

When a forced air duct system is installed in a house, it is intentionally connected to the interior of the house by registers and grilles. If the duct system has no connections or leakage to the outside, then the air inside the duct system will be at the same pressure as the interior of the house during a Blower Door test. However, if the duct system is connected to the outside by leaks, the air inside a duct system will be at different pressure than the interior of the house during a Blower Door test. The larger the pressure difference between the duct system and the inside of the house, the more connected (and leaky) the duct system is to the outside.

The pressure pan can be used to quickly estimate the degree to which a duct run is connected to the outside. Let's consider a house with all the ducts located in a well vented attic. With the Blower Door depressurizing the house by 50 Pa (and the air handler fan off), place the pressure pan over each register and grille and measure the pressure difference between the duct system and the interior of the house using a pressure gauge connected to the pan. If the duct system is perfectly sealed and airtight, you will measure no pressure difference (0 Pa) when the pressure pan is placed over each of the registers.

Now imagine that one supply run is totally disconnected from a trunk line. When the pressure pan is placed over the register that is attached to the disconnected supply run, you will measure a large pressure difference (close to 50 Pa) between that duct run and the interior of the house. This large pressure difference is due to the duct run being disconnected from the supply trunk line and open to an attic space which is at approximately the same pressure as outside. When the air handler is operating, this supply duct is dumping conditioned air directly into the attic.

Typical pressure pan readings found in existing houses with external duct systems are commonly in the 0 - 20 Pa range (with the house depressurized to 50 Pa). However, pressure pan readings up to 50 Pa can be found in cases of catastrophic failure (such as complete disconnects). Generally speaking, the higher the pressure pan reading, the more connected (or leaking) that part of the duct system is to the outside.

### Important Points to Keep in Mind

1. Pressure pans do not measure leakage rates. Rather, a pressure pan is used to measure the pressure between the house and a duct run during a Blower Door test. This pressure reading can be used to estimate the degree to which a particular duct run is connected to the outside.



Because the pressure pan does not measure leakage rates, there will be times when a direct measurement of duct leakage to the outside using a Duct Blaster® and Blower Door will be necessary to determine if duct repair is cost effective. Pressure pan readings should only be used as a screening tool, not as an absolute pass/fail standard.

2. Pressure pan readings are sometimes hard to interpret. See Chapter E for tips on interpreting pressure pan readings.
4. Chapter F presents criteria which have been developed to screen houses for duct repair potential. These criteria should only be used for houses where a significant portion of the duct system is located outside of the conditioned house space (e.g. attics, crawlspaces, garages).
5. Experience to date has shown that in many retrofit applications, pressure pan readings can be brought down to or below 1.0 Pa with cost-effective duct sealing techniques. This allows the pressure pan to be used as a quick quality control tool in many houses.
6. Significant duct leakage to the inside of the house will tend to lower (or dilute) pressure pan readings. As a result, pressure pan readings tend to be unreliable in houses with large amounts of interior duct leakage. **Note:** Because many basement houses have large amounts of interior duct leakage (and the majority of the duct system is often inside the house), we typically do not recommend that pressure pans be used in basement houses.
7. Sealing duct leaks can significantly affect operation of the air handler and duct system. Duct leakage repairs should always be part of a larger total system diagnostic procedure which includes examining total system air flow, airflow balancing, and proper operation of combustion appliances.

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## Chapter C Typical Field Procedure

- Install the Blower Door and prepare the house for a Blower Door test. Be sure all interior doors are open and that combustion appliances (e.g. water heaters, furnaces, boilers) do not turn on during the test.
- Turn the air handler fan off, remove the filter(s) from the duct system and make sure that all registers, grilles and dampers are fully open.
- Temporarily seal outside combustion air inlets or ventilation system connections which are hard ducted into the duct system. These connections will show up as large leaks if you do not seal them prior to your test. If supply ducts are located in a garage or other semi-conditioned space, seal these registers so that the register opening does not show up as a duct leak.
- If there are duct runs located in attics, crawlspaces or garages, open those areas to the outside as much as possible by opening adjustable vents or doors.
- Turn on the Blower Door system and depressurize (or pressurize) the house by 50 Pa with respect to the outside.
- If ducts are located in unconditioned spaces such as attics or crawlspaces, measure the pressure between the house and the unconditioned space. If the measured pressure is less than 45 Pa, re-check to be sure all operable vents or openings in that space are open to the outside. We want unconditioned spaces containing ducts to be as close to outside pressure as possible. If the pressure difference between the house and the unconditioned space is significantly less than 45 Pa, it will be difficult to correctly interpret pressure pan numbers.
- Connect a piece of tubing between the pressure pan and your pressure gauge.
  - ⇒ If you are using an Energy Conservatory digital gauge, connect a piece of tubing from the pressure tap on the pan to either Input pressure tap on the gauge. Set up the gauge to measure pressure (in Pascals) on the pressure Channel connected to the pan. The gauge should be set to use 1 second averages and 0.1 Pascal resolution.
  - ⇒ If you are using a Magnehelic gauge and depressurizing the house, connect the tubing from the pan to the top pressure tap on the gauge. If you are pressurizing the house, you will need to connect the tubing from the pan to the bottom pressure tap on the Magnehelic gauge. Once the tubing is connected, steady the gauge so it is approximately level, and zero the gauge using a screwdriver and the adjustment screw below the face plate.
- With the Blower Door running, firmly place the pressure pan completely over each register or grille to be tested until the EPDM gasket forms a seal around the register.
- Once the reading has stabilized, record the pressure pan reading shown on your gauge. (If using a Magnehelic gauge, make sure the gauge is level and has not been moved since it was zeroed.)
- Repeat the test for each register and grille in the house.
- Determine if duct repairs are necessary (see Chapters D, E and F below).

*Tips on Taking Pressure Pan Readings*

1. If the register or grille is larger than the opening of the pressure pan, you can either temporarily seal off the register completely and insert the hose connected to the gauge through the seal (preferably in the middle of register or grille), or seal off part of the register and place the pressure pan over the remaining open area. To temporarily seal off registers, you can use masking tape and paper, or The Energy Conservatory sells a convenient adhesive backed film called Duct Mask. Once you have taken the pressure pan reading, remove the temporary seal before proceeding to the next register. **Note:** When completely sealing off the register and inserting a hose, leaks between the boot and the drywall or floor may cause artificially high readings from jets of air striking the end of the hose.
2. When 2 registers or grilles are closely connected to the same duct run (e.g. two registers on opposite sides of the same partition wall), seal one of the them closed and use the pressure pan on the other unsealed register or grille. Once you have taken the pressure pan reading, remove the seal before proceeding to the next register.
3. Only one person at a time should be taking pressure pan readings. Having 2 registers in different parts of the duct covered by a pressure pan at the same time could affect your readings.

## Chapter D Example Field Results

Figures #1 and #2 show field results on two houses where pressure pan readings were taken before and after comprehensive duct repairs were performed. These results are part of an 18 house study conducted by Bruce Davis of the North Carolina Alternative Energy Corporation for the Arkansas Energy Office in 1991. In both houses, there are eight supply runs (labeled S1 - S8) and a single return (labeled R1). Pressure pan readings were taken at each of the registers with the house depressurized by 50 Pa with respect to outside. Readings taken before duct repairs were made are shown by the unshaded bar, and post-repair readings are shown by the shaded bar.

In House #1, the highest pressure pan readings were in S3 and R1 indicating significant connections in those duct runs to the outside (remember, the largest reading possible would be 50 Pa). Duct sealing was first concentrated on these two runs. Supply runs S1 and S4 were also sealed because a visual inspection found poor boot connections. Following these repairs, we see that all pressure pan readings were significantly reduced, with most readings falling at or below 1.0 Pa. Because all readings were near 1.0 Pa, no further duct repairs were made.

In House #2, all of the duct runs show elevated pressure pan readings of 2.5 Pa or greater. Visual inspection in this house found that all flex duct connections to trunk lines and boots were very poor. All of these connections were sealed along with sealing around the platform return in the garage. Pressure pan readings taken after the repairs were made showed significant reduction. In this case all readings are below 1.0 Pa, except for the return which was at 1.8 Pa. It was decided that further sealing of the return run was not cost-effective because of difficult access to the leakage site.

Figure #1

Tri-level house with upflow gas furnace located in garage mechanical room.  
 Single return under the 1st floor stairway cavity. Supplies run through  
 vented crawlspace and attic.

Sealed return stairway cavity (R1) and AH filter slot. Floor boot connections  
 for S1, S3 and S4 were also sealed.

Duct Leakage: Before Repair = 660 CFM50  
 After Repair = < 25 CFM50

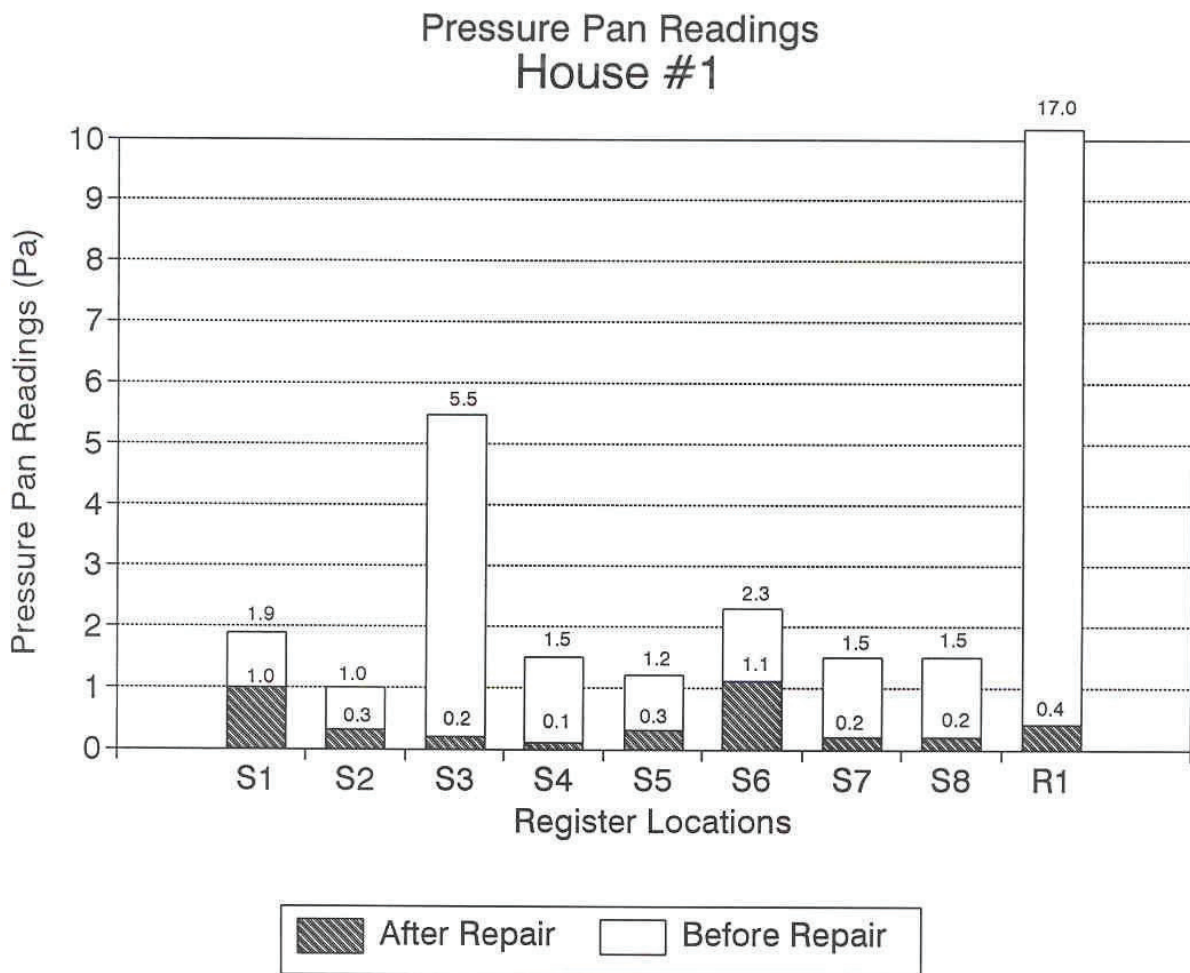
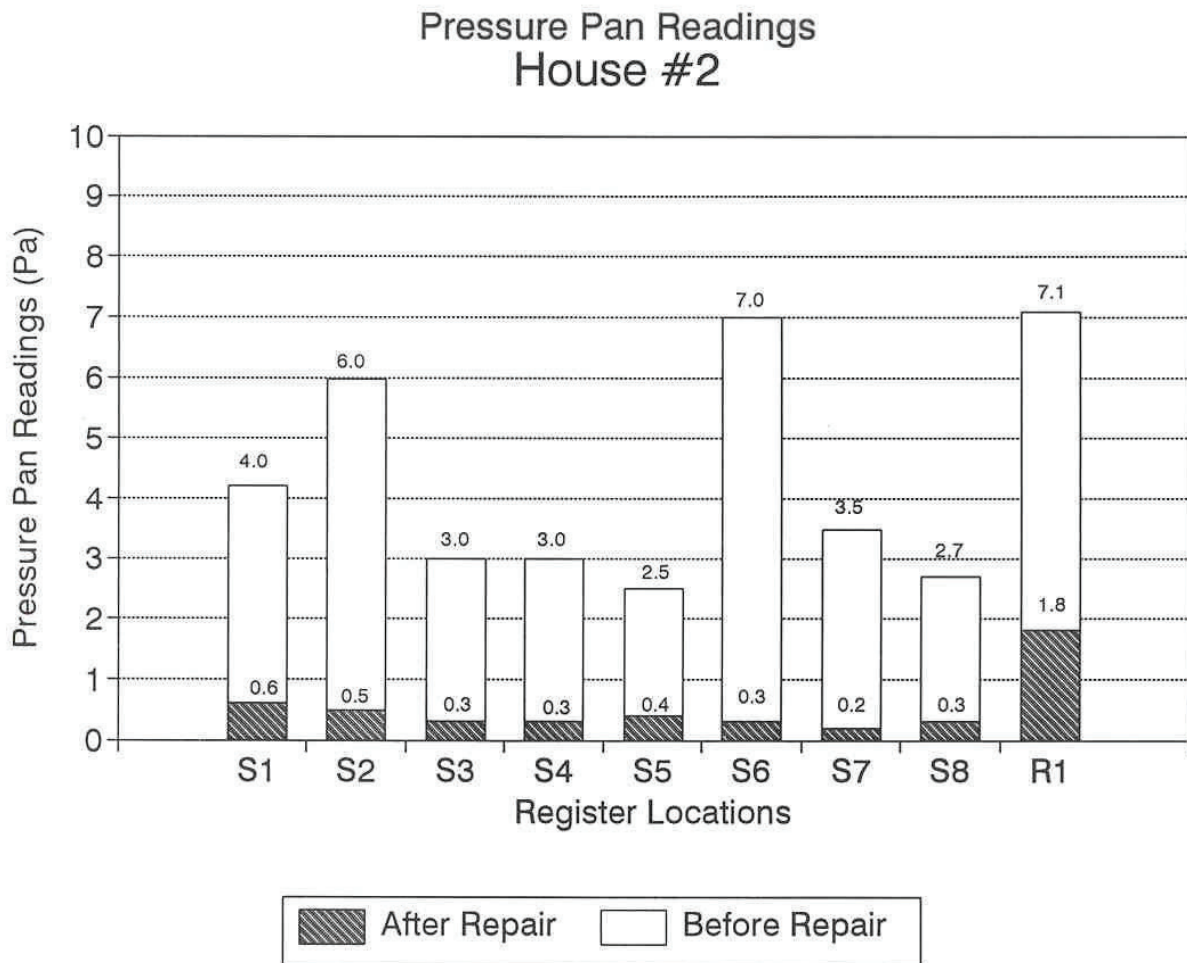


Figure #2

Single story house with upflow gas furnace placed on platform return in the garage. Supply and return duct runs located in vented attic. Very poor flex duct connection with metal trunk lines.

Sealed all flex duct connections to trunk lines and boots. Sealed platform return.

Duct Leakage: Before Repair = 375 CFM50  
 After Repair = 85 CFM50



## Chapter E Tips on Interpreting Pressure Pan Readings

### *Prioritizing Duct Leaks*

1. The size of the pressure pan number can be used to prioritize repair of leakage sites. A larger reading (e.g. 10.0 Pa) is typically more important than a smaller reading (e.g. 1.0 Pa). Big connections to the outside that are close to a register will cause a large pressure pan reading at that register.
2. The proximity of the register or grille to the air handler can also be used to prioritize repair of leakage sites. When comparing pressure pan readings of equal size, duct runs closer to the air handler should generally receive a higher priority than ones located farther away from the air handler because leaks closer to the air handler will see higher pressures when the air handler is operating.
3. When comparing pressure pan readings of equal size, supply side leaks should typically be given higher priority than return side leaks from an energy savings standpoint. This is because the supply air has already been conditioned (heated or cooled) and generally has more energy value than air being drawn in through a return leak. **Note:** Return leaks that create a negative pressure in an area that contains natural draft combustion appliances should always be considered as high priority due to health and safety concerns from pressure induced spillage of combustion products.
4. When prioritizing between return leakage sites, you should consider the temperature of the air being drawn into the return leak. The larger the temperature difference between the conditioned air inside the house and the air being pulled into the return leak, the greater the priority to repair. For example, in a cooling application a return leak pulling in 120 F attic air would be more important (from an energy loss stand point) than the same size leak drawing in air from a 75 F crawlspace.

### *Factors That Complicate Interpretation of Pressure Pan Readings*

1. Significant duct leakage to the inside of the house will tend to lower (or dilute) pressure pan readings. As a result, pressure pan readings tend to be unreliable in houses with large amounts of interior duct leakage. **Note:** Because many basement houses have large amounts of interior duct leakage (and the majority of the duct system is often inside the house), we typically do not recommend that pressure pans be used in basement houses.
2. Pressure pan readings from duct runs located in unconditioned spaces, such as attics and crawlspaces, may require special interpretation. During the Blower Door test, we want unconditioned spaces containing ducts to be as close to outside pressure as possible. If the unconditioned space is well connected to outside (i.e. the unconditioned space is at approximately the same pressure as the outdoors during the Blower Door test), then pressure pan readings from ducts in that space can be interpreted normally. However, if the unconditioned space is not well connected to the outside (e.g. unvented crawlspaces or unvented attics) or has very large connections to the house, then the unconditioned space will be at a pressure somewhere between the outside and inside house pressure during the Blower Door test. In this case, the pressure pan reading will show an artificially low number.

You can measure the degree of connection between an unconditioned space and the outside by measuring the pressure difference between the house and the space during the Blower Door test. If the pressure between the house and the unconditioned space is 45 Pa or greater (assuming the house to outside pressure difference is 50 Pa with the Blower Door running), then pressure pan readings on duct runs in that space can be interpreted normally. If the pressure is less than 45 Pa, check to be sure all operable vents or openings in that space are open to the outside. If they are open and there is no way to better connect the unconditioned space with the outdoors, you will need to interpret pressure pan readings on duct runs in that space carefully, using the following guidance:

*Always compare the measured pressure pan reading with the maximum possible reading. Under standard test conditions, the maximum possible pressure pan reading is 50 Pa. However, if ducts are located in an unconditioned space which is not at the same pressure as outdoors during the Blower Door test, then the maximum possible reading is no longer 50 Pa, but rather it becomes the pressure between the house and that unconditioned space. For example, if ducts are located in an unvented crawlspace, and the pressure difference between the house and the crawlspace is 10.0 Pa with the Blower Door depressurizing the house by 50 Pa, then the maximum possible pressure pan reading for duct runs in that crawlspace becomes 10.0 Pa. A pressure pan reading of 2.5 Pa (one-quarter of the maximum possible of 10.0 Pa) in this case is approximately equivalent to a 12.5 Pa reading for a duct located in a space at outdoor pressure.*

**3.** Gaps between duct boots and sheetrock (or flooring) will show up as duct leaks when using a pressure pan. Always check for these gaps on duct runs having elevated pressure pan readings. Although these leaks are usually less important because of the low pressure they normally experience, they are easy to access and should almost always be sealed.

**4.** Pressure pan readings from "toe space" registers found under kitchen and bathroom cabinets often require special interpretation. With many toe space registers, the register is not physically connected to the supply duct. Instead of a direct connection, the cavity underneath the cabinet is often used as a plenum to connect the register with the supply duct run. Because this cavity plenum is typically quite leaky and is connected to either the house or an outside wall (or both), pressure pan readings can sometimes be misleading.

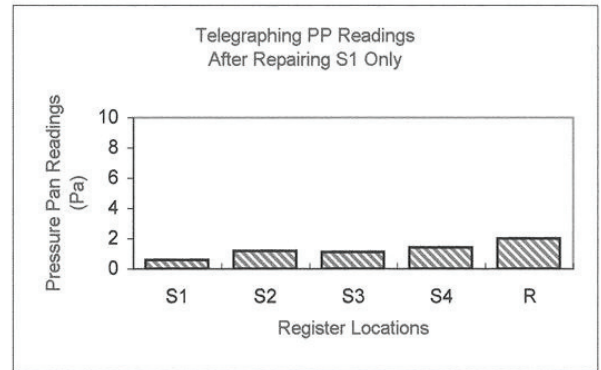
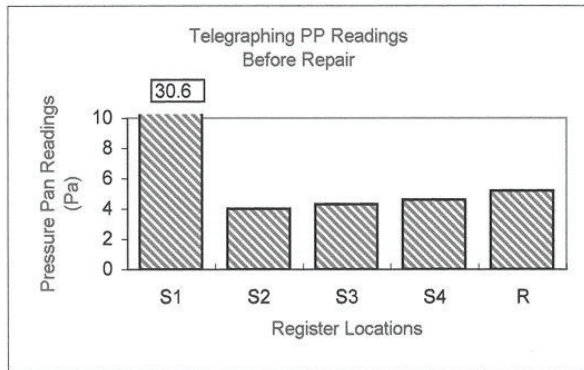
For example, a significant duct leak to the outside might not show up as an elevated pressure pan reading because a connection between the cavity plenum and the house is providing pressure relief to that register. In addition, a high pressure pan reading could be caused by a connection between the plenum cavity and an exterior wall, rather than a leak in the supply duct run. In many cases, you will need to remove the register and use chemical smoke to diagnose potential leakage paths and determine appropriate repairs.

**5.** A dirty AC coil will tend to increase pressure pan readings. Always check the condition of the AC coil before pressure pan testing.

**6.** Closed or partially closed registers or dampers will create large pressure pan readings. Always check that registers and dampers are fully open before pressure pan testing.



7. Large duct leaks often telegraph their presence to other portions of the duct system. Once the large leaks are repaired, many other pressure pan readings can drop significantly. This concept can be seen in the pair of graphs below. The left hand graph shows pressure pan readings before any repairs were made. Duct run S1 shows a large duct leak to the outside. After making repairs on duct run S1 only, all the readings dropped significantly. In this case, performing a mid-repair pressure pan test would be very useful in reducing the amount of time required to repair the system. Without a mid-repair test, we may have unnecessarily spent time looking for leaks in the other supply duct runs. The return is probably still worth repairing because it shows a 2.0 reading.



8. If you are testing a house with a very leaky building shell and are not able to create a 50 Pa pressure difference with the Blower Door, perform your pressure pan tests with the house at the highest achievable pressure. In this case, you will need to interpret your pressure pan readings carefully. As mentioned in item 2 above, compare the measured pressure pan reading with the maximum possible reading.

## Chapter F Using Pressure Pans to Screen Houses for Duct Repair Potential

Pressure pan test criteria have been established for use in large scale duct retrofit programs, to screen houses for duct repair potential. These criteria were developed as a way to quickly assess the need for duct repairs, thereby reducing the need to perform more time-consuming direct duct leakage measurement tests (in CFM) for all houses.

The pre-qualifying pressure pan criteria shown below were developed by John Tooley of Advanced Energy using measured field results from 460 systems located in 349 houses in the southeastern and southern United States. These criteria were developed for existing duct systems with a significant portion of the duct system located outside of the conditioned house space (e.g. attics, crawlspaces, garages). Houses with all or large portions of the duct system inside the structure may need special considerations not included in these criteria.

### *Pre-Qualifying Criteria:*

There are 3 pre-qualifying criteria for determining the need to measure and repair duct system leakage for energy use reduction. All pressure pan measurements listed below are to be taken with the house depressurized by 50 Pascals with respect to outside. It is assumed that a pressure pan reading will be taken at every register and grille in the house, and that all unconditioned spaces containing ducts are well connected to the outside.

- **Criteria #1 (Tight Duct Systems):** All pressure pan readings are less than 1.5 Pascals, and not more than 2 readings can be greater than 1.0 Pascals.

Duct systems in **Criteria #1** houses are considered tight for typical existing systems. **Criteria #1** houses should require no direct measurement of duct leakage, and repairs for duct leakage are not recommended unless they are very easy to make, or repair is needed to correct a health, safety, durability or comfort problem. Of the 460 systems tested in the Tooley sample, 97 (or 21%) fell into **Criteria #1** with an average leakage to the outside of 75 CFM25.

- **Criteria #2 (Leaky Duct Systems):** 3 or more pressure pan readings are greater than 2.0 Pascals.

Duct systems found in houses meeting **Criteria #2** are considered leaky and repair is suggested for energy use reduction. Measurement and quantification of duct leakage is not needed because the pressure pan readings have told us that the duct system is leaky enough to warrant immediate repair work. In the Tooley sample, 167 systems (or 36%) fell into **Criteria #2** with an average leakage to outside of 940 CFM25.

Each pressure pan reading above 1.5 Pascals should be identified and the associated duct run repaired, starting with the highest pressure pan reading and working to the lowest. It is often useful to perform mid-repair pressure pan testing to reduce the amount of time required to

repair the system. Often large leaks telegraph their presence to other portions of the duct system, and once the large leaks are repaired, many other pressure pan readings drop.

**Note:** You may still need to measure and quantify pre and post-retrofit duct leakage in **Criteria #2** houses if you are providing duct sealing services under a program which requires leakage testing.

- **Criteria #3 (Gray Area Systems):** All houses not meeting **Criteria #1 or #2** above are classified as Gray Area Systems.

Gray Area Systems require direct measurement and quantification of leakage to determine whether or not repairs will be cost effective. Pressure pan readings alone will not provide enough information to determine if duct repair is needed. Direct measurement is defined as measuring duct leakage to the outside in cubic feet per minute (CFM), using either a duct airtightness tester in combination with a Blower Door, or using the modified Blower Door subtraction technique. If duct leakage measurements using these methods are greater than specified program target leakage rates for your area, then repair is recommended. Forty-three percent (196) of the systems in the Tooley sample were **Criteria 3** houses, with an average leakage to outside of 353 CFM25.

These criteria can also be used following repairs to assure that a cost effective repair has been accomplished. Houses that required no direct CFM leakage measurement going in (Criteria #2 houses), may require a leakage measurement before leaving (because they are now Criteria #3 houses) to assure that adequate repairs have been accomplished. The expected results of using the pressure pan criteria is that at least 50% of the houses tested can be properly diagnosed for outside duct leakage problems without having to conduct a direct duct leakage measurement (in CFM).

#### ***Qualifications on Criteria Use:***

- The criteria above were developed for electric heating and cooling at a cost of \$0.07 to \$0.08 per kwh and higher. Lower rates or different fuel types may require slight adjustments to the criteria.
- The criteria were developed to assess the potential for cost effective repair of duct leakage to the outside. The criteria can not be used to assess interior duct leakage problems or duct leakage problems resulting in health, safety, durability or comfort concerns. If duct leakage repair is performed, examining total system air flow, airflow balancing, and proper operation of combustion appliances should be included in your work plan.
- The criteria were developed for existing duct systems with a significant portion of the duct system located outside of the conditioned house space (e.g. attics, crawlspaces, garages). The criteria are not intended for use in new construction.

- The criteria assume that all unconditioned spaces containing ductwork are well connected to the outside (e.g. at least a 45 Pa pressure difference between the house and the unconditioned space with the house depressurized by 50 Pa to outside). If the unconditioned space is not well connected to the outside (e.g. ducts located in an unvented crawlspace or unvented attic), then the pressure pan reading will show a lower number and the criteria may require adjustment.

## Chapter G Special Considerations for Ducts in Garages

Garages containing ductwork (e.g. tuck under garages, or garages with air handlers) present a special concern because of the potential for indoor air quality contamination from automobile exhaust and stored household chemicals. Because of this concern, it is extremely important to find and seal all ducts running through garages, particularly leaks in return ductwork or the return side of the air handler cabinet which may be pulling garage air into the duct system. When diagnosing houses with garages containing ductwork, we suggest that you always set up the house so that the garage is effectively *outside the house*.

- Open the main garage door(s) to the outside.
- Close any doors between the house and the garage.
- Temporarily seal off any combustion air inlets or ventilation system connections which are hard ducted into the duct system. These connections will show up as large leaks if you do not seal them prior to your test.
- Temporarily seal any supply registers located in the garage (**Note:** you will probably want to permanently disconnect and seal garage supply registers if the homeowner agrees).
- Conduct your pressure pan tests and record the readings.
- Interpret all elevated pressure pan readings as leaks to the outside.