ALASKA HOUSING FINANCE CORPORATION

AHFC-BD1.97

Blower Door Test

DETERMINING AIR FLOW THROUGH A
BUILDING AIRTIGHTNESS BOUNDARY
BY THE FAN DEPRESSURIZATION METHOD

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ACKNOWLEDGMENTS

This blower door test method is modeled after the Canadian General Standards Board CAN/CGSB-149.10-M86 depressurization method. Although the CAN/CGSB-149.10-M86 method is well used and proven in Alaska, modifications were needed to better fit the Alaska blower door testing conditions and programs. The Alaska Housing Finance Corporation wishes to thank the CGSB for use of their standard as the model from which Alaska's standard could be developed.

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DETERMINING AIR FLOW THROUGH A BUILDING AIRTIGHTNESS BOUNDARY BY THE FAN DEPRESSURIZATION METHOD AHFC-BD1.97

1. **SCOPE**

1.1. This is a method for determining the equivalent leakage area of, and the amount of air flow through, openings in a building's air-tightness boundary under specific, induced air pressures. This method does not determine *actual* air leakage through the airtightness boundary under the natural influences of wind and air buoyancy pressures.

This test can also produce a profile of the building's air leakage characteristics. These characteristics could then be used to estimate air flow at other specific pressures.

The blower door test (BDT) evaluates the actual behavior of the building, and all of its systems, in a depressurized condition. This means that the integrity of ventilation and heating equipment and ducting may be evaluated together with the integrity of the building envelope. When exhaust fans in the kitchens and bathrooms are not sealed, poorly functioning dampers may be identified during the test. Similarly, leaky ducting from the furnace can be noted for correction when heating vents are left untreated. Nevertheless, there are a number of deliberate openings in the building envelope that require preparation.

1.2. This method is applicable to all buildings or units where the entire air tightness boundary can be tested with one blower door.

1.3. This air tightness test method is commonly called a blower door test (BDT).

1.4. The mathematical principals of AHFC-BD1.97 are identical to those detailed in the CAN/CGSB-149.10-M86 fan depressurization method. Therefore, AHFC-BD1.97 is specifically written to avoid reprinting, in duplicate, the CAN/CGSB-149.10-M86 mathematical methods. Instead, this method refers to the CAN/CGSB method when necessary.

2. **PRINCIPLE**

2.1. A fan or fans are used to exhaust air from the building at rates required to maintain specified pressure differences across the building air tightness boundary to a simultaneous and similarly directed air pressure. The flows are corrected to reference temperature and pressure. The relationship between air flow and corresponding pressure is used to calculate equivalent leakage area and air flow through the building's air tightness boundary.

3. **TERMINOLOGY**

3.1. **Air Change per Hour:** is the volume of indoor air exchanged with an equivalent volume of outdoor air each hour, expressed as a whole or fraction of the total volume of indoor air.

3.2. **Air tightness:** is the degree to which unintentional openings in the building's air tightness boundary have been avoided.

3.3. "Attached but not connected": describes a building, such as a heated garage, that is attached – shares a common wall, roof, and/or foundation - to a building but there is not air exchange between the two buildings, such as a man-door between a heated garage and a home. See discussion of how to address these buildings in the AKWarm Home Energy Rater Manual [link].

3.4. **Building Air tightness Boundary:** is that plane where interior heated air is separated from, and is intended not to freely flow to, the unheated outdoor environment. Generally, this will include all conditioned spaces.

3.5. **Conditioned space:** is a room or other enclosed space which has the capability to be intentionally heated to a temperature of 50^{o}F or more, either directly or indirectly, from one or more heating appliances. For example, a space that contains a thermostat, heat distribution source, uninsulated warm air ducts, uninsulated hydronic heating pipes, a furnace, boiler, or water heater should be considered a conditioned space even if the space is not considered living space.

3.6. **EqLA:** is the Equivalent Leakage Area -- the assumption that leakage openings in the building airtightness boundary at a pressure differential of 10 Pa can be combined and represented by a single sharp-edged "equivalent" orifice.

3.7. **Intentional opening:** is an opening in the building envelope deliberately made to fulfill a particular function. For example, heating system flue vents, chimneys, combustion air vents, and crawlspace vents are intentional openings.

3.8. **NLA:** is the Normalized Leakage Area -- expressed as square inches of opening per 100 square feet of building air tightness boundary area.

3.9. **Thermal Envelope:** is the complete (usually insulated) surface area separating conditioned space from unconditioned space.

3.10. **Unconditioned space:** is a room or other enclosed space which is not designed or intended to be "conditioned."

Table 1, CAN/CGSB-149.10-M86 (available for viewing at AHFC's Resource information Center web site (http://www.ahfc.state.ak.us/energy/ric.cfm) provides a list of quantity definitions for those quantity symbols included in this document.

4. **EQUIPMENT**

4.1. **Fan:** The fan or fans shall have a total air flow capacity capable of producing a pressure difference of at least 50 Pa across the building air tightness boundary or have an air flow capacity of at least 5000 cubic feet per minute.

4.1.1. The fan shall have a variable speed control.

4.1.2. The fan shall have a measured accuracy of ±5% of actual air flow. A certificate of calibration accuracy for each fan is not required. However, the equipment manufacturer shall include a statement in product literature noting the calibrated accuracy of each specific model of fan.

4.1.3. The fan shall be capable of measuring pressure or air flow at all fan speeds.

4.2. **Pressure Measuring Device:** The pressure-measuring device shall have an accuracy of 2 Pa and shall only be operated within its calibration and environmental range.

4.3. **Capillary Tubes:** All capillary tubes connected to the pressure-measuring device shall have the same interior diameter. In addition, all capillary tubes used for pressure averaging shall be of equal length. Pressure averaging tubes may be headered and a single tube connected to the pressure-measuring device.

4.4. **Thermometer(s):** The temperature-measuring device shall measure in degrees Fahrenheit and shall have an accuracy of ± 5°F.

4.5. **Door sealing Equipment:** This device shall be used to seal the fan into one of the building's doorways. It generally consists of a portable, expandable door frame with weather-stripped edges and a fabric that installs around the frame which together is set into the building doorway to seal off the entire door opening. The fabric contains an opening where the fan is set and sealed into the complete assembly.

5. **FIELD CALIBRATION OF EQUIPMEN:** According to manufacturers of the two most common blower door units used in Alaska, field calibration ensures quality data and indicates when laboratory calibration may be necessary, Refer to the manufacturers field calibration instructions, which may include weekly gauge checks, Additional parts may be required for field calibration. It is a good practice to record field calibration results in a notebook dedicated for the equipment. Instructions for Tectite™ calibration are available at http://www.energyconservatory.com/support/support7.htm. Instructions for RetroTec™ unit calibration are available at http://www.retrotec.com/QuickGuide-DoorFan-Q46.pdf.

6. LABORATORY CALIBRATION OF EQUIPMENT

6.1. The fan, pressure-measuring device, and thermometers shall be calibrated by the manufacturer. If a major component of the fan, pressure-measuring device, or thermometers is replaced, that device shall be recalibrated by the manufacturer. Recalibrate any equipment when it appears to have been damaged. All equipment should be recalibrated at intervals recommended by the manufacturer. A record of manufacturer calibration dates shall be maintained with the blower door unit or accessible upon request by AHFC.

7. DETERMINING THE BUILDING'S AIRTIGHTNESS BOUNDARY

7.1. This blower door test method requires a calculation of the building's total air tightness boundary area and its corresponding conditioned volume.

7.2. Usually, a building's air tightness boundary aligns with its thermal envelope. For example, the interior surface of exterior walls, ceilings, and floors, and the ground of a heated crawlspace will generally make up the complete air tightness boundary of the building. In some cases, however, the air tightness boundary being tested may not align with the thermal envelope. A determination must be made in the field as to the location and extent of the air tightness boundary for each test routine.

8. DETERMINING THE INTERIOR VOLUME OF THE BUILDING

8.1. Determine the total interior volume enclosed by the building's air tightness boundary specific to each of the three test routines below. Do not reduce the volume for such things as interior partition walls, floors between conditioned spaces, cabinets, furniture, equipment, plumbing fixtures, and so on.

9. TEST ROUTINES

9.1. Test 1 Air tightness of All Conditioned Space

9.1.1. For buildings that include an attached, conditioned garage: close the auto overhead door and open the garage-to-building man door.

9.1.2. For buildings that include a "connected but not attached" building (refer to the Home Energy Rater

Manual for definitions): complete a separate BDT for the building. Close all doors (including overhead garage doors) except for the one used to conduct the BDT.

9.1.3. For buildings that include a conditioned crawlspace: open the crawlspace access door and close crawlspace vents.

9.1.4. For all buildings: follow the building preparation checklist given in Table 1.

9.2. **Test 2 Air tightness of Living Space**

9.2.1. For buildings that include an attached, conditioned garage: open the auto overhead door and close the garage-to-building man door.

9.2.2. For buildings that include a conditioned crawlspace: OPEN the crawlspace access door and CLOSE crawlspace vents.

9.2.3. For all buildings: follow the building preparation checklist given in Table 1.

9.3. **Test 3 Air tightness Under Normal Operating Conditions**

9.3.1. For buildings that include an attached, conditioned garage: close the auto overhead door and close the garage-to-building man door.

9.3.2. For buildings that include a conditioned crawlspace: close the crawlspace access door and leave crawlspace vents as found upon arrival.

9.3.3. For all buildings: follow the building preparation checklist given in Table 1 except that all heating appliance flue vents and combustion air openings shall be left in their natural operating position.

9.4 Air Tightness Tests in Multi-family Units

9.4.1 Testing Individual Units - Where units in a multifamily structure are individually owned, a blower door test should be done on each dwelling unit or only on the specific unit being rated. The blower door test report and the "Notes to AHFC" section of AKWarm should note the status of adjoining unit fenestrations. All exterior and common surface areas should be considered in the surface square footage entry for the blower door test.

9.4.2 Testing Entire Buildings – Where all units in a multifamily dwelling are served by a common entry and the units are not individually owned, the energy rating should generally be for the entire structure. All dwelling units must be open to the common area and the building prepared as is appropriate for the type of test being performed. Only exterior walls should be considered in the surface area.

9.5 Air Tightness Test Using Multiple Blower Doors **-** Where a single-owner, multifamily building or a large, single-family home, is too large to depressurize with a single blower door, multiple blower doors should be used in separate common entries.

- If multiple blower doors are not available then the building should be partitioned for testing. In the latter case, the test result should be considered as a guideline for estimating air leakage rates rather than an empirical value.

10. SET-UP PROCEDURES

10.1. Equipment Set-up and Building Preparation

NOTE: If there are combustion appliances within the thermal envelope, perform a negative pressure test within the Combustion Appliance Zone (CAZ). Refer to the BPI *Technical Standard for Certified Building Analyst*, available at http://www.bpi.org/documents/Building_Analyst_Standards.pdf .

NOTE **Pressurizing vs. De-pressurizing the building**: The best method to accurately assess the home's air tightness is the depressurization method. However, if **any** combustion appliance in the home must be left ON, including wood stoves, you must perform a *pressurization* test.

10.1.1. Before commencing the test(s), consider the holes that are a deliberate part of the building's design. Refer to TABLE 1 – "Building Preparation for Blower Door Test," located on the web site at http://www.ahfc.state.ak.us/iceimages/manuals/blower_door_test_table_bld_prep.pdf .

NOTE on **intentional openings**: Combustion air openings are necessary for vented combustion appliances. If new combustion air openings are found during a post-rating, determine if they were present during the as is. If it was not present during the as-is rating, seal the opening for the post-rating blower door test. If a new or additional appliance was added and combustion air openings are not present, alert the customer to the safety issue and document in the "Notes to AHFC" and "Notes to Homeowner."

NOTE: HRVs are a common retrofit. If the intake is left open and a backdraft damper is installed on the intake, air can be introduced to the inside. HRV openings may be sealed at the energy rater's discretion, since HRVs do not have dampers.

10.1.2. Measure and record the outdoor air temperature, t_o, and the indoor air temperature, t_i.

10.1.3. Include in the test all conditioned space described in Paragraph 3.4 and any other space as required for each test described in Section 8.

10.1.4. Switch off all fuel combustion equipment, furnace blower fans, exhaust fans, vented clothes dryers, room air circulation fans, humidifiers, and air conditioners.

10.1.5. Prepare intentional openings as detailed in Table 1 and document in the AKWarm "Notes to AHFC." Conduct post-ratings with intentional openings in the same configuration as for the as-is, and note any changes in the "Notes to AHFC."

10.1.6. Remove or cover ashes in fireplaces and wood stoves. Check chimneys and fuel combustion equipment vents for excessive soot and do not perform the test if soot is likely to enter the building.

10.1.7. Open all interior doors to spaces included in the test.

NOTE: Check latches holding storage doors in knee walls to make sure they will remain shut during depressurization. Block door shut if necessary, and note it in the "Notes to AHFC."

10.1.8. Pressure averaging shall be required whenever wind speed at the site renders the pressure-measuring device incapable of producing stable pressures. Pressure averaging shall be accomplished using capillary tubes set according to Paragraph 4.3 and Figures 2 and 3 in CAN/CGSB-149.10-M86.

10.1.9. Install the fan and door sealing equipment such that air will be exhausted from the building. Ensure that no obstruction is placed within three feet in front of the door frame and cover assembly. Ensure that the outflow side of the fan has a clear and unobstructed air flow path. Ensure that there are no obstructions within at least four feet of the door apparatus that might obstruct air flow and alter the test results. Even stationary features of the building, such as corners and railings, can disturb the flow to the fan enough to make it impossible to achieve the correlations necessary for a valid test.

10.1.10. Outside pressure taps for the fan door should be protected from the wind as much as possible. It may be necessary to string capillary tubing to all sides of the building and then lead them to a pressure averaging box where the effects of pressure differences can be minimized. Locate external pressure taps out of the area of influence of the fan, away from comers of the building, and in a protected area to ensure that pressure gauges stabilize and yield valid pressure readings. If necessary, duct tape the external pressure tap against the side of the house, a few feet from the ground in a protected location.

10.2. **Routine Inspection**

After setting up the test equipment, take the following steps to check the equipment and building setup.

10.2.1. Visually inspect all test equipment for physical defects. Pay special attention to the capillary tubing, as even the smallest holes can destroy the accuracy of the test, and to the unit gauges to ensure the needles are not sticking (manual gauge) and that the readings stabilize (digital and manual gauges)

10.2.2. Ensure the pressure taps of the pressure-measuring device are out of the direct path of fan air flows.

10.2.3. Visually inspect for proper installation of all equipment in accordance with manufacturer's specifications.

10.2.4. Ensure devices which require leveling (for example, magnahelic gauges) are correctly installed.

10.2.5. Ensure the blower door frame and cover is set into the building door frame as required. Ensure the fan is also set into the blower door frame and cover assembly as required.

10.2.6. When the building to be tested has walls, ceilings, or floors common with spaces that are not included in the test, make provision to ensure those spaces remain as close to outdoor pressure as possible throughout the test. In other words, open a door or window of that space to the outside when possible.

10.2.7. For fireplace chimneys without a damper, perform the test with no chimney sealing unless the air flow is so large that the test cannot be performed. In this case, seal the chimney and report this matter as a deviation from usual test procedures (see test report Paragraph 14.1).

NOTE when using **analog/magnehelic gauges**: ensure that the manometer is ***level***. Make sure at the beginning of each test, and before connecting the pressure tubes, that all indicators on the gauges are at zero settings. You may want to tap the face of the gauges slightly if it sticks, but pay attention to needles that stick throughout the range of the reading. Sticky needles indicate the gauge may need to be cleaned or calibrated by the manufacturer. Connect the tubes and, with the fan off, check to see if the gauges register a pressure difference. If so, record this pressure as the bias pressure, and compare it against results from tests with the fan on, to document cross-envelope pressure differences that were not induced by the fan.

Digital gauges: Follow manufacturer's instruction for zeroing the unit prior to initiating the test.

11. **TEST PROCEDURES**

11.1. After equipment has been setup, seal the fan such that no air flows through the fan at this time.

11.2. Zeroing the Pressure-Measuring Device (fan off):

11.2.1. a. Magnahelic

11.2.1.1. Attach one end of a capillary tube to the high pressure tap of the indoor/outdoor building magnahelic. Place the opposite end of this tube outdoors. Now zero the magnahelic.

11.2.1.2. Attach one end of a capillary tube to the low pressure tap of the "fan" magnahelic and lay the other end of the tube on the floor. Zero the magnahelic. Now attach the floor end of the tube to the measuring tap on the fan.

11.2.2. b. Self-zeroing digital pressure-measuring device

11.2.2.1. Attach a capillary tube to the “reference” tap on the building-side of the digital device and place the other end outdoors. Leave the “input” tap open. Record the existing “fan off” pressure difference (if any) between indoors and outdoors and adjust all indoor/outdoor pressure readings thereafter to compensate for a possible non-zero start.

11.2.2.2. Attach a capillary tube to the “input” on the fan-side of the digital device and attach the other end to the measuring tap on the fan. Leave the “reference” tap open. No adjustment is necessary for fan flow measurements.

11.3. Remove the seal on the fan and switch the fan on.

11.4. Adjust fan speed to produce an indoor/outdoor pressure difference, ΔP_m, of 25 to 30 Pa. Now recheck to ensure the building setup has not changed.

11.5. Adjust fan speed to produce a ΔP_m of at least 50 Pa but no more than 70 Pa across the building air tightness boundary. If ΔP_m 50 Pa is not possible, follow equipment manufacturer's procedure for adjusting the maximum achievable fan pressure.

11.6. Caution: Some spaces included in the test may have materials such exposed polyethylene, ceiling tile, and some kinds of plastic lens for recessed light fixtures that will collapse if exposed to the direct pressure of the fan. When this situation is encountered, use a reduced maximum ΔP_m or relieve the pressure across the material. When conditions have stabilized across the building envelope, measure and record the ΔP_m and the corresponding fan pressure difference, in Pa.

11.7. For tests 1 and 2 reduce fan speed by approximately 5 to 10 Pa . When conditions have stabilized across the building envelope, measure and record this ΔP_m and corresponding fan pressure. Repeat until at least 5 ΔP_m recordings are taken.

11.8. For test 3, only one ΔP_m, at 50 Pa, is required.

12. VERIFICATION OF DATA

12.1. If using a self-zeroing digital pressure-measuring device, correct the ΔP_m readings in the following manner:

12.1.1. If the initial fan-off ΔP_m was negative, then subtract this amount of pressure from the tested pressure differential. For example, if the initial ΔP_m was -2 Pa and the tested pressure was -50 Pa, the final *adjusted* pressure would be -48 Pa.

12.1.2. If the initial fan-off ΔP_m was positive, then add this amount of pressure to the tested pressure differential. For example, if the initial pressure was +2 Pa and the tested pressure was -50 Pa, the final *adjusted* pressure would be -52 Pa.

12.1.3. Use absolute values for all fan-on readings described in subparagraphs a and b above.

12.2. Using the corrected ΔP_m from Paragraph 11.1 determine the following in accordance with Appendix C of the CAN/CGSB-149.10-M86:

12.2.1. the regression coefficients (C and n) and the correlation coefficient (r) of the fit of the data;

12.2.2. the percentage difference between the estimated air flow, $\hat{Q}_I$ and the measured air flow Q_i at each measured pressure difference ΔP_i.

12.3. Repeat the entire test if any of the following conditions are not met:

a. $0.50 \leq n \leq 1.0$
b. $r > 0.990$
c. $\left[\frac{\hat{Q}_i - Q_i}{Q_i}\right] < 0.06$ for all i

13. **COMPLETION OF THE TEST**

After the test:

a. remove all air seals applied in accordance with Table 1;
b. reopen dampers as necessary;
c. relight all gas pilot lights that were on prior to the test;
d. return the building and all its components to the position(s) encountered before preparing the building for the test.

14. **CALCULATIONS**

14.1. General Description: This method gives an Equivalent Leakage Area (EqLA), a Normalized Leakage Area (NLA), a C_r value, and an air flow rate which are constant for all test ambient conditions.

ΔP, C_r and Q_r are defined as follows:
ΔP is the *corrected* pressure difference across the building airtightness boundary, in units of Pa.
C_r is a constant used to determine Q_r.
Q_r is a constant used to determine EqLA.

14.2. Correction of Air Flow Readings: Air flow readings shall be corrected in a manner similar to Paragraph 11.1.

14.3. Determination of Correlation Coefficient: See Appendix C of the CAN/CGSB-149.10-M86.

14.4. Calculation of Equivalent Leakage Area (EqLA)*

$$EqLA = 0.001157 \sqrt{\rho_r} \times C_r \times 10^{n-0.5} \times 1396.524$$

Where: EqLA is in inches squared

* See Paragraph 7.7 of the CAN/CGSB-149.10-M86.

14.5. Calculation of Normalized Leakage Area (NLA)
To calculate NLA, use the following equation:

$$NLA = \frac{EqLA}{\text{Area of the Building Envelope}} \times 100$$

where: NLA is in units of in^2 per 100 ft^2
EqLA is in units of in^2
Area of the building envelope is in units of ft^2

14.6. Calculation of Air Changes Per Hour At 50 Pa
To calculate air changes per hour at ΔP_m of 50 Pascals, use the following equation:

$$ACH_{50} = \frac{\text{Volume}}{CFM_{50} \times 60}$$

where: ACH_{50} is air changes per hour at 50 Pa
Volume is the interior volume described in section 7, in ft^3
CFM_{50} is the rate of air flow through the fan at ΔP_m of 50 Pascals, in ft^3 per minute
60 is a factor to convert cubic feet per minute to cubic feet per hour

14.6.1 To determine the air changes per hour, in either case, add the CFM50 results, multiply by 60, and divide by the total building volume. For surface area, use the exterior walls only.

15. **TEST REPORT**

15.1. The test report shall include the following information:

a. The name and address of the company which conducted the test;
b. The name of the tester;
c. The address of the building under test;
d. The date of test;
e. The indoor and outdoor temperatures, in degrees Fahrenheit;
f. Wind speed, in mph;
g. A description of the building style/type;
h. The area of the building airtightness boundary, in square feet;
i. The interior volume of the building, in cubic feet;
j. The original measured data of ΔP_m and corresponding fan pressure, in Pascals;
k. The corrected data for each ΔP_m (when using a digital pressure-measuring device), in Pascals;
l. Values for C_r and n;
m. The determined correlation coefficient, r;
n. The equivalent leakage area (EqLA), in square inches
o. The calculated NLA;
p. Any deviation from the method prescribed.

15.2. It is recommended that the test report also include the following:

15.2.1. A sketch floor plan of the building showing locations of pressure averaging taps, if used, and dimensions of the building's air-tightness boundaries including length, width, and height;
15.2.2. A plot of air flow, in cfm, versus the corresponding ΔP_m on a log-log graph to produce the building�s air leakage characteristics.

15.2.3. Submit testing results as produced by either a field-use computer or office based computer.

NOTE: **Repeat the entire test if**:
The flow exponent (n) is less than 0.5 or greater than 1.0
The correlation (r) is less than 0.990
If the error of any data point is 6% or greater
The standard error at 10 Pa is 7% or greater

NOTE: **If you cannot reach 50 Pa**:
The EqLA should be computed using the airflow reading for the highest building pressure you can achieve. Zero the gauges with the tubes connected. Make sure there is zero pressure at zero flow. Refer to TABLE 2, "Estimating Air Change Rates When BDT Can't Attain 50 CFM," located at http://www.ahfc.state.ak.us/iceimages/manuals/blower_door_test_table_no50.pdf and TABLE 3 – "Conversion Chart for BDT < 50 Pa," located at http://www.ahfc.state.ak.us/iceimages/manuals/blower_door_test_table_bld_prep_cfm50_convert.pdf .