

Air Distribution Retrofit Strategies for Affordable Housing

Jordan Dentz, The Levy Partnership, Inc.
Francis Conlin, High Performance Building Solutions

Overview

- Duct sealing can be difficult, costly and disruptive
- Two techniques were compared in 40 one and two story units
 - Manually-applied sealants
 - Injecting an aerosol sealant (Aeroseal®)



Research Questions

- What is the cost and effectiveness of the AeroSeal[®] system compared to manual duct sealing for this building type?
- What logistical and technical issues might affect community-scale duct sealing retrofit productivity and effectiveness?



OUTLINE

FIELD STUDY

RESULTS

MODELING

BILLING ANALYSIS

LESSONS

CONCLUSION

FIELD STUDY

RESULTS

MODELING

BILLING ANALYSIS

LESSONS

CONCLUSION

Building Characteristics

- 40 units in two North Carolina public housing complexes
 - 50 years old
 - ~1,000 ft²
 - Central air conditioning
 - Natural gas fired forced air heating



Unit Characteristics

Development	Unit type	Hand sealing	Aeroseal®
Terrace Park	1 story 2 bedroom	0	2
	1 story 3 bedroom	3	2
	2 story 3 bedroom	7	6
Berkshire Village	1 story 3 bedroom	7	7
	2 story 3 bedroom	3	3
Total		20	20

Variety of Duct Configurations

	Terrace Park		Berkshire Village	
Unit type	1-story	2-story	1-story	2-story
Supply duct	Flex	Unknown (inaccessible)	Metal trunk, flex branches	Floor 2: Metal trunk, flex branches; Floor 1: Unknown
Supply location	Attic	Floor	Attic	Floor and attic
Return duct	Metal			
Return, A/H location	Conditioned space			
Returns	1	2 (1/floor)	1	2 (1/floor)

Hand Sealing

- *Register boots* to the ceiling/floor with mastic or foil tape from below/above



Hand Sealing

- *Return plenums* from the inside with mastic



Hand Sealing

- *Air handler with mastic*



Hand Sealing

- *Rigid trunk duct and trunk to flex duct connections in the attic with mastic – where accessible*



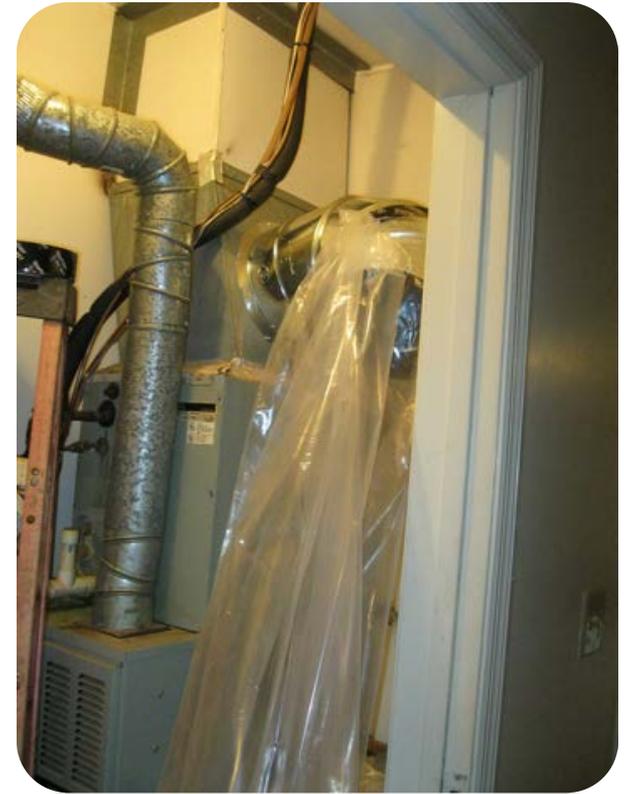
Aeroseal®

- Invented at Lawrence Berkeley National Laboratory in 1994
- Internally seals duct leaks by injecting aerosolized sealant particles into a pressurized duct system
- Polymer particles stick first to the edges of a leak, then to each other until the leak is closed



Aeroseal®

- Isolate registers and air handler from ducts
- Connect Aeroseal® system to supply duct



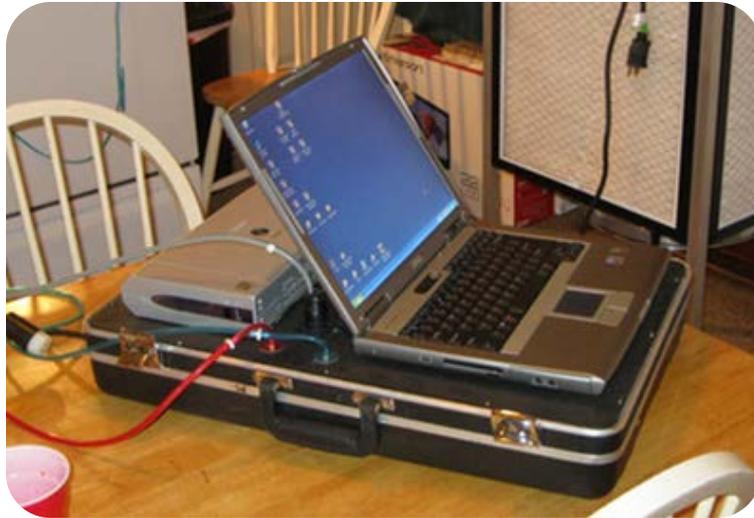
Aeroseal®

- Injector system connected to a heating element attached to a 8-10 foot plastic tunnel



Aeroseal®

- Airflow and leakage continuously monitored throughout sealing process



Aeroseal®

- Hand-seal return plenum, air handler, junction between registers and wall/ceiling/floor



FIELD STUDY

RESULTS

MODELING

BILLING ANALYSIS

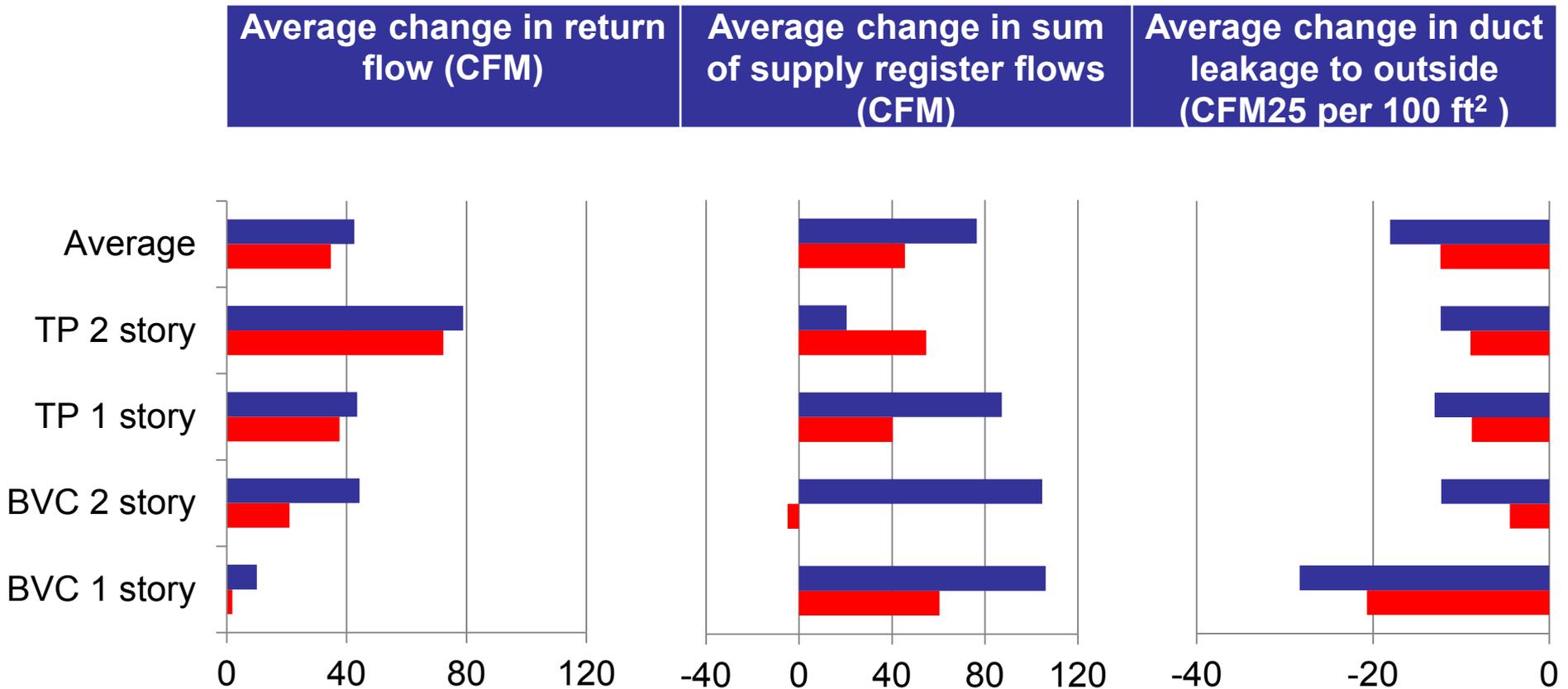
LESSONS

CONCLUSION

Results

- Aeroseal[®]-treated units improved more than in the units sealed solely by hand
- Return flow and supply register flows increased on average in most retrofit units

Test Results



Test Results

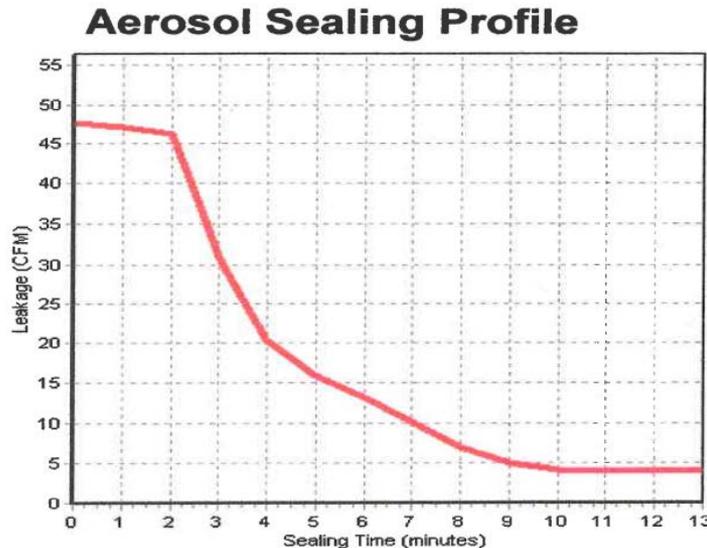
Method	Number floors	Average pre-retrofit leakage to outside (cfm/100 ft ²)	Average post-retrofit leakage to outside (cfm/100 ft ²)	Leakage to outside reduction (%)
Hand sealing	1 story	16.0	5.1	68%
	2 story	15.6	8.0	49%
Aeroseal®	1 story	17.5	1.6	91%
	2 story	13.6	1.3	91%

Air Flow

- Return flow increased by an average of 40 CFM, slightly over 7%
- Flow increased more for the AeroSeal[®] units than the hand sealed units
- Supply register flows increased in most homes

Aeroseal®

- The Aeroseal® system records total duct leakage during the sealing process.
- Approximately **70%** of the total leakage reduction was due to hand sealing at the air handler, return and registers.



When we arrived,
YOUR DUCTS HAD:

45 CFM of Leakage, equivalent to a
9 Square Inch Hole

After we finished,
YOUR DUCTS HAVE:

7 CFM of Leakage, equivalent to a
1 Square Inch Hole

This corresponds to a **85%**
Reduction in Duct Leakage

FIELD STUDY

RESULTS

MODELING

BILLING ANALYSIS

LESSONS

CONCLUSION

Annual whole house MBtu savings

- Four representative units modeled with Beopt to predict post-retrofit whole-house energy savings

Annual whole-house MBTU savings

Method	Number floors	Terrace Park	Berkshire
Hand sealing	1 story	3.9%	4.8%
	2 story	4.2%	3.2%
Aeroseal	1 story	4.8%	7.0%
	2 story	5.9%	6.9%

Costs

Method	Floors	Cost per unit
Hand sealing	1	\$511
	2	\$275
Aeroseal	1	\$700
	2	

Cost Effectiveness – Annualized Energy Expense

Method	Plan	Pre-retrofit annualized energy expense	Post-retrofit annualized energy expense	Annual savings	% Change
Hand sealing	TP1	\$1,550	\$1,514	\$36	2.3%
	TP2	\$1,667	\$1,615	\$52	3.1%
	BV1	\$1,567	\$1,517	\$50	3.2%
	BV2	\$1,673	\$1,594	\$79	4.7%
Aeroseal®	TP1	\$1,565	\$1,520	\$45	2.9%
	TP2	\$1,670	\$1,605	\$65	3.9%
	BV1	\$1,568	\$1,495	\$73	4.7%
	BV2	\$1,717	\$1,679	\$38	2.2%

FIELD STUDY

RESULTS

MODELING

BILLING ANALYSIS

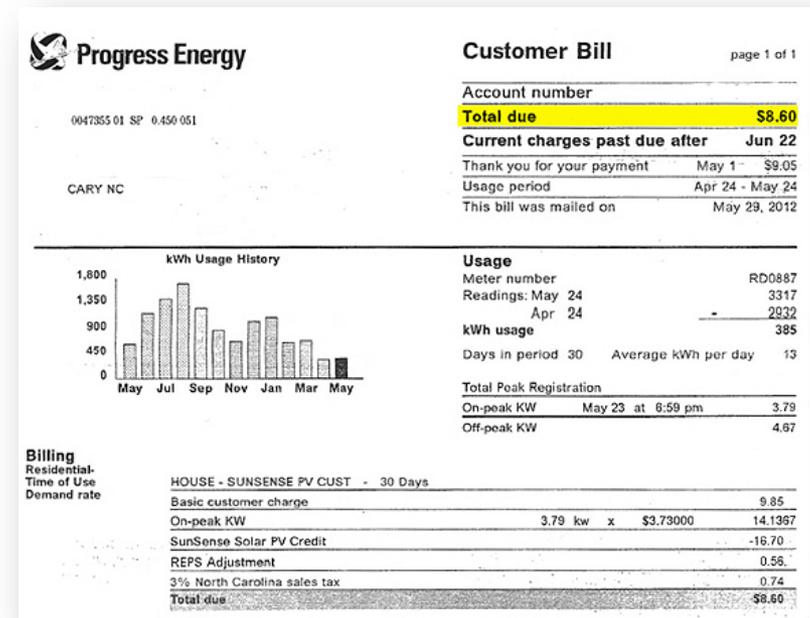
LESSONS

CONCLUSION

Utility Bill Analysis

- One year pre-post utility bills
- Average savings:

Method	Heating energy	Cooling energy
Hand	16.2%	16.3%
Aeroseal	13.7%	15.5%



Average Annual Utility Bill Savings

Method	Energy Savings (therms)	Energy Savings (kWh)	Utility Bill Savings/Unit	Simple Payback (years)	Sample Size
Hand sealing	30	809	\$179	2.2	7, 1-story 4, 2-story
Aeroseal®	19	731	\$150	4.7	5, 1-story 2, 2-story

FIELD STUDY

RESULTS

MODELING

BILLING ANALYSIS

LESSONS

CONCLUSION

Aeroseal® Benefits

- Allows sealing of inaccessible ducts
- Avoids some hassles of manual sealing:
 - Removing duct insulation, cleaning ducts, applying mastic, waiting for mastic to dry, and reapplying insulation
- Avoids some quality control issues of hand sealing

Aeroseal® Challenges

- Small units required slow air flow
- High ambient relative humidity required slower air flow
- Spray nozzle clogged due to low air flow and sequential jobs
- Arranging equipment challenging for small homes
- Connecting to the supply plenum challenging due to lack of clearance between air handler and ceiling

Production Scale Retrofits

- Most time spent on AeroSeal[®] is setup and cleanup
- Equipment was idle, being moved or set-up 70% of the time
- Connect two duct systems simultaneously using a “Y” connector
- Smaller system suitable for lower flow would have made work in these units simpler and quicker

FIELD STUDY

RESULTS

MODELING

BILLING ANALYSIS

LESSONS

CONCLUSION

Conclusion

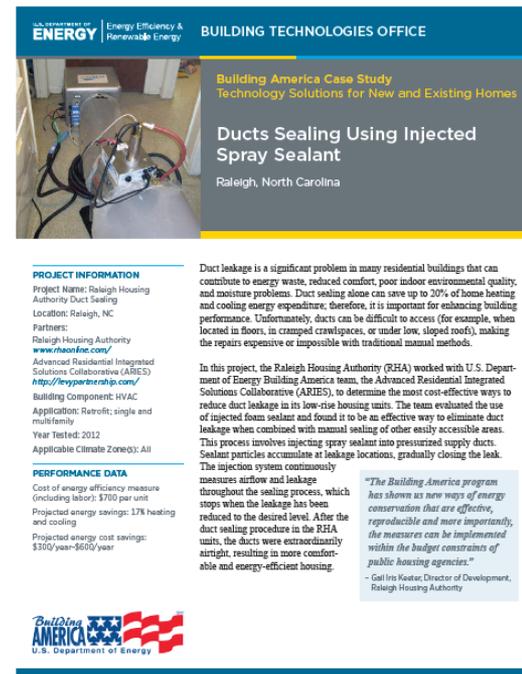
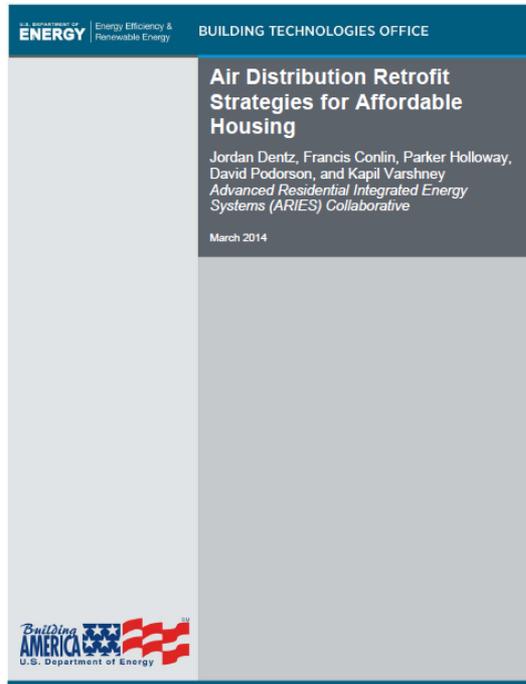
- Both methods reduced duct leakage
- Reduction greater for Aeroseal[®], especially for inaccessible ducts
- Manual sealing required for Aeroseal[®] units (70% of leakage reduction due to hand sealing)
- Annualized energy expenditure reduction same for both methods

Conclusions

- Simple payback 4.7 years for Aero seal and 2.2 years for hand sealing
- Utility bill analysis shows 15% space conditioning energy savings for both methods
- Opportunity exists to streamline Aero seal[®] technology for production scale work and smaller homes

Report

Report and case study on the Building America website



PROJECT INFORMATION

Project Name: Raleigh Housing Authority Duct Sealing
Location: Raleigh, NC
Partners:
Raleigh Housing Authority
www.raleighnc.com/
Advanced Residential Integrated Solutions Collaborative (ARIES)
<http://levypartnership.com/>
Building Component: HVAC
Application: Retrofit; single and multifamily
Year Tested: 2012
Applicable Climate Zone(s): All

PERFORMANCE DATA

Cost of energy efficiency measure (including labor): \$700 per unit
Projected energy savings: 17% heating and cooling
Projected energy cost savings: \$100/year-\$600/year

Duct leakage is a significant problem in many residential buildings that can contribute to energy waste, reduced comfort, poor indoor environmental quality, and moisture problems. Duct sealing alone can save up to 30% of home heating and cooling energy expenditure; therefore, it is important for enhancing building performance. Unfortunately, ducts can be difficult to access (for example, when located in floors, in cramped crawlspaces, or under low, sloped roofs), making the repairs expensive or impossible with traditional manual methods.

In this project, the Raleigh Housing Authority (RHA) worked with U.S. Department of Energy Building America team, the Advanced Residential Integrated Solutions Collaborative (ARIES), to determine the most cost-effective ways to reduce duct leakage in its low-rise housing units. The team evaluated the use of injected foam sealant and found it to be an effective way to eliminate duct leakage when combined with manual sealing of other easily accessible areas. This process involves injecting spray sealant into pressurized supply ducts. Sealant particles accumulate at leakage locations, gradually closing the leak. The injection system continuously

measures airflow and leakage throughout the sealing process, which stops when the leakage has been reduced to the desired level. After the duct sealing procedure in the RHA units, the ducts were extraordinarily airtight, resulting in more comfortable and energy-efficient housing.

"The Building America program has shown us new ways of energy conservation that are effective, reproducible and more importantly, the measures can be implemented within the budget constraints of public housing agencies."

- Gill Iris Keeter, Director of Development, Raleigh Housing Authority