400 Final Inspection Tests

Best Practice Recommendations:

- Blower door tests should be done when all weatherization work has been completed to evaluate effectiveness of air sealing work. If this test was not done, it must be completed during the final inspection.
- Homes should be visually inspected for evidence of effective air sealing work. Zone pressure diagnostics may be helpful to evaluate air sealing activities when "hidden" air sealing has occurred (bypass sealing under attic insulation, for example).
- Visual inspection and duct testing should be done during the final inspection to verify work results when duct repair and sealing has been specified.
- If a worst-case draft test was not done after weatherization work was completed, it must be completed during the final inspection.
- If a steady-state combustion efficiency test for gas- and oil-fired appliances was not done and thoroughly documented following completion of heating system work, it must be completed during the final inspection.
- If gas range inspection and testing was not done and thoroughly documented during the weatherization work, it must be inspected and tested during the final inspection.

411 Blower Door Testing

4111 Introduction

A blower door test should be done at the final inspection in order to determine that the air sealing work for the job was successful. Some programs require the weatherization workers to perform a blower door test after all the work has been completed, but before final inspection. This is the preferred method. For these programs, the final inspector performs a blower door test to verify that the post-weatherization CFM_{50} value determined by the workers is correct.

In other programs, the only post-weatherization blower door test is done by the inspector. This method is not recommended because the inspector might find problems that require the workers to return to the site. This is expensive and can upset schedules. If the workers perform a post-weatherization blower door test themselves, it is likely that they will find any weatherization deficiencies themselves. It is always better for crews or contractors to perform a post-weatherization blower door test and strongly recommended that blower door testing be performed during the air sealing activities to help guide those tasks.

The job file should be examined for documentation of other blower door test readings taken before, during, and after the weatherization process. These results should be checked for reliability; the progressive tightening of the dwelling should demonstrate a realistic reduction in the blower door readings.

4112 Blower Door Test Setup

The house setup for the blower door test performed during the final inspection must be the same as the setup for the pre- and post-weatherization blower door tests. The inspector should set the blower door up in the same opening and the house must be setup the same way. In order to do this, the inspector must have a record of the house opening used and other details so the previous tests can be replicated.

Please refer to Section 111, “Blower Door Test” for the instructions on the proper setup and operation of the blower door. Also, refer to the blower door operation manual.

In addition to proper setup, it is important, especially in cold climates, that the inspector know the exterior temperature at the time of the inspection test and at the time of the other significant tests, such as the pre- and post-weatherization tests. For every 10^{O}F reduction in temperature between one test and another with an open fan, there is a 50 CFM_{50} reduction.[34] For example, if the post-weatherization test was done at 70 ^{O}F outdoors, but the final inspection test was done at 10 ^{O}F outdoors, the 60 degree temperature difference will result in a final inspection test 300 CFM_{50} lower.

4113 Interpretation of Results

The results of the final inspection blower door test should be significantly less than the pre-weatherization blower door test results and similar to the post-weatherization blower door test, if one was performed.

As stated in Section 1115, “Air Sealing Guidelines”, the guidelines established for air leakage reductions may take the form of a cost limit per 100 CFM_{50} reduction or may be based on the existing CFM_{50} leakage rate.

If a cost-effective guideline per 100 CFM_{50} is not established, target CFM_{50} levels based on a range of existing leakage rates may be used. Target CFM_{50} levels relate existing CFM_{50} leakage rates to expected post-weatherization leakage rates. Refer to Section 1115, Table 5 for target CFM_{50} levels.

The final inspection blower door test should verify that:

- The CFM_{50} reduction level achieved met the cost-effective guideline for the dwelling. This will require the appropriate data in the job file recorded by the crew or contractor.
- If cost-effective air sealing guidelines were not established for the job, the target CFM_{50} level was reached, based on Table 5 in Section 1115.
- That there is no evidence of remaining significant air leakage in the dwelling. This will require a walk-through inspection during blower door operation.

If significant air leakage is discovered during the final inspection, verify that:

[34] This assumes a depressurization blower door test and an open fan. If the “A” ring is used in the fan, there is a 20 CFM_{50} reduction for each 10 ^{O}F reduction in outdoor temperature. If the “B” ring is used in the blower door fan, there is a 10 CFM_{50} reduction for each 10 ^{O}F reduction in outdoor temperature.

- The weatherization installers made every reasonable attempt to reach the cost-effective guideline or target.
- Further air sealing was not cost effective, or
- The home is at or below the BTL.

When significant air leakage is discovered, there must be a written explanation for the reason in the job file.

412 Zone Pressure Diagnostics Testing

4121 Introduction

Using zone pressure diagnostics (ZPD) pre- and post-weatherization can be a very useful tool for determining the thoroughness of weatherization work. As explained in Section 112, "Zone Pressure Diagnostics", ZPD methods can indicate the square inches[35] of leakage in a pressure boundary, such as the total square inches of leakage in an attic floor.

Whenever possible, inspect the parts of the dwelling that have been air sealed during the weatherization process. In most cases, there should be evidence of air sealing. For example, if the basement walls were tightened, there will be clear indication of the work. However, in some cases, it is very difficult to visually inspect air sealing work. The best example of this "hidden" air sealing work is that done to an attic floor before the insulation is blown. At final inspection, all of this air sealing work is covered by the insulation, making it very difficult, if not impossible, to perform a visual inspection. In such cases zone pressure diagnostics can be very useful.

4122 Inspection Procedures

41221 Zone Pressure Diagnostics for Primary Zones

Primary zones are spaces that can be physically accessed and inspected. Typical primary zones include attics, crawl spaces, basements, and attached garages. Because temporary openings can be created to the house and/or to the outdoors from these primary zones, an air leakage rate (CFM_{50}) between the house-to-zone and zone-to-outside can be determined.

These methods can determine the effectiveness of air sealing efforts. For example, if the pre-weatherization leakage area in an attic floor was 200 square inches and the inspector determines the post-weatherization leakage area is 40 square inches, it is obvious that air sealing was a success.

Whether to perform ZPD during a final inspection should be guided by the work order. If ZPD was done before or during weatherization, it is usually helpful to

[35] This is done by determining the flow in units of CFM_{50} through the pressure boundary and then dividing the CFM_{50} flow by 10. For example, if the flow through the attic floor is 2000 CFM_{50}, the approximate leakage in this pressure boundary is 200 square inches.

use ZPD during the final inspection to either verify other ZPD results and/or to determine the effectiveness of air sealing efforts.

If ZPD was not done before or during weatherization, it is usually not very useful to perform during a final inspection. However, if there is suspicion the air sealing work was performed poorly or not at all, determining the leakage area in a pressure boundary with ZPD may be helpful.

41222 Zone Pressure Diagnostics for Secondary Zones

Secondary zones are spaces where only pressure differences can be determined, the inspector cannot determine CFM_{50} flow nor square inches of leakage in a pressure boundary.

As described in Section 112, ZPD for secondary zones can be very misleading because the house-to-zone and zone-to-outside pressures always add up to 50 Pa. When using ZPD techniques for secondary zones, the inspector must be very careful to interpret the results correctly.

413 Duct Leakage Testing

4131 Introduction

Duct leakage test procedures and standards are discussed in Section 113, "Duct Leakage Tests". When duct repair and sealing has been specified on the work order, inspection and testing should be done during the final inspection to verify work results. Duct repair and sealing is most important for mobile homes.

4132 Inspection Procedures

During final inspection, ensure that:

- All disconnected ducts have been repaired.
- Boots are sealed as specified in the work order.
- Ductwork is sealed as specified in the work order.
- All duct sealing is done with the proper materials.
- Ductwork is insulated as specified in the work order.
- Ensure that temperature rise of furnace is within range.
- Pressure pan values measured during the final inspection are similar to those measured by the workers.
- Duct Blaster™ results obtained during the final inspection are similar to those measured by the workers.

414 Duct-Induced Pressure Testing

4141 Introduction

Dwellings with ductwork, mobile homes in particular, should be tested for duct-induced room pressure differences during final inspection. Refer to Section 114, "Duct-Induced

Pressures", for instructions. Significant pressure differences from one room to the next can cause wasted energy by increasing air leakage and can lead to occupant discomfort. In homes with ductwork, this testing should be completed before the worst-case draft test is performed.

4142 Inspection Procedures

Follow the procedures for duct-induced room pressure testing, including proper house setup. Confirm that the pressure difference from each room to the main body of the dwelling is 3 Pa or less when the door to the room is closed and the air handler is operating.

If a mobile home has been converted from a belly-return system to a central return, make sure that:

- All return registers in the floor have been properly sealed.
- The return grate in the floor of the furnace closet has been properly sealed.
- The furnace room closet door has been changed to a louvered door.
- The return air system is performing as it should.

421 Worst-Case Draft Testing

4211 Introduction

Worst-case draft testing is a very important health and safety procedure. This test must be carefully completed after all weatherization work is completed and the workers are about to leave the job. Please see Section 123, "Worst-Case Draft Testing", for step-by-step instructions. Chances are that this test will have been completed by the time of the final inspection with a record of the test results in the job file. If the test has not been done, it must be completed by the inspector.

Worst-case draft testing must be done in all dwellings. The following are *exceptions* to this requirement:

1. If the house or mobile home is all-electric with no combustion appliances, woodstoves or fireplaces, or all combustion appliances are sealed combustion (direct vent) or unvented (vent free).
2. If the dwelling has a boiler and/or an atmospheric water heater ***and*** has no exhaust equipment, including clothes dryers, vented bath and kitchen fans, vented central vacuum systems, fireplaces, woodstoves, etc.
3. If the CAZ is located outside of the thermal boundary, such as mobile home water heater closet or a garage, a worst-case draft test does not have to be performed. However, always perform this important test if the CAZ in is in a basement.
4. In apartments with no combustion appliances other than unvented or direct-vent combustion appliances.

Before the final worst-case draft test is done, make sure all weatherization work and all diagnostic testing has been completed, particularly the duct-induced room pressure test.

4212 Inspection Procedures

Inspect the job file for a record of worst-case draft test results. If there is no record of worst-case draft testing and you are certain that none was performed, conduct the test according to the procedure in Section 123.

If any vented combustion appliances fail the worst-case draft test, specify corrective action as soon as possible. Warn the client of the potential backdrafting hazard and condemn the failed appliances, if appropriate.

422 Combustion Efficiency Testing

4221 Introduction

A steady-state combustion efficiency test for gas- and oil-fired furnaces and boilers is usually done before the final inspection by either an assessor or a heating system subcontractor. Check the job file for a record of these test results. If there is no record of a test and an efficiency test is appropriate, perform the steady-state efficiency test according to the procedure in Section 121, “Furnaces and Boilers”. Acceptable combustion efficiency results should be within the range of Table 121-1 in that section.

4222 Inspection Procedures

Follow the procedures in Section 121 for completing the final inspection. The final inspection procedures include conducting these tests:

- Smoke test (oil-fired units only).
- Combustion efficiency testing.
- Worst case draft testing.
- Carbon monoxide testing.
- Gas leak testing for gas distribution lines and gas appliances.
- Temperature rise for forced air furnaces.

In addition, ensure that combustion air requirements are in accordance with NFPA 54 for gas-fired systems, NFPA 31 for oil-fired systems, and NFPA 211 for solid-fuel appliances.

423 Gas Range Testing

4231 Inspection Procedures

Follow the procedures in Section 124, “Gas Range Testing”, for completing the final inspection of gas ranges. The final inspection procedures should include conducting these tests:

- General range inspection.

- Range top inspection.
- Oven area inspection.
- Range top burner carbon monoxide emissions testing.
- Oven bake burner carbon monoxide emissions testing.

Appendix 111 Blower Door Tests

A11131 Building Tightness Limit (BTL method), Basic Calculation

Occupancy

BTL based on occupancy is based on actual number of people living in the home or number of bedrooms plus one person, whichever is larger. A minimum of 5 occupants shall be used for each home.

$$BTL_{occupancy} = \text{Occupants} \times 15\ \text{CFM/person} \times n$$

where:

$BTL_{occupancy}$ = CFM_{50} based on occupancy,
Occupants = number of occupants (or number of bedrooms, plus one),
15 CFM/person = requirement of ASHRAE 62-2001,
n = LBL correlation factor (varies between 9.8 and 25.8); see http://homeenergy.org/archive/hem.dis.anl.gov/eehem/93/930309.html.

Consider increasing the number of occupants for each of the following conditions.
1. Add one additional "occupant" for each smoker in the home.
2. Add one additional "occupant" for every pet or group of pets over 75 pounds that live in the home.

Volume

Determine BTL based on the volume of the home. Include the volume of the basement if it is a conditioned space and could be converted to living space in the future.

$$BTL\ CFM_{50volume} = (\text{Volume} \times 0.35 \times n) \div 60$$

where:

$BTL\ CFM_{50volume}$ = BTL based on house volume,
Volume = volume of house (ft^3), above grade and conditioned,
0.35 = air changes/hour natural (ACH), requirement of ASHRAE 62-2001,
n = LBL correlation factor (varies between 9.8 and 25.8),
60 = minutes/hour.

A11132 Building Tightness Limit (BTLa method), Advanced Calculation

The complexity of this calculation requires the use of a computer or programmed calculator. For the advanced BTLa method, these values must be entered into the computer or programmed calculator:

- House CFM_{50},
- Weather factor,
- House square footage,
- House volume,
- House height, and
- Number of occupants (or bedrooms, plus one).

The program then determines the output values of:

- Effective leakage area,
- Equivalent leakage area,
- Natural air leakage, CFM,
- Air Changes per Hour (ACH),
- Natural air leakage CFM per person,
- Minimum CFM of fresh air required,
- CFM_{50} Building Tightness Limit (BTLa), and
- CFM of mechanical ventilation, if needed.

Some versions of The Energy Conservatory software for Windows called TECTITE calculate the output values listed above, except for the CFM_{50} Building Tightness Limit (BTLa). For information, see www.energyconservatory.com.

The ZipTest Pro and ZipTest Pro[2] software for the Texas Instruments TI-86 programmable calculator calculate all of the output values listed above. For information, see www.karg.com/software.htm.

A1115 Air Sealing Guidelines

A commonly used cost-effective guideline format is to calculate the maximum dollar amount (labor and material) that should be spent to produce a 100 CFM_{50} reduction. Air leakage reduction is checked by performing a "one-point" blower door test every one or two hours by the crew or contractor as they perform their air sealing activities. If the cost to achieve the last 100 CFM_{50} reduction is greater than the cost-effective guideline, air sealing work should stop. If the cost per 100 CFM_{50} reduction is less than the guideline, then air sealing work should continue until the guideline is exceeded.

Annual heating and cooling savings per 100 CFM_{50} reduction must first be calculated. Cooling savings should be calculated and added to space heating savings if cooling is present in the home. These calculations are shown next. Annual savings must then be converted to life cycle savings and labor and material cost must then be determined to calculate cost effective. The manner in which life cycle savings is determined and estimating local labor and material costs are left to the State Weatherization Programs.

- Annual Heating Savings/100 CFM_{50}

  \$ Heating Savings/100 CFM_{50} = [(26)(100)(HDD)(\$ Fuel)/(n)(SE)] x 0.60

where:

26 = constant
HDD = typical annual heating degree days, base 65°F
\$ Fuel = cost of fuel per Btu
n = LBL correlation factor (varies between 9.8 and 25.8)
SE = seasonal efficiency of heating system
0.60 = correction factor

- Annual Cooling Savings/100 CFM_{50}

$ Cooling Savings/100 CFM_{50} = [(0.037)(100)(CDD)($ Fuel)/(*n*)(SEER)] x 0.60
where:

0.037 = constant
CDD = typical annual cooling degree days, base 70^{o}F
$ Fuel = cost of fuel per Kwh
n = LBL correlation factor (varies between 9.8 and 25.8)
SEER = seasonal efficiency of cooling system
0.60 = correction factor

The ZipTest Pro[2] software for the Texas Instruments TI-86 programmable calculator calculates the cost-effective guideline for air sealing work. The user of the software is instructed to continue or stop air sealing, depending on the information entered during a series of air sealing work sessions. For information, see www.karg.com/software.htm.

Appendix 112 Zone Pressure Diagnostics

CFM_{50} flow rates may be measured between the house and zones or between zones and the outside. Leakage areas between the house and zones or zones and outside may then be determined.

Total path air leakage (CFM_{50}) between the house and outside through zones may also be determined. Total path air leakage provides an indication of total house leakage that may be attributed to air flows through zones. For example, a house has an existing leakage rate of 3800 CFM_{50}, total path air leakage from the attic measured 800 CFM_{50} and total path air leakage from the conditioned crawl space measured 500 CFM_{50}. Therefore, a total of 1300 CFM_{50} leakage is occurring through these two zones and 2500 CFM_{50} is occurring through the remaining shell of the home (walls, windows and doors).

A1121 Flow Rates with Opening Created between House and Zone

House-to-zone flow rates may be determined when an opening can be made between the house and zone. An estimate of the leakage area between the house and zone may then be determined. Typical zones and openings between the house and zone are listed below.

- Unfinished attic (hatch, door)
- Space behind knee walls (hatch)
- Attached garage (door between house and garage)
- Crawl space (hatch between house and crawl space)
- Basement (door between basement and house)

1. Select zones where pressure readings will be taken. Determine where openings between the house and zone (hatches, doors) may be created. The opening should be created in the pressure boundary with the highest pressure difference reading. For example, if the house-to-attic pressure is 40 Pascals and the attic-to-outdoors pressure is 10, it is best to create the opening between the house and the attic.

2. Depressurize the house to -50 Pa (pressurization may be used, also).

3. Record the house-to-zone pressure with the opening closed. This is P1.

4. Open the door or hatch to the zone to drop the house-to-zone pressure by at least 15 Pa while maintaining the house-to-outdoor pressure at -50 Pa with the blower door. Now record the house-to-zone pressure with the air flowing through the temporary opening. This is P2.

5. Measure the size of the opening.

6. Refer to Table A112-1. Find the house-to-zone pressure from step 3 in the left-hand column (P1). Find the house-to-zone pressure with air flowing through the

opening from step 4 at the top of the table (P2). Read down and across to find the CFM_{50} per square inch of opening added.

7. Multiply the value from step 6 by the area of the opening (step 5) to find the CFM_{50} flow between the house and zone.

8. Using Table A112-2, the flow from the zone to the outside can be determined with P1 and the house-to-zone flow rate determined in step 7. Find the initial P1 (step 3) and multiply the corresponding value by the house-to-zone flow rate (step 7).

- Leakage Area
  Leakage areas from the house to the zone and from the zone to the outdoors are approximately 10% of the calculated CFM_{50} values.

- Total Path Air Leakage
  Using Table A112-3, total path air leakage may be determined from P1 and the flow rate from step 7. Find the initial P1 (step 3) and multiply the corresponding value by the house-to-zone flow rate (step 7). This represents the combined flow, in units of CFM_{50}, taking into account the resistance of *both* of the pressure boundaries.

Unfinished Attic Example (Opening between House and Zone)
An initial house-to-attic pressure of -42 Pa was measured (step 3, P1). The attic hatch was opened and the blower door was adjusted to bring the house back to -50 Pa. The house-to-attic pressure measured -14 Pa (step 4, P2). The value from Table 2 is 2.0 CFM_{50} per square inch of opening.

HOLE ADDED BETWEEN HOUSE & ZONE

CFM_{50} (House-to-Zone) per Square Inch of Added Hole

Table A112-1

P2

P1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
14	3.7																	
16	3.2	5.5																
18	2.7	4.6	6.8															
20	2.4	4.0	5.7	7.8														
22	2.1	3.4	4.9	6.5	8.6													
24	1.9	3.0	4.2	5.5	7.1	9.2												
26	1.7	2.6	3.6	4.7	6.0	7.6	9.6											
28	1.5	2.3	3.1	4.0	5.1	6.3	7.8	9.8										
30	1.3	2.0	2.7	3.5	4.3	5.3	6.5	7.9	9.8									
32	1.2	1.8	2.4	3.0	3.7	4.5	5.4	6.5	7.9	9.6								
34	1.0	1.6	2.1	2.6	3.2	3.8	4.5	5.3	6.4	7.6	9.3							
36	0.9	1.4	1.8	2.2	2.7	3.2	3.8	4.4	5.2	6.1	7.3	8.8						
38	0.8	1.2	1.5	1.9	2.3	2.7	3.1	3.6	4.2	4.9	5.7	6.8	8.2					
40	0.7	1.0	1.3	1.6	1.9	2.2	2.6	2.9	3.4	3.9	4.5	5.3	6.2	7.4				
42	0.5	0.8	1.1	1.3	1.5	[illegible]	2.0	2.3	2.7	3.0	3.5	4.0	4.6	5.4	6.4			
44	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.3	2.6	2.9	3.4	3.9	4.5	5.3		
46	0.3	0.5	0.6	0.7	0.9	1.0	1.1	1.3	1.4	1.6	1.8	2.0	2.3	2.6	2.9	3.4	4.0	
48	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.6	1.8	2.1	2.4

The size of the opening to create this pressure drop was 8” x 36” (288 in^2). The area of the opening is multiplied by 2.0 CFM_{50} per square inch, giving a CFM_{50} flow rate of 576 CFM_{50} between the house and attic without the opening.

The total area of bypasses between the house and zone is approximately 10% of the flow rate, or 58 in^2 (576 CFM_{50} x .10 = 57.6 in^2).

The zone-to-outside flow rate may be calculated with Table A112-2 with the initial house-to-zone pressure (P1) and house-to-zone flow rate. In the above example, the initial house-to-attic pressure was -42 Pa and the flow from the house to the attic was 576 CFM_{50}. From Table 3, 2.9 is multiplied by 576 CFM_{50} to yield an attic-to-outside flow of 1670 CFM_{50}.

Pressure Without Added Hole (P1)
Zone-to-Outside (CFM_{50})
Table A112-2

P1	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
	0.4	0.6	0.7	0.8	0.9	0.9	1.1	1.2	1.3	1.5	1.6	1.8	2.1	2.5	2.9	3.7	4.9	7.9

Total leakage area is about 10% of the flow rate, or approximately 167 in^2 (1670 CFM_{50} x .10 = 167 in^2) between the attic and outside. This value provides an approximate area of vents and roof construction air leakage (damaged soffits, missing fascia, etc. and typical air leakage).

Using Table A112-3, the initial house-to-attic pressure of -42 Pa and the house-to-zone flow of 576 CFM_{50} is used to determine total path air leakage. Total path air leakage from the outside to the house through the attic is 518 CFM_{50} (0.9 x 576 CFM_{50} = 518 CFM_{50}). This represents the combined flow, in units of CFM_{50}, taking into account the resistance of *both* of the pressure boundaries.

Total Path Air Leakage (House-to-Zone-to-Outside)
CFM_{50}
Table A112-3

P1	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8

A1122 Flow Rates with Opening Created between Zone and Outdoors

Zone-to-outside flow rates may be taken where an opening can be made between the zone and outside. An estimate of the leakage area between the zone and outside may then be determined. Typical zones and openings between the zone and outside are listed below

- Attached garage (garage door to outside)
- Crawl space (exterior access hatch, vents)
- Basement (basement windows or door between basement and outside)

1. Select zones where pressure readings will be taken. Determine where openings between the zone and outside may be made or opened (hatches, vents, windows, doors).

2. Depressurize the house to -50 Pa (pressurization may be used, also).

3. Record the house-to-zone pressure with the opening closed. This is P1. Note that this is the house-to-zone pressure – not the zone-to-outside pressure.

4. Create the opening from the zone to the outside to increase the zone-to-outside pressure by at least 15 Pa while maintaining the house to outdoor pressure at -50 Pa with the blower door. Now record the house-to-zone pressure with the air flowing through the temporary opening. This is P2.

5. Measure the size of the opening.

6. Refer to Table A112-4. Find the house-to-zone pressure from step 3 in the left-hand column (P1). Find the house-to-zone pressure with air flowing through the opening from step 4 at the top of the table (P2). Read down and across to find the CFM_{50} per square inch of opening added.

7. Multiply the value from step 6 by the area of the opening (step 5) to find the CFM_{50} flow between the house and the outdoors.

8. Using Table A112-5, the flow from the house to the zone can be determined with P1 and the zone-to-outside flow rate determined in step 7. Find P1 (step 3) and multiply the corresponding value by the zone-to-outside flow rate (step 7).

- Leakage Area

  Leakage areas from the house to the zone and from the zone to the outdoors are approximately 10% of the calculated CFM_{50} values.

- Total Path Air Leakage

  Using Table A112-6, total path air leakage may be determined from P1 and the flow rate from step 7. Find the initial P1 (step 3) and multiply the corresponding value by the house-to-outdoor flow rate (step 7). This represents the combined flow, in units of CFM_{50}, taking into account the resistance of *both* of the pressure boundaries.

Crawl Space Example (Opening between Zone and Outdoors)

An initial pressure of -20 Pa (step 3, P1) was measured between a house and crawl space. An exterior hatch was opened. The blower door was adjusted to bring the house back to -50 Pa. The house-to-crawl space pressure increased to -38 Pa (step 4, P2). The value from Table 5 is 5.3 CFM_{50} per square inch of opening.

HOLE ADDED BETWEEN ZONE & OUTDOORS

CFM_{50} per Square Inch of Added Hole

Table A112-4

P2

P1	14	18	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
2	2.4	2.1	1.8	1.6	1.4	1.3	1.1	1.0	0.9	0.8	0.7	0.7	0.6	0.5	0.4	0.4	0.3	0.2
4		4.0	3.4	2.9	2.6	2.3	2.0	1.8	1.6	1.4	1.3	1.1	1.0	0.9	0.7	0.6	0.5	0.3
6			5.3	4.5	3.9	3.4	2.9	2.6	2.3	2.0	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4
8				6.4	5.4	4.6	4.0	3.5	3.0	2.7	2.3	2.0	1.8	1.5	1.3	1.1	0.8	0.5
10					7.4	6.2	5.3	4.5	3.9	3.4	2.9	2.6	2.2	1.9	1.6	1.3	1.0	0.7
12						8.2	6.8	5.7	4.9	4.2	3.6	3.1	2.7	2.3	1.9	1.5	1.2	0.8
14							8.8	7.3	6.1	5.2	4.4	3.8	3.2	2.7	2.2	1.8	1.4	0.9
16								9.3	7.6	6.4	5.3	4.5	3.8	3.2	2.6	2.1	1.6	1.0
18									9.6	7.9	6.5	5.4	4.5	3.7	3.0	2.4	1.8	1.2
20										9.8	7.9	6.5	5.3	4.3	3.5	2.7	2.0	1.3
22											9.8	7.8	6.3	5.1	4.0	3.1	2.3	1.5
24												9.6	7.6	6.0	4.7	3.6	2.6	1.7
26													9.2	7.1	5.5	4.2	3.0	1.9
28														8.6	6.5	4.9	3.4	2.1
30															7.8	5.7	4.0	2.4
32																6.8	4.6	2.7
34																	5.5	3.2
36																		3.7

The size of the opening to create this pressure difference is 7" x 24" (168 in^2). The area of the opening is multiplied by 5.3 CFM_{50} per square inch yielding a CFM_{50} flow rate of 890 CFM_{50} between the crawl space and outdoors without the opening.

The total area of leakage between the crawl space and outside is approximately 10% of the flow rate, or 89 in^2 (890 CFM_{50} x .10 = 89 in^2).

The house-to-zone flow rate may be then calculated with Table A112-5 with the initial house-to-zone pressure (P1) and house-to-outdoor flow rate determined from Table 5. The initial house-to-crawl space pressure was -20 Pa and the calculated house-to-outdoor flow was 890 CFM_{50}. From Table 6, 1.3 is multiplied by 890 CFM_{50} for a house-to-crawl space flow of 1157 CFM_{50}.

Pressure without Added Hole (P1)

House-to-Zone (CFM_{50})

Table A112-5

P1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
	7.9	4.9	3.7	2.9	2.5	2.1	1.8	1.6	1.5	1.3	1.2	1.1	0.9	0.9	0.8	0.7	0.6	0.5

Total leakage area between the house and crawl space is approximately 116 in^2 (1157 CFM_{50} x .10 = 115.7 in^2).

The initial house-to-crawl space pressure of -20 Pa and the house-to-outdoor flow of 890 CFM_{50} is used to determine total path air leakage from Table A112-6. Total path air leakage from the outside to the house through the crawl space is 623 CFM_{50} (0.7 x 890 CFM_{50} = 623 CFM_{50}). This represents the combined flow, in units of CFM_{50}, taking into account the resistance of *both* of the pressure boundaries.

Pressure without Added Hole (P1)

Total Path Air Leakage (House-to-Zone-to-Outdoors) CFM_{50}

Table A112-6

P1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.4

HOLE ADDED BETWEEN HOUSE & ZONE

CFM_{50} per Square Inch of Added Hole

Pressure with Added Hole (P2)

Pressure Without Hole (P1)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
14	3.7																	
16	3.2	5.5																
18	2.7	4.6	6.8															
20	2.4	4.0	5.7	7.8														
22	2.1	3.4	4.9	6.5	8.6													
24	1.9	3.0	4.2	5.5	7.1	9.2												
26	1.7	2.6	3.6	4.7	6.0	7.6	9.6											
28	1.5	2.3	3.1	4.0	5.1	6.3	7.8	9.8										
30	1.3	2.0	2.7	3.5	4.3	5.3	6.5	7.9	9.8									
32	1.2	1.8	2.4	3.0	3.7	4.5	5.4	6.5	7.9	9.6								
34	1.0	1.6	2.1	2.6	3.2	3.8	4.5	5.3	6.4	7.6	9.3							
36	0.9	1.4	1.8	2.2	2.7	3.2	3.8	4.4	5.2	6.1	7.3	8.8						
38	0.8	1.2	1.5	1.9	2.3	2.7	3.1	3.6	4.2	4.9	5.7	6.8	8.2					
40	0.7	1.0	1.3	1.6	1.9	2.2	2.6	2.9	3.4	3.9	4.5	5.3	6.2	7.4				
42	0.5	0.8	1.1	1.3	1.5	1.8	2.0	2.3	2.7	3.0	3.5	4.0	4.6	5.4	6.4			
44	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.3	2.6	2.9	3.4	3.9	4.5	5.3		
46	0.3	0.5	0.6	0.7	0.9	1.0	1.1	1.3	1.4	1.6	1.8	2.0	2.3	2.6	2.9	3.4	4.0	
48	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.6	1.8	2.1	2.4

Zone-to-Outside (CFM_{50})

Pressure Without Added Hole (P1)

P1	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
	0.5	0.6	0.7	0.8	0.9	0.9	1.1	1.2	1.3	1.5	1.6	1.8	2.1	2.5	2.9	3.7	4.9	7.9

CFM_{50} Total Path Air Leakage (House-to-Zone-to-Outside)

Pressure Without Added Hole (P1)

P1	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8

HOLE ADDED BETWEEN ZONE & OUTDOORS

CFM_{50} per Square Inch of Added Hole

Pressure with Added Hole (P2)

Pressure Without Hole (P1)

	14	**18**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
2	2.4	2.1	1.8	1.6	1.4	1.3	1.1	1.0	0.9	0.8	0.7	0.7	0.6	0.5	0.4	0.4	0.3	0.2
4		4.0	3.4	2.9	2.6	2.3	2.0	1.8	1.6	1.4	1.3	1.1	1.0	0.9	0.7	0.6	0.5	0.3
6			5.3	4.5	3.9	3.4	2.9	2.6	2.3	2.0	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4
8				6.4	5.4	4.6	4.0	3.5	3.0	2.7	2.3	2.0	1.8	1.5	1.3	1.1	0.8	0.5
10					7.4	6.2	5.3	4.5	3.9	3.4	2.9	2.6	2.2	1.9	1.6	1.3	1.0	0.7
12						8.2	6.8	5.7	4.9	4.2	3.6	3.1	2.7	2.3	1.9	1.5	1.2	0.8
14							8.8	7.3	6.1	5.2	4.4	3.8	3.2	2.7	2.2	1.8	1.4	0.9
16								9.3	7.6	6.4	5.3	4.5	3.8	3.2	2.6	2.1	1.6	1.0
18									9.6	7.9	6.5	5.4	4.5	3.7	3.0	2.4	1.8	1.2
20										9.8	7.9	6.5	5.3	4.3	3.5	2.7	2.0	1.3
22											9.8	7.8	6.3	5.1	4.0	3.1	2.3	1.5
24												9.6	7.6	6.0	4.7	3.6	2.6	1.7
26													9.2	7.1	5.5	4.2	3.0	1.9
28														8.6	6.5	4.9	3.4	2.1
30															7.8	5.7	4.0	2.4
32																6.8	4.6	2.7
34																	5.5	3.2
36																		3.7

House to Zone (CFM_{50})

Pressure without Added Hole (P1)

P1	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**
	7.9	4.9	3.7	2.9	2.5	2.1	1.8	1.6	1.5	1.3	1.2	1.1	0.9	0.9	0.8	0.7	0.6	0.5

Total Path Air Leakage (House-to-Zone-to-Outdoors - CFM_{50})

Pressure without Added Hole (P1)

P1	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**
	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.4

Appendix 114 Duct-Induced Pressures

In order to keep supply air from pressurizing closed rooms by more than 3 Pa, transfer grilles or jump ducts are installed to allow supply air to flow back to the central system return. The transfer areas and ducts are sized based on the equation shown below. To calculate the finished grille size, no more than 80% free area should be assumed, requiring that the transfer area – A – be divided by at least 0.8.

$$A = Q/1.853$$

where:

A = area in square inches
Q = air flow rate (ft3/min)

For example, a bedroom supply register has a flow rate of 100 CFM. The free area required for return air is 54 in^2 (100/1.853 = 54). If a transfer grille is to be installed between the bedroom and hallway, the area of the grille should be at least 68 in^2 (54/0.8 = 68).

Appendix 130 Health & Safety

Water may be found in three physical states; solid (ice), liquid (water) and gas (vapor). The liquid and gaseous states of moisture are the most important to weatherization because they can impact occupant health and building durability. It is helpful to understand the four moisture movement mechanisms. Understanding these principles can help identify solutions to indoor moisture problems.

Moisture Movement Mechanisms

1. Liquid - Moisture can enter a building as a liquid. Examples are rain or water resulting from poor subsurface drainage. Roofs should be watertight. Gutters and downspouts should direct water away from the home. The grade around the home should be sloped away from the home.

2. Capillary - This is the movement of water through tiny pores in a material and is the mechanism by which water is drawn into the leaves of trees or what happens when the corner of a paper towel is dipped in water. Capillary action also readily occurs in concrete and bricks. If there is no capillary break in a concrete foundation wall, water can be drawn up the wall. Installing a capillary break is usually outside the scope of weatherization, however, the source of the moisture should be identified and corrected if possible. The moisture source is often poor drainage around the home.

3. Air transported - Air will carry water vapor along with it (think of the moisture as hitch-hiking with the air). Moisture that gets into building cavities is often carried there by air. During the winter, warm air moves upward in a home and into the attic through bypasses. This warm air will carry water vapor with it. Depending upon the amount of air movement and its moisture content, the moisture may condense on cold attic surfaces. Air sealing attic bypasses will stop this moisture movement. Air transported moisture is stopped by creating an air barrier in the building assembly separating the conditioned spaces from the outdoors. Examples of air barriers are polyethylene plastic, drywall, and most rigid insulation materials.

4. Diffusion - This is the movement of water vapor through microscopic spaces in a material. The direction of this moisture movement is always from an area of high moisture content to one of lower moisture content. Moisture movement by diffusion is slowed – or retarded – by vapor barriers or retarders. Examples of vapor retarders include polyethylene plastic, aluminum foil, and special vapor retarding paints.

It is always more important to first control the source of the moisture before other remedial measures are done. For example, if rain water drains towards the building and, as a result, there is water in the crawl space, the rain water should be directed away from the foundation before a ground cover is installed and the crawl space walls insulated.

Bulk & Chronic Moisture Loads

Moisture problems may be related to bulk moisture or chronic moisture loads. Bulk moisture loads are periodic events caused by poor site drainage, a leaky plumbing fitting or an unvented clothes dryer. These events may temporarily elevate moisture levels in the home but do not necessarily cause problems because the home can dry over time. Chronic moisture problems are constant and may lead to persistent mold growth in the home. Chronic moisture problems include wet crawl spaces with no ground covers or unvented space heaters.

Health & Safety Assessment Form[1]

Client Name: ____ File Number: _________________________

Address: ____City, Zip: ____________________________

Phone Number: ____ ☐ Rent ☐ Own

1. Moisture Areas

Existing conditions *(check all that apply)*

	Damp atmosphere in house
	Client complaint of allergy-like symptoms
	Visible mold growth *(if "Yes", go to #2)*
	Evidence of water penetrating the home *(stains, moist areas)*
	Evidence of conditions that might allow water in the home *(poor grading, bad flashing, bad/missing gutters)*
	Actual construction defect or deterioration that allows water into the home *(roof, decks, windows, concrete slabs, lack of vapor barrier, missing crawl space ground cover)*
	Plumbing defects *(leaking drains, pipes or toilet seats, missing caulk on sinks or tubs, non-operable sump pump)*
	HVAC problems *(dirty, moist filters, poor condensation drainage, unvented space heater)*
	Dryer vented indoors, inadequate ventilation for a kitchen, bath or other high moisture area
	Any source of condensation

2. Mold Areas

Checklist		Existing Mold	Sq. Ft. of Area	Cleanup to be Done by Client/Landlord
	Bath *(location)* ______________________	☐		☐
	Shower *(location)* ____________________	☐		☐
	Kitchen	☐		☐
	Laundry area	☐		☐
	Basement walls	☐		☐
	Crawlspace	☐		☐
	Exterior walls	☐		☐
	Attic/Ceilings	☐		☐
	Other *(specify)*______________________	☐		☐

☐	Existing mold was found in your home. The mold is located in the areas checked under the Existing Mold column.	
	☐	Weatherization work cannot be done until the mold in the areas checked under the Cleanup column has been cleaned up. You (or your landlord) are responsible for the cleanup.
	☐	Any item checked in the Existing Mold column but not requiring client cleanup will either be cleaned by the agency or will not be disturbed during the weatherization work and therefore, does not need to be cleaned up in order to proceed with weatherization. However, it is advisable to clean up all mold.

Additional Comments: ____

By signing below, I acknowledge that I have been notified there is existing mold in the home prior to any weatherization work being done. If the mold has to be cleaned up before weatherization work can begin, I agree to have it cleaned up and then contact the agency so the weatherization work may proceed.

Client Signature: ___________________________________ Date: ____

Agency Representative: ______________________________ Date: ____________ Phone Number: _____________