Blower Door Basics

Train the Trainer

Key Terminology

Air Changes per Hour (ACH)

Building Tightness Limit (BTL)

Can't Reach Fifty (CRF)

Cubic Feet per Minute (CFM)

CFM_{50}

$CFM_{natural}$

Low-flow rings

Manometer

Minimum Ventilation Requirement (MVR)

N-factor

Pascals (Pa)

Stack effect

Wind effect

Winter mode

With Reference To (WRT)

Worst-case draft Combustion Appliance Zone (CAZ) testing

Section Transition

Learning Objectives (Slide #2)

By attending this session, participants will:

- Name and understand the natural driving forces that cause pressure differences.
- Understand units of pressure and the measurement of air leakage.
- Be able to set up and operate a blower door to measure air leakage and conduct zonal pressure diagnostics.
- Understand the meaning and importance of minimum ventilation requirements (MVR).
- Be able to convert blower door readings to the total size of an opening in square inches, and to cubic feet per minute (CFM) of air leakage under natural conditions.
- Understand the relationship between CFM_{50}, $CFM_{natural}$, and air changes per hour (ACH).

Blower Door Testing (Slide #3)

- Blower door testing locates and quantifies air leakage by using a calibrated fan to depressurize a house.

This photo is of a Minneapolis Blower Door manufactured by the Energy Conservatory in Minneapolis, MN.

Ask students what types of blower door they are familiar with.

Point out the fan rings in the right photo.

Does anyone still use magnahelic gauges?

Measuring Building Air Leakage #1 (Slide #4)

- Natural driving forces – Pressure differences caused by natural driving forces of ***wind effect***, ***stack effect***, and combustion and ventilation are too small to measure reliably. These naturally occurring pressure differences change with the wind and temperature, and are not repeatable.
- Blower door – This controlled driving force exaggerates pressure differences so they can be measured reliably and the results are repeatable. With this tool, we can measure leakage from a standard baseline.

We can convert the exaggerated air leakage measured with the blower door to air leakage that would occur under natural conditions.

Ask students to name the natural driving forces.

Measuring Building Air Leakage #2 (Slide #5)

- The standard baseline for blower door reading is a pressure of -50 ***pascals*** (Pa) in the home ***with reference to (WRT)*** the outside.
- Air leakage measured by the blower door is proportional to the size of the holes in the house between inside and outside. Air leakage is measured in ***cubic feet per minute*** at -50 Pa, also written as ***CFM_{50}***. To convert the blower door reading at CFM_{50} to the total size (in square inches) of the holes between the inside and outside of the home, divide the blower door reading at CFM_{50} by 10.
- Conducting blower tests before and after air sealing helps determine the effectiveness of our work. Post-testing reveals whether any big leaks were missed while air sealing.
- Blower door testing tells us which houses have the most potential for energy savings through air sealing. If the house is already fairly tight, it isn't cost-effective to spend hours finding and sealing tiny leaks. In these homes, concentrate time and effort on installing insulation, base load, and mechanical measures. In this way, the blower door helps develop an effective work scope.

Measuring Pressure & Airflow (Slide #6)

- Measure pressure difference between one space and another, not total pressure.
- Always measure one pressure with reference to another – You would never simply say the attic is at 50 Pa.
- Sometimes measure pressure under controlled, artificial conditions, and sometimes under normal operating conditions.

Q: Besides the blower door, can anyone name another controlled, artificial condition we create to test pressure?

*A: **Worst-case draft combustion appliance zone (CAZ) testing***

Measuring Pressure Difference (Slide #7)

Units for measuring pressure difference:

- Pascal is the metric standard and the standard in building science. Some HVAC technicians use the American standard, inches of water column.
- 1 Pa = approximately the weight of one Post-It note
- 249 Pa = 1 inch of water column
- 1” water column = pressure required to suck 1” of water up a straw

Ask if there are any in the class from the HVAC industry. What do they use the metric inches of water column for?

Units for Measuring Airflow (Slide #8)

Cubic feet per minute

- Rate of airflow – A cubic foot of air is about the amount in a basketball. When we measure CFMs, we're determining how many basketballs per minute leak into and out of the home.

The MVR is the amount of fresh air a home requires when it is closed up to maintain healthy indoor air quality based on the size of the home and the number of occupants. MVR is the target number of CFMs not to go below when air sealing the home.

CFM_{50} (standard for blower door)

- A blower door measures the rate of airflow in CFM when the pressure inside of the house is -50 Pa with reference to outside. The exaggerated pressure difference is reliably measurable and repeatable.

Blower Door Components (Slide #9)

- Fan
- Frame
- Speed controller
- ***Manometer*** – the pressure gauge.
- Hoses

Blower Door Fans (Slide #10)

- Left photo – Minneapolis Brand from the Energy Conservatory.
- Right photo – Retro-Tech, originated in Europe and focused on commercial buildings.
- A third manufacturer, Infiltech, is not pictured here. Its blower door fans are blue.

Blower Door Frame #1 (Slide #11)

Photo of adjustable frame and case from the Energy Conservatory.

- These frames are quick to assemble and disassemble. Installers have probably seen this type of frame.

Blower Door Frame #2 (Slide #12)

Photo of the Energy Conservatory's Minneapolis Blower Door set up in an exterior door

- Fan hangs on the cross member.
- Mounting place for the manometer and fan speed control.
- It is wise to keep controls off the ground to avoid accidental damage.

Some of the Retro-Tech doors have hard panels instead of fabric.

Manometers & Gauges (Slide #13)

Devices used to measure pressure differences:

- Magnahelic gauges – These are largely relics now.
- DG-700 – The Energy Conservatory. Many installers are familiar with the DG-2, DG-3, or the newest DG-700 pictured here.
- DM-2 – Retro-Tech.

Blower Door Setup (Slide #14)

- Set up blower door in an exterior door – Indicate which door you install the blower door in on your data sheets. This helps ensure repeatable results during monitoring.
- Put the house in ***winter mode*** by closing all exterior doors and windows and opening all interior doors.
- Turn off heating and cooling systems and fuel-fired water heaters – There are two reasons for turning off all combustion appliances:
  - Most importantly, so dangerous combustion gasses don't get sucked down the flue into the house.
  - So the air handler is not fighting with the blower door.
- Close fireplace dampers.
- No wood stoves in use! Call ahead to make sure residents don't use the wood stove for at least 24 hours before the visit.
- Remove ashes or cover with wet newspaper. There are many stories about forgetting to cover the ashes. Statistically, this happens most often in homes with white carpeting. You only do that once.

Anecdote: One client ignored the auditor's request and used the wood stove the day before the auditor came. There were ashes in the stove, so the energy auditor and helper decided to pressurize the house (instead of normal depressurization) so they wouldn't suck ashes out of the wood stove. After a while, they heard a roar that had been covered up by the sound of the blower door fan. By pressurizing the house, they had basically created a blast furnace in the wood stove. They rushed outside to see the stove flue glowing red! Luckily, no permanent damage was done.

Remember to turn the appliances back on before you leave. An old energy auditor trick is to leave your truck keys on the water heater so you remember to turn the water heater and furnace back on. It's unfortunate to be 50 miles away when you get the call from the client that the hot water heater stopped working.

Blower Door: Things to Know (Slide #15)

- ***Low-flow rings*** (for tighter homes) – In tight homes, you need to use low-flow rings so air rushes past the sensors fast enough to give you a reliable reading. The hose takes a reading from the fan by converting the amount of air rushing past the four sensors to CFM_{50}. If the house is really tight, a low fan speed is needed to create -50 pascals of pressure in the home. This leaves the air flowing past the sensors too slowly to get a reliable reading. Adding rings creates a smaller hole, which equals faster flow.
- ***Can't reach fifty*** (CRF) – In very leaky homes, it is sometimes impossible to depressurize the home to -50 pascals because air rushes in too fast. In this case, digital manometers will read CRF. Since most standards and calculations are based on achieving a blower door reading of CFM_{50}, new sensors automatically calculate what the leakage would be at this rate. Older sensors come with tables of multipliers that allow auditors to put readings in context of CFM_{50}.

- Check flow sensors – If readings seem unusual, make sure the flow sensors aren't blocked.
- Hose to outside – The end should be at least 5 feet on one side of the fan or the other (not in front of the fan). If the end of the hose that is taking the outside reading is too close to the fan, the reading will not be accurate. Also keep the hoses clear of the fan on the inside so they aren't sucked up into the fan.

Blower Door Setup: Air Leakage (Slide #16)

Always set up the manometer the same way so it becomes automatic to you.

When measuring whole home air leakage:

- Channel A measures the pressure difference of the inside of the house with reference to outside – Adjust rings and/or fan speed until the reading on this channel is -50.
- Channel B measures the pressure difference of the fan with reference to inside – This tells you the leakiness of the building or can be converted to pressure.

Fan Pressure #1 (Slide #17)

- Airflow across the sensor in the hub of the fan causes air pressure.
- The manometer compares this fan pressure to the pressure inside the house and converts the pressure difference to a rate of airflow.
- Airflow induced by the fan creates a pressure difference between the inside and outside of the house. The manometer uses this pressure difference to calculate a rate of airflow.

Fan Pressure #2 (Slide #18)

- The flow sensor is a plastic ring with four holes in the outer circumference.
- An airtight tunnel inside the sensor connects the holes to the hose coming out of the sensor.
- This hose connects to a tap mounted on the top of the fan.
- A hose connects this tap to the manometer.

Older blower doors had channels to the sensors that were caulked. That seal failed and leaked occasionally. With an older blower door, test this seal by putting your fingers over the holes. With fingers in place, suck on the tube. It should stick to your tongue.

Blower Door Setup #1 (Slide #19)

- Check upper left portion of screen to ensure correct DEVICE is displayed. If not, toggle DEVICE button until it indicates Blower Door (BD).
- Check upper right portion of screen to ensure the correct flow ring is displayed. If not, toggle the CONFIG button. This reads OPEN, indicating there are no flow rings to restrict flow.

Blower Door Setup #2 (Slide #20)

- Check the lower left portion of screen to ensure correct MODE is displayed. If not, toggle MODE button – Typical mode is PR/FL@50, flow at 50 Pa pressure difference.
- Lower right portion of screen displays time average setting – Toggle TIME AVG button to desired setting. Options on this model are 5 seconds, 10 seconds, or long term. The manometer takes around 40 measurements per second, so in 5-second mode, the readout is an average of hundreds of readings taken over 5 seconds. Longer TIME AVG settings can help correct for fluctuating readings on windy days.

Q: What does the PR/50 in the lower left window indicate?

A: PR/50 in the lower left window means the manometer does the CRF calculations automatically when the house can't reach -50 pascals.

Blower Door Setup #3 (Slide #21)

- In typical PR/FL@50 mode, the left portion of the screen displays the pressure of the house with reference to outside.
- The right portion of screen displays house air leakage in cubic feet per minute at -50 Pa, CFM_{50}.

Blower Door Setup #4 (Slide #22)

- To set up in typical PR/FL@50 mode, turn on DG–700 and press MODE button twice.
- With fan cover on, calibrate the manometer to account for the baseline house pressure with reference to outside by pressing BASELINE then START. After 30 seconds, or when the pressure reading is steady, press ENTER.

Set mode before baseline. Setting mode second wipes out the baseline.

Blower Door Test (Slide #23)

Run the blower door test:

- Remove the fan cover.
- Turn the blower door on and slowly increase speed to achieve a pressure difference between the house with reference to outside of -50 pascals (Channel A).
- Read the whole-house infiltration rate on Channel B.

CFM_{50} vs. $CFM_{natural}$ (Slide #24)

CFM_{50} refers to the amount of air leakage measured while running the blower door – There is no direct, constant ratio between this number and the amount of air leakage that occurs in the home under natural conditions.

$CFM_{natural}$ is the amount of air leakage under natural conditions.
CFM_{50}/***"N" factor*** = $CFM_{natural}$ – To determine the amount of air leakage that occurs naturally, divide the reading attained at CFM_{50} by the N-factor.

- The N-factor depends on climate, building height, and shielding from wind.
- N ranges from 9.8 to 29.4, but typically averages about 20 – A higher N-factor means the blower door is creating more exaggerated conditions. A lower N-factor means the blower door reading is closer to the natural leakiness of the home.
- Example: 4,000 CFM_{50}/20 = 200 $CFM_{natural}$ – In this case, a blower door reading of 4,000 cubic feet per minute air leakage translates into 200 cubic feet per minute of air leakage under natural conditions.

Approximate Leakage Area (Slide #25)

Calculating the approximate leakage area is a good way to think about the overall leakiness of the home and to express that leakiness to clients.

Divide CFM_{50} by 10 to determine approximate square inches of holes in the home.

5,000 CFM_{50}/10 = 500 square inches.

This simple equation indicates that starting with the equivalent of a 500-square-inch hole, air sealing reduced the size of the hole to only 150 square inches.

> *Q: If the pre-air-sealing reading were 5,000 CFM_{50}, what post-air-sealing blower-door reading would indicate a reduction of 350 square inches of leakage area?*
>
> *A: 1,500 CFM_{50}*

Air Changes per Hour #1 (Slide #26)

Air changes per hour (ACH) refers to how often the air in the home is refreshed. ACH_{50} refers to how often the air is refreshed when the pressure difference is 50 Pa. This puts blower door readings in context with the size of the home.

Air changes per hour at 50 Pa (ACH_{50}):

- 4,000 CFM_{50} is leaky for a small house, but may be tight for a larger house – A reading that shows a small home is quite leaky might indicate that a much larger house barely meets ***minimum ventilation requirements (MVR)***.
- ACH_{50} takes the size of the house into account.
- CFM_{50} x 60 min/hr/house volume = ACH_{50}.
- New houses: ACH_{50} = 5 to 10.
- Older houses: ACH_{50} = 11 to 15.

Some weatherization-eligible houses have ACH_{50} of up to 30, meaning if you run the blower door for one hour, all the air in the house is changed 30 times within that hour!
The old ASHRAE standard 62.1989 requires 0.35 $ACH_{natural}$ per person.

Air Changes per Hour #2 (Slide #27)

A sample calculation to convert a blower door reading of CFM_{50} to ACH_{50}:

- House volume = length x width x height.
- Conditioned space only.
- House dimensions: 40' long, 28' wide, 8' high.
- Blower door reading = 4,500 CFM_{50}.

ACH_{50} = CFM_{50} x 60 min/hr/house volume.

The sample house is a simple rectangle: 40 feet long, 28 feet wide, with 8-foot ceilings throughout.

Only air within the conditioned space is measured for this calculation. The unconditioned attic and basement are not included.

To figure out the ACH_{50}, first multiply the blower door reading at CFM_{50} times 60 to convert minutes to hours and determine the volume of air being moved every hour.

Divide that number by the volume of the home. The result is how many times all the air in the house is refreshed each hour:

- 30 ACH at 50 Pa.

  Q: Do you think that's a leaky house or a tight house?

  A: If our N-factor is 20, we could divide 30 by 20 to get an $ACH_{natural}$ of more than 1.

Minimum Ventilation Requirement (MVR) (Slide #28)

- Also called ***building tightness limit (BTL)***.
- Amount of natural ventilation for adequate indoor air quality – MVR is a "fresh air" target. Sealing a home tighter than the MVR results in indoor air quality that is no longer healthy for residents.
- If the blower door reading is below MVR, mechanical ventilation must be added.
- MVR can be computed with ASHRAE 62-1989 and ASHRAE 62.2.

ASHRAE Standard 62-1989 (Slide #29)

ASHRAE Standard 62-1989 states that natural ventilation shall be the higher of:

- 15 CFM per person
- 15 CFM per (bedroom + 1)
- 0.35 air changes per hour

The standard requires you to work each of these three calculations. The one with the highest result is the MVR.

ASHRAE Standard 62-1989 – Sample Calculation

In this example, five people live in a three-bedroom home with a volume of 8,960 cubic feet.

- 5 occupants
- 3 bedrooms
- 8,960 ft^3 volume

Using the calculation based on number of occupants, MVR is 75 $CFM_{natural}$.

15 CFM x 5 people = 75 $CFM_{natural}$

MVR using the bedroom-based calculation is 60 $CFM_{natural}$.

15 CFM X (3 bedrooms + 1) = 60 $CFM_{natural}$

Based on minimum air changes per hour, MVR is 52.3 $CFM_{natural}$.

0.35 ACH x 8,960 ft^3/60 min/hr = 52.3 $CFM_{natural}$

MVR in this example is 75 $CFM_{natural}$, the highest of the three results. This number is the basis of the post-air-sealing blower door target.

Use the N-factor to convert the MVR under natural conditions into the target blower door reading, under which the indoor air quality is unhealthy:

75 $CFM_{natural}$ x N = CFM_{50}

75 $CFM_{natural}$ x 20 = 1,500 CFM_{50} = MVR

In this example, if post-testing blower door results are lower than 1,500 CFM_{50}, mechanical ventilation must be added.

Air Sealing Target (Slide #30)

The air sealing target must be at or above the MVR, but programs have flexibility determining their own targets.

- Usually somewhere between pre-weatherization blower door reading and MVR.
- Different programs determine air-sealing target differently.
- Some programs require a reduction in CFM_{50} of:
  - 40% for leaky houses.
  - 20% for somewhat tighter houses.
  - 0% for substantially tight houses.

Ask students if they have air sealing target tables in their programs.

Summary (Slide #31)

- The blower door is a controlled driving force used to quantify air leakage.
- Air leakage is measured in cubic feet per minute at a pressure difference of 50 pascals with reference to another space.
- Minimum ventilation requirements assure adequate fresh air.
- Air changes per hour relate air leakage to building size.
- Blower door readings can be converted to air leakage under natural conditions, total size of opening, and ACH.