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BY

J. R. SASAKI

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An apparatus and the technique for determining the air leakage performance of a wall, window or door under laboratory conditions are available; they are set out in ASTM test method E 283. In its simplest configuration, the test apparatus consists of an airtight chamber that is sealed against the test specimen, and a blower that supplies air to the chamber through a flow meter (Figure 1).

Air is supplied to the chamber at a rate sufficient to maintain a specified static air-pressure difference across the specimen. Neglecting extraneous leakage from the chamber, the air leakage through the specimen at the specified pressure difference is equal to the air flow measured by the flow meter. The measured air leakage for openable windows and doors is usually expressed in terms of the length of crack around the perimeter of the openable sash or door panel. Leakage through a wall is expressed in terms of the over-all wall area.

The actual details of test apparatus meeting the intent of the test method vary considerably from the foregoing simple description. All apparatus, however, have these essential features: an air-tight chamber; a flow meter; an air-flow generator; and, a manometer.

Before discussing the uses and limitations of this test method, it might be helpful to first review the implications of air leakage on the performance of a building, and to describe the forces causing air leakage.

AIR LEAKAGE

Air leakage is the uncontrolled flow of air that occurs between the outdoor and indoor environments through the building envelope, that is, through the walls, windows, doors and roof. Both infiltration (the air flow in to the building) and exfiltration (the air flow out of the building) affect comfort conditions inside the building and the durability of the building envelope itself.

Air infiltration increases the heating load of a building in winter and the cooling load in summer (1). A reasonably accurate estimate of the air tightness of the building envelope is required, therefore, to determine the proper size of the heating and cooling equipment. Infiltration of cold, dry, outdoor air in winter tends to reduce the indoor relative

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humidity below that desired for occupant comfort, and produces uncomfortable drafts on occupants situated adjacent to the leakage locations. In addition, cold air infiltration reduces the inside surface temperature of the building envelope and this can produce surface condensation and uncomfortable radiation conditions. Air infiltration also introduces contaminants such as smoke, soot, dust and odours into the building.

It must be recognized, however, that not all air infiltration is bad. In buildings without mechanical ventilation, infiltration is one of the primary mechanisms for removing odours and excess moisture from the occupied space. Walls and windows in such buildings, therefore, do not require perfect air tightness, but do require some limiting leakage characteristic that will allow the required air change without producing excessive heat loss or discomfort.

The exfiltration of moist indoor air in winter often leads to interstitial condensation within the elements of the building envelope. A visible example of this is interpane condensation in openable double windows. Interstitial condensation within the hidden parts of a wall or roof can be even more serious since its occurrence may not become apparent until severe deterioration has occurred.

A great deal of attention has recently been focused on building air tightness because of its effect on fire safety in high-rise buildings. The air leakage characteristic of the building envelope affects the movement of air inside a building and this, in turn, affects the spread of smoke during a fire. Many of the methods being considered for controlling smoke movement in high buildings, especially those utilizing the building's own mechanical ventilation system, require an accurate estimate of building air tightness.

A building designer, therefore, desires not only a building with maximum air tightness, but also a method for predicting the air tightness of the completed building. ASTM test method E283 is one of the means available for achieving these aims.

PRESSURE DIFFERENCE

The pressure difference that causes air leakage in a building can result from a number of factors, the main ones being wind action on the building, a temperature difference between inside and outside air, and the operation of the building mechanical ventilation system.

Wind action on a building produces positive pressures on the windward faces of the building causing infiltration, and negative pressures on leeward faces causing exfiltration. The magnitude and distribution of the pressure differences depend on the direction and speed of the wind, the influence of terrain and surrounding buildings, and the height and shape of the building. It should be noted that air leakage, unlike structural integrity, does not affect the safety of either the building or its occupants, except in case of fire. The air leakage experienced under short-term maximum wind conditions is, therefore, not usually important. Of great importance, however, is the leakage experienced under wind conditions that occur more frequently and for longer periods. For most buildings, wind speeds in excess of 25 mph do not significantly affect air leakage problems.

A temperature difference between indoor and outdoor air produces a pressure difference across the building envelope called chimney or stack effect, and is the same mechanism that produces a draft in a chimney. This air pressure difference is a function of the building height and the magnitude of the temperature difference between indoor and outdoor air.

For example, a 25-storey heated building exposed to an outdoor air temperature of 15°F can experience an inward pressure difference equivalent to the stagnation pressure of a 20-mph wind at the bottom of the building. A corresponding outward pressure difference causing exfiltration occurs at the top of the building. Stack effect can, therefore, be a major mechanism for air leakage in high-rise buildings exposed to severe winter conditions.

Stack effect is dramatically illustrated in a multi-storey building with operable double windows. In cold weather, windows in the upper stories will experience interpane condensation due to exfiltration of indoor air, while those in the lower stories will be free of condensation because of the infiltration of dry outdoor air. Stack effect is also a primary cause of roof condensation in houses in cold weather. The stack action induces the flow of moist indoor air from the occupied space into the cold attic where it condenses.

The air pressure difference produced by the mechanical ventilation system depends on the air tightness of the building and on the imbalance between the supply and exhaust fans. Building designers at one time sought to pressurize buildings mechanically in an effort to reduce air leakage into them. This practice, however, is of doubtful value in most cold-weather regions since building pressurization will increase the exfiltration of moist indoor air and aggravate the problem of interstitial condensation.

Anyone intending to use ASTM test method E283 should have some knowledge of the forces causing air leakage in buildings since it is their responsibility to specify, not only the limiting value of permissible air leakage, but also the pressure difference at which the air leakage is to be measured.

Adequate information can be obtained by testing at one or both of two air pressure differences, depending on the intended use of the element tested. The air leakage of walls and windows intended for a low building in a moderate wind region can be determined at a pressure difference of 1.56 psf, the static pressure equivalent of a 25-mph wind. The leakage of walls and windows intended for a very high building in a cold-weather region or a high-wind region can be determined at a pressure difference of 6.24 psf, the static pressure equivalent of a 50-mph wind. The foregoing air pressure differences are used throughout the window and curtain wall industry for testing purposes (2, 3, 4).

USES AND LIMITATIONS OF ASTM TEST METHOD E283

A test method similar to E283 has been used for many years for determining window air leakage performance. The method was used to rate the leakage performance of a specific window against an arbitrary performance level contained in a window standard or established by those requesting the test. Method E283 is still used widely for this type of check on the quality of the design and manufacture of factory-assembled elements such as windows, doors and curtain walls.

The other major use of E283 is in prototype testing of a wall-window system intended for a specific building. An air leakage test performed on a prototype of a real wall system will indicate the leakage sources that can occur during its field assembly, and will identify the joints that must be sealed on site. This use of a laboratory test to check the quality of the field assembly technique is a very powerful tool for ensuring good air tightness of the completed building.

The leakage results obtained from prototype testing should not, however, be misused for heating and cooling load calculations or for designing smoke control measures. There is no guarantee that an air leakage value obtained in a laboratory test is representative of the air tightness of the complete building envelope, and this is due to the inherent limitations of the test method.

A laboratory test such as E283 must be conducted on a relatively small segment of the total building envelope. Tests are rarely conducted on specimens greater than 30 ft square and are more often performed on much smaller specimens. A test specimen of limited size usually does not include the columns and floor beams that occur in the building. The absence of these structural elements in the specimen is a real deficiency since it is the interference of these components that can produce poor workmanship on site and reduce the air tightness of the wall and window elements as installed in the building.

Another shortcoming of laboratory testing is that usually the test specimen is relatively new. The leakage values obtained for such a specimen cannot be expected to indicate the leakage performance of the same specimen after it has aged in use.

The inability of laboratory test method E283 to duplicate or account for real workmanship and aging is the reason why this method should not be relied upon entirely for predicting the in-use air leakage performance of walls and windows.

There is another method for predicting the air tightness of a building, namely, to look at the leakage characteristics of different building envelopes obtained from tests performed on complete buildings. Studies of this type have been conducted by the Division of Building Research for the past few years on a number of multi-storey buildings (5, 6). The leakage characteristic of the building envelope is obtained by pressurizing the building with its own mechanical ventilation system and then measuring the air flow through the supply fan and the resultant pressure drop across the building envelope.

In high-rise buildings, the leakage through the walls of the mechanical equipment room and the first floor lobby differ substantially from the leakage through the remaining walls. DBR has recently evolved a method that permits leakage through non-representative wall sections to be separated from the total leakage, thereby yielding the leakage characteristic of only the representative wall-window section (7). The results of leakage tests conducted in this manner on four buildings are shown in Table I. The four buildings had different wall designs but, unfortunately, did not include a metal curtain wall system. The buildings ranged in height from 11 to 22 storeys, and had fixed glazed or semi-fixed windows.

The leakage values listed in Table I are for a pressure difference of 1.56 psf, and are only for the representative portions of the building envelope. The leakage values for brick walls obtained in laboratory tests (1), and the limiting leakage rate recommended for metal curtain walls by the National Association of Architectural Metal Manufacturers (8) are shown for comparison.

The variation in leakage for the four buildings was not large; the highest leakage was only twice the lowest rate. The measured values were similar to that for a plain brick wall, but were much higher than the National Association of Architectural Metal Manufacturers limit for curtain walls.

The leakages measured in the buildings were probably higher than the leakages that would have been measured in the laboratory on the same wall systems, due to the poorer quality of workmanship achieved on the buildings. One might even conjecture that the variation in leakage values found on the four buildings was due as much to variation in workmanship as it was due to differences in wall design.

SUMMARY

It was the intention of this paper to indicate the uses and limitations of the ASTM laboratory air-leakage test method, E283. Its primary uses are for checking the quality of design and manufacture of factory-assembled walls, windows and doors, and for checking the adequacy of the technique used to install these elements in a building. Both of these uses are intended to ensure maximum air tightness of the completed building. They are not very well suited, however, for providing the building designer with quantitative air leakage data for calculating heating and cooling loads, or for smoke control design. For these purposes, a more reliable estimate of the air leakage characteristic of real wall-window systems might be obtained from leakage studies performed on completed buildings.

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TABLE I

AIR LEAKAGE RATES AT 1.56 psf

Wall Construction (out to in)		Leakage (CFM/ft^2)
(A) DBR Field Study		
Bldg 1:	Concrete - Tile - Insul. - space - Tile - Plaster	0.48
Bldg 2:	Concrete - Insul.	0.38
Bldg 3:	Steel - Space - Insul.	0.31
Bldg 4:	Concrete - Space - Insul. - Parge - Block - Plaster	0.25
(B) ASHRAE Laboratory Values		
$8\frac{1}{2}$" Brick Wall - Plain		0.40
$8\frac{1}{2}$" Brick Wall - Plaster Inside		0.003
(C) NAAMM METAL CURTAIN WALL STANDARD		0.06

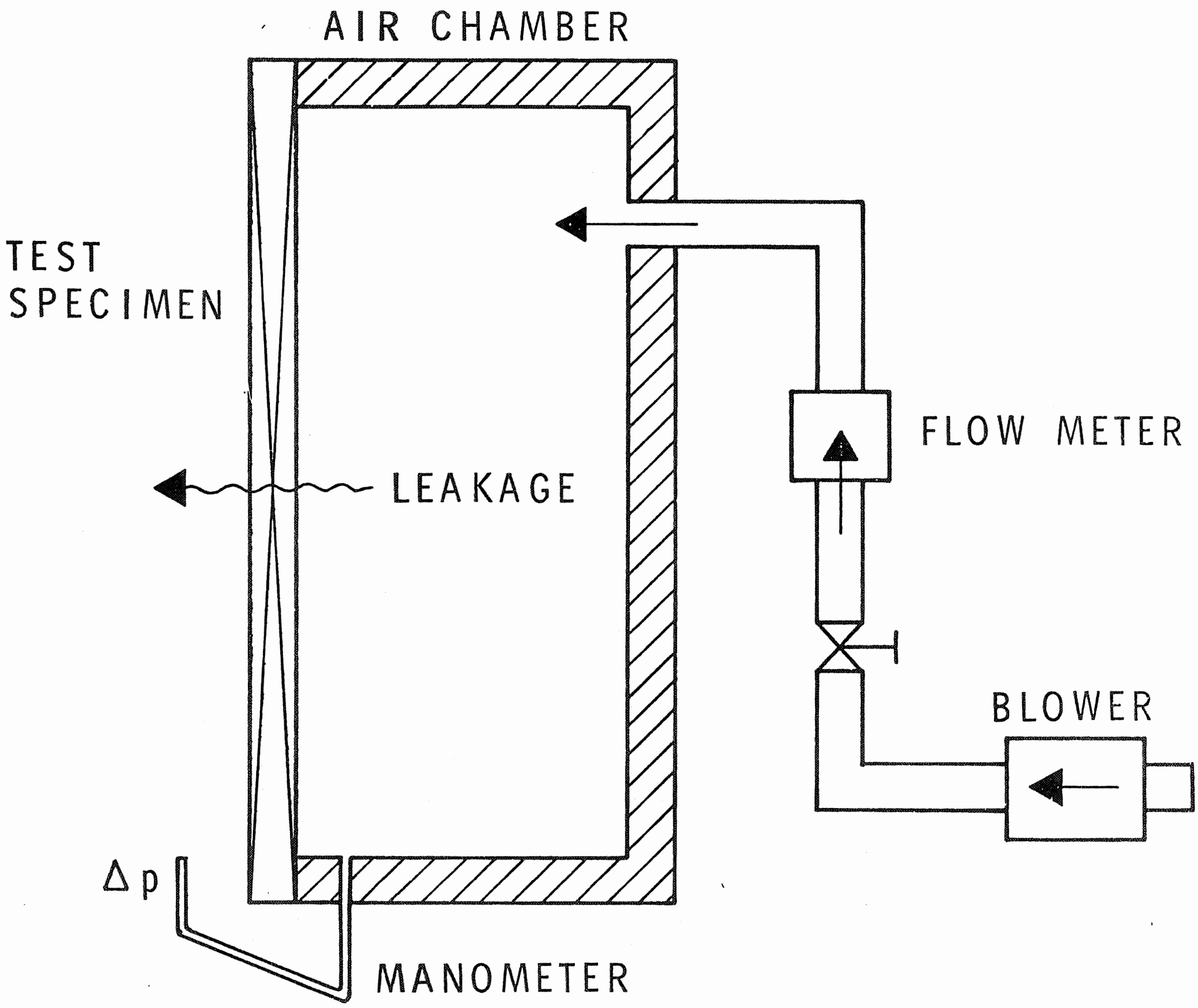

Figure 1

Air Leakage Test Apparatus (E283)

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