Water Mist Extinguishment of Exhaust Duct Fires

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Exhaust ducts in industrial occupancies

- Food processing
- Semiconductor fabrication
- Pharmaceutical production
- Metal processing
- Power generation
- Paper and pulp production
- Textile
- Chemical processing
- Spray painting
- ……









Advantages of Water Mist Protection

- Better spray dispersion in ventilated tight space
- Less water runoff
- Effective for flame extinction to extinguish fire quickly in ventilated ducts
- Easier nozzle installation in ducts

Outline

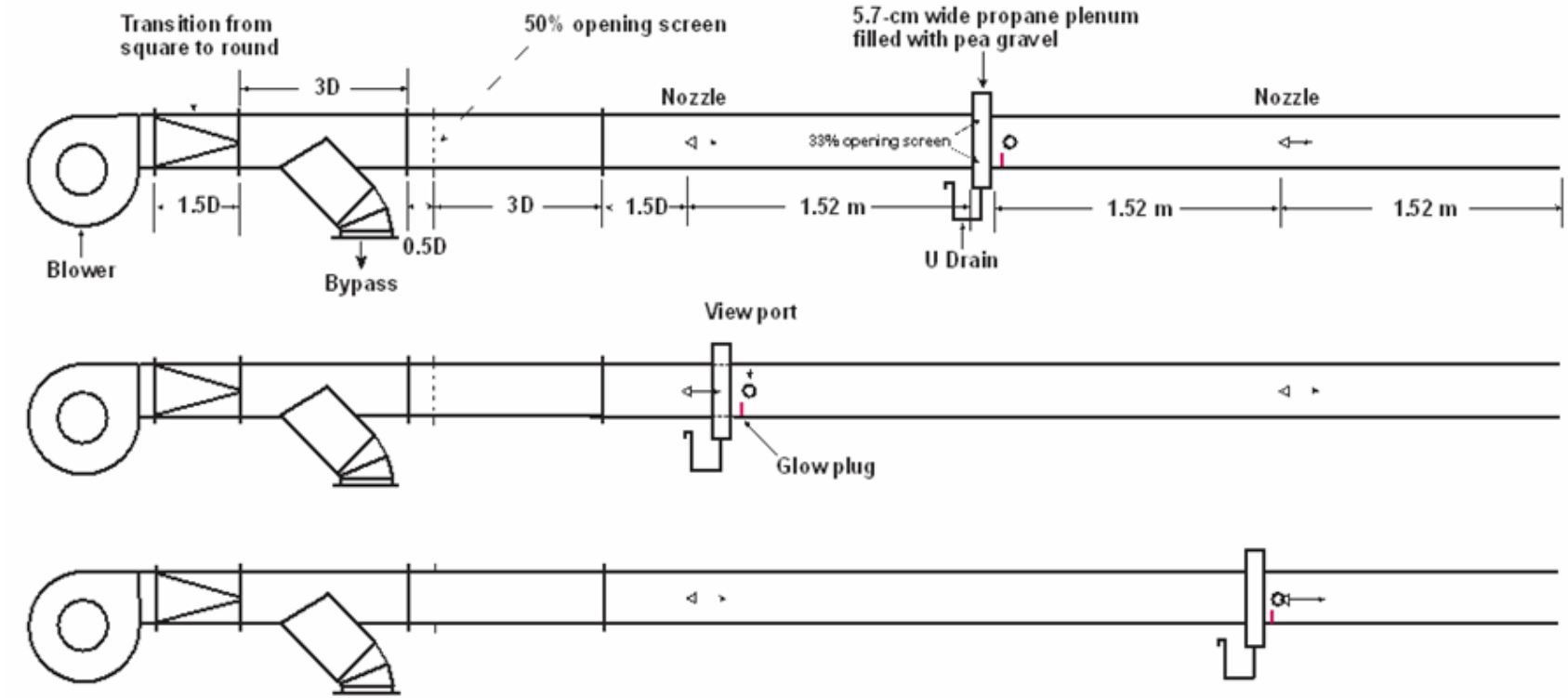
- Test fires
- Evaluation of fire extinguishment in 0.3-m duct
  - Test facility
  - Water mist protection
  - Fire test results
- Evaluation of fire extinguishment in 0.61-m duct
  - Test facility
  - Water mist protection
  - Fire test results
- Conclusions

Test Fires

- Simulate fires fueled by combustible deposits on duct's inside surface
- Use propane as the surrogate fuel

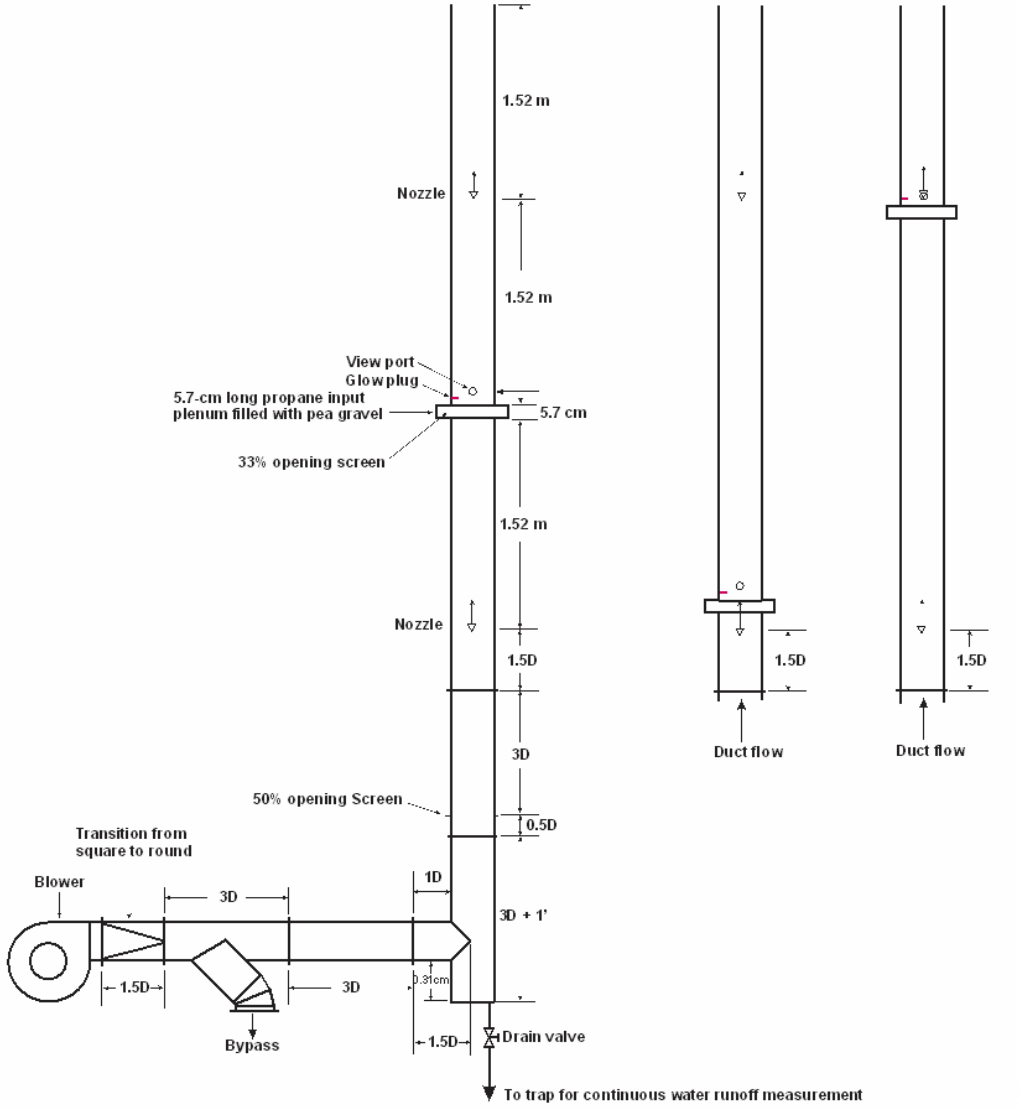
Duct Diameter (m)	Freeburn Fire Heat Release Rate (kW)	Propane Release Rate (liter/min)	Duct Length for Propane Release (mm)	Exhaust Air Velocity (m/s)	Volumetric Air Flow Rate at Duct Entrance (m^3/min)
0.30	105	74	57	0.84	3.7
0.30	205	144	57	1.68	7.4
0.30	310	218	57	2.52	11.0
0.30	475	331	57	3.89	17.0
0.61	410	295	114	0.84	14.7
0.61	820	590	114	1.68	29.4

0.3-m Duct Test Facility – Horizontal Orientation

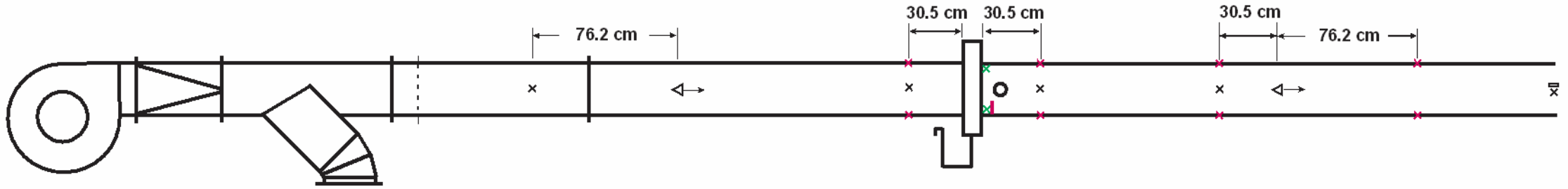


- Stainless steel ductwork
- Blower
- Bypass
- Flow conditioning screen
- Two water mist application locations at 3 m apart
- Propane-release plenum
- Viewport
- Drain

0.3-m Duct Test Facility – Vertical Orientation



0.3-m Duct Test Facility - Instrumentation



× TCs in the duct centerline, K-type, 26 gage

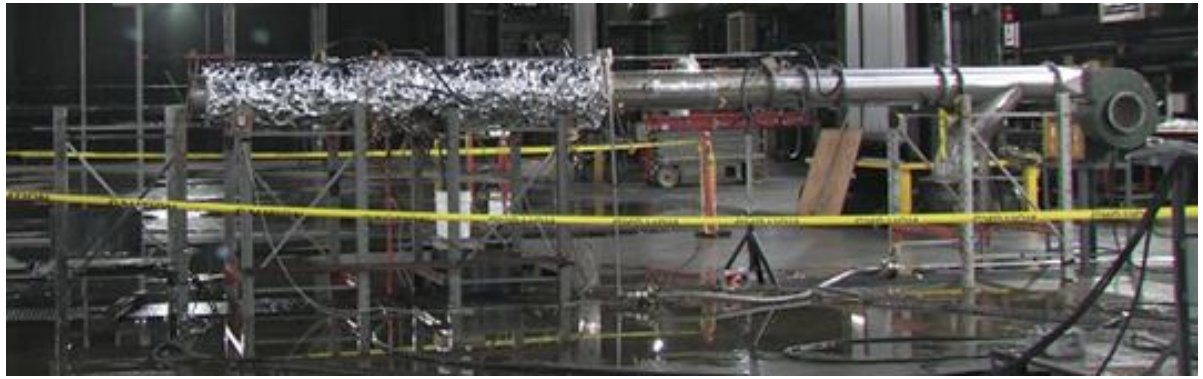
× Four TCs on the duct's outer surface at each location (90° apart at top, bottom, left, right), K-type, 20-gage

× Four TCs 2.5 cm downstream of plenum, 2.5 cm away from duct wall (90° apart at top, bottom, left, right), 20-gage

▭ Bidirectional probe

- Duct wall temperature
- Gas temperature
- Gas velocity at duct opening
- Propane release rate
- Nozzle operating pressure
- Total water mist discharge rate

0.3-m Duct Test Facility – Horizontal Orientation



Duct insulated to simulate the thermal response of 0.3-m diameter combustible ducts made of:

- **Fiber Reinforced Plastic (FRP)**
- **Polypropylene (PP)**
- **Fiberglass**
- **PVC**

0.3-m Duct Test Facility – Vertical Orientation

Water Mist Protection for 0.3-m Duct Tests

- **Targeted water mist concentration: 300 cc/m^3 or higher**

- **Water mist application**
  - **Spacing for the water mist application: 3 m**
  - **Water mist concentration provided from the upstream application**
    - **√ 471 cc/m^3 at midpoint between the two application locations**
    - **√ 303 cc/m^3 right before the downstream application location**

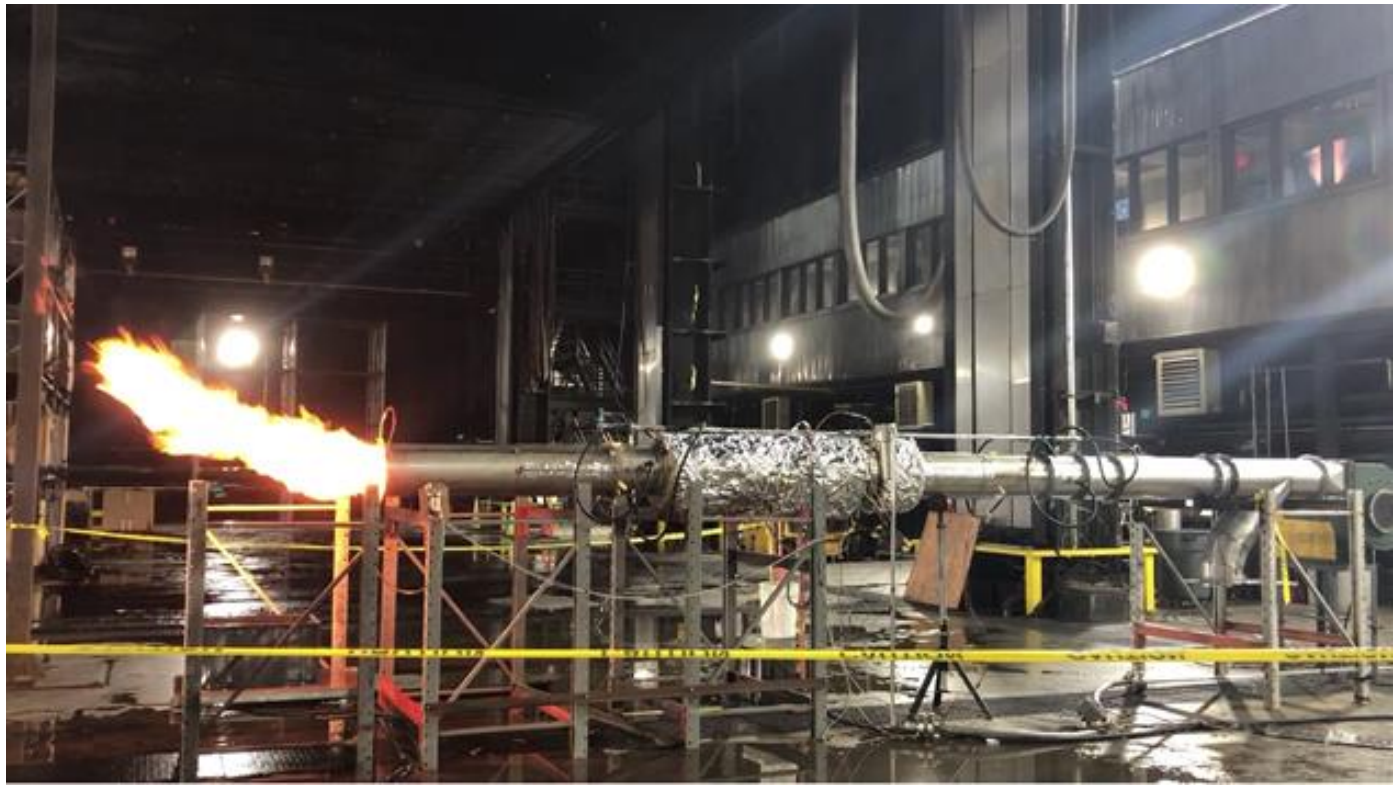
- **Volume-median droplet size: 77 μm**

Horizontal 0.3-m Duct Test Results

Freeburn Fire Heat Release Rate (kW)	Air Ventilation Rate (m^3/min)	Propane Release Location	Preburn Time (s)	Number of Tests	Fire Extinguished ?
105	3.7	upstream	30	4	4 of 4
205	7.4	upstream	30	4	4 of 4
310	11.0	upstream	30	3	3 of 3
475	17.0	upstream	30	3	3 of 3
105	3.7	midpoint	15	2	2 of 2
205	7.4	midpoint	15	2	2 of 2
310	11.0	midpoint	15	2	2 of 2
475	17.0	midpoint	15	2	2 of 2
105	3.7	downstream	15	2	2 of 2
205	7.4	downstream	15	4	2 of 4
310	11.0	downstream	-	-	-
475	17.0	downstream	-	-	-

A Horizontal 0.3-m Duct Test Video

- **Fire size: 475 kW**
- **Fire origin: Midpoint between upstream and downstream water mist applications**



Horizontal 0.3-m Duct Tests with an Increased Water Mist Concentration

- Water mist concentration at the downstream fire location: 395 cc/m^3
- Volume-median droplet diameter: 88 µm

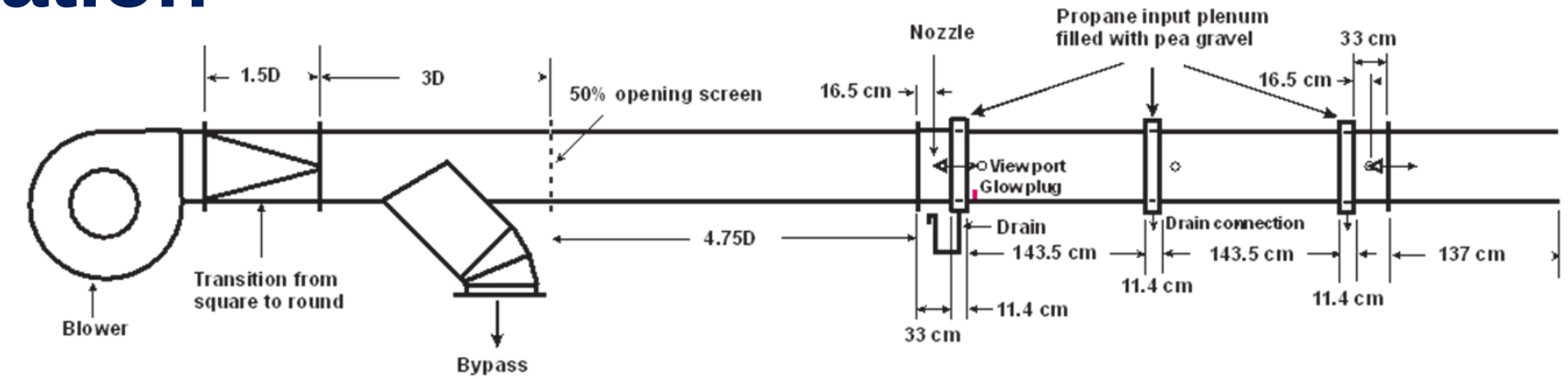
Freeburn Fire Heat Release Rate (kW)	Air Ventilation Rate (m^3/min)	Propane Release Location	Preburn Time (s)	Number of Tests	Fire Extinguished ?
205	7.4	Downstream	15	2	2 of 2
310	11.0	Downstream	15	2	2 of 2
475	17.0	Downstream	15	2	2 of 2

- Tests also showed that, with same protection, fire in the vertical duct could be extinguished similarly as in the horizontal duct.

Duct Wall Temperature – 0.3-m Duct Tests

- **Measurement: Not higher than 200°C.**
- **Protection applicable to ducts made of steel, fiber-reinforced plastic and fiberglass, but not for polypropylene and PVC due to the lower softening temperature.**

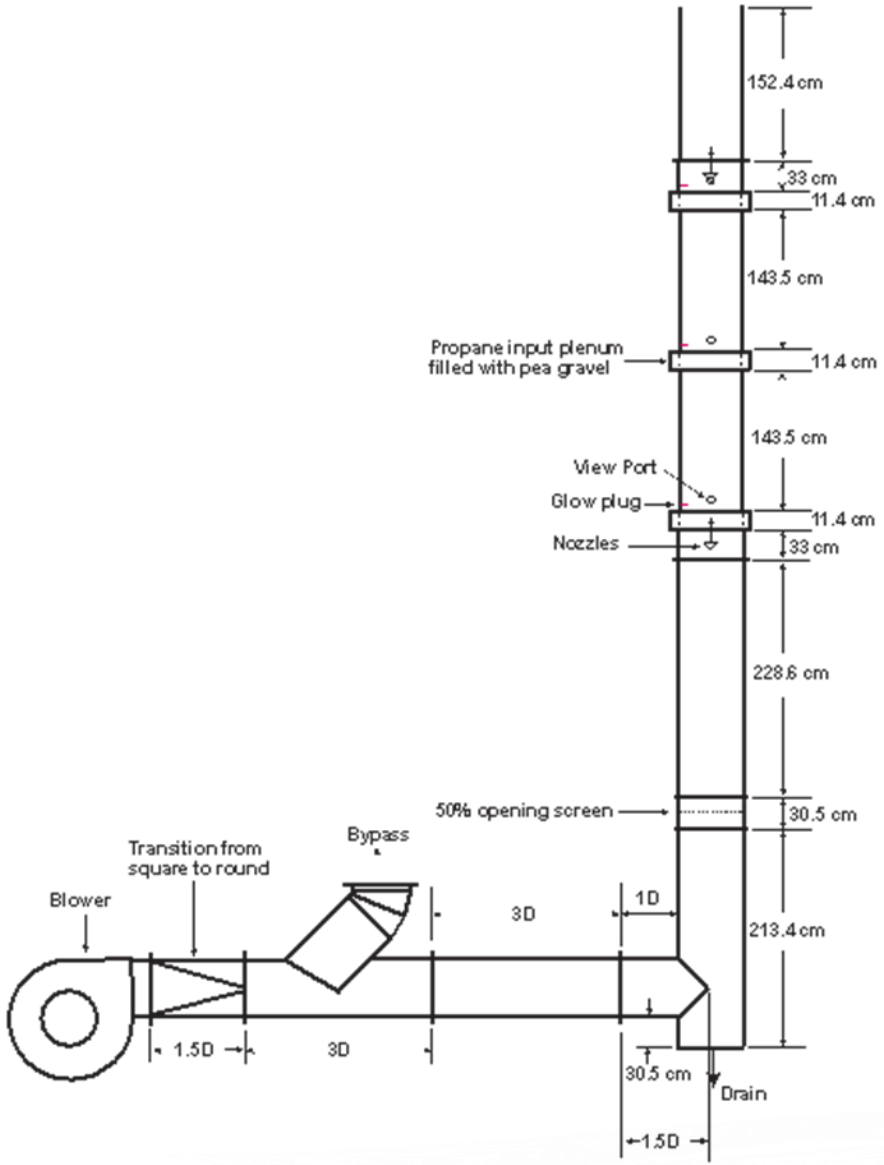
0.61-m Duct Test Facility – Horizontal Orientation

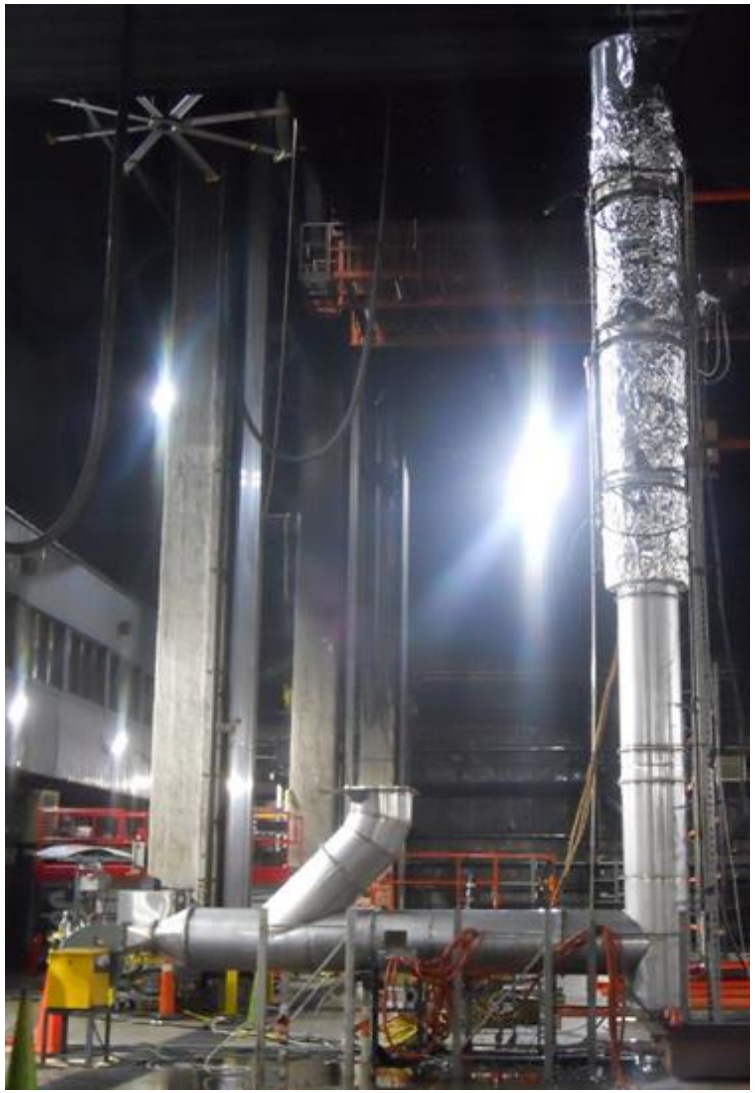


- Stainless steel ductwork
- Blower
- Bypass
- Flow conditioning screen

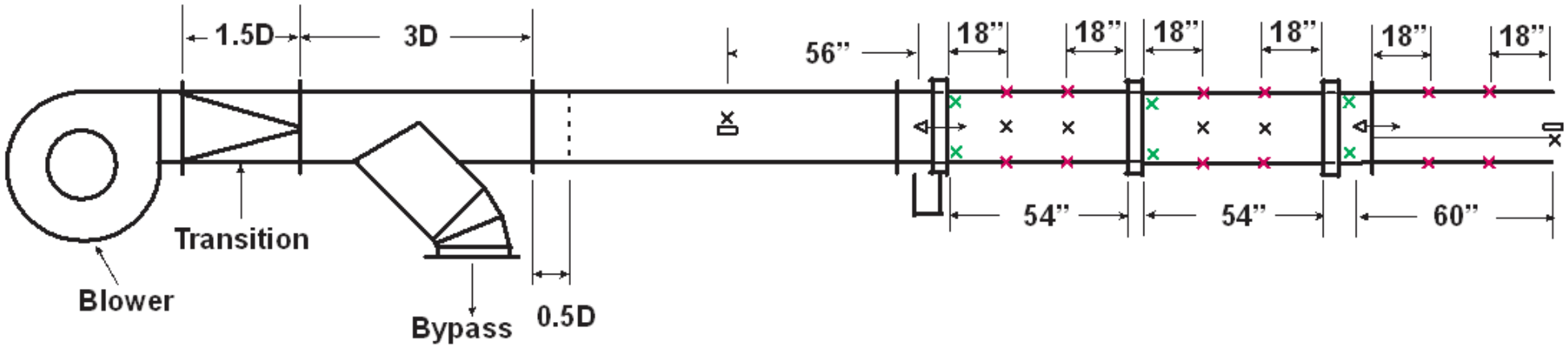
- Two nozzle locations 3.3 m apart
- Three propane-release plenums
- Viewport
- Drain

0.61-m Duct Test Facility – Vertical Orientation





0.61-m Duct Test Facility - Instrumentation



× TC for gas temperature in duct centerline, K-type, 26 gage
× Four TC on the duct outer surface at each location (90° apart at top, bottom, left, right)
× Four TC 2" downstream of each plenum, 2" away from duct wall (90° apart at top, bottom, left, right)
▭ Bidirectional probes in duct centerline

- Duct wall temperature
- Gas temperature
- Gas velocities before test section and at duct opening
- Propane release rate
- Nozzle operating pressure
- Total water mist discharge rate

Test Conditions and Results – Horizontal 0.61-m Duct

- Water mist concentration at midpoint between the upstream and downstream application locations: 422 cc/m^3
- Volume-median droplet diameter: 115 μm

Free-Burn Fire Heat Release Rate (kW)	Air Ventilation Rate (m^3/min)	Propane Release Location	Preburn Time (s)	Number of Tests	Fire Extinguished ?
410	14.7	upstream	15, 30	2	2 of 2
820	29.4	upstream	15, 30	2	2 of 2
410	14.7	midpoint	15, 30	2	2 of 2
820	29.4	midpoint	15, 30	2	2 of 2
410	14.7	downstream	15, 30	2	2 of 2
820	29.4	downstream	15, 30	2	2 of 2

- Similar test results were obtained for fire situated in the vertical duct.

Duct Wall Temperature – 0.61-m duct Tests

- 15-s preburn: Peak temperature not higher than 195ºC
- 30-s preburn: Peak temperature up to 320ºC

To protect FRP and fiberglass ducts, a preburn time not longer than 15 s is recommended.

Conclusions

- Water mist is capable of extinguishing exhaust duct fires with a water mist concentration of 300 cc/m^3 or higher.
- Besides steel ducts, water mist protection is applicable to combustible ducts made of FRP and fiberglass.
- A preburn time not longer than 15 s is recommended for the protection of FRP and fiberglass ducts.

Thank you!

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