Designation: E 1186 – 87

Standard Practices for Air Leakage Site Detection in Building Envelopes[1]

This standard is issued under the fixed designation E 1186; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These practices describe standardized techniques for locating air leakage in building envelopes.

1.2 These practices offer a choice of methods to determine air leakage sites with each method offering certain advantages.

1.3 Some of the practices require a knowledge of infrared scanning, building pressurization or depressurization, smoke generation techniques, sound generation and detection, and tracer gas concentration measurement techniques.

1.4 The practices described are of a qualitative nature in determining the air leakage sites rather than determining quantitative leakage rates.

1.5 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*

E 631 Terminology of Building Constructions[2]

E 741 Test Method for Determining Air Leakage Rate by Tracer Dilution[2]

E 779 Test Method for Determining Air Leakage Rate by Fan Pressurization[2]

2.2 *Other Standards:*

ANSI-ASHRAE Standard 101 Application of Infrared Sensing Devices to the Assessment of Building Heat Loss Characteristics[3]

ISO Standard 6781 Thermal Insulation—Qualitative Detection of Thermal Irregularities in Building Envelopes—Infrared Method[3]

3. Definitions

3.1 See Definitions E 631.

3.2 *air leakage rate*—the volume of air movement per unit time across the building envelope. This movement includes flow through joints, cracks, and porous surfaces, or combinations thereof. The driving force for such air leakage in buildings can be either mechanical pressurization or evacuation, natural wind pressures, or air temperature differentials between the building interior and the outdoors, or combinations thereof.

3.3 *air leakage site*—a location on the building envelope where air enters or exits the building causing air leakage to occur.

3.4 *building envelope*—the boundary or barrier separating the interior volume of a building from the outside environment. For the purpose of these practices, the interior volume is the deliberately conditioned space within a building, generally not including the attic space, basement space, and attached structures, unless such spaces are connected to the heating and air conditioning system, such as a crawl space plenum. The actual building envelope may extend beyond these boundaries because of ducting or other construction features.

4. Summary of Practices

4.1 These practices present the following five methods to detect air leakage sites in building envelopes:

4.1.1 Combined building depressurization (or pressurization) and infrared scanning,

4.1.2 Building pressurization (or depressurization) and smoke tracers,

4.1.3 Building depressurization (or pressurization) and airflow measurement devices,

4.1.4 Generated sound and sound detection to locate air leakage sites, and

4.1.5 Detection of tracer gas concentration after adding tracer gas upstream of the leakage site. Additional methods may be specified as advances in air leakage site detection are made. These methods are described as follows:

4.1.5.1 *Building Depressurization (or Pressurization) with Infrared Scanning Techniques to Detect Air Leakage Sites*—The method relies on the existence of an inside-outside temperature difference of at least 5°C. In most locations these conditions are met during some portion of the day over a large fraction of the year. The different temperature outside air is moved through the building envelope by depressurizing the building interior with a fan (see Test Method E 779), or by using the building's own mechanical system. Because the incoming air is at a different temperature than the interior surface of the building envelope, local interior surface temperature changes take place which can be detected by the infrared scanning equipment. The infrared pattern for air leakage is different from that associated with varied levels of thermal conductance in the envelope and thus can be readily identified as air leakage. Pressurizing the building results in the air leakage patterns appearing on the building exterior. Infrared scanning from the outside reveals such patterns. However, local weather influences, such as wind or solar

[1] These practices are under the jurisdiction of ASTM Committee E-6 on Performance of Building Constructions and are the direct responsibility of Subcommittee E06.41 on Infiltration Performances.

Current edition approved Sept. 25, 1987. Published November 1987.

[2] *Annual Book of ASTM Standards*, Vol 04.07.

[3] Available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

radiation, can make outside scanning difficult and influence inside scans as well. Because of the nature of the air leakage site, inside and outside scans may reveal different aspects of the air leakage paths. It is essential that sufficiently sensitive infrared equipment is used and proper practices followed as outlined in ANSI-ASHRAE Standard 101 and ISO Standard 6781.

4.1.5.2 *Smoke Tracer in Conjunction with Building Pressurization or Depressurization*—If the building is pressurized, and the smoke tracer source is moved over the inner building envelope surface, air leakage will draw smoke from the tracer to the site thus revealing its location. Alternatively the building can be depressurized, then air jets at each air leakage site will cause the smoke to move rapidly inward. Similar techniques can be employed on the exterior of the building.

4.1.5.3 *Airflow Measurement Devices, or Anemometers*—If the building is depressurized, air jets will be present within the building at each leakage site. This will allow the anemometer to register an air velocity peak at that location when the instrument is moved over the wall surface. If the building is pressurized, interior air will flow toward each air leakage site. In that case the resulting velocity peak will be less distinct as the instrument is moved over the interior wall surface.

4.1.5.4 *Generated Sound to Locate Leaks*—With the sound generator located within the building, the procedure is to move a sound detection device over the outer surface of the building. Increased sound intensity is indicative of an air leakage site. The sound generator can be moved outside the building and the procedure is then reversed, that is, the inner surface is surveyed.

4.1.5.5 *Tracer Gas*—Tracer gas is released on one side of the air leakage site and a tracer gas detector on the other side to detect the pressure of the tracer gas. A measurable tracer gas concentration indicates the location of the air leakage site. Again, as with methods described in 4.1.5.1, 4.1.5.2, and 4.1.5.4, use of building pressurization (or depressurization) will speed the process of air leakage site detection.

4.1.5.6 *Other Practices*—Practices such as the use of a smoke bomb are not described here since they would appear very specialized and require extreme caution and can cause additional difficulties such as triggering smoke alarms or causing lingering odors.

5. Significance and Use

5.1 Air infiltration accounts for a significant portion of the thermal space conditioning load. It affects occupant comfort and indoor air quality. Differential pressure across the building envelope and the presence of air leakage sites account for air infiltration (**1**).[4]

5.2 In most commercial or industrial buildings, outdoor air is introduced by design using air-distribution and air-handling systems in addition to the uncontrolled air infiltration that takes place through the building envelope. In most residential buildings, indoor-outdoor air exchange is attributable primarily to air leakage through cracks and construction joints, the leakage associated with building components, leaky ductwork that passes outside the building envelope, and airflow bypasses. Airflow bypasses often occur between the living space and the attic and constitute a major source of air infiltration not obvious to visual inspection.

5.3 Air leakage sites are often difficult to locate because airflows may be small under prevailing weather conditions. Wind conditions can aid air leakage site detection by forcing air to enter a building; however, where air is exiting, the building envelope construction may make observations difficult. For these reasons forced pressurization or depressurization is strongly recommended for those methods that require controlled flow direction.

5.4 The techniques for air leakage site detection covered in these practices allow for a wide range of flexibility in the choice of techniques that are best suited for evaluating various types of air leakage sites.

5.5 The depressurization or pressurization with infrared scanning technique for air leakage site detection has the advantage of rapid surveying capability. Entire building exterior surfaces or inside wall surfaces can be covered with a single scan or a simple spanning action, provided there are no obscuring thermal effects from construction features or solar heating. The details of the air leakage site may then be probed more closely by focusing on the local area. Local problems are also well addressed with smoke tracer techniques, anemometer techniques, the sound detection technique or trace gas techniques, but often these techniques are time consuming for large surfaces.

5.6 Complexity of building air leakage sites may diminish the ability for detection. For example, using the sound detection approach, sound may be absorbed in the tortuous path through the insulation. Air moving through such building leakage paths may lose some of its temperature differential and thus make thermographic detection difficult. Lack of jet-like flow may make velocity measurements difficult with an anemometer.

5.7 Stack effects in multistory commercial buildings can cause gravity dampers to stand open. Computer-controlled dampers should be placed in normal and night modes to aid in determining the conditions existing in the building. Sensitive pressure measurement equipment can be used for evaluating pressure levels between floors and the exterior. Monitoring systems in high-tech buildings can supply qualitative data on pressure differences.

6. Method Description

6.1 Each method involves locating air leakage sites and, if sealing methods are employed, the site can be resurveyed to check the degree of success of the sealing procedure. Some air leakage sites involve preferred directional flow, requiring the correct choice of pressurization or depressurization to ensure detection. The following are more detailed descriptions of each of the methods previously described.

6.2 *Depressurization (or Pressurization)/Infrared Method*—This method is based upon the principle that outside air, when drawn through openings in the building envelope with the building depressurized, will cool down (or heat up) the inside surfaces surrounding the air leakage site so that infrared scanning methods may be used to detect the site by sensing differences in the adjacent interior surface tempera-

[4] The **boldface** numbers in parentheses refer to the list of references at the end of these practices.

tures **(2,3,4)**. Training in the use of this equipment is essential.

6.2.1 *Background*—It is clear from using pressurization and depressurization techniques, such as described in Test Method E 779, that airflow through leakage sites is markedly increased with higher inside to outside pressure differences. During almost any day of the year temperature differences of 5°C or more between inside and outside environments are present for at least part of the day. When this different temperature air is drawn through the leakage site, the local surface temperatures are subsequently altered. Infrared equipment with sufficient sensitivity and resolution (see ISO Standard 6781 and ANSI-ASHRAE Standard 101) can easily identify the altered surface temperature, thereby locating the air leakage site. The character of the thermal pattern on the air-cooled (or heated) surface assists in separating such areas from other thermal differences due to conduction variations in the building envelope. Nighttime external observations normally require higher differential temperatures because of obscuring effects from air movement (wind) and residual radiation effects (solar). See ISO Standard 6781.

6.2.2 *Depressurizing (or Pressurizing) Systems*—These systems may consist of blower doors, window fans, fans associated with the mechanical system of the building, etc., that may be operated to induce pressure differences across the building envelope. The ability of such systems to provide pressure differentials as high as 50 Pa will aid in the rapid achievement of the enhanced flow and the subsequent cooling (or heating) of the building surfaces. Pressure differentials of 20 Pa or less are commonly used in air leakage site detection.

6.2.3 *Infrared Equipment*—Detection of the surface temperature changes which result from the heating or cooling effects of air leakage requires sensitive infrared scanning equipment. Typical specifications are found in ISO Standard 6781.

6.2.4 *Details of the Method*—Using building depressurizing (or pressurizing) equipment, or employing blower doors or similar equipment, the building is depressurized and the resultant air leakage is allowed to alter local surface temperatures near the air leakage sites for a period of over 10 min. Normally, a pressure differential from 10 to 50 Pa has been found to be adequate in most cases to provide flow in one direction, that is, free from weather effects such as wind pressure. Systematic interior scanning with infrared equipment begins at this point, emphasizing the exterior building envelope but not ignoring interior surfaces. Leakage from the attic, for example, will show up on interior surfaces as streaking from the upper portions of those walls that are affected. Masking of these effects can take place where solar radiation influences the local temperatures. Application in commercial buildings where ceiling panels must be removed to obtain envelope access can be complicated by interactions with return plenums and possible heating, ventilating, and air conditioning (HVAC) system imbalance.

6.2.5 *Limitations of the Method*—The method can be compromised if one does not discriminate between air leakage sites and local thermal bridges (that is, locations where there are significant increases in the envelope conduction losses). Because different materials have different thermal emissivities, these may also influence the interpretation. Thermal mass effects of building materials will affect the required times for surface temperatures to change and thus may slow down the process in the case of masonry buildings, or other heavy construction.

6.3 *Smoke Tracer Method*—This method is based upon the principle that air moving out through the leakage sites in the building envelope will draw smoke-seeded air that is in close proximity of the site through the same opening, thereby allowing air leakage site detection by visual means. Minimum training is required to use this method.

6.3.1 *Background*—Pressurization or depressurization techniques can provide enhanced air flows that allow a greater opportunity for using a smoke tracer that will be drawn through envelope air leakage sites.

6.3.2 *Depressurizing (or Pressurizing) Systems*—See 6.2.2.

6.3.3 *Smoke Generating Systems*—Commercial smoke tracer systems include guns, pencils, and sticks. These systems provide a controlled smoke source such that a thin stream of smoke may point the way to the leakage site.

6.3.4 *Details of the Method*—With flow established in one direction through the air leakage sites, via pressurization or depressurization of the building interior, the controlled smoke source is moved close to the suspected leakage site and the smoke direction carefully noted. Pressurizing the interior and thereby causing the smoke to flow outward through any openings appears to be the preferred method.

6.3.5 *Limitations of the Method*—Knowledge of suspected leakage sites is necessary to limit the effort for leak detection by this means. Normally the controlled smoke source must be close to the leak site (to within 10 cm) for best results. The smoke is often an acid vapor so one must use it sparingly realizing the annoyance to building occupants, or possible material damage, or both. This is a local technique and therefore no extensive use of smoke is recommended in the building interior.

6.4 *Anemometer Method*—This method is based on the principle that air close to the leakage site will be moving at a different velocity than other room air. If the building is depressurized, jet-like airflow will be encouraged at the sites. This would represent a large velocity gradient and generally result in rapid detection of the leak site. Some of the velocity measurement devices work on differential velocity, which discriminates the leak from local flow variations.

6.4.1 *Background*—Air velocities near wall surfaces tend to approach zero except where building air distribution systems are causing local flow disturbances. Normal inflow or outflow of infiltration air would result in variations in local velocities. Use of building pressurization (or depressurization) establishes a regular pattern and thereby aids detection of the air leakage sites.

6.4.2 *Pressurizing Systems*—See 6.2.2.

6.4.3 *Anemometers*—Anemometers may be designed in many shapes and forms. Examples include: small pin-wheel units, heated single or multiple thermistors, and high-frequency response constant-temperature hot-wire anemometers. Each of these classes of anemometers could have application using this method. Techniques that indicate the airflow direction should prove more suitable. The back of the hand is a sensitive but nonqualitative method that can be used advantageously in finding air leakage sites.

6.4.4 *Details of the Method*—Just as in the case of the smoke tracer in 6.3, this method relies on local air movement near the leakage site to locate that site. Pressurization or depressurization methods are necessary if all sites are to be located. Although there is uncertainty in the flow pattern, some measure of relative leakage rates may be gained from the air velocity readings.

6.4.5 *Limitations of the Method*—A knowledge of suspected air leakage sites is necessary to limit the effort for leak detection by this means. If the anemometer does not possess directional readout, use of additional information (that is, a wool tuft on the sensor) may be required to clarify readings. Only air leakage sites that can be reached can be surveyed, therefore cathedral ceilings and other difficult to reach locations can be problems.

6.5 *Acoustic Method*—This method is based upon the principle that sound passes readily through openings in building structures in the same way that air does. The method is simple, low cost, and could be used with minimum training **(5)**.

6.5.1 *Background*—Small openings through building structures serve as paths for both air infiltration and sound. A quieter interior acoustical environment is a noticeable factor after building envelope crack sealing procedures. Even very small openings in walls can significantly increase the acoustic transmission compared to the same wall when sealed. The difference in decibels between the two sides of the wall as a function of frequency is related to the size of the barrier, the amount of acoustical absorption on either side of the wall, the angle of incidence of the sound at the wall, the acoustic properties within the wall, and other less important parameters such as humidity. Probing is done close to the sound-output side of the wall seeking local increases in sound level.

6.5.2 *Sound Sources*—Almost any sound source of sufficient loudness can be used. The preferences are: steady and broad-band (that is, white noise containing many frequencies) and a saw-tooth warble tone that sweeps in frequency from 500 to 8000 Hz about three times per second. The broad-band sound can be produced by something as simple as a vacuum cleaner. Both sounds can be readily generated using a cassette tape and portable tape recorder. The warble tone works best in that it is readily discernible. However, if the sound source needs to be placed outside the building, the white noise is preferable in that it is less annoying to neighbors.

6.5.3 *Sound-Detecting Equipment*—On the listening side of the building envelope, it is necessary to provide a means for detecting the sound near the surface and over a very small area, preferably less than 1-cm diameter. The following equipment has been used: (*1*) mechanic's stethoscope, (*2*) airline plastic headset, (*3*) Type I and Type II sound level meters, and (*4*) low-cost sound meters consisting of a battery-powered microphone and headphones. A microphone end piece with a limited opening of 4-mm diameter aids Choice 4 in probing for small cracks and will be the method that is further described.

6.5.4 *Details of the Method*—The noise source is activated on one side of the building envelope. On the other side, the operator moves the microphone back and forth between locations that are sealed and those that may prove to be potentially leaky, looking for a noticeable increase in sound level. (Meters can be used to provide quantitative indications of sound level variations.) The process moves quickly because the closer the microphone is to the leak opening, the louder the sound.

6.5.5 *Limitations of the Method*—Lightweight barriers will only slightly reduce sound levels making it difficult to discriminate leaks from normal sound transmission. Insulation in the wall will greatly reduce the sound transmission, especially through a complicated air passage (that is, not a straight-through passage), making it difficult to find the leak. Reflections at corners will cause a sound level increase of 3 dB where two walls meet and a 6 dB increase where three walls meet. This will cause anomalous indications that should not be confused with a leak site. Noisy environments can also pose problems in use of this method.

6.6 *Tracer Gas Method*—This method is based on the principle that a detector for a specific substance, in this case a tracer gas as described in Test Method E 741, may be used to locate where air containing the tracer gas is leaking through the building envelope.

6.6.1 *Background*—It is clear from the tracer gas decay method, as described in Test Method E 741, that there are various tracer gases and various detection methods suited to each. Some of the detection systems are easily portable and can be operated in a continuous mode, that is, constantly sampling. Both of these characteristics aid this method of air leakage site detection. As with many of the other methods described, a known flow direction is necessary for optimum use of the method. Therefore, depressurization or pressurization equipment would be recommended.

6.6.2 *Depressurization (or Pressurizing) Systems*—See 6.2.2.

6.6.3 *Tracer Gas Injection (Seeding)*—To identify the air on one side of the building envelope, tracer gas is injected (seeded) and mixed with that air using either a single injection or constant injection. The resulting tracer gas concentration must be high enough so that the detector can sense the seeded air after it passes through the leakage site. However, the tracer gas concentration must be limited so that the seeded air does not saturate the detector, causing delays while the detector recovers.

6.6.4 *Details of the Method*—With flow established in one direction through the air leakage sites, by means of pressurization or depressurization of the building interior, the interior or exterior air is seeded with tracer gas to suitable concentration levels. For interior seeding this means a specific quantity of tracer gas based upon interior volume. The portable detector is moved over the surface of the building envelope, while it is operating in a continuous sampling mode. Increased tracer gas concentrations indicate a possible air leakage site, encouraging additional probing with the detector near that location to further evaluate the air leakage site. Some sense of the quantitative air leakage level may be gained from this method.

6.6.5 *Limitations of the Method*—Unlike the smoke tracer method (6.3), the tracer gas method can provide an overall indication if there is any significant leakage through the building envelope based on an evaluation of the tracer gas level. A detailed survey over the building envelope surfaces must be made if air leakage site details are to be obtained.

7. Hazards

7.1 Glass should not break at the pressure differences normally applied to the test structure. However, for added safety, adequate precautions such as the use of eye protection should be taken to protect the personnel. Occupant protection must also be considered.

7.2 Since the test is conducted in the field, safety equipment required for general field work also applies, such as safety shoes, hard hat, etc.

7.3 Because air-moving equipment may be involved in these tests, provide a proper guard or cage to house the fan or blower and to prevent accidental access to any moving parts of the equipment.

7.4 Noise may be generated by the moving air from pressurization systems. Therefore, make hearing protection available to personnel who must be close to the noise source.

7.5 Use of the smoke tracers often involves pungent and caustic fumes. Although extremely localized, precautions should be taken so that the smoke is not inhaled.

7.6 Moving air from the pressurization devices can mean cold drafts entering the building affecting plants, birds, wall-mounted pictures, papers on desks, etc. These sensitive items should be moved out of the air path. If prolonged depressurization testing is anticipated, lower temperatures in critical areas of the building could result in damage, for example, frozen pipes.

7.7 Depressurization in buildings with fireplaces can mean entrained ashes and movement of ashes into the room. Close dampers or cover fireplaces, or both, prior to depressurization.

7.8 Caution must be exercised as to the choice of tracer gases used and the levels of concentration provided. Health guidelines and fire and explosive limits must not be exceeded. See Test Method E 741.

8. Precision and Bias

8.1 The procedures described in these practices are meant to qualitatively locate the air leakage sites rather than provide a quantitative airflow rate for the sites. Properly used all but the smallest leakage sites should be detected by any of these methods.

REFERENCES

(1) *Measured Air Leakage of Buildings, ASTM STP 904*, ASTM, 1986.

(2) Pettersson, B., and Axen, B., "Thermography: Testing of Thermal Insulation and Airtightness of Buildings," *Swedish Council for Building Research Report D5*, 1980.

(3) Harrje, D. T., Dutt, G. S., and Beyea, J., "Locating and Eliminating Obscure But Major Energy Losses in Residential Housing," *ASHRAE Transactions*, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Vol 85, Part 2, 1979.

(4) Harrje, D. T., Dutt, G. S., and Gadsby, K. J., "Isolating the Building Thermal Envelope," *Thermal Infrared Sensing Applied to Energy Conservation in Buildings—Thermosensense III*, Society of Photo-Optical Instrumentation Engineers, 1981.

(5) Keast, D. N., "Acoustic Location of Infiltration Openings in Buildings," *Report No. 3942*, Bolt Beranek and Newman Inc., Cambridge, MA, 1978.

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effects on the indoor and outdoor environment of the systems and components in their responsibility, while maximizing the beneficial effects which these systems provide, consistent with the accepted standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor or outdoor environment to a greater extent than specified by the standards as established by itself and other responsible bodies.

As an on-going goal, ASHRAE will, through its Standards Committee and extensive technical committee structure, continue to generate up-to-date standards where appropriate and adopt, recommend and promote those new and revised standards developed by other responsible organizations.

Through its Handbook, appropriate chapters will contain up-to-date standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with research and dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations which is pertinent, as guides to updating standards.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use, and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.