



**US Army Corps
of Engineers®**

ENGINEERING AND CONSTRUCTION BULLETIN

No. 2012-16

Issuing Office: CECW-CE

Issued: 1 May 2012

Expires: 1 May 2014

Subject: Building Air Tightness and Air Barrier Continuity Requirements

Applicability: Directive and Guidance

1. References:

- a. Anis, W. (2001) The Impact of Air tightness on System Design. ASHRAE Journal, 43:12.
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- d. ASTM. (2010) E779-10. Standard Test Method for Determining Air Leakage Rate by Fan Pressurization. American Society for Testing and Materials.
- e. Benne, K. and Deru, M. (February 2009) Reference Barracks Building. National Renewable Energy Laboratory, Golden, CO, in preparation.
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- g. CGSB. (1996) CAN/CGSB-149.15-96. Determination of the Overall Envelope Air tightness of Buildings by the Fan Depressurization Method Using the Building's Air Handling Systems. Canadian General Standards Board.
- h. Genge, Collin. (April 2009) Controlling Air Leakage in Tall Buildings. ASHRAE Journal, pp 50-60.
- i. ISO. (1996) Standard 9972. Thermal Insulation – Determination of Building Airtightness – Fan Pressurization Method. International Standards Organization.

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k. U.S. Department of Energy (DOE) (2007) *Energy Plus 3.0*. (software program).
<http://apps1.eere.energy.gov/buildings/energyplus/>

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m. Energy and Process Assessment Protocol. (2009) International Energy Agency, Energy Conservation in Buildings and Community Systems Annex 46.

n. Zhivov Alexander, David Bailey, Dale Herron, Don Dittus, Michael Deru, Colin Genge, and Brian Erickson. (2010) Air Tightness Improvement of U.S. Army Buildings. ASHRAE Transactions. Atlanta, GA: American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). In publication.

o. Zhivov Alexander, David Bailey, Dale Herron, Don Dittus, Michael Deru, and Colin Genge. (2009) Testing and Analyzing U.S. Army Buildings Air Leakage. Proceedings of the 30th AIVC Conference „Trends in High Performance Buildings and the role of Ventilation” and the 4th International Symposium on Building and Ductwork Air Tightness (BUILDAIR). Berlin, Germany. October 1-2, 2009.

p. ASTM E 2178 (2003) Standard Test Method for Air Permeance of Building Materials

q. ASTM E 1827 (2011) Standard Test Methods for Determining Air tightness of Buildings Using an Orifice Blower Door

r. ISO 6781 (1983) Thermal Insulation – Qualitative Detection of Thermal Irregularities in Building Envelopes – Infrared Method First Edition

s. ASTM C 1060 (1990; R 2003) Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings

t. ASTM E 1186 (2003; R2009) Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems

u. UFC 3-101-01 (2011) Architecture

2. Purpose: This ECB directs compliance and provides guidance by the following sections which outline Army requirements for building air tightness and building air leakage testing for new and renovation construction projects. The requirements below shall be included in all new

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Army construction projects in or after Fiscal year 2012. The requirements outlined below apply to all renovation Army construction projects in or after Fiscal Year 2012 when the renovation costs are greater than or equal to 25 percent of the replacement cost of the building. In this case, the entire building shall be brought into compliance with the requirements below. The renovation cost of the building is exclusive of the cost to bring the building into compliance with this ECB.

3. Background: The air tightness of the building enclosure or envelope is a significant factor in the overall energy consumption of buildings (Figure 0-1). The energy required to heat, cool and maintain humidity control in buildings is increased significantly due to uncontrolled air transfer through the enclosure, as well as by convection. Investigations of building enclosure problems have led many building science consultants, investigators and researchers to conclude that air leakage is the leading cause of moisture problems in exterior building enclosures. Moisture related problems include mold and durability in exterior walls and wall cavities connected to the exterior, excessive rain penetration into wall cavities, poor indoor temperature and humidity control, high heating and air conditioning costs, compromised noise, fire and smoke control measures, spalling of masonry, premature corrosion of metal parts in exterior walls, high wood moisture content and rot and in colder climates icicles on exterior facades. In hot humid climates infiltrating air can cause mold due to condensation on cooler surfaces.



Figure 0-1. Cold climate exfiltration problems (left) and hot humid air infiltration problems (right).

Air leakage in buildings results from assemblies that do not have a designated layer selected as the airtight layer “an air barrier,” and when airtight layers of adjacent assemblies are not joined together. Figures 0-2 to 0-5 show some typical examples. The most common problems are between adjacent assemblies, in particular, the wall-to-roof juncture, canopies and soffits, wall to foundation connection and window-to-wall air barrier; these kinds of problems cause “orifice” and “channel” air flow. Occasionally building materials are selected that are not tight enough by air barrier standards, causing “diffuse” air flow through them. In existing buildings,

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operable windows and doors generally are a target for either replacement or re-gasketing and weatherstripping.



Figure 0-2. Examples of unsealed chases between floors and the attic.



Figure 0-3. Examples of unsealed pipe penetrations through walls and floors.



Figure 0-4. Blower door tests complemented by thermography identify problems with building air tightness and areas with poor insulation where leakage occurs (shaded and white areas in the photo to the right)



Figure 0-5. Penetration through the walls designed to accommodate outdoor air supply to individual room's fan-coil units.

Application of air barrier theory in a building design requires the selection of a component or layer in an assembly to serve as the airtight layer.

4. Requirements for the Air Barrier

A continuous air barrier should be used to control air leakage into, or out of, the conditioned space of buildings including office buildings, dining facilities, barracks, instructional/training facilities (e.g. schools, child development centers), air conditioned warehouses, and office portions of mixed use facilities (i.e. office space and open space such as company operations facilities, TEMFs, hangars). Clearly identify all air barrier components of each envelope assembly on construction documents and detail the joints, interconnections and penetrations of the air barrier components. Clearly identify the boundary limits of the building air barriers, and of the zone or zones to be tested for building air tightness on the drawings.

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Trace a continuous plane of identifying the air barrier throughout the building envelope and make flexible and seal all moving joints. The air barrier material(s) must have an air permeance not to exceed 0.004 cfm/sf at 0.3" wg [0.02 L/s.m² @ 75 Pa] when tested in accordance with ASTM E 2178. Join and seal the air barrier material of each assembly in a flexible manner to the air barrier material of adjacent assemblies, allowing for the relative movement of these assemblies and components.

Support the air barrier to withstand the maximum positive and negative air pressure to be placed on the building without displacement, or damage, and transfer the load to the structure. Seal all penetrations of the air barrier. If any unavoidable penetrations of the air barrier by electrical boxes, plumbing fixture boxes, and other assemblies are not airtight, make them airtight by sealing the assembly and the interface between the assembly and the air barrier or by extending the air barrier over the assembly. The air barrier must be durable to last the anticipated service life of the assembly. Do not install lighting fixtures with ventilation holes through the air barrier.

Provide a motorized damper connected to the fire alarm system that is in the closed position during typical operation but opens on alarm call and fails in the open position for any fixed open louvers such as at elevator shafts. Damper and control to close all ventilation or make-up air intakes and exhausts, atrium smoke exhausts and intakes, etc to prevent leakage during inactive periods. Compartmentalize garages under buildings by providing air-tight vestibules at building access points. Provide air-tight vestibules at building entrances with high traffic (Figures 0-6, 0-7, and 0-8).



Figure 0-6. Unprotected building entrances with a high traffic.

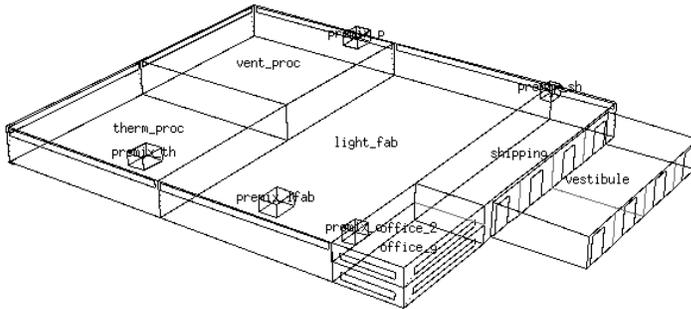


Figure 0-7. Schematic of external vestibule for an industrial building shipping entrance



Figure 0-8. Examples of vestibules at the high traffic doors of admin buildings (left) and the dining facility (right).

Compartmentalize spaces under negative pressure such as boiler rooms and provide make-up air for combustion. Existing buildings undergoing major renovations shall be sealed to the same standard as newly constructed ones.

In buildings undergoing renovation, the need for and reasonableness of destructive analysis of the state of exiting air barrier shall be evaluated based on the type of renovation considering related cost issues. This can be challenging due to difficulty in accessing gaps through hard or expensive finishes. Removable ceiling tiles allow easy access to problem areas; walls require destructive access through finishes to expose gaps such as around windows; occasionally if a gap is discovered it may be possible to blind-seal with spray polyurethane foam injected through holes drilled in the

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drywall. For large holes, bulkheads can be built out of studs and drywall sealed with spray polyurethane foam (SPF); smaller gaps up to 50 mm (2”) can be sealed with one part SPF; larger gaps can be sealed with two-component SPF. Note that stuffing glass-fiber insulation in cracks is not useful, because glass-fiber merely acts as a dust filter and allows air under a pressure differential to pass through it. Air leaks shall be sealed in the following order of priority:

1. Top of building
 - Attics
 - Roof/wall intersections and plenum spaces
 - Mechanical penthouse doors and walls
 - HVAC equipment
 - Other roof penetrations
2. Bottom of Building
 - Soffits and ground floor access doors
 - Underground parking access doors
 - Exhaust and air intake vents
 - Pipe, duct, cable and other service penetrations into core of building
 - Sprinkler hangar penetrations, inspection hatches and other holes
 - Seal core wall to floor slab
 - Crawl spaces
3. Vertical shafts
 - Gasket stairwell fire doors
 - Fire hose cabinets or toilet room recessed accessories connected to shafts
 - Plumbing, electrical, cable and other penetrations within service rooms
 - Elevator rooms, electric rooms- reduce size of cable holes, firestop and seal bus bar openings
4. Exterior Walls
 - Weather-strip windows, doors, including balcony/patio doors and seal window trim
 - Exhaust fans and ducting
 - All service penetrations
 - Baseboard heaters
 - Electrical receptacles
 - Baseboards
5. Compartmentalize
 - Garages
 - Vented mechanical rooms

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- Garbage compactor rooms
- Emergency generator rooms
- High voltage rooms
- Shipping docks
- Elevator rooms
- Workshops.

5. Building Air Leakage Testing

The construction contractor's testing agency shall demonstrate performance of the continuous air barrier for the building envelope by the following tests:

1. Test the completed building in accordance with the "U.S. Army Corps of Engineers Air Leakage Test Protocol for Building Envelopes, Version 3, February 21, 2012" (http://www.wbdg.org/references/pa_dod_energy.php), in accordance with UFC 3-101-01, and using the methods identified in ASTM's E 779 and E 1827. Demonstrate that the air leakage rate of the building envelope does not exceed 0.25 cfm/ft² at a pressure differential of 0.3" w.g.(75 Pa) . Accomplish tests using both pressurization and depressurization unless extenuating circumstances dictate testing in only one direction. Divide the volume of air leakage in cfm @ 0.3" w.g. (L/s @ 75 Pa) by the area of the pressure boundary of the building, including roof or ceiling, walls and floor to produce the air leakage rate in cfm/ft² @ 0.3" w.g. (L/s.m² @ 75 Pa) (example given in the air leakage test protocol). Do not test the building until verifying that the continuous air barrier is in place and installed without failures in accordance with installation instructions so that repairs to the continuous air barrier, if needed to comply with the required air leakage rate, can be done in a timely manner. If the building fails the air tightness test, corrective actions must be made until the building until it passes a subsequent test.
2. Inspect the completed building using Infrared Thermography whether or not the building passes the fan pressure test. Use infrared cameras with a resolution of 0.1deg C or better. Perform inspection on the building envelope in accordance with ISO 6781 and ASTM C1060. Determine air leakage pathways using ASTM E 1186 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems. If the building did not pass the fan pressure test perform corrective work as necessary to achieve the whole building air leakage rate specified in (1) above and complete a second thermal scan.
3. Notify the Government at least three working days prior to the tests to provide the Government the opportunity to witness the tests. Provide the Government written test results confirming the results of all tests.

Figure 0-9 shows some visualization techniques that can be used to identify location or leaks.



Figure 0-9. Identification of leakage pathways using theatrical fog (left), smoke pencil (center), and infra-red thermography (right).

6. Conclusion

Potential energy conservation due to reduced energy used for building heating, cooling and dehumidification is demonstrated by the graph shown in **Figure 0-10**. The data based on the study of computer simulation of the typical barrack building located in different US climate zones (Zhivov et al., 2009) show that air leakage reduction from 1cfm/ft² at a pressure differential of 0.3" w.g. (75 Pa) to 0.25 cfm/ft² results in the total building energy conservation between 5% and 45% depending on climate zone. In addition, to energy conservation tighter building envelop results in decreased O&M costs for mold problems remediation.

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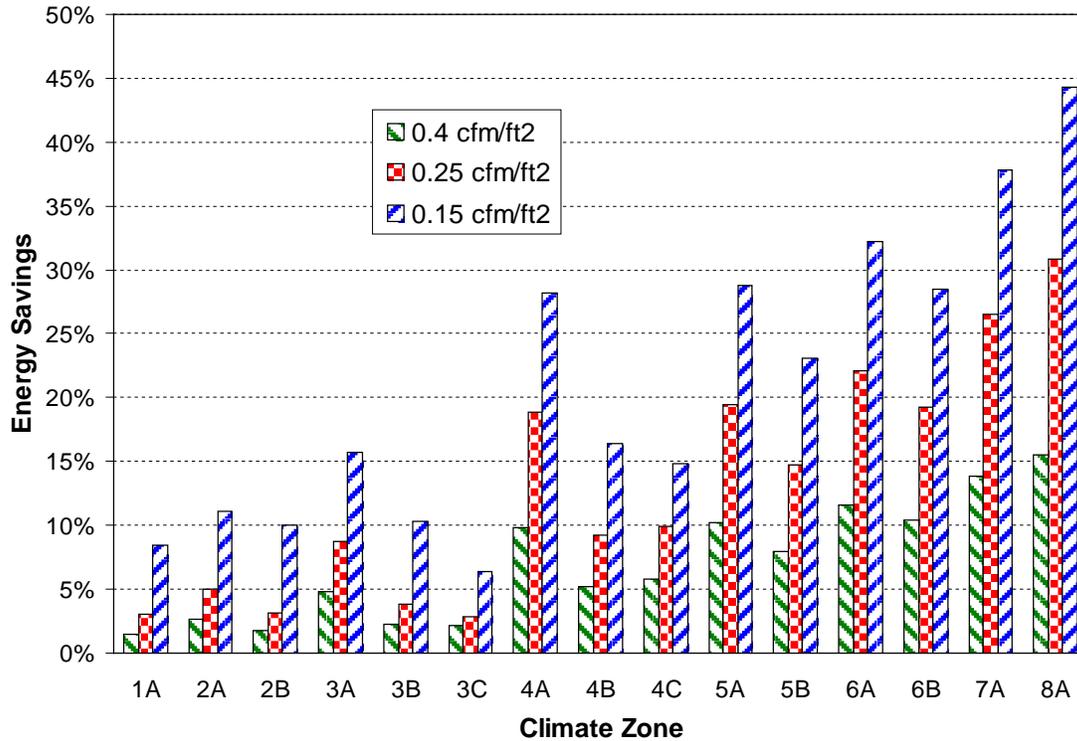


Figure 0-10. Annual energy savings due to reduced air leakage calculated for a typical barrack building for different US climate zones.

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