Aerosol Sealing of Occupied Homes from Attics and Crawlspaces

Curtis Harrington, Frederick Meyers, and Timothy Levering, UC Davis Western Cooling Efficiency Center
Dave Bohac, Center for Energy and Environment

ABSTRACT

Retrofit air sealing of homes provides a significant opportunity for reducing residential energy use. According to results published on the impact of national weatherization efforts, major air sealing (leakage reduction ≥ 1,000 cfm at 50 Pa) in single-family homes resulted in an average natural gas savings of 7.2%. Greater envelope leakage reduction has required more intrusive and expensive sealing methods that are either cost prohibitive or can only be applied during renovations. This paper describes the results of recent studies investigating a new application of an aerosol-based sealing technology for sealing occupied homes.

These projects are documenting application protocols for applying aerosol sealing to existing occupied homes from the exterior through a ventilated attic or crawlspace. The process involves depressurizing the home while releasing the aerosol fog to the attic and/or crawlspace. As particles are drawn in through leaks, the particles impact the edge of leaks and stick, forming a seal. Since the bulk of the particles are isolated to unfinished zones, minimal particles ultimately enter the home, reducing the preparation time. Furthermore, the fan used for de-pressurizing the home allows the particles that do enter through leaks to be directed outside.

This process has been shown to significantly reduce the time required to prepare the home for retrofit air sealing with aerosols while also being highly effective at reducing air leakage. The results presented in this paper show an average leakage reduction of 42% with four of eight sites achieving leakage reductions of more than 50%.

Introduction

Residential homes consume about 21% of total U.S. energy use (EIA 2022). Infiltration of outdoor air has been estimated to be responsible for 29% of residential heating and cooling loads (DOE 2014). California has adopted aggressive energy codes to reduce greenhouse gas emissions, but to meet California's stated climate goals it will be necessary to retrofit existing homes to improve efficiency and reduce their carbon footprint. Weatherization programs have provided opportunities and resources for addressing air leakage in existing homes. Air sealing efforts in the national Weatherization Assistance Program were reported in over 90% of the homes that participated in the program (Blasnik et al. 2015) and contributed the highest fraction of natural gas savings of all measures achieving 28% of the program gas savings. The existing state-of-the-art sealing methods employed in these programs are all manual and rely on contractors to visually identify and seal leaks. A review of the impact of these programs has shown that air sealing work has resulted in average air leakage reduction of 27% in single family homes, 31% in mobile homes, and 18–20% in multifamily homes (Tonn et al. 2015). Another study reviewed the air sealing impacts from 85 homes in a program for the city of Lafayette, IN, showing an air leakage reduction of about 18% (Ye 2014). Achieving air leakage reductions beyond that using standard air sealing practices would require more intrusive and expensive air sealing methods.

Background

Aerosol sealing has been successfully deployed in new residential construction to achieve much tighter envelope assemblies than other methods. The basic process involved pressurizing the home while injecting an aerosol fog of sealing material to the inside. As air escapes through leaks in the envelope, the sealant is transported with the air to the leak where it sticks and ultimately forms a seal. This process therefore finds and seals leaks in the building shell. The sealant particles require a significant impact force to adhere and generally do not deposit on walls or the underside of horizontal surfaces. The sealant does deposit on the tops of horizontal surfaces due to settling from gravity. In new construction, the deposition on floors is not an issue due to the building being in an early stage of construction. For the retrofit applications, this creates a significant challenge to avoid sealant deposition on finished surfaces. All finished horizontal surfaces must be covered which takes a significant amount of time and creates waste.

A previous project for the Department of Energy (DOE) Building America program applied the interior aerosol sealing process to existing homes and found a significant amount of time was needed to prepare the home for sealing, which reduced its cost effectiveness (Bohac, Harrington and Meyers 2024). It was also found that protection used to prevent unwanted deposition blocked leakage pathways resulting in reduced air sealing performance. At the end of that project, a new installation method was attempted on a limited scale. The new method distributed the sealant material in the attic space while the home was depressurized causing the sealant to be drawn in through leaks in the ceiling of the homes. This limited study showed very promising results with about 55% of the total air leakage of the homes being sealed from the attic approach. This process also did not require any preparation of contents within the home (Harrington et al. 2022). The impact of sealing attics on a larger scale could be significant. A study of newly constructed California homes in 2011 showed that 51% of the total air leakage was between the ceiling-attic surface (Proctor et al 2011). There is also potential for sealing the floor-crawlspace surface. A model based on a large survey of residences shows that houses with vented crawlspaces are 20% more leaky than with concrete slab foundations (LBL RDS 2011). This paper describes results from recent applications of the aerosol sealing process to attics and crawlspaces performed for projects funded by the California Utilities Emerging Technologies program (CalNEXT), California Energy Commission, and DOE.

Methodology & Approach

The objective of these projects was to evaluate the performance of a new aerosol sealing method applied from the exterior of a home for air sealing occupied residences. A novel method is used, involving the release of sealant in the adjoining attic or crawlspace areas while the residence is depressurized. Eight homes in California were selected to demonstrate the air sealing process. The homes were single-family and multifamily residences with either a ventilated attic and/or crawlspace.

The new aerosol envelope sealing approach for occupied residences follows the same basic principle as the more traditional aerosol sealing process. The key change for sealing occupied homes is that the home is depressurized relative to outside, and sealant is released in a ventilated attic or crawlspace zone. The sealant is drawn through leaks in the ceiling or floor where particles impact and seal the leaks. Most of the sealant material is contained within the unfinished attic or crawlspace zones so there is no need to protect contents within the home.

The process starts with an initial walk-through to identify leakage pathways and identify large leaks that should be sealed manually. The aerosol sealing process is most effective for leaks smaller than about 3/8” to avoid extended sealing times and slow sealing rates. Application protocols were developed that include common leak locations that should be reviewed and potentially sealed manually prior to aerosol sealing. After the preliminary review, the blower door and sealing equipment is set up. The blower door is set up as it would be for a standard depressurization leakage test. The sealing equipment is set up in the attic and crawlspace areas where sealant will be dispersed. A preliminary leakage test is conducted and recorded for the baseline measurement. The blower door is then set to control the pressure between 100–150 Pa and windows in the home are opened minimally in order to increase airflow while maintaining at least 100 Pa. Opening the windows allows additional airflow to transport sealant particles that make it through leaks into the home to be removed quicker. Sealing begins by remotely engaging the sealant pumping stations while the home is depressurized. The sealing progress can be monitored using data from the blower door allowing determination of when sealing has stopped progressing. The total amount of sealant used depends on the amount of leakage present. Sealant flow rate is directly proportional to leakage flow, so in general, the attic approach uses less sealant than the traditional whole-house application since only leaks in the attic are accessible. Sealant injection rates are impacted by humidity conditions with warmer and drier conditions allowing for higher injection rates and faster sealing times. After reaching the intended leakage target or when sealing progress has sufficiently slowed, the sealing stations are turned off. The blower door remains running for 10-15 minutes to allow sealant particles to be flushed from the home. The equipment is then removed, and occupants are allowed to return.

The sealant is a diluted version of a synthetic acrylic polymer material used as a spray or roll-on exterior air barrier. While the particles generally do not pose an issue for unwanted deposition on building materials using this new application of aerosol sealing, they can pose a health risk if breathed for an extended period. High levels of particulate matter inside the home have been measured during sealing, requiring the operators and anyone present in the home at that time to wear an N95 mask to avoid breathing a potentially high concentration of particles. Once the particles are removed from the space, it is safe for occupants to return. The material is UL-certified Greenguard Gold, which is a standard for low VOC materials that can be safely applied around humans and pets.

Application Protocols

This project began developing application protocols for the attic and crawlspace aerosol sealing approach. A preliminary protocol was developed for the initial work and will be expanded with more experience from future field demonstrations. The following is the preliminary application protocol:

1. Screening
    a. Verify safe access to attic and crawlspace/basement.
    b. Check condition of insulation, and if any exists, remove for sealing
2. Baseline test
    a. Install blower door for depressurization and perform a baseline envelope leakage test
3. Initial walk through
    a. Identify potential injection locations including attics, crawlspaces, attached garages, unconditioned basements, wall cavities, etc.

    b. If possible, perform a guarded fan-pressurization test to determine leakage from attic or crawlspace zones
    c. Identify and temporarily seal any airflow paths between injection zones and conditioned zones that are not intended to be sealed. This could include exhaust fans that are not ducted to the outside, whole house fans, access doors, etc.
    d. Manually seal any known leaks that are larger than ~3/8” wide. Common penetrations are exhaust fan ducts, wiring, furnace vent, water heater vent, and plumbing.
4. Setup equipment
    a. Place injection nozzles in appropriate locations in the injection zones. Avoid pointing nozzles at obstructions within six feet from the nozzle if possible. Attempt to distribute aerosol evenly by directing nozzles toward different sections of the injection zone.
    b. Connect compressed air lines to the nozzles
    c. Test nozzles with water to ensure proper operation (i.e. no nozzle clogging or water dripping from connections, proper communication with Master Control Unit)
    d. Close access doors to injection zone
5. Begin depressurization
    a. Set fan to depressurize to -150 Pa using the blower door ‘Open’ ring
    b. If additional fan flow is available, crack windows in several rooms furthest from the fan until fan is running full and house is at roughly 100 Pa
6. Begin injection
    a. Start sealant pumps to begin injecting aerosol
7. Monitor sealing
    a. Monitor envelope leakage using blower door data
    b. Monitor sealing rates to identify progress and possible issues
    c. Inspect for obvious fog intrusion from injection zone into home
8. Complete seal and exhaust remaining particles
    a. When sealing rates slow to <1 CFM50/min, then switch nozzles to water and purge
    b. Continue operating blower door until purge is complete
    c. Open windows and continue running blower door for at least 15 minutes
9. Cleanup
    a. Breakdown equipment (except blower door)
    b. Remove temporary seals
10. Final test
    a. Perform a final envelope leakage test

Field Test Results

Site 1

Test Site 1 was the first application of the exterior aerosol sealing approach. The apartments tested were all single-story with two floorplans—938 ft^2 and 764 ft^2. The apartments were slab-on-grade with ventilated attics so only the attics were targeted for the sealing process (Figure 1). In all cases, the attic insulation was removed prior to the sealing so pre and post air leakage testing was performed with no insulation in the attic. The aerosol testing opportunity coincided with a larger scale project that included air sealing and insulation allowing direct comparison of the aerosol method to traditional canned foam, and an elastomeric paint product. This section describes the results from the air sealing efforts using each of the three methods.

Figure 1. Apartment at Site 1 during attic insulation removal

Aerosol sealing. Three apartments at Site 1 were the first attempt to apply aerosols from the attic. This was also the first application in an occupied building that did not require significant effort protecting surfaces to prevent unwanted sealant deposition. Each apartment took about one hour to seal, in addition to one hour of setup and 30 minutes of cleanup after sealing, for a total of about 2.5 hours. This is significantly faster than the retrofit applications that require more preparation and cleanup for protecting surfaces (Harrington et. al. 2022). The aerosol sealed apartments reduced total envelope leakage by an average of 55% from an average initial leakage of 8.0 air changes per hour at 50 Pa (ACH50) to a final leakage of 3.6 ACH50. The results were also very consistent, with all three apartments achieving a leakage reduction of over 50%. An example of how the sealant collects and seals around penetrations is shown in Figure 2.

Minor fogging of the interior was apparent during the sealing process. High volume air cleaners were used to scrub out aerosols from the living space, but any particles were quickly exhausted by the blower door. That said, this reinforced the need to wear proper personal protective equipment (N95 particle filter mask) when inside the home during sealing, or the system could be operated from outside the home. After sealing, no noticeable deposition was apparent on surfaces in the home and the tenant was allowed to reoccupy the home shortly after the sealing was completed.

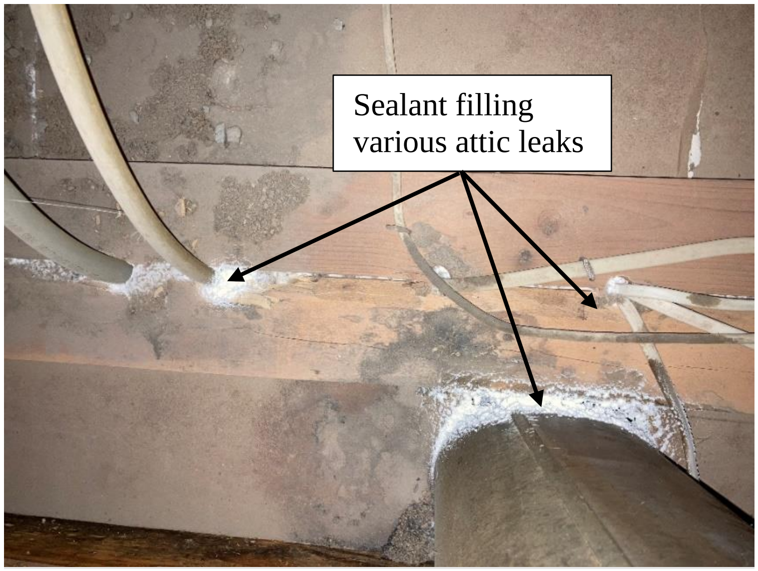

Figure 2. Photo of aerosol seals formed in the attic at Site 1

Manual sealing. Manual sealing with expanding foam in pressurized cans was applied to two apartments and considered the "business as usual" approach by the contractors. After vacuuming the insulation, a team of two entered each attic and sprayed foam on wall caps, electrical penetrations, and register boots. How and where foam was applied was entirely up to the experience of the technician. Each attic took approximately 90 minutes to seal using this method. The manually sealed attics achieved a leakage reduction in the homes by an average of 14% from an initial leakage of 7.2 ACH50 to a final leakage of 6.2 ACH50.

Figure 3. Photo of seals formed with can foam during manual sealing effort

Elastomeric paint. A low VOC elastomeric paint product specifically designed for air sealing attic floors and other building assemblies was applied to three apartments. The product is supplied in 5-gallon buckets and is applied using a 2.2 horsepower or larger airless sprayer. Similar to canned foam, the product is applied manually to areas where air leaks are expected. It differs from canned foam in that it does not expand when exposed to air, but it flows into gaps. The product is advertised as penetrating and sealing gaps as small as 1/8" when applied correctly.

Researchers were able to observe the application of the elastomeric paint and take measurements before and after. The application process was labor intensive and required a trained operator to properly apply on wall caps, mechanical and electrical penetrations, and other common leak sites. The product requires a powerful airless sprayer which one person operated while another fed hoses and replaced buckets as needed. Each attic took approximately 2.5 hours to seal with this product, including time to address issues with the nozzle clogging and sprayer motor overheating. The three apartments with this product applied had an average leakage reduction of 23% from 7.9 ACH50 to 6.1 ACH50.

Figure 4. Photo of elastomeric seal product in attic

Site 2

Site 2 was a 1,450 ft^2 one-story single-family home in Oakland, CA, that was over 100-years old but recently renovated. The renovation included significant attention to air sealing details resulting in a relatively tight baseline leakage of 3.0 ACH50. The attic was conditioned and sealed, so the aerosol process focused on sealing the remaining leakage in the floor of the home by applying the product from the crawlspace (Figure 5). There was an unconditioned basement under a portion of the floor of the house open to the crawlspace. This area had a small workshop and equipment including a home battery, which needed protection from the fogging process. The preparation was primarily handled by the homeowner and required about an hour of time to cover the contents.

Figure 5. Aerosol sprayer setup in crawlspace at Site 2. Water is used to check functionality before injecting sealant.

Because the basement had a full-size exterior door, it was possible to perform guarded testing of the floor leakage. With the basement depressurized to -50 Pa the house reached -10 Pa relative to outside, which provides a qualitative assessment of the extent to which the house and basement were connected through air leakage. A guarded test showed that there was a total of 283 cubic feet per minute at 50 Pa (CFM50) of envelope leakage through the floor between the house to the basement.

Four nozzles were installed with each set of nozzles placed in the center of the crawlspace and pointed in opposite directions along the length of the house. Fogging inside the house was noticeable, but very minor and no deposition on contents was observed. One window was opened a small amount to clear out some aerosol without affecting the sealing process (pressure was maintained), but the impact of this strategy on the indoor fogging was unclear. Particulate matter sensing inside the home was conducted in later tests at Sites 4 and 5. The process took about 1 hour and sealed 247 CFM50 or 35% of the overall house leakage, reducing the total leakage to 1.9 ACH50. This also amounted to 87% of the leakage through the floor, and later guarded testing showed no measurable pressurization of the main home when pressurizing the basement, demonstrating that very little leakage connection remained between the zones.

Site 3

Site 3 was a 1,614 ft^2 two-story single-family home that was over 100 years old with an unknown history of additions and renovations. The baseline leakage was 3,738 CFM50, or about 18.6 ACH50 and included an attic and crawlspace. The sealing preparations included temporary blocking of leaks including large door undercuts leading to the attic and wiring penetrations near the entertainment center. This prep resulted in a reduction of 665 CFM50, showing significant potential for further sealing with permanent sealing of those particular leakage sources. The sealing process took about 3.25 hours including setup and teardown. Partway through sealing, a large hole under a sink was identified and manually sealed, which represented 250 CFM50 of total leakage. There was also a decision to move two crawlspace nozzles to the attic during the sealing process to improve sealing of the top envelope. In the future, more injection units would be desired to avoid the additional time required to move equipment. Overall, the process was quite successful considering the initial state of the envelope. The leakage sealed, including the manual sealing under the sink, was 1,639 CFM50 (8.1 ACH50), or 44% of the total, for an end result of 10.4 ACH50.

Site 4

Site 4 site was a 1,191 ft^2 one-story single-family home with a vented attic and crawlspace. The owner was in the process of replacing the HVAC system and windows so there were some rough openings that had to be temporarily blocked for the sealing work. Prep work was minor with some holes in the wall from renovation work that needed to be taped over. In addition, the attic access hole was covered with a plywood board screwed into the ceiling and crawlspace access was taped at the seams to avoid sealing the door. The only manual sealing was a small amount of canned foam around a bath fan housing.

The crawlspace access was very tight with abandoned ductwork making it difficult to navigate, and some areas were not visible at all. Compressed air for the injectors was routed around the outside of the house through a crawlspace vent. Due to the limited access in the crawlspace, proper development of a high-humidity aerosol fog faced multiple challenges and resulted in humidity levels that were lower than optimal. Even with these challenges, the aerosol sealing process was very effective. The initial house leakage was 1,628 CFM50 or 10.2 ACH50, and sealing was able to reduce that by 596 CFM50 (3.7 ACH50) or 37%, for an end result of 5.7 ACH50. The lack of adequate fogging due to limitations with the prototype equipment caused sealing rates to be slow. Ultimately, the research team ran out of time before fully completing the sealing. This impacted the total amount of sealing accomplished, and it is expected that additional nozzles would have resulted in more leakage sealed and faster sealing rates. After sealing, some deposition was noted on the ball-joint in a ceiling fan (Figure 6). This deposition was easily cleaned but was noted as an area potentially requiring surface protection in future installations.

Figure 6. Photo of sealant buildup on ceiling fan (left), and foam applied around bath fan housing (middle and right)

Site 5

Site 5 was a 2,491 ft^2 two-story single-family home with denim insulation in the attic and an approximately 600 ft^2 crawlspace below part of the home. The attic insulation would have been very labor intensive to remove so the team elected to attempt crawlspace sealing only which limited the potential for leakage reduction. The initial house leakage was 4,190 CFM50, and running the fan at full speed was only able to depressurize the space to 70 Pa. It was later discovered that the chimney damper was open causing additional airflow during the leakage tests. The open damper was not an issue for measuring sealing performance but did reduce the application pressure the team was able to achieve.

Figure 7. Photo of crawlspace sealed at Site 4

The weather on the day of sealing was considered the worst-case scenario for aerosol sealing, with high levels of humidity and significant moisture on the ground. The aerosol sealing process is sensitive to humidity levels and relies on some evaporation of moisture around the particles to achieve the appropriate tackiness. It rained most of the day and local observations recorded 100% humidity with a high temperature of 60°F. To address the high humidity levels, the team used a 30 kBTU/hr propane space heater to raise the temperature of air entering the crawlspace. The heater was placed at the outdoor entrance of the crawlspace allowing preheating of the makeup air entering the cavity. Two sets of nozzles were used for the sealing, each with independent pump controls to manage humidity levels. The heater allowed stable operation of one set of nozzles while the other set was cycled off intermittently due to high humidity.

Sealing was conducted for 2.5 hours with very little impact on home leakage. The total leakage reduction was only 129 CFM50 or 3% of the total home leakage (with fireplace damper open). It was unclear the amount of leakage that was available to seal from the relatively small section of floor that was the target of the sealing (floor area above crawlspace), but particles were noticeable in the zone above the floor suggesting that leaks with the crawlspace were present. Researchers identified some leaks, including a large hole behind the washer, baseboard leaks, and around a chimney, but manual sealing efforts at those locations showed no measurable impact on total home leakage flow. It is possible that there were other holes too large for the aerosol to effectively seal, but this could not be verified.

For this test site the team placed two particulate matter (PM) sensors in the house (Sensirion SPS30). One near the blower door and the other upstairs. The purpose of the PM sensors was to give some indication of particle size and concentration in the living space, and potentially provide additional information to the installer about the status of the sealing. The PM sensor downstairs by the blower door initially read a low baseline concentration of only 10 particles/cm^3. After sealing started, PM counts increased significantly, as expected, to a maximum of 13,000 particles/cm^3.

One useful PM measurement was to determine the impact of opening windows during the sealing process. In this case, a sliding door was opened a small amount, and the PM was measured with the door closed and open. Particle concentrations near the blower door when the sliding door was open dropped to about 750–1,000 particles/cm^3 for PM2.5. These measurements confirmed high particle concentrations in the home during the sealing process, reinforcing the need to wear respirators when inside during the sealing. This result also shows the value of using operable windows and doors to increase the air change rate in a zone of the house to reduce particle levels.

Site 6

Site 6 was a 2,136 ft^2 one-story single-family home built in 1972 with slab-on-grade construction. A ventilated attic covered approximately 1,500 ft^2 of the building footprint, with the rest being vaulted ceilings. Blower door tests were conducted before and after manual sealing of large openings was performed showing a relatively high leakage of 12.7 ACH50. The leaks identified for manual sealing included a large gap around a light fixture and around an exhaust fan housing. The home was preparing for a full electrification upgrade including replacing a natural gas furnace and hot water heater. These systems were both located in the home, but the new systems were getting installed outside of the conditioned space. Large openings for combustion makeup air were present between the location of the gas appliances and the attic space. These openings were temporarily blocked for the aerosol sealing but scheduled to be permanently sealed as part of the retrofit work, so the results do not include the flow through those openings. Another blower door test was performed after the temporary seals were placed and considered the baseline condition for the aerosol sealing effort, which showed 8.6 ACH50.

Weather conditions were relatively cool and damp during this installation with intermittent rain showers, but attic conditions were much drier than experienced at Site 5. Two propane heaters were stationed in the attic during the sealing that provided adequate heating to avoid reaching humidity limits for the aerosol injection system. Even with these challenges, the air sealing was successful, sealing 1,250 CFM50 (4.3 ACH50) or 50% of the total home leakage.

Another advantage of the attic and crawlspace sealing approach is that any ductwork in those locations in the building could potentially be sealed in the process. Site 6 had metal ductwork present in the attic, and a duct leakage test before and after sealing was performed to determine the impact on duct leakage. The metal ducts were wrapped in fiberglass insulation which was not removed as part of the attic insulation removal process. The insulation on the ductwork impacted the duct sealing effectiveness, but the exposed parts near register boot connections were available to be sealed (Figure 8). Overall, the process sealed 133 CFM25 or 34% of the total duct leakage. There were signs of leakage beneath the insulation as evident by sealant buildup on the insulation and it is expected that removing the duct insulation prior to sealing would have resulted in better performance.

Figure 8. Sealant deposition on ductwork at register boot connection

Discussion

Aerosol sealing methods have proven to be very effective at sealing building envelope leaks (Bohac and Harrington 2020). The main benefit of the attic and crawlspace method is for existing homes where applying aerosols to the occupied space would be too intrusive. Field testing of the new method in eight residences has proven successful at avoiding sealant deposition on contents in the home leading to significant reductions in the time required to perform the aerosol sealing work. Figure 9 shows the results from each of the nine demonstrations, as well as the results from manual canned foam sealing, and an elastomeric product used for attic air sealing.

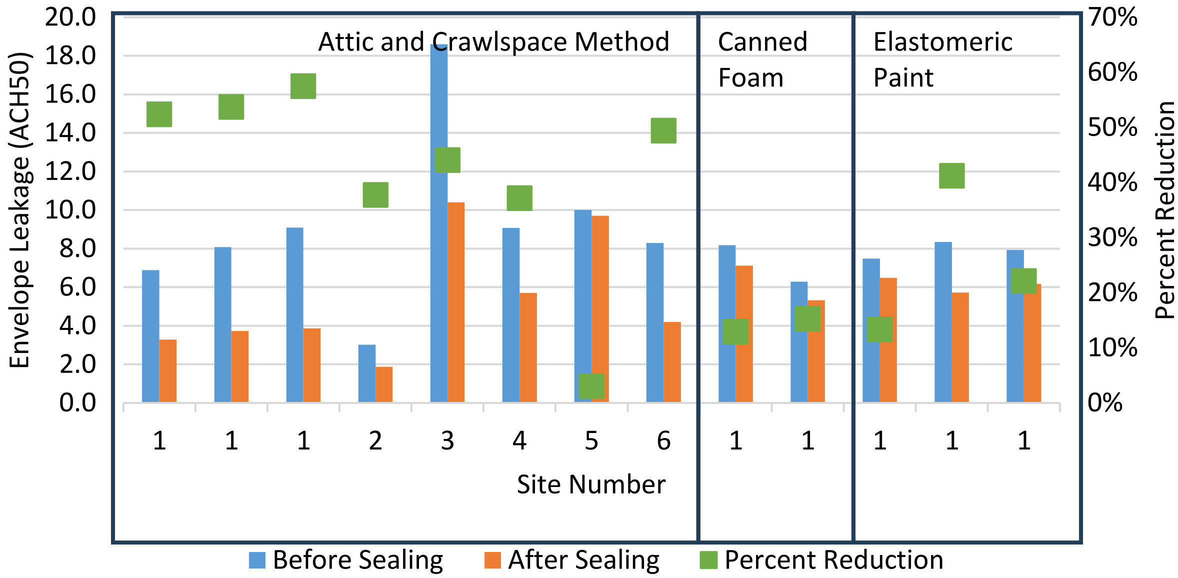

Figure 9. Summary of sealing results for the aerosol sealing method vs. other sealing approaches

The average leakage reduction for the aerosol method was 42% compared to 14% for manual foam sealing and 23% for the spray-applied elastomeric. Four of the eight aerosol sealing efforts resulted in a leakage reduction of more than 50%, which is impressive considering the application is limited to only one or two key surfaces in the home (i.e., ceiling-attic surface, or floor-crawlspace surface). The homes with the largest reductions were all in applications where the sealing was performed only from the attic. This could be due to the fact that gravity settling of particles works in favor of the attic application or elevated temperatures allows for higher particle concentrations, but more testing of the process in crawlspaces is needed to investigate this observation.

The attic sealing approach also showed the ability to seal duct leaks at the same time with 34% of the duct leakage sealed in Site 6. The duct sealing process would have been more successful if the insulation was removed from the duct prior to sealing. Significant sealant deposition was found on the insulation material suggesting leaks that exist below the insulation. Insulation acts as a filter preventing the aerosol from reaching and sealing leaks reducing sealing rates and effectiveness.

Although the attic aerosol sealing tools are not currently on the market, it is still feasible to compare material costs and labor hours between the methods. At site 1 researchers were able to compare canned foam, elastomeric paint, and aerosols directly. As summarized in Table 1, it was found that the aerosol method took about the same amount of time as the elastomeric paint, but longer than canned foam. The sealant material costs for the aerosol and canned foam methods were lowest, and the elastomeric product had the highest material costs at over five-times the cost of the other methods. Additionally, another study of the elastomeric paint found it was not cost effective (SBW 2016). The labor required for applying the canned foam was lower than the elastomeric paint and aerosol methods. It should be noted that the aerosol product is not yet commercially available so contractor pricing could not be gathered. The price for other commercial aerosol sealing products is typically determined by local dealers and includes a licensing fee that is not reflected in the costs below.

Table 1: Site 1 cost comparison for three types of sealing approaches. Costs and hours are per apartment.

	Aerosol method	Canned foam	Elastomeric paint
Person hours	5	3	5
Material cost	$75	$80	$400

One key consideration of this aerosol sealing approach is that the insulation must be removed from the attic floor or from below the floor in a crawlspace prior to sealing. This is the case for other manual sealing methods as well since getting access to some leaks require removal of the insulation; however, some weatherization efforts can be completed with insulation in place as they only require the insulation to be removed from small areas to gain access to leaks for sealing. The process of removing insulation would add cost to the application in situations where insulation already exists in the attic or crawlspace. Homes recruited for the demonstrations in this project either did not have any existing insulation or the insulation was removed as part of a larger weatherization effort. Often insulation upgrades in the attic involve adding insulation on top of old insulation. Pricing for the removal of insulation was roughly the same as the cost of adding new insulation, which would impact the cost effectiveness of the sealing strategy. Insulation may be removed for other reasons including for the removal and mitigation of pests so the aerosol sealing process would be more cost-effective in those situations.

Conclusions

Aerosol sealing of existing residences from attic and crawlspaces was performed on eight homes in California. The process was performed from unconditioned spaces of the home, which reduces the preparation time required to avoid unwanted deposition on building surfaces. The retrofit aerosol sealing achieved an average total envelope air leakage reduction of 42%. This is compared to 14% for manual sealing with canned foam, and 26% when using a spray-applied elastomeric sealant product. Slab-on grade homes sealed from only the attic achieved the highest leakage reductions with 50% or more of the leakage sealed. Applications from the crawlspace showed lower leakage reductions, with one home showing minimal sealing when installed in the crawlspace during cold and damp weather conditions. This project also showed the ability for the aerosol sealing approach to seal exposed ductwork in the attic, with one site achieving a 34% reduction in total duct leakage. The results suggest that the aerosol sealing approach could be used to achieve air leakage reduction goals for the existing building stock. Combining the aerosol attic and crawlspace sealing with other common sealing strategies such as installing weatherstripping or replacing windows would result in even further leakage reductions.

References

EIA (U.S. Energy Information Administration). 2022. *Monthly Energy Review.* Table 2.1a, and Table 2.1b. https://www.eia.gov/consumption/

Department of Energy (DOE), 2014. Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies.

Blasnik, M., G. Dalhoff, D. Carroll, F. Ucar, D. Bausch. 2015. *Evaluation of the National Weatherization Assistance Program During Program Years 2009-2011 (American Recovery and Reinvestment Act Period): Energy Impacts for Single Family Homes.* Oak Ridge National Laboratory. ORNL/TM-2014/582

Tonn, B., D. Carroll, E. Rose, B. Hawkins, S. Pigg, D. Bausch, G. Dalhoff, M. Blasnik, J. Eisenberg, C. Cowan, and B. Conlon. 2015. *Weatherization Works II – Summary of Findings From The ARRA Period Evaluation of the U.S. Department of Energy's Weatherization Assistance Program.* Oak Ridge National Laboratory. ORNL/TM-2015/139

Ye, Jia. 2014. *Effectiveness Of Air Sealing Measures and Other Energy Retrofit Measures in Lafayette Energy Improvement Program.* Open Access Theses. 286. https://docs.lib.purdue.edu/open_access_theses/286

Bohac, D., C. Harrington, and F. Meyers. 2024. "Aerosol Envelope Sealing of Existing Residences." Minneapolis, MN. DOE/GO102024-6121. www.nrel.gov/docs/fy24osti/85625.pdf.

Bohac, D., C. Harrington, and F. Meyers. 2024. *(In Review) Aerosol Envelope Sealing of Existing Residences*. Minneapolis, MN. DOE Building America Program Final Report

Harrington, C., F. Meyers, D. Bohac, M. Anders, and L. Genty. 2022. *Aerosol Sealing of Existing Residences*. ACEEE Summer Study Proceedings. Pacific Grove, CA.

Proctor, J., R. Chitwood, B. Wilcox. 2011. *Efficiency Characteristics and Opportunities for New California Homes*. California Energy Commission. Public Interest Energy Research Program Final Project Report.

LBL RBS (Lawrence Berkeley Labs Residential Building Systems), 2011. *Residential Diagnostics Database.* https://resdb.lbl.gov

Bohac, D., and C. Harrington. 2020. *Aerosol Envelope Sealing of New Residences*. Minneapolis, MN. DOE/GO-102020-5475. www.nrel.gov/docs/ fy21osti/78112

SBW Consulting. 2016. *Energy Trust of Oregon New Homes Air Sealing Pilot II Evaluation Report. https://www.energytrust.org/documents/new-homes-air-sealing-pilot-ii-evaluation-report/*