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ATTN: Byron Degen

Dear Sir:

Enclosed is a report on the testing of the Building America prototype Degen residence in Houston, TX that was completed on June 16, 2005. An executive summary of our results is found on the following page. This home was also tested by NREL using tracer gas measurements to monitor more long-term air infiltration and house mixing.

Once you get a chance to look over this report, please feel free to call or email me (phil@buildingscience.com) with any questions.

Sincerely,

Philip Kerrigan Jr.
Building Science Corporation

cc: Joseph Lstiburek, Betsy Pettit (Building Science Corporation)

encl: TECTite Test
Snapshot Form Result

Executive Summary

Building Science Corporation tested the Degen residence in Houston, TX on June 16, 2005. It was given a full battery of tests, including multipoint blower door measurements; duct leakage (total and to the exterior), air handler static pressure measurements and airflow, and individual register flows.

Degen Residence

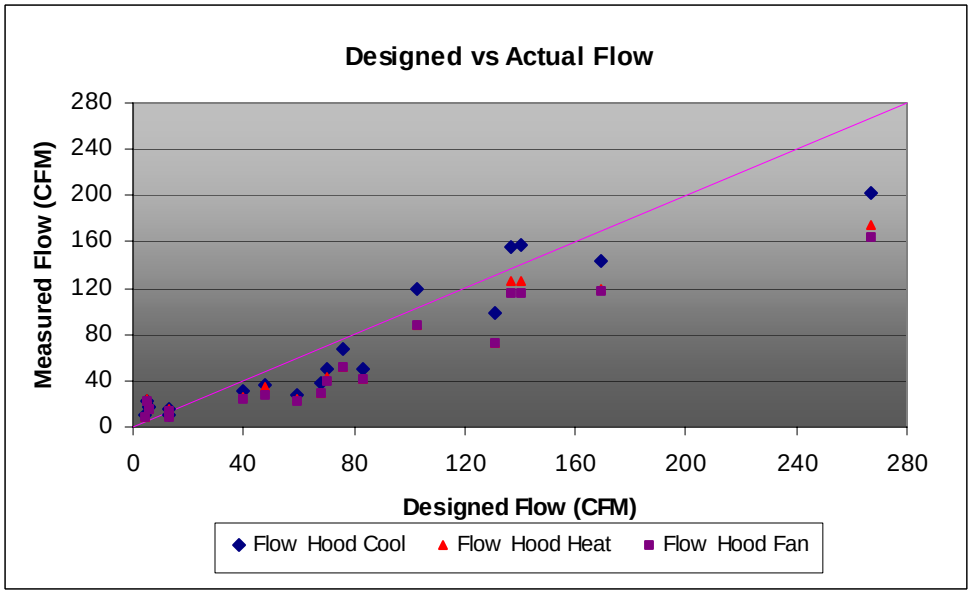
One multipoint blower door was taken to measure the airtightness of the building enclosure. The summary of our blower door data was as follows:

Test Description	CFM 50_{meas} CFM 50 Pa	CFM 50_{goal} CFM 50 Pa	Pass/ Fail	Leak Ratio
Normal operation (Fresh Air damper normally closed)	2850	935	Pass	0.08

The building enclosure is extremely airtight, due to the application of Icynene® spray foam on the walls and roof deck.

A duct airtightness test was run on the Degen residence; it met our requirement of 5% or less of nominal air handler flow duct leakage to outside (CFM 25), at about 2.5%. Total duct leakage was on the order of 20% (276 CFM), but this was a “finished stage” test, which includes the air handler leakage and the extra joints at the register terminals.

Individual register flows were measured as well; detailed information is provided in the report. Flows were close to the rates called out on the mechanical plans (~88%), and at ~363 CFM/ton, the flow is reasonably close to the 400CFM/ton that we specified (and used in our HVAC sizing calculations). Below is a chart showing the relationship between the designed flow and what was measured. Points above the line show flows that were measured above what was designed, and points below are flows below that were designed. The lower CFM flows were meeting the design, however most of the larger flows were missing.



The static pressures in the supply and return plenum were slightly higher than specification, due to the Aprilaire 5000 air cleaner. However, performance should not be affected too much.

Pressure levels in the bedrooms were measured and the Master Bedroom was slightly high. This is due to high flows in the Master Bath. The Master Bath can be dampered down to meet the occupant's comfort level.

We were impressed by the HVAC system layout as well as the spray foam application itself. As the pictures below show, installations were neat and clean, with straight duct runs and well-sealed joints.

Lastly, the homeowner observed high electricity bills throughout the first few months of occupancy. Upon arrival, BSC observed that the thermostat was set to FAN ON. Rather than having the fan on 100% of the time, the fan was set to AUTO to allow the fan cycling controller intermittently turn on the fan to provide mixing. Also, the dehumidification settings on the Carrier air handler were disabled because the Aprilaire system is responsible for dehumidifying the house air. Both of these changes should alleviate much of the problem

It appears that the system is over ventilating, which could be contributing to the high electric bills. A manual damper was NOT installed to dial in the correct flow separate of the mechanical open/shut damper.

A manual damper should be installed on the fresh air duct to allow altering of the fresh airflow.

Airtightness (Blower Door)

Measured (normal operation): 935 CFM 50 (0.08 leak ratio; pass)

Target: 2850 CFM 50 (2.5 leak ratio)
Leak ratio is square inches of leakage area (EqLA) per 100 sf of building envelope surface area.

Data from multipoint test (normal operation): C=67.1; n=0.674; r^2 (correlation coefficient)=0.99947

Building Envelope (Other)

Duct leakage

We measured total duct leakage at finish stage; this is different from the leakage test done at rough, since it measures the entire duct system (supply ductwork, air handler, and return plenum), and also allows leakage around the boot to the attic (since the face of the duct is taped, instead of the raw boot). As a result, the leakage is typically higher than rough stage tests. (276 CFM 25 total duct leakage).

Next, we measured duct leakage to the outside; an explanation of this method is found on Energy Conservatory's website, as well as BSC's site (under Building America -> Performance Targets -> Snapshot Instructions). Basically, using the blower door and duct blaster together can isolate duct leakage to what is connected to the outside. The result met specifications (~32 CFM 25 to outside; 70 CFM 25 goal with 3.5 ton AHU).

Duct Distribution System

The individual register flows were measured with an Alnor Flow Hood. Our goal was to compare our measurements with design flows.

	Room	Spec Flow	Qty	Dia	Flow per Reg	Alnor Flow Hood Flow Cool On	% of spec	Alnor Flow Hood Flow Heat On	% of spec	Alnor Flow Hood Flow Fan On	% of spec
1	Family	70	1	6	70	50	71%	43	61%	40	57%
2	Entry	59	1	5	59	27	46%	24	41%	22	37%
3	Powder	4	1	4	4	10	250%	8	200%	8	200%
4	Bedroom 3	131	2	6	66	98	75%	72	55%	72	55%
5	Bath 3	13	1	4	13	16	123%	16	123%	14	108%
6	WIC	13	1	4	13	10	77%	10	77%	8	62%
7	Utility	48	1	5	48	37	77%	34	71%	27	56%
8	Study	83	1	6	83	50	60%	41	49%	41	49%
9	Dining Room	103	1	7	103	120	117%	89	86%	88	85%
10	Master Bath	140	2	6	70	158	113%	127	91%	115	82%
11	M. Bedroom	137	2	6	69	156	114%	127	93%	116	85%
12	Family Room	267	3	6	89	202	76%	174	65%	164	61%
13	Master WIC	6	1	4	6	17	283%	16	267%	16	267%
14	Kitchen	68	1	6	68	38	56%	29	43%	29	43%
15	Bath 2	5	1	4	5	22	440%	24	480%	22	440%
16	Breakfast	169	2	6	85	144	85%	120	71%	117	69%
17	Pantry	6	1	6	6	18	300%	17	283%	16	267%
18	Bedroom 2	76	1	4	76	68	89%	52	68%	51	67%
19	Over Garage	40	1	4	40	31	78%	26	65%	24	60%
Total		**1438**				1272	88%	1049	73%	990	69%

Taking into account the duct loss, the total measured cooling airflow is 1548 CFM (1272+276 CFM). A 3.5-ton air handler should provide enough airflow to condition the home.

Duct blaster taken at ceiling return

AHU with Aircleaner at right

Air Handler Flow/Static Pressures

The total air handler flow was also measured (at cooling/fan-on speed) using the TrueFlow flow plate; the result was 1195 CFM (within 6% of the flow measured above). The TrueFlow plate was placed in the Aprilaire 5000 air cleaner filter slot (shown in previous picture).

The table below shows the two cooling CFM measurements and the CFM/ton delivered to the home.

Measurement	CFM	CFM/ton
Total airflow at registers	1272	363
TrueFlow @ AHU	1195	341
Total flow - Design	1438	411

Aprilaire 5000 air cleaner at return

Aprilaire 5000 air cleaner filter media

The static pressures were within spec as well. We measured for E.S.P. (external static pressures) 18.6 Pa (0.0744 WIC) in the supply plenum, and 135 Pa (0.540 WIC) in the return, for a total of 153.6 Pa (0.614 WIC). Although these are good pressures, the high reading at the return plenum comes from the air cleaner. The return pressure take upstream of the air cleaner was 61.7 Pa (0.2468 WIC), resulting in a pressure drop of 73.3 Pa across the air cleaner. Most manufacturers prefer to have their equipment at 0.5 WIC (125 Pa) ESP or less; Building Science Corporation would ideally like to see pressures at +30 Pa (0.12 WIC) supply side; and -40 to 50 Pa (0.16-0.20 WIC) return side.

The return is installed in the ceiling of the family room. The installed 32”x25” grille was larger than the 26”x28” sized by BSC, resulting in a very quiet HVAC operation.. BSC designed the return duct to be 22”, however the return duct was 18”. However, the extra large grille compensates for the increased return velocity and no whistling or fan noise was noticed.

Ventilation/Dehumidification System

The HVAC system was designed with the typical 6" duct feeding into the return of the air handler, along with an Aprilaire damper to open and close the fresh air per the ventilation system control.

Separate Aprilaire dehumidification system

Fresh air intake going into return box

The system was designed to provide ventilation consistent with ASHRAE Standard 62.2. Below is the ventilation rate, Equation (1), dependant on the number of occupants and the size of the conditioned area:

$$\dot{Q}_{cont} = 7.5P + 0.01Area \quad (1)$$

where:

$\dot{Q}_{cont}$ = Continuous ventilation rate in CFMs.
P = # of occupants = # Bedrooms + 1
Area = Nominal sf area

This is a net average of 67 CFM according to ASHRAE 62.2.

Pressures were taken at the fresh air duct at the three operating modes. Below is a table outlining the measured pressures and corresponding flows.

Measurements	**Cooling**	**Heating**	**Fan**
Fresh air duct pressure	-56.0 Pa	-40.5 Pa	-31.9 Pa
CFM flow in 6" duct	120 CFM	105 CFM	90 CFM

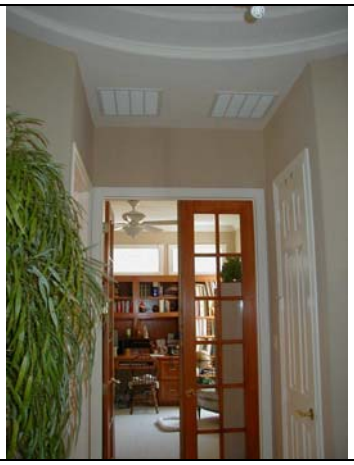
It appears that the system is over ventilating, which could be contributing to the high electric bills. A manual damper was NOT installed to dial in the correct flow separate of the mechanical open/shut damper.

A manual damper should be installed on the fresh air duct to allow altering of the fresh airflow.

A separate dehumidification system was installed to provide dry air independent of HVAC operation. It was installed correct

Room Pressures/Transfer Grilles

Air pathways were provided through jump ducts in the unvented attic.

	
Jump duct grilles at ceiling	Jump duct up in unvented attic space

Conditioned Attic

This home was insulated at the roof deck using 8" of Icynene spray foam. Below are some pictures showing the installation.

	
Roof deck insulation	8" covering rafters

The spray foam sealed the roof and walls and was primarily responsible for the excellent blower door results.

Hot Water Heater

A Rinnai Continuum instantaneous water heater was installed in the unvented attic space. The unit is a sealed combustion appliance and exhausts through concentric pipes through the roof. A remote control is installed in the attic next to the unit.

If the homeowner wants to have easier access to the remote it can be relocated to the master bath or kitchen.

Rinnai Continuum Instant Hot Water in Attic

Rinnai sealed combustion through roof

The foam was sprayed directly to he pvc exhaust pipe to provide an excellent air seal.

Rinnai sealed combustion through foam

Rinnai flue on roof

Miscellaneous

Two Solatubes were installed to provide natural lighting in the Master WIC and the main living area.

	
Solatube on roof	Solatube in Master WIC

Weep hole were left on the bottom of the brick veneer and above the windows.

	
Weep hole	Weep hole over window

Monitoring Setup

After testing the home, 5 T/RH HOBO's were installed in the Master Bedroom, Family Room, TSTAT, Office space, and the unvented attic. These will track the temperatures and % relative humidities every hour in these individual spaces.

The added complexity of the ECM airhandler and the separate dehumidification system prevented a full runtime-monitoring configuration to be setup. Also, BSC is interested in installing temperature sensors in in the shingles and roof foam. This will have to be finished on the next field visit.