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Field Trial of an Aerosol-Based Enclosure Sealing Technology

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NOTICE

Field Trial of an Aerosol-Based Enclosure Sealing Technology

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The work presented in this report does not represent performance of any product relative to regulated minimum efficiency requirements.

The laboratory and/or field sites used for this work are not certified rating test facilities. The conditions and methods under which products were characterized for this work differ from standard rating conditions, as described.

Because the methods and conditions differ, the reported results are not comparable to rated product performance and should only be used to estimate performance under the measured conditions.

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Unless otherwise noted, all figures were created by the ARBI team.

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Definitions

ARBI	Alliance for Residential Building Innovation
CFM50	Cubic Feet per Hour at 50 Pascals
HVAC	Heating, Ventilation, and Air Conditioning

Acknowledgments

The authors would like to acknowledge De Young Properties for allowing the ARBI team to demonstrate the aerosol sealing process on several of its new homes in Clovis, California, and helping to coordinate the installations.

Executive Summary

This report presents the results from several demonstrations of a new method for sealing building envelope air leaks. These demonstrations used an aerosol sealing process that was developed by the Western Cooling Efficiency Center at the University of California-Davis, which is part of the U.S. Department of Energy's Building America research team Alliance for Residential Building Innovation. The process involves pressurizing a building while applying an aerosol sealant to the interior. As air escapes through leaks in the envelope, the aerosol particles are transported to the leaks where they collect and form a seal that blocks the leak. Standard blower door technology is used to facilitate the building pressurization, which allows the installer to track the sealing progress during the installation and automatically verify the building's final tightness.

This project has addressed the following research questions:

1. What enclosure sealing rates can be achieved?
2. What is the estimated cost for applying the aerosol sealing process to new single-family homes?
3. What is the feasibility of using the aerosol sealing process on a production scale compared to standard sealing practices?
4. How can the aerosol sealing process be worked into a typical construction schedule?

The demonstrations showed that the process successfully sealed 60%–85% of building envelope air leaks within 90 minutes of aerosol injection. Each installation required about 11 person-hours of labor to set up, seal, and clean up. Considering that many of the installation staff had little to no experience applying the aerosol sealing process on a building and that the team was using prototype equipment, this was a very encouraging result. With a commercial technology and trained installation personnel, two contractors would be expected to require 4 hours to seal a single-family home. At a labor rate of $30/hour, the labor cost would be $240 per installation. Material costs include $100 for sealant and $15 for other disposables. Thus, the complete cost for each installation would be about $355.The sealing rates measured during the process tend to decrease as a building is sealed. The average sealing rate achieved with the aerosol sealing system was 560 CFM50 per 10 minutes at the beginning of the tests and 130 CFM50 per 10 minutes at the end of the test. The average sealing rate achieved throughout the entire sealing process was 290 CFM50 per 10 minutes of injection.

Each aerosol envelope sealing was performed after the drywall was installed and taped. The process did not appear to interrupt the construction schedule or interfere with other tradespeople working in the homes. The labor needed to physically seal bulk air leaks in typical construction will not be replaced by this technology. However, for a building that was built with standard construction techniques and Home Energy Rating System-verified sealing, this technology can reduce air leakage to levels that would meet the U.S. Department of Energy's Zero Energy Ready Homes program requirements. Small leaks, which are often missed by typical construction methods, are the most appropriate ones to seal with the aerosol process. When a developer is striving to meet a tighter envelope leakage specification to meet building code requirements or striving to build a higher-performance home, this technology could greatly reduce the cost to achieve that goal—by providing a simple and relatively low-cost method for

reducing the air leakage of a building envelope with little to no change in common building practices.

1 Introduction and Background

1.1 Introduction

This project aimed to demonstrate a technology that was recently developed for sealing air leaks in building envelopes. With the onset of new standards that require specific levels of airtightness in homes, it has become evident that the standard methods used to seal leaks are falling short of the goals. Traditional methods for reducing infiltration in buildings are highly labor intensive—and in many cases inadequate—to meet some of the more aggressive airtightness standards such as California Title 24 (5 ACH50), the U.S. Department of Energy's Zero Energy Ready Program (3 ACH50 in California) and the Passive House Standard (0.6 ACH50). Other than providing code-required sealing, builders are generally naïve about where to place and how to apply air barriers and about the costs associated with achieving low leakage. Besides the inherent difficulty of sealing air leaks, the contractors who are responsible for installing the air barrier typically provide no direct feedback that any sealing is being accomplished. Not until long after this work is completed is the infiltration tested, which shows the actual infiltration level.

The U.S. Department of Energy's Building America research team Alliance for Residential Building Innovation conducted this research, which directly responds to a high-priority area as defined by the U.S. Department of Energy in the FY 2014 Residential System Research Needs: Item 1 – High Impact System Innovations. Specifically, this references the following gap identified in the 2011 Building America Enclosures Standing Technical Committee Strategic Plan: Gap #3, Airtightness - Document known strategies to achieve "good, better, best" enclosure airtightness goals.

Air sealing is essential to achieving the level of efficiency required to attain performance benchmarks such as those for Zero Energy Ready Homes, California Energy Commission and California Public Utilities Commission 2020 zero net energy, or others. Reducing conditioning loads in buildings is the first step toward achieving a high-performance home. Once the conditioning load is reduced, downsizing the conditioning equipment can further improve energy efficiency and reduce equipment costs. Studies have indicated that reducing the infiltration of existing buildings can reduce the conditioning energy use by 30% (Emmerich et al. 2005; Sherman 2006). Emmerich et al. used CONTAM and TRANSYS to model the impact that reducing apartment building envelope leakage has on building energy use in several U.S. cities with very different climates.

Sealing building envelopes is also a critical component of a successful ventilation strategy. Homes traditionally rely on uncontrolled infiltration through building leaks to supply the makeup air for an exhaust ventilation system. Thus, determining the source of the fresh air is nearly impossible. One study shows that for homes with attics and attached garages, an average of 51% of the total house air leakage occurs between the house and the attic and 11% of the air leakage occurs between the house and the garage (Proctor et al. 2011). Air exchange with the attic can waste considerable energy, because (1) an attic experiences wider temperature extremes than the outdoors, and (2) air exchange with the garage poses a serious health risk, because the garage can be a source of many harmful air contaminants.

1.2 Background

As building codes demand ever tighter building envelopes, significant effort has been made to reduce the leaks in building shells through current construction practices. However, the problems of excessive labor costs, constant vigilance, and quality control remain. Traditional air-sealing methods are well documented[1] but even when diligently applied can fall short of the ACH50 goal due to unrecognized leakage pathways. A recently developed technology at the University of California-Davis for automating the envelope sealing process using aerosol particles has been successfully tested in the laboratory and demonstrated in multiple full-scale applications. A similar process, developed by Lawrence Berkeley National Laboratory and commercialized under the name Aeroseal, has been used with great success to seal leaks in ducts. The work presented in this paper looks at a similar process that is applied instead in a nominally quiescent environment without the use of a carrier flow to deliver the aerosol sealant to the leaks. The aerosol envelope sealing process involves briefly pressurizing a building to normal testing pressures while applying an aerosol "fog" to the building interior. As the air escapes through leaks in the exterior shell of the building (including leaks between rooms), the aerosolized sealant is transported to the leaks and seals them as the sealant tries to escape. Blower door equipment is used to facilitate the sealing process and to provide real-time feedback and a permanent record of the sealing. This technology can thus simultaneously measure, locate, and seal leaks in a building envelope and provide permanent documentation of the sealing process.

The appeal of the proposed technology is that it should be able to seal buildings at a low cost (reducing sealing costs to tens of dollars per 100 ft^2 of building floor area) and to automatically and simultaneously provide verification of the sealing process and certification of the building envelope airtightness. Laboratory experiments in an 8-ft-tall box (Harrington and Modera 2012) and preliminary field tests in single-family and multifamily dwellings suggest that the aerosol process should be able to use current technologies to cost-effectively seal leaks in multifamily buildings and provide automated certification of the airtightness. These results also suggest that the process should be applicable to new construction and to retrofits (at least at the time of tenant changeover). The aerosol process can be employed with any type of building construction and now uses "standard" building sealants to be more attractive to builders and consumers. Recent tests of the technology on multiple apartments in Queens, New York, demonstrated excellent performance—sealing at least 80% of the air leakage in less than 2 hours. This project will demonstrate that these previous tests and successes with smaller multifamily units can be replicated on single-family production homes.

1.3 Research Questions

The data gathered from the aerosol envelope sealing demonstrations will be used to address the following research questions:

1. What enclosure sealing rates can be accomplished?
2. What is the estimated cost for applying the aerosol sealing process to new single-family homes?
3. What is the feasibility of using the aerosol sealing process on a production scale compared to standard sealing practices?
4. How can the aerosol sealing process be worked into a typical construction schedule?

[1] http://www.toolbase.org/PDF/DesignGuides/doe_airsealingFS.pdf

2 Research Methods

The aerosol sealing process has been successfully demonstrated; it can seal as much as 90% of the available leaks in an enclosure (Maxwell and Berger 2015). To answer the research questions for this project, the sealing demonstrations focused on the time required to apply the sealing process to new single-family homes.

The University of California-Davis Western Cooling Efficiency Center completed demonstrations of the aerosol sealing process on six single-family homes in Clovis, California.The homes were sealed during the rough-in stage of construction after drywall was installed and taped and included one- and two-story homes of 2,000 ft^2 to 3,500 ft^2 (Figure 1). Table 1 provides a summary of some of the building characteristics of each homes sealed.

Figure 1. Photo of housing development where the aerosol envelope sealing installations were performed and photo showing stage of construction the homes were in before sealing.

Table 1. Characteristics of Each House Sealed

Test #	LOT #	# Floors	Floor Area (ft^2)	Building Volume (ft^3)
1	LOT 4	2	3,550	33,725
2	LOT 13	1	2,019	20,190
3	LOT 9	1	2,324	23,240
4	LOT 10	2	3,550	33,725
5	LOT 15	1	2,324	23,240
6	LOT 12	1	2,324	23,240

2.1 Description of Aerosol Sealing Setup

The preparation of the homes before each installation was not extensive, because they had no finished surfaces to protect. The crucial items that required preparation to prevent unwanted deposition were exterior doors and heating, ventilating, and air-conditioning (HVAC) ducts. Because California Title 24 building codes require heating and cooling ducts to be blocked during construction to prevent dust from entering the duct systems, much of this work was already completed (Figure 2).

Figure 2. Photo showing supply ducts covered to prevent dust from entering the duct system

Large holes were taped off including undercuts on exterior doors, large plumbing penetrations, and network access points that were unfinished (Figure 3). The impetus for taping over large holes was not due to the potential of unwanted deposition on surfaces but rather to increase sealant use efficiency by preventing large plumes of aerosol from escaping to the outside. Although the size of hole that can be sealed by the aerosol sealing process has no theoretical limits, it does have a practical one. The time required to seal a hole with the aerosol sealing process has been shown to increase with the square of the increase in the size of the leak measured by the leak's minimum dimension (Carrie and Modera 1998). Figure 3 shows significant deposition on electrical access points that were not taped before the process. Although the sealant can be easily removed in this case, the material that deposited in this location was wasted, because it will not result in tightening the building envelope.

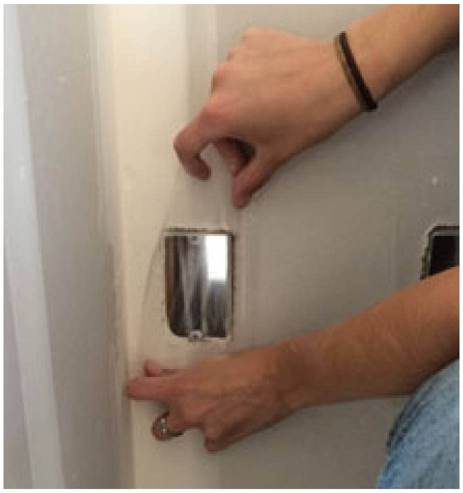

Figure 3. Photo of a network access point being taped in preparation of the aerosol sealing process

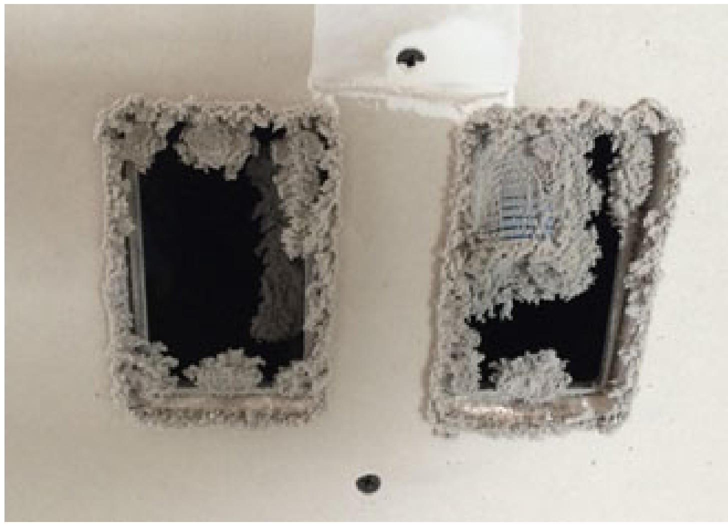

Figure 4. Photo showing untaped network access points on an interior wall with significant deposition

The time required to block a hole versus the impact it will have on the sealing process needs to be considered. If a hole, which will likely not be sealed by the aerosol process, has little potential to lead to deposition on an unwanted surface and taping would be considered too time consuming, it can be left uncovered during the sealing process. The result is a decrease in sealant application efficiency but also a decrease in the time required to set up the sealing process. An example of a hole that was considered too time-intensive to tape is shown in Figure 5. This air leak would probably be sealed by the builder at a later date, and taping over the larger hole could result in a seal that was formed on an appropriate part of the leak being damaged when the tape was removed.

Figure 5. Photo showing hole near ventilation supply duct that was not expected to be sealed by the aerosol process and left uncovered to reduce the time required for setup

Another critical component of the preparation for aerosol sealing is to ensure the pressure imposed on the building does not blow a hole open during the process. In the case of the demonstrations for this project, the covering the contractors used to block the heating and cooling ducts were in some cases insufficient to handle the 75 Pascal pressure that was used to perform the sealing, and these covers required some additional reinforcement. The attic access also needed to be taped to avoid lifting the access door during the sealing process.

2.2 Nozzle Placement

When applying the aerosol envelope sealing process to a space with dividing interior walls, nozzles should be placed in each room to improve aerosol distribution and maximize the sealing efficiency. The aerosol sealing equipment used for this project could deliver spray to a maximum of eight nozzles, which in some cases did not allow for optimal spacing of the nozzles. Figure 6 shows the nozzle placement used on the home with the largest floor plan of the development (3,550 ft^2).

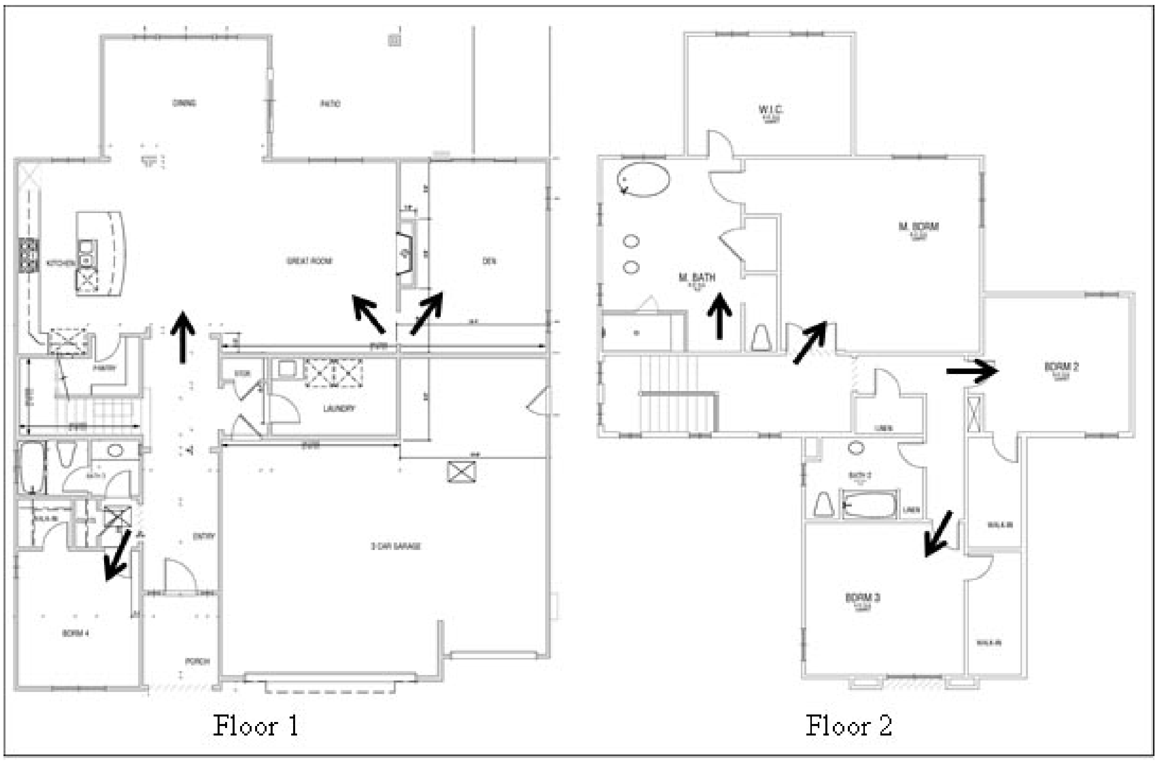

Figure 6. Diagram showing nozzles placement for one of the aerosol envelope sealing installations

A common mistake is to assume that interior walls do not contribute to the overall leakage of a building. Previous applications of the aerosol sealing process have revealed significant deposition on interior walls where leak paths are lead to an attic or other space that is open to the outdoors. Therefore, spaces completely enclosed by interior walls should still be treated by the aerosol sealing process.

2.3 Installation Process

The primary equipment needed for the aerosol installation is listed below and shown in Figure 7:

- Air compressor

- Generator
- Pump
- Sealant
- Blower door with associated instrumentation (DG700 pressure gauge and controller)
- Computer with TECLOG3 software
- Compressed air hoses and liquid lines to go to each nozzle.

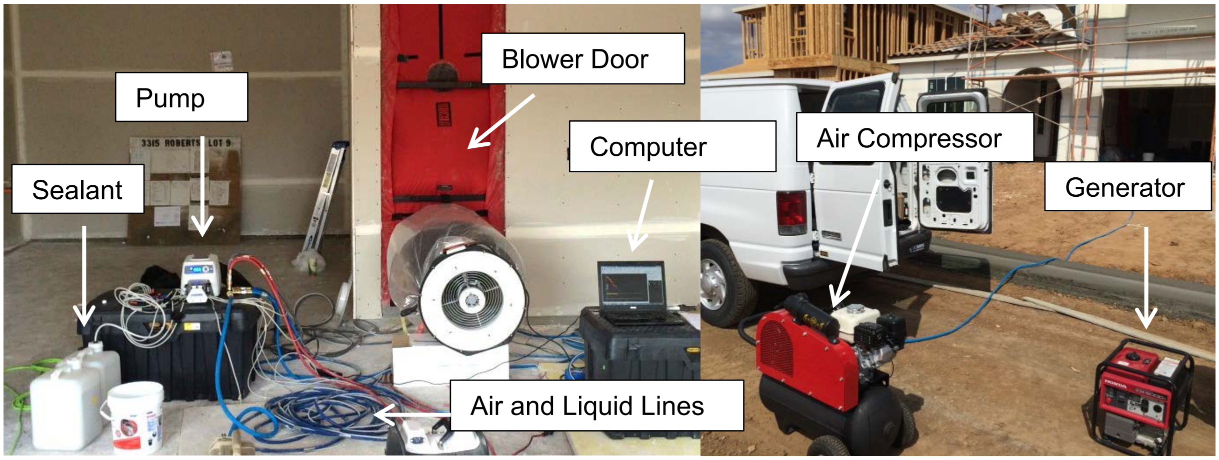

Figure 7. Primary equipment used for aerosol sealing installation

Each step of the process was documented, including the time required and the materials used to complete the sealing. The steps are broken into three main categories: setup, sealing, and cleanup. The entire sealing process is outlined here:

Setup

1. Set up blower door and run compressed air and liquid lines through the doorway to the exterior where the aerosol equipment is located (Figure 8).

Figure 8. Routing of cords for aerosol nozzles through exterior doorway

2. Run a single point test at 50 Pa manually (depressurization).

3. Turn the blower door fan around and connect to a blank fan housing to prepare for pressurization (Figure 9).

Figure 9. Blower door and aerosol injection hoses installed

4. Tape off major known leaks:
    A. Supply registers, return grilles, and outdoor ventilation air supply (if provided)
    B. Exterior doors
    C. Open plumbing connections.
5. Cover anything that should not have sealant deposition (tile, electrical panels, etc.).
6. Put nozzles in desired locations (Figure 10) and place an indoor temperature and relative humidity probe in a room that is equipped with a nozzle.
7. Spray water through the nozzles to set the preferred orientation.

Figure 10. Nozzle test using water

8. Purge the sealant up to each nozzle.
9. Tape up the door used to access the house.

10. Control the blower door to maintain 75 Pa pressurization.
11. Set the injection rate to achieve a calculated 90% relative humidity.
12. Initiate the sealing process by injecting aerosol solution into the nozzles.

Sealing

1. Monitor sealing profile using manometer connected to a computer (Figure 11).

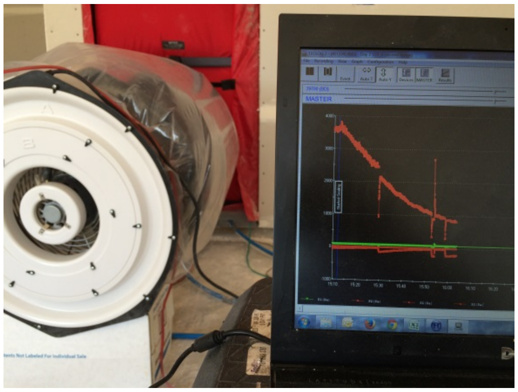

Figure 11. Sealing underway and results being plotted in real time

2. Monitor indoor relative humidity and adjust sealant injection rate accordingly (~90%).
3. When sealing is complete, switch to water, and continue until all lines are purged.

Cleanup

1. Purge the house of aerosol by opening doors and windows and running the blower door fan.
2. Remove nozzles, disassemble, and clean by rinsing with water.
3. Remove and coil combo cords.
4. Remove any plastic or tape that was used to block known leaks.
5. Turn the blower door fan around and mount in door for a single-point depressurization test at 50 Pa.
6. Remove the blower door.

The calculated sealant injection rates are heavily influenced by ambient air conditions and blower door airflow rate. These tests were all performed in relatively dry conditions (the dew point was consistantly around 50°F and dry bulb was 68°–82°F), which allowed for higher sealant injection rates and thus better sealing rates. Heating the air blown into the building during the sealing process is one method for improving performance in humid and cold climates.

3 Results

Table 2 presents the results of sealing each test home. The pre- and postsealing test results are based on the single-point depressurization measurements performed before and after the sealing, as opposed to the monitored leakage data collected during pressurization of the building for the aerosol application.

Table 2. Summary of Sealing Results Based on Single-Point Depressurization Tests

Test #	Sealing Time (min)	Sealing Pretest (CFM50)	Sealing Posttest (CFM50)	ACH50 Presealing (CFM)	ACH50 Postsealing (CFM)	Percent Reduction
1	90	5,100	1,936	9.1	3.4	62%
2	81	4,603	1,690	13.7	5.0	63%
3	74	4,472	676	11.5	1.7	85%
4	112*	4,758	1,018	8.5	1.8	79%
5	82	4,813	969	12.4	2.5	80%
6	77	5,095	1,226	13.2	3.2	76%

* Air compressor ran out of fuel causing a pause in the sealing

Because the process was applied at a rough-in stage of new construction a significant amount of leakage (except duct leakage) would be expected to be sealed in later stages of construction. The leakage data presented in Table 2 show the infiltration measurement performed with HVAC ducts blocked and large holes covered as described in Section 2.1. Test 2 indicates a significantly higher ACH50 result at the end of sealing, which may have been caused by multiple HVAC ducts becoming unblocked during pressurization.

The sealing profiles for each ealing demonstration are presented in Figure 12. The initial sealing rates were similar for each demonstration and showed about 1,000 CFM at 50 Pa sealed in the first 20 minutes of injection. This result appears to be independent of the size of the home being sealed or initial leakage level.

The pressurization leakage measurements obtained during the sealing and the depressurization measurements obtained before and after each sealing installation showed a significant discrepancy. The two potential causes for this discrepancy are: (1) a poorly calibrated fan that has had significant sealant deposition on it in the past and required cleaning, and (2) the the fan is ducted into the blower door frame, which may affect the manufacturer's calibration. Current methods for installing the aerosol envelope sealing process have nearly eliminated sealant deposition on the fan by using a short duct to separate the blower door fan from the space being sealed.

The depressurization tests were performed as the manufacturer intended with a different fan and are assumed to be more accurate. The blower door manufacturer has confirmed that a special calibration could be performed to include the impact of ducting the fan into the blower door frame, which will be considered for future demonstrations.

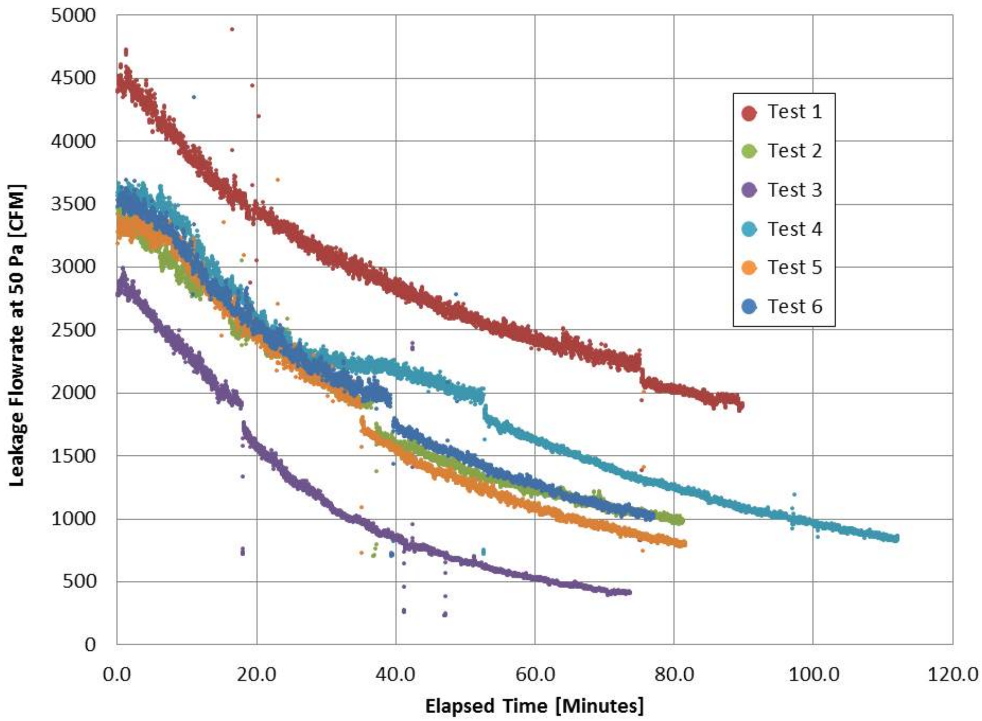

Figure 12. Sealing profiles for each of the sealing demonstrations performed

Table 3 presents the data collected on the time required to complete each sealing demonstration. With three people performing the demonstrations, the average time to perform the sealing was less than 4 hours. The time spent sealing the house is relatively short compared to that required for setup and cleanup. With a more mature technology and trained installation personnel, the labor required to perform the sealing is expected to be reduced.

Table 3. Summary of Time Required To Complete the Sealing for Each Demonstration

Test #	# Floors	Floor Area (ft^2)	Time Required (person h)		
			Setup	Sealing	Cleanup
1	2	3,550	6.3	1.5	5.0
2	1	2,019	5.9	1.3	3.4
3	1	2,324	6.7	1.2	4.2
4	2	3,550	6.9	1.9	4.0
5	1	2,324	3.5	1.4	1.9
6	1	2,324	4.6	1.3	3.4

Sealant accounted for most of the disposable costs for each demonstration. The sealant is a commercially available air-barrier product that can be purchased for about $40 per gallon. The sealant is diluted with water for use in the aerosol application.

Table 4 lists the sealant costs for each demonstration site. The average cost was about $3.60 per 100 ft^2 home floor area, but this value ranged from $2.75 to $4.51. Other disposable costs including tape, fuel for the compressor and generator, and peristaltic pump tubing were estimated to cost less than $15 for each installation.

Table 4. Summary of Sealant Costs for Each Demonstration

Test #	# Floors	Floor Area (ft^2)	Diluted Sealant Used (gal)	Sealant Cost	Sealant Cost/100 ft^2
1	2	3,550	10	$160	$4.51
2	1	2,019	5	$80	$3.96
3	1	2,324	5	$80	$3.44
4	2	3,550	7.5	$120	$3.38
5	1	2,324	5	$80	$3.44
6	1	2,324	4	$64	$2.75

4 Discussion

Overall, the builder that provided the sites for the tests was extremely pleased with the result, because it helped the builder surpass the California Title 24 minimum requirement for residential envelope airtightness of 5 ACH50. Thus, these homes are expected to qualify for incentives from the local utility through the California Advanced Homes Program for exceeding the minimum requirements for airtightness.

This project has addressed each of the research questions as follows:

1. What enclosure sealing rates can be accomplished?

The leakage rates measured during the sealing process continuously fell as leaks were sealed. The average sealing rates achieved were 560 CFM50 per10 minutes at the beginning of the tests and 130 CFM50 per 10 minutes at the end of the test. The average sealing rate achieved throughout the entire sealing process was 290 CFM50 per 10 minutes of injection. Figure 13 presents an exponential fit of the sealing rate data for each of the six tests.

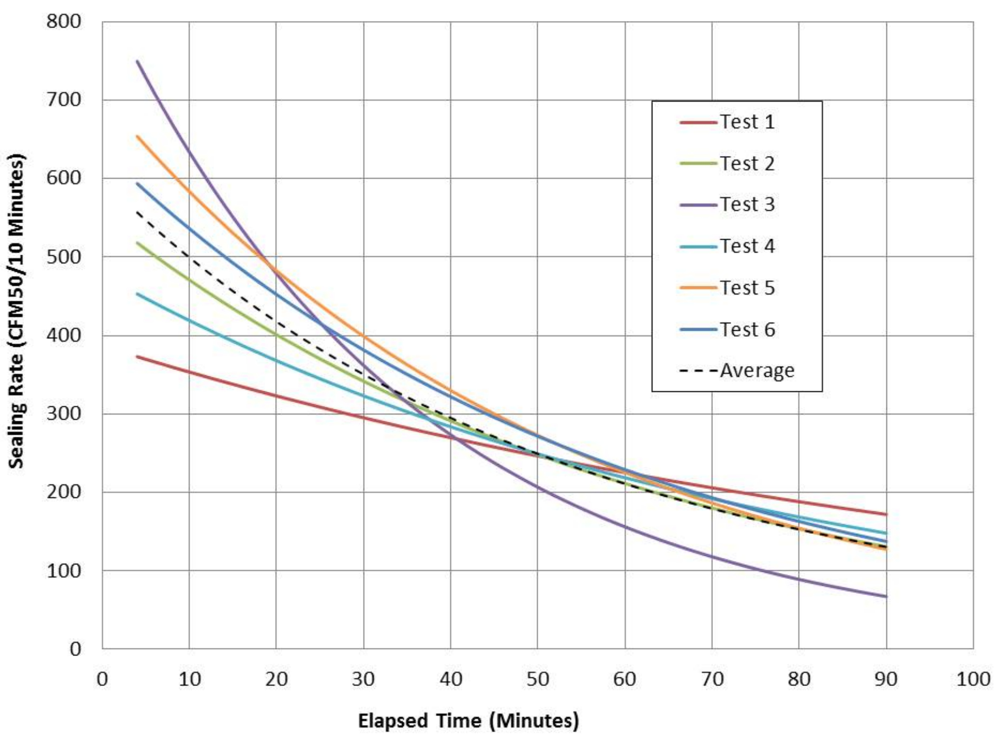

Figure 13. Sealing rate profile for each sealing demonstration performed

When the sealing process begins smaller leaks seal much more quickly than larger leaks, which results in high initial sealing rates. As the smaller leaks begin to close off the sealing rates begin to drop as the larger leaks begin to seal. The installer can continue the sealing process until the targeted ACH50 leakage rate is achieved or can mechanically seal leaks that are too large to seal effecively with aerosol before completing the final depressurization test. Future research could focus on procedures for attaining a particular target airtightness and when to stop the aerosol injection.

2. What is the estimated cost for applying the aerosol sealing process to new single-family homes?

The average labor time required to complete the aerosol envelope sealing installations at the six sites was less than 11 person-hours. Only one person on the installation team had previous experience using the technology to seal homes, and the data collected on the time to complete each step of the process clearly showed that the team's speed improved during the second round of sealing demonstrations. If the technology were commercialized, the labor required to complete the sealing would be expected to decrease significantly. The equipment used for this system is a prototype that could be made more efficient. One example of how the process could be simplified would be to employ hose reels. A substantial amount of time was spent winding and unwinding the compressed air lines used to operate the nozzles, and using hose reels to manage the hoses would significantly shorten set-up and break-down time. Managing the hoses required on average about 2 person-hours for each installation, or about 17% of the total time required.

With fully developed equipment and trained installation personnel, two contractors would require about 4 hours to seal a single-family home. Assuming each contractor earns $30/hour, this would be $240 in labor for each installation. The material costs add another $100 for sealant and $15 for other disposables including tape and fuel. Thus, the complete cost for each installation would be about $355. Depending on construction quality and other factors, this is likely to be a much lower cost than what would be required to achieve similar airtightness using strictly manual caulking and sealing methods.

3. What is the feasibility of using the aerosol sealing process on a production scale compared to standard sealing practices?

The labor needed to seal bulk air leaks in typical construction will not be replaced by this technology. However, this technology can reduce the air leakage of a building that was built with standard building techniques to extremely low levels. Aerosol sealing is most effective for blocking small leaks that are often missed by traditional sealing methods. When a developer is striving to meet a tighter envelope leakage specification to meet building code requirements or build a higher performance home, this technology could greatly reduce the cost to achieve that goal by providing a simple and relatively inexpensive method for reducing the air leakage of a building envelope with little to no change in common building practices.

4. How can the aerosol sealing process be worked into a typical construction schedule?

As builders become more familiar with the aerosol envelope sealing process construction schedules might need to be modified slightly, which would reduce the preparation time needed for aerosol sealing. Better coordination with the other trades may reveal a more suitable time to apply the aerosol sealing to a building that would reduce the time required for all aspects of the sealing process.The demonstrations completed for this project were all performed after the drywall was installed and taped. This stage of contruction seems to be the most appropriate for the aerosol sealing process, because most of the larger leaks have already been sealed, which allows the process to target the smaller leaks that are the most appropriate for this technology to seal.

This process would also be able to adapt to alternative contruction techniques. Current construction practices typically use the drywall to create the air barrier for a home; however, the many penetrations of drywall, including electrical boxes and plumbing, make it a relatively poor barrier. As building air leakage requirements become more difficult to achieve, builders may instead adopt strategies that place the air barrier on the outer surface of a wall that has significantly fewer penetrations. The aerosol process could still be used to seal the small distributed leaks on the inside of the "exterior envelope" that are not obvious to contractors at an earlier stage of contruction as long as windows and doors are installed on the home.

5 Conclusion

This project verified that the aerosol envelope sealing technology developed by the University of California-Davis can cost-effectively reduce air infiltration in new homes. The sealing method could seal 60%–85% of the air leakage within 90 minutes of sealant injection. The installations were performed by University of California-Davis engineers and students, only one of which had previous experience with a prototype injection system. Each installation required about 4 hours to set up, seal, and clean up—about 11 person-hours. Considering the limited experience of the installation crew, this was a remarkable result. With commercial equipment and trained installation personnel the estimated cost would be $355 to seal a large single-family home, which is much lower than what standard building practices can achieve.

The market potential for this technology is extensive and growing as codes and standards start tightening the requirements for building envelope air leakage. Although large obvious air leaks will continue to be sealed manually, the aerosol sealing technology can quickly and cost-effectively address the small distributed leaks in buildings and make them extremely tight. An additional benefit of the technology is that it provides immediate feedback and certification of the building tightness, which could satisfy a home's testing requirements. This technology will likely be deployed through a manufacturer that would provide equipment and training to contractors such as Home Energy Rating System raters or HVAC contractors.

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