



Photo 1: Rear entrance of the ASHRAE headquarters building.

Measuring Airtightness At ASHRAE Headquarters

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Building envelope air leakage can have important impacts on building energy consumption, indoor air quality and building moisture issues.^{1,2} While the importance of controlling building envelope air leakage has long been appreciated by some designers and building investigators, awareness of the issue has been increasing in recent years.³ Although only limited airtightness data on commercial buildings exists, these data reveal that commercial building envelopes are generally quite leaky and that there is no trend of increasing airtightness in newer buildings.^{4,5}

As the ASHRAE headquarters renovation started moving into the design phase of the efforts to achieve a high level of building performance, the lack of an envelope airtightness value was identified

as a gap in the pre-design assessment of the building. As a result, an airtightness test of the building was conducted in late April 2007, and the results are presented in this article. Also, since these tests have

not always been part of common building practice, but are expected to become more common in the near future, this article describes the test procedure in detail.

Building Description

The ASHRAE headquarters building, located north of downtown Atlanta, is two stories with a heavy steel frame on a slab-on-grade foundation. It is clad with

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a curtain wall system composed of glass and spandrel panels. Two variable air volume (VAV) air handlers and two smaller perimeter units provide heating, cooling and dilution ventilation for the building. Pressure relief for the air-side economizer on the two VAV units is provided by relief dampers located in the return air plenum of each floor. Outlets for the pressure relief are located on the roof. Toilet exhaust is provided by a rooftop exhaust fan. There is 15,160 ft² (1408 m²) of floor space on each of the two floors. It was originally constructed in 1965 and was last renovated in 1991. A photograph of the building is shown in *Photo 1*, and *Table 1* contains the building dimensions.

Pressure Testing of Building Airtightness

The tests of the building's envelope airtightness were conducted in accordance with the American Society of Testing and Materials Test Method E779.⁶ In these tests, a fan is used to create a series of pressure differences across the building envelope between the building interior and the outdoors. The airflow rates through the fan that are required to maintain these induced pressure differences are then measured. Elevated pressure differences of up to 75 Pa are used to override weather-induced pressures, such that the test results are independent of weather conditions and provide a measure of the physical airtightness of the exterior envelope of the building.

The pressure difference and flow data are generally fit to a curve of the form:

$$Q = C \times \Delta p^n \quad (1)$$

where

Q is the airflow rate, Δp is the indoor-outdoor pressure difference, C is referred to as the flow coefficient, and n is the flow exponent. Once the values of C and n have been determined from the test data, the equation can be used to predict the airflow rate through the building envelope at any given pressure difference. The test results are generally reported in terms of the airflow rate at some reference pressure difference divided by the building volume, floor area, or envelope surface area. Such normalization accounts for building size when interpreting the test results. Test results are often expressed as an effective leakage area, which is the equivalent orifice area across which the airflow rate through the building envelope would occur at a particular reference pressure. The effective leakage area (ELA) is determined using the following equation:

$$Q_{ref} = ELA (2 \Delta p_{ref} / \rho)^{1/2} \quad (2)$$

where

Q_{ref} is the airflow rate through the building envelope at the reference pressure Δp_{ref} and ρ is the air density.⁷

Testing Protocol in the HQ Building

To prepare the building for fan pressure testing of the enclosure, the exterior doors were closed, the air handlers and exhaust fans were shut down, and the outdoor air and exhaust dampers were closed. Dampers were checked to see how well they closed, and all but one relief damper were tightly closed. The vanes on

Floor Area (each floor)	15,160 ft ² (1408 m ²)
Building Height	24.3 ft (7.4 m)
Building Volume	368,900 ft ³ (10 430 m ³)
Surface Area: Above-Grade Enclosure	27,600 ft ² (2564 m ²)

Table 1: Building enclosure data for ASHRAE HQ.



Photo 2 (left): Relief dampers from the second floor plenum to rooftop did not close. Photo 3 (right): Blower doors installed in exterior doors.



Figure 1: Building floor plan showing location of blower doors.

the relief damper in the second floor plenum were open an inch (*Photo 2*). These were closed manually until the seal was tight. Rooftop openings for the exhaust, relief, and outdoor air intakes were sealed using duct mask. All the interior doors were opened, including the stairway doors between the first and second floors, to better equalize the interior air pressure in the building.

Three blower doors were set in polyethylene shrouds in two of the exterior doors. The blowers were initially set to depressurize the building. One of the blower doors was placed so that it could depressurize the second floor through the fire egress stairs. *Photo 3* shows a blower door in one of the shrouds. *Figure 1* shows the locations of the blower doors on a first floor plan.

A data logger with pressure difference sensors was used to continuously collect and display the pressure differences across all four exterior walls, between the first floor and the second floor and across the nozzles of the three blower doors. The pressure sensors attached to the blower door flow nozzles allow calculation of airflow through the fans.

By monitoring the real-time display, the effect of wind on the pressure differences can be assessed and many data pairs of flows and induced pressure differences can be collected.

The blower doors were turned on one at a time and the flows adjusted to maintain a zero pressure difference between the first and

second floors over a range of indoor to outdoor pressure differences. When enough data was collected to provide a good curve fit, the fans were reversed and the process repeated to determine whether pressurizing the building produced different results. The flow-induced pressure data pairs were sorted for times when the wind effects were low and fit to an equation of the form of Equation 1.

The results of the measurements are shown in *Figure 2*. The uncertainty of the airflow rate measurements are on the order of 5%, and, therefore, the difference between the results from depressurizing and pressurizing the building are not significant. This indicates that the test pressures are not blowing or sucking open any significant leaks.

How Tight is the Building?

Table 2 contains the test results in the form of a number of metrics commonly used to express the airtightness of building enclosures. The effective leakage area or ELA at a reference pressure of 0.016 in. w.g. (4 Pa) is listed first, followed by the airflow rate through the building enclosure at a reference pressure of 0.2 in. w.g. (50 Pa), normalized by the building volume. This latter metric is commonly referred to as the ACH50. The ELA is normalized by the above grade enclosure surface area in the third row of the table. Finally, the airflow rate at reference pressures of 0.2 in. w.g. (50 Pa) and 0.3 in. w.g. (75 Pa) normalized by the enclosure surface area are presented in the last two rows.

The National Institute of Standards and Technology (NIST) has been maintaining a commercial building airtightness database since the 1980s,^{4,5} which provides a means to put the results for the HQ building in the context of other commercial buildings. This database has recently been updated with the inclusion of 22 additional buildings in New York state⁸ and now contains about 230 buildings. *Figure 3* is a plot of the dataset with the ASHRAE HQ building shown as a solid blue hexagon on the graph. The plot shows the airflow rate through the building enclosure at a reference pressure of 0.3 in. w.g. (75 Pa) plotted against the year of building construction. These data exhibit no trend with year of construction, providing no support to the common assumption that new buildings are tighter than older ones.

There are no target tightness levels required by regulation or building programs for commercial buildings in the United States. The Battery Park City Authority Residential Environmental Standards⁹ requires residential apartments to be compartmentalized by air sealing to a tightness of 1.25 in.² ELA per 100 ft² of apartment enclosure, including the bounding walls, ceiling, and floor area of each apartment. British Building Regulations have had an airtightness requirement of 10 m³/h·m² enclosure area at 50 Pa for newly constructed buildings since 2002. However, 2006 building regulations requiring significant reductions in building energy use have resulted in lower airtightness targets.¹⁰ Guidance in the British Air Tightness and Testing

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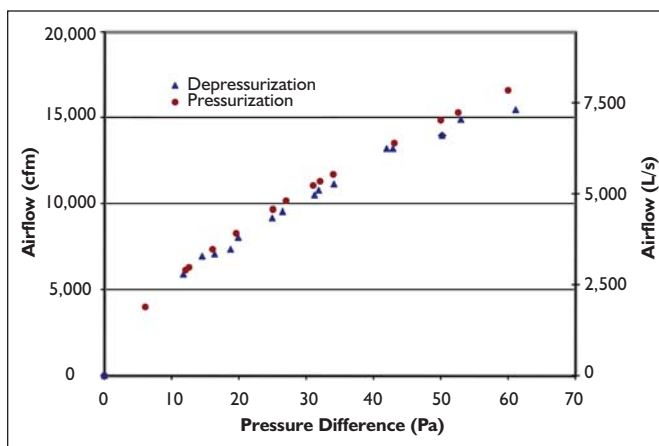


Figure 2: Pressure test data.

Measurement Association (ATTMA) Technical Standard 1 lists best practice and normal practice tightness levels for a number of different building types.¹¹ For air-conditioned office buildings, best practice is 2 m³/h·m² enclosure area at 50 Pa, and normal is listed as 5 m³/h·m².

Where Are the Leaks?

The largest air leaks in many commercial buildings occur in the interstitial spaces. These are locations where the enclosure

	Depressurization	Pressurization
ELA4, in ² (cm ²)	872 (5630)	891 (5750)
ACH50, h ⁻¹	2.3	2.4
ELA/Enclosure Area in. ² /ft ² (cm ² /m ²)	0.031 (2.2)	0.032 (2.2)
Airflow Rate at 0.2 in. w.g. (50 Pa), cfm/ft ² (m ³ /h·m ²)	0.514 (9.4)	0.542 (9.9)
Airflow Rate at 0.3 in. w.g. (75 Pa), cfm/ft ² (m ³ /h·m ²)	0.651 (11.9)	0.689 (12.6)

Table 2: Test results.

finishes, air sealing goes unseen, and where utilities and HVAC equipment penetrate the enclosure. The most likely location for leaks in a building with a soffit design like ASHRAE HQ is in the soffit area, which has been described previously.¹² Soffits are often poorly detailed for air leakage control, or if the details are in the construction documents they are often poorly installed.

In the case of the ASHRAE building, the details are in the architectural drawings (Figure 4) and have been fairly well

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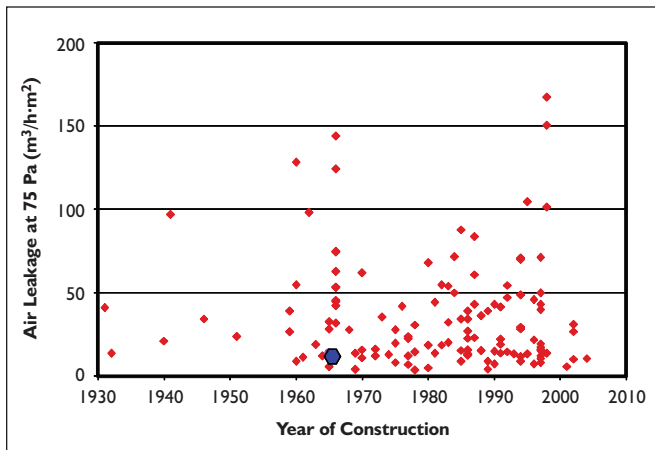


Figure 3: Commercial building airtightness showing ASHRAE HQ building (blue hexagon).

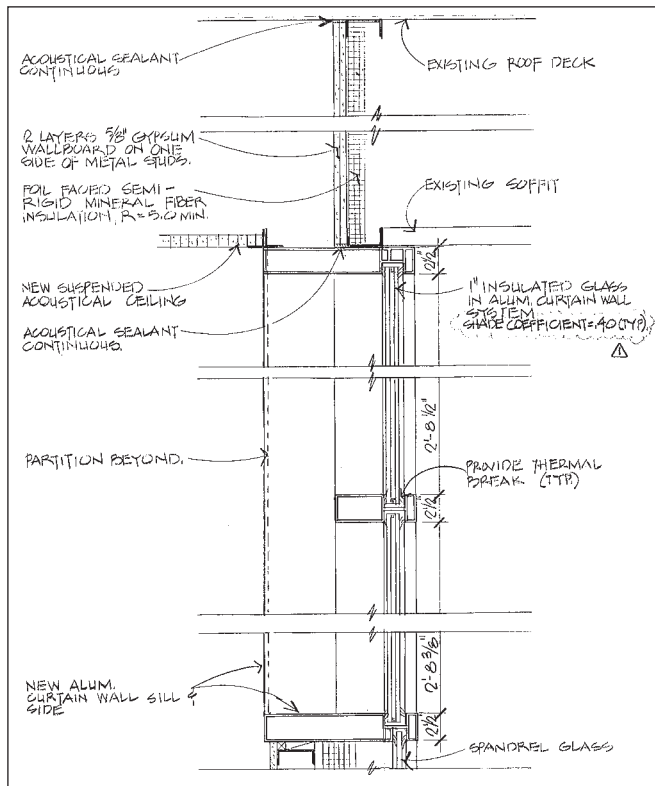


Figure 4: Soffit detail from architectural drawings for the 1991 renovation of the ASHRAE HQ building (Newcomb and Boyd).

installed (Photo 4). The renovation included using gypsum board and mineral wool insulation board to extend the air and thermal barrier provided by the curtain wall system from the top of the curtain wall to the bottom of the roof deck. Although generally well installed, a few areas exist where air leakage still occurs. For example, the joint between the top of the curtain wall and the gypsum board has not been sealed and shows no sign of the acoustic sealant specified in the drawings (Photo 5). In areas where the wall below jogs, the detail in the soffit area above was not clear and is difficult to seal (Photo 6). It is



Photo 4: Gypsum board separating the second floor plenum from the soffit has been installed with a good fit around structural steel and sealed with joint compound.



Photo 5: Joint at bottom of gypsum board has not been sealed.



Photo 6: Sealing detail at a jog in the wall section is incomplete.

likely that air leaks occur where the flutes of the steel roof deck meet the gypsum board seal.

Conclusions

Although built in 1965, the ASHRAE HQ building just meets the 2002 U.K. requirement of $10 \text{ m}^3/\text{h}\cdot\text{m}^2$. With some air-sealing work, it could perhaps meet or exceed the 2006 normal practice of $5 \text{ m}^3/\text{h}\cdot\text{m}^2$. It would probably take a lot of effort to reduce enclosure leakage by more than a factor of three to meet the best practice target of $2 \text{ m}^3/\text{h}\cdot\text{m}^2$.

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