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# Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems<sup>1</sup>

This standard is issued under the fixed designation E1186; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 These practices cover standardized techniques for locating air leakage sites in building envelopes and air barrier systems.

1.2 These practices offer a choice of means for determining the location of air leakage sites with each offering certain advantages for specific applications.

1.3 Some of the practices require a knowledge of infrared scanning, building and test chamber pressurization and depressurization, smoke and fog 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 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 6.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

<sup>1</sup> These practices are under the jurisdiction of ASTM Committee E06 on Performance of Buildings and are the direct responsibility of Subcommittee E06.41 on Air Leakage and Ventilation Performance.

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## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

E631 Terminology of Building Constructions

E741 Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution

E779 Test Method for Determining Air Leakage Rate by Fan Pressurization

2.2 *Entertainment Services and Technology Association (ESTA) Standards:*<sup>3</sup>

ANSI E1.5 Entertainment Technology—Theatrical Fog Made with Aqueous Solutions of Di- and Trihydric Alcohols

ANSI E1.23 Entertainment Technology—Design and Execution of Theatrical Fog Effects

2.3 *Other Standards:*<sup>3</sup>

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

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

## 3. Terminology

3.1 *Definitions:*

3.1.1 *air barrier system, n*—a system in building construction that is designed and installed to reduce air leakage either into or through the building envelope.

3.1.2 *air exfiltration, n*—air leakage out of the building.

3.1.3 *air infiltration, n*—air leakage into the building.

3.1.4 *air leakage rate, n*—the volume of air movement per unit time across the building envelope or air barrier system, including flow through joints, cracks, and porous surfaces, or

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

combinations thereof, in which the driving force for such air leakage in buildings is either mechanical pressurization or evacuation, natural wind pressures, or air temperature differences between the building interior and the outdoors, or combinations thereof.

3.1.5 *air leakage site, n*—a location on the building envelope or air barrier system where air can move between the building interior and the outdoors.

3.1.6 *building system, n*—the boundary or barrier separating the interior volume of a building from the outside environment.

3.1.6.1 *Discussion*—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.

3.1.7 *test specimen, n*—the part of the air barrier system on the building to be tested that may consist of the selected areas of materials comprising the principle resistance to airflow, joints between such materials and joints between the materials and structural, mechanical, or other penetrations through such materials, and excludes any material which does not form an integral part of the air barrier system.

3.1.8 *theatrical fog, n*—visible vapor generated by a fog generator, more commonly used in theatrical productions, and as supplied by the manufacturer of the fog generator. (See ANSI E1.5 and ANSI E1.23.)

3.1.9 *tracer gas, n*—a gas that is mixed with air and measured in very small concentrations in order to study air movement.

3.2 For other definitions, see Terminology E631.

## 4. Summary of Practices

4.1 This standard presents the following seven practices for detecting air leakage sites in building envelopes:

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

4.1.2 Building depressurization (or pressurization) and smoke tracers or theatrical fog,

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

4.1.4 Generated sound and sound detection,

4.1.5 Tracer gas detection,

4.1.6 Chamber depressurization (or pressurization) and smoke tracers or theatrical fog, and

4.1.7 Chamber depressurization and leak detection liquids.

4.2 These practices are described as follows:

4.2.1 *Building Depressurization (or Pressurization) with Infrared Scanning Techniques*—This practice relies on the existence of an indoor–outdoor temperature difference of at least 5 °C. In most geographic locations, this condition is met during some portion of the day over a large fraction of the year. Outdoor air is moved through the building envelope by depressurizing the building interior with a fan (see Test Method

E779) or using the mechanical system in the building. Because the infiltrating air is at a different temperature than the interior surfaces of the building envelope, local interior surface temperature changes take place which can be detected by infrared scanning equipment. The infrared pattern resulting from air leakage is different from that associated with varied levels of thermal conductance in the envelope, allowing air leakage sites to be identified. This practice can also be performed by pressurizing the building and scanning the exterior of the building envelope.

4.2.2 *Smoke Tracer or Theatrical Fog in Conjunction with Building Pressurization or Depressurization*—This practice consists of pressurizing or depressurizing the building using a fan or the mechanical system in the building and moving a smoke tracer source or theatrical fog over the interior or the exterior surface of the building envelope. If the building is pressurized and the smoke tracer source or theatrical fog is moved over the interior of the building envelope, air exfiltration through air leakage sites will draw smoke from the tracer source to the site, revealing its location visually. Alternatively, if the building is depressurized and the smoke tracer source or theatrical fog is moved over the interior of the building envelope surface, then air jets at each air leakage site will cause the smoke or fog to move rapidly inward. Similarly, the smoke tracer source or theatrical fog can be employed on the exterior of the building envelope.

4.2.3 *Building Depressurization (or Pressurization) in Conjunction with Airflow Measurement Devices, or Anemometers*—This practice consists of depressurizing or pressurizing the building using a fan or the building’s mechanical systems and moving an anemometer over the interior building envelope surface. If the building is depressurized, air jets will be present within the building at each air leakage site. As the anemometer is moved over the building envelope surface, it will register an air velocity peak at the location of the air leakage site. If the building is pressurized, interior air will flow toward each air leakage site. In this case, the resulting measured air velocity peak will be less distinct.

4.2.4 *Generated Sound in Conjunction with Sound Detection*—This practice consists of locating a sound generator within the building and moving a sound detection device over the exterior of the building envelope. Increased sound intensity is indicative of an air leakage site. Alternatively, the sound generator can be located outside the building and the interior surface of the building envelope can be surveyed using the sound detection device.

4.2.5 *Tracer Gas*—This practice consists of releasing a tracer gas on one side of the building envelope and using a tracer gas detector to measure the concentration of the tracer gas on the other side. A measurable tracer gas concentration indicates the location of an air leakage site. Pressurizing or depressurizing the building envelope using a fan or the building’s mechanical system improve the results obtained by this method.

4.2.6 *Chamber Pressurization or Depressurization in Conjunction with Smoke Tracer or Theatrical Fog*—This practice consists of sealing an approximately airtight chamber to a section of the interior or exterior of the air barrier system and

using a fan to create a pressure differential across the air barrier specimen. If a smoke tracer source or theatrical fog is moved over the surface of the test specimen on the higher pressure side, air leakage will draw smoke or fog toward an air leakage site, visually indicating the location. Conversely, if a smoke tracer or theatrical fog is moved over the surface of the test specimen on the low pressure side, air jets at air leakage sites will cause smoke or fog to move away from the air leakage site.

**4.2.7 Chamber Depressurization in Conjunction with Leak Detection Liquid**—The practice consists of applying a leak detection liquid to the test specimen surface, sealing a transparent chamber around the specimen and depressurizing the chamber with a fan. The location of an air leakage site is indicated by bubbling of the detection liquid at the air leakage site.

**4.2.8 Other Practices**—Practices such as the use of a smoke bomb are not described here since they are very specialized and require extreme caution due to additional difficulties such as triggering smoke alarms and causing lingering odors.

## 5. Significance and Use

**5.1** Air infiltration into the conditioned space of a building accounts for a significant portion of the thermal space condition load. Air infiltration can affect occupant comfort by producing drafts, cause indoor air quality problems by carrying outdoor pollutants into occupied building space and, in hot humid climates, can deposit moisture in the building envelope resulting in deterioration of building envelope components. In cold climates, exfiltration of conditioned air out of a building can deposit moisture in the building envelope causing deterioration of building envelope components. Differential pressure across the building envelope and the presence of air leakage sites cause air infiltration and exfiltration **(1)**.<sup>4</sup>

**5.2** In some buildings, restricting air movement between interior zones of a building may be desired to separate dissimilar interior environments or prevent the movement of pollutants. Although not dealt with specifically in this standard, the detection practices presented can also be useful in detecting air leaks between interior zones of the building.

**5.3** Air leakage sites are often difficult to locate because air flows may be small under the prevailing weather conditions. Wind conditions can aid in air leakage 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 practices which 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 detecting various types of air leakage sites in specific situations.

**5.5** The infrared scanning technique for air leakage site detection has the advantage of rapid surveying capability.

<sup>4</sup> The boldface numbers in parentheses refer to a list of references at the end of this standard.

Entire building exterior surfaces or inside wall surfaces can be covered with a single scan or a simple scanning action, provided there are no obscuring thermal effects from construction features or incident solar radiation. The details of a specific air leakage site may then be probed more closely by focusing on the local area. Local leak detection is well addressed with the smoke tracer, theatrical fog, anemometer, sound detection, the bubble detection, and the tracer gas techniques, however these techniques are time consuming for large surfaces. The pressurized or depressurized test chamber and smoke tracer or a depressurized test chamber and leak detection liquid practices can be used in situations where depressurizing or pressurizing the entire envelope is impractical, such as is the case during construction. Both of the practices enable the detection of very small leaks. To perform these practices requires that the air barrier system be accessible.

**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. The absence of jet-like air flow at an air leakage site may make detection using the anemometer practice difficult.

**5.7** Stack effect 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. Hazards

**6.1** 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 shall be taken to protect the personnel. Occupant protection must also be considered.

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

**6.3** 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.

**6.4** 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.

**6.5** Use of smoke tracers often produces pungent and caustic fumes. Although extremely localized, precautions shall be taken so that smoke inhalation is minimized and respiratory protection is provided as required. Hands shall be washed before eating if large quantities of pungent or caustic fumes have been generated.

**6.6** Moving air from the pressurization devices can produce cold drafts affecting plants, birds, wall-mounted pictures,



papers on desks, etc. These sensitive items shall be moved out of the air path. Prolonged depressurization testing may result in lower temperatures in critical areas of the building and may adversely affect building components, for example frozen pipes.

6.7 Depressurization in buildings with fireplaces can cause movement of ashes into occupied spaces. Close dampers or cover fireplaces, or both, prior to depressurization.

6.8 Caution must be exercised as to the choice of tracer gases used and the level of concentration provided. Health guidelines, fire, and explosion limits must not be exceeded. (See Test Method E741.)

6.9 Some chemicals used to produce theatrical fogs may be respiratory irritants, especially to those with reactive airways. The safety of the type and allowable airborne concentration of the fog chemical shall be determined before use. Persons with reactive airways, who may be exposed, shall take precautions to minimize exposure or use the proper personal protection equipment. Consult the fog fluid manufacturer's SDS sheet for detailed information.

6.10 Use only fog generating materials solely intended for safe use in occupied spaces. Some theatrical fog fluids may leave behind a residue that may support organic growth. This residue shall be removed, cleaned, or otherwise treated.

6.11 *Fire and Explosion Hazards*—Some formulations of compounds that can be used to create a theatrical fog that can be used for this standardized procedure may increase the potential for fires and explosions. The user shall fully research the properties of the compound used to create the fog to avoid such compounds.

## 7. Procedure

7.1 Each practice enables the locating of air leakage sites and, if sealing methods are employed, enables the sites to be resurveyed to evaluate qualitatively 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 practices previously presented.

7.2 *Depressurization (or Pressurization)/Infrared Practice*—This practice is based upon the principle that outside air, when drawn through the building envelope by building depressurization, will induce a temperature change in the inside surfaces surrounding the air leakage site. Infrared scanning methods can be used to detect the sites by sensing differences in the adjacent interior surface temperatures (2, 3, 4). Training in the use of this equipment is essential.

7.2.1 *Background*—It is clear from using pressurization and depressurization techniques, such as described in Test Method E779, that airflow through leakage sites is markedly increased with higher inside-outside pressure differences. During almost any day of the year, temperature differences of 5 °C or more between the inside and outside environments are present for at least part of the day. Under these conditions, air drawn through an air leakage site will alter the local surface temperatures

around the site. 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 air leakage sites. The character of the thermal pattern on air-cooled (or heated) surfaces assists in separating such areas from other thermal differences due to conduction variations in the building envelope. Exterior observations at night normally require higher differential temperatures because of obscuring effects from wind and residual solar radiation. (See ISO Standard 6781.)

7.2.2 *Depressurization (or Pressurization) 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 of as high as 50 Pa will enhance airflow through the air leakage sites and aid in the rapid cooling (or heating) of the building surfaces. Pressure differentials of 20 Pa or less are commonly used in air leakage site detection.

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

7.2.4 *Details*—Using building depressurization 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 at least 10 min. Normally, a pressure differential of 10 to 50 Pa is adequate in most cases to provide flow in one direction free from weather effects such as wind pressure. Systematic scanning of the building interior with infrared equipment begins at this point, emphasizing the interior of the building envelope but not ignoring other interior surfaces such as partition walls. Leakage from the attic, for example, will show up on the 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 surface temperatures. Application of this method in commercial buildings where ceiling panels must be removed to obtain access to the underside of the floors and the roof can be complicated by interactions with the return air plenums and possible heating, ventilating, and air conditioning (HVAC) system imbalance. The practice can also be carried out by pressurizing the building and scanning the exterior of the building envelope. Local weather influences such as wind and or solar radiation can make outside scanning difficult and influence the results of 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.

7.2.5 *Limitations*—The effectiveness of the practice can be compromised if the analysis does not correctly discriminate air leakage sites from thermal bridges. Thermal bridges occur at locations where there are significant increases in the thermal conduction across the building envelope, and are therefore not associated with air leakage sites. Different building envelope materials also have different thermal emissivities which may