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Evaluation of Program Standards and Enforcement in Three Duct Sealing Programs

Program Designs Make a Difference

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ABSTRACT

The purpose of this evaluation was to provide guidance to utilities and other entities contemplating duct-sealing programs for peak reduction and energy savings. The research questions included: How do program specifications and enforcement effect the amount of duct sealing accomplished in a program as well as the energy savings attributable to that level of duct sealing.

The research included direct measurement of duct systems on over 2000 homes utilizing three different program standards. These standards and their enforcement resulted in almost a two to one difference in electrical peak reduction potential.

This paper discusses the responses of the implementing contractors to different program standards and how to utilize this information in program design.

This research reinforces the need for quality assurance during the life of a program, flexibility in program standards to ensure maximum effectiveness, and the advantages of applying the evaluation results of one program into the design of succeeding programs.

Introduction

Background

In the 1980s the pervasive presence of duct leakage and the effects of this leakage began to be documented. For example, a 1989 analysis of homes in the Pacific Northwest (Parker 1989) showed that homes with duct systems used 27% more energy for heating than homes with direct heat (baseboards). In Tennessee, infiltration rates were found to be 77% higher when the air handler was operating (Gammage et al. 1984) In Florida, measurements of both duct leakage and changes in infiltration rates with the air handler on were reported in the late 1980s (Cummings 1988; Tooley and Moyer 1989). Since that time there have been over 100 studies, articles, and professional papers (including Andrews 2001; Blasnik et al. 1995; Cummings et al. 1990; Delp et al. 1997; Neme, Proctor, and Nadel 1999; Palmiter and Francisco 1994; Proctor, Blasnik and Downey 1995) documenting the losses from duct systems and the energy savings from sealing them.

Twenty-five to forty percent of the cooling (and heating) never makes it into the home (Andrews 2001). Typical duct systems lose that much energy between the air conditioner and the registers. Similar results have been found on small and large commercial duct systems (Delp et al. 1997; Fisk et al. 2000).

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) worked for 9 years to reach a consensus method of calculating the seasonal and peak efficiency of duct systems. These calculations were developed from all available data on the effects of leakage and conduction. During the development stage the Standard's calculations were tested and refined (Siegel, McWilliams, and Walker 2003; Proctor 1998). ASHRAE Standard 152-2004 is the standard.

Scope

A number of states and utilities have adopted programs to encourage, promote, and incentivize duct testing and sealing on both new duct installations and existing systems. The energy efficiency and peak reductions from duct sealing are documented, however in many cases the documented tests are of small pilot projects of from 4 to 100 units.

The energy savings is obviously dependent on how well the duct systems are sealed relative to their initial (baseline) state. It is possible that the amount of sealing (and savings) is dependent on the program design, including standards and enforcement of the standards.

This paper analyzes the results of three high volume programs that were implemented to provide duct testing and sealing in single-family homes.

Potential

Duct sealing saves energy and reduces peak watt draw. The average savings from a compilation of studies is 17% (Neme, Proctor, and Nadel 1999). The compiled studies include pre- post-retrofit energy consumption measurements as well as calculations using ASHRAE 152-2004.

The amount of duct sealing needs to be sufficient to save the energy and reduce peak. The 17% average savings has occurred in small programs when the amount of sealing was held to tight standards.

Duct sealing can also have a significant effect on peak electrical consumption. Figure 1 shows the peak reduction from a home monitored in Phoenix that was alternately tested with supply leakages of 16% (as found) and 2% as well as return leakages of 11% (as found) and 3%.

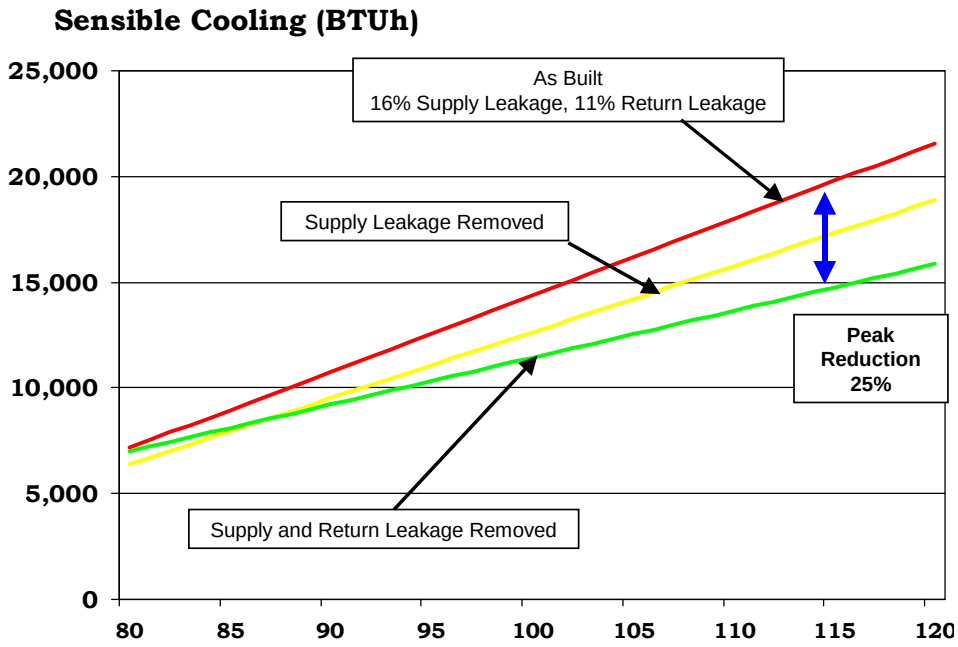

Figure 1. Monitored Peak Reduction from Duct Sealing (Proctor 1997)

ASHRAE Standard 152 provides proven estimates of energy savings and peak reductions for changes in duct systems. Table 1 shows the electric and gas energy savings for a duct system in Sacramento CA. This table is based on a 14% (of coil airflow) reduction in duct leakage.

Table 1. Duct Efficiency and Sealing Savings for 14% Reduction

	Duct Efficiency		Savings
	Pre-Repair 15% Supply Leakage 15% Return Leakage	Post-Repair 8% Supply Leakage 8% Return Leakage	
Electric Cooling Season	64%	72%	11.1%
Electric Cooling Peak	51%	62%	17.7%
Gas Heating Season	72%	77%	6.5%
Gas Heating Peak	69%	74%	6.8%

Methodology

These programs field trained duct sealing crews in three-day hands-on trainings with final certification written and practical tests for certification.

For these programs an initial duct leakage was recorded. The duct leakage was tested by sealing the delivery and supply registers, pressurizing the duct system to 25 pascals (0.10 IWC) and precisely measuring the flow required to maintain that pressure with a Duct Blaster®. Commonly known as the Total Leakage Test, this test captures the duct leakage whether the air escapes inside the conditioned space or outside the conditioned space. An incentive was paid to the participating contractors for each initial duct leakage test. The results of the initial test were recorded either on a paper form or through a telephone connection.

Within each program, the contractors decided when to proceed with duct sealing to meet the program standards and when to leave the duct system as found. When duct sealing was done the contractors manually sealed the duct system using mastic on the leaks with embedded fiber mesh on the larger leaks.

After the leaks were sealed a second Total Leakage Test was run. The results of the final leakage tests were recorded either on a paper form or through a telephone connection.

Program Standards and Enforcement

Each program had a different set of standards and enforcement.

Program A. This program used paper forms or phoned data to report the results of the initial and final duct leakage. Paper forms were sent to the utility for review along with an incentive form and invoice. The program provided an incentive for each initial test and an additional incentive if the system met either sealing criteria. The program standards were enforced by random post inspections of submitted jobs.

Sealing standard:

1) Initial leakage must be > 12% and must be reduced to < 12% of unit nominal airflow (400 cfm per ton) or,
2) Initial leakage must be > 12% and must be reduced by 15% of unit nominal airflow (400 cfm per ton).

Program B. In this program, the duct sealing crew reported all data to a central call center while they were at the job site. Initial test results were phoned in, the accuracy of test data were verified, and the relationship to the program standard reported. After sealing the final test data were phoned in, verified, and compared to the program standards. If program standards were not met, the crews were encouraged to continue until the standards were met. Experienced technicians on-call provided the encouragement. They discussed the situation with the crews while they were still in the field. Enforcement consisted of statistical evaluation of the data from each duct system and each crew. This statistical evaluation identified patterns and relationships that are likely to come from crews not doing the work properly or not accurately reporting the data. These statistical evaluations were reviewed weekly. The statistical analysis targeted certain systems/crews for inspection. The statistical method was supplemented by random inspection of some systems. Crews and contractors who were not properly following the program standards were removed from the program.

The program provided an incentive for each initial test and an additional incentive for each successful repair.

Sealing standard: Leakage must be reduced by 14% of unit nominal airflow (400 cfm per ton)

Program C. This program followed the same protocols as Program B for data capture, statistical analysis and enforcement. The primary difference was the level of sealing needed to obtain the repair incentive.

The program provided an incentive for each initial test and an additional incentive for each successful repair.

Sealing standard:

1) If initial leakage <=30%, leakage must be reduced by 14% of unit nominal airflow (400 cfm per ton)
2) If initial leakage >30%, leakage must be cut in half.

Data Processing

For Program A, the data were entered from the forms into a common evaluation database. Programs B and C data were transferred from the central file to the evaluation database. All data table construction and analysis were performed in STATA. Data tables were transferred from STATA to Excel to produce the graphs in this paper.

Savings Calculations

The savings calculations were performed in accordance with ASHRAE Standard 152-2004. These calculations were performed in as Excel spreadsheet used in the ASHRAE 152 committee during the development of the standard. Sacramento California conditions were used for the analysis. The calculations were done for a 2000 sq. ft. house with a three-ton air conditioner and a 60,000 btu per hour furnace. The fan flows for the calculation were 1000 cfm in cooling and 800 cfm in heating.

Assumptions. The homes in this analysis were predominantly slab-on-grade homes with duct systems and air handlers in the attic. The savings analysis assumes:

- 90% of the total leakage is leakage to outside,
- the attics do not have radiant barriers,
- the leakage is equally divided between supply and return,
- the regain factor is .1
- the heating and cooling equipment are single speed
- the attic is vented
- the air conditioner metering device is a TXV
- when the initial duct leakage tested at 25 pascals exceeded the airflow, savings did not exceed 30% on heating and 40% on cooling

Results

Table 2. Percentage of Duct Systems Addressed and Sealing Success

Category	Program A	Program B	Program C
Sealing not Attempted (Initially Tight)	13.7%	3.9%	14.0%
Sealing not Attempted (Good Potential)	9.5%	7.1%	31.4%
Sealed Did Not Make Standard	9.3%	0.9%	3.4%
Sealed to Standard	67.6%	88.1%	51.3%

Program A and C had an equal percentage of tight ducts (less likely to be worth the cost to seal). Program B had very few tight ducts on the original test.

Program C did not attempt sealing on a very large percentage of systems even though the systems had good potential leakage reductions. We hypothesize that the contractors did not attempt sealing the leakier systems because they feared they would not achieve the 50% reduction specified.

Program A had the highest failure rate in achieving the standard. These failures occurred on the leakier duct systems and seem to have driven the contractors to avoid trying to seal the leakier systems (see comments below Table 3).

Program C had the lowest percentage of units sealed to the standard; the contractors did not attempt to seal the leakier systems.

Table 3. Average Initial and Final Duct Leakage by Category

Category	Program A	Program B	Program C
Initially Tight (No Sealing)	11%	10%	10%
Good Potential (No Sealing)	NA	20%	29%
Sealed Units Initial Leakage	38%	52%	45%
Sealed Units Final Leakage	17%	24%	16%

Contractors in both Program A and Program C avoided the leakier systems as evidenced in the initial leakage of the units they sealed. Given the higher level of contractor confidence that they could at least get a 14% of airflow leakage reduction Program B contractors sealed the leakier ducts as well.

Program A had a particular problem. Inadvertently, the program standards left a loophole. Contractors could concentrate on systems with leakage slightly greater than 12% that presented easy fast opportunities to bring the leakage below 12%. These easy quick fixes still qualified for the incentive in spite of their small energy savings.

Table 4. Average Energy and Peak Savings

	Program A	Program B	Program C
Treated Units			
Heating Peak	13%	16%	17%
Heating Seasonal	11%	14%	13%
Cooling Peak	26%	34%	30%
Cooling Seasonal	18%	21%	22%
Overall (including both Treated and non-Treated Units			
Heating Peak	10%	14%	9%
Heating Seasonal	8%	13%	7%
Cooling Peak	20%	31%	16%
Cooling Seasonal	14%	18%	11%

Since contractors in both Program A and Program C avoided the leakier systems they achieved less savings than Program B on the units they sealed. As important is the fact that Program B sealed a much higher percentage of units and thus achieved a significantly higher savings in heating and cooling, seasonal and peak.

Conclusions and Recommendations

Conclusions

The most obvious conclusion from this study is that contractors are motivated by money. If incentives are properly placed (where energy savings actually occur) and the standards are enforced, the contractors will work diligently to achieve monetary goals.

The energy savings and peak reduction increases with improved standards that are actively enforced.

The program that had the highest success rate (Program B) had the following features:

1. The standard set a threshold of duct leakage reduction (14% of nominal airflow) that was sufficient for cost effectiveness.
2. The standard leakage reduction threshold was not too high; therefore almost 90% of the systems could be sealed to meet program standards.
3. The achievable standard resulted in contractors working on systems that they avoided in the other two programs. These systems were the leaker systems that have a higher potential savings.

Program A had a loophole (initial leakage had to exceed 12% and final leakage had to be less than 12%). This loophole encouraged some contractors to work on systems with little sealing potential and to avoid systems where a good deal of sealing was warranted.

Recommendations

We recommend that duct sealing programs incorporate immediately verifiable and enforced standards.

We recommend a two level incentive structure. Within that structure some incentive would be available to the contractors at the lowest cost effective leakage reduction levels so that they will address nearly every system that has potential. Beyond the threshold level incentive an additional incentive would be applied at a higher level of sealing to encourage contractors to continue sealing on systems that have potential beyond the threshold potential.

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