FIRE DAMPERS 101
BACK TO BASICS – LIFE SAFETY DAMPERS

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September 9, 2019

TAMCO

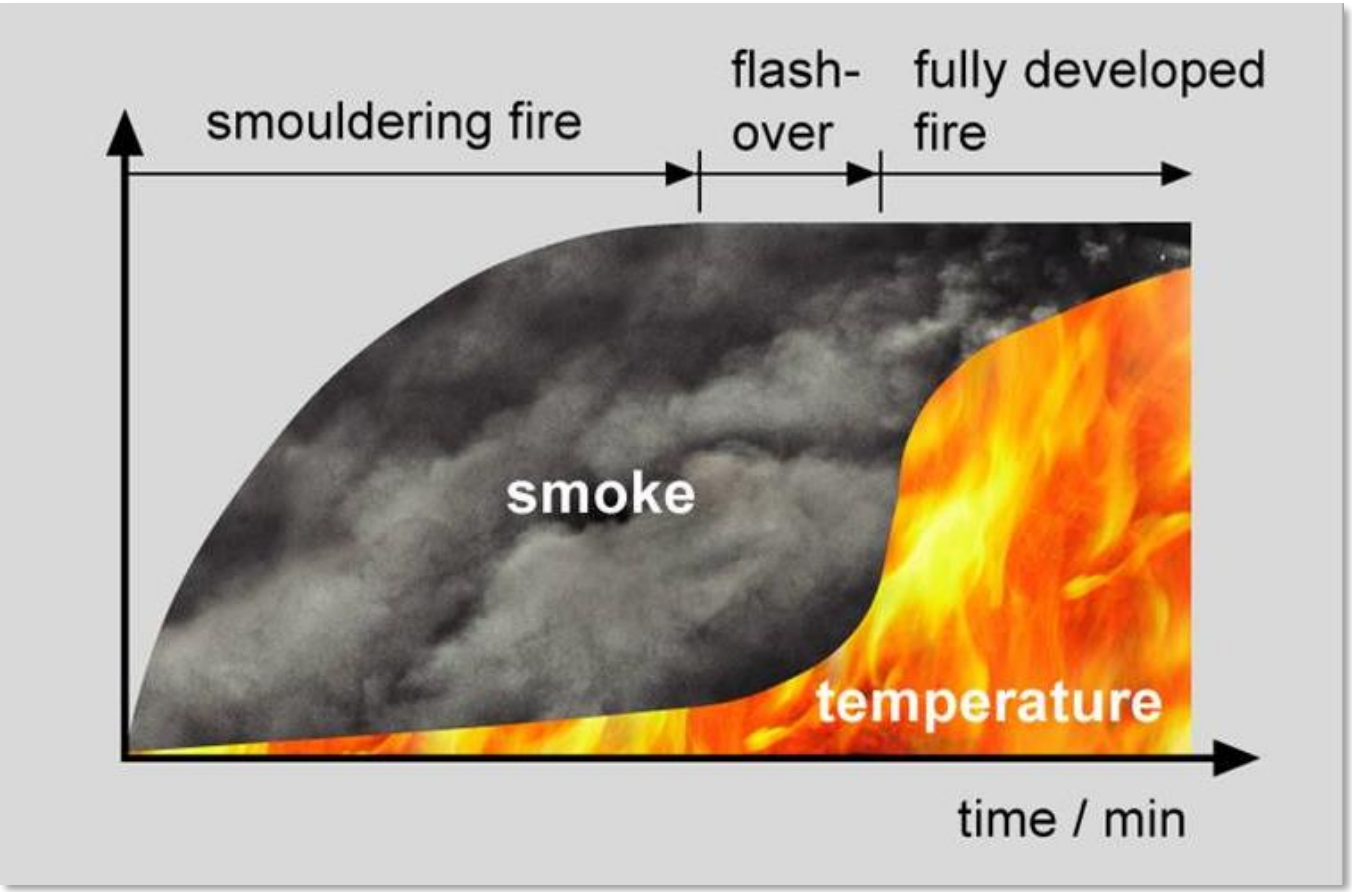
amca INTERNATIONAL

PRODUCT OVERVIEW

- **FIRE DAMPERS**
  Protect duct and air transfer openings, penetrating fire rated partitions
- **SMOKE DAMPERS**
  Leakage and elevated temperature rated dampers for smoke barriers
- **COMBINATION FIRE/SMOKE DAMPERS**
  Dampers that meet both fire and smoke damper requirements
- **CEILING FIRESTOP FLAP ASSEMBLIES**
  (*Ceiling/radiation dampers)* rated ‘heat barrier’ damper/component

PREDOMINANT THREAT

SMOKE



- Smoke is present from the beginning of a fire until it is too late.

PREDOMINANT THREAT

SMOKE

- Is the leading cause of firefighter injuries and fatalities.
- Impedes visibility.
- Can contain toxic and unburned gases.
- Fire consumes the oxygen in the air.
- CO poisoning accounts for 50% of fatalities.
- Can reach temperatures as high as 1,300 °C (2,370 °F)

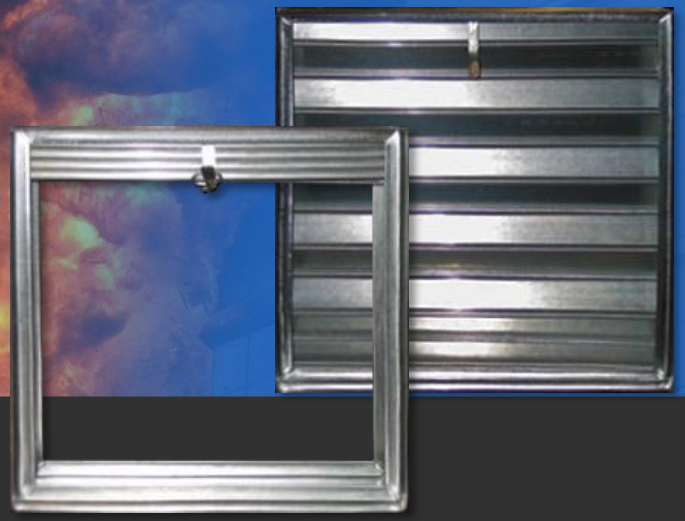
STANDARDS & GOVERNING BODIES

- National Building Code of Canada (NBC)
- National Fire Code of Canada (NFC)
- National Farm Building Code of Canada (NFBC)
- National Plumbing Code (NPC)
- National Energy Code of Canada for Buildings (NECB)

STANDARDS & GOVERNING BODIES

- Underwriters Laboratories of Canada (ULC)
  a) ULC-S112 / UL 555 – Fire Damper Standard
  b) ULC-S112.1 / UL 555S – Leakage Rated (Smoke) Damper Standard
  c) ULC-S112.2 / UL 555C – Ceiling Firestop Flap (Radiation Damper) Standard
  d) ULC-S101 / UL 263 – Structural Ceiling Test Standard
- National Fire Protection Association (NFPA) – NFPA 90A, 80, 92, 105
- SMACNA – Break Away Duct Connections
- Air Movement & Control Association Intl. (AMCA) – AMCA 500D
- Others: Warnock-Hersey (Intertek), ETL, ARL, FM, Gypsum Assoc.

CURTAIN FIRE DAMPERS



FIRE DAMPERS

TYPICAL SPECIFICATIONS	
Hourly Fire Rated	1½ or 3 hours
Static Systems	Airflow stops in fire-alarm mode.
Dynamic Systems	Airflow Continues in Fire- Alarm Mode.
Mounting Position	Horizontal or Vertical
Installation	“In Wall” or “Out of Wall”
Blade Type	Curtain or Multi-Blade
Closure Speed	Motorized or Instantaneous

FIRE DAMPERS

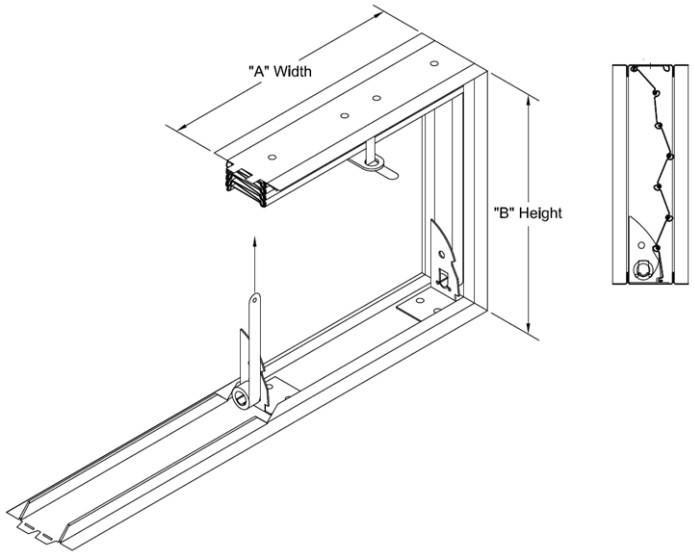
BASIC MODELS

- For Static Systems Only
  Heat Response Device: Standard 71 °C (165 °F),
  Optional 100 °C
- For Dynamic or Static Systems
  Heat Response Device: Standard 71 °C (165 °F),
  Optional 100 °C, 121 °C, 177 °C

(NBC of Canada, section 3.1.8.10 states 30°C above max. system temperature)

OPTIONS:

- Horizontal or Vertical Mount
- Out of Wall/Floor
- Grille Mount
- Multi-Blade, 3V, or Airfoil
- Static HRD/Fuse Link Temp., 71-100 °C (165-212 °F)
- Dynamic HRD/Fuse Link Temp., 71-177 °C (165-350 °F)
- Motorized (Multi-Blade only)

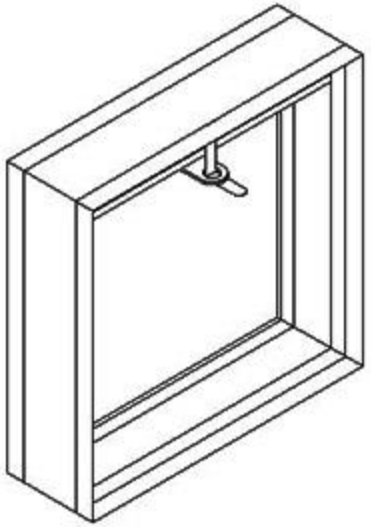


CURTAIN FIRE DAMPERS

OPTIONAL TRANSITIONS

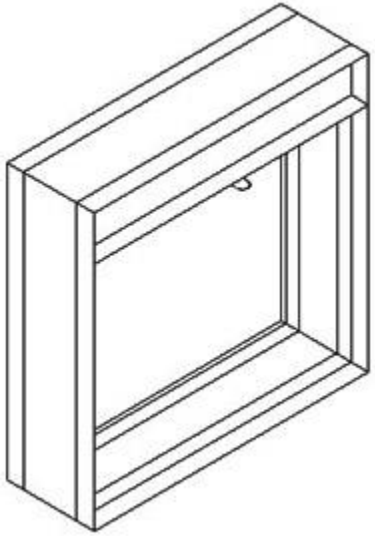
TYPE “A”

DAMPER OD SAME AS DUCT ID



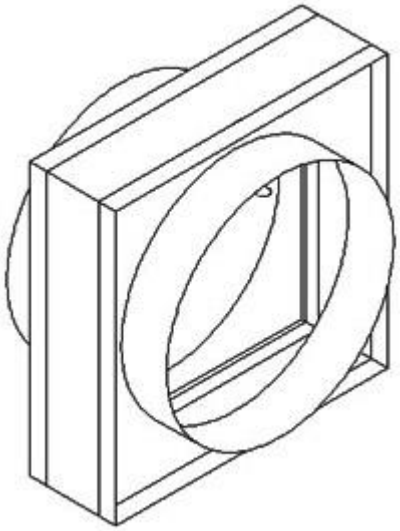
TYPE “B”

DAMPER OPENING HEIGHT SAME AS DUCT HEIGHT



TYPE “CR”

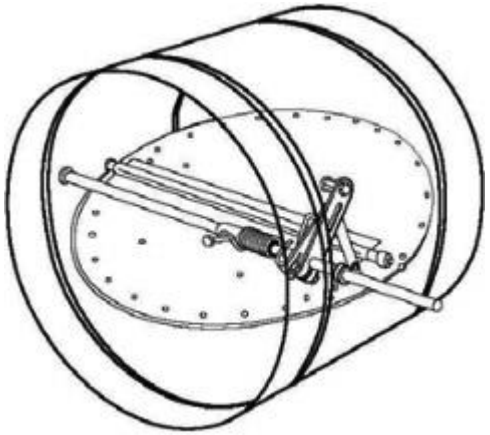
ROUND TRANSITION



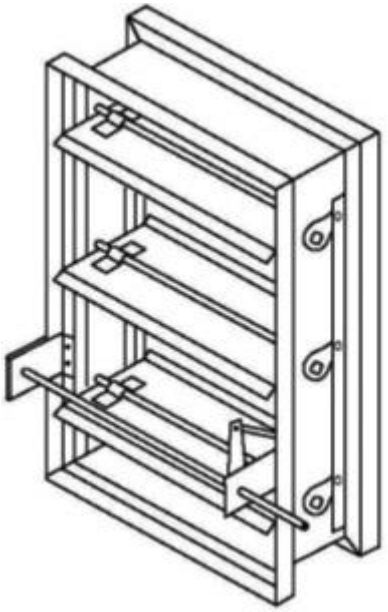
FIRE DAMPERS

OPTIONAL STYLES

TRUE ROUND



MULTI-BLADE



FIRE DAMPERS

ULC LISTING EXAMPLE – FD, STATIC VS. DYNAMIC, ULC RATED SIZES

Fire Dampers for Use in Static Systems *(No Airflow)*

Model	Hr Class	Damper Mounting Position	Single-Section Damper Size *(mm)*		Multiple-Section Damper Size *(mm)*	
			W	H	W	H
FD, FD-XX	1½	V	1524	1524	3048	3048
		H	1219	1219	2438	1219
		H	1016	1016	3048	1016

Fire Dampers for Use in Dynamic Systems

Dampers rated 2000 fpm @ 4.0" WC *(10.2 m/s @ 1.0 kPa)*

Model	Hr Class	Damper Mounting Position	Single-Section Damper Size *(mm)*		Multiple-Section Damper Size *(mm)*	
			W	H	W	H
FDD, FDD-XX	1½, 3	V	914	914	1829	914
					914	1829
		H	610	610	914	914

FIRE DAMPERS

STATIC AND DYNAMIC

STATIC FIRE DAMPERS	Are designed to be used where the HVAC system shuts down in the event of a fire. There is a great chance this type of damper may not close fully under airflow and/or static pressure.
DYNAMIC FIRE DAMPER	Are used in systems where the fan pressure and airflow will be running during a fire incident. The damper is tested and shown to close under a specific airflow and pressure. All combination Fire/Smoke Dampers, Smoke Dampers, and Dynamic Fire Dampers have been tested to close under heated airflow.

FIRE DAMPERS

DYNAMIC

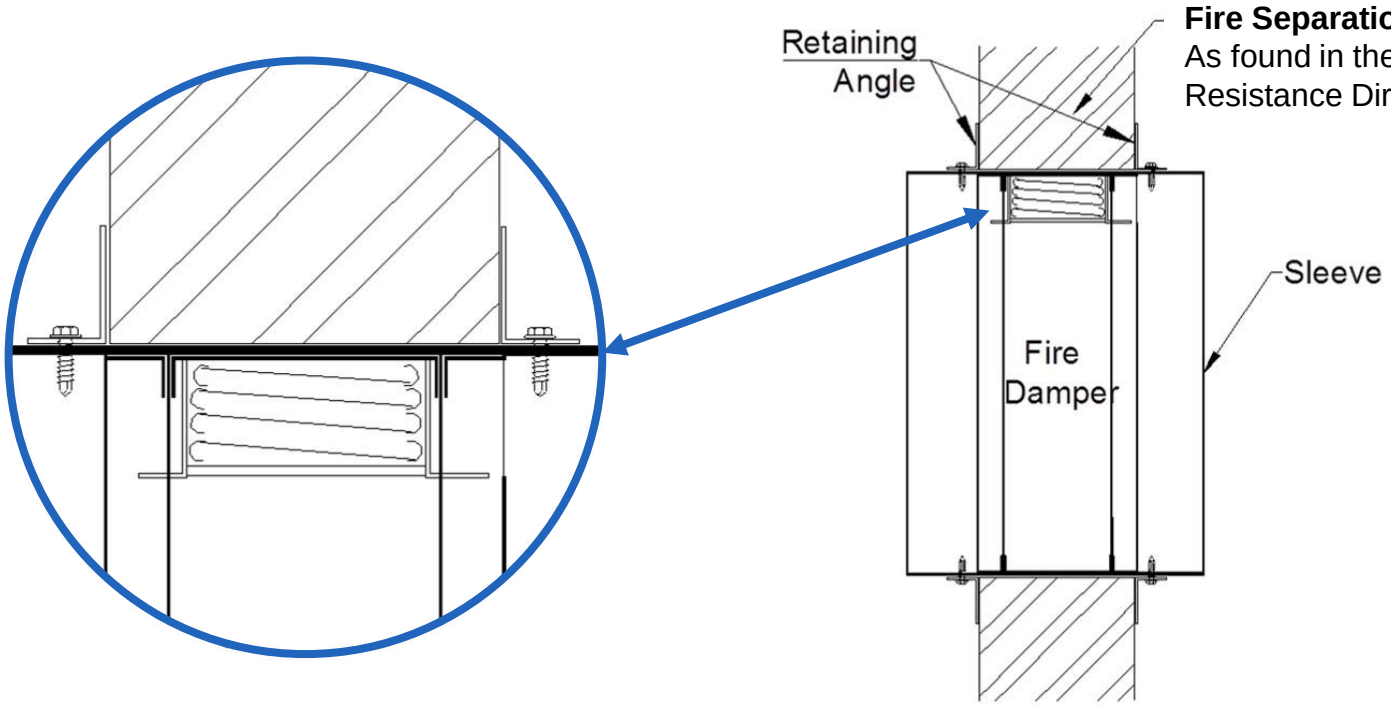
TESTING:

- Dampers are labeled for mounting in Horizontal plane or Vertical plane.
- Maximum approved single section size and assembled size must be tested.
- Just because the damper has springs, does not mean it is approved for Dynamic Systems.
- Dampers have labels showing: ”TOP OF UNIT”.

HORIZONTAL HEATED AIRFLOW

FIRE DAMPERS

BASIC OR TYPICAL INSTALLATION



TWO-SIDED ANGLE INSTALLATION

- Angle on each side of the wall

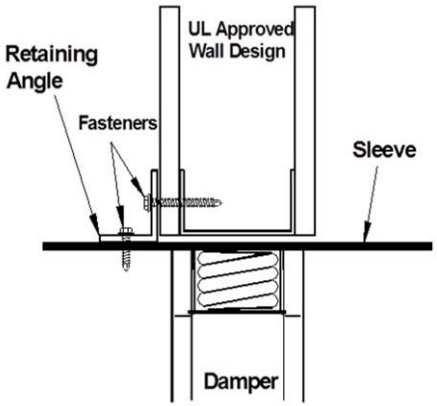
Every fire damper and combination fire/smoke damper must have an access door installed next to it.

FIRE DAMPERS

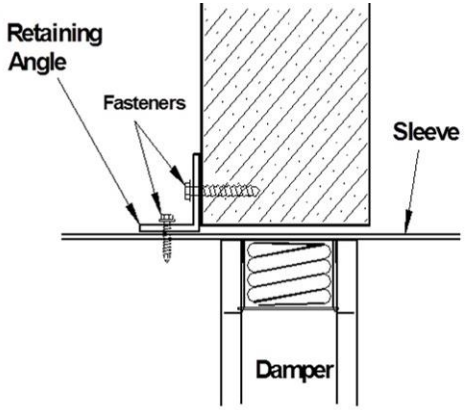
OPTIONAL INSTALLATIONS

(Check with manufacturer and local municipalities)

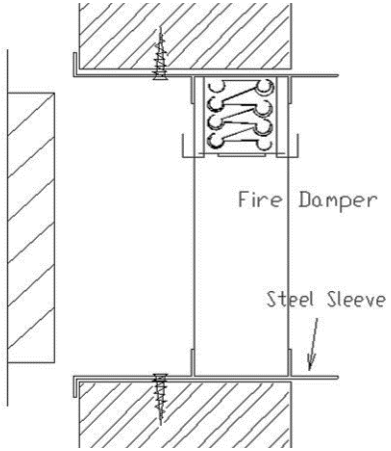
STEEL/GYPSUM WALL



MASONRY WALL



GRILLE MOUNT



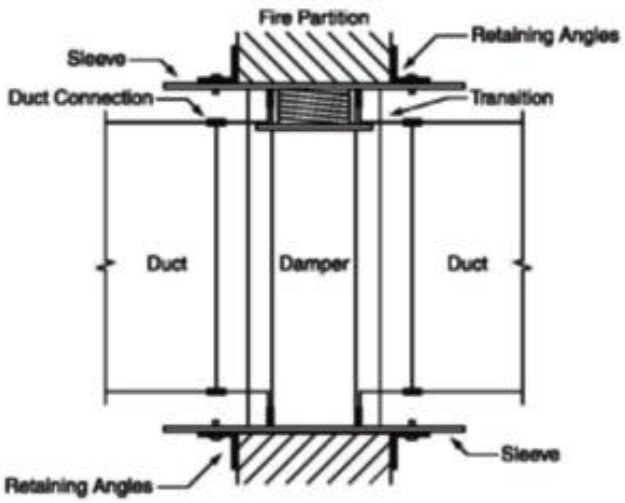
IN WALL TYPE

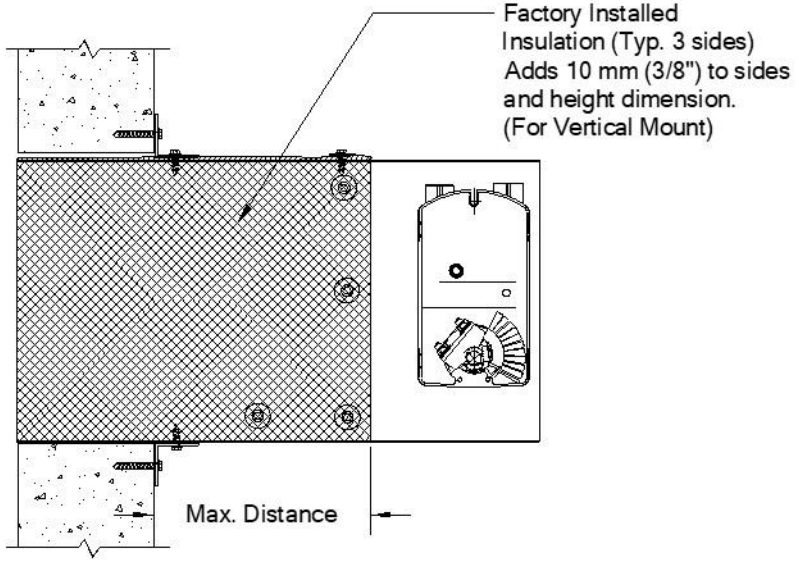
- One retaining angle method

FIRE DAMPERS

OPTIONAL INSTALLATIONS

(Check with manufacturer and local municipalities)





IN WALL TYPE B

- Retaining angle around outer sleeve

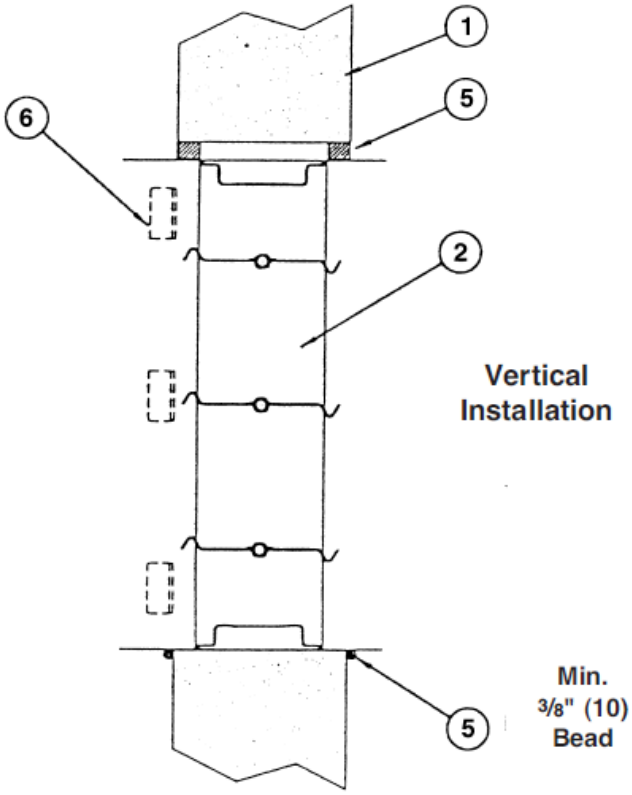
OUT OF WALL TYPE

- Factory-supplied
- Insulation required

FIRE DAMPERS

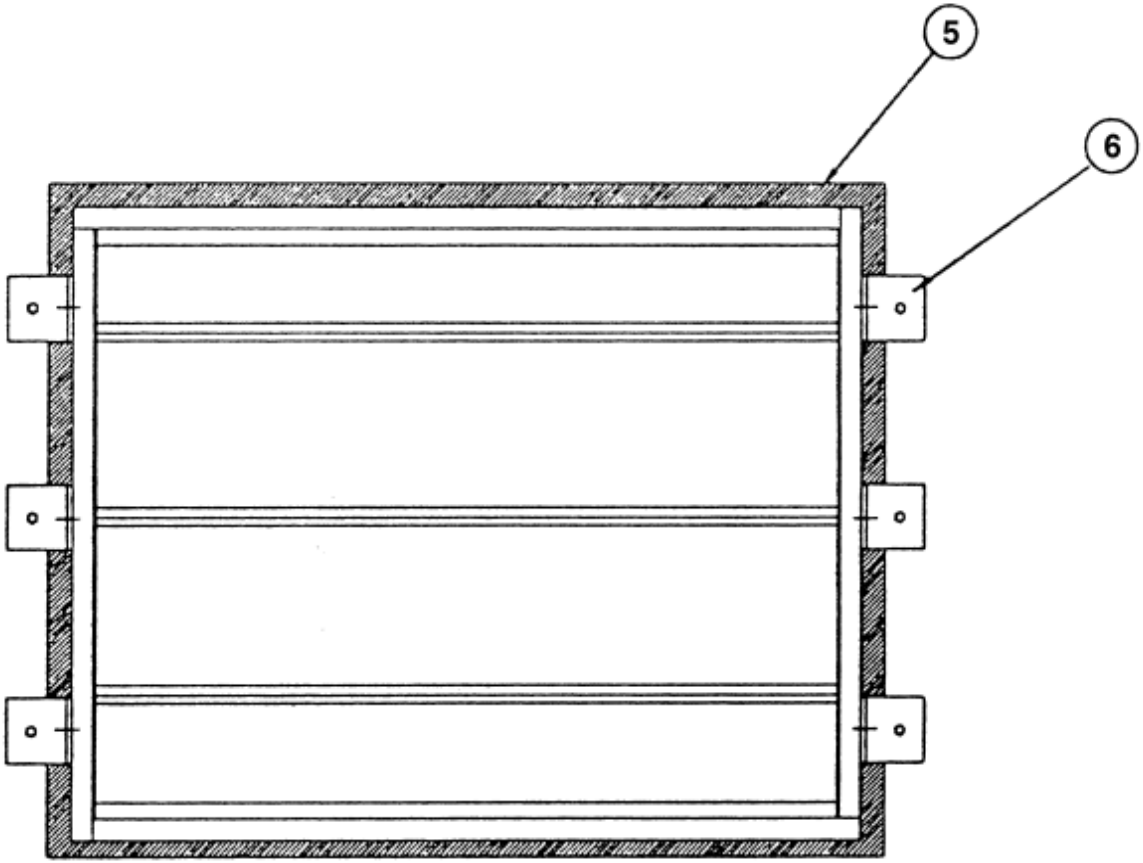
OPTIONAL INSTALLATIONS – Firestop Caulking in Annular Space

(Check with damper manufacturer and local municipalities)



Vertical Installation

Min. 3/8" (10) Bead



FIRE DAMPERS

STATIC FIRE DAMPER BASE TEST

ULC S112	
CYCLING	Non-motorized damper is cycled manually, from open to close: 250 times.
FIRE ENDURANCE & HOSE STREAM	1½ Hour Test: (205 kPa hose for 16.2 s/m²) 3 Hour Test: (310 kPa hose for 32.5 s/m²) *Both side of a damper are tested.*
RIGIDITY	**Lateral** and **longitudinal** forces must be applied to the largest damper. There is a limit to how far it can move.
SALT SPRAY EXPOSURE	Dampers subjected to 20% salt spray solution for 5 days Followed by 24 hours in ambient air to dry.
SPRING CLOSURE	If spring is used, then it must be 2.5 times the required closing force.

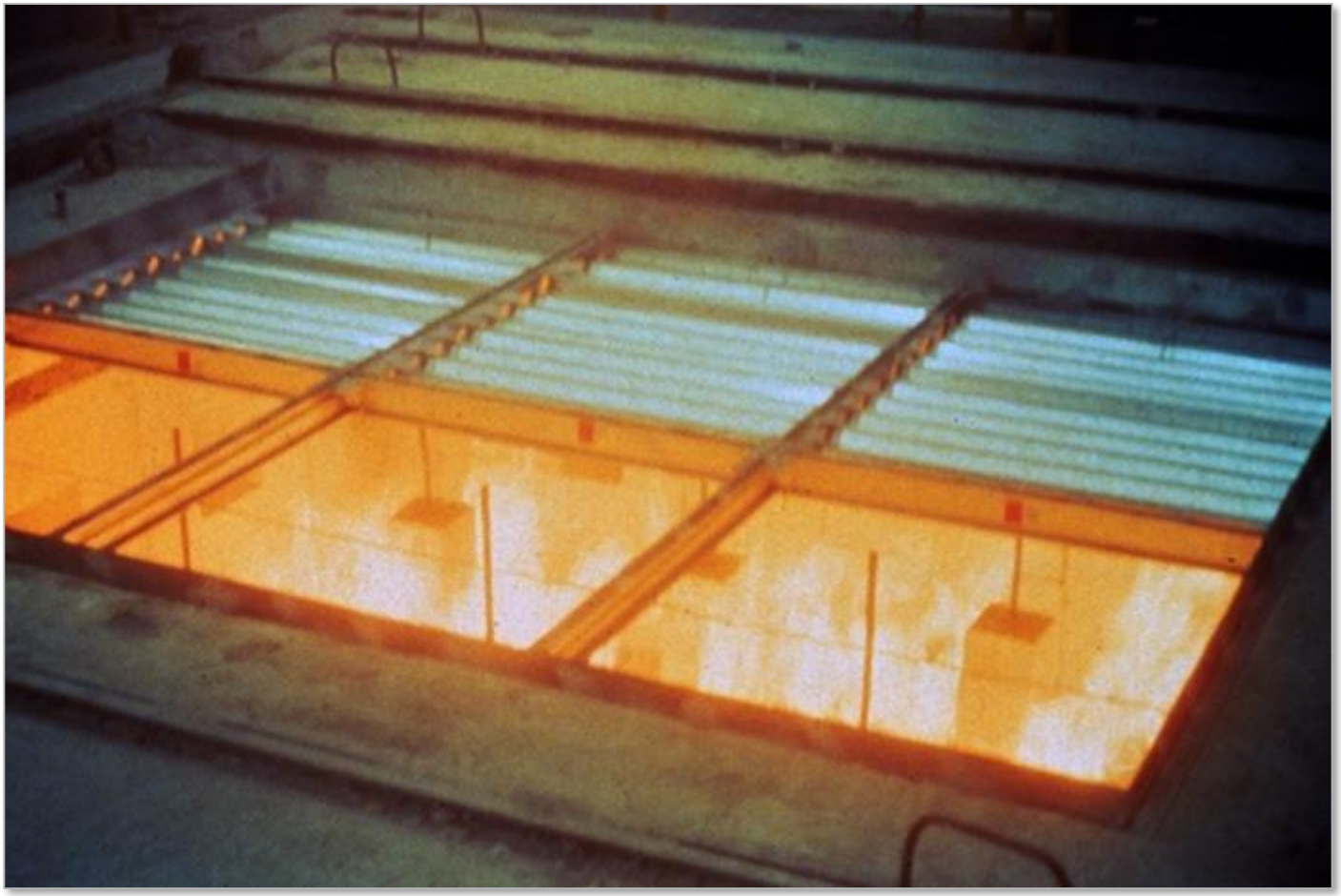
FIRE DAMPERS

DYNAMIC FIRE DAMPER TEST – ADDITIONAL TO STATIC FIRE DAMPER TEST

	ULC S112
DYNAMIC CLOSURE	Cycled 250, 20,000 or 100,000 times. Installed in a duct and cycled 3 times under ambient airflow and static pressure. *(min. 10.2 m/s @ 1 kPa)* Ramped heated airflow allowing the HRD to close the damper. *Dampers are run with airflow in both directions.*
HYDROSTATIC STRENGTH TEST	For pneumatic actuators. 5X operating pressure for 1 minute.

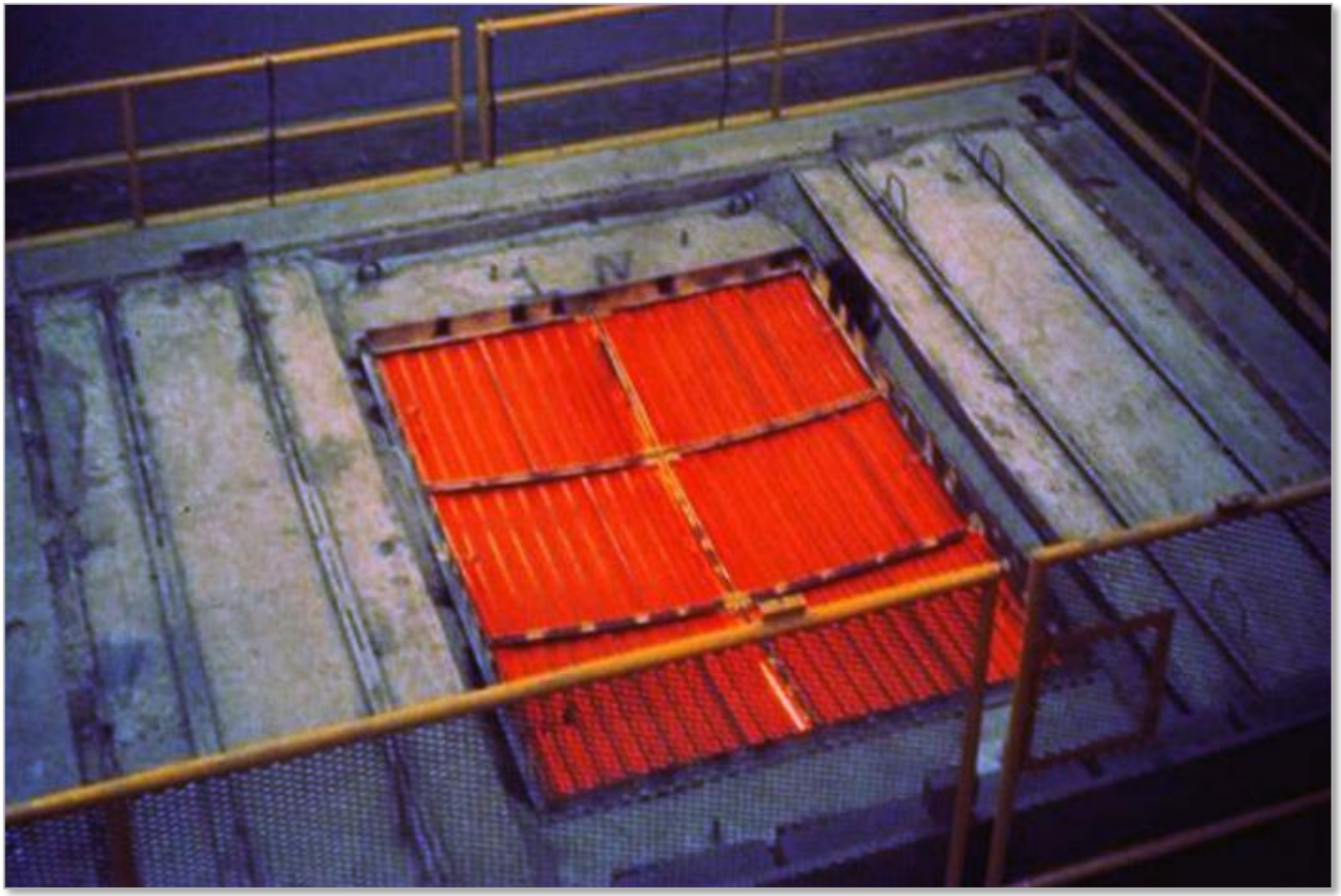
FIRE DAMPERS

HORIZONTAL FIRE TEST – BEGINNING



FIRE DAMPERS

HORIZONTAL FIRE TEST – 1.5 HOURS



- 980 °C (1792 °F)

FIRE DAMPERS

HORIZONTAL FIRE TEST – AFTER FIRE EXPOSURE

- Hose stream immediately after fire exposure
- 207 kPa *(30psi)* or 310kPa *(45 psi)*
- From 6.1 m *(20 ft.)* away

FIRE DAMPERS & COMBINATION FIRE/SMOKE DAMPERS

APPROVED BREAKAWAY DUCT CONNECTIONS

PLAIN “S” SLIP

HEMMED “S” SLIP

DOUBLE “S” SLIP

INSIDE SLIP JOINT

FLAT DRIVE SLIP

DRIVE SLIP JOINT

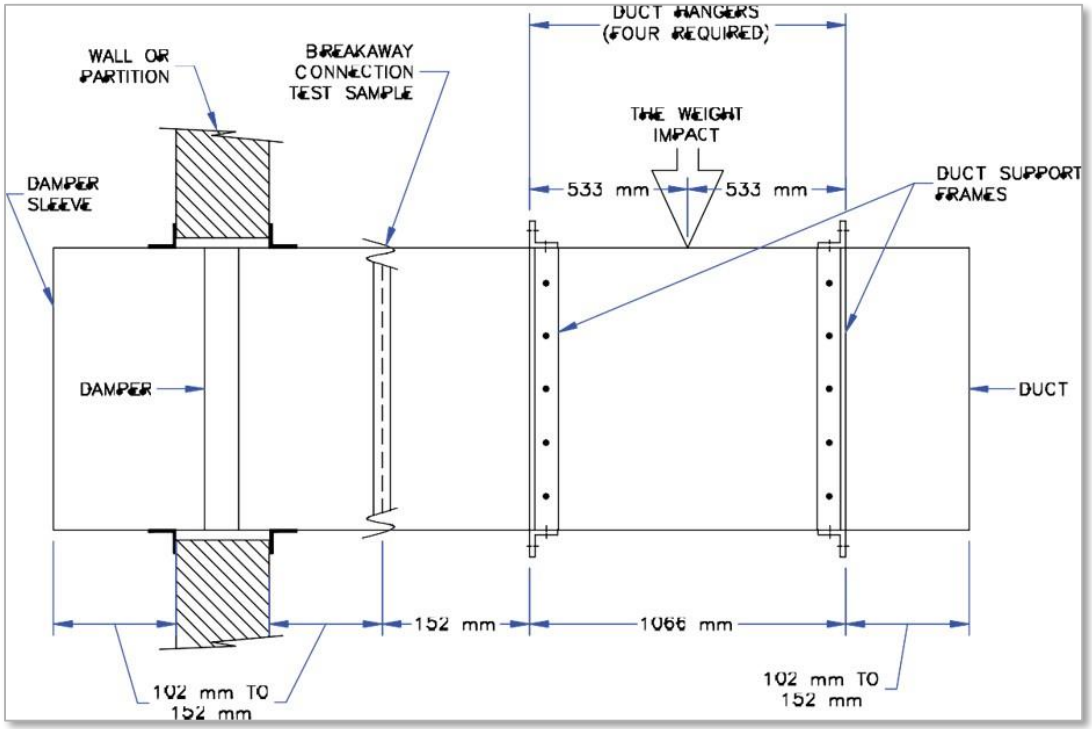
STANDING “S”

STANDING “S” BAR REINFORCED

STANDING “S” ANGLE REINFORCED

FIRE DAMPERS

DUCT IMPACT TEST



REFERENCES: CLAUSES 12.2, 12.3	
DUCT SIZE	**SAND-FILLED DRUM**
≤ 610 mm *(24 in)*	125 kg *(275 lb)*
> 610 mm *(24 in)*	181 kg *(400 lb)*

SMOKE DAMPERS

SMOKE DAMPERS SAVE LIVES

WHAT HAPPENS WHEN YOU INHALE SMOKE?

- Smoke contains chemicals and poisons (CO & Cyanide) that cause your lungs to become irritated, swollen, and blocked.

HOW LONG DOES IT TAKE TO DIE FROM SMOKE INHALLATION?

- It can take from 2 to 10 minutes to pass out or die.
- Fire burns oxygen, so the bigger the fire, the less oxygen.

SMOKE DAMPERS

TYPICAL SPECIFICATIONS	
Leakage Class	I: 0.0406 $m^3/s/m^2$ @ 1.1kPa *(8 cfm/ft^2)*
	II: 0.1016 $m^3/s/m^2$ @ 1.1kPa *(20 cfm/ft^2)*
	III: 0.4064 $m^3/s/m^2$ @ 1.1kPa *(40 cfm/ft^2)*
Airflow	Minimum duct velocity: 10.2 m/s *(2000 fpm)*
Static Pressure	Minimum: 1 kPa *(4 in wg)*
Temperature	121 or 177 °C *(250 or 350 °F)*
Mounting Position	Horizontal or Vertical
Installation	Up to 24” out of the smoke barrier

SMOKE DAMPERS

BASIC MODELS

- Triple-V blade damper
- Air-foil blade damper
- True round damper

OPTIONS:

- Transition: A, CR, CO, C, Sleeved, Not Sleeved
- Leakage Class: I, II, III
- Temperature Rated: 121 °C or 177 °C
- Actuator Mounting: Internal, External
- Actuator Power Source: 24v, 120v, 230v, Pneumatic
- Blade Indicators: Open, Closed
- Smoke Detectors: Photoelectric, Ionization

SMOKE DAMPERS

MINIMUM TEST SIZES

- SINGLE SECTION

  MAXIMUM HEIGHT X MINIMUM WIDTH:

- SINGLE SECTION

  MINIMUM HEIGHT X MAXIMUM WIDTH:

SMOKE DAMPERS

MAXIMUM TEST SIZES

- SINGLE SECTION

  MAXIMUM HEIGHT X MAXIMUM WIDTH:

  - Internal actuator
  - Approved for internal and external actuator mounting.

- SINGLE SECTION

  MAXIMUM HEIGHT X MAXIMUM WIDTH:

  - External actuator
  - Approved for external actuator mounting only.

SMOKE DAMPERS

MAXIMUM TEST SIZES

- MULTIPLE SECTION APPROVAL

  TWO SECTIONS HIGH BY
  TWO SECTIONS WIDE:
  External actuators direct-coupled to drive rods

SMOKE DAMPERS

BASE TEST (LEAKAGE RATED)

ULC S112.1	
1. CYCLING	Damper and actuator are cycled, from open to close. Two-Position: 20,000 times Modulating: 100,000 times
2. AMBIENT OPERATION	Following cycle test, damper must be opened and closed 3 consecutive times at 12.2 m/s *(2400 fpm)* and 1.12 kPa *(4.5" wg)*, under ambient airflow.
3. TEMPERATURE DEGRADATION	Cycled damper is exposed to 121 °C *(250 °F)* at 12.2 m/s *(2400 fpm)* for 15 minutes.
4. HEATED OPERATION	Damper must close and re-open under the following conditions: Airflow: 12.2 m/s *(2400 fpm)* *Static Pressure:* 1.12 kPa *(4.5" wg)* Temperature: 121 °C *(250 °F)*
5. LEAKAGE	Damper is reheated to 121 °C *(250 °F).* Blades are closed. Damper is leakage tested at this temperature.
STEPS 2 THROUGH 5	Repeated with same damper or another cycled damper with airflow in the opposite direction.

SMOKE DAMPERS

ADDITIONAL TESTING

ULC S112.1	
RIGIDITY	**Lateral** and **longitudinal** forces must be applied to the largest damper. There is a limit to how far it can move.
SALT SPRAY EXPOSURE	Dampers subjected to 20% salt spray solution for 5 days Followed by 24 hours in ambient air to dry.
ACCELERATED AGING	Non-metallic components tested for 1440 hours at 125 °C *(257 °F).*
HYDROSTATIC STRENGTH TEST	For pneumatic actuators. 5X operating pressure for 1 minute

SMOKE DAMPERS

CYCLE TESTING

MINIMUM REQUIREMENTS

ONE OF EACH OF THE FOLLOWING DAMPERS PER ACTUATOR MODEL:

- Minimum Width x Maximum Height
  Maximum Width x Minimum Height
  Maximum Width x Maximum Height

APPROVAL OBTAINED

- Temperature rating
- At a specific airflow
- For one damper model, one actuator model
- No options

Portion of samples in queue for cycle testing

SMOKE DAMPERS

ELEVATED TEMPERATURE CHAMBER

SMOKE DAMPERS

ELEVATED TEMPERATURE CHAMBER

SMOKE DAMPERS

ELEVATED TEMPERATURE LEAKAGE CHAMBER

SMOKE DAMPERS

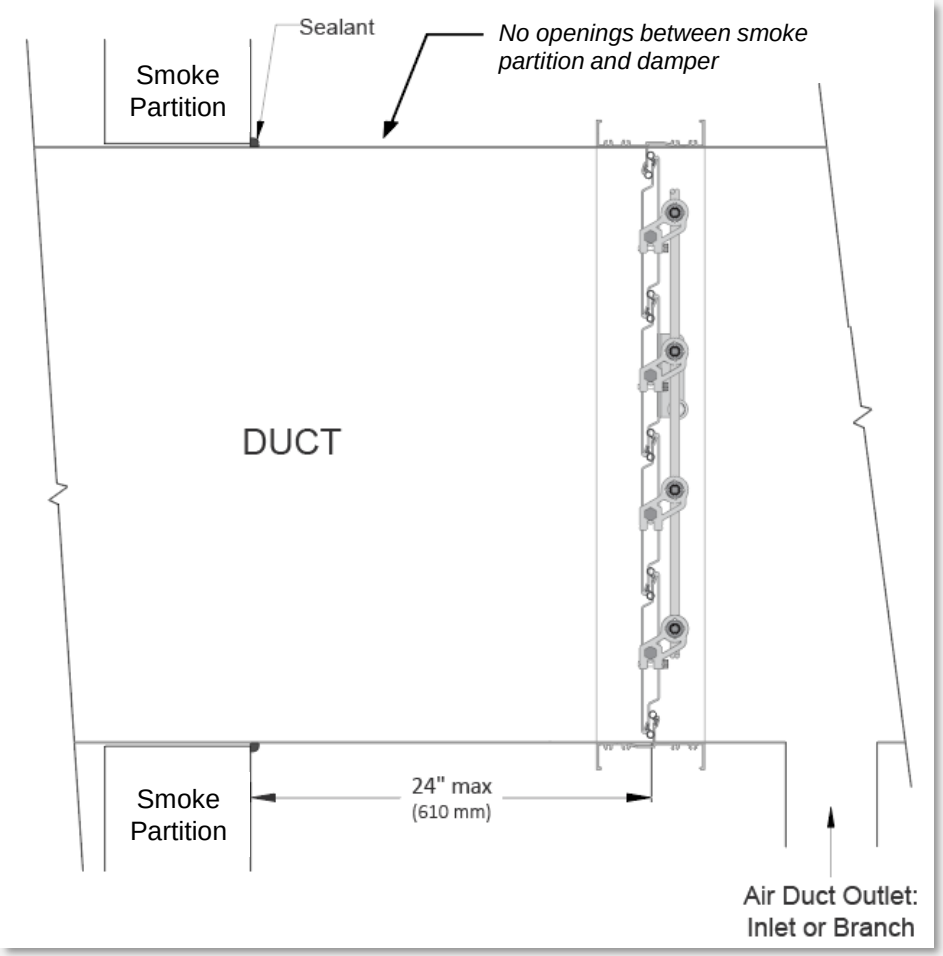
TESTING: ULC WITNESSES

- Verify operation
- Approve all test results

SMOKE DAMPERS

INSTALLATION REQUIREMENTS
NFPA 90A-15, 5.3.5.1

- Maximum allowable distance from smoke barrier:
  610 mm (*24”*)



COMBINATION FIRE/SMOKE DAMPERS

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	III: 0.4064 $m^3/s/m^2$ @ 1.1kPa *(40 cfm/ft^2)*
Airflow	Minimum duct velocity: 10.2 m/s *(2000 fpm)*
Static Pressure	Minimum: 1 kPa *(4 in wg)*
Temperature	121 or 177 °C *(250 or 350 °F)*
Mounting Position	Horizontal or Vertical
Installation	"In Wall" or "Out of Wall"
Actuator	Factory-installed

COMBINATION FIRE/SMOKE DAMPERS

BASIC MODELS

OPTIONS:

- Transition: A, CR, CO, C, Sleeved, Not Sleeved
- Higher Static Pressure: 2.0 or 3.0 kPa *(6.0" or 8.0" wg)*
- Higher Airflow: 15.2, or 20.3 m/s *(3,000 or 4,000 fpm)*
- Leakage Class: I, II, III
- Temperature Rated Damper: 121 °C or 177 °C
- Heat Response Device: 71 °C, 100 °C, 121 °C, 177 °C
- Actuator Mounting: Internal, External
- Actuator Power Source: 24v, 120v, 230v, Pneumatic
- Hourly Rating: 1½ or 3 Hour
- Blade Indicators: Open, Closed
- Smoke Detectors: Photoelectric, Ionization
- Re-openable: Primary and secondary heat sensors

COMBINATION FIRE/SMOKE & SMOKE DAMPERS

STATIC AND DYNAMIC SYSTEMS

TESTED AND APPROVED FOR USE IN:

- Dynamic Systems
- Static Systems

Tested for closure under heated airflow (Dynamic Systems).

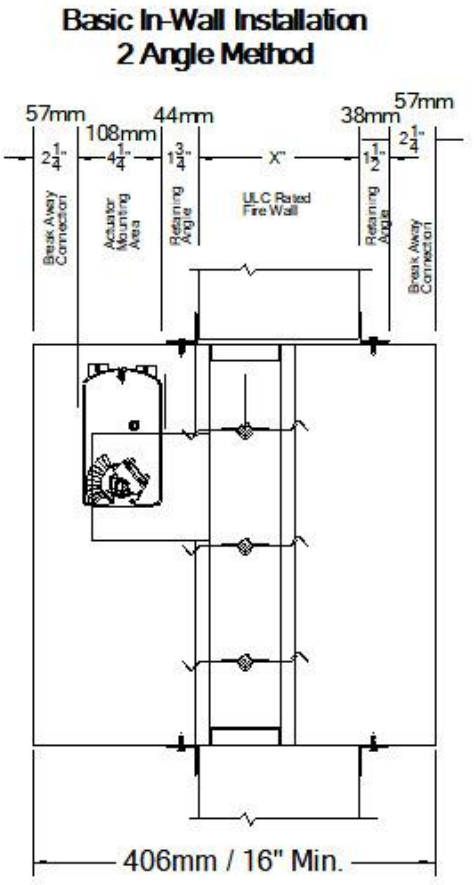
TWO UTILIZATION METHODS:

1. CONTAINMENT
   - Maintain compartmentalization. Use local duct smoke detectors to close damper to prevent spread of smoke spread.
2. RE-OPENABLE
   - As part of an engineered smoke control system.
   - When properly located in or immediately adjacent to returns, area smoke detectors are clear indicators of where the fire is located.
   - Sprinkler flow switches are necessary back-up.

COMBINATION FIRE/SMOKE DAMPERS

TYPICAL INSTALLATION

IN FLOOR



IN WALL

COMBINATION FIRE/SMOKE DAMPERS

TYPICAL INSTALLATION

METAL STUD / GYPSUM FIREWALL

COMBINATION FIRE/SMOKE DAMPERS

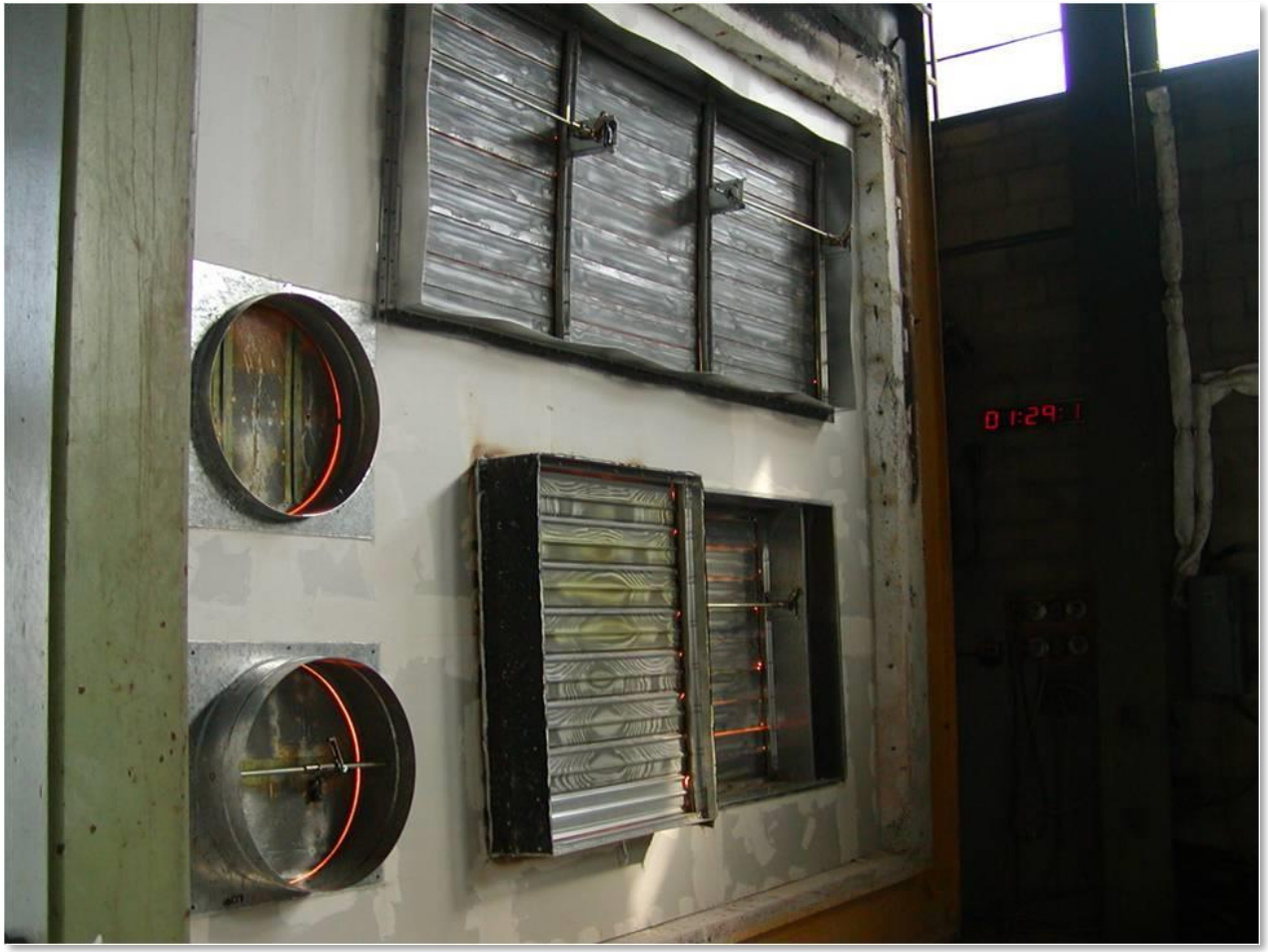
VERTICAL FIRE TEST

COMBINATION FIRE/SMOKE DAMPERS

VERTICAL FIRE TEST

COMBINATION FIRE/SMOKE DAMPERS

VERTICAL FIRE TEST



1½ hours elapsed test time – Approximately 978 °C *(1800 °F)*

COMBINATION FIRE/SMOKE DAMPERS

VERTICAL FIRE TEST

Fire side just before hose stream

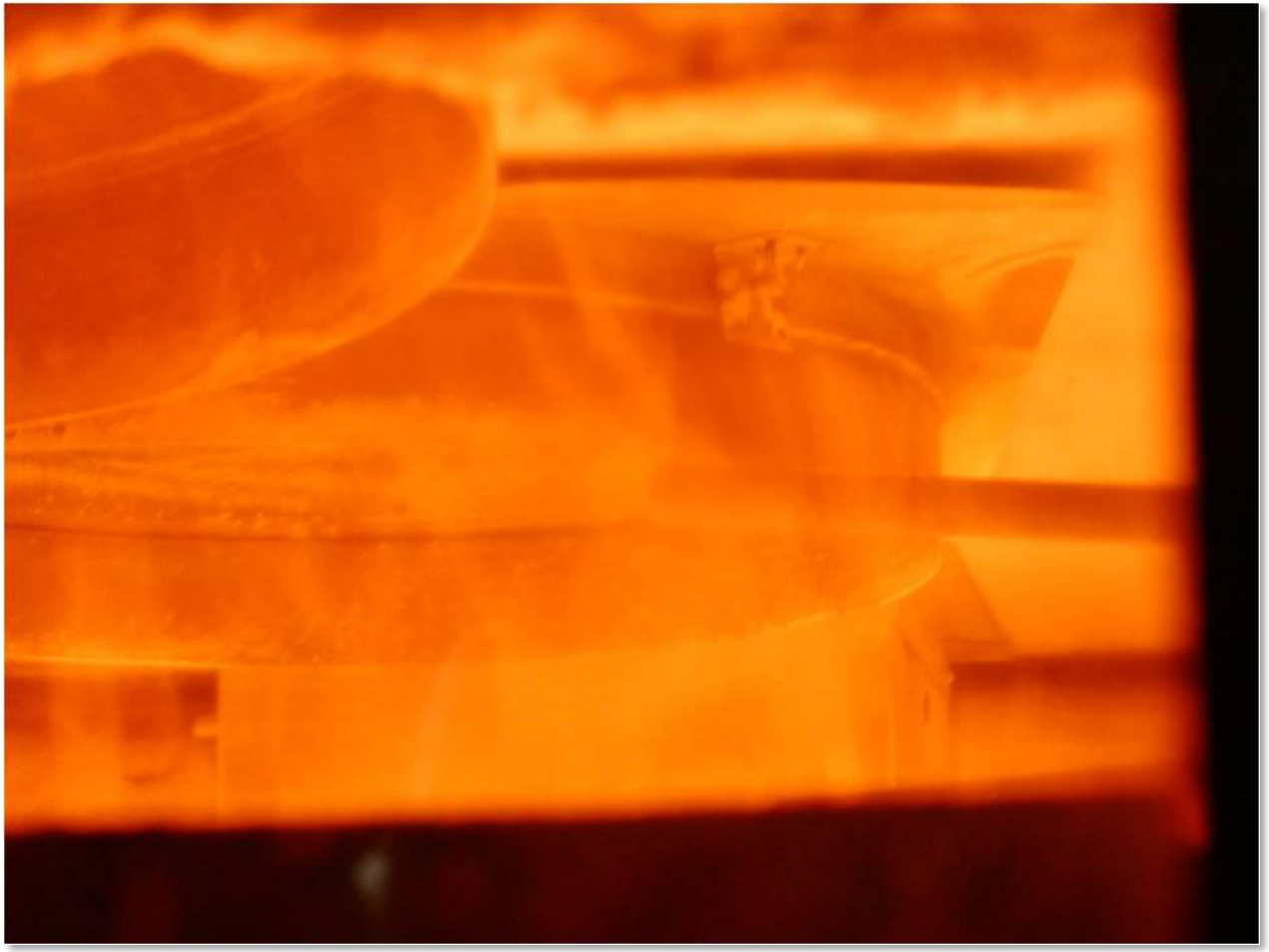
COMBINATION FIRE/SMOKE DAMPERS

VERTICAL FIRE TEST

207 kPa *(30 psi)* for 3 minutes

COMBINATION FIRE/SMOKE DAMPERS

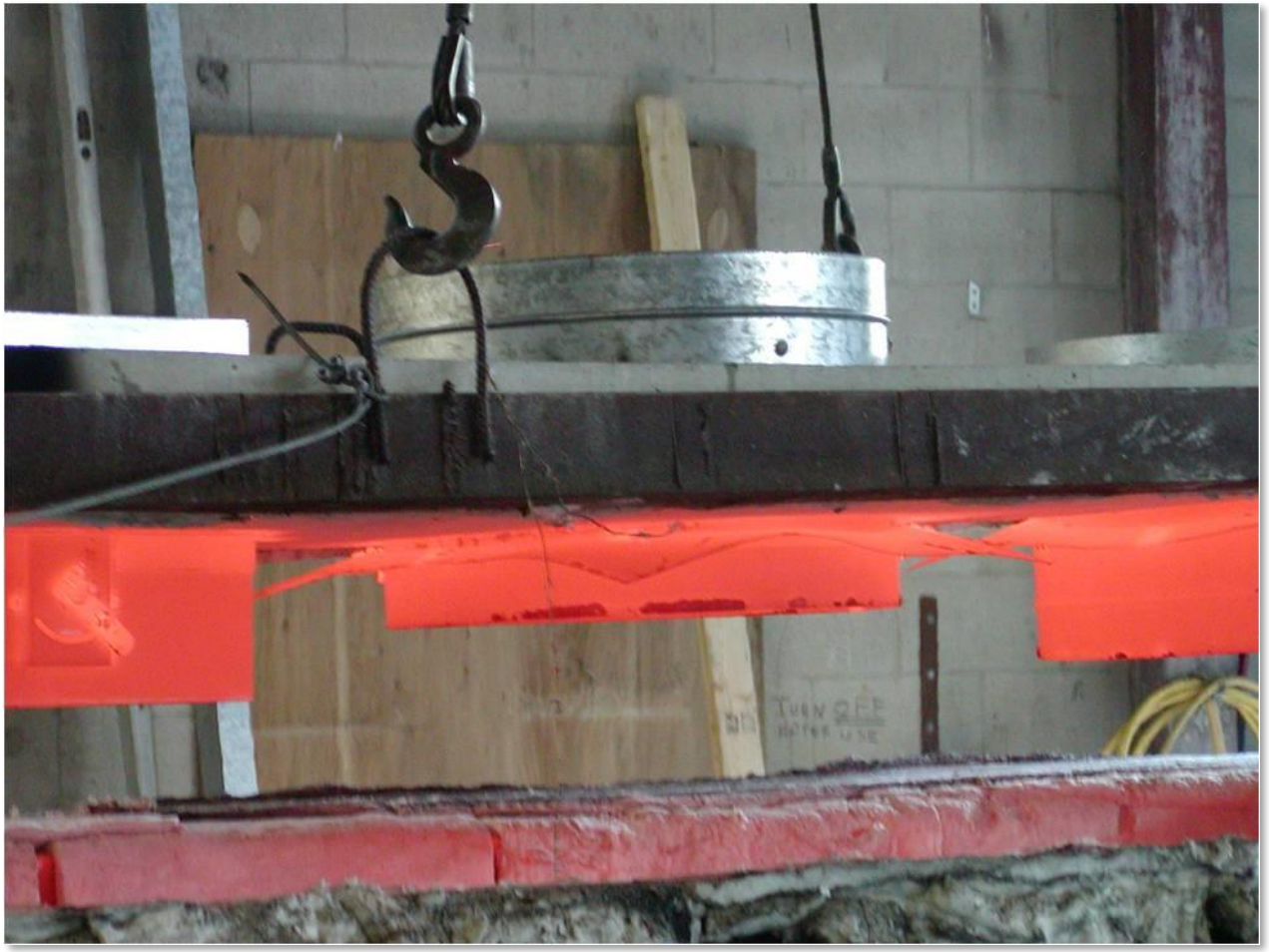
HORIZONTAL FIRE TEST



During test

COMBINATION FIRE/SMOKE DAMPERS

HORIZONTAL FIRE TEST



End of test: 978 °C *(1800 °F)*

COMBINATION FIRE/SMOKE DAMPERS

HORIZONTAL FIRE TEST

Hose stream after test

COMBINATION FIRE/SMOKE DAMPERS

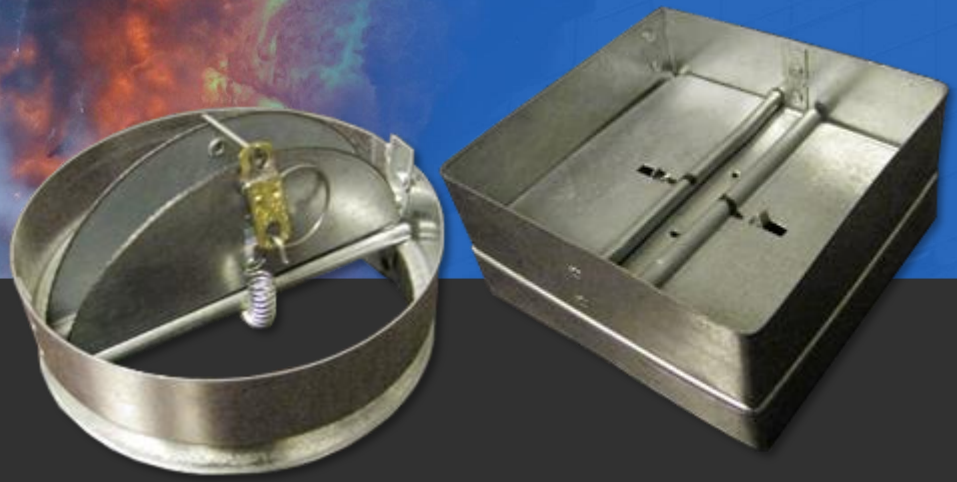
HORIZONTAL FIRE TEST

Single-blade damper after test

SMOKE DETECTORS

CEILING FIRESTOP FLAP ASSEMBLIES

Ceiling Radiation Dampers

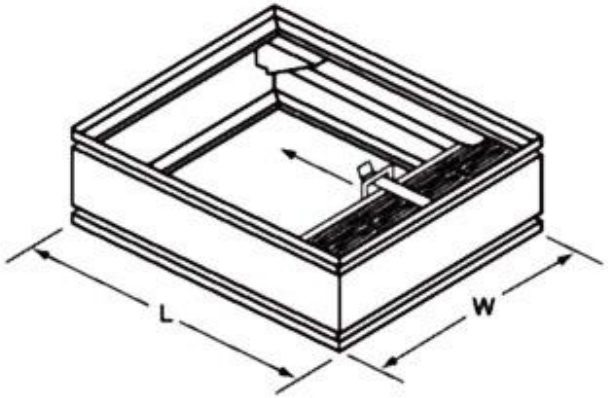


CEILING FIRESTOP FLAP ASSEMBLIES

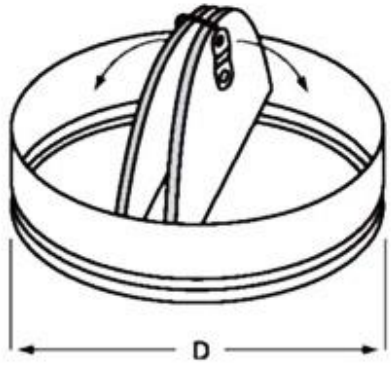
TYPICAL SPECIFICATIONS	
Rated for Installation	in Specific ULC Approved Ceilings
Type	Round or Rectangular
Testing	Static Rated Only
Mounting Position	Horizontal Only
Blade Types	Butterfly or Fabric
Installation	Usually within 7.6 – 10 cm of ceiling
Fuse Link	Usually 71 °C or 100 °C *(160 °F or 212 °F)*

CEILING FIRESTOP FLAP ASSEMBLIES

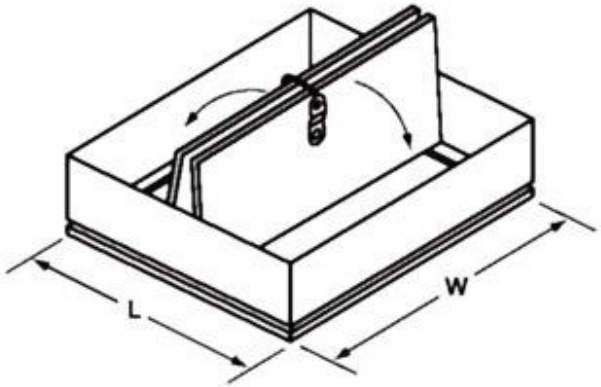
BASIC MODELS – HORIZONTAL MOUNT TYPE ONLY



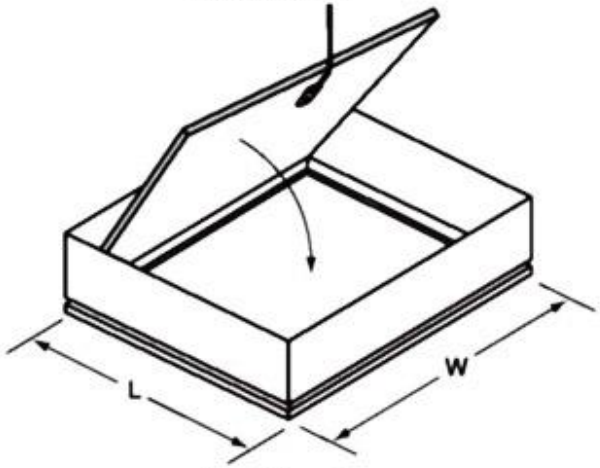
Fabric Curtain



Round Butterfly



Rectangular Butterfly



Trap/Hinge Door

CEILING FIRESTOP FLAP ASSEMBLIES

BASIC MODELS

- Round damper
- Rectangular or square damper
- Fabric blade damper, rectangular

OPTIONS:

- Fuse Link: 100 °C *(212 °F)* Standard, 71 °C *(160 °F)* available
- Volume Control: Adjustable feature to vary blade position from below damper
- Thermal Blanket: Provides thermal protection on square diffusers with round necks
- Hourly Rating: Not hourly rated
  Rated as part of an assembly
- Approved with or without a grille *(See manufacturer)*
- Approved for ducted or non-ducted applications *(See manufacturer)*

CEILING FIRESTOP FLAP ASSEMBLIES

TYPICAL INSTALLATIONS

Figure 1

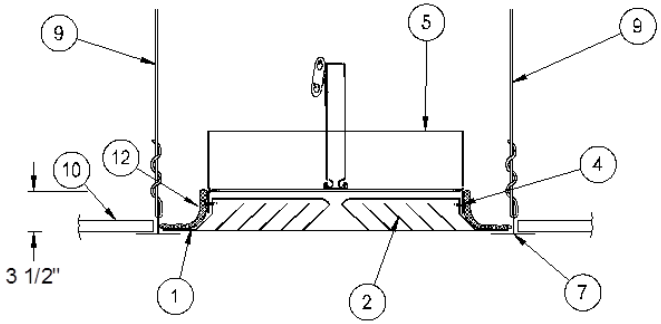


Figure 1A

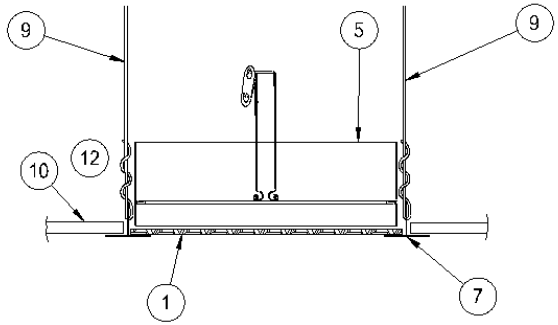


Figure 2

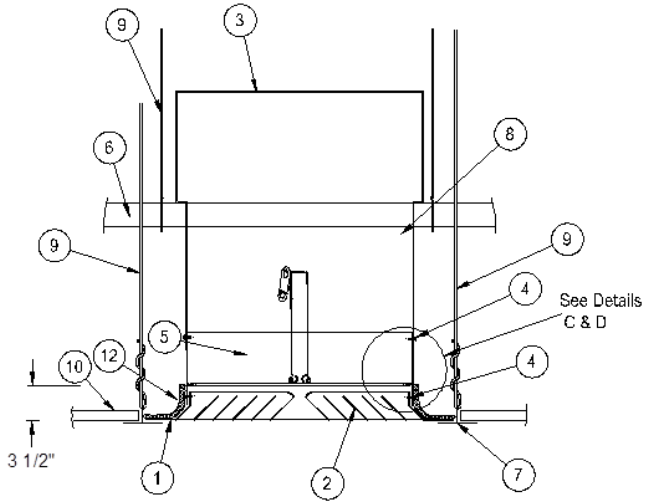
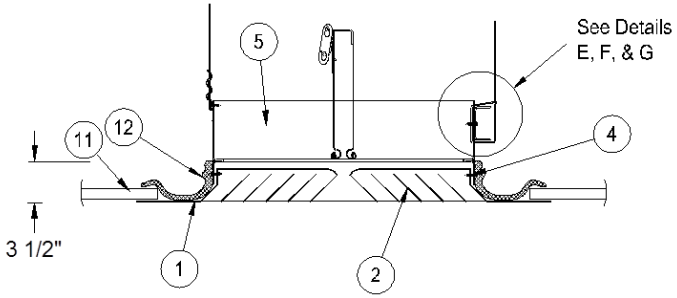
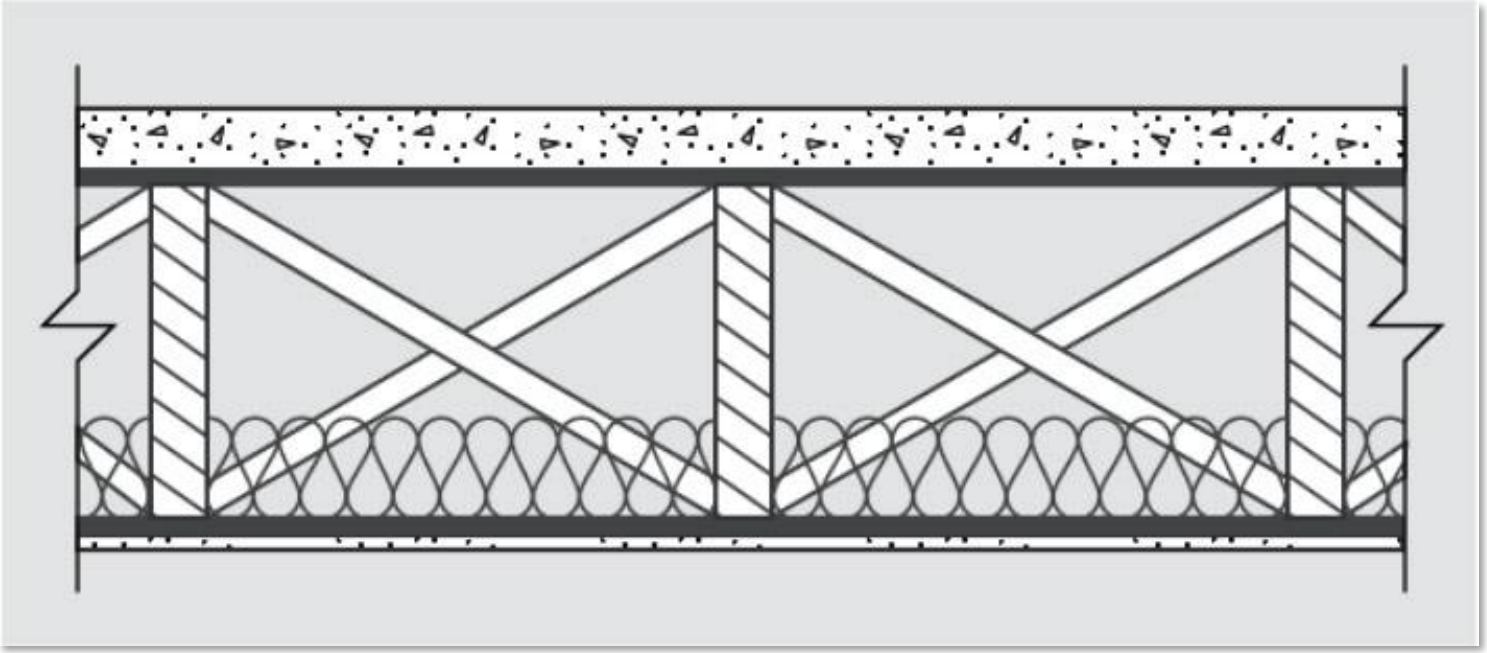


Figure 7



CEILING FIRESTOP FLAP ASSEMBLIES

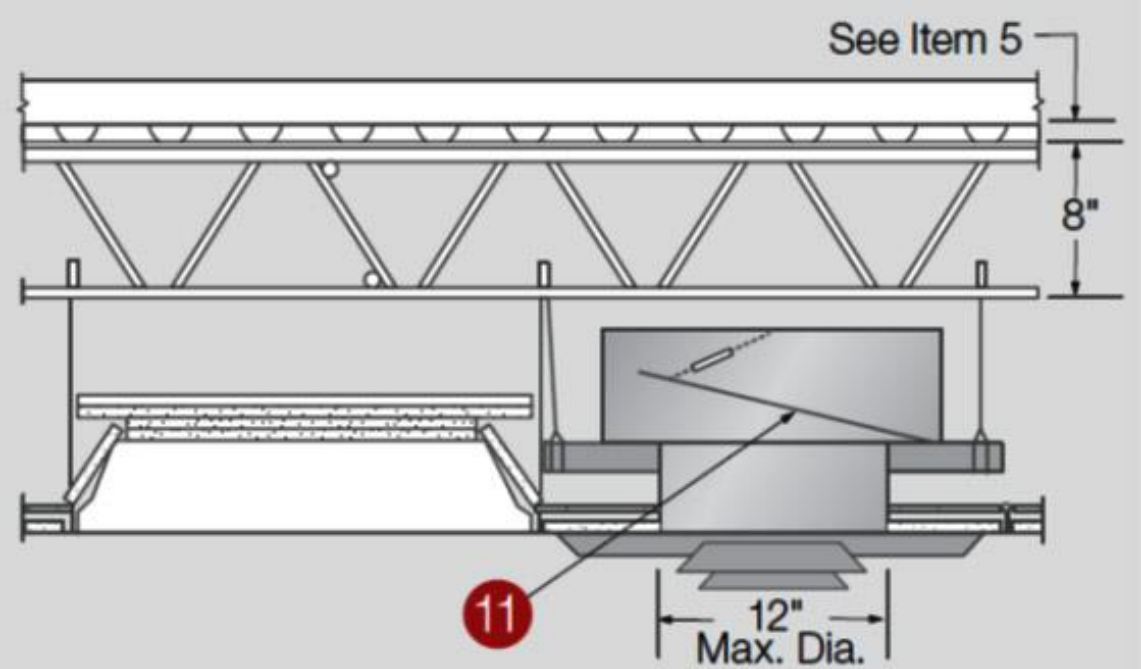
ULC CEILING DESIGN



- No damper.
- Thus “No Penetration” can be made through the lower membrane.

CEILING FIRESTOP FLAP ASSEMBLIES

ULC CEILING DESIGN

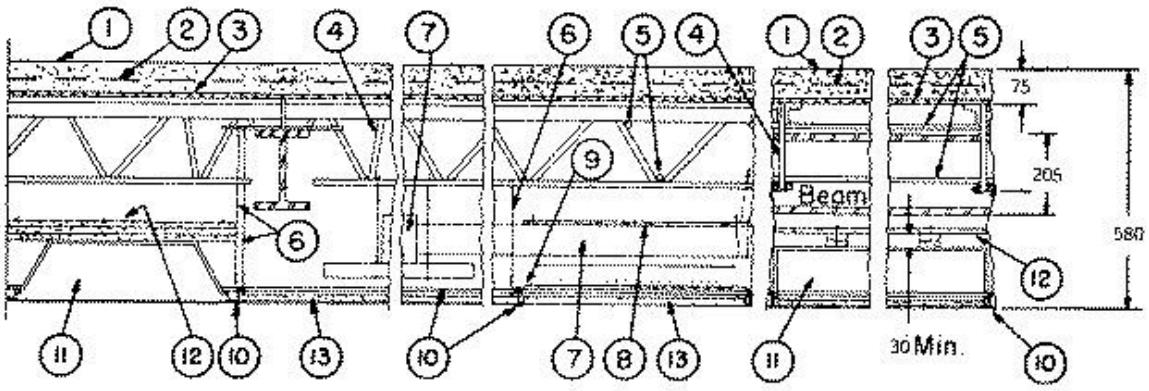


11. Damper — No. 13 MSG galv steel, 14 by 14 in. Protected on both surfaces with 1/16 in. ceramic fiber paper and held open with a Fusible Link. (Bearing the UL Listing Mark). Damper to overlap duct outlet 1 in. min.

- Hinged door type damper
- Any damper listed as a ceiling firestop flap.

CEILING FIRESTOP FLAP ASSEMBLIES

ULC CEILING DESIGN



8(b). **Ceiling Firestop Flap** – (CABSC). May be used as an alternate to acoustical material described in 8(a) above.

For alternate means of protecting air duct outlets, see Air Handling Systems under the General Information Section under "Floor and Roof and Ceiling Constructions and Beam Protection" and listings of Air Terminal Units under (BXUVC). 1-1/2A

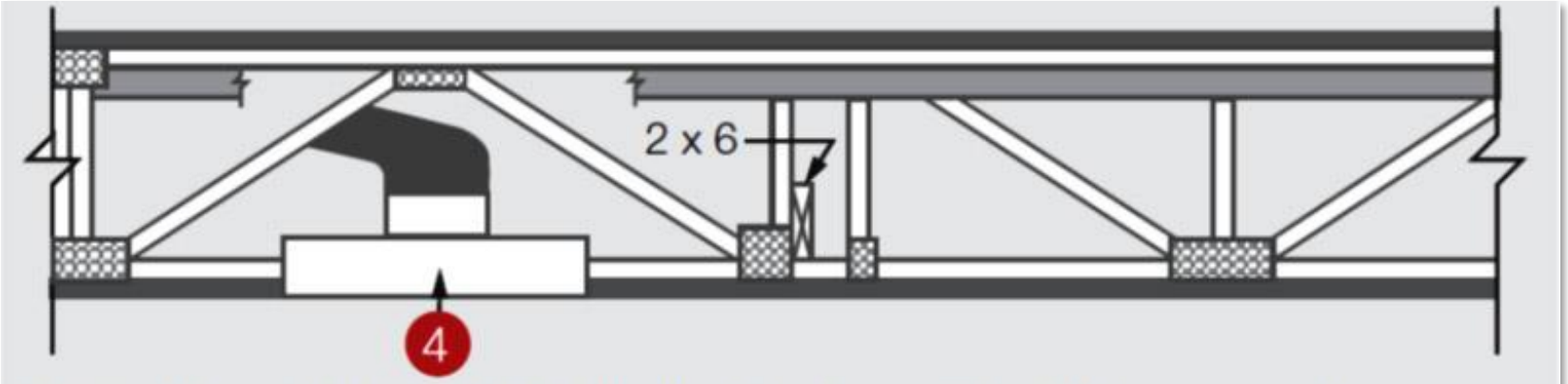
CARNES CO INC
CENTRAL VENTILAION SYSTEMS CO LLC
NCA MFG LTD
NAILOR INDUSTRIES INC
NAILOR INDUSTRIES (WESTERN) INC

PRICE INDUSTRIES LTD
REVERSOMATIC MFG LTD
RUSKIN COMPANY
UNITED ENERTECH CORP

- Hinged door type damper
- Any damper listed as a ceiling firestop flap.

CEILING FIRESTOP FLAP ASSEMBLIES

ULC CEILING DESIGN



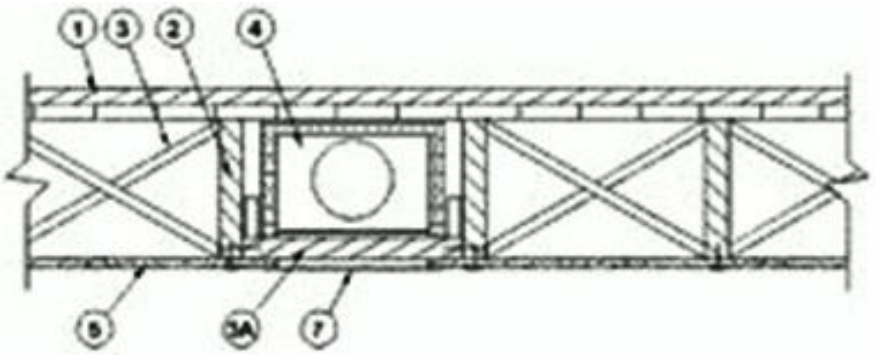
4. Damper (Optional, To be used with Air Duct Item 3) — For use with min 18 in. deep trusses. Max nom 21 in. long by 18 in. wide, fabricated from galvanized steel. Plenum box max size nom 21 in. long by 18 in. wide by 14 in. high (inner dimension) fabricated from either galvanized steel or min 1 in. thick Listed Duct Board bearing the UL Listing Marking having a min R-Value of 4.3. Installed in accordance with the instructions provided by the manufacturer. Max damper openings not to exceed 180 sq in. per 100 sq ft of ceiling area.

Damper Brand XXX – Model CRD-YYY

- Only Dampers Listed in Design are Approved.

CEILING FIRESTOP FLAP ASSEMBLIES

ULC CEILING DESIGN



4. **Ceiling Damper* — (Optional) —** Max nom area shall be 0.128 sq m (198 sq in.) Max rectangular size shall be 305 mm wide by 419 mm long. Max height of damper shall be 238 mm Aggregate damper openings shall not exceed 0.064 sq m per 9.29 sq m (99 sq in. per 100 sq ft) of ceiling area. Damper installed in accordance with the manufacturers installation instructions provided with the damper. A steel grille (Item 7) shall be installed in accordance with installation instructions.

AIR KING VENTILATION PRODUCTS — Series AS, Series AK

PRICE INDUSTRIES LTD — Models CD-S/R-HC, CD-RD-HC

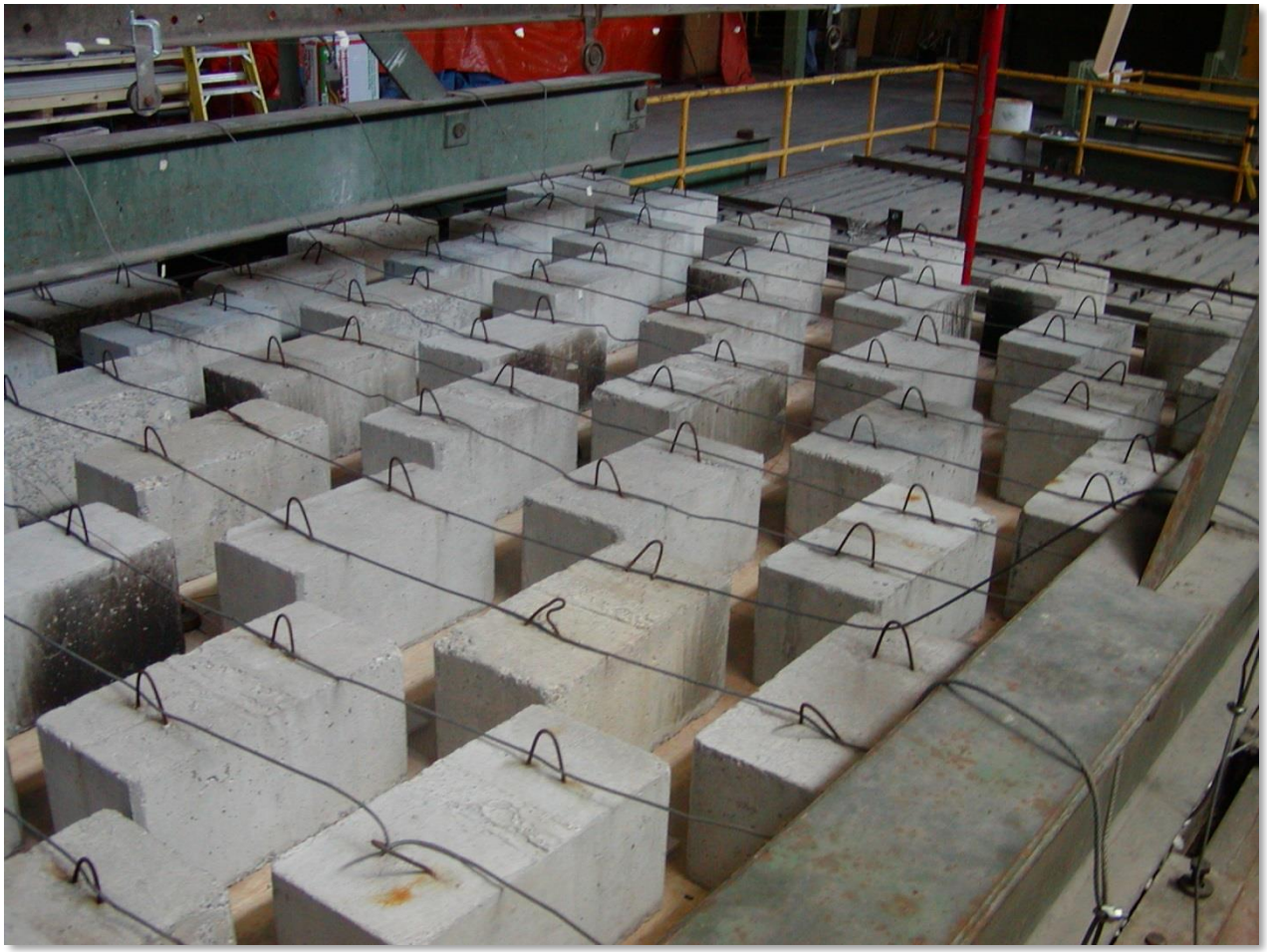
- Hinged door type damper
- Any damper listed as a ceiling firestop flap.

CEILING FIRESTOP FLAP ASSEMBLIES

INSTALLATIONS

CEILING FIRESTOP FLAP ASSEMBLIES

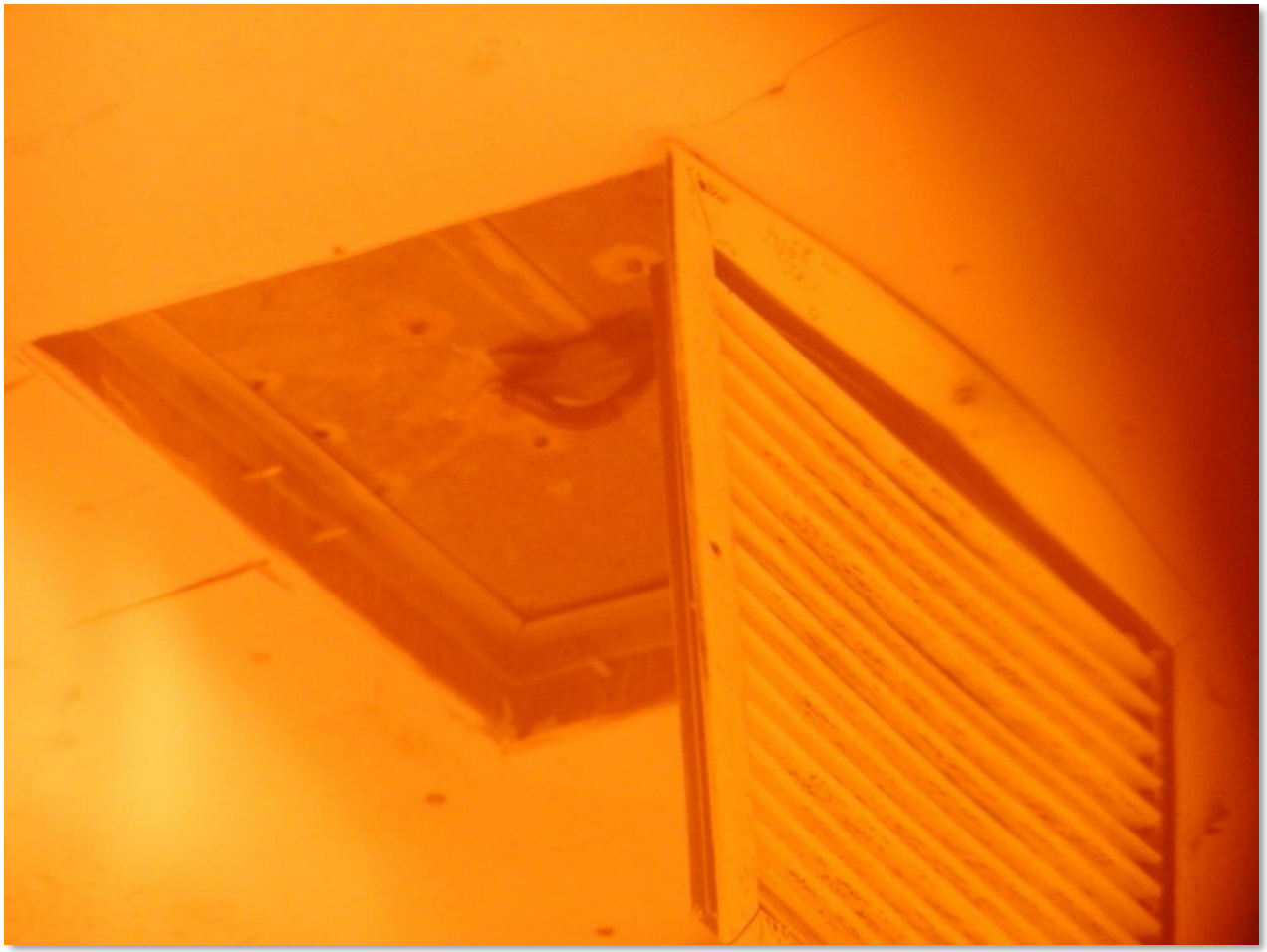
FIRE TEST – ULC S101/UL 263



Ceiling is loaded to its design load

CEILING FIRESTOP FLAP ASSEMBLIES

FIRE TEST



Grille falls of during 1 hour test

CEILING FIRESTOP FLAP ASSEMBLIES

FIRE TEST – CEILING DESIGN L501

At 1 hour

CEILING FIRESTOP FLAP ASSEMBLIES

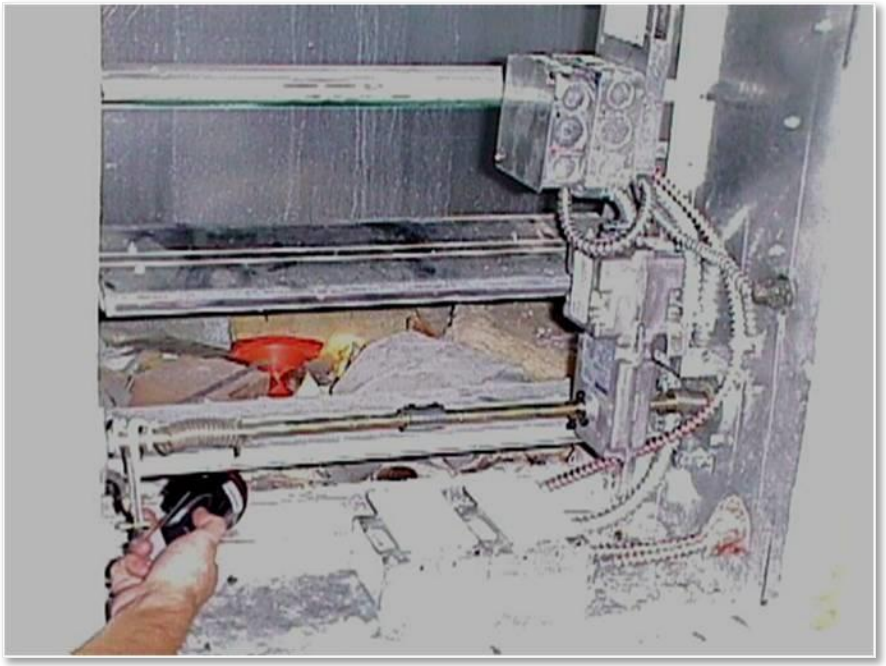
FIRE TEST – CEILING DESIGN L501

1 Hour test, 2 x 10’s and sheet rock

LIFE SAFETY DAMPERS
Uh-Oh!

TROUBLESHOOTING

FIELD ISSUES

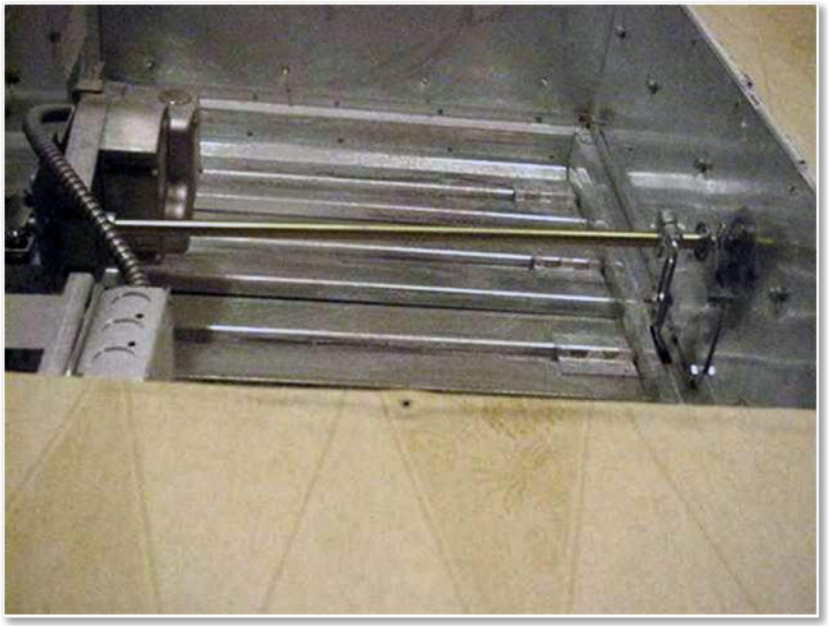


Garbage found behind damper.

TROUBLESHOOTING

FIELD ISSUES

Damper installed racked.



Misaligned jackshaft on damper, or the jack shaft was used as a ladder.

TROUBLESHOOTING

FIELD ISSUES

Screw fastened through linkage, through middle of warning label

Field-bent blades

Screw fastened in track of curtain damper

TROUBLESHOOTING

FIELD ISSUES

TROUBLESHOOTING

FIELD ISSUES

TROUBLESHOOTING

FIELD ISSUES

AGE OLD DILEMMA:

How to install a square damper in a round hole.

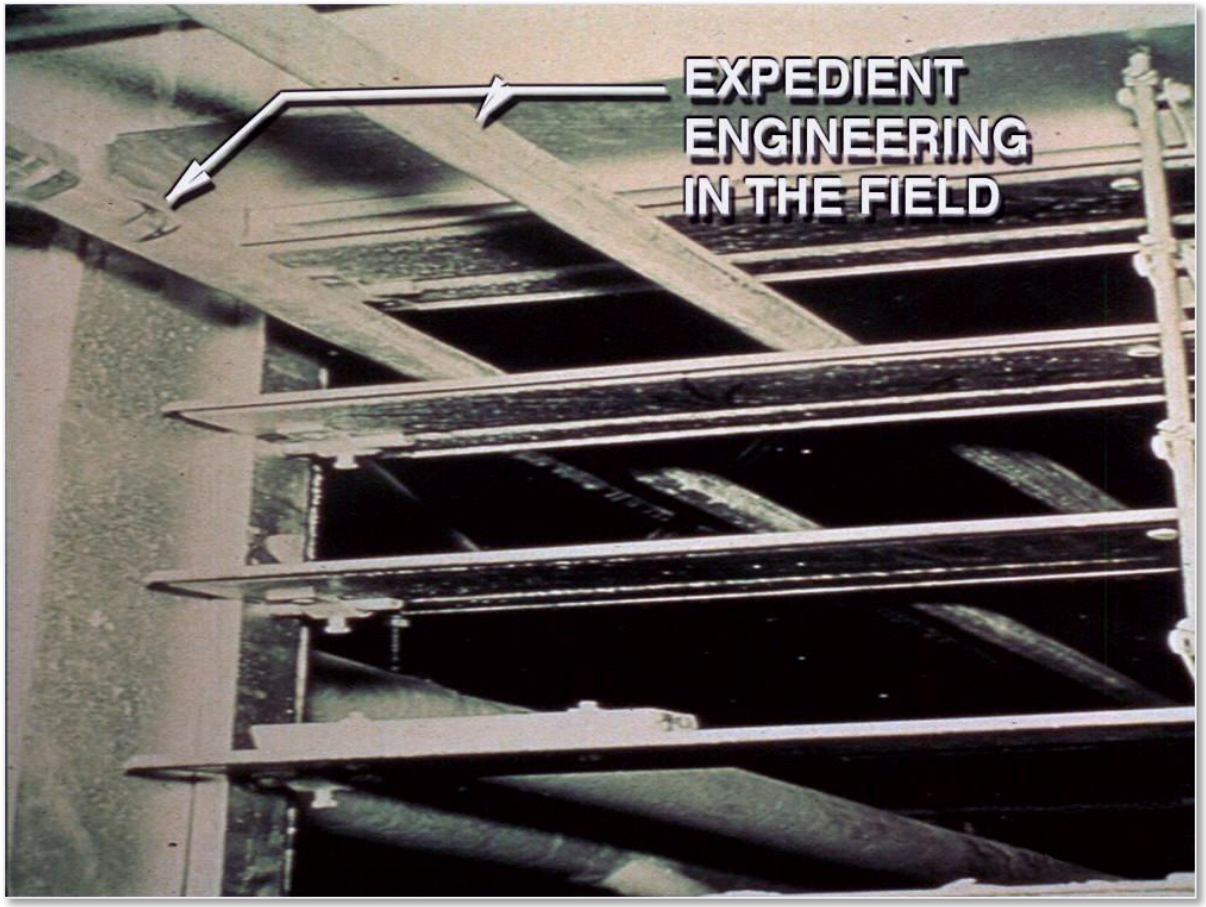
TROUBLESHOOTING

FIELD ISSUES

Humm, We may have several issues here

TROUBLESHOOTING

FIELD ISSUES



DEALING WITH CREATIVE PROBLEM SOLVING

TROUBLESHOOTING

STORAGE

WATER DAMAGED

- Actuators now contain circuit boards.
- Should have been stored in a dry environment.

QUESTIONS?

THANK YOU