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BUILDING TECHNOLOGIES PROGRAM

Test Plan Protocols: Energy Savings with Acceptable IAQ through Air Flow Control in Residential Retrofit

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Partnership for Advanced Residential Retrofit

February 2016

Building AMERICA
U.S. Department of Energy

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Test Plan Protocols:

Energy Savings with Acceptable IAQ through Air Flow Control in Residential Retrofit

Prepared for:

Building America

Building Technologies Program

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Definitions

BA	Building America
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
NREL	National Renewable Energy Laboratory
PARR	Partnership for Advanced Residential Retrofit

1 Background

The goal of this Building America (BA) project is to reduce the ventilation energy used to assure acceptable indoor air quality (IAQ) in existing residential homes by using a systems approach to controlling the three contributing air streams: ventilation, infiltration, and duct system losses. The savings will be associated with system balancing, infiltration control, and duct leakage control to ensure acceptable IAQ without negatively impacting combustion safety. Key success factors include: (1) minimizing fan-driven ventilation air volume, (2) controlling infiltration from undesirable sources, and (3) reducing duct system losses in areas that produce no IAQ benefit.

The Partnership for Advanced Residential Retrofit (PARR) will study a minimum of 20 treatment homes and 20 control homes over 24 months to evaluate the proper systems approach. Baseline testing on all homes will be conducted over a six month period. Following this baseline period, treatment and control houses will be tested for 12-18 months.

Houses will be recruited from the pool of houses that will be upgraded as part of the Illinois Home Performance or Iowa HVAC SAVE programs. Respondents will be screened for having a crawl space or unoccupied basement, a ducted space conditioning system, and a ventilation system. A project investigator will visit each property to determine appropriateness of the house for the project. At that first visit the investigator will conduct blower door tests and zone pressure tests, will assess the condition of the basement and lowest level floor, will photograph the conditions, and will prepare a work order for the contractor.

The instrumentation package for each test home includes one on-site evaluation using a blower door, air handler flow meter, zone pressure readings, duct leakage assessment tools, infrared thermography, and a checklist to log housing characteristics. An instrumentation package will be left in place including sensors for temperature, relative humidity, radon, formaldehyde, CO_2 and state loggers for major exhaust fans as well as energy meters and temperatures in the plenum. Particle measurements may also be made. In order to get the most information from the project budget, an equal number of treatment houses and control houses will be evaluated for a period of 4-6 weeks and then the instruments will be moved to the next set of homes.

2 Test Plan Protocols

2.1 Purpose

The test plan protocols will outline the approach for the development of the project test plan. The development of protocols will allow team members to consider and select the most appropriate methods and equipment. These protocols will be established based on their ability to detect the energy savings associated with changes proposed in the project. For example, the team will need to measure infiltration, ventilation, and duct system air flow rates accurately. A calibration of circulation air flow, exhaust system flow fans, and air infiltration rates can be done as a static measure and then used in the energy savings calculation based on event timers. How those flow rates change with outdoor conditions or other parameters will need to be assessed in order to best calculate the energy impact in the overall project.

2.2 Test Measurements

The investigator will conduct blower door tests prior to the air-sealing work and again once the air-sealing work is completed. The blower door test will include zone pressure measurements of the foundation area (basement or crawl space). The zone pressure measurements will include add-a-hole methods to permit estimation of the actual net opening area from the house to the zone, and from the zone to the outside. These estimates will be used as the basis for determining the extent of the air-sealing work done in each of the homes.

The investigator will conduct pressure pan tests and duct pressurization tests as appropriate. When ducts are outside the conditioned space, such as in a vented crawl space, pressure pan testing will be done first and duct pressurization testing may be considered if the pressure pan testing indicates substantial leakage. When ducts are inside the conditioned space then either the space will be temporarily placed outside if possible (e.g. opening a door between the basement and outside while simultaneously closing the door to upstairs) with pressure pan testing done first, or duct pressurization testing will be done.

2.3 Measures

2.3.1 Air-Sealing Work

The aim of the contractor's work will be to provide a substantial reduction in net opening area between the basement or crawl space and the lowest living area as well as appropriate air sealing at the ceiling plane. The air-sealing target will be to achieve a 50% reduction, or 100 in^2, in net opening area between the foundation zone and the lowest living area – whichever is lower – as determined by add-a-hole zone pressure techniques. Standard air-sealing techniques will be used, including:

- Two-part foam for small to medium openings
- Metal flashing and code-approved heat resistant caulk for sealing around chimneys and flues
- Use of rigid foam or other panels and two-part foam for larger openings
- Duct sealing

The contractor will use smoke and other methods for determining the locations of leakage sites. The contractor may use blower door operation during air sealing. When selecting material for air

sealing the properties of adjacent materials will be considered. For example, no flammable materials will be installed adjacent to combustion vent systems. If isolation between the foundation space and the first floor requires duct sealing then appropriate duct sealing materials will be used such as mastic and metal tape; duct tape will not be used.

2.3.2 Duct Sealing Work

Ducts in foundation spaces, attics, and garages will be sealed as indicated by duct leakage tests. The goal will be to have leakage levels based on duct pressurization tests be no more than those shown for new construction in ACCA Standard QI5 (10% total duct leakage or 6% leakage to outside, calculated as a ratio of the leakage at 25 Pa to the air handler flow) with a minimum target being that shown in ACCA QI5 for existing homes (20% total duct leakage) (ACCA 2010). The latter will be more practical in homes in which building cavities are used for returns. When pressure pan tests are used as the metric, ducts shall have no more than 3 Pa pressure difference across registers/grilles (BPI 2015).

2.3.3 Ventilation

The goal is to have two ventilation systems installed in a subset of the treatment homes. One will be an exhaust system, as is commonly installed in existing homes undergoing retrofit. The second will be a supply system, in which a duct will be connected between outdoors and the return plenum of the space conditioning system, which is commonly used in new homes and occasionally in existing homes. The supply system will be controlled to provide a minimum run time regardless of furnace demand, and will include a motorized damper which will close when the system is off. A weekly flip/flop test will be done to compare the performance of the two systems.

2.4 Assessment and Instrumentation Protocols

2.4.1 Client Visits

During the instrumentation and treatment period for a treatment home, another home from the recruitment pool will be instrumented and used as a control. The control will be used to baseline performance with a standard set of measures and to assist in accounting for weather effects.

Once a control or treatment home is selected as being a strong prospect for program participation, a series of visits will take place.

1. Assessment. A project investigator will visit the client at the home. The nature of the project will be discussed. The client and investigator will sign the agreement form. The investigator will assess the property and take photographs. The investigator will conduct a blower door test, with add-a-hole zone pressure measurements. The investigator will prepare a work order for the contractor. A field test site agreement will be provided to the homeowner.
2. Instrument placement. This visit will occur approximately 4-6 weeks prior to the intervention in the subject house. The investigator will schedule a visit by the contractor to the subject house. Baseline data will be collected.
3. Intervention. The contractor will do all work required by the program. For treatment homes, the airflow management protocol will also be followed with appropriate measures being installed. Upon completion of the work, a second blower door test with zone

pressure measurements will be conducted. The instruments will be read out and re-launched. The work will be approved by the client. For the control houses, the set of measures selected by the homeowner will be installed.

4. Retrieval. A visit to both the treatment house and the control house will be conducted approximately 4-6 weeks following the intervention.

2.4.2 Test Sequence

In order to evaluate the performance of the different ventilation options, sampling may occur in a "flip-flop" fashion for a subset of the homes, where the ventilation will be switched weekly (or periodically) between supply and exhaust.

2.4.3 Instrumentation Protocols

Table 1 provides the preliminary list of instruments to be used in the project. The instruments are currently under review and will be updated in the development of the test plan.

Table 2 shows the preliminary approach to protocols used by the team for set up, placement, reading, and retrieval of the instruments. These protocols will also be reviewed and revised as a part of test plan development. For the purpose of the table, the research team is referred to as the engineers, and the field technicians are referred to as the technicians. In some cases, the engineers will be installing the field equipment, and in some cases it will be done by the technicians.

In general, instruments will be placed to provide a good bulk reading of conditions in the space. Temperatures will not be measured on exterior walls, humidity will not be measured near showers, baths, cooking, or laundry equipment. Outdoor sensors will be placed out of the weather – under a covered porch or under the eaves.

All instruments will be logged when they are placed – unit number, location, and date and time of placement. A photo will be taken of each sensor that shows the surrounding environment.

All sensors will be checked to make sure they are present and operating each time an engineer or technician is in the house for any reason.

Table 1. Equipment Table

Measurement	Equipment Needed	Notes	Image
Temperature/Relative Humidity (indoor, outdoor)	HOBO loggers	Multiple locations	
Radon	Radelec E-Perm electrets	Deployed in pairs; same location as HOBO loggers.	
Formaldehyde	Passive aldehyde badges (source/lab TBD)	Measurements will last about one week per badge.	
Carbon Dioxide	Tellaire monitors connected to HOBO loggers	These monitors will be connected to the HOBO loggers.	
Particles	DustTrak (not in budget)	Instruments capable of measuring particle mass at sizes of interest are costly and beyond the budget of this project. Measurement is desired, if instrumentation can be acquired. The TSI DustTrak 8530 is preferred. Project team is requesting NREL assistance in locating/borrowing DustTraks.	

Measurement	Equipment Needed	Notes	Image
Fan State (Ventilation, HVAC)	HOBO state loggers	State loggers will be placed on ventilation fans and furnace air handlers.	
Furnace Gas Consumption	Current transducer connected to HOBO logger	Transducer will be placed on the gas valve and attached to a HOBO logger to determine when the furnace is on. The gas meter will be clocked to determine usage. Together these will allow for estimation of gas consumption.	
Air Handler Energy	Watt meter	Technician will place current transducer on the furnace fan wiring. HOBO logger will be used to log current/Watts at a 5 minute interval. Need for electrical consumption of the air handler.	
Plenum Temperature	HOBO temperature sensor	Thermocouple connected to a HOBO logger. Indicates whether the system is in heating or cooling mode and gives an indication of if the equipment is in low or high stage.	

Table 2. Instrumentation Protocols

Measurement / Instrument	Set Up	Placement	Reading	Retrieval
Temperature, RH / HOBO loggers	Set up by the engineers (launched). Placed by technicians.	Place on a shelf away from sun and water, not against exterior walls. Hang from the thermostat by fishing line or on a nail in the lower level.	Placed before baseline. Storing data at 5 second intervals.	End of control/treatment period.

Measurement / Instrument	Set Up	Placement	Reading	Retrieval
Radon / Radelec E-Perm electrets	Kept closed and opened on the site by technicians.	Place on a shelf with HOBO loggers. One in a basement/crawl space and one on the first floor above the basement/crawl space. Avoid wet areas and kitchen. Large chamber or small chamber sampler may be deployed based on the expected radon level. Placed in pairs.	Placed before baseline and retrieved after a week. A new sampler will be placed post-treatment.	Each sampler will be retrieved one week after placement.
Formaldehyde / Passive aldehyde badges (source/lab TBD)	Kept closed and opened on the site by technicians.	Placed on a shelf on the first above grade floor (next to the radon detector). Assure date/time of placement and sample ID is logged.	Measurements will last about one week per badge. Badges deployed for baseline and post-treatment. Will be changed weekly for houses using a flip flop ventilation protocol (supply and exhaust).	After 1 week for each test period.
Carbon Dioxide / Tellaire monitors connected to HOBO loggers	Deployed at the site by technicians or engineers.	Requires a power supply. Do not place in kitchen.	Placed before baseline and retrieved at the end of the test.	End of control/treatment period. Return to engineers for reading.

Measurement / Instrument	Set Up	Placement	Reading	Retrieval
Particles / DustTrak (not in budget)	Deployed at the site by technicians.	Likely to make a noise. Avoid bedrooms or other quiet rooms. Requires a power supply.	Placed before baseline and retrieved at the end of the test.	End of control/treatment period. Return to engineers for reading.
Fan State (Ventilation, HVAC) / HOBO state loggers	Deployed at the site by technicians (training required).	State loggers will be placed on ventilation fans and furnace air handlers. Clamp on current transducers will require identifying the wire to the fan.	Placed before baseline and retrieved at the end of the test.	End of control/treatment period. Return to engineers for reading.
Furnace Gas Consumption / Current transducer connected to HOBO logger	Deployed at the site by technicians (training required).	Clamp on current transformer to the wire providing power to the gas valve. The gas meter will need to be clocked to determine how much gas is burned per minute the gas valve is open.	Placed before baseline and retrieved at the end of the test.	End of control/treatment period. Return to engineers for reading.
Air Handler Energy / Watt meter	May be combined with furnace fan state instrumentation. Deployed at the site by technicians (training required).	Clamp on current transducer with Watt meter inside the air handler housing.	Logging real-time consumption at 5 minute intervals. Placed before baseline and retrieved at the end of the test.	End of control/treatment period. Return to engineers for reading.

Measurement / Instrument	Set Up	Placement	Reading	Retrieval
Plenum Temperature / HOBO temperature sensor	Deployed at the site by technicians (training required).	Thin probe – use an existing hole in the supply plenum or remove a screw from the sheet metal. Confirm only air temperature is being measured. Duct tape in place.	Placed before baseline and retrieved at the end of the test.	End of control/treatment period. Return to engineers for reading.

3 Schedule

Measurements and testing will take place over a 24 month period. **Error! Reference source not found.** displays the sequence and timing of interventions throughout the testing period. provides a high-level project schedule.

Table 3. Testing Intervention Sequence

Baseline	**Group A** - "treatment" with systematic flow treatment
Post-treatment	**Group B** - "control" with business as usual

3 – 4 week test periods

	1	2	3	4	5	6	7	8	9	10	11	12
Group 1A												
Group 1B												
Group 2A												
Group 2B												
Group 3A												
Group 3B												
Group 4A												
Group 4B												

4 Next Steps

The project team will build upon these initial protocols to develop a complete test plan, including details about equipment, instrumentation, data collection, and analysis. The test plan will also contain additional logistical detail.

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