ORNL/CON-480

Field Test of Advanced Duct-Sealing Technologies within the Weatherization Assistance Program

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ABSTRACT

A field test of an aerosol-spray duct-sealing technology and a conventional, best-practice approach was performed in 80 homes to determine the efficacy and programmatic needs of the duct-sealing technologies as applied in the U.S. Department of Energy Weatherization Assistance Program. The field test was performed in five states: Iowa, Virginia, Washington, West Virginia, and Wyoming. The study found that, compared with the best-practice approach, the aerosol-spray technology is 50% more effective at sealing duct leaks and can potentially reduce labor time and costs for duct sealing by 70%, or almost 4 crew-hours. Further study to encourage and promote use of the aerosol-spray technology within the Weatherization Assistance Program is recommended. A pilot test of full-production weatherization programs using the aerosol-spray technology is recommended to develop approaches for integrating this technology with other energy conservation measures and minimizing impacts on weatherization agency logistics. In order to allow or improve adoption of the aerosol-spray technology within the Weatherization Assistance Program, issues must be addressed concerning equipment costs, use of the technology under franchise arrangements with Aeroseal, Inc. (the holders of an exclusive license to use this technology), software used to control the equipment, safety, and training. Application testing of the aerosol-spray technology in mobile homes is also recommended.

EXECUTIVE SUMMARY

According to Lawrence Berkeley National Laboratory data, existing air distribution (duct) systems in U.S. homes are typically only 50 to 75% efficient due to a combination of air leaks and thermal losses. The current best practice for sealing leaks in duct systems is to use a combination of duct leakage measurements (total duct leakage and duct leakage to the outside), pressure pan measurements, and, less frequently, the measured change in indoor air pressure when the air handler fan is turned on to determine if duct sealing is needed and to locate duct leakage sites. Ducts are then sealed manually on the basis of these measurements as well as on the basis of visual inspections that identify obvious or potential leakage sites based on what weatherization crews have learned from past experience. Duct sealing work includes reattaching ducts that have become disconnected, repairing major leakage sites, and manually applying sealants to all visible and accessible leaks and joints. Cost-effective energy savings have been demonstrated from this technology approach in multiple field tests sponsored by the U.S. Department of Energy (DOE) in a range of climates.

DOE and Aeroseal, Inc., have jointly developed an advanced technology using an aerosol-spray sealant to decrease the amount of diagnostic work needed to identify leakage sites and to increase the amount of leakage sites sealed at reduced costs. The aerosol-spray equipment measures the total leakage of the entire duct system (supply and returns) before and after sealing in a manner similar to that for the conventional, best-practice approach. The aerosol spray is applied inside the ducts using the automated aerosol-spray equipment. This allows cracks up to ½ in. in width (and possibly wider) to be sealed without the need to directly access the leaks. Before or while the aerosol spray is applied, major leaks like disconnected ducts and open return plenums are repaired manually using conventional approaches. This technology has the potential to reduce diagnostic and repair times, as the locations of minor leaks do not need to be identified, and wall, ceiling, and floor cavities do not need to be opened to gain access to these leakage sites. In addition, small leakage sites that could not be sealed manually before can be sealed with this technique.

A field test of the aerosol-spray technology and the conventional, best-practice approach to duct sealing was performed in the winter of 1999–2000. The field test involved 80 homes eligible for the DOE Weatherization Assistance Program in five states: Iowa, Virginia, Washington, West Virginia, and Wyoming. All the houses were single-family, site-built homes (no mobile homes) heated by a central forced-air gas or oil furnace. The field test was performed to determine the efficacy and programmatic needs of the duct-sealing technologies as applied in Weatherization Assistance Program homes and to support the U.S. Department of Housing and Urban Development's (HUD's) Partnership for Advancing Technology in Housing (PATH) in speeding the widespread use of the advanced duct-sealing technologies, especially the aerosol-spray approach, in the nation's housing.

The study found that duct leakage problems in homes eligible for the Weatherization Assistance Program are prevalent and perhaps worse than in the general population of homes. The average duct leakage of 500–600 cfm25 measured in the field test homes is larger than the average leakages found in many other studies of non-low-income homes.

Although both the best-practice and the aerosol-spray technologies are successful at sealing leaks in ducts, the aerosol-spray technology combined with manual sealing of large leaks is more effective at sealing duct leaks by 50% or more compared with use of the best-practice approach alone. When the aerosol-spray technology was used to seal small leaks while major leaks were sealed manually, between 60 and 70% of the total duct leakage, on average, could be sealed, whereas only about 40 to 50% of duct leakage was sealed when manual methods alone were employed. Duct leakage reductions were also more consistent and more predictable in the houses receiving the aerosol-spray treatment than in those receiving best-practice duct sealing alone. Pressure pan readings further support these findings.

An average savings of 5% was measured in space-heating energy use from the duct sealing performed in this field test. However, in homes where the ducts were clearly located outside the conditioned space of the home (i.e., in insulated attics or carports) rather than inside the home or in spaces partially connected to the conditioned space of the house (i.e., basements and uninsulated crawlspaces), the measured space-heating energy savings is nearly twice the average value, or about 9%. Scatter in the energy usage data are too great to measure the difference in energy savings between the two duct-sealing methods. However, the larger air leakage reductions measured in the homes using the aerosol-spray technology would be expected to translate into higher energy savings compared with the homes using just the best-practice approach.

The aerosol-spray technology can potentially reduce labor time associated with just sealing the ducts by 70%, or almost 4 crew-hours. The average time to seal ducts using the aerosol-spray technology was 98 min, and one person could operate the equipment and perform the necessary manual sealing during this time period. The best-practice approach took an average of 147 min and required 330 crew-minutes. The material costs associated with both methods are about the same. Setup, tear-down, and diagnostic times must also be considered in determining the overall or total labor costs associated with a particular duct-sealing method. These times could not be determined from the field test. Although times to perform these tasks are probably greater for the aerosol technology than for the conventional, best-practice technology, the difference is not likely to offset the four additional crew-hours needed to seal the ducts under the best-practice approach.

The five weatherization agencies that participated in the field tests were given a questionnaire to obtain their feedback on the technologies used in the tests. Three of the four responding agencies felt that the aerosol-spray technology was superior to the best-practice approach, although they recognized that it was not the correct tool for all applications. Implementation issues raised by the agencies included equipment costs, equipment size, and the existing software used to operate the equipment. The agencies also generally saw some value in making duct leakage measurements in addition to just pressure pan readings as part of the best-practice approach, although a strong consensus was not reached.

Duct sealing using the best available method should continue to be a recommended weatherization measure. Continued training on conventional, best-practice approaches is needed to achieve better duct leakage reductions and lower post-retrofit duct leakage rates than those observed in this field test. Training should also promote more consistent results among agencies and perhaps faster installation times.

Because of the benefits observed in this field test — namely, better and more consistent air leakage reductions and lower repair times compared with conventional, best-practice technologies alone — as well as the positive input received from the participating weatherization agencies, we recommend further study to encourage and promote use of the aerosol-spray technology within the Weatherization Assistance Program. A pilot test of full-production weatherization programs using the aerosol-spray technology is recommended to develop approaches for integrating this technology with other energy conservation measures and minimizing impacts on weatherization agency logistics. Implementation approaches that allow aerosol-spray duct sealing to be performed while other measures such as air sealing and side-wall insulation are installed must be established. The potential time savings of the automated aerosol-spray technology, which could allow crews to work on other tasks while the sealing takes place, needs to be verified. The need for speciality crews to perform duct sealing because of required skill levels and considerations of equipment cost and hauling must be determined.

In order to allow or improve adoption of the aerosol-spray technology within the Weatherization Assistance Program, four issues identified during the field test and raised by the participating weatherization agencies need to be addressed:

- The franchise structure and equipment/franchise costs established by Aeroseal, Inc., which holds an exclusive license to use this technology on residential and small commercial buildings, is likely to prohibit widespread adoption within the Weatherization Assistance Program. DOE should discuss with Aeroseal how costs could be reduced and the franchise approach and requirements altered to speed adoption of this technology in the Weatherization Assistance Program. DOE should investigate to what extent it is bound by Aeroseal's exclusive licensing agreement, since DOE and the U.S. government helped fund the initial development of the technology.

- The software used in the field test to control the equipment was developed by Aeroseal for use by HVAC contractors in its franchise approach. DOE should discuss the development of a considerably scaled-down and simplified version of this software with Aeroseal for use within the Weatherization Assistance Program.

- Aeroseal has stated that aerosol sealing "has been tested by Underwriters Laboratories Inc. (UL) and the Indoor Environment program at Lawrence Berkeley National Laboratory." DOE should further investigate and document the safety of this product before recommending full-scale implementation within the Weatherization Assistance Program.

- The agencies used in the field test were experienced in basic duct diagnostics (primarily pressure pans) and manual duct sealing and, in some cases, were state trainers themselves. As less experienced crews are trained on the aerosol-spray technology, the training program should be more extensive than the three-day training provided under this field test and should include a field monitoring component to provide immediate feedback to the newly trained crews.

Finally, application testing of the aerosol-spray technology in mobile homes is recommended. The Weatherization Assistance Program is serving more and more mobile homes each year, and mobile homes are the predominant house type served by many weatherization agencies. The aerosol-spray technology has been tested in mobile homes only on a very limited basis, and this field test addressed application of this technology to site-built, single-family homes only.

ABBREVIATIONS AND ACRONYMS

ASAP	Achieved Savings Assessment Program
CEE	Center for Energy and Environment
DOE	U.S. Department of Energy
HUD	U.S. Department of Housing and Urban Development
HVAC	heating, ventilating, and air-conditioning
LBNL	Lawrence Berkeley National Laboratory
PATH	Partnership for Advancing Technology in Housing (HUD)
SIR	savings-to-investment ratio
TRAIN	Teaching, Rehabilitating, Aiding Iowa’s Needy

1. INTRODUCTION

1.1 BACKGROUND

According to Lawrence Berkeley National Laboratory data, existing air distribution (duct) systems are typically only 50–75% efficient due to a combination of air leaks and thermal losses. The current best practice to reduce air leakage in duct systems is a two-step process. The first step is to quantify the leakage (air flow rate in cubic feet per minute [cfm] needed to pressurize the ducts to 25 Pa) and identify the leakage sites using a combination of blower-door testing, duct pressurization via a duct blower, and duct pressure measurements. The second step is to manually reconnect ducts and seal identified leakage sites using mechanical fasteners (screws, clamps, etc.), duct materials (sheet metal, duct board, drywall, plywood, rigid board insulation, etc.), and sealants (mastic, spray foams, caulk, etc.). Cost-effective energy savings have been demonstrated from these technologies in multiple field tests in a range of climates.

Aerosol-spray sealants are an advanced technology developed to decrease the amount of diagnostic work needed and increase the number of leakage sites sealed at reduced costs. The aerosol spray is applied inside the ducts using automated equipment. This allows cracks up to ½ in. in width (and possibly wider) to be sealed without the need to have direct access to the leaks. Before or while the aerosol spray is applied, major leaks like disconnected ducts and open return plenums are repaired manually using conventional approaches. This technology has the potential to reduce diagnostic and repair times because the locations of small leaks do not need to be visually identified, and wall, ceiling, and floor cavities do not need to be opened to gain access to these leakage sites. In addition, small leakage sites that could not be sealed manually before can be sealed with this technique.

Aerosol-based duct sealing has been identified by Nadel et al. (1998) as a high-priority emerging technology that, if adopted, could lead to substantial energy savings. The aerosol spray technology has been used in the field as part of the development process (Modera et al. 1996) and has been included in a utility-based program in California (Kallett et al. 2000), but it has not been implemented routinely within the U.S. Department of Energy's (DOE's) Weatherization Assistance Program or other efficiency programs in varying climates.

1.2 PROJECT OBJECTIVES

The purpose of this project was to determine through field testing the efficacy of advanced duct-sealing technologies in housing weatherized by the Weatherization Assistance Program and to assess the training and material requirements needed to implement these advanced technologies within the program (provided they proved to be effective). In accomplishing these objectives, this project would support the U.S. Department of Housing and Urban Development's (HUD's) Partnership for Advancing Technology in Housing (PATH) in speeding the widespread use of advanced duct-sealing technologies and especially the aerosol-spray approach in order to radically improve the quality, durability, energy efficiency, environmental performance, and affordability of the nation's housing.