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IFC White Paper – Fire Resistive Duct Assemblies
ASTM E119, ASTM E2816, ISO 6944-1 and the I-Codes

Introduction

Recently, there has been much speculation about the interpretation of the International Building Code (IBC), International Mechanical Code (IMC) and related I-Codes in regards to the requirements applicable to fire resistance rated ducts installed in buildings, specifically air distribution duct systems. As the use of fire resistive duct systems is becoming more widespread within the industry, it is important to undertake a review of the International Building Code and International Mechanical Code requirements that pertain to fire resistance ratings, shafts, and these fire-resistive duct assemblies.

The ASTM E2816 and ISO 6944 standards represent rigorous and realistic criteria for evaluating passive fire protection of HVAC duct enclosure assemblies. When specifying or approving fire resistive duct assemblies as alternatives to code prescribed shaft enclosures, it is critical to know the system limitations and corresponding fire resistance ratings that the Codes prescribe. In order for ASTM E2816 and ISO 6944 tested systems to provide an alternative to an ASTM E119 code prescribed fire resistance rating, they must fully satisfy the intent of the Codes, and prevent the passage of flame and hot gases, resist the transmission of heat up to predetermined temperature limits, and provide a level of residual structural integrity. These criteria are prescribed directly from ASTM E119. Consequently, for the purposes of Code equivalency to shafts, the rating of a fire-resistive air duct assembly is the point at which any one of these failure conditions first occurs during the tests. Although ISO 6944 permits separate ratings for Stability, Integrity, and Insulation, the comparable ASTM E119 pass/fail criteria would define the fire resistance rating as the lowest of these three criteria.

Common Misconceptions

There are several common misconceptions regarding the IBC and IMC requirements for fire-resistive HVAC duct enclosures. Some of these are as follows:

1. *ISO 6944 and ASTM E2816 require both open and closed ducts to be tested in order to achieve a rating: **FALSE**.* While ASTM E2816 and ISO 6944 make provisions for testing both open and closed ducts (referred to as Duct A (closed) and Duct B (open) in ISO 6944), in a vertical or horizontal orientation, or both, compliance with these Standards can be achieved based on any one of the four possible configurations. This is comparable to ASTM E119, for example, which can be used to test numerous assemblies and components. It is not necessary to test all of them in order to achieve a fire resistance rating.

2. *ISO 6944 Duct B satisfies IBC Section 703.2.1 requirements to test asymmetrical wall assemblies from both sides:* **FALSE.** Testing of “open ducts”, or Duct B as defined by ISO 6944, is not equivalent or comparable to the IBC requirement to test an asymmetrical fire barrier wall from both sides. This is because in order to conduct an ASTM E119 test on a fire barrier wall assembly, measurements of the pass/fail criteria need to be conducted on the unexposed surface of the assembly (non-fire side). In this case, that would mean applying the pass/fail criteria to the inside and outside of the duct simultaneously, while they are engulfed within the fire. That is not done.
3. *The unexposed surface temperature measurements referred to in ASTM E2816 and ISO 6944 are measured in the in the same location as ASTM E119 requires:* **FALSE.** When unexposed surface temperature measurements are made on the portion of the assembly that penetrates an adjacent fire separation, that part of the testing is comparable to an ASTM E814, Standard Test Method for Fire Tests of Penetration Firestop Systems test (e.g. as required for a through penetration fire stop as tested under IBC Section 714), not ASTM E119.
4. *In order to claim to have a fire resistance rating based on ASTM E119, the temperature rise rating is always required:* **TRUE.** Temperature rise limits are fundamental and integral to the concept of fire separations, fire containment, and fire resistance ratings determined in accordance with ASTM E119.
5. *All UL Listing categories for Fire-Resistive ducts result in a rating that mirrors the pass fail criteria of ASTM E119 for fire-resistance ratings:* **FALSE.** Although all UL listings for ventilation duct assemblies have a 'V-' prefix, they reside in one of two distinctly different categories - HNLJ (Ventilation Duct Assemblies) and HNLN (Uninsulated Duct Assemblies). UL category HNLJ covers the fire-resistive performance of ventilation duct assemblies investigated to ISO 6944, "Fire Resistance Tests - Ventilation Ducts," and/or ASTM E2816, "Standard Test Methods for Fire Resistive Metallic HVAC Duct Systems." Ventilation Duct Assemblies Listed under the HNLJ Category provide a single hourly rated value, which mirrors the base ASTM E119 principle that the assigned fire-resistance rating must be based on the first occurrence of one of the failure criteria (e.g. occurrence of flaming, excess temperature rise, or loss of structural stability). In contrast, the UL HNLN category covers the fire-protective, not fire-resistance, performance of uninsulated ventilation duct assemblies investigated to ISO 6944. Though uninsulated ventilation duct assemblies provide three separate hourly fire protection values (Stability, Integrity, and Insulation) the insulation rating is not mandatory. Therefore, these systems do not limit the temperature rise on the surface of the ventilation duct assembly in a non-fire environment. These uninsulated ventilation duct assemblies are intended for use in environments where the clearance to combustible materials and combustible assemblies is at least 18 inches. Consequently, while the HNLJ category mirrors the definition of a “fire resistance rating” as defined by ASTM E119 and the Codes, the HNLN category mirrors the performance of a “fire protection rating” in the Codes, which is used for opening protectives such as fire doors and fire dampers. Fire protection ratings are not permitted to be used in lieu of fire resistance ratings for fire walls, fire barriers, smoke barriers or fire partitions in the Codes and likewise should not be used for duct systems either. Similarly, the IBC does not recognize, or permit, the use of clearances in lieu of compliance with ASTM E119 unexposed surface temperature criteria.

6. *An insulation rating is not required for horizontal ducts penetrating fire resistant rated walls or shaft walls because a T-Rating is not required per Code:* **FALSE**. While a T-Rating is not required when penetrating a vertical assembly as tested per ASTM E814, this is NOT the same as the insulation rating and resulting fire resistance rating of the duct assembly itself. The “T-Rating” applies only to the through penetration firestop system itself while the insulation rating, and resulting fire resistance rating, apply to the entire length of the duct system.
7. *The IMC and UL Listing requirement to maintain 18" clearance to combustibles is waived if the duct enclosure materials comply with plenum requirements for Flame Spread and Smoke developed rating of 25 and 50 (i.e. is "plenum rated"):* **FALSE**. These two requirements are independent, and protect against different potential hazards. Flame spread and smoke developed deal with the fire spread along the outside surface of the duct or duct enclosure materials themselves. Clearances are required to be measured between the heat-producing surface of a device or equipment and the surface of the combustible material or assembly around them, in order to prevent their ignition.

Background

The basic test method used to evaluate the fire resistance rating of products, materials and assemblies in the model Codes has long been ASTM E119 and/or UL 263. ASTM E119 and UL 263 are equivalent test methods. These test methods are applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies or floors and roofs. They are also applicable to other assemblies and structural systems that form permanent integral parts of a finished building. The first edition of ASTM E119 was published in 1918, with the most recent edition issued in 2016. Throughout the world, similar fire test methods are published by organizations such as the International Standardization Organizations' (ISO) ISO 834.

Fire-resistance ratings have long been used by building codes to measure the performance of various constructions for fire containment purposes. As applied to elements of buildings, the fire-resistance rating classifies the ability of an assembly to confine and isolate fire within a zone comprised of fire-resistance rated walls, ceiling and floor assemblies. The ratings relate to fire tests designed to determine how quickly fire can raise the temperature to unacceptable levels as measured across the assembly on the non-fire exposed surface of a wall or floor. Fire-rated assemblies are tested and certified in their entirety. ASTM E119 is used to generate data to measure the integrity of building assemblies subjected to a standardized fire exposure.

ASTM E119 is the general fire resistance test Standard prescribing various conditions of performance testing for construction assemblies and building elements under standardized fire conditions. These basic test conditions and methods also form the foundation for other adjunct test methods, which use the same principles to focus on various additional products and applications used for fire containment within building structures. The fire performance of individual products and applications, including fire doors, fire stopping, and fire-resistant joint systems, are examples. These complimentary standards take the principles of ASTM E119, including the standard time-temperature fire exposure curve and the prescribed temperature rise limits, and customize them to apply to the specific applications and needs of the Building Codes.

IBC Shaft Requirements

The 2015 IBC Section 717.6 requires shaft enclosure walls around HVAC ducts penetrating more than two floors to be fire-resistance-rated in accordance with Section 713.4. That section of the IBC requires the fire-resistance rating to be one or two hours, depending on the number of floors penetrated by the shaft. Where ducts are enclosed within a shaft, Section 713 of the IBC requires the shaft enclosure walls to satisfy the requirements of a fire barrier in accordance with Section 707, or horizontal assemblies in accordance with Section 711, or both. Fire-resistance-rated shaft enclosures are required for vertical HVAC duct penetrations of fire-resistance-rated floors or floor/ceiling assemblies, with the following exceptions: (1) In occupancies other than groups I-2 and I-3, a fire damper placed at the floor line is allowed when connecting not more than two stories; or (2) a maximum 4-inch-diameter HVAC duct is allowed to connect up to three stories without damper or shaft protection, provided all the exceptions to IBC Section 717.6.1 are satisfied.

IBC section 717 also contains requirements for ducts penetrating horizontal and vertical fire separations. For duct penetrations, the Code requires the use of a fire damper or a through-penetration firestop system, unless enclosed in a fire resistance rated shaft. Ducts that penetrate horizontal assemblies that are not required to be contained within a shaft, and not required to have dampers, must have an F rating and T rating of at least 1 hour, but not less than the required rating of the floor penetrated.

Fire Resistance Testing of Shaft Enclosures for I-Code Compliance

As discussed, the purpose of a fire separation (i.e. fire barrier, smoke barrier, fire wall, floor/ceiling assembly etc.) is to isolate a fire on one side of the separation, from breaching the barrier, and spreading beyond the unexposed side of the fire separation. Fire barriers and horizontal assemblies are required to have a fire resistance rating determined per ASTM E119 or UL 263. IBC section 713 identifies the requirements for vertical shafts required to protect openings and penetrations through floor/ceiling and roof/ceiling assemblies.

Where a shaft enclosure is constructed using fire barrier walls, the IBC requires those fire barriers to meet Section 703.2.1, which states:

“703.2.1 Nonsymmetrical wall construction. Interior walls and partitions of nonsymmetrical construction shall be tested with both faces exposed to the furnace, and the assigned fire-resistance rating shall be the shortest duration obtained from the two tests conducted in compliance with ASTM E 119 or UL 263. Where evidence is furnished to show that the wall was tested with the least fire resistant side exposed to the furnace, subject to acceptance of the building official, the wall need not be subjected to tests from the opposite side (see Section 705.5 for exterior walls).”

Consequently, walls are to be assigned a fire resistance rating based on fire exposure from the side with the least resistance.

Fundamentally, in order for a non-load-bearing wall assembly to be assigned a fire resistance rating in accordance with ASTM E119, the assembly must comply with all of the conditions identified below. The assigned fire-resistance rating is based upon the time (typically expressed in minutes or hours) of

first occurrence of any one of these failure criteria relating to structural stability, temperature rise resistance on the unexposed surface of the test assembly (insulation), and prevention of the passage of flame or hot gases, and subsequent passage of hose stream (integrity). The specific language defining the pass/fail criteria used to determine when a limiting condition is reached is below:

1. The wall or partition withstands the fire endurance test without passage of flames or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired,
2. The assembly limits temperature rise to a maximum average temperature rise of 250°F by making measurements during the conduct of the fire exposure test,
3. The assembly limits the maximum temperature at any individual location to a maximum of 325°F by making measurements during the conduct of the fire exposure test, and
4. The wall or partition withstands the impact of the hose stream test. The assembly is considered to have failed the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the application of the hose stream test.

Because the ASTM E119 standard is only designed to test vertical (e.g. walls) and horizontal assemblies (e.g. floor/ceiling) from one side at a time, evaluation of asymmetrical wall assemblies can only be achieved by conducting two separate fire tests – one from each side. This allows for evaluation of all of the ASTM E119 fire resistance criteria identified above, irrespective of which side of the vertical fire separation is exposed to fire. This is necessary because fire resistance ratings are intended to isolate a fire hazard to the area of origin.

As indicated in the pass/fail criteria summarized above, in order to claim to have a fire resistance rating based on ASTM E119, the temperature rise rating is always required. It is fundamental and integral to the concept of fire separations, containment, and fire resistance ratings for fire barriers and horizontal assemblies.

How FR HVAC Ducts are Tested – ASTM E2816 and ISO 6944-1

Traditionally, duct shaft enclosures were constructed using a set of adjoining fire barrier walls, usually gypsum shaft walls. Section 713 of the IBC assumes this to be the case, since shaft enclosures tested to ASTM E119 are evaluated as individual fire resistance rated assemblies, tested from one side at a time. ASTM E119 does not require, or make any allowance for, shaft enclosures evaluated in the actual configuration required for HVAC duct protection systems as constructed (i.e. as a 4-sided boxed enclosure of a duct). Similarly, they are not specifically evaluated for horizontal runs or for circumstances where the duct and enclosure incorporate access openings.

With the evolution of fire tests specifically designed to evaluate fire-resistive duct protection systems, as they are installed and intended for use, the need to construct shaft enclosures using fire barriers is no longer necessary. In 2011, ASTM published its first edition of ASTM E2816, *Test Methods for Fire Resistive Metallic HVAC Duct Systems*. This ASTM Standard was comparable to the ISO 6944, *Fire resistance tests -- Ventilation ducts*, which was first published in 1985. The test was intended to provide the building codes with a test method specifically designed to test a heating, ventilation and air conditioning duct system and its materials for fire resistance and other durability requirements. Like other adjunct tests, this standard utilizes the time-temperature exposure, and

basic principles of ASTM E119, but is specifically designed to evaluate duct enclosure protection systems for fire resistance, as enclosures installed around HVAC ducts. Unfortunately, neither ASTM E2816 nor ISO 6944 is currently cited in any US building code. Consequently, use of these standards as alternatives to current code provisions requires approval from an Authority Having Jurisdiction. The fire engulfment test described in ASTM E2816 provides an alternative to an ASTM E119 code prescribed fire resistance rating ONLY when the test specimens (Condition A, B, C and/or D) meet all of the following criteria in Section 16.4 of the Standard are used in combination:

1. For all configurations tested (i.e. A, B, C, or D) there shall be no visible through openings created into the HVAC duct that is unexposed to the furnace fire during the fire-engulfment test,
2. The unexposed surface temperatures as measured by the unexposed surface thermocouples on the HVAC duct does not exceed a temperature rise of 325°F (181°C) during the fire engulfment test,
3. No flaming occurs on any portion of the unexposed surface of the test specimen during the fire-engulfment test,
4. No visible through openings shall occur on any portion of the unexposed surface of the test specimen during the fire-engulfment test., and
5. The support system shall carry the load of the HVAC duct (Condition A, B, C, and D) during the fire-engulfment test, sustain the test conditions, and conform with the pass/fail criteria for a period of time equal to the reported fire resistance rating.

Subsequent to the publication of the ASTM Standard, the Acceptance Criteria for Metallic HVAC Duct Enclosure Assemblies (AC 179) issued by ICC-ES was updated to reference ASTM E2816 for evaluating fire-rated HVAC duct work configurations. Acceptance Criteria (AC) are a set of defined provisions developed by ICC-ES for building products and systems that are alternatives to what is specified in the code, but otherwise meet or exceed the intent of the code. Systems that comply with AC 179, thus having been tested to ASTM E2816, offer tested solutions equivalent to shaft enclosures permitted by code.

ASTM E2816 and ISO 6944 tested systems also include provisions for penetrations at both the floor & wall assemblies. Fire testing per ASTM E2816 evaluates duct systems based on the ASTM E119 standardized time temperature curve for fire resistive assemblies. Full size duct configurations are tested in four separate conditions: horizontal-open, horizontal-closed, vertical-open, and vertical-closed. These configurations evaluate ductwork systems with fire exposures inside (open) and outside (closed) the ductwork. Each one of these configurations represents a conceivable HVAC application.

Conclusions

Overall, the ASTM E2816 and ISO 6944 standards represent rigorous and realistic criteria for evaluating passive fire protection of HVAC duct enclosure assemblies as an alternative to code prescribed shaft enclosures. However, while the basic principles required by ASTM E119 testing are addressed, the tests are adapted for testing duct enclosures because there are no provisions within ASTM E119 itself to test a duct enclosure system. As such, the four duct specimen configurations identified in ASTM E2816 (and ISO 6944) are not the same as the general ASTM E119 test specimen configurations.

It is critical when specifying or approving fire resistive duct assemblies as alternative to code prescribed shaft enclosures to know the system limitations and corresponding fire resistance ratings. ISO 6944 tested systems provide an alternative to an ASTM E119 code prescribed fire resistance rating ONLY when all three of the reported performance criteria - namely the Stability, Integrity, and INSULATION ratings - are used in combination. For code application purposes, the resulting Fire Resistive Duct rating can only be assigned based on the first occurrence (e.g. the earliest occurrence) of ANY of these three failure criteria.

Similarly, the assigned fire resistance rating determined from the ASTM E2816 test is the time at which the first occurrence of any of the above mentioned failure conditions occurs.