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Impacts of Duct Leakage on Infiltration Rates, Space Conditioning Energy Use, and Peak Electrical Demand in Florida Homes

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Abstract

Testing for duct leakage was done in 91 homes. Tracer gas tests found that infiltration rates were four times greater when the air handler was operating than when it was off. Return leaks were found to average 10.0% of air handler total flow. House airtightness, in 63 of these homes, determined by blower door testing, averaged 12.38 air changes per hour at 50 Pascals (ACH50). When the duct registers were sealed, ACH50 decreased to 10.93, indicating that 11.7% of the house leaks were in the duct system.

Duct repairs were made on 25 homes. Blower door tests found 12.30 air changes per hour at 50 Pascals pressure (ACH50). When the registers were sealed off, ACH50 decreased to 10.58, indicating that 14.0% of the house leaks are in the duct system. Repair of duct leaks reduced house ACH50 from 12.30 to 11.13, indicating that 68% of the duct leaks were repaired. The duct repairs caused infiltration with the air handler operating to decrease from 1.13 air changes per hour (ach) to 0.54 ach, and return leaks to decrease from 16.7% to 4.5%.

Cooling energy use was monitored on 24 homes before and after duct repair. Air conditioner energy use decreased by 18.0% because of duct repair. At an average cost of $200 per home, duct repairs have a simple payback of less than two years. Duct repairs are also shown to reduce winter peak demand in electrically heated Florida homes by about 1.6 kW per house at about one-sixth the cost of building new electrical generation capacity.

Introduction

Duct leakage has been observed in many homes by the authors of this paper and others. The authors have observed significant duct leakage in the majority of the 370 homes they have tested with blower doors (Tooley and Moyer, 1989). They have also reported on duct leakage in about 25 homes, indicating that significant duct leakage has been found (Cummings, 1988; Cummings and Tooley, 1989a; Cummings and Tooley 1989b). Other authors across the nation have detected duct leakage, as well. Infiltration rates in 31 Tennessee homes were found to be 77% higher when the air handler was operating (Gammage, et al., 1984). Tracer gas measured infiltration rates in 187 new Pacific Northwest homes were found to be 70% higher in those with forced-air systems for a four month winter period compared to those which used baseboard and radiant heating systems, even though blower-door testing indicated they should only be 12% leakier (Parker, 1989). Blower door tests done on 20 homes in the Pacific Northwest found about 10% of the house leak area in the duct system (Robinson and Lambert, 1989).

Project Description

A study was begun in the spring of 1989 to investigate duct leakage in central Florida homes. It will be completed in the fall of 1990. Because the project is not complete, the following description of the project will be in the future tense, even though more than 50% of the work effort has been completed at the time of this writing.

In phase I of the project, a sample of 150 homes will be tested for evidence of duct leakage. The housing sample will be randomly selected and the only screening criteria will be that the house must have a forced air system. It was also decided that the sample should fall into five groups, based mostly on air handler (AH) location. Therefore, 30 houses will be selected in each of the following categories: (1) AH in the garage, (2) AH in an interior closet, (3) AH in the attic, (4) AH outdoors, and (5) manufactured homes.

Duct leakage will be measured by means of tracer gas testing, blower door testing, and visual inspection. Tracer gas tests will be done once with the AH operating continuously, interior doors open, and once with the AH off. If the infiltration rate is higher when the AH is operating, then the possibility of duct leaks is indicated. If the infiltration rate is much higher (say three to five times higher) because of AH operation, then duct leakage is strongly indicated. A more powerful measure of duct leakage is the return leak fraction (RLF). It is the proportion of air returning to the AH which originates from outside the conditioned space. RLF is determined by measurement of tracer gas dilution from the return (in the room at the return register(s)) to supply registers. Tracer gas concentration is also measured in the attic at the return leak site. It provides a rather precise method for quantifying leaks on the return side of the air distribution system.

Infiltration tests will be done using the tracer gas decay method and a portable infrared specific vapor analyzer. A 20 minute period is used to mix the tracer gas throughout the house using the AH as the mixer. In the test with the air handler operating, sulfur hexafluoride samples will be taken every five minutes for 30 to 40 minutes (data collected at a minimum of 7 time increments) at the intake to each of the return registers (typically Florida homes have one or two return registers). Mixing is maintained by the continuous operation of the AH.

In the tests with the air handler turned off (this test immediately precedes the AH on test), samples will be taken every 10 minutes for a minimum of 50 minutes (data collected at a minimum of 6 time increments). Tracer gas measurements will again be taken at the return registers. Mixing of the tracer gas will be maintained by turning the air handler on for about 1 minute during each 10-minute period. A change in this test protocol has been recently made because duct leakage during the minute of AH operation causes error in the result. Sampling is now done at four distributed locations throughout the house, and the AH is not turned on during this test at all. All of the testing procedures are described in more detail in Cummings (1989).

Because of funding limitations, blower door tests will be done on 100 of these homes. These tests will be done in the depressurization mode only. It is the belief of the authors that pressurization artificially opens up "holes" in the house, such as awning windows, exhaust fan dampers, etc., while depressurization generally pulls them closed. Fan air flow will be measured at 5 to 8 house pressure points, generally across the range from 10 to 60 Pascal (Pa). These tests will be repeated with all the supply and return registers (register only) covered by paper and tape. These tests will permit determination of house air leakage at 50 Pa (ACH50), and by subtraction, the proportion of the house leak (at 50 Pa) which is in the air distribution system. Infiltration testing has been completed on 91 homes. Blower door testing has been completed on 63 homes.

Phase II will consist of repairing the duct system of 50 homes and monitoring air conditioner energy use for four weeks before and after repair. Monitoring will be accomplished in the following manner. Watt-hour and run-time meters will be installed on the air conditioner (AC). The homeowner will be asked to read the run-time and watt-hour AC meters and the whole-house watt-hour meter daily. In order to obtain comparable data, they will be asked to maintain their thermostats at the same setting throughout the testing and take their meter readings at about the same time each day. A weather station will be located in each of the two counties where monitoring will be done, collecting temperature, dewpoint, solar radiation, and wind speed data. Repairs and AC energy monitoring have been completed on 25 homes. Twenty-five more will be repaired and monitored during the summer of 1990.

Project Test Results

Three different tests were performed to detect duct leakage: (1) tracer gas tests, (2) blower door tests, and (3) smoke test inspection. In each phase of testing, extensive evidence of duct leakage was found.

Tracer Gas Testing

Infiltration tests revealed that duct leaks are large and widespread in central Florida homes. The average infiltration rate of the 91 homes tested was four times higher with the AH operating than when it was off. Figure 1 shows these results. Infiltration averaged 0.93 air changes per hour (ach) when the AH was on, while only 0.21 ach with it off. Three-quarters of the homes have natural infiltration less than 0.25 ach, while only 3% have less than 0.25 ach when the air handler is operating. The increase in house infiltration due to AH operation and duct leaks is dramatic. (These tests were all performed during the hours of 9 A.M. to 6 P.M. and usually in the summer months of April through October. Because daytime winds in Florida are typically stronger than nighttime winds, the measured natural infiltration rates are probably greater than actual annual average rates.)

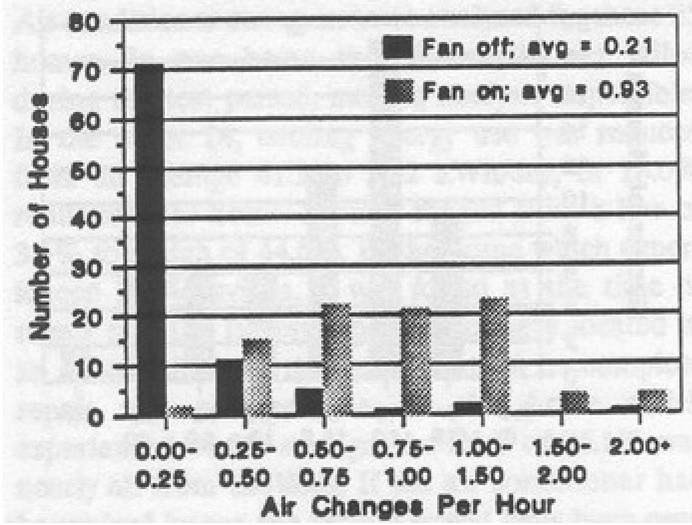

Figure 1. Tracer Gas Infiltration Rates in 91 Homes with the Air Handler Off and On

To some readers, 0.21 ach natural infiltration may seem lower than expected. We offer the following observations as an explanation for low infiltration. Infiltration is driven by pressure differentials. Pressure is caused by wind and stack. Florida winds are less than other parts of the country. Stack effect is small because: (1) temperature differences are less than 15 degrees most hours of the year, (2) homes are typically short (one story), and (3) concrete slabs (>90% of homes) and block walls (>80% of homes) do not offer many inlets for stack infiltration.

The return leak fraction (RLF) was measured in each home with the AH operating (Figure 2). Sixty percent were found to have return leaks equal to or greater than 5% of the AH total air flow. Thirty percent have greater than 10% RLF. The average for 91 homes was 10.0% RLF.

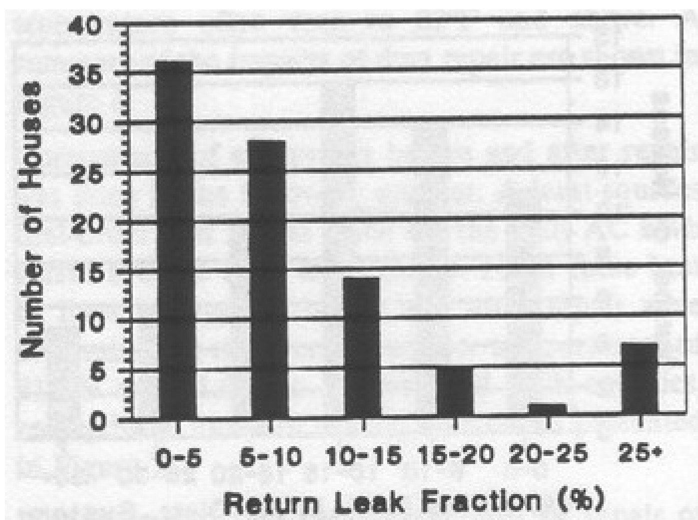

Figure 2. Return Leak Fraction in 91 Homes Measured by Tracer Gas Dilution;
Average = 10.0%

Blower Door Testing

Blower door tests were done on 63 homes. ACH50 averaged 12.38 in 61 homes which have complete test results (Figure 3). When the supply and return registers were sealed by means of paper and tape, ACH50 dropped to 10.93 indicating that holes in the duct system account for 11.7% of the total house air leakage at 50 Pa pressure (Figure 4). Since the duct system is less than 1% of the volume of the house, it is remarkable that it contains such a large proportion of the leak area of the house. This indicates that there are significant problems in air distribution system construction which must be addressed. The significance of leaks in the duct system becomes more important when it is considered that most of the duct system is under an order of magnitude greater pressure differential than the remainder of the house. It is interesting to note that 11.7% of the house leaks located in the duct system account for 71% of the infiltration when the fan is on.

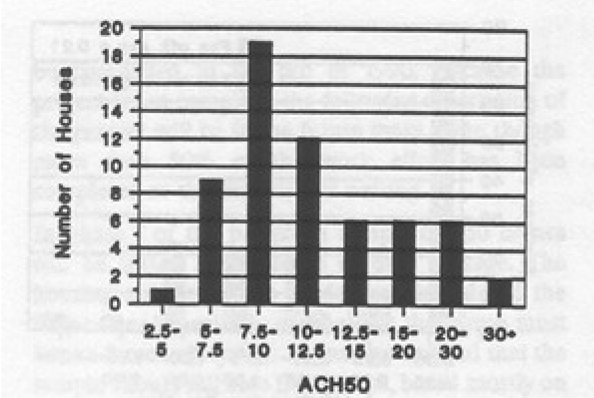

Figure 3. Air Changes Per Hour at 50 Pascals (ACH50) in 61 Florida Homes (avg = 12.38 ACH50)

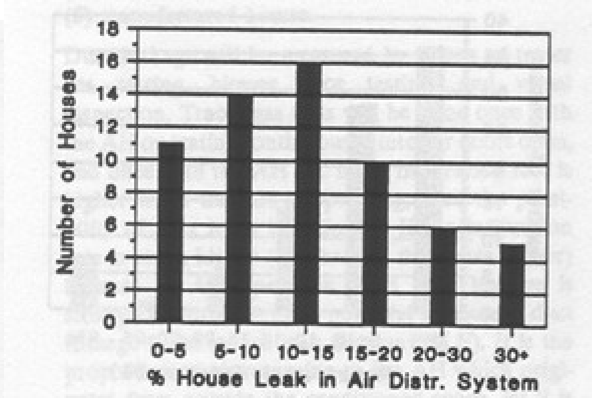

Figure 4. Percent of House Air Leakage @ 50 Pascals Which is Located in the Air Distribution System of 62 Homes (avg = 11.7%)

The 63 homes selected to have blower door tests are very similar to the larger sample of 91 homes. Infiltration with the AH on is 0.96 in these 63 homes compared to 0.93 for the 91 homes. Infiltration with the AH off is 0.28 compared to 0.21. RLF is 11.0% compared to 10.0%.

House airtightness is a function of age (Figure 5). Older homes are leakier. Homes built in the last 10 years have ACH50 of about 8.0. Those over 20 years old have an average ACH50 of about 17.0.

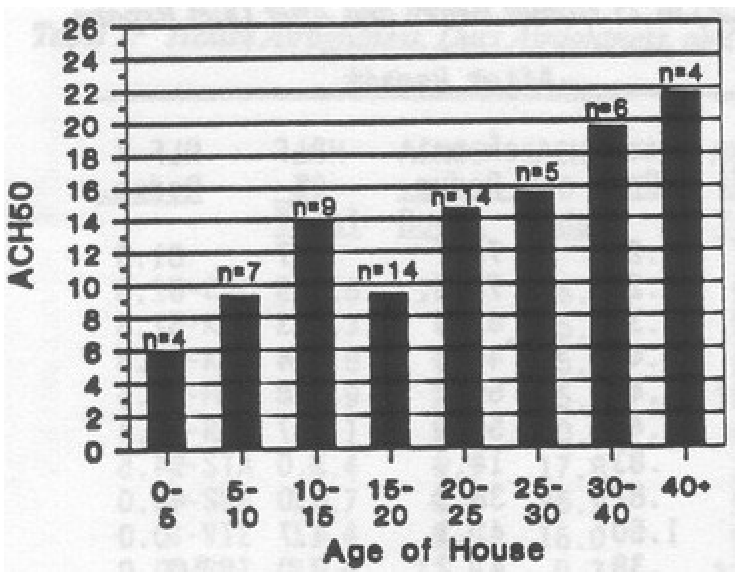

Figure 5. Air Changes Per Hour at 50 Pascals (ACH50) in 63 Homes with Respect to House Age.

Smoke Test Inspection

Visual inspection of the duct leaks was done in two ways. First, with the blower door in place, the house was pressurized to about 15 Pa. Using a smoke stick (titanium tetrachloride) each supply and return register was checked (with the AH off) to see if smoke would pass into it, and at what velocity. If the smoke did not enter the grill, or entered it slowly, then little or no leak was located in the nearby ducts. However, if the smoke "raced" into the register, then leakage existed in the ducts nearby. Second, the duct system was inspected with the AH operating (blower door off). All connections, ducts, plenums, and air handlers were inspected, typically with the smoke stick, for leaks.

Based on visual inspection using the smoke and blower door test, return leak air flow is estimated to be about twice as large, as supply leakage in the tested homes. In the majority of cases, the source of the largest return leaks is the return plenum. This plenum is frequently the support platform for the air handler. While it is usually lined with duct board for sound deadening and insulation, it is typically not airtight. Leaks in these return plenums commonly range from 5% to 25% of the AH air flow, though RLFs have been measured as high as 55%. Remember RLF is percent of air coming from outside the house.

Return plenums are typically located in the garage, interior closet, or utility room. They are commonly constructed so that they join into adjacent walls in the room in which they are located. When they are not made airtight on the inside, they can draw air down these walls. Because we estimate 50% or more of the return leaks are from the attic, the impact upon air-conditioner performance is dramatic.

Duct Repairs on 25 Homes

Duct leaks were repaired on 25 homes. Tracer gas and blower door test results are summarized in Tables 1 and 2 for before and after repair. In the 24 homes which had complete blower door tests, ACH50 averaged 12.30, nearly the same as for the larger sample. While overall house tightness is similar to the larger sample, duct leakage is larger in these 24 homes than in the larger sample. The proportion of the whole-house leakage at 50 Pa attributed to the air distribution system was 16.0%, compared to 11.7% in the larger sample. Tracer-gas-measured infiltration with the air handler on averaged 1.13 ach (compared to 0.93 ach in the larger sample), and the RLF averaged 16.7% (compared to 10.0% in the larger sample).

Repair of duct leaks reduced ACH50 to an average 11.13. This reduction in ACH50 of 1.17 indicates that 68% of the duct leaks were sealed. Infiltration with the AH on decreased from 1.13 ach to 0.54 ach after repair. It is interesting to note that duct repairs, which reduced house ACH50 by 9.5%, caused a 52% reduction in infiltration with the air handler operating. Perhaps more significantly, infiltration with the air handler on was reduced 67% of the way to the natural infiltration rate of 0.25 ach. RLF was reduced 73%, from 16.7% to 4.5%.

Air conditioner energy use was analyzed for these 25 homes. In one home the air conditioner failed during the test period, making analysis impossible. In the other 24, cooling energy use was reduced from an average 41.3 to 34.2 kWh/day, or 18.0% reduction per home. Savings ranged from a low of 3.5% to a high of 44.6%. In the home which experienced 3.5% savings, it was found at the time of repair that the largest supply leaks were located in an inaccessible portion of the attic, so complete repair was not possible. In the home which experienced 44.6% savings, the RLF of 26.1% was nearly all from the attic. If the air conditioner had been sized larger, the savings would have been even greater since the air conditioner could not meet the cooling load during most afternoons. While the house thermostat was set at 79°F, the house temperature often rose to 82°F and above. A summary of the impacts of duct repair are shown in Figure 6.

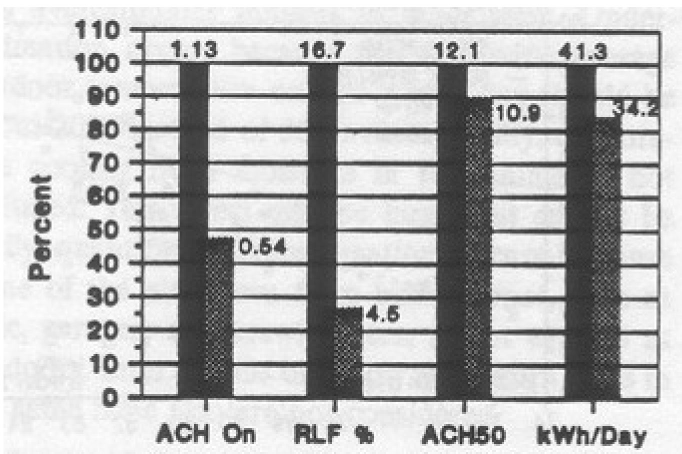

Figure 6. Infiltration Rate with Air Handler on, Return Leak Fraction, ACH50, and Cooling Energy Use Before and After Repair of the Duct System on 25 Homes. Before is shown on 100% axis.

Comparison of energy use before and after repair was done in the following manner. A least-squares first-order best fit was made for the daily AC kWh versus average daily temperature. From these best fit lines, energy use before and after repair were determined at the average summer temperatures of 81.3°F and 81.8°F in Brevard and Polk counties, respectively. Plots for several houses are presented in Figure 7.

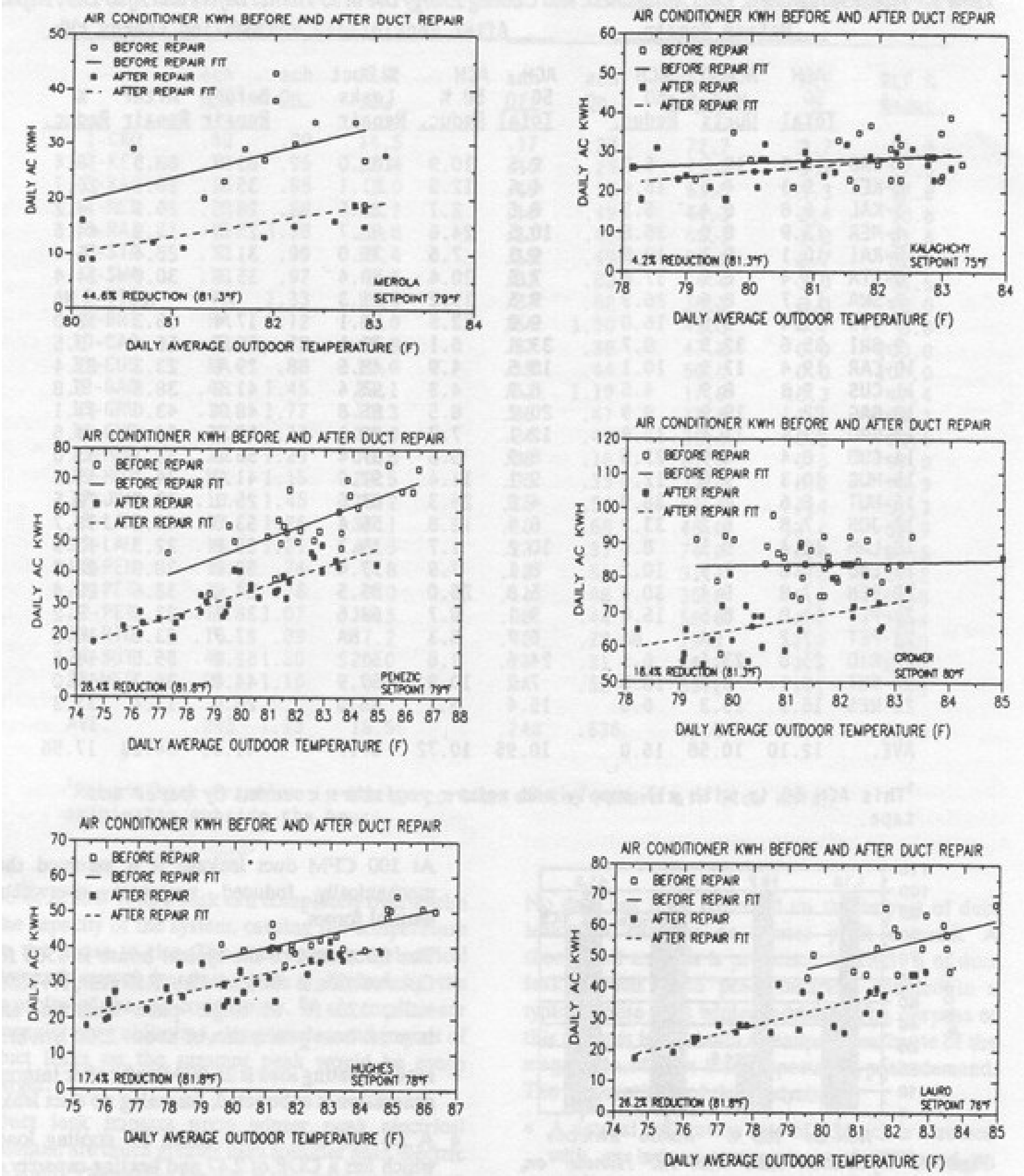

Figure 7. Measured Cooling Energy Use Before and After Duct Repair on Six Florida Homes

It is estimated that the average cost of repair of these systems is about $200. With an average energy saving of 7.1 kWh/day, cooling season savings of $85 could be expected. Including heating season savings of perhaps $25, duct repairs would have a simple payback of less than 2 years.

Duct Leak Impacts Upon Peak Electrical Demand

The benefits of duct leak repair are significantly greater for peak electrical demand reduction than for total energy use reduction. Figure 8 shows the impact of return duct leaks from the attic upon AC energy efficiency ratio (EER). Since the utility's summer peak occurs at about 5PM, when the attic is likely to be 120°F and have a dewpoint temperature of about 85°F, a 15% return leak can reduce the effective capacity and EER of the system by 50%. A 30% return leak can completely overwhelm the capacity of the system, causing the temperature in the house to rise. The total increased electrical demand caused by duct leaks is limited by the capacity of the air conditioner. If air conditioner capacity were unlimited, the peak demand impact of duct leaks on the summer peak would be much larger.

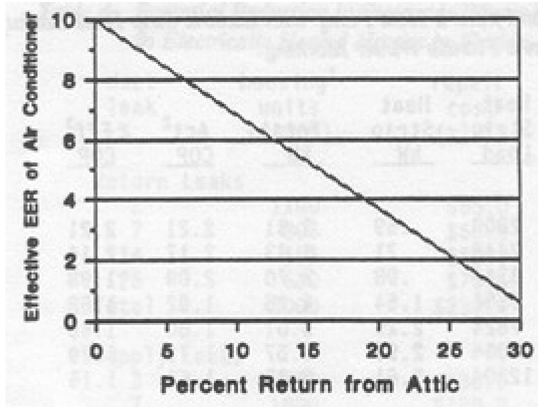

Figure 8. Performance Degradation of Air Conditioner When Attic Air is Drawn into Air Handler, Assuming Room is 78° and Attic Air is 120°F.

Duct leak impacts upon winter peak electrical demand are much greater than summer peak electric demand. The reason for this is that heat pumps have electric resistance backup which can supply heat when the heat pump capacity is inadequate.

No data has been collected on the impact of duct leaks on summer or winter peak demand. A theoretical analysis is presented in Table 3 of duct leak impacts upon peak electrical demand in a typical house on a winter morning. The purpose of this analysis is to obtain a "ballpark" estimate of the magnitude of duct leak impacts on peak demand. The assumptions of the analysis are:

- A natural infiltration rate of 0.35 ach is assumed with an indoor temperature of 72°F and an outdoor temperature of 30°F. Fifty CFM duct leakage is assumed to interact with natural infiltration to produce 80 CFM of infiltration. At 100 CFM duct leakage it is assumed that mechanically induced pressures overwhelm natural forces.
- The floor area of the typical house is 1500 ft2. Construction is concrete slab, R19 attic, R4 block walls, 120 ft2 of single pane windows, and internal heat generation of about 1500 Btu/hr.
- House heating load is 25,000 Btu/hr after internal generation is subtracted, assuming no duct leaks.
- A 2.5 ton heat pump (sized for cooling load) which has a COP of 2.47 and heating capacity of 23,000 Btu/hr at 30°F

Because the heating load of the building is greater than the capacity of the heat pump, the AH will run constantly and the strip heat will cycle on and off to meet the load. Table 3 shows the added infiltration heating load, the added kW demand, and the resulting effective COP of the heating system relative to the initial heating load of 25,000 Btu/hr caused by duct leaks. A 30% return leak causes a 90% increase in electrical demand. The added infiltration heating load caused by the supply leaks is greater than for return leaks because the air lost from the house is hotter. A 30% supply leak causes more than 200% increase in electrical demand.

This analysis underestimates impacts in some ways and overestimates impacts in other ways. Underestimation occurs because the statewide average outdoor temperature on this winter day should be about 20°F instead of 30°F. Additionally, evaporative cooling from moisture in furnishings is not included. This affect may be large, but cannot be easily quantified. Overestimation occurs because some of the air drawn from buffer zones, such as attic, garages, and crawl spaces, is not as cold as outdoors. Inter actions of supply and return leaks in the same zone also are not considered.

Table 4. presents an analysis of the potential reduction in winter peak electrical demand and the associated construction costs for new generation capacity in the whole state of Florida. The following assumptions apply to this analysis:

- The distribution of duct leaks in the 3,000,000 electrically heated Florida homes (which also have duct systems) is the same as we have found in our sample of 91 homes. The supply leak estimates are based upon visual inspections in over 400 other homes.
- The kW demand reduction for each duct leak size is derived from Table 3.
- The cost of duct repair is based on the fee schedule of $40/man-hour.
- The cost of new electrical generation capacity is $700/kW.
- In determination of the combined reduction in demand from return and supply repairs, the total reduction is less than the sum of the two. This is because return leaks do not create added load when supply leaks are larger than the return leaks. The reason for this is that supply leaks draw in air to make up for that "pumped" out of the house by the supply leak. As an example, if you have a 1500 ft2 house with a large supply leak of 200 CFM, and no return leak, the infiltration rate will be 1.0 ach. If a return of 100 CFM develops, the house ach will remain 1.0 ach. Because the mix and interaction of return and supply leaks is difficult to assess, the total demand reduction at the bottom of Table 4. is an estimate based on only half of the return leak repairs producing actual demand reduction.

The results of this analysis show that repair of duct leaks can dramatically reduce Florida's winter electrical peak demand (most of Florida's utilities are winter peaking). At a typical cost of $200, duct repairs produce a 1.6 kW peak demand reduction per house, which has a new construction cost value of about $1100. Total peak demand reduction in the entire state of Florida is estimated at 5000 mw, or about 13% of the state's nameplate generation capacity. The cost of duct repair is estimated at $600 million and the avoided cost of new capacity is about $3.5 billion. Thus, duct repairs are a very cost-effective means of "building" new generating capacity.

Conclusions

Forced air distribution systems in Florida are leaky. Blower door tests found that on the average about 12% of the house ACH50 infiltration is in the duct system. These leaks cause the average infiltration rate of the sample of houses to increase by fourfold when the air handler is turned on.

Duct leaks cause significant increase in air conditioning energy use. Air conditioning energy use decreased 18% when duct repairs were made, which indicates that duct leaks were causing a 22% increase in energy use. Duct leak repair is very cost-effective. A typical $200 duct repair should save about $110 per year in cooling and heating costs, yielding a simple payback of less than 2 years.

The impacts upon peak electrical demand are even more dramatic, because the air handler is operating at its maximum (and thus, AH induced infiltration is at a maximum) and the air brought into the house is at its greatest temperature difference from inside. Based on theoretical calculations, a 15% return leak from the attic can decrease the effective capacity and efficiency of an air conditioner by 50%. Winter peak demand impacts are even greater, because when heat pumps run out of capacity, electric resistance backup kicks in to meet the added load caused by duct leaks. Repairing duct systems is an excellent means to provide "new" capacity to the electrical generation system. Calculations indicate that a typical $200 duct repair should reduce the winter peak by about 1.6 kW, which has an avoided capacity cost of about $1100.

Some recommendations follow from these findings. Utilities should consider beginning duct repair programs. Training programs should be established to train appropriate trades people in duct leak diagnostics, duct leak repair, and correct installation of duct systems. Building/energy codes need to establish guidelines which will ensure that new homes will have airtight duct systems, using materials which last the life of the building.

Acknowledgements

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Table 1 Infiltration and return Leak Fraction* (RLF) in 25 Homes Before and After Duct Repairs

	Before Repair			After Repair				

	ach Off	ach On	RLF %	ach Off	ach On	ach On % Reduc.	RLF %	RLF % Reduc.
1-CRO	.39	.99	14.5	.17	.27	72.7	2.7	81.3
2-KET	.33	.95	22.4	.16	.25	73.6	3.9	82.5
3-KAL	.15	.96	7.0	.19	.35	63.5	3.3	52.8
4-MER	.19	.88	26.1	.16	.49	44.3	2.4	90.8
5-RAI	.49	1.36	21.6	.13	.42	69.1	1.8	91.6
6-STA	.10	.99	15.4	.15	.49	50.5	2.7	82.4
7-SWA	.10	.97	6.6	.81	.83	14.4	3.0	54.5
8-VIE	.10	1.33	15.4	.27	.82	38.3	8.0	48.0
9-BRI	n/a	2.12	0.0	.64	1.5	42.3	4.7	0.0
10-CAR	.49	.72	8.8	.27	.38	47.2	0.0	100.0
11-CUS	n/a	.88	10.0	.19	.44	50.0	0.0	100.0
12-GAG	.46	1.45	29.1	.62	1.19	17.9	15.3	47.4
13-GRU	.10	1.77	10.3	.36	.47	73.4	1.1	89.3
14-GUD	.32	.77	32.9	.24	.49	36.4	10.5	68.1
15-HUG	.30	1.29	16.8	.08	.16	87.5	0.5	97.0
16-HUT	n/a	1.15	22.5	.05	.33	71.3	5.2	76.9
17-JON	.18	1.45	15.2	.15	.56	61.4	7.4	51.3
18-LAM	.07	1.26	36.1	.10	.68	46.0	13.4	62.9
19-LAU	.16	1.21	45.5	.23	.31	74.3	5.4	89.5
20-PEN	.14	.74	5.8	.13	.51	31.1	4.8	17.2
21-PET	.38	.76	4.0	.11	.48	36.8	0.0	100.0
22-PET	.10	1.07	19.5	.08	.44	58.8	4.2	78.4
23-RID	.16	.89	7.2	.42	.72	19.1	7.9	0.0
24-SUT	.44	1.20	23.0	.23	.31	74.2	3.5	84.8
25-WES	.24	1.16	0.7	n/a	.52	55.2	1.1	0.0
AVE.	.245	1.13	16.66	.248	.536	52.6	4.51	72.9

*Return Leak Fraction is the proportion of the return air flow which originates outside the house.

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Table 2 House Airtightness, Duct Airtightness, and Cooling Energy Use in 25 Homes Before and After Duct Repairs

	Before Repair			After Repair			Cooling Energy kWh		
	ACH50 Total	ACH50* w/o Ducts	ACH50 Reduc.	ACH50 Total	ACH50 % Reduc.	%Duct Leaks Repair	Before Repair	After Repair	% Reduc.
1-CRO	10.6	10.0	5.9	9.5	10.9	100.0	83.9	68.5	18.4
2-KET	5.3	4.5	15.4	4.6	12.5	81.1	35.6	26.1	26.7
3-KAL	6.8	6.4	8.3	6.6	2.1	39.6	28.0	26.9	4.2
4-MER	13.9	8.9	35.8	10.5	24.6	68.7	25.2	13.9	44.6
5-RAI	10.1	9.1	10.0	9.3	7.5	75.0	31.7	26.4	16.4
6-STA	8.4	6.9	17.8	7.5	10.4	58.4	35.1	30.0	14.4
7-SWA	11.7	8.6	26.9	9.5	19.2	71.3	n/a	n/a	n/a
8-VIE	11.4	9.6	16.0	9.9	12.5	78.1	17.4	15.3	12.0
9-BRI	35.6	32.5	8.7	33.4	6.1	70.1	58.5	56.4	3.5
10-CAR	19.4	17.5	10.1	18.5	4.9	48.5	29.6	23.3	21.4
11-CUS	9.3	8.9	4.6	8.9	4.3	93.4	41.2	38.8	5.8

12-GAG	22.1	19.9	9.9	20.2	8.5	85.8	48.4	43.0	11.1
13-GRU	13.1	11.4	12.8	12.1	7.7	60.1	57.1	54.6	4.5
14-GUD	6.4	4.9	23.5	5.9	8.8	37.4	56.8	38.1	33.0
15-HUG	10.3	9.0	12.4	9.1	11.4	91.9	41.3	34.1	17.4
16-HUT	6.6	4.1	38.9	4.9	26.3	67.6	25.1	17.7	29.5
17-JON	7.8	5.2	33.3	6.4	18.8	56.4	53.3	46.5	12.7
18-LAM	10.4	9.5	8.6	10.2	1.7	19.7	25.8	22.3	13.9
19-LAU	8.8	7.9	10.2	8.1	7.9	77.4	52.8	38.9	26.2
20-PEN	7.8	5.4	30.4	5.8	26.0	85.5	54.0	38.6	28.4
21-PET	10.0	8.5	15.0	9.1	9.7	64.6	36.5	33.9	7.2
22-PET	7.2	n/a	n/a	6.7	8.3	n/a	27.7	23.0	16.8
23-RID	25.0	23.4	6.5	24.6	1.8	51.2	62.2	55.0	11.6
24-SUT	8.1	6.6	18.8	7.2	10.9	57.9	44.8	36.7	18.0
25-WES	16.3	15.3	6.0	15.4	5.1	85.0	20.0	13.4	33.3
AVE.	12.10	10.58	16.0	10.95	10.72	67.7	41.33	34.23	17.96

*This ACH50 is with all supply and return registers covered by paper and tape.

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Table 3 Increased Heating Load (Btu/hr) and kW Demand from a Heat Pump with Electric Strip Heat Backup as a Result of Return and Supply Duct Leaks on a Florida Winter Morning

Duct Leak CFM	House ACH	Infil Load*	Duct Leak Added Load	Total Load	Heat Strip Load	Heat Strip kW	Total kW	Act˜ COP	EFF^ COP
Return Leaks									
0	.35	3136	-	25000	2000	.59	3.31	2.21	2.21
50	.40	3584	448	25448	2448	.71	3.43	2.17	2.14
100	.50	4480	1344	26344	3344	.98	3.70	2.09	1.98
150	.75	6720	3584	28584	5584	1.64	4.36	1.92	1.68
200	1.00	8960	5824	30824	7824	2.29	5.01	1.80	1.46
250	1.25	11200	8064	33064	10064	2.95	5.67	1.71	1.29
300	1.5	13440	10304	35304	12304	3.61	6.33	1.63	1.16
Supply Leaks									
0	.35	3136	-	25000	2000	.59	3.31	2.21	2.21
50	.40	4915	1779	26779	3779	1.11	3.83	2.05	1.91
100	.50	7385	4249	29249	6249	1.83	4.55	1.88	1.61
150	.75	11552	8415	33416	10416	3.05	5.77	1.71	1.27
200	1.00	16520	13384	38384	15384	4.51	7.23	1.56	1.01
250	1.25	22154	19018	44018	21018	6.16	8.88	1.45	0.82
300	1.5	28294	25158	50158	27158	7.96	10.68	1.38	0.69

*Calculation of house heat load resulting from return leak infiltration assumes that the house temperature is 72°F and the outdoor temperature is 30°F. Calculation of house heat load from supply leak infiltration assumes that the average temperature rise across the coil varies from 24°F to 47°F, depending on the amount of strip heat required, so that the air lost to the outdoors is considerably warmer than house air. The heat pump has a heating capacity of 23,000 Btu/hr at 30°F outdoor temperature, a 2.72 kW demand, and a 1000 CFM blower.
˜Actual heat pump COP is based on total load, including the load caused by the duct leaks.
^Effective heat pump COP is based on the original house heating load (25,000 Btu/hr), not including the load caused by the duct leaks.

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Table 4 Potential Reduction in Statewide Winter Peak Electrical Demand Resulting From Repairing Duct Leaks in Electrically Heated Homes in Florida.

duct leak %	housing* units (x1000)	repair cost (x10^6)	demand reduction kW/house	demand reduction mW	capacity value (x10^6)
Return Leaks					
2	1100	$55.0	0.05	55	$38.5
7	805	$60.4	0.26	209	$146.3
14	585	$58.5	0.92	538	$376.6
25	510	$76.5	2.36	1204	$842.8
total	3000	$250.4	0.67	2006	$1404.2
Supply Leaks					
2	450	$36.0	0.31	140	$98.0
7	1800	$180.0	0.91	1638	$1146.6
14	600	$90.0	2.22	1332	$932.4
25	150	$34.5	5.57	836	$585.2
total	3000	$340.5	1.32	3946	$2762.2
Return and Supply Leaks Combined					
total	3000	$590.9	1.65˜	4949	$3464.3

*The proportion of duct leaks in Florida's 3,000,000 electrically heated homes is extrapolated from tests results on 100 homes.

˜This assumes that only 1/2 of the calculated demand reduction due to return duct leak is counted. This assumption is made because repair of return duct leaks does not reduce the heating load when supply leaks are larger than the return leaks.

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