96.113

Prepared by:
Proctor Engineering Group, Ltd.
San Rafael, CA 94901
(415) 451-2480

Assessment of the Lawrence Berkeley National Laboratory Aerosol-Based Duct Sealing Technology

Prepared for:
Conservation Services Group,
Pacific Gas and Electric Company
and
Wisconsin Public Service

Final Report
May 16, 1996

Contributors:
Tom Downey
John Proctor, P.E.

Creators of CheckMe!®

EXECUTIVE SUMMARY

Pacific Gas and Electric Company and Wisconsin Public Service Company, contracted with Proctor Engineering Group to demonstrate the Lawrence Berkeley National Laboratory aerosol-based duct sealing technology. This demonstration has involved field testing the aerosol duct sealing technology on a variety of duct systems and housing stock in three geographical locations; assessing achievable improvements to the duct systems; and assessing the labor and materials requirements of the new technology. The investigation found that the technology is capable of dramatically reducing the duct leakage of most existing duct systems. Fifteen to twenty percent of the systems examined could not be effectively sealed by the aerosol-based technology due to the size of the duct leaks encountered. Half of the tested systems were previously sealed using conventional techniques, or were also sealed using conventional techniques during this visit.

The key findings of this study include:

- Technology performs well in sealing most duct systems to levels unattainable in conventional duct sealing
- Technology performs well in sealing small leaks including large numbers of small leaks
- Materials costs are significantly reduced over conventional duct sealing
- Overall time requirements on-site are not significantly reduced over conventional duct sealing
- Technology does allow for personnel to perform other tasks while aerosol duct sealing takes place
- Technology is capable of sealing inaccessible duct leakage that conventional duct sealing doesn't address
- Houses must be screened for combustion safety and catastrophic leakage prior to aerosol-based sealing
- Suitable for use in new construction both prior to and after installation of finish materials
- Suitable for use in most retrofit applications (limited by amount and type of leakage)

1

INTRODUCTION

In December 1995, Proctor Engineering Group was invited by Lawrence Berkeley National Laboratory to beta-test an aerosol-based duct sealing technology. Proctor Engineering Group performed the tests reported here under the sponsorship of Conservation Services Group, Pacific Gas and Electric Company, and Wisconsin Public Service Company.

The technology was tested on homes on the west coast, on the east coast, and in the midwest. Personnel experienced with ducts and duct sealing were used to perform the tests and sealing work. Data was recorded for each home and is summarized in the Field Investigation section of this report. Detailed information on each house is contained in Appendix A.

In this study, the sealing potential and applicability of the aerosol-based technology was assessed along with the labor requirements of all aspects of job completion.

2

FIELD INVESTIGATION

Field testing of the beta-test aerosol duct sealing technology was completed the staff of Conservation Services Group in the Boston, MA area. Staff from Proctor Engineering Group completed the testing in the San Francisco Bay area and Green Bay WI.

Both CSG and PEG used highly trained and experienced field staff to perform the testing of the beta-test technology. It is believed that the personnel used in this beta-test are above average in their understanding of duct systems and their ability to understand complex testing procedure and computer data acquisition systems. Field personnel of less experience would be expected to take longer to fully understand the testing and data acquisition procedures.

FIELD DATA COLLECTION PROTOCOL

Several data acquisition forms were completed at each of the houses in the beta-test project. A summary of the testing and/or tracking completed at each house is contained in Table 2-1.

Table 2-1
Summary of Data Acquisition and Test Procedures

Parameter	Description / Use
Customer Interview	explain to the customer what tests and retrofits will take place in their house, explain materials used and obtain permission
Time Requirements	tracked time requirements for all tasks involved in beta test
House Information	documented house characteristics including location and square footage
Duct Information	documented distribution system characteristics including location, materials, previous sealing, R-value of insulation and normal plenum operating pressures
Duct Leakage Tests	measured duct leakage before and after the aerosol duct sealing process
Combustion Safety Test	tested safety of combustion appliances including tests for adequate draft in vent system, spillage of combustion products from draft hood, carbon monoxide and gas leaks before and after the aerosol duct sealing process

TIME REQUIREMENTS

The time required to perform the tasks in the pilot are summarized in Table 2-2. Different crews were used in the East Coast houses and the California houses. The same 2 person crew performed the work on all 8 East Coast houses. The 10 California houses were also completed by a 2 person crew.

Table 2-2
Summary of Time Requirements (in person minutes)

	California	East Coast
Customer Presentation	13	Not Reported
Unload Truck	12	Not Reported
Pre Comb Safety	24	All Electric Houses
Pre Leakage Test	29	25
Register Sealing	98	71
Heat Exchanger Sealing	49	38
Aerosol System Set-up	61	34
Aerosol Sealing Time	67	142
Manual Sealing Time	40	0
Post Leakage Test	14	Not Reported
Post Comb Safety	16	All Electric Houses
Clean up	106	83

The pre-leakage test time reported in Table 2-2 are believed to be higher than the actual required time. Both crews utilized a beta test version of the Energy Conservatory ADP logger (an automated pressure and analog channel data logger). The times reported were inflated by the time required by the crew to learn the computer program for the ADP. A real advantage of using the ADP was the ability to visually see the pressures and flows related to the aerosol sealing process in graphical format on the computer screen. Any problems that arose, such as a blockage at a register failing, was easily seen using the ADP computer program.

The register sealing done by the California crew took longer due to the fact that the majority of the blocking done at the registers was done by pulling the registers and cutting cardboard to fit inside the boot and using duct tape to temporarily seal it in place. The East Coast crew favored a method of slipping cardboard under the carpeting on floor registers and using weight or extending poles to hold it in place. While the technique used by the East Coast crew is quicker at sealing the registers, the time needed to run the aerosol injector to seal the gaps around the boots was much longer for the East Coast crew. The California crew saved time on the aerosol injection process by sealing the gaps around the boots manually while the aerosol injector was sealing the remainder of the duct system.

The difference in the East Coast and California housing stock accounts for the difference in time between crews in sealing the heat exchanger and setting up the aerosol injector. While the East Coast crew was able to cut a large diameter hole in the plenum on the upflow furnaces located in basements to use for both sealing off the heat exchanger and attaching the collar for the aerosol injector, the California crew almost always had to inject through a register (which requires more set up time) and the majority of furnaces in California were downflows with the supply plenum located in the crawl space so the heat exchanger blocking had to be done by removing the evaporator coil access panel and the blockage completed around the evaporator coil.

The sample of homes done by each crew was small and the time requirements listed should not be interpreted as the time that would be required by a crew once they had reached the top of the learning

curve (although it should be noted that the crew personnel used in this pilot were highly trained individuals who are believed to perform better than the average crew personnel). Additionally, with a two person crew many of the tasks listed above are done simultaneously (i.e. the customer presentation is done by one of the crew members while the other crew member unloads the truck).

While the times required of a crew that has had time to reach the top of the learning curve are believed to be less than those reported in Table 2-2, both the East Coast and California crews believed that unless some way is found to speed up the ; 1) heat exchanger separation process, 2) register sealing process, and 3) the aerosol injection system process, the true time requirements will never be such that a two person crew can do more than two houses a day. Both crews also believe that it is best to structure the work so that there are two crew members performing the duct sealing.

ACHIEVABLE IMPROVEMENTS

The sealing results using the aerosol injection system are impressive. While the time requirements did not show significant time savings over conventional sealing techniques, the percentage of reduction achievable is higher than normally seen in conventional sealing programs. Table 2-3 summarizes the results of the sealing reductions in the pilot.

Table 2-3
Summary of Achievable CFM25 Reductions

	California	East Coast	Wisconsin	Overall
Pre-Test CFM25	184	288	460	311
Post-Test CFM25	20	78	137	78
Reduction	163	210	323	232
% Reduction	89%	73%	70%	75%
Sealing Time (in Hours)	1.12	2.37	1.89	1.73
CFM25/Hour	146	89	171	135

Another benefit of the aerosol injection sealing technique is the cost reduction in materials used. While this project did not track the amount of materials used and the costs associated with the materials it is known that the average house in the project required less than $50 in materials (many houses were under $20).

While the technology is effective at sealing most duct systems it was found to be unable to seal duct systems with large slot widths or large diameter holes. If the number of these type of problems found in the duct system are few (e.g. a few disconnected ducts) then the duct system can still be sealed using the aerosol injection system after repairs have been made to the problem areas. In this pilot two houses were found that had numerous problems with large slot widths and/or disconnected ducts that could not be easily repaired which limited the possibility of sealing the system with the aerosol technology. Duct systems with multiple problems of this type will still require traditional mastic and fiber mesh sealing due to the mastic and mesh combination not being able to withstand the high pressures exerted in the duct system until the mastic has had time to cure.

An unmeasured benefit of the technology is the work environment. Current duct sealing programs require a special breed of worker, one that is willing to spend their entire work day in cramped and often hot and uncomfortable locations. This technology will allow the crew members to spend the majority of their day in a more comfortable environment and should lead to improved working conditions for the crew members.

COMBUSTION SAFETY

Combustion safety testing completed on the California and Wisconsin houses indicates the need for comprehensive combustion safety testing taking place on all houses that receive duct sealing. House pressure imbalance testing indicated no problems with combustion appliances safety on the 12 houses examined. Thorough combustion safety testing that tests the actual operation of the appliances found that 4 of the 12 houses had problems that needed to be fixed prior to any duct sealing taking place.

The main reason for the concern with combustion safety when sealing duct systems is that duct sealing reduces the air leakage rate of the house so that any combustion products or pollutants that might be introduced into the house are not diluted as quickly. Sealing the duct system can cause pressure imbalances that can back draft appliances that were venting properly before duct sealing. By testing the appliances combustion characteristics and venting ability directly, instead of inferring it through testing of the house pressure imbalance the safety of the appliances can be assured.

The combustion safety testing included checking for:

- Gas leaks
- Fireplace / wood stove zone depressurization
- Heat rise through the furnace
- Carbon monoxide level in the water heater and furnace flues
- Draft levels in the water heater and furnace venting systems
- Spillage of combustion products from the water heater and furnace draft hoods
- Shut off temperature of the furnace limit switch

The problems identified with the combustion safety testing were:

- Carbon monoxide levels in the flue above 100 Parts Per Million (PPM) on one water heater and above 2000 PPM on one furnace.
- Inadequate draft and spillage on the water heater in one house.
- Inadequate draft and spillage on a furnace and an unvented water heater.

In addition one of the houses in Wisconsin had a chimney clean out cap that was falling out and a return grille mounted on the return plenum. Both of these problems can cause inadequate draft and/or spillage. These problems were corrected before the tests were performed on the appliances.

3

CONCLUSIONS AND RECOMMENDATIONS

The aerosol injection process developed by Lawrence Berkeley National Laboratories has proven to be very capable of achieving significant duct leakage reductions at a cost savings when compared to conventional duct sealing programs.

CONCLUSIONS

- Technology performs well in sealing most duct systems to levels unattainable in conventional duct sealing
- Technology performs well in sealing small leaks including large numbers of small leaks
- Materials costs are significantly reduced over conventional duct sealing
- Overall time requirements on-site are not significantly reduced over conventional duct sealing
- Technology does allow for personnel to perform other tasks while aerosol duct sealing takes place
- Technology is capable of sealing inaccessible duct leakage that conventional duct sealing doesn't address

RECOMMENDATIONS FOR APPROPRIATE APPLICATIONS

- Houses must be screened for combustion safety and catastrophic leakage prior to aerosol-based sealing
- Suitable for use in new construction both prior to and after installation of finish materials
- Suitable for use in most retrofit applications (limited by amount and type of leakage)

RECOMMENDATIONS FOR FURTHER RESEARCH

- Develop a less labor intensive method of isolating the air handler from the duct system
- Develop a less labor intensive method of achieving seals at the individual registers
- Develop a more effective method of "scrubbing" excess sealant in houses with basement systems
- Perform testing to confirm durability of the aerosol sealant on residential systems

- Perform additional literature search/analysis of possible effects of inhalation of aerosol sealant

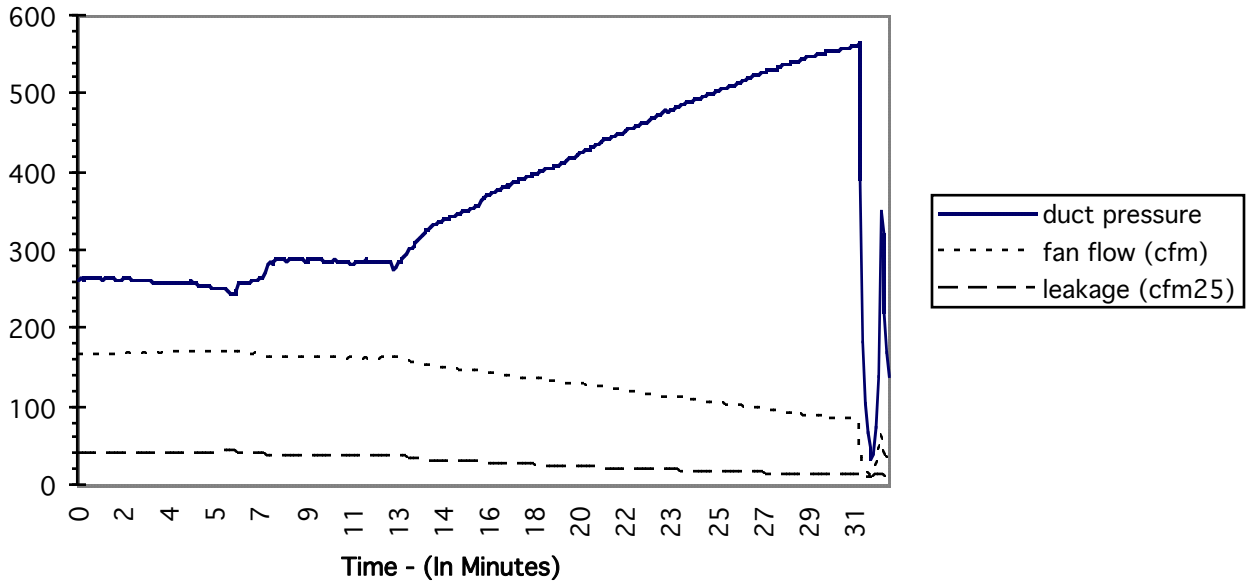
Appendix A

HOUSE CHARACTERISTICS AND SEALING EFFECTIVENESS

CALIFORNIA - HOUSE # 1

- Two story house with 1600 square foot of living space.
- The duct system had previously been sealed with mastic.
- A downflow furnace located in a first floor utility closet.
- Flexible aluminum supply duct system located in the crawl space.
- 4 supply registers located in the floor.
- Supply system chosen for sealing (all return system leakage had been sealed).
- Registers sealed with cardboard under carpeting and duct mask over tiled floor register.
- * Heat exchanger not blocked off but rather a blocking was placed at the opening for the blower on the opposite side of the air handler.
- Aerosol injection point at supply register (no access to supply plenum).
- All register seals held tight, no odor of aerosol in living space.
- Furnace failed to pass the initial combustion safety check on the house. The furnace was creating 2000+ ppm CO.
- Supply system operating pressure found to be 190 pascals. The reason for the high operating supply system pressure is believed to be because the house only had 4 supply runs for a 100,000 btu/hr furnace.

* This blocking is easier to install but is not suggested due to the fact that the heat exchanger was exposed to the sealant and the occupants could smell the sealant burning off every time the furnace was turned on over the next three to four days.



CALIFORNIA - HOUSE # 2

- Single story house with 2200 square foot of living space (at least two additions).
- The duct system had not previously been sealed.
- A downflow furnace located in a hallway utility closet.
- Mixture of rigid sheet metal (80%) and flex duct (newest addition) supply system located in the crawl space.
- 13 supply registers located in the floor and in walls.
- Supply system chosen for sealing (only two return system seams that could leak).
- Registers sealed with cardboard under carpeting and pans with poles for support or the LBNL tensioning device on the wall registers.
- Furnace blockage completed by removing the evaporator coil cabinet access panel and blocking between the evaporator coil and the supply plenum with cardboard and tape.
- Aerosol injection point at supply register (no access to supply plenum).
- All register seals held tight.
- * Odor of aerosol in living space.
- Duct system not effectively sealed due to large leakage areas in a portion of the crawl space that was not accessible.

* The aerosol particles were obviously present in this house during the sealing process due to several mistakes made by the crew. First the combustion air vents and the gap in the flooring around the supply plenum allowed sealant from the crawl space to come into the house. The second mistake was leaving the crawl space access hatch open while the crew was in the crawl space looking for large leaks to seal. This resulted in an aerosol fog coming into the house.

The aerosol sealing process was abandoned after it was apparent that no CFM drop or duct pressure increase was occurring. Also the customer requested that the process be stopped because he said he felt a tightness in his chest that he associated with the aerosol. The customer later reported that his wife had experienced an allergic reaction to something in the house after the aerosol sealing process that he attributed to the sealant being allowed into the living space. He reported that after the house was given a thorough cleaning his wife's allergic reaction went away.

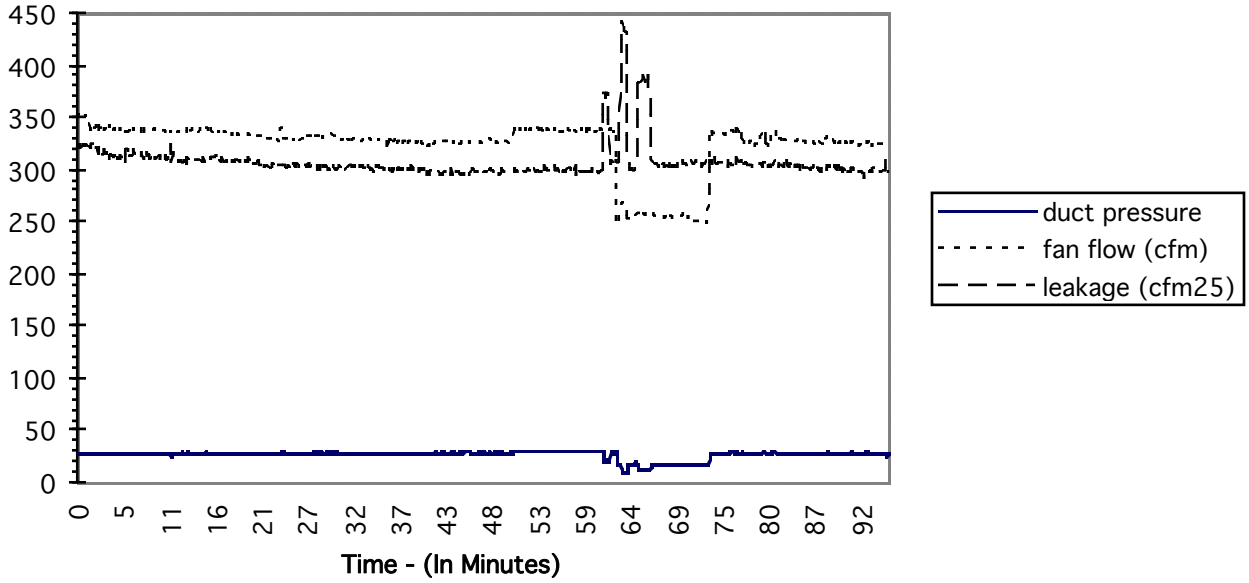


Figure A-2
California House # 2

CALIFORNIA - HOUSE # 3

- Single story house with 2250 square foot of living space.
- The duct system had not previously been sealed.
- A downflow furnace located in a hallway utility closet.
- Rigid sheet metal duct supply system located in the crawl space.
- 11 supply registers located in the floor (two kick-space registers).
- Supply system chosen for sealing (only two return system seams that could leak).
- Registers sealed with cardboard under carpeting and the LBNL tensioning device on the wall registers.
- Furnace blockage completed by removing the evaporator coil cabinet access panel and blocking between the evaporator coil and the supply plenum with cardboard and tape.
- Aerosol injection point at supply register (no access to supply plenum).
- All register seals held tight.
- * Odor of aerosol in living space.
- ** Duct system not effectively sealed due to large leakage areas in duct system.

* A scrubber fan was used to reduce the smell and potential for fogging but sealing process was abandoned after just a few minutes due to strong smell coming from master bathroom lavatory cabinet and lack of CFM reduction. The master bathroom lavatory had a kick space register that could not be removed due to tile being in the way so the aerosol was being blown into the space under the cabinet.

** An examination of the supply duct system under the house found three disconnected ducts that were reconnected and sealed (not all ducts got checked so there may have been more). Large leaks at the supply plenum that were also found and manually sealed with mastic and two of the three disconnects were corrected. The third disconnect was at the master bedroom bath and the disconnect was in the kickspace area and was not reachable without cutting out the bottom of the cabinet (the register had been tiled in place). The original installation had been completed by making wyes for the branch ducts by cutting holes in the rigid sheet metal ducts and inserting the branched duct run instead of using a manufactured wye. The manual sealing process was abandoned after the large gaps were discovered at the wyes where the duct runs branched off.

CALIFORNIA - HOUSE # 4

- Single story house with 1850 square foot of living space.
- The supply duct system had not previously been sealed but had been checked for disconnects by the occupant.
- An upflow furnace located in the garage.
- Rigid sheet metal duct supply system located in the attic.
- Supply duct system has been insulated over with approximately 16″ of cellulose.
- 8 supply registers located high on interior walls.
- Supply system chosen for sealing (garage platform return had been sealed with drywall, mastic and caulk by the occupants son).
- Registers sealed with a combination of inserting cardboard and duct tape around the perimeter on some wall registers and the LBNL tensioning device on the other wall registers.
- Furnace blockage completed by removing the evaporator coil cabinet access panel and blocking between the evaporator coil and the supply plenum with cardboard, screws and tape.
- Aerosol injection point at supply register (no access to supply plenum).
- All register seals held tight.
- No odor of aerosol in living space.

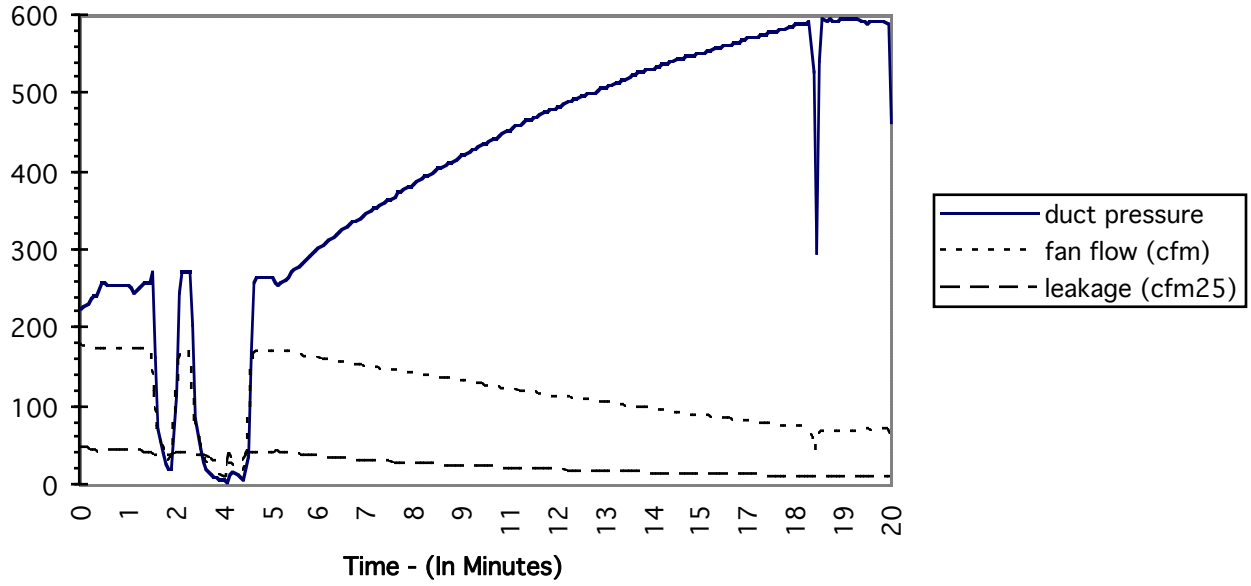


Figure A-3
California House # 4

CALIFORNIA - HOUSE # 5

- Single story house with 1700 square foot of living space.
- The supply duct system had been installed 5 years ago and was sealed with an epoxy type of tape (not butyl backed metal tape).
- A horizontal furnace located in the attic.
- Flexible duct supply system located in the attic.
- 9 supply registers located in the ceiling.
- Supply system chosen for sealing (single return system with short return run).
- * Registers sealed duct mask, pans and extending poles.
- ** Furnace blockage completed by removing the end cap on the supply plenum and blocking the junction of the supply plenum to evaporator coil cabinet with cardboard, screws and duct tape.
- Aerosol injection point at supply register (no access to supply plenum).
- Slight odor of aerosol in living space due to leakage at pans.

* All registers were all blocked using the duct mask, pans and poles. This system worked okay but it was very hard to get a good seal if there was something directly below the register that caused the pole to have to be installed at an angle (e.g. bath vanity). The other problem encountered was the slits created in the duct mask sealed themselves and the pressure started coming out behind the duct mask (between the duct mask and the ceiling surface). Learned that there must be holes created in the duct mask not just slits. Also have some concerns about using duct mask on sprayed acoustical ceilings. It tends to pulls a lot of the material off and if there was any weakness at that area the entire duct mask area may pull off. Also had problem getting good pan seals on sprayed ceiling.

** The end cap then had to be reinstalled for the sealing process. This was very time consuming due to difficulty in replacing the end cap and the difficult access to the supply plenum in the small attic space.

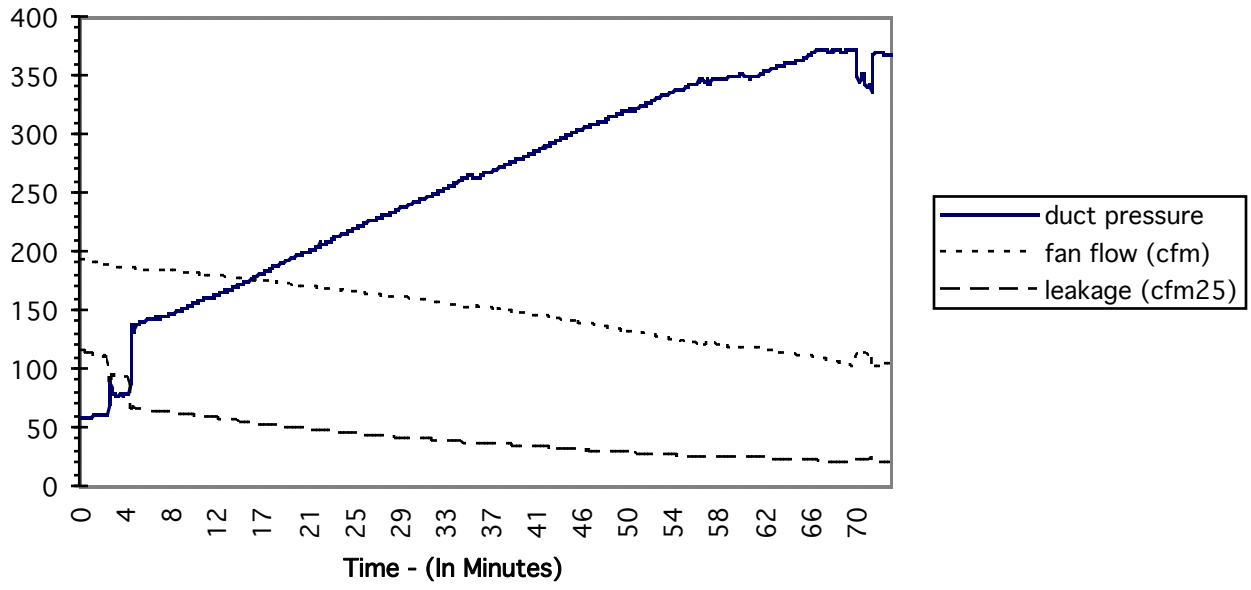


Figure A-4
California House # 5

CALIFORNIA - HOUSE # 6

- Two story house with 3120 square foot of living space.
- The duct system had not previously been sealed.
- A downflow furnace located in the garage.
- Flexible metal duct supply system located in the crawl space and the attic.
- 13 supply registers located in the floor and the ceiling.
- Supply duct system used a 14" rigid sheet metal duct rising vertically off of the plenum to direct conditioned air to the attic distribution system.
- Supply system chosen for sealing (return system used the entire floor cavity between the first and second floors as a plenum).
- Downstairs supply registers in floor sealed with card board inside and duct tape, upstairs ceiling registers sealed with duct mask, pans and extending poles.
- Furnace blockage completed by removing the evaporator coil cabinet access panel and blocking between the evaporator coil and the supply plenum with cardboard (no tape around perimeter - the weight of the evaporator coil held the cardboard in place).
- Aerosol injection point at supply register (no access to supply plenum).
- All register seals held tight.
- No odor of aerosol in living space.

The crew had trouble with the liquid injection on this house. There was a substantial puddle of liquid in the lay flat tubing and the nozzle was almost completely clogged after one hour of operation.

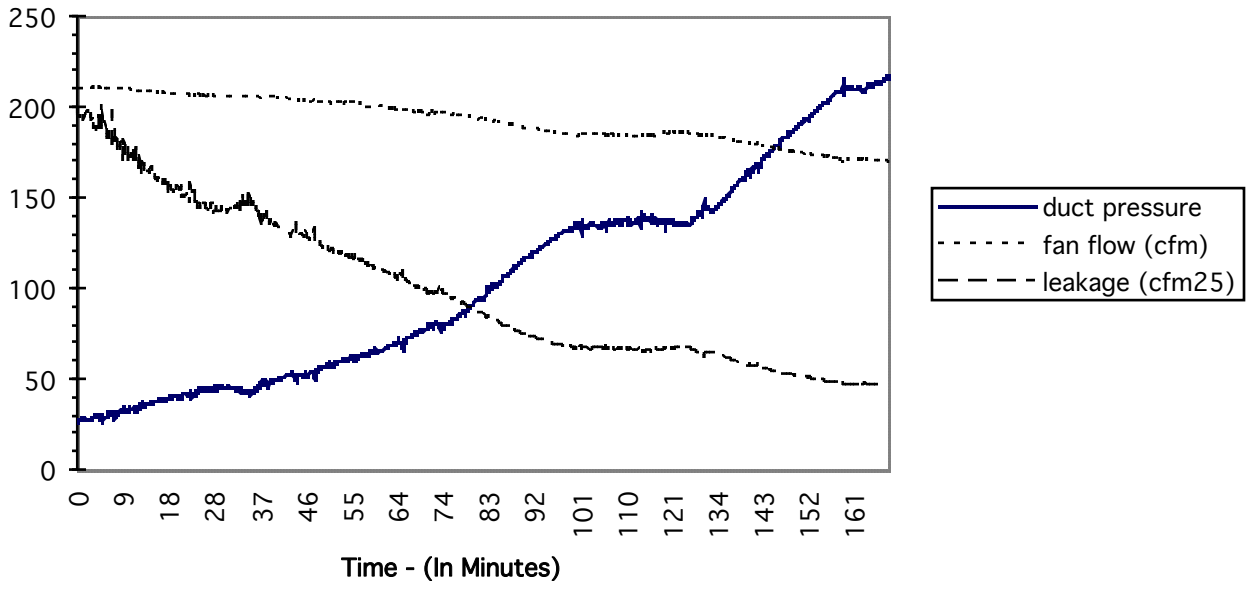


Figure A-5
California House # 6

CALIFORNIA - HOUSE # 7

Duct testing or sealing not completed on the house because the water heater did not pass the safety test (inadequate draft and slight spillage). The water heater is located in a closet in the downstairs bathroom (split level house - has 3 levels). The water heater closet has both high and low openings in the door to the bathroom and a low opening to outside through an exterior wall. The water heater vent is 3″ single wall for 2 foot then connects to a 4″ ceramic tile type vent system (there is a big gap where the 3″ pipe enters the 4″ pipe). The ceramic tile vent starts with a 90° turn to a horizontal run for 6′ to 8′ to another 90° turn upwards to roof.

There was also a problem with the furnace having an opening of approximately 10″ X 8″ on the return plenum in the crawl space. This opening had a filter slot so that the crawl space air would be filtered.

CALIFORNIA - HOUSE # 8

- Two story house with 2350 square foot of living space.
- The duct system had previously been sealed with mastic by both a contractor and the occupant. .
- A downflow furnace located in a first floor utility closet.
- Flexible metal duct supply system located in the crawl space and the attic.
- 12 supply registers located in the floor and the walls.
- Supply duct system used a rigid sheet metal duct rising vertically off of the plenum to direct conditioned air to the kneewall attic distribution system.
- Supply system chosen for sealing (return system had been adequately sealed).
- * Downstairs supply registers in floor sealed with card board inside and duct tape, wall registers sealed with duct mask, pans and LBNL tensioning tool.
- ** Furnace blockage completed by removing the evaporator coil cabinet access panel and blocking between the evaporator coil and the supply plenum with cardboard.
- Aerosol injection point at supply register (no access to supply plenum).
- All register seals held tight.
- *** Slight odor of aerosol in living space.

* A wall register seal failed at higher pressures, so the system was not sealed as tight as some of the other systems. The duct mask, pan and LBNL tensioner didn't work that well. The tensioner couldn't be pulled tight enough seal to stop the leakage between the duct mask and foam strip on pan.

** This was the hardest system encountered for blocking between the evaporator coil and supply plenum. Coil sits under furnace and the only way to block it was to cut out the sheet metal front on the coil (could not be removed whole because of refrigerant distribution tubing) and seal it by slipping card board under the coil and taping from inside of coil. Very time consuming and not a method that is suggested unless the person knows how to work around refrigerant coils.

*** No fogging of house but you could smell sealant in the kitchen where there was a kick space register that had to be sealed at the register because the register couldn't be pulled.

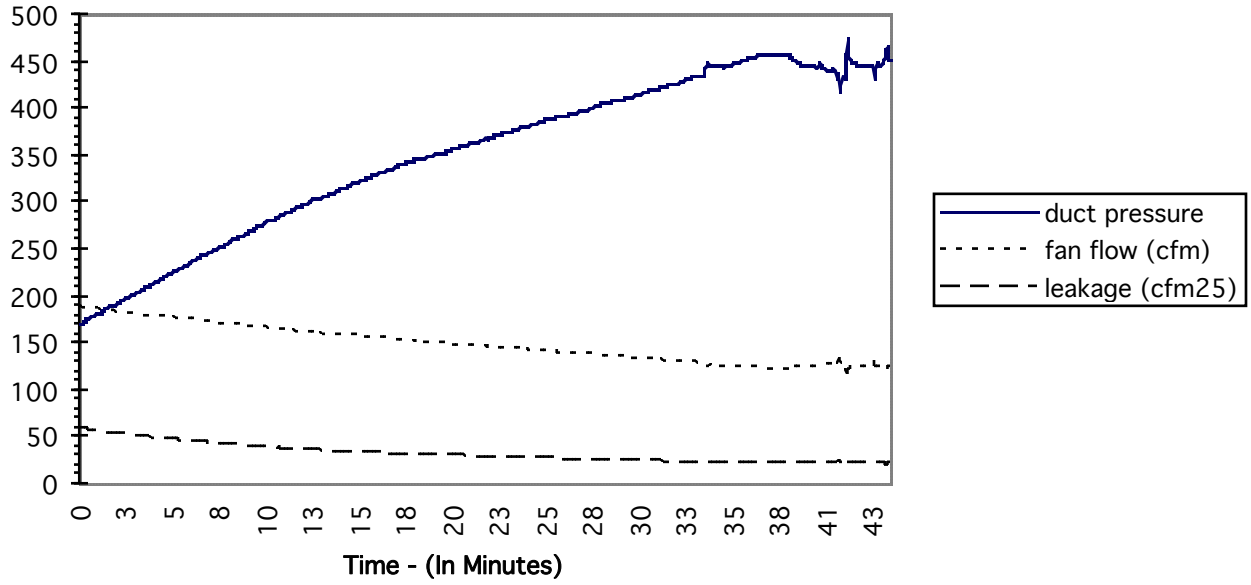


Figure A-6
California House # 8

CALIFORNIA - HOUSE # 9

Duct testing or sealing not completed on the house because neither the water heater or furnace passed the combustion safety tests.

The water heater had been recently moved to the garage by the occupant and was not vented to outside. The water heater vent pipe was terminated in the garage approximately 3′ above the draft hood. There was no carbon monoxide being generated by the water heater.

It is interesting to note that the reason the water heater was moved to the garage was that the downstairs bath room where the water heater used to be located (in a closet) was recently remodeled. The upstairs bath room located directly above the downstairs bathroom was also remodeled at the same time. The reason for the remodeling was that the drywall had become saturated with water and had fallen off the ceiling and walls in both bathrooms. When the water heater was removed, the occupant found that the vent for the water heater terminated between floors instead of being vented outside.

CALIFORNIA - HOUSE # 10

- Two story house with 2190 square foot of living space.
- Two furnace/air conditioners, one serving the upstairs and one serving the downstairs. Remaining comments apply to the downstairs unit only.
- The supply duct system had previously been sealed with mastic during a training.
- The unit was a downflow located in the garage.
- Flexible metal duct supply system located in the crawl space.
- 6 supply registers located in the floor on a trunk and branch system.
- Return system used two grilles that fed into the space between the first and second floor. This return system needed replacement with a ducted system.
- Supply system chosen for sealing (return system needed replacement).
- Downstairs supply registers in floor sealed with card board inside and duct tape.
- ** Furnace blockage completed by removing the evaporator coil cabinet access panel (there was no coil) and blocking the heat exchanger with cardboard.
- Aerosol injection point at coil cabinet access.
- All register seals held tight.
- No fogging or smell observed.

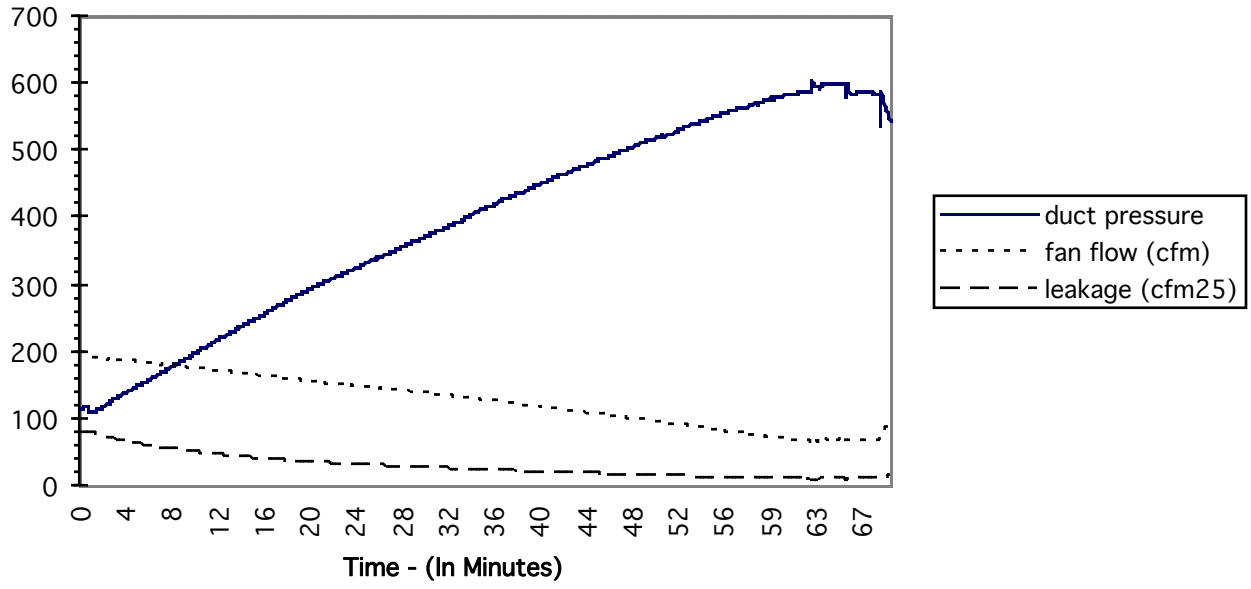


Figure A-7
California House # 10

EAST COAST - HOUSE # 1

- Split level house with 1900 square foot of living space.
- The duct system had not been previously been sealed.
- A horizontal furnace located in the attic.
- Sheet metal extended plenum in attic with flex duct runs to individual registers.
- 6 supply registers located in the ceiling.
- Supply system chosen for sealing.
- Ceiling registers sealed with duct mask, pans and extending poles.
- Furnace blockage completed by cutting hole in supply plenum and blocking with cardboard and duct tape.
- Aerosol injection point at supply register (not enough room for a straight run in attic).
- * Register seals did not hold tight. There was quite a bit of fogging in the living space.
- Air in liquid injection line caused the sealing process to be slow and contributed to there being a large accumulation of liquid puddled in the lay flat tubing.

* This was the first house done by the east coast crew and the register seals popcorn ceiling leakage between might have forgotten to put slits leakage at edge of pan

No Graph Available

EAST COAST - HOUSE # 2

- Single story house with 850 square foot of living space.
- The supply side of the duct system had previously been sealed with metal tape.
- An upflow furnace located in the unconditioned basement.
- Sheet metal supply duct runs to individual registers. Return system used panned floor joist spaces for ducting to the return plenum.
- 2 return grilles located on the walls.
- Return system chosen for sealing (due to limited access for blocking the heat exchanger on the supply side).
- Return grilles sealed with duct mask, cardboard and extending poles. .
- Furnace blockage completed by cutting hole in return plenum and blocking opening to furnace with cardboard and duct tape..
- Aerosol injection point at return trunk in basement.
- Some aerosol odor in the house, lots of fogging in the basement.
- Register seals held tight but the injection point collar did not.
- Air in liquid injection line caused the sealing process to be slow and contributed to there being a large accumulation of liquid puddled in the lay flat tubing.

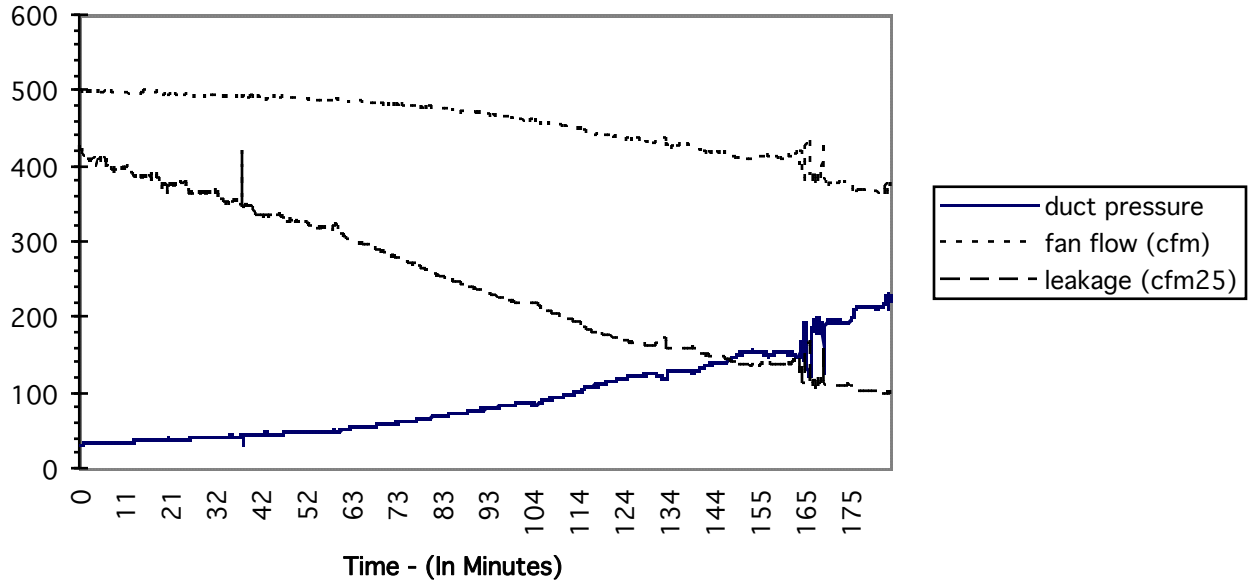


Figure A-8
East Coast House # 2

EAST COAST - HOUSE # 3

- Three story "Philadelphia style" duplex with 2700 square foot of living space.
- The duct system services only the top two floors of the duplex.
- The duct system had not previously been sealed. Duct system approximately 80 years old with recent additions in the basement.
- An upflow furnace located in the unconditioned basement.
- Sheet metal duct system.
- 11 supply registers located in the floor and the walls.
- Supply system chosen for sealing (one central return).
- Registers sealed with cardboard inserted under the carpeting with either weights or extending poles to hold in place. Wall registers sealed with duct mask, pans and LBNL tensioning device.
- Furnace blockage completed by cutting hole in supply plenum and blocking with cardboard and duct tape.
- Aerosol injection point at supply plenum access hole.
- Some aerosol odor in the house, lots of fogging in the basement.
- Register seals held tight.
- * Air in liquid injection line caused the sealing process to be slow and contributed to there being a large accumulation of liquid puddled in the lay flat tubing.

* The reason for the air in the liquid injection line was discovered to be a loose fitting at the liquid reservoir. The fitting was sealed with silicone caulk and the problem with air in the liquid line was solved.

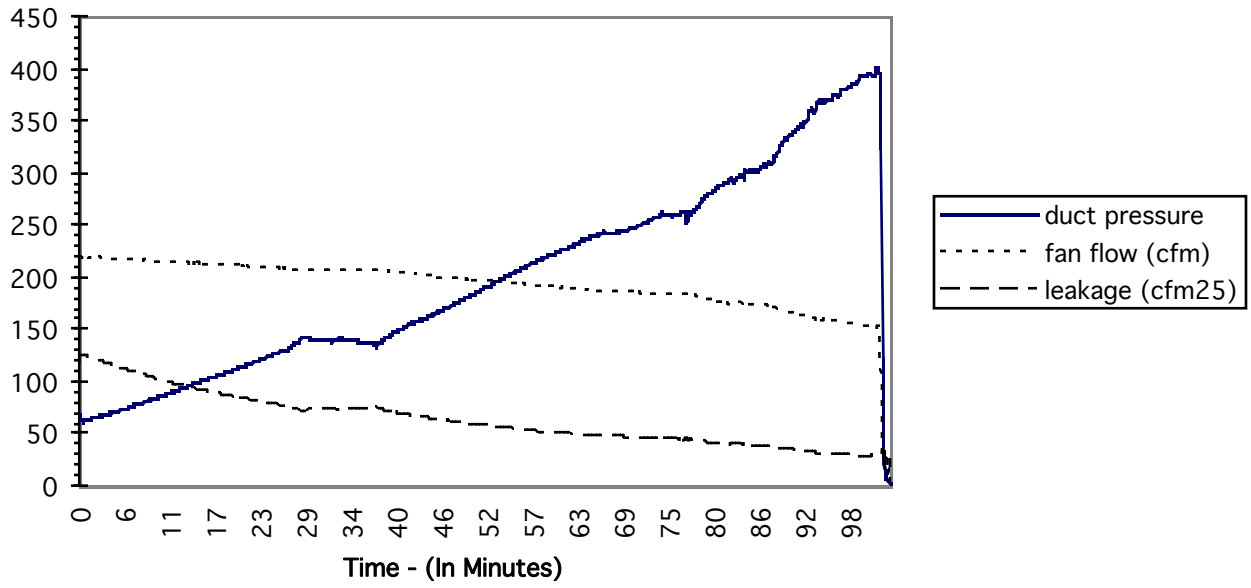


Figure A-9
East Coast House # 3

EAST COAST - HOUSE # 4

- First floor apartment with 750 square foot of living space.
- The duct system had not previously been sealed.
- An upflow furnace located in the unconditioned basement.
- Sheet metal duct system.
- 5 supply registers located in the floor.
- Supply system chosen for sealing.
- Registers sealed with duct mask, cardboard and extending poles to hold in place. Furnace blockage completed by cutting hole in supply plenum and blocking with cardboard and duct tape.
- Aerosol injection point at supply plenum access hole.
- Some aerosol odor in the house.
- Test results are inaccurate due to a pinched hose. Sealing process graph covers only the last eighteen minutes of aerosol injection.

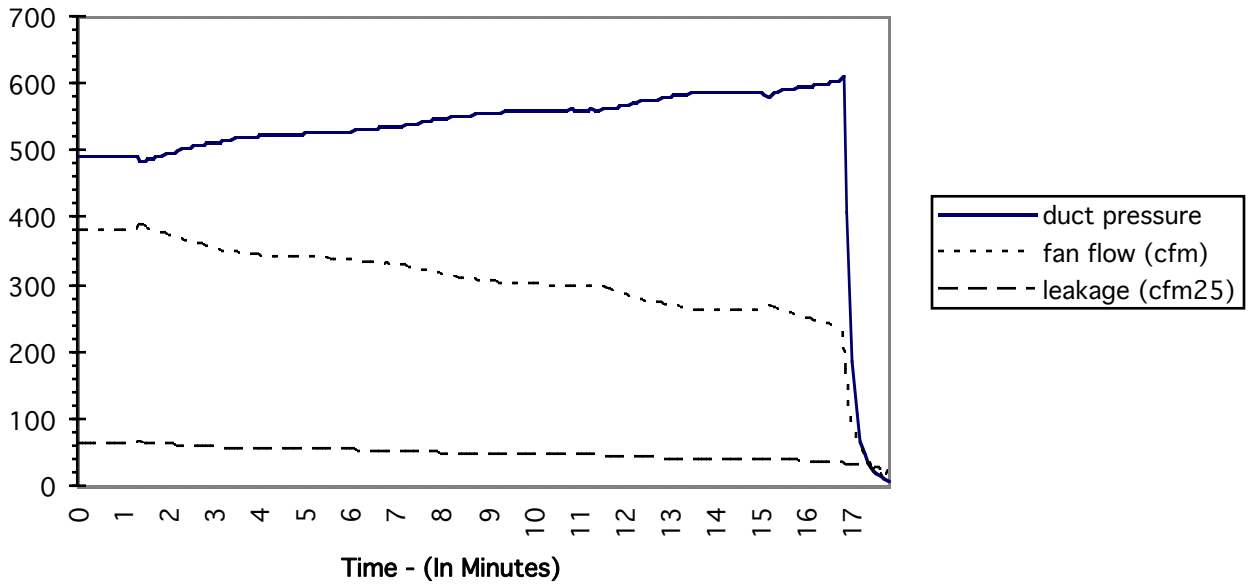


Figure A-10
East Coast House # 4

EAST COAST - HOUSE # 5

- Two story "cape style" house with 1800 square foot of living space.
- The duct system had not previously been sealed.
- An upflow furnace located in the unconditioned basement.
- Sheet metal duct system.
- 11 supply registers located in the floor and the walls.
- Supply system chosen for sealing.
- Registers sealed with cardboard inserted under the carpeting with either weights or extending poles to hold in place. Wall registers sealed with duct mask, pans and LBNL tensioning device. A "Draft Stopper" inflatable fireplace insert was used to seal two kick space registers (they did not provide a complete seal).
- Furnace blockage completed by cutting hole in supply plenum and blocking with cardboard and duct tape.
- Aerosol injection point at supply plenum access hole.
- Some aerosol odor in the house from the leaking register seals.
- * Injection process had to be stopped before the duct system was completely sealed due to running out of sealant.

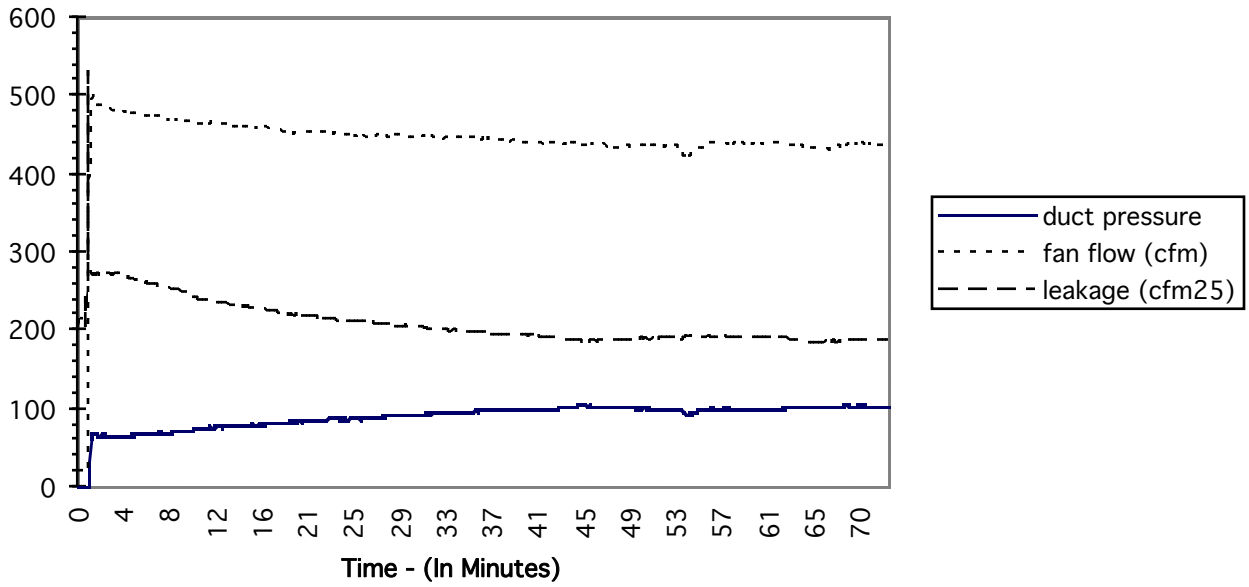


Figure A-11
East Coast House # 5

EAST COAST - HOUSE # 6

- Two story house with 1400 square foot of living space.
- One of the return ducts had previously been sealed.
- An upflow furnace located in the unconditioned basement.
- Sheet metal duct system.
- 11 supply registers located in the floor and the walls.
- Supply system chosen for sealing (due to return system sealing).
- Registers sealed with cardboard inserted under the carpeting with either weights or extending poles to hold in place. Wall registers sealed with duct mask, pans and LBNL tensioning device. Baseboard registers were sealed by cutting cardboard to fit inside of register opening and taping in place.
- Furnace blockage completed by cutting hole in supply plenum and blocking with cardboard and duct tape.
- Aerosol injection point at supply plenum access hole.
- No odor of aerosol in living space.

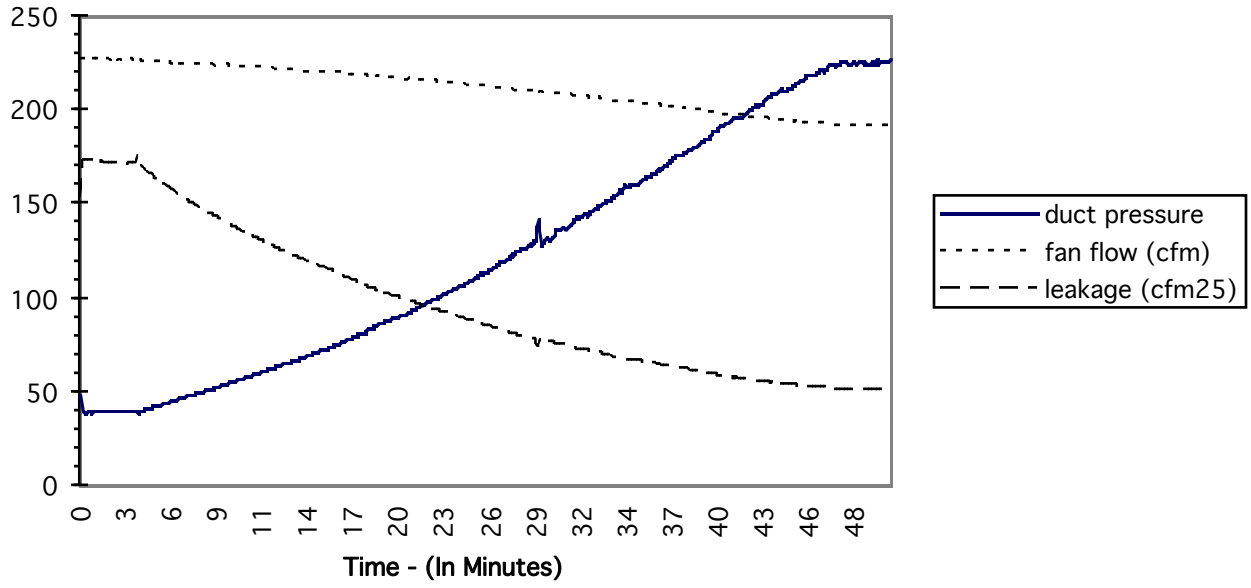


Figure A-12
East Coast House # 6

EAST COAST - HOUSE # 7

- Two story house with 2300 square foot of living space.
- The duct system had not previously been sealed.
- An upflow furnace located in the unconditioned basement.
- Duct system consist of sheet metal ducts in the basement with some flex duct runs to the second floor.
- 14 supply registers located in the floor.
- Supply system chosen for sealing (small return system).
- Registers sealed with cardboard inserted under the carpeting with either weights or extending poles to hold in place.
- Furnace blockage completed by cutting hole in supply plenum and blocking with cardboard and duct tape.
- Aerosol injection point at supply plenum access hole.
- No odor of aerosol in living space. Lots of fogging in the basement.
- Long injection time believed to be due to leaks around boots that were not sealed prior to injection.

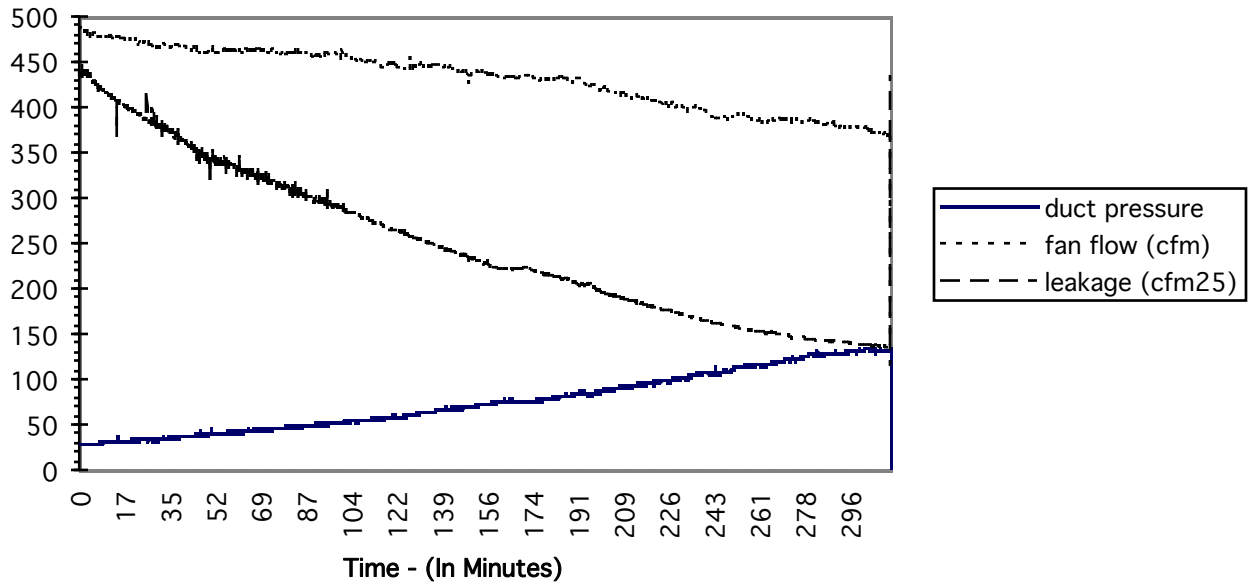


Figure A-13
East Coast House # 7

EAST COAST - HOUSE # 8

- Second floor townhouse with 800 square foot of living space.
- The duct system had not previously been sealed.
- A horizontal heat pump located in the attic.
- Duct system consist of sheet metal ducts in the attic.
- 10 supply registers located in the ceiling and walls (2).
- Supply system chosen for sealing (only one central flex duct run on return).
- Ceiling registers sealed with duct mask, cardboard and extending poles to hold in place. The wall registers were sealed in the same fashion.
- Furnace blockage completed by cutting hole in supply plenum and blocking with cardboard and duct tape.
- Aerosol injection point at supply register (not enough room for a straight run in attic).
- No odor of aerosol in living space.

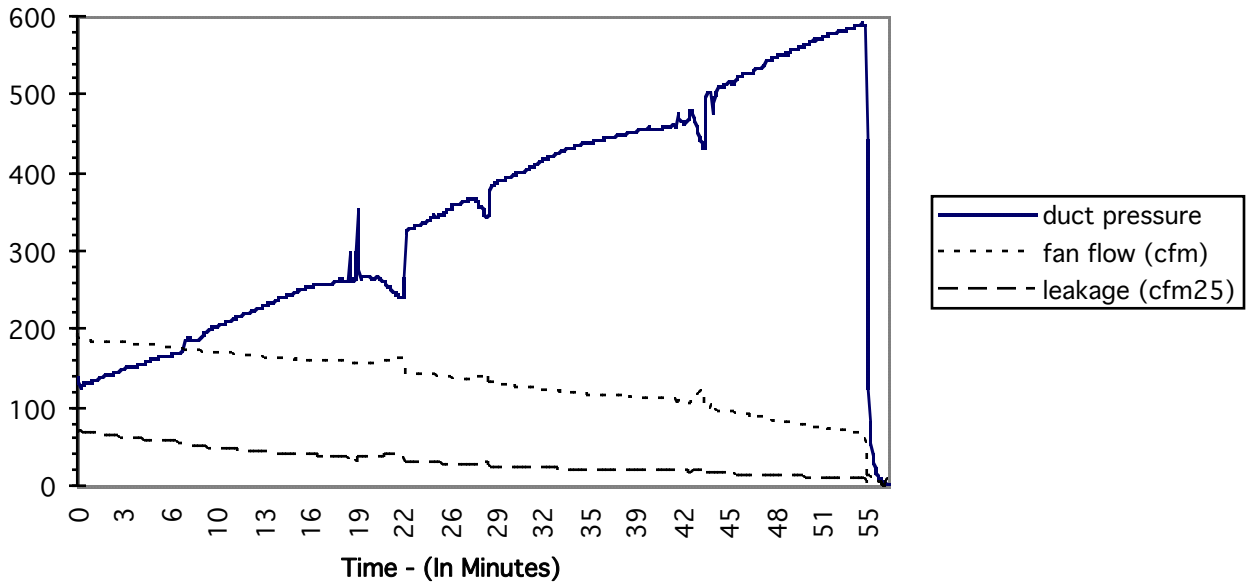


Figure A-14
East Coast House # 8

WISCONSIN - HOUSE # 1

- Two story, three bedroom house.
- The duct system had not previously been sealed.
- An upflow furnace located in an unconditioned basement.
- Duct system consist of sheet metal ducts in the unconditioned basement and metal duct runs in wall cavities to the second floor.
- 8 supply registers located on the interior walls.
- 6 return grilles located in the baseboards on exterior walls
- Return system chosen for sealing (house pressure imbalance test indicated it was the leakier system).
- Baseboard registers sealed by cutting cardboard to fit inside of boot opening and duct taped in place
- Furnace blockage completed by cutting hole in return plenum and blocking opening to furnace with cardboard and duct tape.
- Aerosol injection point at access hole cut in return plenum.
- * Slight odor of aerosol in living space. Extensive fogging in basement.

* There were 6 panned floor joist spaces for the return in the basement. All of these floor spaces had large amounts of leakage at the spaces between the sub-flooring boards (approximately 1/2 to 1 inch space between the sub-flooring boards) where they met the joist. The spaces between the sub-flooring boards were sealed with caulking. Even with a scrubber fan running there was a lot of fog visible in the basement.

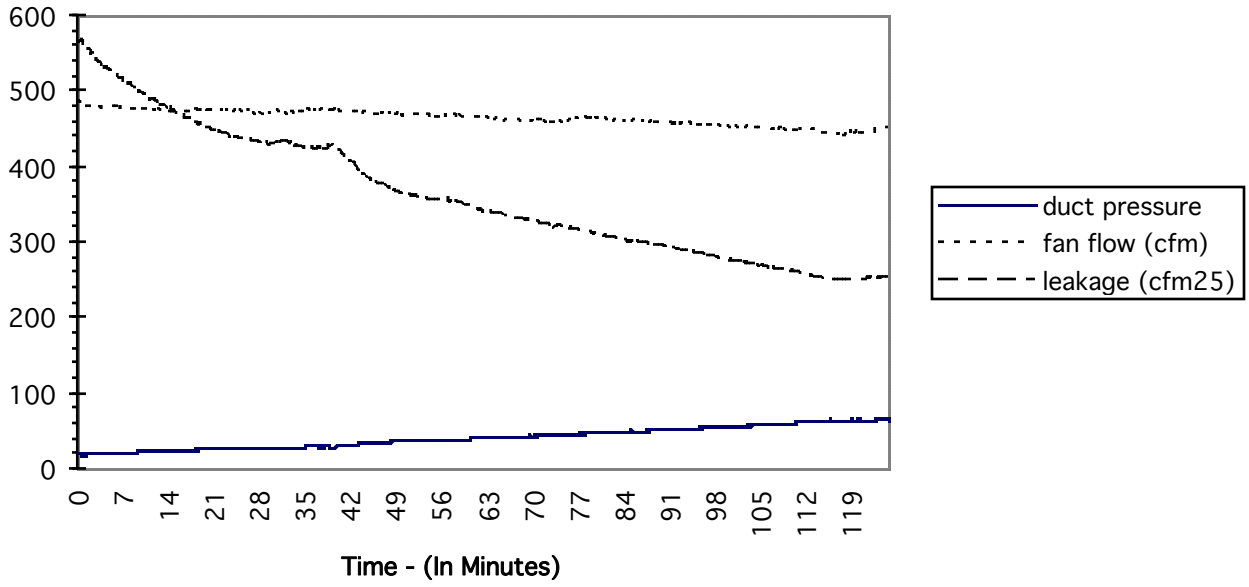


Figure A-15
Wisconsin House # 1

WISCONSIN - HOUSE # 2

- Two story, three bedroom house.
- The duct system had not previously been sealed.
- An upflow furnace located in an unconditioned basement.
- Duct system consist of sheet metal ducts in the unconditioned basement and metal duct runs in wall cavities to the second floor.
- 16 supply registers located on the floors (2 located in extended supply plenum in basement).
- 4 return grilles located interior walls
- Supply system chosen for sealing (return system used the building cavity space between floors as a duct).
- Registers sealed by cutting cardboard to fit inside of boot opening and duct taped in place or covered with duct mask and weights placed on top.
- Furnace blockage completed by cutting hole in supply plenum above the evaporator coil and blocking with cardboard and duct tape.
- Aerosol injection point at access hole cut in extended supply plenum.
- Slight odor of aerosol in living space. Extensive fogging in basement.

The basement was all on one breaker so power for the aerosol injection machine had to be gotten from upstairs so that the lights and the scrubber fans could be left on in the basement.

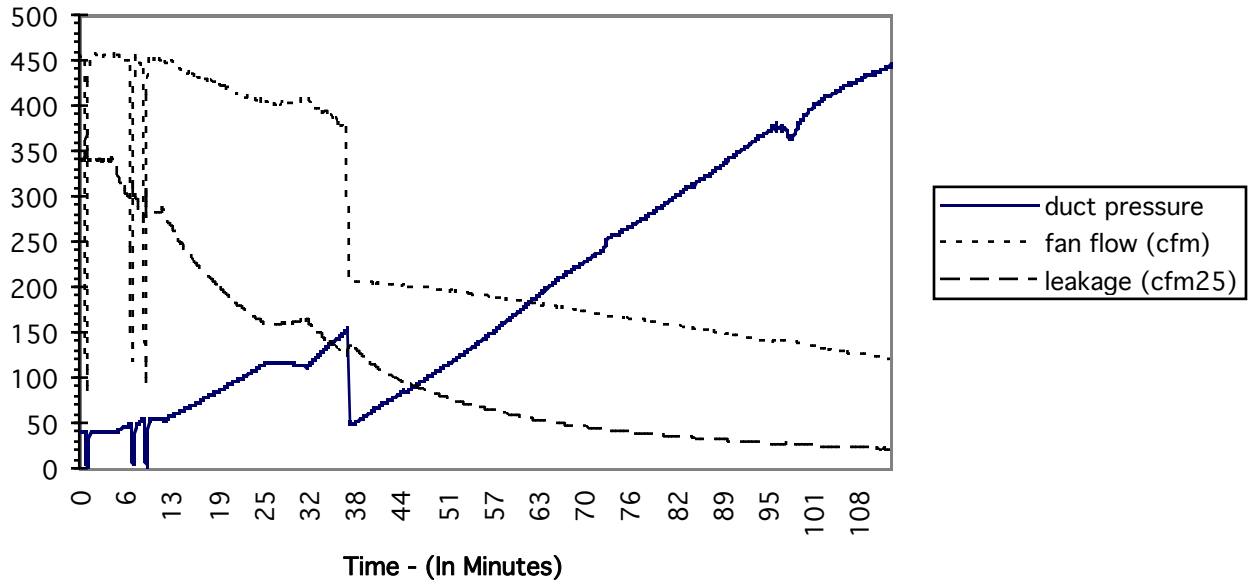


Figure A-16
Wisconsin House # 2