Air Handler Leakage Testing: Sierra Air Conditioning, Las Vegas, Nevada

Research Report - 0996

17-Sept-1999

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Abstract:

Duct leakage is a concern in the HVAC field, due to energy consumption, pressure balance problems, bypassing of the filter by leakage air, and contaminant draw from unconditioned spaces. Therefore, certain energy efficiency programs set duct leakage performance requirements that must be met to enter the program. However, the overall duct system tightness is limited by leakage at the air handler.

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Executive Summary

Duct leakage is a concern in the HVAC field, due to energy consumption, pressure balance problems, bypassing of the filter by leakage air, and contaminant draw from unconditioned spaces. Therefore, certain energy efficiency programs, such as Greenstone's Engineered for Life™, set duct leakage performance requirements that must be met to enter the program. However, the overall duct system tightness is limited by leakage at the air handler.

Tests were run on several air handler units, with cooling coils and plenums attached, to determine the unit leakage. Measurements were made by attaching a duct blaster calibrated fan to the return plenum. The supply plenum was a sealed box with no penetrations. Multipoint pressurization and depressurization tests were run, obtaining leakage values over a range of pressures. Similar tests were then conducted with the air handler unit alone (without cooling coils and plenums). The goals of these tests were as follows:

- Quantify the leakage of various air handlers, using a common test so units can be compared uniformly.
- Determine permissible field modifications to seal the air handler/furnace cabinet. This has been the stopgap measure in the past, but some manufacturers have considered the warranty void due to these modifications.
- Discuss possible modifications to air handler design in order to increase airtightness, and discuss status of these changes in progress by the manufacturers.
- Determine the approximate amount of leakage that can be attributed to the air handler in duct system leakage tests, to re-evaluate leakage targets for the Engineered for Life™ program.

Conclusions included the following points:

- Total air handler leakage, including the coils and plenums, ranged from 45 to 60 CFM 25. This was less than the expected 75 to 100 CFM 25.
- Air handler unit leakage alone ranged from 13 to 45 CFM 25; in general accounting for half of the total leakage. Coil and plenum leakage was calculated by subtraction, and ranged from 20 to 45 CFM 25. Since it will be easier to improve the sealing of the cooling coil section and plenums than the air handler units, the focus should be here first, while continuing discussions with the air handler unit manufacturers.

- Sealed combustion 90% AFUE furnaces were more leaky than the 80% powervented furnaces of the same manufacturers. The single-cabinet First Company hot water coil/DX coil air handler gave the tightest measurement (28 CFM 25), due to its unitized construction.

- Leaving the joints unsealed between the air handler unit and the cooling coils and plenums increased leakage by approximately 40%.

- All manufacturer installation directions should be followed, such as use and placement of cabinet screws, the removal of grommet plugs when soldering, and sealing of unused condensate line openings.

Background

Duct leakage is a concern in the HVAC field, due to energy consumption, pressure balance problems, bypassing of the filter by leakage air, and contaminant draw from unconditioned spaces. Therefore, certain energy efficiency programs, such as Greenstone's Engineered for Life™, set duct leakage performance requirements that must be met to enter the program. However, the overall system tightness reached by current duct-sealing methods is limited by leakage at the air handler unit (AHU).

Therefore, tests were run on 80% and 90% AFUE furnace/air handlers from various manufacturers (see Appendix A for complete list). Leakage values were measured both with attached coils and plenums, and standing alone (see Appendices B and C). Measurements were made by attaching a duct blaster calibrated fan to the return plenum. The supply plenum was a sealed box with no penetrations. Multipoint pressurization and depressurization tests were run, obtaining leakage values over a range of pressures.

The results included a CFM 25 measurement, the C and n values (flow coefficient and exponent), and R^2 (correlation coefficient). The C and n values provide a pressure-flow relationship for these units. However, this test does not simulate the complex pressure field that occurs in the air handler during operation (i.e., negative and positive pressures of various magnitudes in different parts of the unit simultaneously). Instead, it is meant as a way to compare various air handlers, and to determine a reference number for duct whole-system leakage tests.

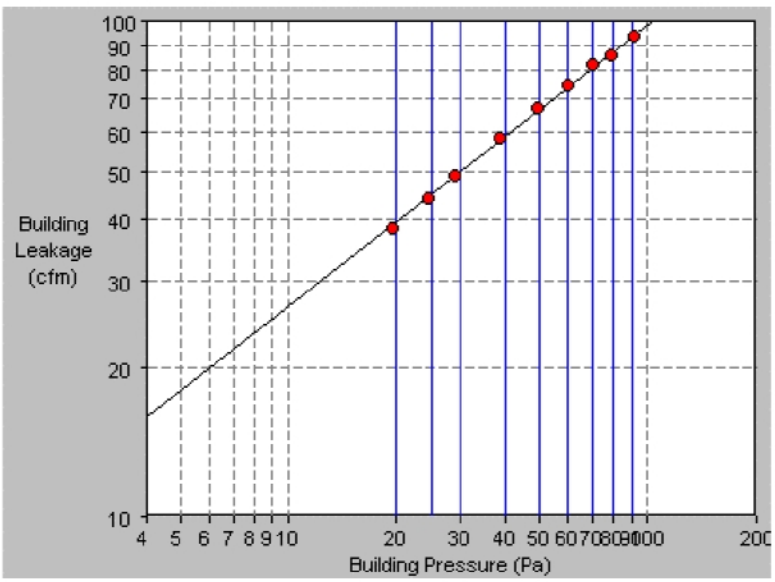
Representatives from International Comfort Products and York observed these tests. They were invited to determine permissible field modifications to seal the air handler/furnace cabinet. This has been the stopgap measure in the past, but some manufacturers have considered the warranty void due to these modifications. They were also on hand to discuss possible modifications to air handler design in order to increase airtightness, and to discuss status of these types of changes in progress.

Experimental Procedure

Five furnaces and one combination system air handler (hot-water fan coil and DX cooling coil unit) were tested. In addition to the basic leakage tests, the effects of sealing and unsealing condensate drain holes, refrigerant line holes, and unit joints were measured.

Air handler unit (AHU) with coil and plenums

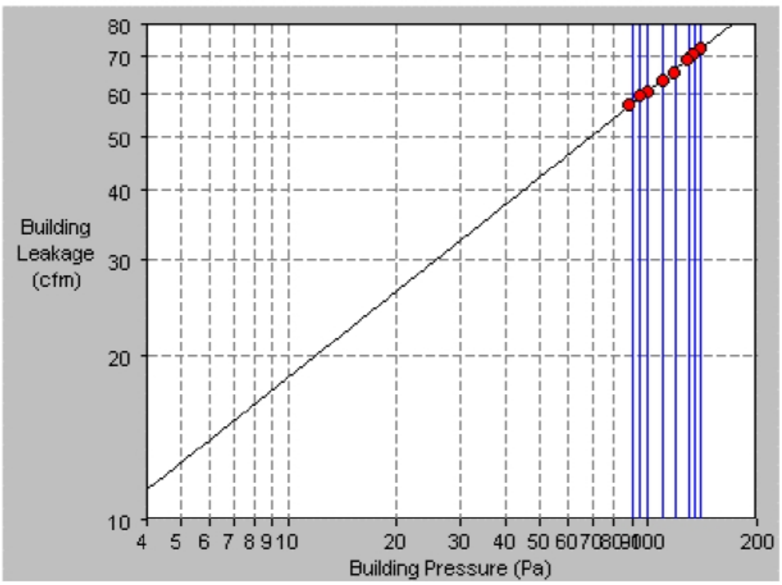
The AHUs were set up with a cooling coil unit, supply plenum, and return plenum attached, as per typical field installation. Joints between these units were taped. No takeoffs were attached to the supply plenum; the duct blaster was attached and sealed to the return side. Multipoint pressurization and depressurization tests were run; a typical run is shown below. Pressures of 90, 80, 70, 60, 50, 40, 30, 25, and 20 Pa were used. These values were chosen in order to bracket typical plenum pressures seen in operation (~20 Pa to ~70 Pa), and to have some overlap with the AHU-alone tests.



Typically, depressurization leakage amounts were smaller than pressurization leaks, but only by a small margin. This can be attributed to the fact that a depressurized cabinet would tend to draw loose-fitting parts tighter.

Air handler unit alone

Testing the AHU alone required a different test procedure. The plenums and cooling coil were removed; the supply side was sealed with cardboard and tape, or duct mask, and the duct blaster was attached to the return side. Multipoint pressurization and depressurization tests were run, using 140, 135, 130, 120, 110, 100, 95, and 90 Pa pressures (see below). These higher pressures were needed because the flows at lower pressures were too low for an accurate measurement. Therefore, the CFM 25 numbers shown in the results for these AHU-only tests are extrapolated from the curve calculated by the C and n values. However, the validity of the curve-fit is evidenced by high correlation coefficients (R^2 values). The correlation coefficients ranged between 0.98407 and 0.99991, with an average of 0.99708.



Results

The results of the basic tests were as follows:

AHU Description	Test	AHU w. coil and plenum CFM 25	AHU alone CFM 25	AHU leak % of total	Coil/plenum leakage (by subtract.)
York 80% Furnace	Pressurize	--	15		
50 kBtu input	Depressurize	58	10		
	Average	**58**	**13**	**22%**	**45**
York 90% Furnace	Pressurize	60	28		
50 kBtu input	Depressurize	60	30		
	Average	**60**	**29**	**49%**	**31**
ICP 80% Furnace	Pressurize	63	28		
50 kBtu input	Depressurize	55	27		
	Average	**59**	**28**	**47%**	**31**
ICP 90% Furnace	Pressurize	54[1]	50		
50 kBtu input	Depressurize	45[1]	38		
	Average	**50**[1]	**44**	**89%**[1]	**5**[1]
Frigidaire Furnace	Pressurize	45	29		
60 kBtu input	Depressurize	--	21		
	Average	**45**	**25**	**55%**	**20**
First Company 27J	Pressurize	28			
Fan Coil	Depressurize	27			
	Average	**28**			

[1]: In this test, the refrigerant line openings were sealed with tape; we were not aware of the change until after the test was completed. Therefore, the leakage values that include the coil are lower than the expected values, compared to other tests. This number also explains the anomalous values for % furnace leak of total, and the subtracted coil leakage measurement.

However, the AHU alone values are valid and consistent with the remainder of this test, since the coils were not included.

The table shows the CFM 25 measurements made by depressurizing and pressurizing (1) the air handler unit with cooling coils and plenums, and (2) the air handler alone. The CFM 25 value is computed from the C and n values given by the TECTITE software. Also shown is the fraction AHU leakage of the total leakage, and the coil/plenum leakage calculated by subtracting the AHU alone leakage from the total.

The leakage of the air handler with coil and plenums ranged from 28 to 60 CFM 25. The single-cabinet First Company hot water coil/DX coil air handler gave the tightest measurement, due to its unitary construction.

The leakage of the AHU alone varied from 13 to 44 CFM 25. Furnace leakage generally accounted for half of the total AHU leakage, except for the York 80% furnace, which was about a quarter, and the ICP 90% furnace. In the latter test, the total AHU with coil and plenum leak is not comparable to the other numbers, so the percent leakage is not a valid comparison (see Table footnote 1). The coil leakage values (calculated by subtracting the AHU-alone leakage from the total leakage) ranged between 20 and 45 CFM 25.

Leakage locations: Some tests were run to identify the leakage locations in these furnaces and coils. Furthermore, pressurization smoke tests were run for the same purpose. For the cooling coils, the most significant leak came from around the refrigerant line openings; which were visibly the largest holes in the unit.

In the air handlers alone, the most significant leaks occurred at the partition between the blower compartment and the wiring compartment (especially corners), and around the blower compartment door. These problems should be correctable with gaskets and/or improved design.

Further Tests

Tape and grommets: The York 80% furnace was tested with and without the foil tape at the seams to the plenum and coils, as well as the grommets around the refrigerant lines. These grommets are often melted out when soldering; they should be moved down the line before soldering and replaced after the line has cooled. Leakage increases by over 40% (24 CFM 25); hence, leaving these joints unsealed would have a strong and noticeable effect on duct leakage.

AHU Description	Test	Original CFM 25	No Tape CFM 25	Difference CFM 25	% difference
York 80% Furnace, 50 kBtu input	Depressurize	58	82	24	40%

Condensate drains: The First Company air handler was tested first with both condensate drains taped, then with one open. The resulting CFM 25 values are shown below. The difference is approximately 3 CFM 25. There are often two condensate drain openings on each side of the AHU to facilitate installation from either side. The side that is not used should be capped off. On the side that is used, one opening is for the p-trap and the other is a secondary opening for an overflow pan, if used. For residential units, p-traps are not usually vented because the AHU static pressure is not high enough to cause a backflow or splashing problem, as can be the case in large commercial air handler systems. It is worthwhile to cap off any unused condensate drains, and to use a closed (i.e., non-vented) p-trap on the condensate line.

First Company 27J Fan Coil	Pressurize	28	31
	Depressurize	27	--
	Average	**28**	**31**

It is also worthwhile to check the equivalent leakage areas, as specified by the Canadian EqLA model, and the Lawrence Berkeley Labs ELA model. The results are shown below:

	EqLA @ 10 Pa (Canadian)	**ELA @ 4 Pa** (LBL)
All condensates closed	5.0	2.7
One condensate open	4.4	2.3
Difference	**0.6**	**0.4**
Hole diameter (inches)	0.9	0.7

The equivalent diameter of the hole is on the order of 0.7" to 0.9", the values bracket the size of the opening of a ¾ nominal IPS pipe opening (0.82").

Discussions with Manufacturers and In-field modifications

One manufacturer explained the reasoning behind prohibiting sealing of the air handler cabinet. Currently, some of the leakage air passes out of the blower compartment through the controls section, providing some cooling of the solid state components in the summer. Sealing it may cause excess heat buildup. It may be just a minimal effect that can be measured and accounted for; however, it is logical that manufacturers would want to stay on the conservative side.

The refrigerant lines on the cooling coil case were a significant source of leakage in the whole-unit tests. Although the grommets had some sealing effect, there is room for improvement. A sealant should be chosen based on effective lifetime, adhesion to both surfaces, and compatibility with refrigerant line temperatures. Options mentioned at the test included caulk, mastic alone, mastic with mesh tape, and expanding foam sealant However, it should be noted that this may be a part that requires servicing (i.e., access to the orifice/metering device).

Finding a leakage allowance for duct tightness tests was one goal of these experiments. Brad Townsend (Greenstone) suggested that the coil and plenums be considered part of the duct system; i.e., the only leakage allowance will be for the AHU alone (i.e., 13 to 44 CFM 25 in these tests). The remainder of the system would be considered the responsibility of the contractor; including sealing of the coil box seams and around refrigerant lines. This field change should not have an effect on warranty or UL listings, and will result in a substantial improvement.

Conclusions

Conclusions included the following points:

- Total air handler leakage, including the coils and plenums, ranged from 45 to 60 CFM 25. This was less than the figure commonly used in the duct tightness testing field: 75 to 100 CFM 25.

- Air handler unit leakage alone ranged from 13 to 45 CFM 25; in general accounting for half of the total leakage. Coil and plenum leakage was calculated by subtraction, and ranged from 20 to 45 CFM 25. Since it will be easier to improve the sealing of the cooling coil section and plenums than the air handler units, the focus should be here first, while continuing discussions with the air handler unit manufacturers.

- Sealed combustion 90% AFUE furnaces were more leaky than the 80% powervented furnaces of the same manufacturers. The single-cabinet First Company hot water coil/DX coil air handler gave the tightest measurement (28 CFM 25), due to its unitized construction.

- Leaving the joints unsealed between the air handler unit and the cooling coils and plenums increased leakage by approximately 40%.

- All manufacturer installation directions should be followed, such as use and placement of cabinet screws, the removal of grommet plugs when soldering, and sealing of unused condensate line openings.

Appendix A: Equipment List

AHU Description	Furnace model	Coil model
York 80% Furnace, 50 kBtu input	G8CO5012MUB11A	Aspen BBH 36 + PLH 36
York 90% Furnace, 50 kBtu input	P3DHB12N05501A	Aspen BBH 36 + PLH 36
ICP 80% Furnace, 50 kBtu input	FBF050B12A4	Allstyle ASLB365010T
ICP 90% Furnace, 50 kBtu input	GNK050N12A3	Allstyle ASLB365011T
Frigidaire Furnace, 60 kBtu input	G6RA060C-12	Benchmark B35D36-17PA
First Company Fan Coil	48VAQ4	Included (4 ton coil)

Appendix B: Detailed data, Air Handler Unit with coil and plenums

AHU Description	Test	C	n	CFM 25	R^2
York 80% Furnace	Pressurize	--	--	--	--
50 kBtu input	Depressurize	6.2	0.692	58	0.99956
	Average			**58**	
York 90% Furnace	Pressurize	6.7	0.680	60	0.99768
50 kBtu input	Depressurize	8.2	0.618	60	0.99981
	Average			**60**	
ICP 80% Furnace	Pressurize	11.4	0.532	63	0.99431
50 kBtu input	Depressurize	9.4	0.546	55	0.99981
	Average			**59**	
ICP 90% Furnace	Pressurize	6.3	0.669	54	0.99426
50 kBtu input	Depressurize	7.9	0.542	45	0.99920
	Average			**50**	
Frigidaire Furnace	Pressurize	7.3	0.566	45	0.99925
60 kBtu input	Depressurize	--	--	--	
	Average			**45**	
First Company 27J	Pressurize	3.2	0.674	28	0.99980
Fan Coil	Depressurize	3.2	0.667	27	0.99991
	Average			**28**	

Appendix C: Detailed data, Air handler unit alone

AHU Description	Coil model	Test	C	n	CFM 25	R^2
York 80% Furnace	Aspen BBH 36 + PLH 36	Pressurize	0.9	0.869	15	0.99513
50 kBtu input		Depressurize	1.5	0.604	10	0.99426
		Average			**13**	
York 90% Furnace	Aspen BBH 36 + PLH 36	Pressurize	3.6	0.635	28	0.99225
50 kBtu input		Depressurize	5.4	0.537	30	0.99990
		Average			**29**	
ICP 80% Furnace	Allstyle ASLB365010T	Pressurize	2.2	0.793	28	0.99092
50 kBtu input		Depressurize	*3.9*	*0.603*	*27*	---
		Average			**28**	
ICP 90% Furnace	Allstyle ASLB365011T	Pressurize	11.8	0.449	50	0.98407
50 kBtu input		Depressurize	7.3	0.516	38	0.99988
		Average			**44**	
Frigidaire Furnace	Benchmark B35D36-17PA	Pressurize	5.5	0.519	29	0.99850
60 kBtu input	FAU270024	Depressurize	4.1	0.505	21	0.99931
		Average			**25**	

About the Author

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