Initial House Assessments & Sealing Efforts:

California Builder #1

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Contents

Summary

The AeroBarrier demonstrations for Phase I of this project showed excellent results sealing 79% of the available leakage in the homes ultimately getting the homes to an average of 1.09 ACH50 at a rough stage of construction before drywall was installed. The aerosol process also sealed homes 56% tighter than the homes sealed with open-cell spray foam at the rim joist and roof deck allowing the builder the flexibility of choosing a more cost-effective insulation material. The sealing process required access to the home for about four hours with only 1-3 hours of actual sealing time. Considering the level of air tightness achieved with AeroBarrier and the amount of effort currently employed to reduce air leakage in the homes, it is likely that other manual sealing efforts could be eliminated saving on cost of construction while also achieving superior and most consistent air tightness.

Air Sealing Assessment

On-site visual inspections were used to qualitatively assess the envelope air barrier of recently constructed houses. A checklist of common leakage sites was used to guide the inspection process and provide structure to the results. The visual inspection checklist is based on the Air Leakage section of the EPA ENERGY STAR Rater Field Checklist. The 26 components are divided into seven categories. The inspections provide information about the quality of sealing work (excellent, acceptable, poor, no attempt), who performed the sealing, what material was used, and the potential for AeroBarrier sealing to replace current methods.

Ed VonThoma and Curtis Harrington conducted field inspections of several houses in subdivision in Lodi on April 26 and April 27. The houses were at the various stages of construction including rough-in stage, pre-drywall stage, and after drywall stage. The results from those inspections was used to generate Table 1 shown below and photos of a sample of the sealing details are shown in the photos in Figure 1. The inspections showed an overall high quality of air sealing. The level of quality for all except two components was either excellent (18) or not applicable (7). This qualitative assessment is consistent with the air leakage test results from five preliminary measurements conducted by UC Davis during the construction process.

Four air leakage tests were performed just after insulation was installed and another test was performed after drywall, and two insulation strategies with slight variations were tested. Two homes had spray foam applied below the roof deck, at the rim joist, and in the wall cavity while the other two homes had spray foam applied below the roof deck, at the rim joist, and installed fiberglass batts in the wall cavity. The average tightness of the homes that used only spray foam insulation was 2.95 ACH50 prior to drywall while the homes that used fiberglass batt in the walls had an average tightness of 3.72 ACH50. The one test performed after drywall was installed and taped showed one of the completely spray foamed houses going from 2.60 ACH50 to 1.86 ACH50. Based on this results as well as the incremental cost savings associated with using fiberglass, the builder decided to use fiberglass batt in the walls in the remaining homes of the subdivision. While none of the homes tested were completely finished, it appeared that the air tightness target of 2.0-2.5 ACH50 was achievable and would be well under the State of California code requirement of 5.0 ACH50.

The inspections were also used to identify house components that possibly could be sealed by the AeroBarrier process instead of current methods. Table 1 indicates that over half of the components could be sealed by the AeroBarrier method. In summary, the initial assessments indicate that the tightness of the houses is already consistently below code with some opportunity for leakage reduction. However, it appears that the greatest benefit for the AeroBarrier method would be a possible reduction in overall sealing costs by eliminating many of the current sealing practices. A later section of this report (*AeroBarrier Air Sealing Opportunities*) provides additional information on opportunities to eliminate current sealing practices.

Table 1. Assessment of air sealing details based on visual inspections of recent construction

Category	Component	Who does sealing?	Material used for sealing?	Can AeroBarrier Replace?	Quality of seal work
Ceiling/Attic	Attic access panels		Gasketed Door	No	Excellent
	Drop down stairs	N/A			N/A
	Whole-house fans	N/A			N/A
	Recessed lighting fixtures	N/A	Gasketed fixture	Yes	Excellent
	Drop ceiling/soffit	Insulation Contractor	Closed Cell Spray Foam	Yes	Excellent
Walls	Exterior Walls	Insulation Contractor	Gasket/OSB	N/A	Excellent
	Sill Plate	Carpentry Contractor	Gasket/OSB	Yes	Acceptable
	Top Plate	Insulation Contracor	Gasket	Yes	Acceptable
	Drywall to top plate	Insulation Contracor	Gasket	Yes	Excellent
	Interior partition wall to exterior wall	Carpentry Contractor/Insulation Contractor	Solid Blocking/Can Foam	Yes	Excellent
	Knee walls	Carpentry Contractor	OSB		Excellent
Windows, skylights and doors	Rough openings	Window Installation Contractor	Can Foam	Yes	Excellent
Rim joists		Insulation Contractor	Open Cell Spray Foam	Yes	Excellent
Shafts, penetrations to unconditioned spaces	Ducts	Insulation Contractor	Can Foam/Open Cell Spray Foam	No	Excellent
	Flues	Insulation Contractor	Can Foam/Open Cell Spray Foam	No	Excellent
	Shafts	Insulation Contractor	Can Foam/Open Cell Spray Foam	No	Excellent
	Plumbing	Insulation Contractor	Can Foam/Open Cell Spray Foam	Yes	Excellent
	Piping	Insulation Contractor	Can Foam/Open Cell Spray Foam	Yes	Excellent
	Wiring	Insulation Contractor	Can Foam/Open Cell Spray Foam	Yes	Excellent
	Exhaust fans	Insulation Contractor	Can Foam/Open Cell Spray Foam	Yes	Excellent
	Other				N/A
Garage separation walls	Floor cavities aligned with garage separation walls	Carpentry Contractor/Insulation Contractor	Blocking/Open Cell Spray Foam	No	Excellent
Other	Shower/tub on exterior wall	Carpentry Contractor/Insulation Contractor	OSB/Open Cell Spray Foam	Yes	Excellent
	Stair stringer on exterior wall		None	Yes	N/A
	Fireplace on exterior wall	N/A	N/A	N/A	N/A
	Electrial/low voltage boxes on exterior walls		None	Yes	N/A
	HVAC register boots that penetrate building thermal envelope	N/A		Yes	N/A

Can foam used between double studs

Foam gasket to seal drywall between house and attic

Spray foam used at plumbing penetrations

Figure 1. Air sealing details

Envelope Air Sealing Options

The goal of this project is to determine the best stage(s) of construction to apply AeroBarrier sealing and any current sealing methods that can be eliminated when AeroBarrier is used. The objective is to reduce construction costs, improve house tightness, and seamlessly integrate AeroBarrier sealing into the construction process. The research project tasks have been designed to provide a step-wise, iterative procedure so that experience from initial houses is used to improve the approach for later houses. Results from the initial house assessments were used to identify the first two sealing approaches for four houses.

As part of the house component leakage assessment, we evaluated which current sealing methods could likely be eliminated with the application of AeroBarrier sealing. This was based on an understanding of how each building component is currently sealed, whether the component air leaks would be accessible during the AeroBarrier process, and whether the leakage gaps would be small enough to be sealed by the AeroBarrier process. Table 2 below lists the 13 components that were judged to have current sealing methods that might be eliminated by AeroBarrier sealing. Other factors (e.g. likely cost savings, level of confidence in AeroBarrier sealing to achieve similar or improved tightness, impact on construction process) were also evaluated. A meeting with project staff and builder representatives discussed all these factors and an agreement was reached on the stage of construction. Due to concerns about communicating alternative sealing strategies to the various trades no sealing was eliminated for the first series of demonstrations.

Table 2. Current air sealing that could possibly be eliminated with AeroBarrier sealing

Component	Category	Material used for sealing?	Quality of Seal Work
Carpentry Contractor			
Shower/tub on exterior wall	Other	OSB/Polyethylene sheet	Excellent
Stair stringer on exterior wall	Other	Polyethylene sheet	Excellent

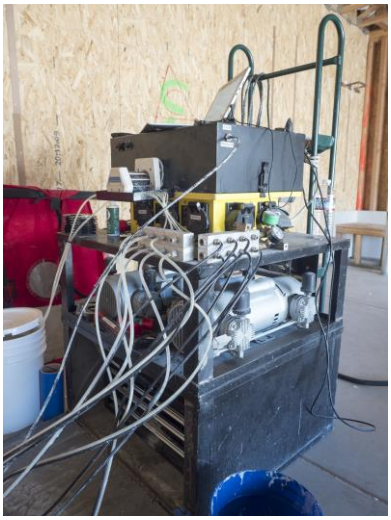
Interior partition wall to exterior wall	Walls	Polyethylene sheet/Caulk	Excellent
Sill Plate	Walls	Sill seal/Caulk	Acceptable
Drywall Contractor			
Attic access panels	Ceiling/Attic	Ceiling texture coat	Poor
Insulation Contractor			
Top Plate	Walls	Polyethylene sheet/Caulk	Acceptable
Rough openings	Windows, skylights and doors	Can Foam	Excellent
Plumbing penetrations	Shafts & penetrations to unconditioned spaces	Can Foam	Excellent
Piping penetrations	Shafts & penetrations to unconditioned spaces	Can Foam	Excellent
Wiring penetrations	Shafts & penetrations to unconditioned spaces	Can Foam	Excellent
HVAC register boots that penetrate building thermal envelope	Other	Can Foam	Excellent
Rim joists	Rim joists	Closed Cell Spray Foam	Excellent
Insulation Contractor/Electrician			
Electrial/low voltage boxes on exterior walls	Other	Polyethylene sheet/Caulk/Gasketed boxes	Excellent
Recessed lighting fixtures	Ceiling/Attic	Polyethylene sheet/Gasketed fixture	Excellent

Based on the initial assessment and conversations with the builder, two options were determined for the AeroBarrier demonstrations. Option 1 had the AeroBarrier installed just after open-cell spray foam at the rim joist and roof deck. Option 2 had the AeroBarrier installed prior to the installation of open-cell spray foam with supplemental can foam for large penetrations that would not be sealed by the aerosol. Both options allow the aerosol sealing to occur closer to the outside surface of the wall, and once drywall is installed the seals would be contained within the wall. The primary stage used in the previous installations of aerosol envelope sealing was after drywall was installed. Installing at an earlier stage was preferable since it prevents unconditioned outside air from entering the wall cavity, allows improved aerosol distribution during the installation process due to there not being any interior partitions, and reduces the likelihood that the seals would be damaged by future trades working on the building.

AeroBarrier Sealing Demonstrations

The AeroBarrier sealing demonstrations were completed by Aeroseal staff on August 29-30, 2017, for houses located at The Vine housing community in Lodi, CA. Building America project team members Curtis Harrington, and Daniel Reif were present and performed pre and post-AeroBarrier air leakage testing as well as building preparation activities for Option 2. The AeroBarrier equipment is shown in Figure 3 below. Four homes were sealed, two using Option 1 and two using Option 2 described above. The homes were all two stories with an attached garage and ranged in size from 2,030-2,570ft².

Pressurization fan installed in garage door



Injection system

Spray nozzle

Figure 2. AeroBarrier sealing equipment

OPTION 1

AeroBarrier sealing for Option 1 occurred after open-cell spray foam was installed at the rim joist and below the roof deck (Figure 3). No additional sealing was performed prior to the AeroBarrier installation. The pre-sealing results showed air leakage of 4.39 and 3.47 ACH50 for the two homes during this stage of construction.

Open-cell spray foam installed at rim joist

Open-cell spray foam installed below roof deck

Figure 3. Photos of homes sealed under Option 1

Aerosol Sealing Installations Phase I: California Builder #1

The AeroBarrier sealing was very successful. The sealing was conducted for 1-1.5 hours (see AeroBarrier sealing reports in the Appendix). The overall time to seal each home including prep and cleanup was about 3 hours. The leakage at the start of the sealing was between 1,200-1,500 cfm50. Figure 4 shows the sealing profile for both sealing demonstrations under Option 1. There were slight differences in the time required for sealing and the starting leakage rate which is likely due to differences in the floorplan for the homes. The AeroBarrier reduced the leakage in both cases by about 75% bringing them down to 1.11 and 0.95 ACH50 which is roughly 80% below the California requirement of 5 ACH50.

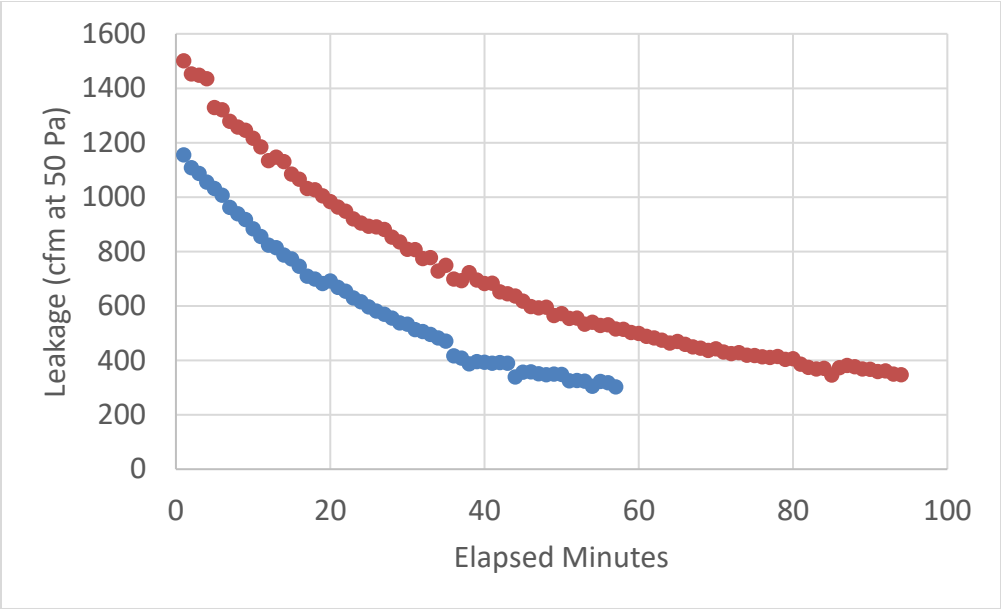


Figure 4. Sealing profile for both houses sealed under Option 1

While the open-cell spray foam sealed a significant amount of air leakage, the AeroBarrier still found locations that the foam did not seal. Figure 5 and 6 show photos of some of the locations that AeroBarrier seals were found. Many of these locations were between wood studs that were too small for the spray foam insulation. These were also not standard locations for installing can foam.

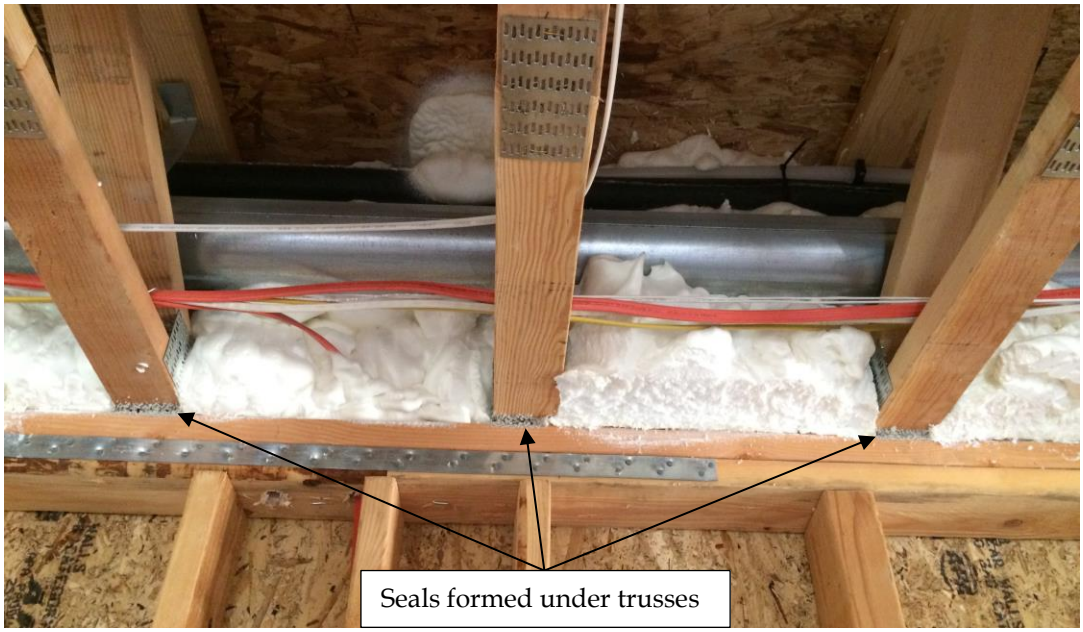


Figure 5. Photo of seals formed below each truss on first floor

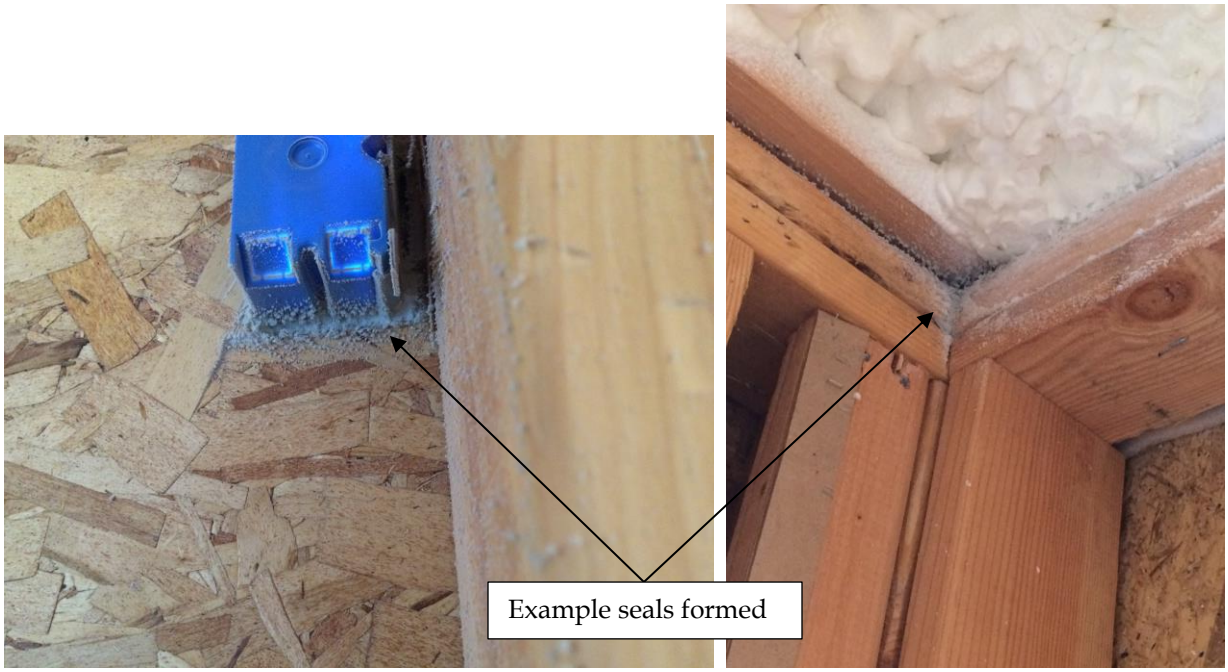


Figure 6. AeroBarrier seals formed at exterior electrical outlet and corner of wall assembly

OPTION 2

AeroBarrier sealing for Option 2 occurred before open-cell spray foam was installed and represents the first opportunity to seal the homes since the building shell is largely complete. Some manual sealing prior to installing AeroBarrier was required to block larger penetrations that would not be sealed efficiently with the aerosol. The time and materials required to perform that sealing were documented. There were also some issues coordinating the sealing demonstrations with the home builder which led to some additional gaps at the eaves of the home that would normally have been blocked prior to the AeroBarrier installation (Figure 7 and 8).

Figure 7. Gap at eaves requiring manual blocking prior to AeroBarrier (left), example of exterior ridged foam used to close the gap prior to open-cell spray foam installation (right)

Figure 8. Gap at eave prior to sealing (left) and after sealing with ridged foam and can foam (right)

Besides the additional sealing at the eaves which would typically not be necessary if the exterior foam were installed, there was also manual sealing of other large penetrations. In the first house the pre-sealing effort was focused on penetrations that would clearly not seal appropriately with the aerosol technology while in the second house more care was taken to seal gaps that were easily identifiable (could see daylight penetrating). The time required and materials used are outlined in Table 3.

Table 3. Time and materials used to manually seal homes prior to AeroBarrier installation

		Sealing Penetrations		Sealing Gap at Eaves	
Stage/Option	Lot	Time for Manual Sealing (person-hours)	Cans of Foam Used	Time for Manual Sealing (person-hours)	Cans of Foam Used
Before Foam	23	1.5	3	1.5	4
Before Foam	24	4.5	6	1	4

After the two pre-sealing efforts the leakage of the homes were 4.39 ACH50 and 3.47 ACH50 for lot 23 and 24 respectively. Clearly the additional manual sealing effort resulted in an improved initial air tightness with an increased cost. Ultimately, the additional cost of manual sealing will need to be compared to the AeroBarrier sealing performance differences and cost.

Open-cell spray foam installed at rim joist

Open-cell spray foam installed below roof deck

Figure 9. Photos of homes sealed under Option 1

The AeroBarrier sealing was also very successful at this stage of construction. The sealing injection time increased from the sealing under Option 1 requiring 2-3 hours to complete (see AeroBarrier sealing reports in the Appendix). The overall time to seal each home including prep and cleanup was about 4-5 hours. Due to slight changes in the manual pre-sealing efforts in each building the leakage at the start of the sealing was between around 5,800 CFM50 in one case and about 3,000 CFM50 in the other. Figure 10 shows the sealing profile for both sealing demonstrations under Option 2. The leakage measured with the AeroBarrier equipment did not produce the same result as the unencumbered blower door used in the pre and post measurements, but the general sealing trend holds showing faster sealing rates at the beginning of the installation which slows as the process goes on. The AeroBarrier reduced the leakage in both cases by about 85% bringing them down to 2.15 and 1.43 ACH50 before spray foam installation was installed which is roughly 60-70% below the California requirement of 5 ACH50.

Another leakage test on each home was performed after the spray foam installation to determine the additional sealing due to the insulation. After spray foam the measured air leakage of the homes were 1.25 and 1.06 ACH50 representing an additional leakage reduction of 42% and 26% respectively. This result is only slightly higher than the result for using AeroBarrier after the spray foam installation under Option 1.

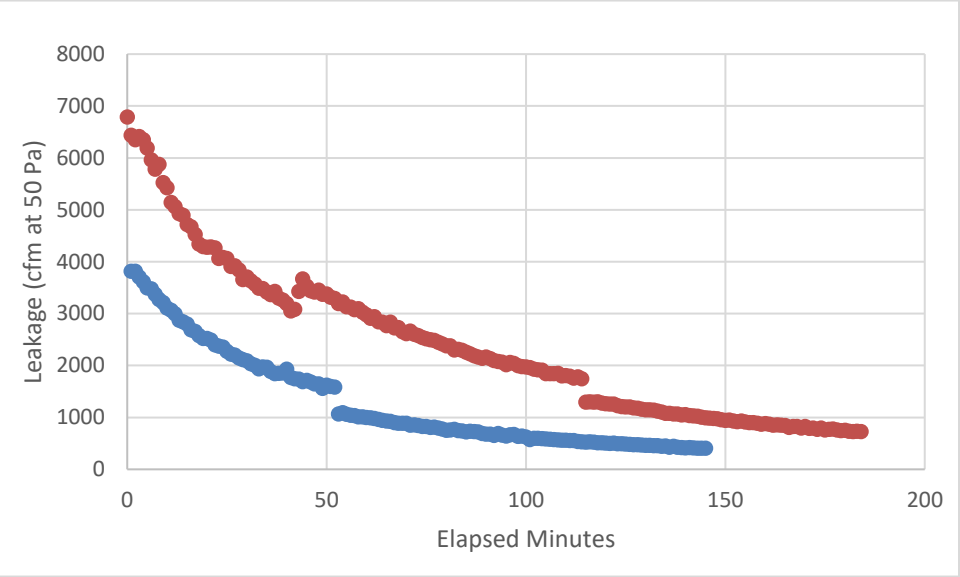


Figure 10. Sealing profile for both houses sealed under Option 2

Table 4 and Figure 11 provide a summary of all of the AeroBarrier sealing results for the first round of tests for the homes in Lodi, CA. Overall, nearly 10,000 CFM50 of air leakage was sealed in 8 hours of total injection time over two days. The average air tightness achieved was 1.09 ACH50 before drywall was installed in the homes. A final air leakage test will be performed once the houses are complete and compared to other homes that did not receive the AirBarrier treatment.

					Pre-Seal		Post-Seal			After Foam		
Stage/Option	Lot	Plan	Floor Area (ft2)	Volume (ft3)	CFM50	ACH50	CFM50	ACH50	% Reduction	CFM50	ACH50	% Reduction
After Foam /Option 1	7	3	2569	23121	1690	4.39	429	1.11	75%			
After Foam /Option 1	8	1	2032	22215	1286	3.47	351	0.95	73%			
Before Foam /Option 2	23	3	2569	23121	5836	15.14	828	2.15	86%	483	1.25	42%
Before Foam /Option 2	24	2	2223	20007	3005	9.01	477	1.43	84%	352	1.06	26%

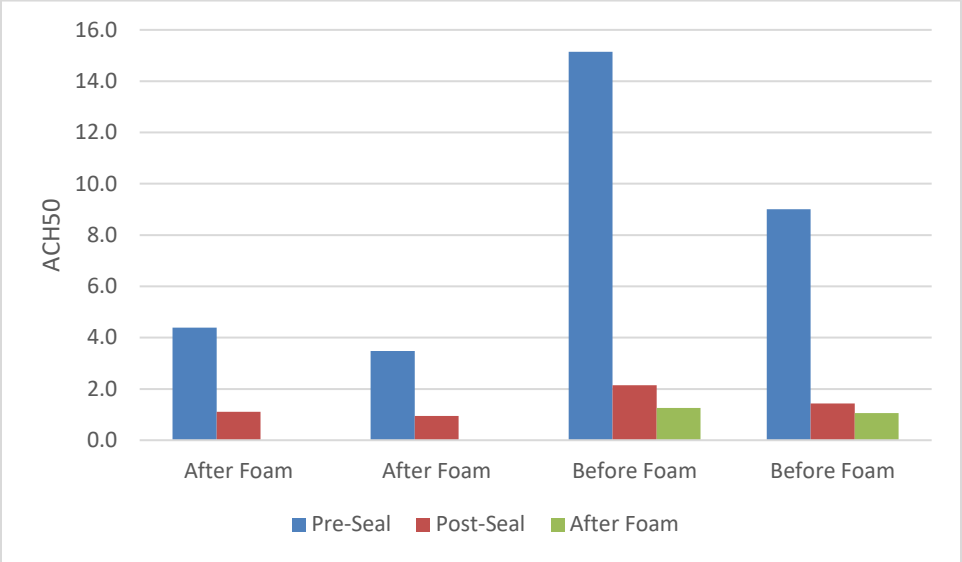


Figure 11. Air leakage results summary for all homes at each stage of process

Conclusion

The AeroBarrier installations were all very effective at sealing air leaks in the homes. The average tightness achieved was 1.09 ACH50 which is nearly 80% below the California requirement of 5 ACH50, and this is before drywall is installed in the homes. That is compared to an average tightness of 4.10 ACH50 for homes at the same stage of construction but not treated with AeroBarrier. Both Options seem like an appropriate time to perform the sealing in houses built with sealed attics. Houses sealed under Option 1 were quicker to seal and required less preparation than housed sealed under Option 2; however, it was demonstrated that Option 2 provided better air sealing results than open cell spray foam insulation allowing the builder to potentially use cheaper alternatives to insulate homes that are sealed with AeroBarrier. It will depend on the overall cost savings of alternative insulation methods to ultimately decide which option should be pursued in the future.

Appendix

AEROBARRIER™
Breakthrough Envelope Sealing Technology By Aeroseal

Certificate of Completion

Envelope Sealing Performed For:

Homes, Grube
Taylor Rd. Lot 7
Lodi, California 95242

Overall Sealing Results

When we arrived,

YOUR HOME HAD:

1512.4 CFM of Leakage, equivalent to a

188.5 Square Inch Hole or 4.4 Air Changes per Hour

*(for your **2569** square-foot structure enclosing an approximate volume of **20552** cubic feet).*

After we finished,

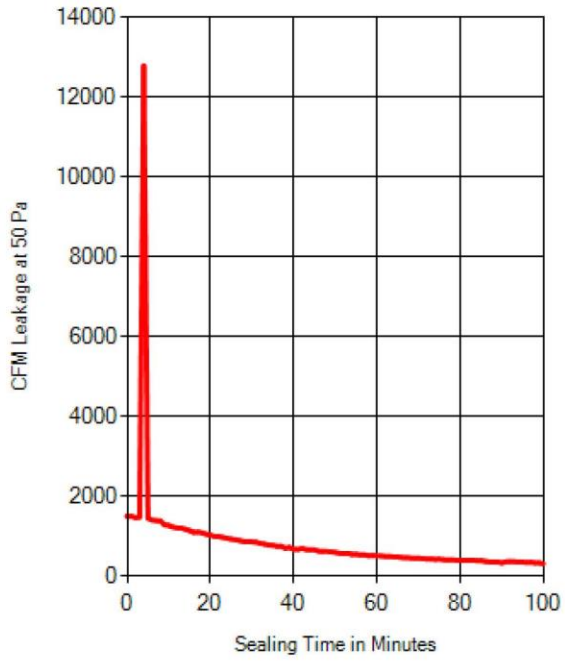
YOUR HOME HAS:

309.3 CFM of Leakage, equivalent to a

38.6 Square Inch Hole or 0.9 Air Changes per Hour

This corresponds to a 79.5% Reduction in Envelope Leakage.

Note: Envelope leakage and air-change results are calculated at a standard pressure of 50 Pa.



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Aeroseal Case ID	**9931**
Date of Seal	**8/30/2017**
System Description	**Home Envelope**
Seal Description	**Envelope Sealing**
Hardware	**EnvelopeSeal**

AEROSEAL®
Duct Sealing From The Inside

Envelope Sealing Performed By:

Aeroseal LLC
7989 S Suburban Rd
Centerville, OH 45458
Phone: 937.428.9300

AEROBARRIER™
Breakthrough Envelope Sealing Technology By Aeroseal

Certificate of Completion

Envelope Sealing Performed For:

Homes, Grube
Taylor Rd. Lot 8
Lodi, California 95242

Overall Sealing Results

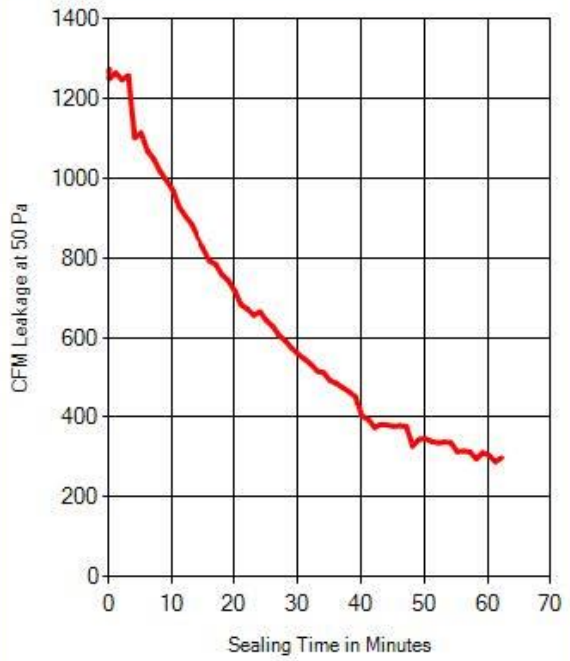
When we arrived,
YOUR HOME HAD:
1275.8 CFM of Leakage, equivalent to a
159.0 Square Inch Hole or **4.7 Air Changes per Hour**

(for your 2032 square-foot structure with 8-foot high ceilings, enclosing an approximate volume of 16256 cubic feet).

After we finished,
YOUR HOME HAS:
298 CFM of Leakage, equivalent to a
37.1 Square Inch Hole or **1.1 Air Changes per Hour**

This corresponds to a 76.6% Reduction in Envelope Leakage.

Note: Envelope leakage and air-change results are calculated at a standard pressure of 50 Pa.



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Envelope Sealing Performed For:

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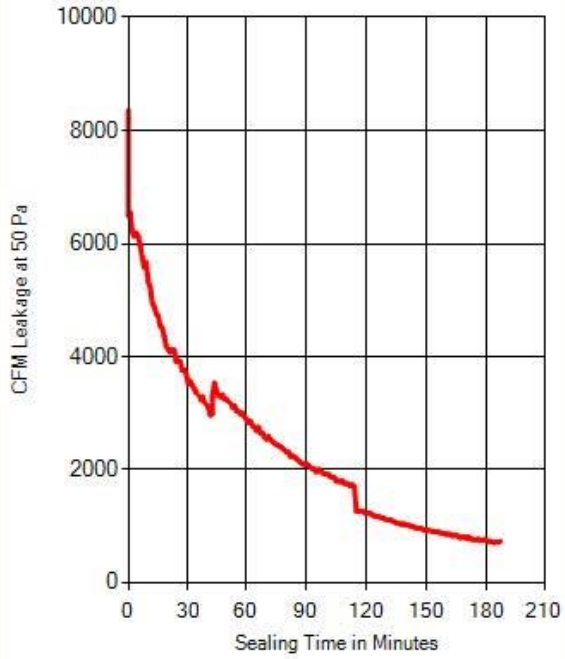
Lodi, California 95242



Overall Sealing Results

When we arrived,
YOUR HOME HAD:
8354.9 CFM of Leakage, equivalent to a
1041.4 Square Inch Hole or **24.4 Air Changes per Hour**

(for your 2569 square-foot structure with 8-foot high ceilings, enclosing an approximate volume of 20552 cubic feet).

After we finished,
YOUR HOME HAS:
721.7 CFM of Leakage, equivalent to a
90.0 Square Inch Hole or **2.1 Air Changes per Hour**

This corresponds to a **91.4% Reduction** in Envelope Leakage.

Note: Envelope leakage and air-change results are calculated at a standard pressure of 50 Pa.

Aeroseal Technician	
Aeroseal Case ID	**9931**
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System Description	**Home Envelope**
Seal Description	**Envelope Sealing**
Hardware	**AeroBarrier**

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Breakthrough Envelope Sealing Technology By Aeroseal

Certificate of Completion

Envelope Sealing Performed For:

Homes, Grube
Taylor Rd. Lot 24
Lodi, California 95242

Overall Sealing Results

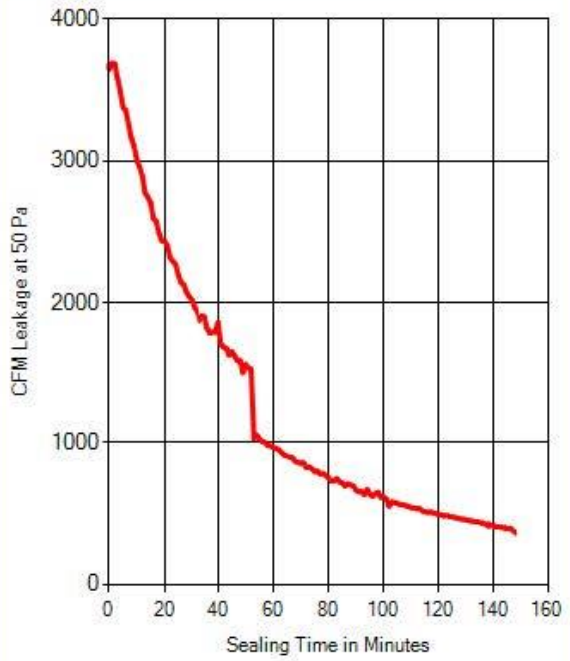
When we arrived,
YOUR HOME HAD:
3685.6 CFM of Leakage, equivalent to a
459.4 Square Inch Hole or **12.4 Air Changes per Hour**

(for your 2223 square-foot structure with 8-foot high ceilings, enclosing an approximate volume of 17784 cubic feet).

After we finished,
YOUR HOME HAS:
358 CFM of Leakage, equivalent to a
44.6 Square Inch Hole or **1.2 Air Changes per Hour**

This corresponds to a 90.3% Reduction in Envelope Leakage.

Note: Envelope leakage and air-change results are calculated at a standard pressure of 50 Pa.



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