Firestopping & Effective Compartmentation

Betty Turowec, P.Eng.
Application Engineer

FCIA
Firestop Contractors International Association

3M Science. Applied to Life.™

Session Objectives

Firestopping overview

- Common terminology
- Compartmentation and containment

National Building Code of Canada (NBC)

- Notable sections: continuity, firestopping
- Important standards

Through-penetrations

- Technologies
- Selecting appropriate systems
- Engineering Judgments (EJ)

Firestopping Overview

Terminology and Theory

Fire Facts

Every year, building fires kill more **people** than natural disasters, damage vital equipment and destroy billions of dollars in **property**.

Smoke travels **120-420 feet per minute** under fire conditions.

Source: Estimate based upon ceiling jet velocity calculations for typical ceiling heights and heat release rates.

3/4 of all fire deaths are caused by smoke inhalation.

Source: Hall, Jr. John R. NFPA Fire Analysis & Research, Quincy, MA. "Burns, Toxic Gases, and other Hazards".

So what can we do to help limit the destructive power of a fire in commercial building?

FIRESTOP!

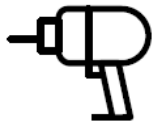
Firestopping Responsibility

Collaborative Effort

Owner

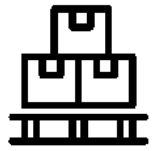
Architect

General Contractor



Sub-contractor

Code Official

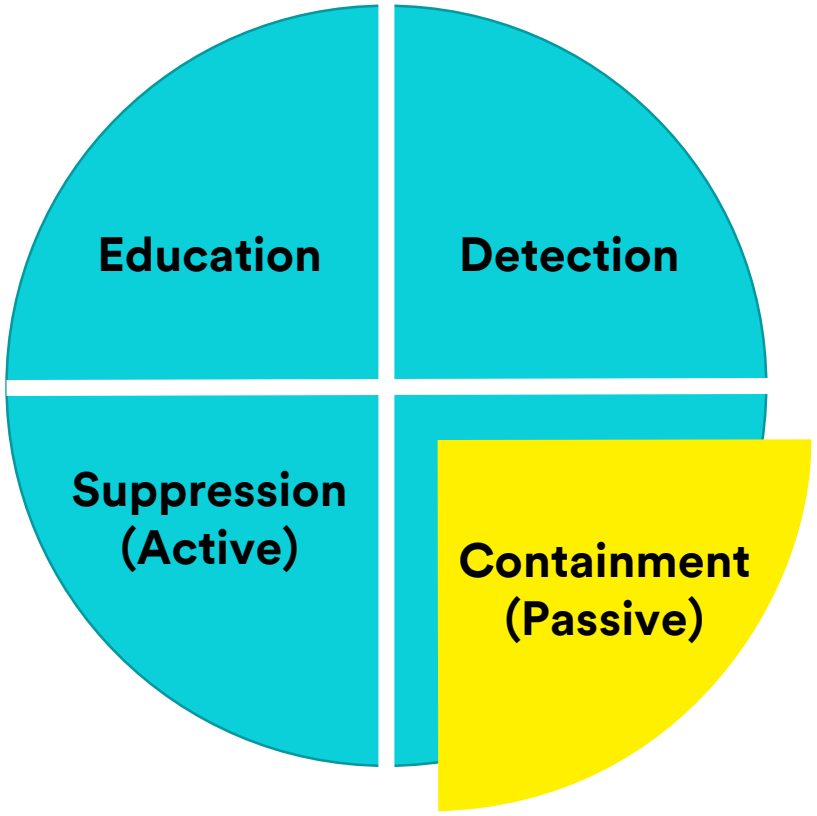


Manufacturer

Balanced Approach to Fire Safety

Exit Signs,
"Stop, Drop and Roll"

Sprinklers,
Fire Departments

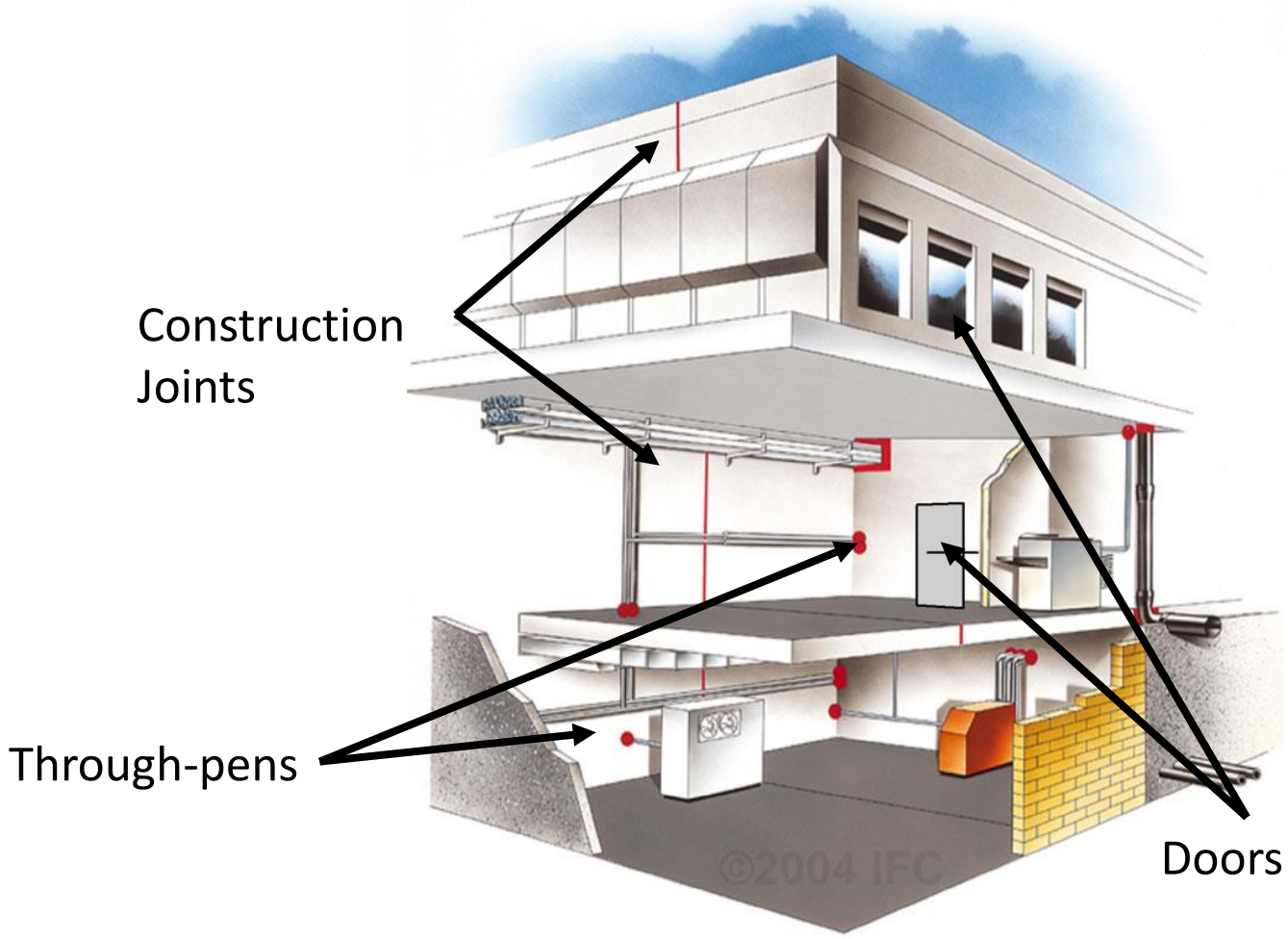


Smoke Detectors

Passive Protection:
Containment

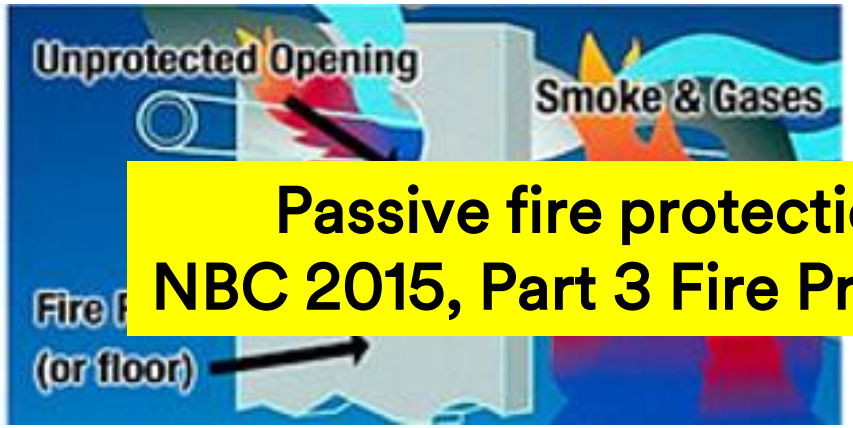
A balanced approach to fire protection uses all available tools to improve fire safety. Passive protection allows occupants to leave prior to gas, smoke and flame spread.

Areas that Allow Flame / Smoke Spread



Purpose of Firestop

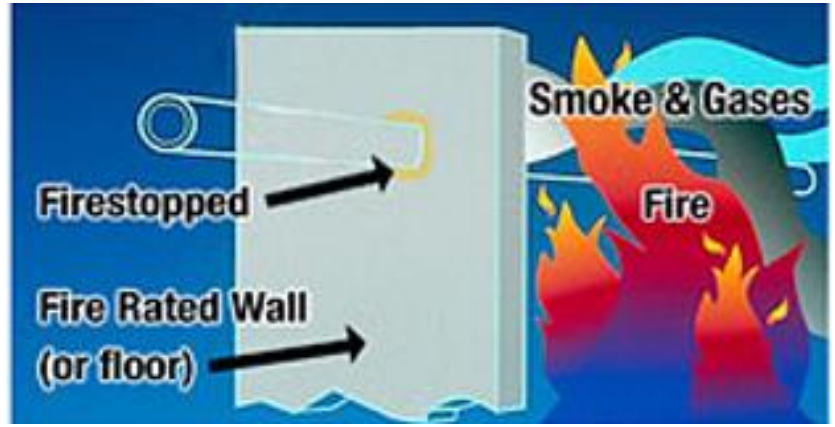
Fire travels through the path of least resistance, such as an unprotected opening in a floor or wall.



Passive fire protection clearly defined in construction codes.
NBC 2015, Part 3 Fire Protection, Occupant Safety and Accessibility.

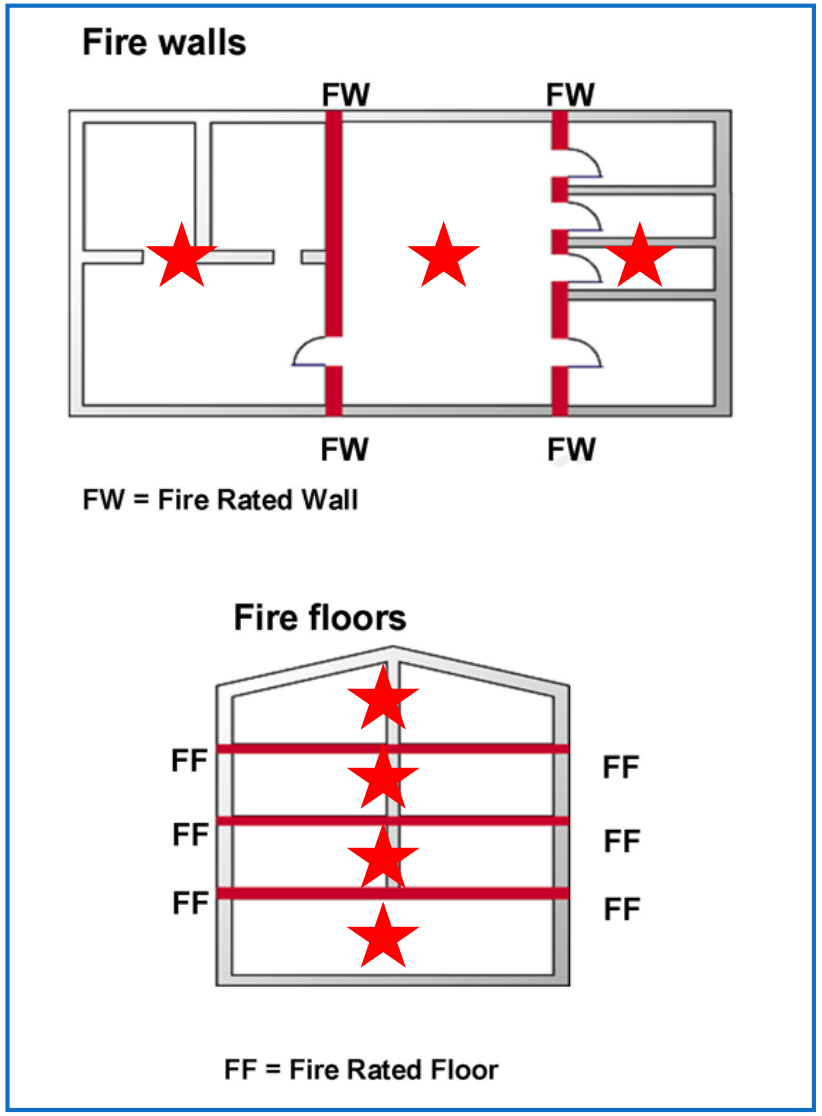
Maintain continuity of *fire separation* via installation of a firestop system. Seal penetrants, gaps or openings.

Restricts movement of fire / smoke into adjacent areas by restoring *fire-resistance rating* of assembly.



Compartmentation

- Confine fire to the zone of origin for a specified time
- Divide building into separate compartments via *Fire Separations*
- Prevents spread of fire, smoke and toxic gases
- Increases evacuation time for occupants
- Considered during building design



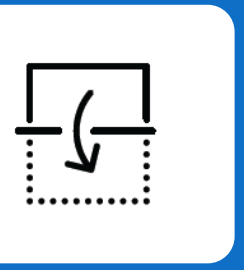
Definitions: Ratings

Fire-Resistance Rating

- Time in minutes / hours that assembly of materials withstands passage of flame and transmission of heat
- Continues to perform given structural function
- Conformance with *CAN/ULC-S101*

Fire Protection Rating

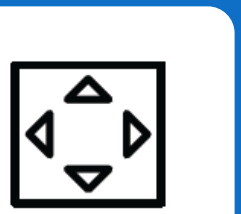
- Time in minutes / hours that a *closure* will withstand passage of flame
- Exposed to fire under specified conditions of test and performance criteria



F Rating

- Time in minutes / hours that firestop system withstands passage of flame
- Firestop system remains in opening during fire test
- Conformance with *CAN/ULC-S115*

Definitions: Assemblies

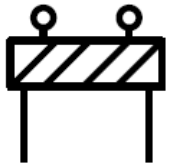


Fire Compartment

- Enclosed space in a building
- Separated from all other parts of building
- Achieved via enclosing construction, providing a *fire separation* having a required *fire-resistance rating*

Firewall

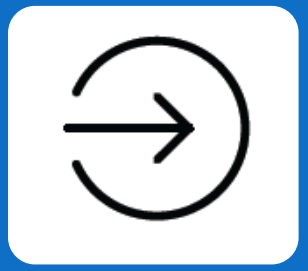
- Separation of non-combustible construction
- Subdivides building or separates adjoining buildings
- Resist spread of fire, *fire-resistance rating*, structural independence, continuous (from foundation to roof)



Fire Separation

- Combustible or non-combustible construction assembly
- Acts as a continuous barrier to spread for fire and / or smoke
- Remain in place, create compartments
- May or may not have a *fire-resistance rating*

Definitions: Restoring Continuity



Firestop

- Material used to fill gaps between *fire separations*
- The term includes both a through-penetration or membrane-penetration *firestop*
- Restores *fire resistance rating* and separation continuity

Fireblock

- Material, component or system that restricts spread of fire within a concealed space
- Or from a concealed space to adjacent space

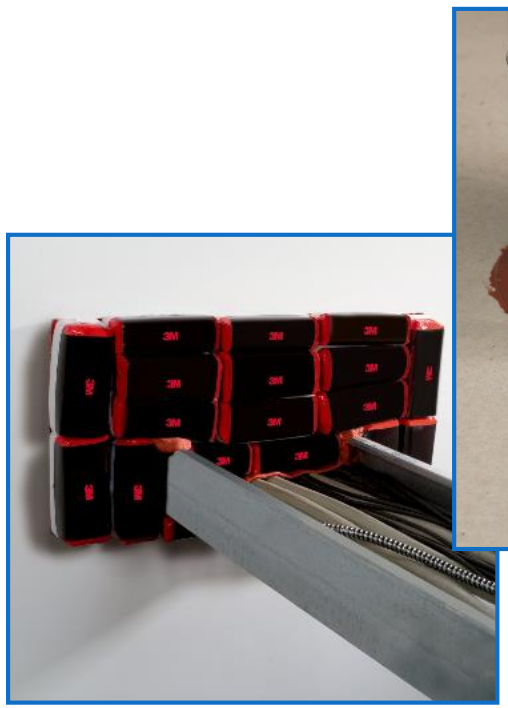
Closures

- Device or assembly for closing opening in a *fire separation*
- Door, shutter, window, etc.
- Includes all components: hardware, closing devices, frames and anchors

Containment (Firestopping)

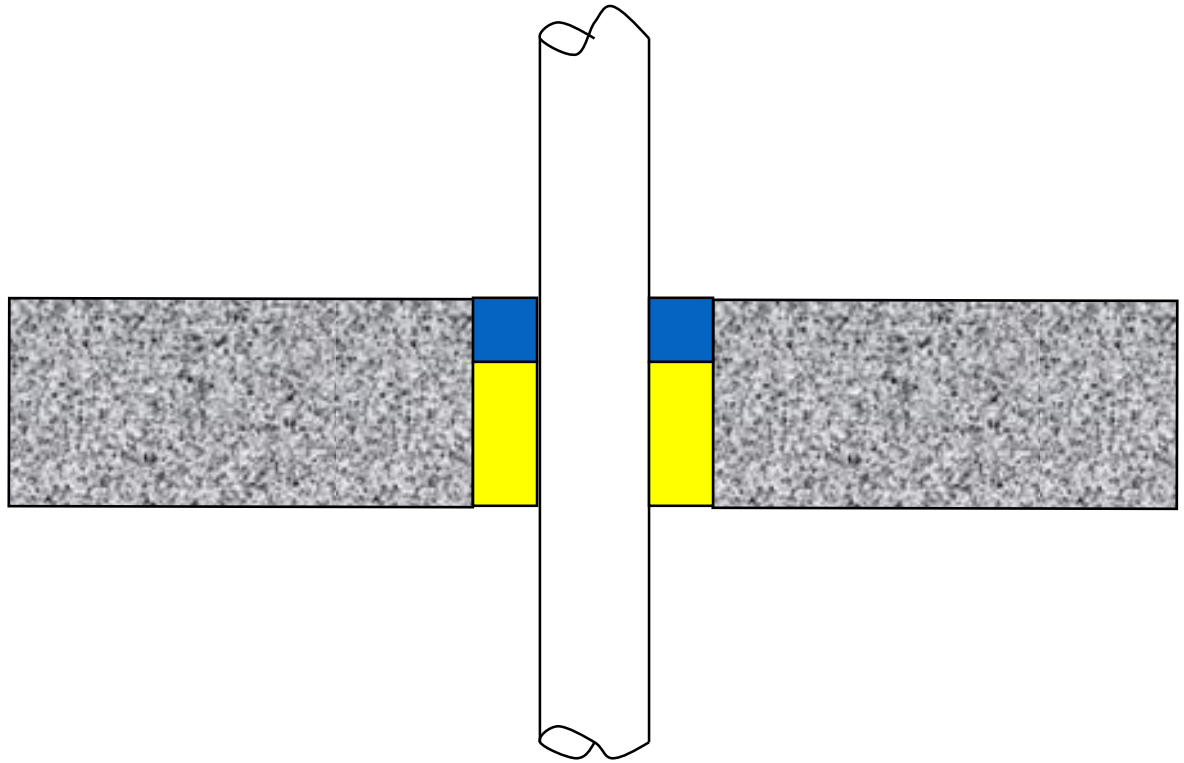
- *Firestop* required when an assembly is penetrated by various building services
- Sealed by a *firestop* system to close off openings between *fire separations*; maintains compartment continuity and *fire-resistance rating*
- Also needed for construction joints, formed between walls and floors

Containment: Through-penetration



Through-penetrations are created where pipes, tubing, ducts, chimneys, optical fibre cables, electrical wires, raceways, etc. **pass completely through** a rated floor / wall assembly.

Containment: Through-penetration



Install an assemblage of specific products that are designed, tested and rated to resist the spread of fire for a prescribed period of time.

Containment: Membrane Penetration

- Opening made **through one side** (wall, floor or ceiling membrane) of an assembly
- To firestop, install material to resist passage of flame and heat for a prescribed time period
- Common items are plumbing pipes and outlet boxes

Containment: Construction Joints

- Linear openings between **adjacent fire-rated assemblies**
- Typically designed to allow independent movement (dynamic joints)
- Includes perimeter joints

Containment: Flexible Wrap Systems

- Endothermic Mats: fire-proofing structural steel: columns, beams
- Electrical circuit protection (ECP): cable trays, conduits
- Insulative blankets: ventilation, grease, chemical fume and boiler exhaust ducts
- Steel / iron standpipe
- Plenum applications

National Building Code of Canada

Relevant Firestop Sections

NBC 2015

3.1.8: Fire Separations, Closures and Compartmentation

3.1.8.1 General Requirements

1) Any wall, *partition* or floor assembly required to be a *fire separation* shall
   a) be constructed as a continuous element
   b) have a *fire-resistance rating* as specified (see A-3.1.8.1(1)(b))

2) Openings in a *fire separation* shall be protected with *closures*, shafts or other means in conformance with Articles 3.1.8.4 to 3.1.8.19, and 3.1.9 and 3.2.8. Means of egress should be free of smoke and doors in *fire separations* should be closed (**A-3.1.8.1.(2) Installation of Closures**).

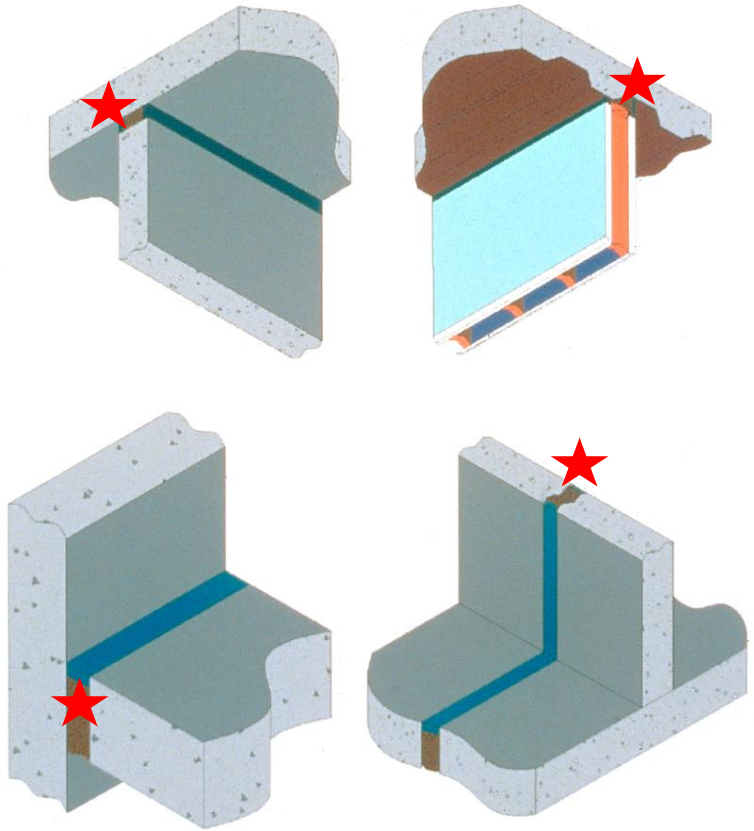
A-3.1.8.1.(1)(b) Barrier to Control Smoke Spread. A *fire separation* may not need a *fire-resistance rating*, but it should still act as a barrier to flame and smoke spread (i.e. waived because of automatic sprinklers).

NBC 2015

3.1.8: Fire Separations, Closures and Compartmentation

3.1.8.3 Continuity of Fire Separations

4) Continuity of *fire separation* maintained where it abuts another *fire separation*, floor or exterior wall assembly



A-3.1.8.3.(4) Fire Separation Continuity. Maintain continuity by filling all openings at the juncture of assemblies with a material that will ensure integrity of the fire separation (at that location).

NBC 2015

3.1.9: Penetrations in Fire Separations and Fire-rated Assemblies

3.1.9.1 Fire Stops

1) Penetrations of a *fire separation* or membrane forming part of an assembly required to have a *fire-resistance rating* shall be:

   a) sealed by a *fire stop* (tested to *CAN/ULC-S115*) with an F rating not less than the *fire-protection rating* required for *closures* in the *fire separation* (Table 3.1.8.4), or

   b) Cast in place (no gaps b/t penetrant and assembly penetrated)

Table 3.1.8.4.
Fire-Protection Rating of Closures
Forming Part of Sentences 3.1.8.4.(2) and 3.1.9.1.(1)

Fire-Resistance Rating of *Fire Separation*	Minimum *Fire-Protection Rating* of *Closure*
45 min	45 min
1 h	45 min
1.5 h	1 h
2 h	1.5 h
3 h	2 h
4 h	3 h

NBC 2015

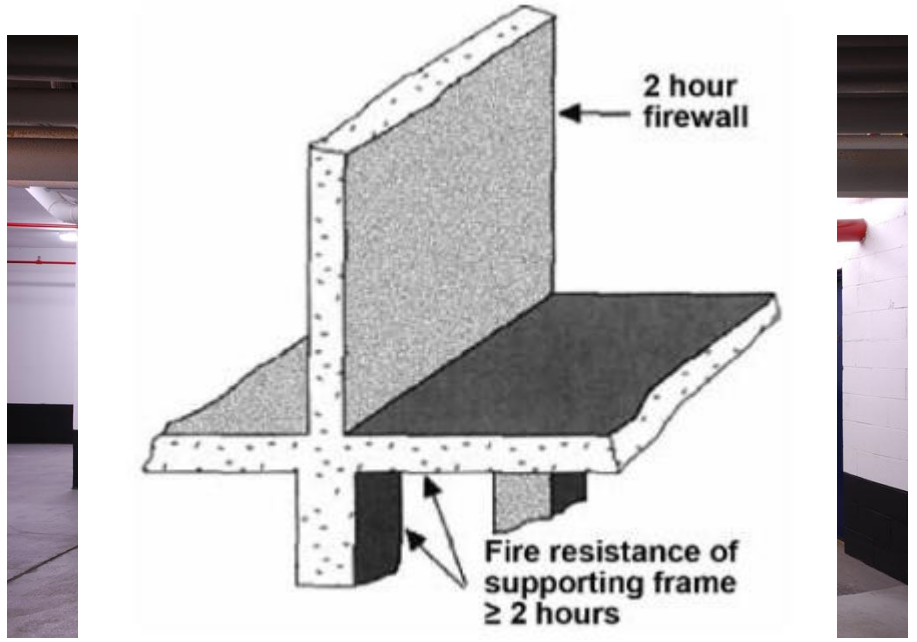
3.1.9: Penetrations in Fire Separations and Fire-rated Assemblies

3.1.9.1 Fire Stops

2) Penetrations of a *firewall* or horizontal *fire separation* that is required to have a *fire-resistance rating* in conformance with Article 3.2.1.2 shall be sealed at the penetration by a *fire stop* that, when tested to *CAN/ULC-S115*, has an FT rating not less than the *fire-resistance rating* for the *fire separation.*

3.2.1.2 Storage Garage Considered Separate Building

- Floor & roof assemblies above the *basement* and exterior walls of *basement* above adjoining ground level are constructed as *noncombustible fire separations*
- *Fire-resistance rating* of at least 2 hours

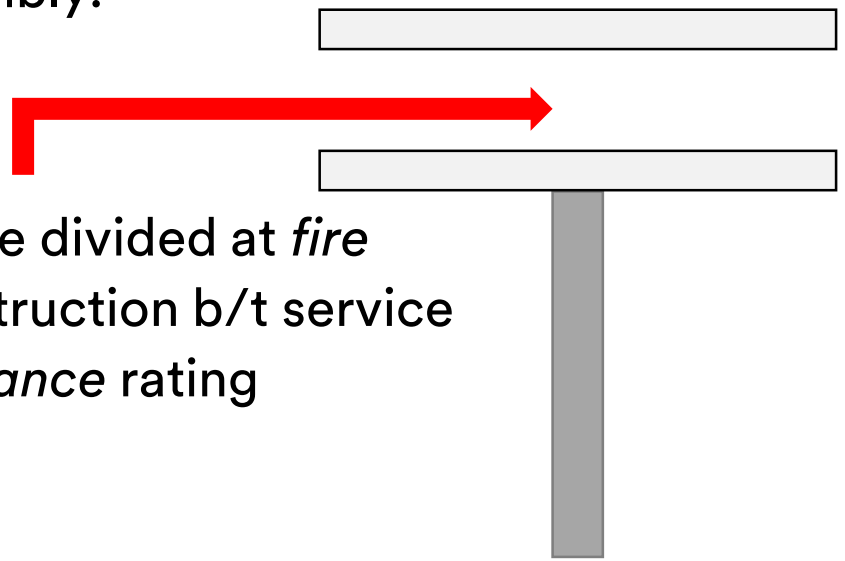


NBC 2015

3.1.9: Penetrations in Fire Separations and Fire-rated Assemblies

3.1.9.1 Fire Stops

3) Penetrations of a *fire separation* in conformance with 3.6.4.2(2) shall be sealed by a *fire stop* that, when tested to *CAN/ULC-S115,* has an FT rating not less than the *fire-resistance rating* for the *fire separation* of the assembly.



3.6.4.2 Fire Separations for Horizontal Service Spaces

2) If located above a vertical *fire separation*, space need not be divided at *fire separation* as required by Article 3.1.8.3, provided the construction b/t service space and space below is a *fire separation* with a *fire-resistance* rating equivalent to that required for the vertical *fire separation*.

3.1.8.3 Continuity of Fire Separation

1) A *horizontal service space* above a vertical *fire separation* shall be divided at *fire separation* by an equivalent *fire separation* within the *service space*.

NBC 2015

3.1.9: Penetrations in Fire Separations and Fire-rated Assemblies

3.1.9.1 Fire Stops

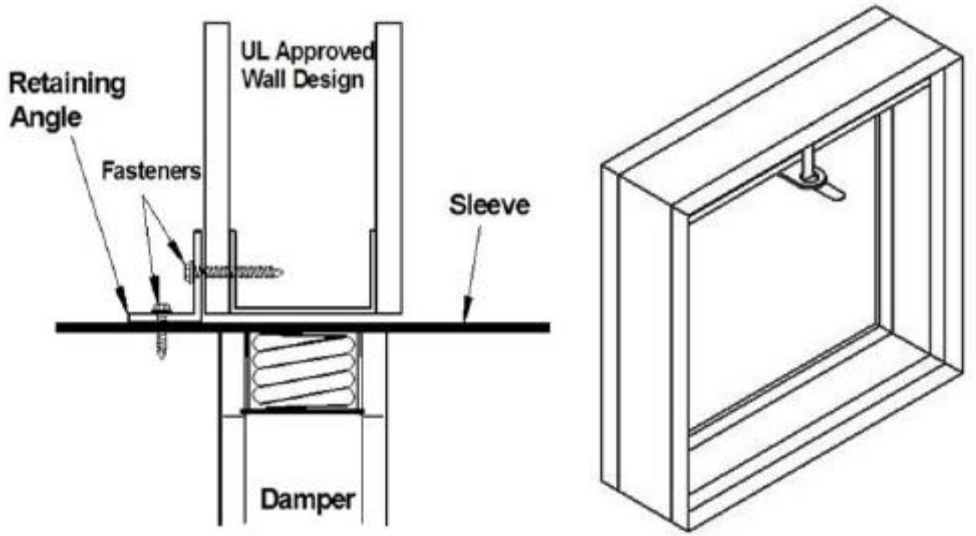
4) Sprinklers may penetrate *fire separations* required to have a *fire-resistance rating* without meeting requirements of Sentences (1) to (3) (no need for *CAN/ULC-S115*). Annular space must be covered by metal escutcheon plate as per NFPA 13 *Installation of Sprinkler Systems*.

NBC 2015

3.1.9: Penetrations in Fire Separations and Fire-rated Assemblies

3.1.9.1 Fire Stops

5) *Fire Dampers* can penetrate a *fire separation* required to have a *fire-resistance rating* without meeting requirements of Sentences (1) to (3) (no need for *CAN/ULC-S115*). *Fire damper* must be installed in conformance with NFPA 80 *Fire Doors and Other Opening Protectives*.



Carey, D., FCIA Montreal 2019, Fire Dampers 101

NBC 2015

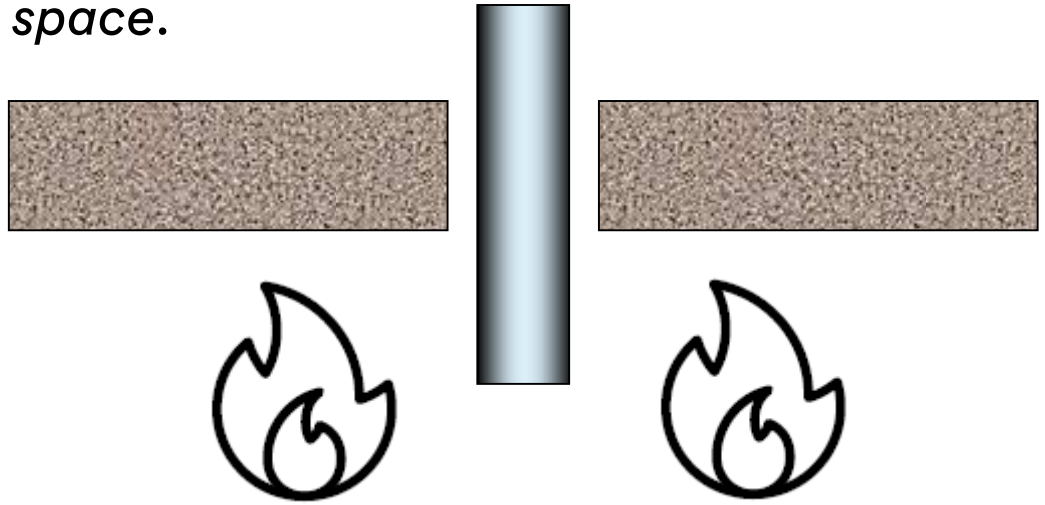
3.1.9: Penetrations in Fire Separations and Fire-rated Assemblies

3.1.9.5 Combustible Piping Penetrations

4) *Combustible* drain, waste and vent piping can also penetrate a *fire separation* (or a membrane) required to have a *fire-resistance rating*, provided

a) The piping is sealed at the penetration by a *fire stop* that has an F rating not less than the *fire-resistance rating* required for the *fire separation* when subjected to *CAN/ULC-S115* with a pressure differential of 50 Pa b/t exposed and unexposed sides (higher pressure on exposed side)

b) piping cannot be located in a *vertical service space*.



Evaluation Standards

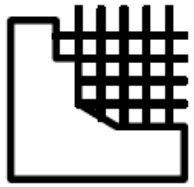
CAN/ULC-S101: Fire Endurance Tests of Building Construction and Materials

CAN/ULC-S115: Fire Tests of Firestop Systems

CAN/ULC-S101

Standard Methods of Fire Endurance Tests of Building Construction and Materials

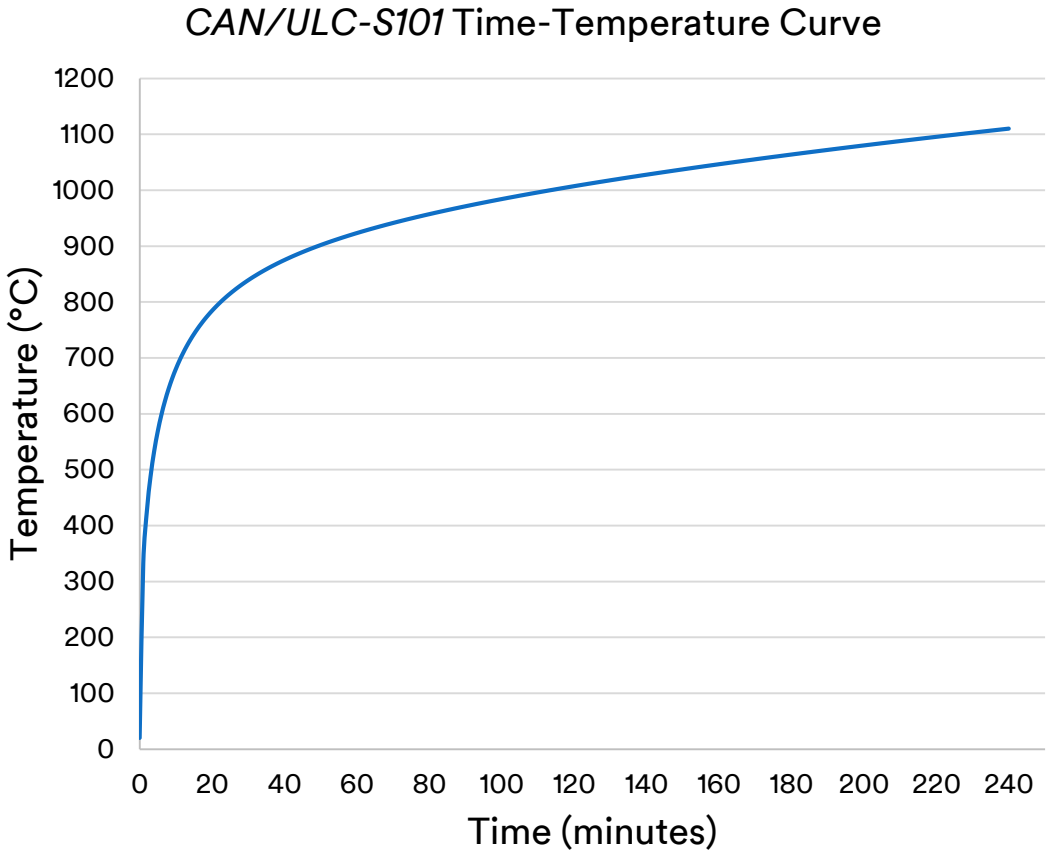
- Overarching fire protection standard (*NBC 3.1.7 Fire-Resistance Ratings*)



<u>Floor, Roof, Walls or Partitions</u>
Require at least 9 thermocouples

<u>Columns</u>
8 (4 pairs), located 1/3 & 2/3 height

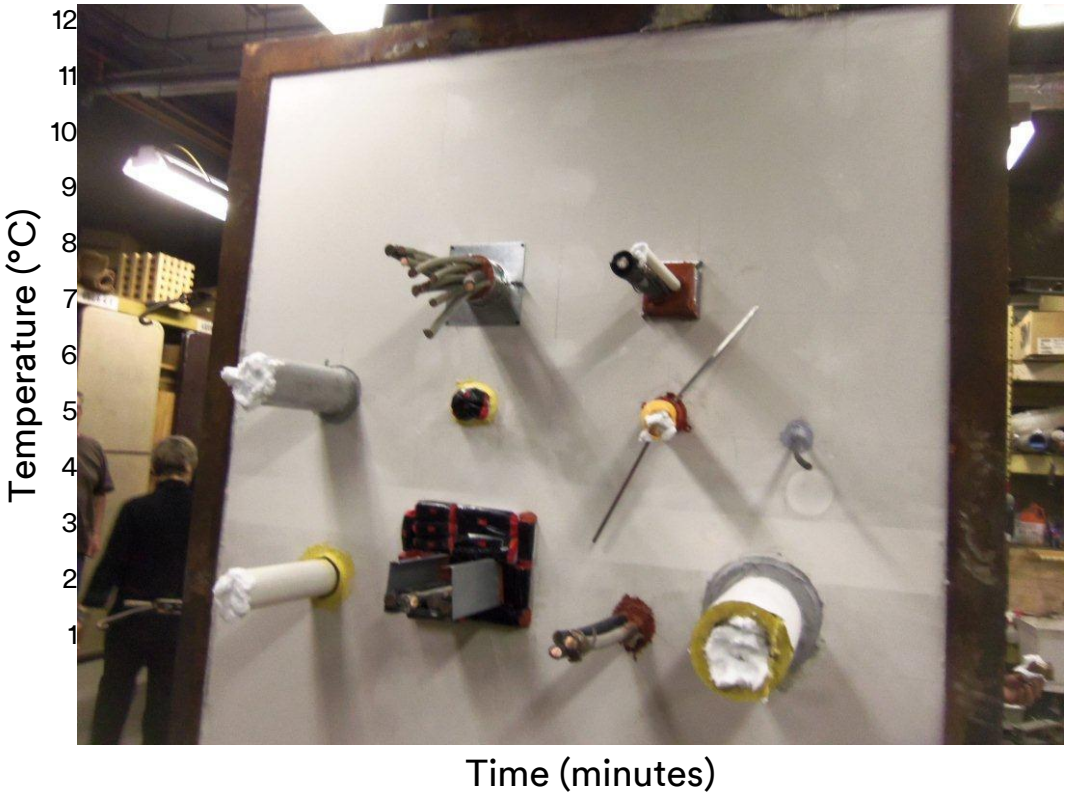
<u>Beams</u>
16, 4 per equally-spaced section

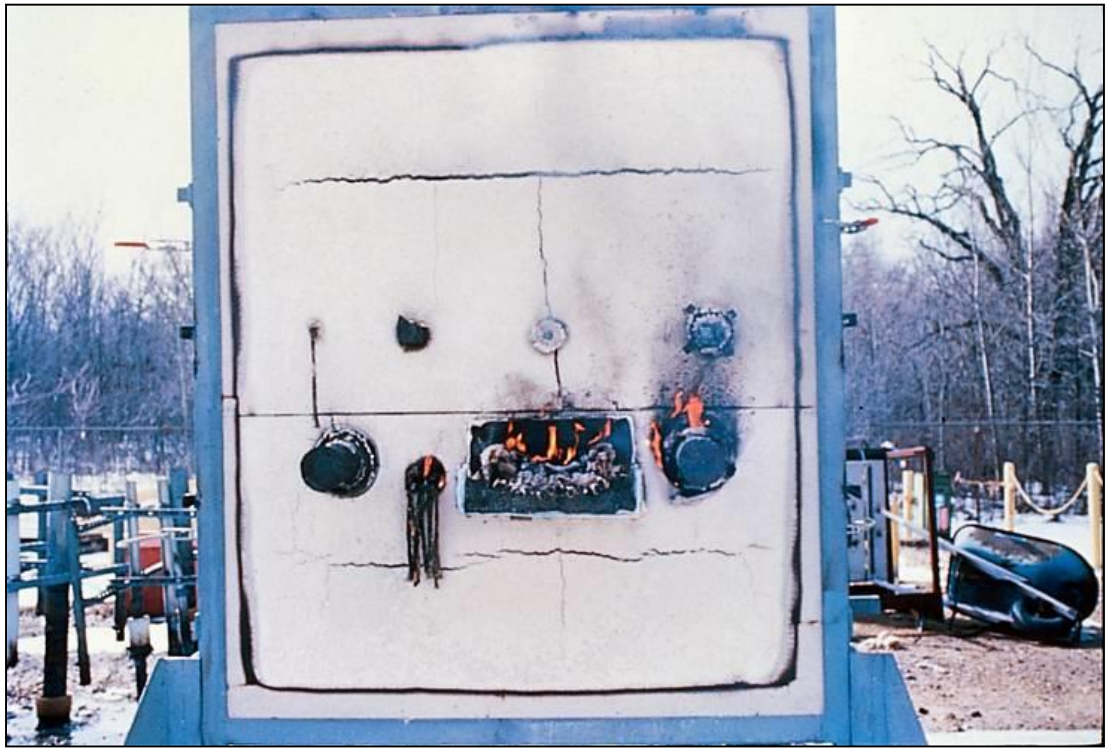


CAN/ULC-S115

Standard Methods of Fire Tests of Firestop Systems

CAN/ULC-S101 Time-Temperature Curve





Acceptance Criteria: F Rating

Firestop system must remain within opening to meet F rating requirements

Firestop system does not permit passage of flame though openings, or flaming of any element on unexposed side

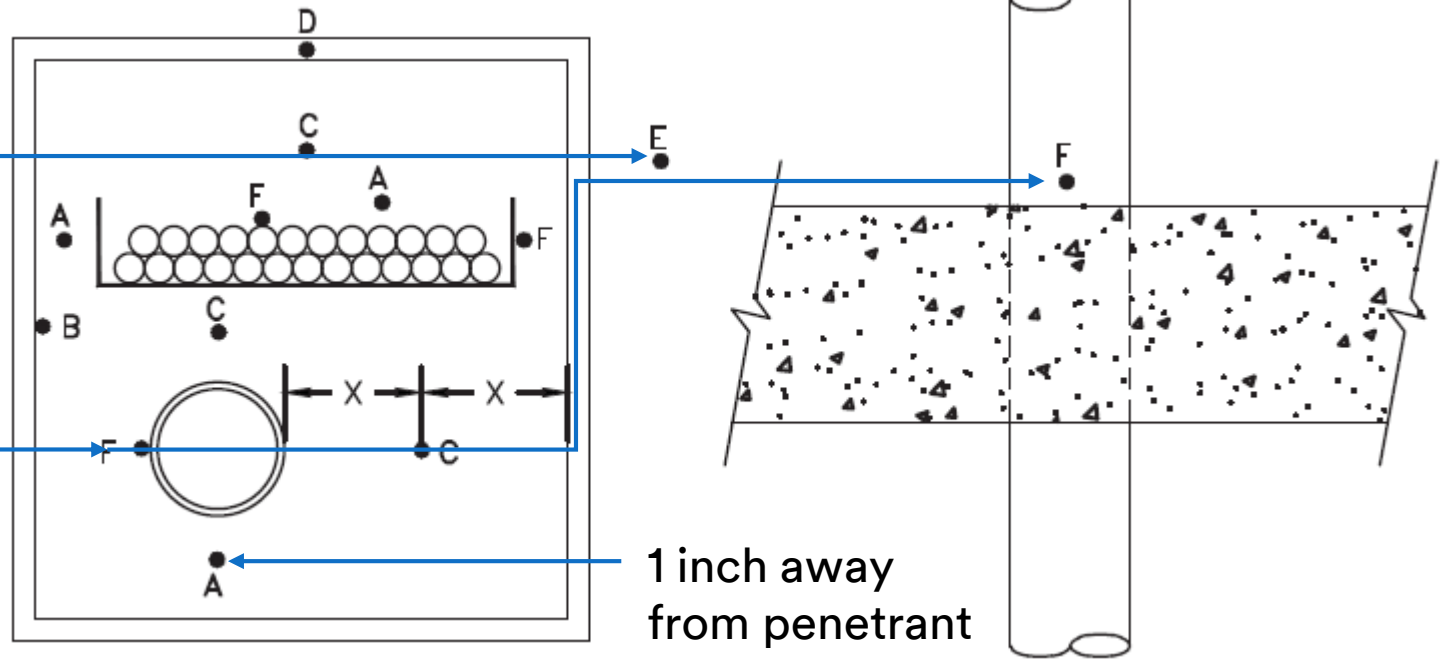
Flames can travel through metallic penetrants to non fireside (not a failure)

Acceptance Criteria: T Rating

Transmission of heat during test cannot raise temperature on non-fire side more than 181°C beyond ambient (initial temperature).

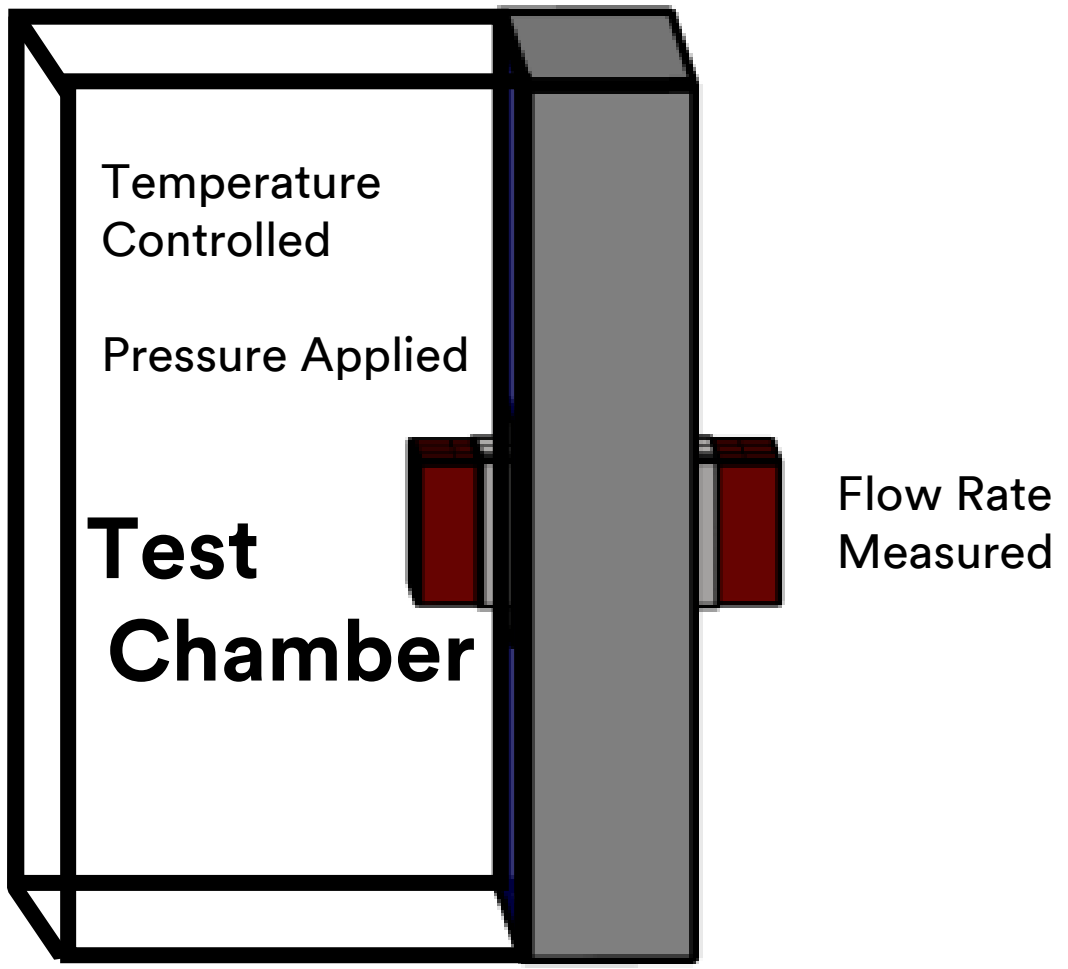
4 inches away from opening on unexposed surface

On penetrant, 1 inch from unexposed surface

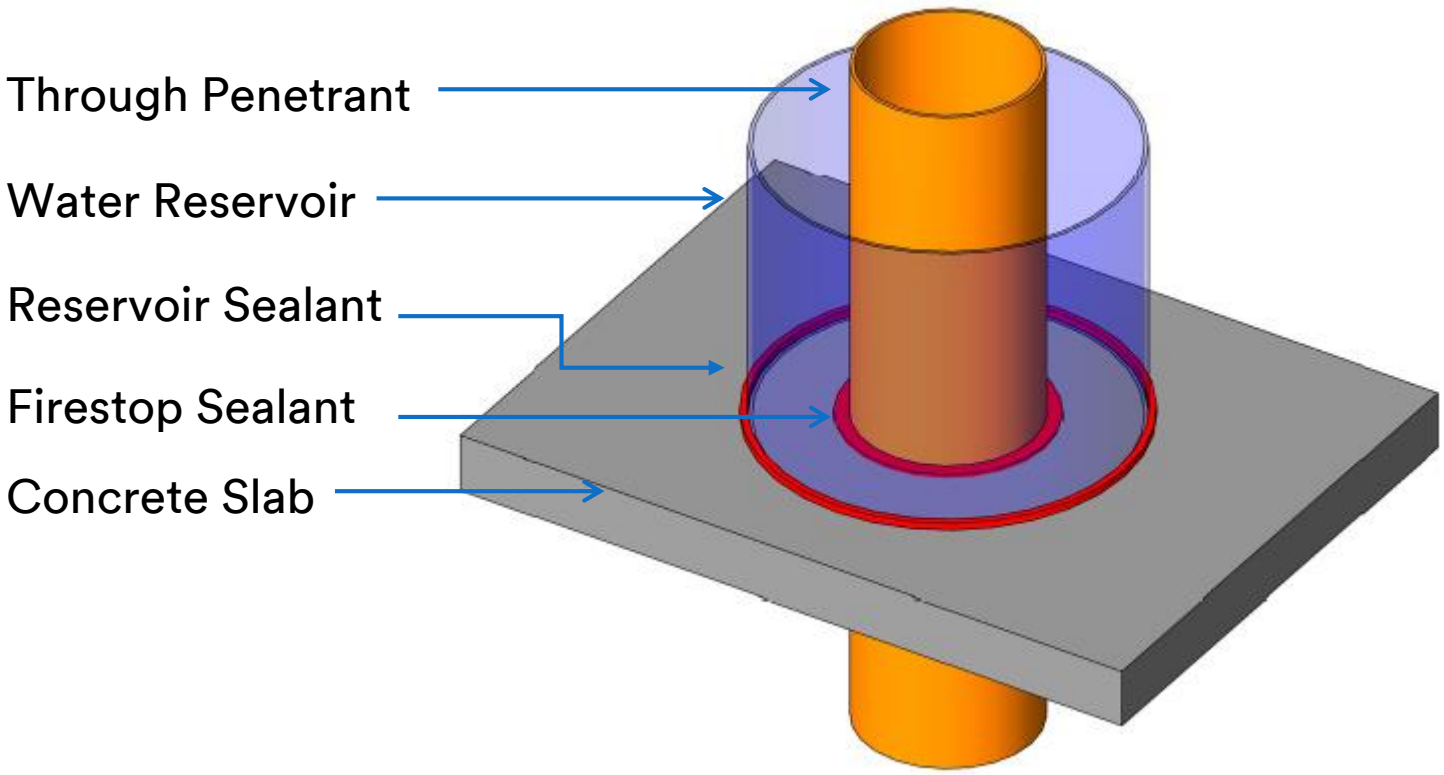


Optional Criteria: L rating

- Volume of air flowing – per unit of time – through openings around test specimens
  - Under specified pressure difference
- Air leakage test chamber: sealed chamber with opening & removable mounting panel
  - 24 ± 11°C and 75 ± 1.25 Pa
  - For elevated conditions, 204 ± °5C
- Reported based on leakage rate, q
  - Firestop systems ($\frac{L}{s \cdot m^2}$)
  - Joint systems ($\frac{L}{s \cdot m}$)



Optional Criteria: W rating

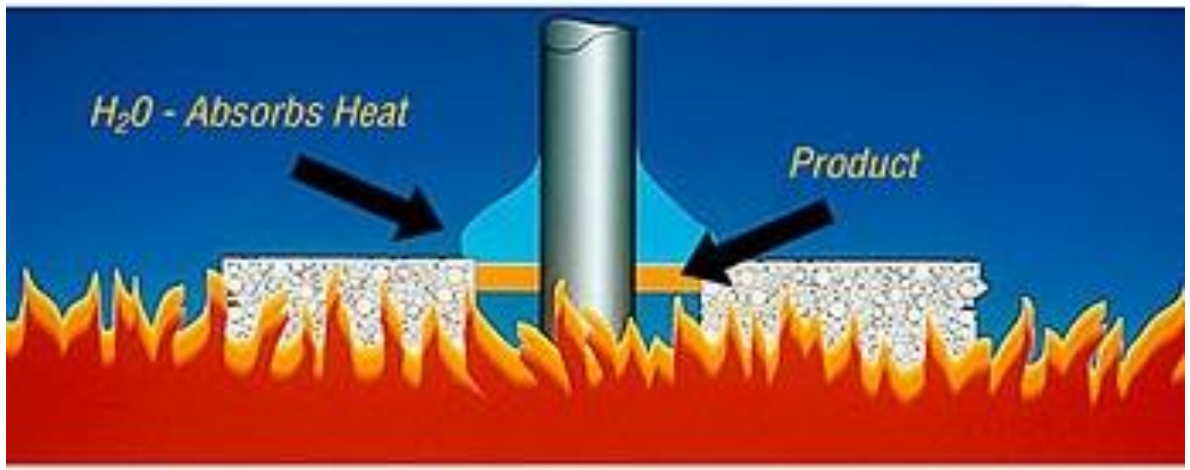


- Based on UL 1479 criteria
- Measures water resistance
- Reservoir installed around desired assembly / firestop system
- 305 mm water pressure head
  - Safety factor of 3
  - Items sealed at bottom of floor
  - Sub-grade buildings (may have substantial water accumulation)
- Water is dyed, remains in reservoir for 72 hours

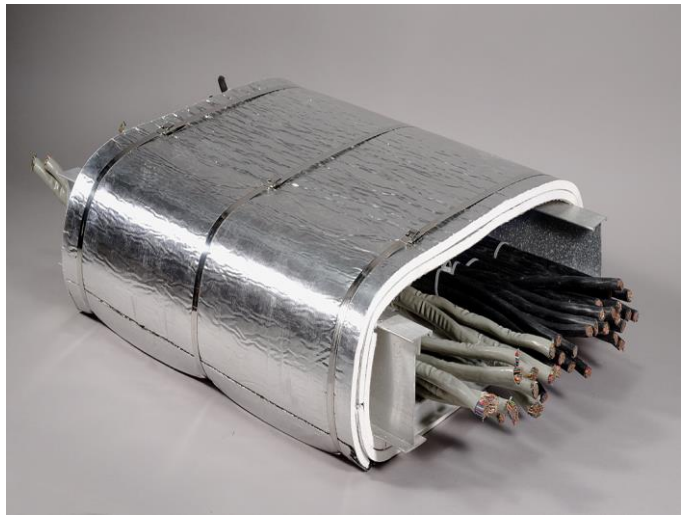
Firestop Technologies: Intumescent

As fire intensifies, product expands and chars

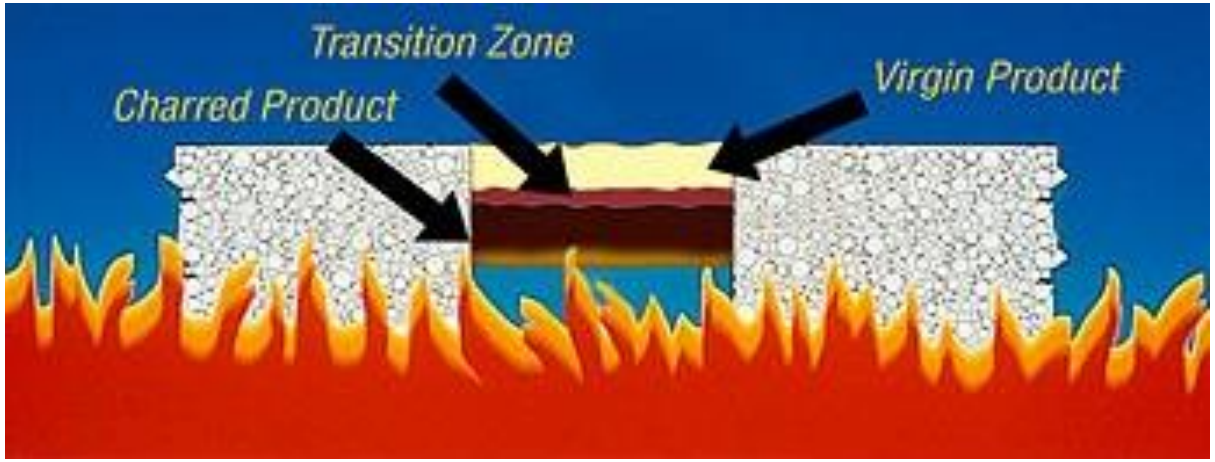
Firestop Technologies: Endothermic



As fire intensifies, chemically-bound water molecules are released.



Firestop Technologies: Ablative



As fire intensifies, a hard char with thermal insulation is formed.

System Selection

Third Party Listings

Primary Considerations

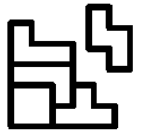
Floor / wall construction type and thickness

Hourly rating requirements

Fire severity

Penetrating item type and dimensions

Annular spacing, Sleeve optional or required



Ease of installation

Cable fill percentage

Packing materials

STC, W-rating, L-rating

Assembly Construction: Type

- Gypsum wallboard
- Concrete
  - Poured in-place concrete
  - Pre-cast concrete
  - Hollow-core concrete
  - Post-tension concrete
  - CMU concrete block wall
- Fluted metal deck
- Wood-framed assemblies

Assembly Construction: Hourly Rating

- Each construction type is designed for a specific hourly rating (*fire-resistance rating*).
- Choosing a firestop system: hourly rating must be equal to the hourly rating of the construction type.

System No. C-AJ-1044

March 15, 2007
F Ratings — 2,3, and 4 hr. (See Items 2A and 4)
T Rating — 0 hr.
L Rating at Ambient — 2 CFM/sq. ft.
L Rating at 400°F — less than 1 CFM/sq. ft.
W Rating — Class I (See Item 4)

Products are part of a firestop system. It is the complete system that receives an hourly rating.

Assembly Construction: Substrate

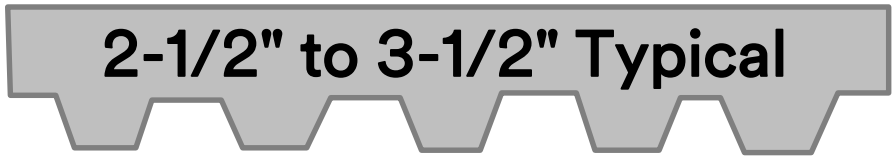
Thicker concrete substrates absorb more heat.

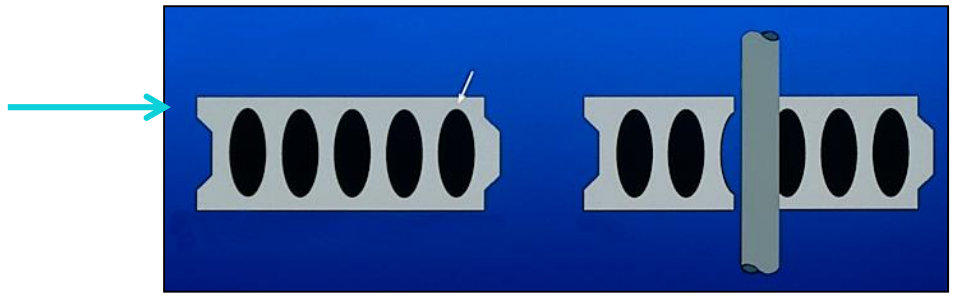
2-1/2 inch slab

4-1/2 inch slab

Composite slabs (fluted metal deck) and hollow core concrete: hone-in on critical dimensions.

Critical Dimension

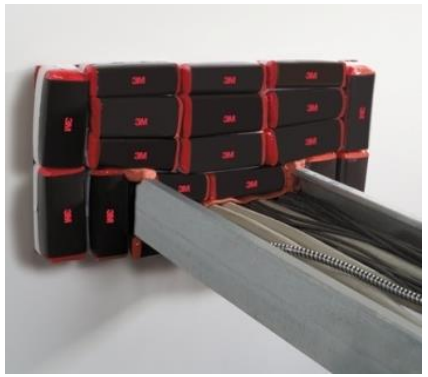




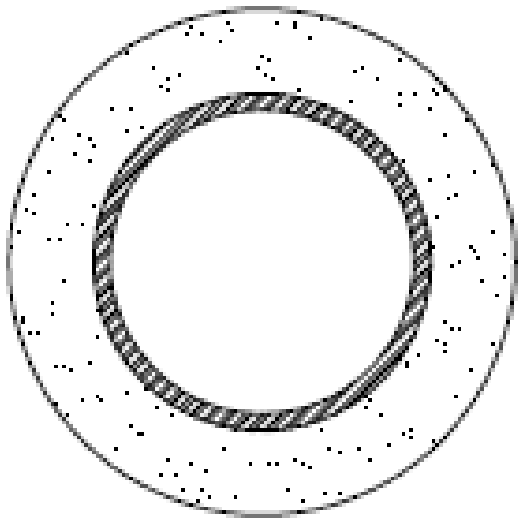
Critical Dimension: ≤ 1-1/4 inch

Penetrant: Type

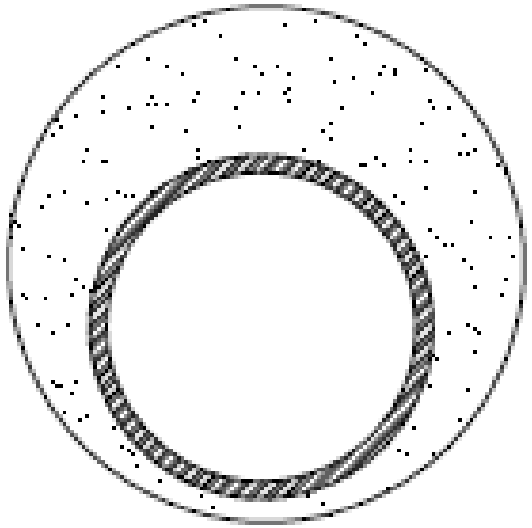
Plumbing	Electrical	Mechanical
• Drains, waste, vents • Chiller lines • Water supply • Acid drains • Sprinkler systems • Steam lines	• Power • Control • Service • Telephone • Fibre-optic • Coaxial	• Heating • Ventilation • Air conditioning



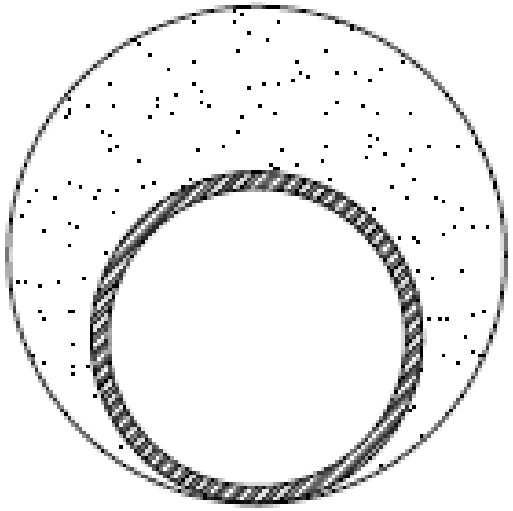
Penetrant: Annular Space



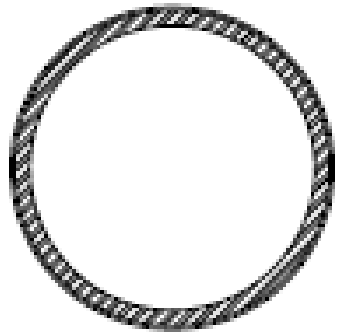
Centred



Off-centred



Point Contact



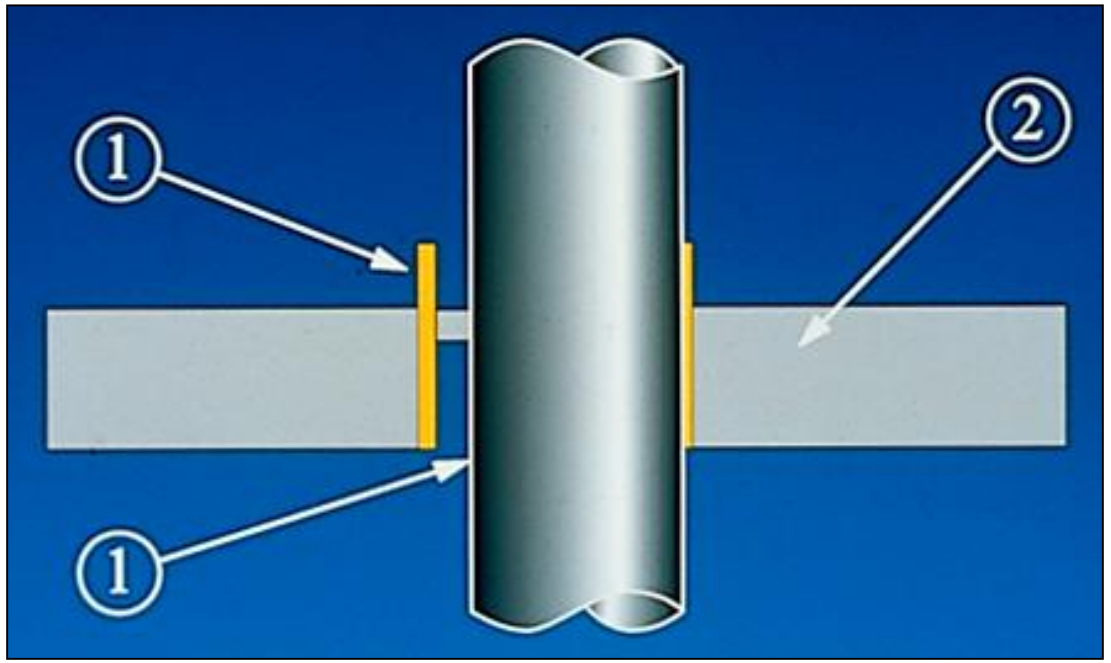
Continuous Point Contact

- Annular space: distance between penetrant and periphery of opening
- Distance between multiple penetrations
- **Be aware of minimums and maximums!**

Penetrant: Sleeve Requirements

In some systems, a steel or non-metallic sleeve is required.
The system detail also indicates when a sleeve is optional.

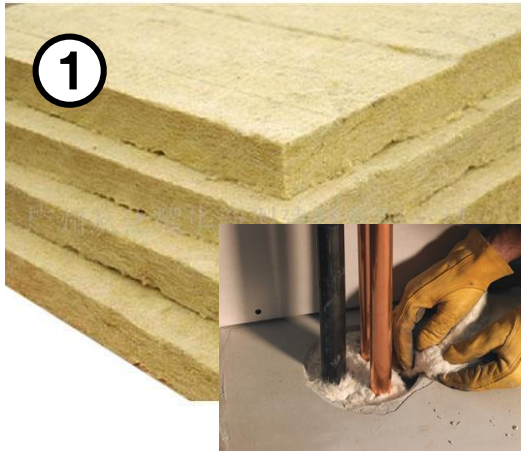
1. Two heat sources affecting firestop
2. Compounded by thinner concrete
3. UL system must indicate sleeve as an option



Packing Material

1. Mineral wool (basalt)
2. Fibreglass
3. Backer rod (paper, cardboard)
4. Nothing

**Listed in order of thermal performance

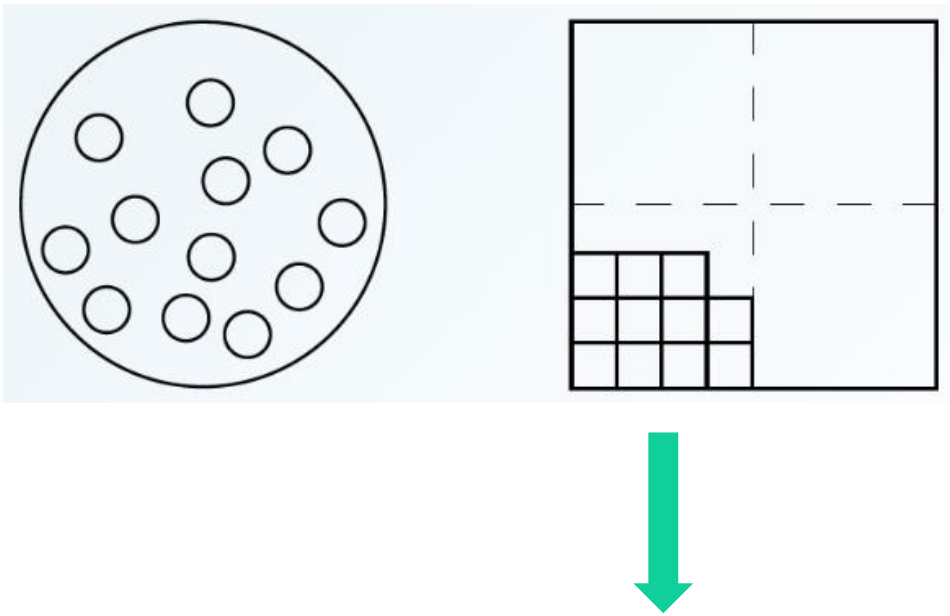


③

④

Percentage Cable Fill

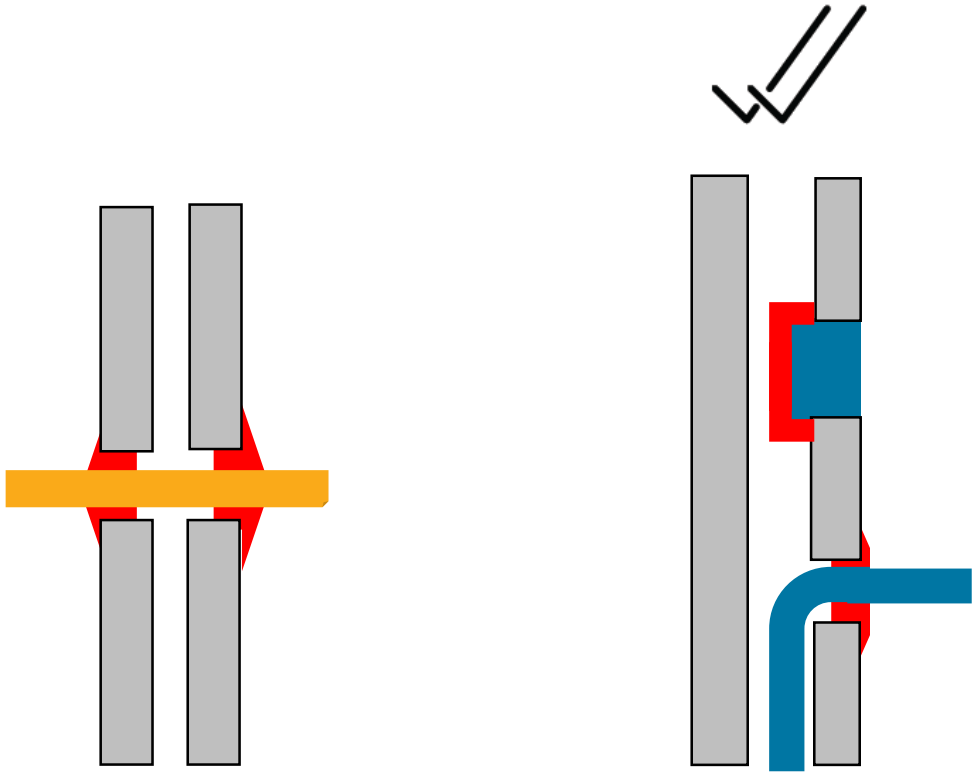
System states calculated percentage cable fill, size and types of cables permissible to penetrate assembly.



Visual fill appears twice as full compared to actual / calculated

Membrane Penetration

- Cables, pipes, electrical boxes, tubes, combustion vents, wires
- Penetration: one side of wall, floor or floor / ceiling assembly
- Common membranes: ceiling tile, gypsum wallboard
- Firestop install: penetrated-side only

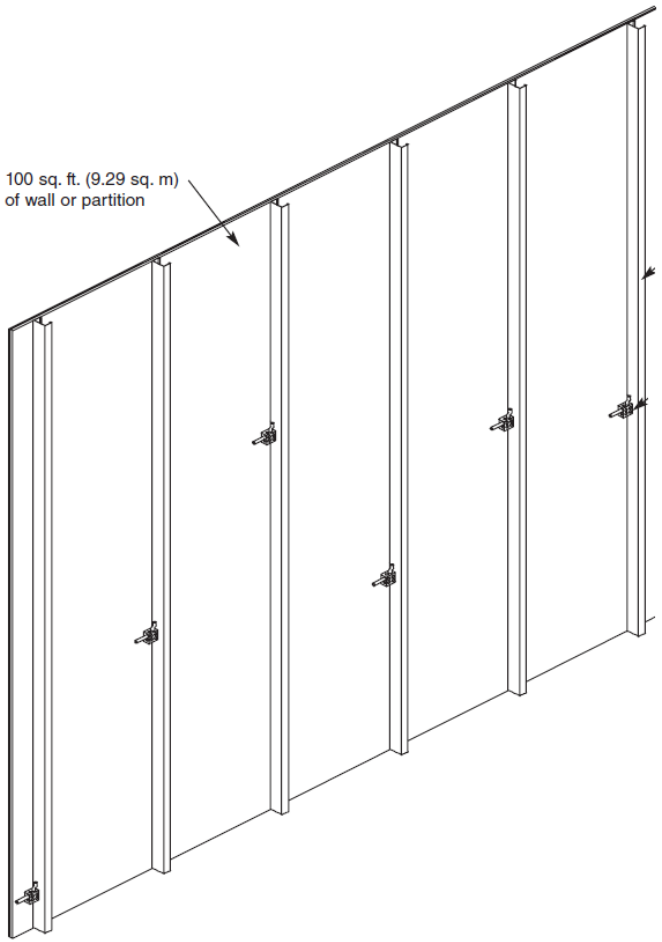


3.1.9.1 Firestops

1) Penetrations of a *fire separation* or a membrane forming part of an assembly required to have a *fire-resistance rating* shall be…

Membrane Penetration

Electrical Metallic Outlet Boxes



U300 or U400 Series
gypsum wallboard assembly

4S electrical box

Does ***not*** require putty pads:

- Each box is 103 cm^2 (16 in^2) or less
- Only six 4S boxes (< 645 cm^2 or 100 in^2) in 9.29 m^2 (100 ft^2) area
- Only one box per stud cavity

NBC / SCC-Recognized Testing Agency

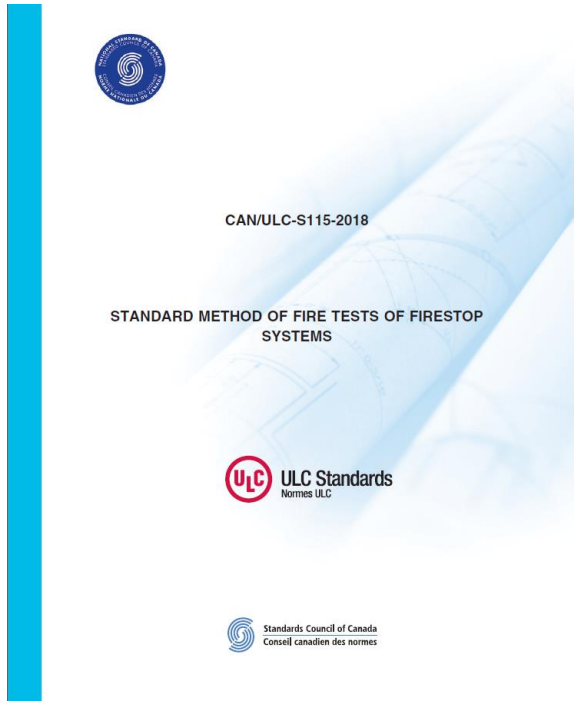
Underwriters Laboratories LLC

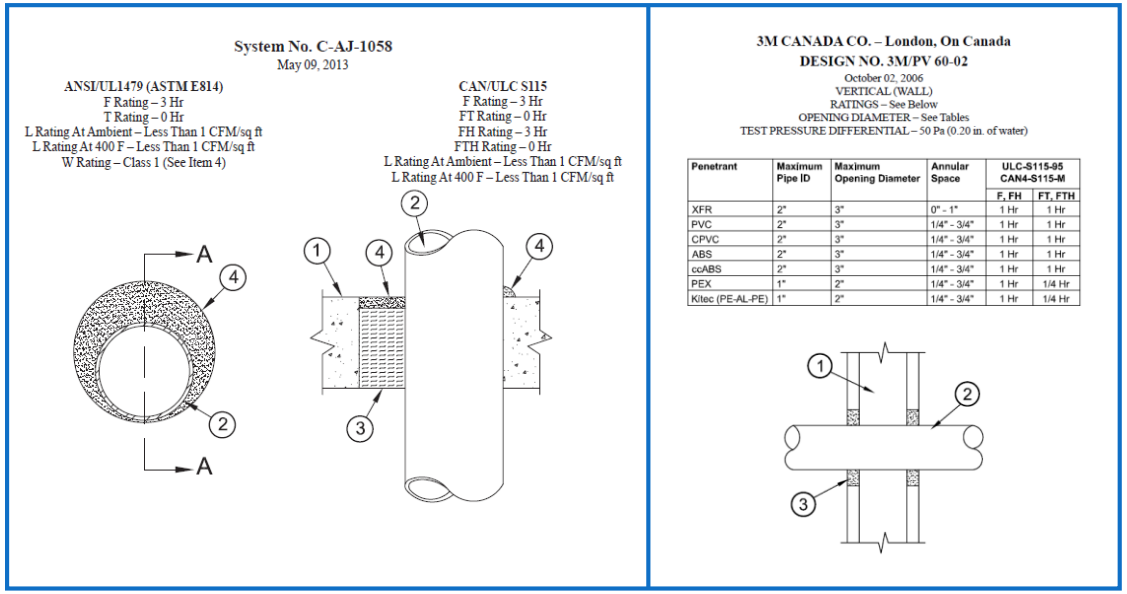
Intertek Group PLC:
Omega Point Laboratories
Warnock Hersey

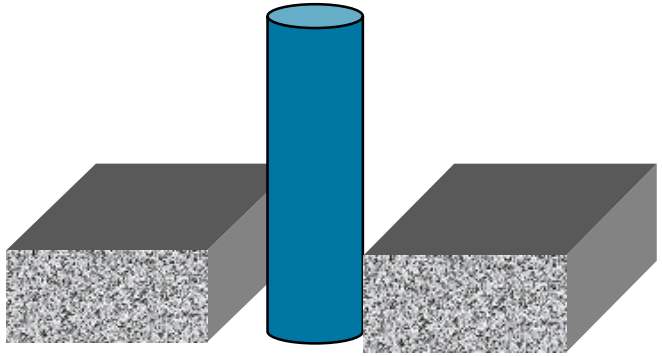
Factory Mutual Research

Responsibility of Test Agency

- To determine whether a firestop system will pass applicable test standard criteria
- To provide listings (designs, cut sheets) for each successfully-tested configuration
- To establish a nomenclature for each category of listed systems



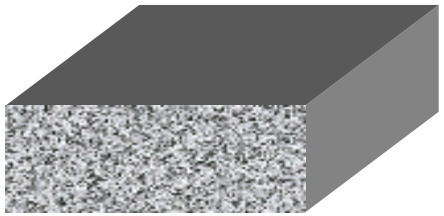


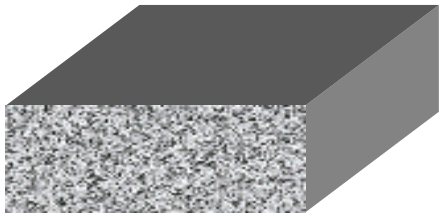


UL: C-AJ – XXXX
Intertek: PHV 120-XX

UL Nomenclature

CAJ – 1552



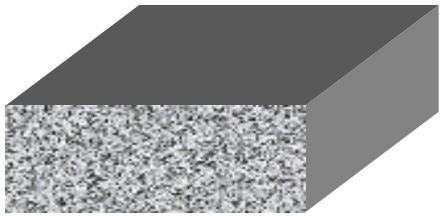


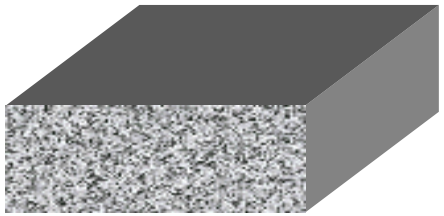
The first alpha component identifies the type of assembly being penetrated:

C combination floor or wall
F floor
W wall

UL Nomenclature

CAJ – 1552



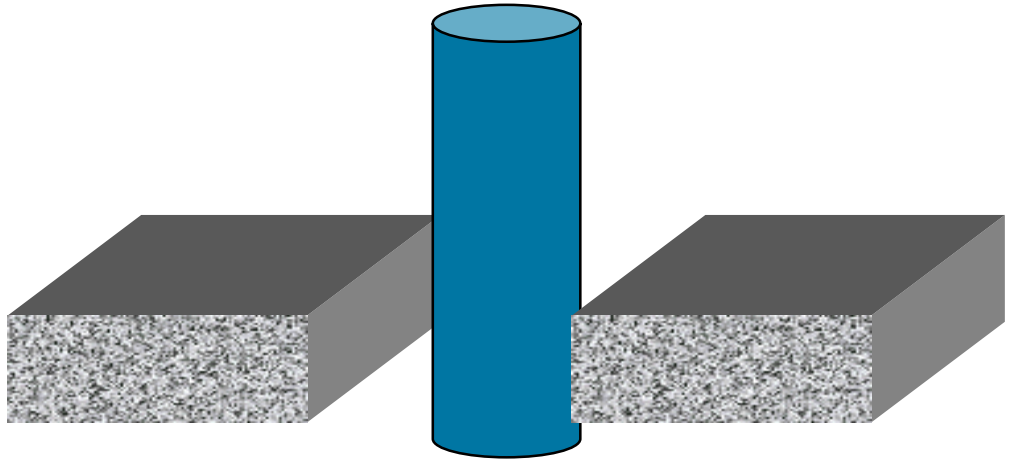


The second alpha component further identifies the construction type:

A signifies a concrete with a minimum thickness less than or equal to 5”
B signifies a concrete with a minimum greater then to 5”
C signifies a framed floor
D signifies a steel deck in a marine vessel
E signifies a floor-ceiling assembly consisting of concrete with membrane protection
F-I currently not used
J signifies a concrete or masonry wall with a minimum thickness less than or equal to 8”
K signifies a concrete or masonry wall with a minimum thickness greater 8”
L signifies a framed wall
M signifies bulkheads in marine vessels
O-Z currently not used

UL Nomenclature

CAJ – 1552



The numeric component uses sequential numbers to identify the penetrating item:

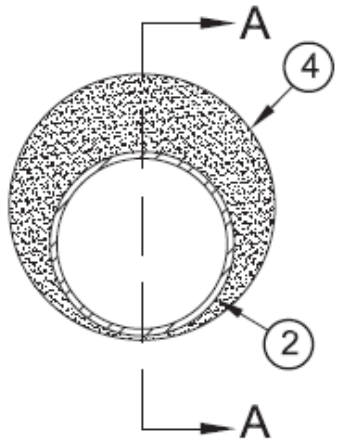
0000–0999	No penetrating items
1000–1999	Metallic pipe, conduit, or tubing
2000–2999	Nonmetallic pipe, conduit, or tubing
3000–3999	Electrical cables
4000–4999	Cable trays with electrical cables
5000–5999	Insulated pipes
6000–6999	Miscellaneous electrical penetrants such as buss ducts
7000–7999	Miscellaneous mechanical penetrants such as air ducts
8000–8999	Groupings of penetrations including any combination of items listed above
9000–9999	Not used at present time

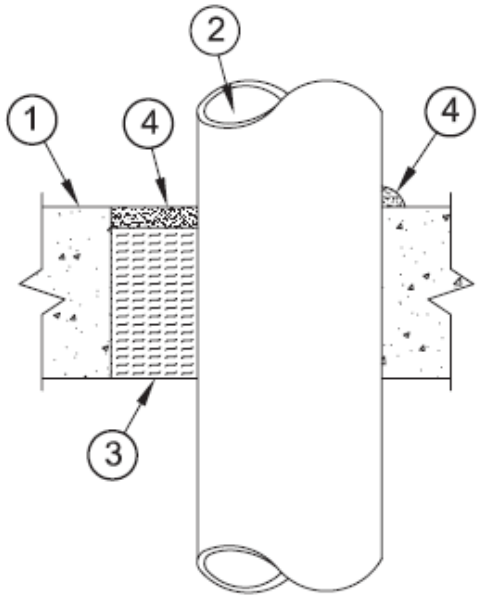
UL System Example

System No. C-AJ-1058
May 09, 2013

ANSI/UL1479 (ASTM E814)
F Rating – 3 Hr
T Rating – 0 Hr
L Rating At Ambient – Less Than 1 CFM/sq ft
L Rating At 400 F – Less Than 1 CFM/sq ft
W Rating – Class 1 (See Item 4)

CAN/ULC S115
F Rating – 3 Hr
FT Rating – 0 Hr
FH Rating – 3 Hr
FTH Rating – 0 Hr
L Rating At Ambient – Less Than 1 CFM/sq ft
L Rating At 400 F – Less Than 1 CFM/sq ft





1. **Floor or Wall Assembly** – Min 4-1/2 in. (114 mm) thick reinforced lightweight or normal weight (100-150 pcf or 1600-2400 kg/m^3) concrete. Wall may also be constructed of any UL Classified **Concrete Blocks***. Max diam of opening) is 27-1/4 in. (692 mm).

   See **Concrete Block** (CAZT) category in the Fire Resistance Directory for names of manufacturers.

1A. **Steel Sleeve** – (Optional, Not Shown) – Nom 28 in. (711 mm) diam (or smaller) Schedule 10 (or heavier) steel sleeve cast or grouted into floor or wall assembly. As an alternate, nom 28 in. (711 mm) diam (or smaller) sleeve fabricated from nom 0.028 in. (0.71 mm) thick galv steel cast or grouted into floor or wall assembly flush with floor or wall surfaces.

2. **Through-Penetrant** – One metallic pipe, conduit or tubing to be installed either concentrically or eccentrically within the firestop system. An annular space of min 0 in. (point contact) to max 3-1/4 in. (83 mm) is required within the firestop system . When optional steel sleeve is used, min annular space shall be 1/2 in. (13 mm). Pipe, conduit or tubing to be rigidly supported on both sides of floor or wall assembly. The following types and sizes of metallic pipes, conduits or tubing may be used:

   A. **Steel Pipe** – Nom 24 in. (610 mm) diam (or smaller) Schedule 10 (or heavier) steel pipe. When Type FB-1000 NS or FB-1003 SL sealant (see Item 4) is used, pipe diam shall not exceed nom 8 in. (203 mm).

   B. **Conduit** – Nom 4 in. (102 mm) diam (or smaller) steel electrical metallic tubing or nom 6 in. (152 mm) diam (or smaller) steel conduit.

   C. **Copper Tubing** – Nom 6 in. (152 mm) diam (or smaller) Type L (or heavier) copper tubing. When Type FB-1000 NS or FB-1003 SL sealant (see Item 4) is used, tubing diam shall not exceed nom 4 in. (102 mm).

   D. **Copper Pipe** – Nom 6 in. (152 mm) diam (or smaller) Regular (or heavier) copper pipe. When Type FB-1000 NS or FB-1003 SL sealant (see Item 4) is used, pipe diam shall not exceed nom 4 in. (102 mm).

   E. **Iron Pipe** – Nom 24 in. (610 mm) diam (or smaller) cast or ductile iron pipe. When Type FB-1000 NS or FB-1003 SL sealant (see Item 4) is used, pipe diam shall not exceed nom 8 in. (203 mm).

3. **Packing Material** – Min 3 in. (76 mm) thickness of min 4 pcf (64 kg/m^3) mineral wool batt insulation firmly packed into opening as a permanent form. Packing material to be recessed from top surface of floor or from both surfaces of wall as required to accommodate the required thickness of fill material.

4. **Fill, Void or Cavity Material* – Sealant** – Min 1/2 in. (13 mm) thickness of fill material applied within annulus, flush with top surface of floor or both surfaces of wall assembly. At the point contact location between pipe and concrete, a min 1/2 in. (13 mm) diam bead of sealant shall be applied at the concrete/pipe interface on the top surface of floor and on both surfaces of wall assembly.

   3M COMPANY – FB-2000, FB-2000+, FB-1000 NS, FB-1003 SL or FB-3000 WT.
   (Note: W Rating applies only when FB-1000 NS, FB-1003 SL or FB-3000 WT is used.)

floor or both surfaces of wall assembly. At the point contact location between pipe and concrete, a min 1/2 in. (13 mm) diam bead of sealant shall be applied at the concrete/pipe interface on the top surface of floor and on both surfaces of wall assembly.

3M COMPANY 3M FIRE PROTECTION PRODUCTS – Types FB-2000, FB-2000+, FB-1000 NS, FB-1003 SL or FB-3000 WT.

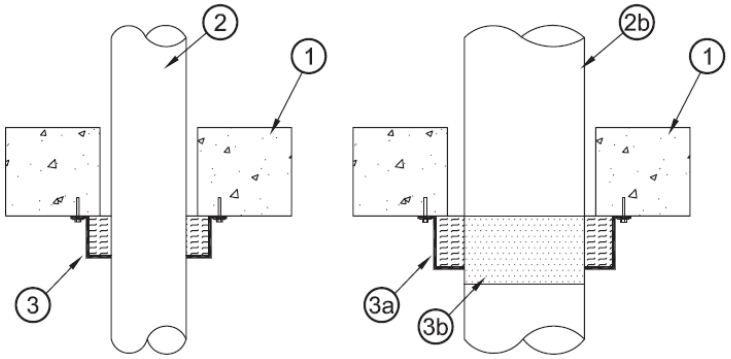
(Note: W Rating applies only when FB-1000 NS, FB-1003 SL or FB-3000 WT Sealant is used.)

*Bearing the UL Classification Mark

Intertek Nomenclature

3M CANADA CO. – London, On Canada
DESIGN NO. 3M/PHV 120-03
July 26, 2006
HORIZONTAL OR VERTICAL (FLOOR OR WALL), RATINGS – SEE BELOW, ANNULAR SPACE – 1/4" MAXIMUM
TEST PRESSURE DIFFERENTIAL – 50 Pa (0.20" OF WATER)

Penetrant	Pipe Size	CAN/ULC-S115 CAN4-S115 F, FH, FT, FTH	ASTM-E814 F, T
PVC	1-1/2" - 6"	2 Hr	2 Hr
System XFR	1-1/2" - 6"	2 Hr	2 Hr
CPVC	1-1/2" - 4"	2 Hr	2 Hr
ccABS	1-1/2" - 4"	2 Hr	2 Hr
ABS	1-1/2" - 4"	2 Hr	2 Hr
FRPP	1-1/2" - 4"	2 Hr	2 Hr
PVC - Thin Wall	2"	2 Hr	2 Hr

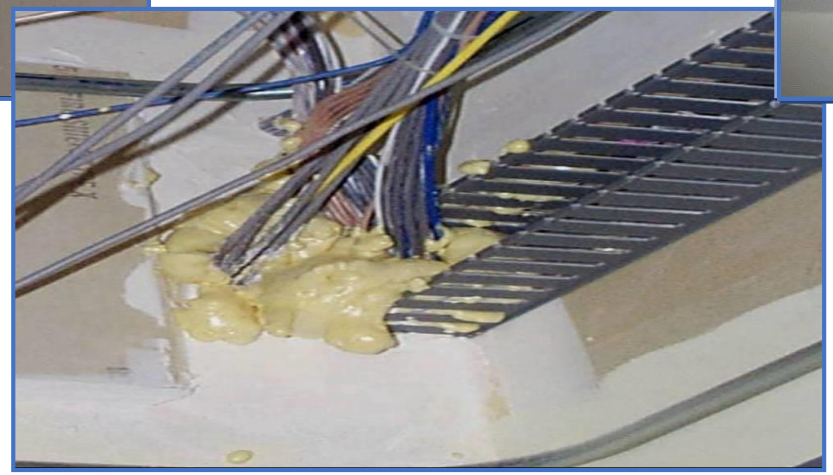


Intertek uses a simplified naming convention.
In general: **AAB/XX(X) YY(Y)-ZZ**

Where:

- AA is unique to every company
- XX(X) is a two or three letter designation for listing type
  - PV = penetrate vertical separation
  - PH = penetrate horizontal separation
- YY(Y) is a two or three number designation for the fire duration in minutes
- ZZ is the unique listing number for similar penetration types staring at 01

Non-compliant Systems



Compliant Systems

Engineering Judgments

System Unavailable

IFC EJ Guidelines

If system available, do not use an EJ

Consider construction elements that require fire protection – probable behaviour

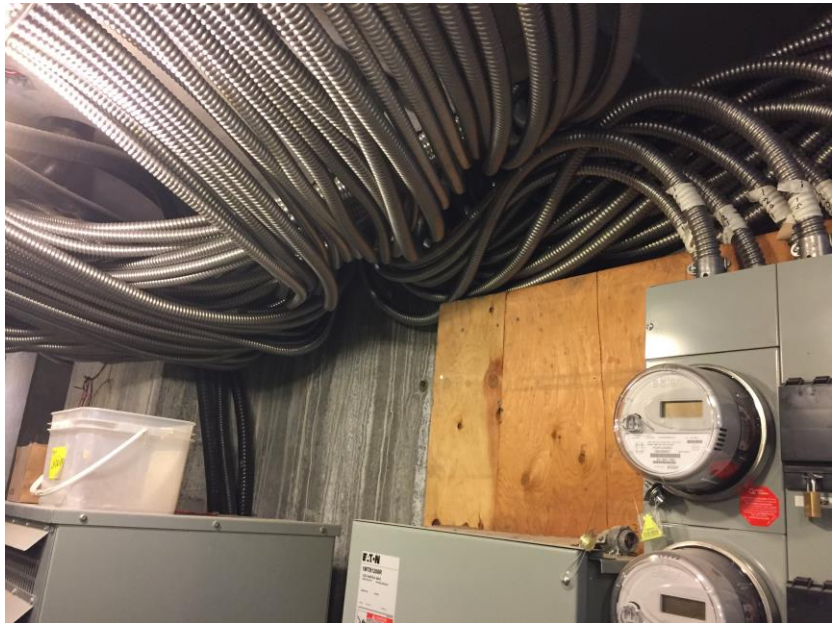
Issued by manufacturer's qualified technical personnel or by a 3rd party agency

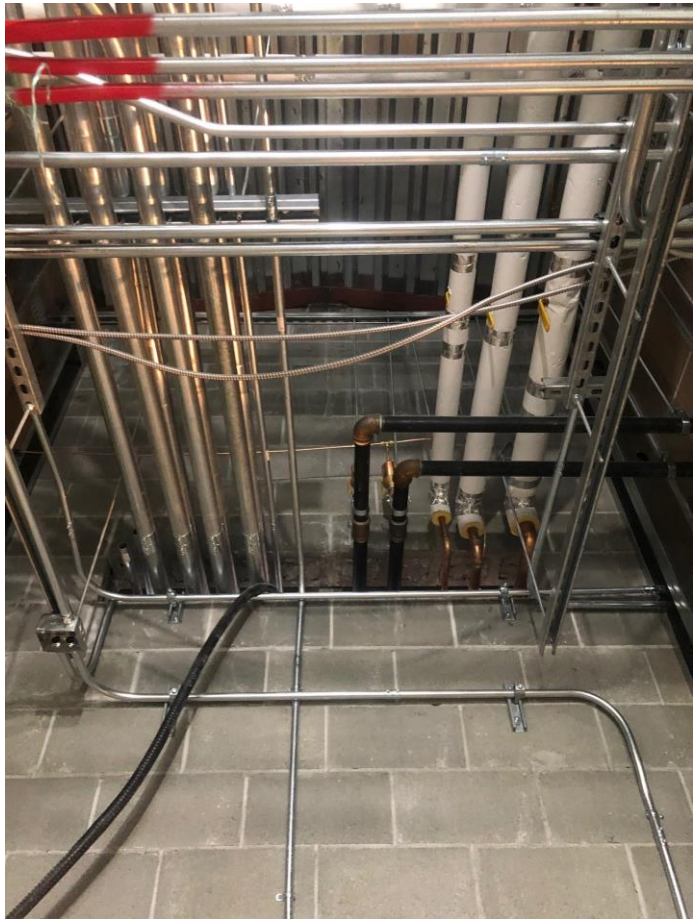
Limited to specific configurations and performance expectations

Based on interpolation of similar, previously tested firestop systems

Accepted for one project location

Challenging EJ Submissions

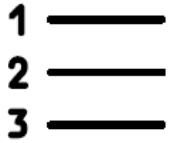




Effective EJs

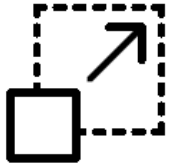
Descriptively written

EJ is required



Installation steps indicated

Date issued



Reference listed design

Job name and location

Proper justification

Critical firestop elements

Questions? Thank you!