Advanced Air Sealing Protocol

for

EmPower New York

April 2012

New York State Energy
Research and Development
Authority

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Introduction

This protocol was developed for use by contractors participating in the EmPower New York program, sponsored by the New York State Energy Research and Development Authority (NYSERDA). The guidelines described here are designed to conform to those of the Building Performance Institute (BPI), the New York State Weatherization Assistance Program, the U.S. Department of Energy Workforce Guidelines for Home Energy Upgrades, and the 2010 Residential Code of New York State.

The Protocol Development Team included Robert Kahabka, Northern Comfort Diagnostics; Dale Sherman and Andy Stone, NYSWDA; Kelvin Keraga, Dave Friello and Bryan Henderson, NYSERDA; Nate Yehle, Carol Sweeney, James Guyer and Chuck Dolinskas, Honeywell International. Additional input was provided by contractors participating in EmPower New York and additional NYSERDA and Honeywell staff. Nate Yehle developed and wrote the initial drafts of the Protocol. Additional assistance was provided by Anthony Cox, New River Center for Energy Research and Training.

This protocol is organized as a step by step process to be followed by participating EmPower contractors. It is not a training manual. It is recommended that staff of participating contractors complete air sealing training available through many training organizations in New York State, including, Hudson Valley Community College, the New York State Weatherization Director's Association, and other venues. Please email kmh@nyserda.org to find training near you.

Consult the EmPower New York "Guidelines and Procedures Manual" for further guidance on program rules and procedures for specific measures.

Questions or concerns regarding these protocols may be addressed to:

Kelvin Keraga, Senior Project Manager, NYSERDA
518-862-1090 Ext. 3374
kk2@nyserda.org

Nate Yehle, Senior Program Coordinator, Honeywell International
315-463-7208
nathan.yehle@honeywell.com

1. Initial Inspection:

Purpose: An initial overview of the air sealing needs of the structure.

1.1. Conduct an initial walk-through, both inside and out. This can be done while calibrating for Carbon Monoxide (CO) monitoring, conducting gas leak testing, or readying the home for initial blower door testing.

(1) BEST PRACTICE: Note any blackened insulation. This may be a sign of air transfer through the insulation.

1.2 Include the following "high focus" air sealing areas if possible:

(1) Attached garages
(2) Attic bypasses
(3) Dropped ceilings
(4) Heating and cooling ducts outside of the thermal/pressure boundary
(5) Dropped soffits
(6) Exterior walls, including any band joist or cantilever
(7) Combustion appliance vent chases and chimneys
(8) Porch and other attached roofs
(9) Basement/Crawlspace rim joist
(10) Basement/Crawlspace electrical and plumbing penetrations
(11) Any intentional penetration in the thermal boundary, such as windows, doors and exhaust fans

1.3 Note any obvious air sealing opportunities or health and safety related issues. Document with photographs.

2. Health and Safety Evaluation:

Purpose: Determine if air sealing is possible without adverse health effects to the occupants.

2.1 Situations considered must include, but not be limited to, the following:

(1) Bulk moisture issues
- These may be seasonal; consult with occupants if no moisture is apparent
- Evaluate water management systems such as gutters, vent terminations, and grading

(2) Apparent mold or mildew
(3) Presumed Asbestos-Containing Material
(4) Respiratory or medical conditions of occupants that may be exacerbated by changes in indoor air quality
(5) Atmospherically venting combustion appliances within the pressure boundary
(6) Volatile Organic Compounds (VOC's) stored on premise.
(7) Gas leaks
(8) Carbon monoxide in the ambient air

2.2 If air sealing or use of blower door is not advisable with present conditions, develop a plan of action to remediate or avoid any health and safety issues impacted by air sealing. Include as needed:

(1) Roof leak repairs prior to attic air sealing
(2) Reduction or elimination of moisture sources that may impact health
(3) Installation of a continuous, durable vapor retarder over exposed earth
(4) Ventilation according to ASHRAE 62.2
(5) Encapsulation or replacement of knob and tube wiring
(6) Other identified remedies

2.3 Do not proceed with any air sealing measures if measures will compromise any of the following:

(1) Occupant safety
(2) Building condition
(3) Worker exposure to hazardous materials or conditions

3. Initial Thermal Imaging (optional)

Purpose: Use thermal imaging to establish baseline reading of shell infiltration prior to running blower door.

3.1 Tour as many accessible areas of the home with infrared imaging to discover unseen pathways of air infiltration or exfiltration.

3.2 Both interior and exterior scans may be helpful.

4. Initial Blower Door Test

Purpose: Obtain initial quantified infiltration reading

4.1 Determine appropriate pressure boundary in building.

(1) Align the pressure boundary with the thermal boundary whenever possible.
(2) Consult with occupant to ensure that pressure boundary is consistent with the occupant's use of the home.
(3) The following areas must be established as either inside or outside of the pressure boundary:
- Attic spaces
- Basements
  - If the combustion appliance zone is in the basement, and if atmospheric appliances or dryers exist in the basement, the basement may be considered to be inside the thermal boundary. However, consideration must be given as to whether it is appropriate to air seal the basement walls, due to the risk of backdrafting.
  - Periodic combustion appliance zone (CAZ) testing during air sealing may ensure that no backdrafting occurs.
- attached garages
- crawlspaces
- cantilevers
- attached porch ceilings
- dropped soffits

(4) Use zonal pressure diagnostics if needed to help define pressure boundary.
(5) Then run diagnostics with respect to the determined pressure boundary.

4.2 Determine minimum building air flow standard (BAS) according to BPI "Building Analyst Professional" standards.

4.3 Conduct baseline reading (pre-test value) with:

(1) All exterior windows and doors closed
(2) All interior doors open
(3) Fireplace dampers and stove doors closed and all fires extinguished
(4) Heating and cooling systems turned off
(5) Exhaust, intake, makeup air, back-draft and flue dampers closed

4.4 Caution: take precautions to ensure that fireplace or woodstove ashes are not drawn into living space.

4.5 Conduct initial worst-case Combustion Appliance Zone (CAZ) testing if atmospherically vented combustion appliances are in use.

4.6 BEST PRACTICE: Initial blower door and CAZ testing can be helpful in determining whether backdrafting is likely to occur from extensive air sealing. If the initial blower door test indicates a high degree of air leakage, and the CAZ test is borderline, it is likely that backdrafting will occur if air leakage is reduced significantly. For this reason, it is recommended that periodic CAZ testing be conducted during air sealing to reduce this risk.

5. Diagnostics:

Purpose: Identify, quantify and prioritize air leakage strategies

With blower door running, employ additional diagnostics.

5.1 Thermal Imaging (Optional):

(1) Perform a follow-up thermal scan while blower door is running to clearly establish pathways of air movement in the home.

5.2 Zonal pressure diagnostics:

(1) Use these techniques to
- Determine the volume of leakage in an area
- Determine whether air leakage into hard-to-reach areas (such as knee wall areas without hatches) is significant enough to require creating access and air sealing.
- Evaluate whether an area has been effectively air sealed.

(2) If the amount of air leakage in the structure is severe enough that the blower door will not reach CFM50 during initial testing, complete air sealing as determined by initial inspection until CFM 50 can be reached.

(3) In some instances it may be more effective to complete priority air sealing areas, such as attic bypasses and garage walls and ceilings, to insulate walls, band joists and cantilevers, and to seal known leaks before employing these techniques.

(4) Perform zonal pressure diagnostics techniques as possible.

- Identify zones that are outside of the established thermal/pressure boundary. (See section 4.1, (3), above)
- Take care to determine whether each zone may be connected to others. If a connection if found, either seal the connection or consider the two zones one.
- Where a hole exists or can be created that will allow of insertion of a differential manometer hose into the zone, take a measurement of the pressure differences between the conditioned space, the zone, and the outside, with the blower door at CFM50. Record measurement of zones outside the pressure boundary “with respect to” (WRT) conditioned space or outdoors.

- Flag conditioned spaces showing high connectivity to spaces outside the pressure boundary for further diagnostics.
- Whenever a moderate opening can be created between the zone and the conditioned space, or between the zone and the outside, use the “Flow Method’ or “Series Leakage Diagnostics” to estimate the amount of air leakage reduction that may be attained in each area.
- BEST PRACTICE: use the “Flow Method” and “Series Leakage Diagnostics” charts developed by Anthony Cox and Collin Olson.

(5) Based on estimates created through diagnostics, determine priorities for air sealing and, if necessary, further evaluation.

- BEST PRACTICE: For a methodology for estimating savings based on CFM reduction, see “Residential Energy” by Krigger and Dorsi (Saturn Resource Management), Appendices A-12 and A13.

5.3 Diagnostic smoke:

(1) Set blower door to a low **positive** pressure (10-15 pa) to assist in visually locating leakage pathways from the conditioned space.
(2) Stand out of the path of the smoke.
(3) Inspect all accessible areas, including ducts.
(4) Bear in mind that slow-moving smoke may lead to large holes that represent significant air leakage. Rapidly moving smoke through small holes may represent a relatively minor leak.

6. Targeted Air Sealing

Purpose: Effective air leakage reduction

6.1 Use materials that meet the following standards:

(1) Products rated to a minimum 20-life.
(2) Air impermeable foams.
(3) Hydrophobic sealants
(4) Backer rod or other support for caulk when filling a gap wider than 3/8”
(5) Materials compatible with their intended surfaces
(6) Materials designed to retain effectiveness and appearance when used on the exterior of the home or in the path of direct sunlight.
(7) Approved non-combustible materials when in contact with chimneys, flues or vents; materials that meet ignition barrier specifications where applicable.

6.2 Perform work to the following installation standards:

(1) Adhere to the Worker Health and Safety Standards outlined in the appendix.
(2) Prioritize permanent air sealing strategies, such as blockages to air leakage paths which will remain undisturbed for long periods of time. Give lowest priority to air sealing strategies which have a short life of measure.
(3) Make sure that sealed surfaces prevent visible air movement using chemical smoke at 50 Pascals of pressure difference.
(4) Install any blown cellulose in an enclosed cavity at 3.5 lbs/cu. ft. or greater density. Install all fiberglass, rock or shag wool, or spray foam at or above the manufacturer’s commended density to limit air flow that corresponds to an air permeance value of ≤3.5 cfm/sq ft at 50 Pascals.
(5) Keep materials out of contact with live knob-and-tube wiring.
(6) Prepare surfaces in a manner that ensures adhesion of installed materials.
(7) Install all materials cleanly and continuously around seams, cracks, joints, edges, penetrations and connections.
(8) Make sure all sealed surfaces are capable of supporting any required load, such as insulation. Reinforce materials over large holes with structural components as needed.
(9) Use methods that allow for expansion and contraction between any dissimilar materials.

(10) Maintain and install materials at temperatures and humidity levels appropriate to ensure their effectiveness. Keep in mind that some foams may not expand or adhere as well on very cold surfaces.

(11) Ensure that air sealing materials are either not visible to, or are attractive in the living area.

(12) Use air-permeable insulation (such as foam rubber or fiberglass) as a sealing material only if it is enclosed in an air-impermeable material (such as a plastic bag).

(13) Isolate combustion zone and ensure that proper combustion air is present.

(14) Perform blower door quick tests periodically during work.

(15) When atmospherically vented combustion appliances are used, perform a worst-case CAZ depressurization test daily during air sealing or more often if appropriate.

- Verify correct drafting of all atmospherically vented appliances each day before leaving the jobsite.

(16) A minimum SIR of 1.1 for all air-sealing measures is required to meet program standards.

(17) Best Practice: consider the use of high density cellulose. It can often be installed quickly and efficiently, and provide both a pressure boundary and resistance to heat transfer. Some potential uses are:

- Band joists
- Enclosed porch ceilings
- Cavities below knee walls
- Partition walls

6.3 Target these "high focus" areas for air sealing based on priority and diagnostic testing:

(1) Garage/Living space interface: Make air sealing between the garage and conditioned space a priority in all cases where garage is attached to home, and where garage is actively used or may be used in the future for automobile or chemical storage.

Include the following:

- Air sealing of any penetrations, gaps, cracks, or holes which by virtue of diagnostic smoke show connectivity to the conditioned space, including:
  - Light fixtures and wiring
  - Plumbing
  - Ducting and gas piping penetrations
  - Cracks at sill plate, rim joists, subfloors or bottom of gypsum board

- Weatherstripping and door sweeps or thresholds on all doors leading from garage to conditioned space.
- Repairs, pointing or replacement of broken between garage and conditioned space.
- High-density insulation material installed, whenever possible, in any accessible common walls or garage ceilings where they align with the building's pressure boundary.

(2) Attics: Make attic air sealing a priority, as per BPI standards. Target areas where diagnostics indicate air leakage from the conditioned space, and areas where there are signs of moisture damage caused by warm moist air from the adjacent conditioned space. Include the following:

- Top plates and chases underneath knee walls
  - Securely install well-fitting and durable blockers.
  - Seal any remaining cracks or holes.
- Chases/Interior wall partitions. Seal these by one of the following means:
  - Span entire hole with rigid material that is cut to fit, fastened securely and sealed around the edges.
  - Fill chase with high density insulation material. This method is particularly effective in structures where the chase or wall partition has an interconnection with the band joist area, such as in balloon framed structures. Caution: make sure that insulation will not be in contact with any combustion appliance vent.
- Non-IC rated recessed lights. Treat these by one of the following means:
  - Install a sealed, rigid air tight enclosure, keeping at least 3" away from the top and side of any fixtures and at least ½" from combustible materials. For the top of the enclosure, use a rigid non-flammable material such as gypsum board, with an R-value no greater than 0.5.
    - BEST PRACTICE: Build the enclosures to the final height of the insulation to be installed. This will ensure that the tops of the enclosures are not insulated, will provide the insulation crew with a guide to the appropriate height of the insulation, and help future attic visitors identify their locations.
  - Replace recessed light with IC-rated airtight fixture.

- Attic stairwells. Treat these by one of the following means:
    - Bring stairwell into conditioned space
        - Span entire opening with a cover of rigid material and insulation.
        - Weatherstrip between stairwell and rigid cover.
        - Make sure cover will be easily removable by anyone wishing to access the attic, and easily replaced in such a manner that the air seal maintains its effectiveness.
    - Keep stairwell outside conditioned space
        - Weatherstrip and install a sweep or air tight threshold on attic door.
        - Dense-pack all cavities between attic and conditioned space, including walls to interior, floors, landings and area beneath stairs.
        - Seal all additional air leakage paths between conditioned space and stairwell area.

(3) Heating and cooling ducts outside of the pressure and thermal boundary

- Treat duct systems outside the pressure boundary (such is in the attic or garage) as a priority.
- Use mastic, pure silicone or other appropriate materials. Do not use tapes that will lose adhesion when subject to air pressure, heat or the force of gravity.
- Pay close attention to floor joist cavities which are covered with sheet metal and used as return ducts ("panned returns"). Seal the sheet metal/joist connection, leaks between joist and floor, and any wire or pipe holes through the joists. Also seal all transitions and seams between the panned joists return trunks.

(4) Dropped ceilings

- If there are holes above a dropped ceiling caused by water damage, such as plumbing problems, be sure that the problems have been treated before sealing up holes.
- Create a continuous air barrier between the ceiling and the unconditioned space above in one of the following ways:
- Create an air barrier above the dropped ceiling. Include the wall cavities as well as the bottom of the upper ceiling.
- Create an air barrier on the unconditioned side of the upper ceiling.

(5) Dropped soffits

- If the dropped soffit is not easily assessable, consider using zonal pressure diagnostics to evaluate the soffit's connection to the outside.
- Treat dropped soffits in either of the following ways:
    - Bring soffit inside the conditioned space
        - Span top of entire soffit with rigid material that is cut to fit and fastened securely.
        - Seal all remaining gaps.
    - Bring soffit outside the conditioned space by either:
        - Sealing all soffit walls aligning with desired pressure boundary with a combination of rigid material and sealant.
        - Installing high density insulation in soffit, if safe and appropriate, and if proper density for air sealing is achievable. Be careful not to compromise any recessed lights in dropped soffit areas.

(6) Empty exterior walls

- Insulate walls only if:
    - The walls are strong enough to support the insulation.
    - No moisture problems that may affect the insulation remain.
    - No live knob and tube wiring is known or suspected in the walls.
- Install high-density insulation.

(7) Band joists & cantilevers

- Evaluate the band joist in structures with platform construction. Thermal imaging can be very useful in this area.
- Access band joist or cantilever from either:
    - Interior upper story floor. A closet on an exterior wall may provide a useful access.
    - Interior lower story ceiling
    - Exterior wall
    - Underside of cantilever.
- Seal these areas with either:
    - High density insulation
    - Rigid insulation sealed in place
    - High expansion, low density foam with a low exothermic reaction.
- Seal all air paths into adjacent building components.
- Take care not to compromise any ductwork, building framework used as ductwork, recessed lights or dropped soffits in this area.

(8) Porch or other attached roofs

- Use zonal pressure testing to assess these areas.
- Treat these by either of the following:
  - Seal the interface between the attached roof and other adjacent building components.
  - Dense pack cavity with high-density insulation.

(9) Basement/Crawlspace rim joists

- Use visual inspection and diagnostics to evaluate leakage in this area, and seal as needed.
- Foam insulation may be used without a thermal barrier provided that it is in compliance with Section 402.4.1 of the 2010 Residential Code of New York State, as follows:
  - The maximum thickness is 3 ¼"
  - The density of the foam ranges between 0.5 and 2.0 pounds per cubic foot
  - The foam insulation has a flame spread index of 25 or less and an accompanying smoke developed index of 450 or less when tested in accordance with ASTM E 84

(10) Basement/Crawlspace electrical and plumbing penetrations

- Use visual inspection and diagnostics to evaluate leakage in this area. Pay particular attention to the area below and around the bathtub.
- Seal penetrations according to the established pressure boundary.
- Ensure that air sealing does not create a thermal barrier between the conditioned space and any water pipes on the exterior shell of the dwelling.

(11) Intentional penetrations in the thermal boundary

- Use visual inspection and diagnostics to evaluate leakage in these areas.
- Seal seams around moldings or window and door frames.
- Seal exhaust fan at interface with ceiling or wall where accessible.
- Install weatherstripping and sweeps on windows and doors as appropriate.

7. Follow-up Diagnostics

Purpose: To evaluate the results of installed measures and assess the techniques used.

7.1 Perform series leakage testing to verify the effectiveness of air-sealing measures in specific zones. This is especially useful for remediation when air-sealing goals are not achieved.

7.2 Review techniques employed in air sealing and assess their effectiveness.

8. Wrap-up

Purpose: Ensure that work has been completed successfully.

8.1 Conduct blower door test.

8.2 Perform test-out procedures according to BPI protocols.

8.3 Evaluate the need for mechanical ventilation according to BPI "Envelope Professional" standards.

(1) If a building falls at or above 70% of the building air flow standard (BAS), evaluate whether ventilation is needed. Consider the indoor air quality of the occupants, any health concerns or any issues related to atmospherically drafting combustion appliances in operation. Propose as needed.
(2) If building falls below 70% of building air flow standard, mechanical ventilation must be installed to provide the appropriate amount of make-up air for occupant safety and safe operations of the combustion appliances.

Appendix: Worker Health and Safety Standards

1. Personal Protective Equipment (PPE)

    1.1 Respiratory protection

        (1) Wear respirators appropriate for the vapor or particulate contaminants present. (E.g., N-95 or equivalent face mask or VOC full-face respirator if applicable).
        (2) Make sure that all installers have appropriate training in proper respirator filtration
        .

    1.2 Protective clothing

        (1) Use removable protective clothing if contaminants are present.
        (2) Always wear either a full face respirator or eye protection.
        (3) Use durable wrist protecting gloves that can withstand work activity and chemical exposure.
        (4) Use footwear that ensures worker safety.

2. Environmental or situational considerations

    2.1 Confined space safety

        (1) Locate all egress points before starting work.
        (2) Check space for frayed electrical wires.
        (3) Make sure space is adequately ventilated.
        (4) Avoid using toxic chemicals whenever possible.
        (5) Make sure that exhaust gasses from compressors and generators will be prevented from entering conditioned space.

    2.2 Tool safety

        (1) Use power tools according to manufacturer specifications. Inspect them periodically and eliminate any hazards related to missing ground prongs, ungrounded circuits, damaged and improper or defective devices.
        (2) Make sure that all electric tools will be protected by Ground Fault Circuit interrupters.
        (3) Use three-wire extension cords and discontinue the use of worn or frayed ones.
        (4) Use hand tools only for their intended purpose.

2.3 Ergonomic safety

(1) Use proper lifting techniques.
(2) Wear proper situational protective equipment (e.g. bump caps or kneepads) as needed.
(3) Use walk boards when practical.

2.4 Electrical safety

(1) Keep water, metal materials and metal ladders away from electrical sources.
(2) Do not use air sealing materials, including cellulose, in close proximity to live knob-and-tube wiring.

2.5 Heat/thermal safety

(1) Provide appropriate ventilation, hydration, rest breaks and cooling equipment.
(2) Store materials and use them in proper temperature range, as specified by manufacturer.

2.6 Fire Safety

(1) Guard against the risk of fire from ignition sources. For example, turn off pilot lights during blower door testing.

3. Materials safety

3.1 Chemicals will be handled according to manufacturer instructions or MSDA standards.

3.2 Use the least toxic effective material.

3.3 Make sure that Material Safety Data Sheets (MSDS) or an MSDS service 800 number are on site and accessible to all workers at all times.