



# 27<sup>th</sup> International Railway Safety Council

## Use of Fire Suppression System in Underground Stations and Metro Tunnels

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2. Underground Station Public Area
  - Current Practice
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  - Current Practice
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4. Conclusion





# 1. Introduction

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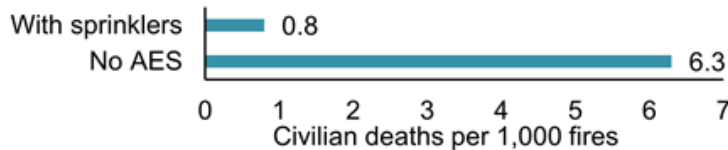
# Fire Suppression System in Building

- Fire Hydrant
- Hose Reel
- Water Based FFFS
  - Sprinkler
  - Water Mist



- “US Experience with Sprinkler”
  - 87% lower** death rate
  - 30% less** dollar loss

Civilian death rates per 1,000 fires in properties with sprinklers and with no AES (Automatic Extinguishing System)



Source of reference: Ahrens, M. (2017, July). U.S. Experience with Sprinklers

# Fire Risk in Station Public Area

	Commercial Building (e.g. Shopping Mall)	Station Public Area <sup>(1)</sup> (e.g. Concourse/Platform)
People Density & Characteristic	<ul style="list-style-type: none"> <li>Can be high during holiday or special events (e.g. Chinese New Year)</li> </ul>	<ul style="list-style-type: none"> <li>Can be high during morning / evening peak hours or special events (e.g. Chinese New Year)</li> <li><b>High passenger density</b></li> </ul>
Likely Cause of Fire	<ul style="list-style-type: none"> <li>Shop fire</li> <li>Rubbish bin fire</li> </ul>	<ul style="list-style-type: none"> <li>Baggage fire</li> <li>Rubbish bin fire <sup>(2)</sup></li> </ul>
Fire Heat Release Rate	<ul style="list-style-type: none"> <li>Shopping mall (<b>5MW</b>)</li> <li>Atrium (<b>7MW</b>)</li> </ul>	<ul style="list-style-type: none"> <li>Baggage (not more than <b>2MW</b>)</li> </ul>
Overall Fire Risk	<ul style="list-style-type: none"> <li><b>Higher</b>, no control for goods in the building</li> </ul>	<ul style="list-style-type: none"> <li><b>Lower</b>, as stricter requirement on building material and goods in the area</li> </ul>
Impact to General Public	<ul style="list-style-type: none"> <li><b>Minor</b>, building closed</li> </ul>	<ul style="list-style-type: none"> <li><b>Huge</b>, interruption or suspension of metro services</li> </ul>

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## Notes:

(1) Station commercial/concession area is excluded.

(2) There are no rubbish bins in public area in Singapore metro station.





# Fire Risk in Tunnels

	Road Tunnel	Metro Tunnel
People Density & Characteristic	<ul style="list-style-type: none"> <li>• <b>Little control</b> of the combustible inventory (vehicle and its contents)</li> <li>• For 1km, 2 lanes, all passenger cars, 5 persons per car → 1,600 people</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Better control</b> of the combustible contents (rolling stock furniture, occupants, luggage)</li> <li>• 2,000~3,000 people per train</li> </ul>
Likely Cause of Fire	<ul style="list-style-type: none"> <li>• Cable</li> <li>• Vehicle</li> </ul>	<ul style="list-style-type: none"> <li>• Cable</li> <li>• Train</li> </ul>
Fire Heat Release Rate	<ul style="list-style-type: none"> <li>• Overall combustibility can be <b>very high</b> (5~300MW)</li> </ul>	<ul style="list-style-type: none"> <li>• Overall combustibility is <b>low</b> (e.g. 5~20MW)</li> </ul>
Overall Fisk Risk	<ul style="list-style-type: none"> <li>• <b>Higher chance</b> of fire (based on previous experience)</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Lower chance</b> of fire</li> </ul>
Impact to General Public	<ul style="list-style-type: none"> <li>• Tunnel closed</li> </ul>	<ul style="list-style-type: none"> <li>• Relevant tunnel closed</li> <li>• Service interruption for at least a few stations</li> </ul>
Remark		<ul style="list-style-type: none"> <li>• Avoid collision effectively</li> <li>• High level of control of traffic</li> </ul>



# 2. Underground Station Public Area

## Current Practice

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# Current Practice in Station Public Area



	Hong Kong	Singapore	Mainland China			Dubai	Toronto	NFPA 130
			Beijing	Shanghai	Hangzhou			
<b>Station Public Area</b>	<ul style="list-style-type: none"> <li>• HR</li> <li>• FH</li> <li>• SP (New station)</li> </ul>	<ul style="list-style-type: none"> <li>• HR</li> <li>• FH</li> </ul>	<ul style="list-style-type: none"> <li>• HR</li> <li>• FH</li> </ul>	<ul style="list-style-type: none"> <li>• HR</li> <li>• FH</li> <li>• SP <sup>(1)</sup></li> </ul>	<ul style="list-style-type: none"> <li>• HR</li> <li>• FH</li> <li>• SP</li> </ul>	<ul style="list-style-type: none"> <li>• HR</li> <li>• FH</li> <li>• SP</li> </ul>	<ul style="list-style-type: none"> <li>• HR</li> <li>• FH</li> </ul>	<ul style="list-style-type: none"> <li>• HR</li> <li>• FH</li> </ul>
<b>Tunnel</b>	<ul style="list-style-type: none"> <li>• FH</li> </ul>	<ul style="list-style-type: none"> <li>• FH</li> </ul>	<ul style="list-style-type: none"> <li>• FH</li> </ul>	<ul style="list-style-type: none"> <li>• FH</li> </ul>	<ul style="list-style-type: none"> <li>• FH</li> </ul>	<ul style="list-style-type: none"> <li>• FH</li> </ul>	<ul style="list-style-type: none"> <li>• FH</li> </ul>	<ul style="list-style-type: none"> <li>• FH</li> </ul>

Abbreviations:

FH – Fire Hydrant, HR – Hose Reel, SP – Sprinkler

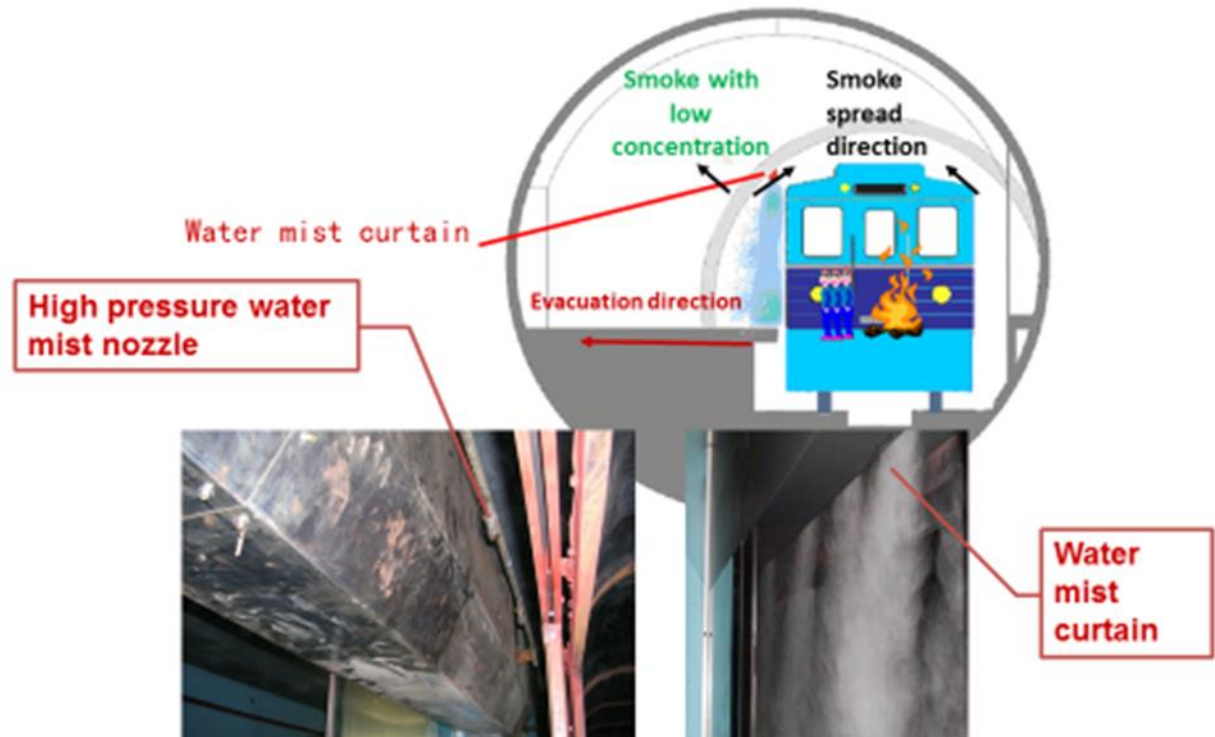
Note:

1. **Water mist system** is installed instead of sprinkler system in station public area and station trackway for stations in Shanghai metro line 11 phase 1.



# Water Mist (Station Trackway)

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# Water Mist (Station Trackway)

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Before activation



After activation



# 2. Underground Station Public Area

Use of Water Based FFFS

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# Concerns related to Water Based FFFS

Visibility

Steam

Slippery  
Evacuation  
Path

False  
Activation

Cost  
Effectiveness

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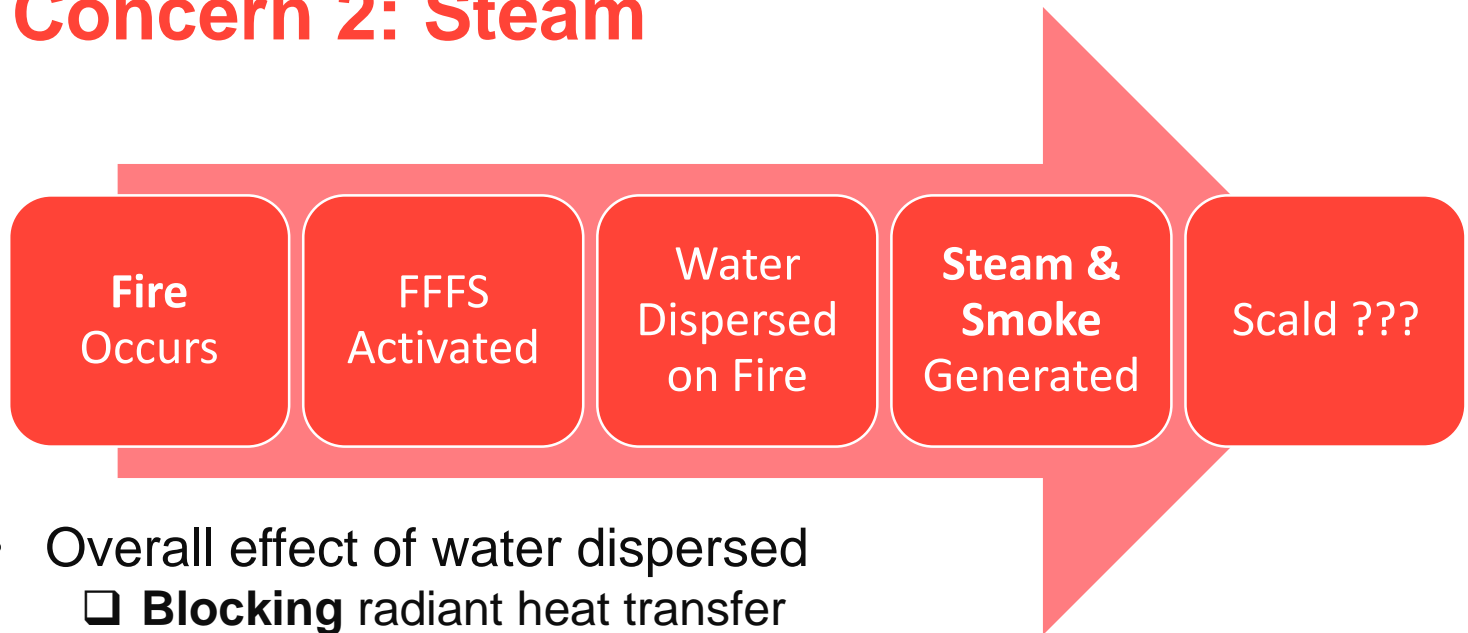
# Concern 1: Visibility



- Close to fire: Visibility reduced
- Away from fire: Remain clear
- Visibility reduced → Difficulties in:
  - Monitoring **fire scene**
  - Identification of **immobile passengers**
  - Identification of **fire source** and **access path**
- Further studies:
  - Impact to **visibility**
  - Associated **human behaviour** under a **congested situation**

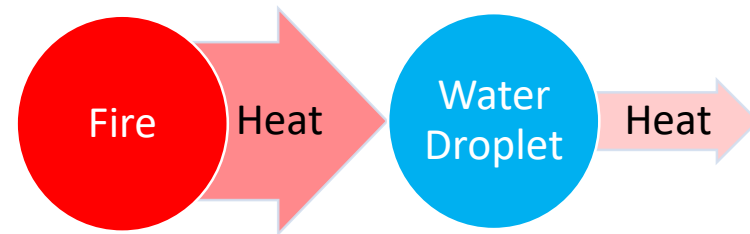


## Concern 2: Steam



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- Overall effect of water dispersed
  - ❑ **Blocking** radiant heat transfer
  - ❑ **Cool down** the fire site
- Warm steam at evacuation path
  - ❑ **Difficulties** in breathing
  - ❑ **Slow** the evacuation process



- Further studies:
  - ❑ **Impact** to evacuation under a very congested situation

## Concern 3: Slippery Evacuation Path

- Floor wetted by water → Slippery
  - ❑ Increase risk of injury
- Proper selection of floor finishes and handrail finishes
  - ❑ Partially mitigated

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Source of reference: [news.sina.com.cn](http://news.sina.com.cn)  
(24<sup>th</sup> June 2011)

# Concern 4: System Fault

- Equipment damage
  - ❑ Quality of equipment
  - ❑ Wear and tear
  - ❑ Inappropriate maintenance
- Affect station operation

## Hong Kong



Source of reference: Hong Kong Apple Daily (19<sup>th</sup> Feb 2017)

## Shanghai

### Metro station flooded by broken fire sprinkler

By Wang Yu | January 29, 2013, Tuesday | ONLINE EDITION



THE Xiaonanmen Station of Metro Line 9 in downtown Huangpu District was flooded this morning, causing all escalators out of service, Xinmin.cn reported.

An overhead fire sprinkler in the station broke at 6:47am, spraying water all over the place. Passengers had to walk the steps carefully. No one was injured.

Metro workers closed the fire pump and turned off the escalators as a precaution. They also put out warning signs to remind people of slippery surface.

Repairmen have arrived to fix the broken sprinkler, the report said.

Source of reference: Shanghai Daily (29<sup>th</sup> Jan 2013)

## Hangzhou



Source of reference: [www.news.cn](http://www.news.cn) (1<sup>st</sup> Dec 2012)



## Concern 5: Cost Effectiveness

- Risk of fire: low
  - Well controlled environment



# Sprinkler System VS Water Mist System

	Sprinkler System	Water Mist System
Working Pressure	<ul style="list-style-type: none"><li>• 2 MPa</li></ul>	<ul style="list-style-type: none"><li>• &lt; 3.5 MPa</li></ul>
Size of Water Droplet	<ul style="list-style-type: none"><li>• 700 – 800 microns</li></ul>	<ul style="list-style-type: none"><li>• 30 – 100 microns</li></ul>



Source of reference: Wikipedia



Source of reference: Global Photos.org



# Sprinkler System VS Water Mist System (Continued)

	Sprinkler System	Water Mist System
<b>Major Fire Fighting Mechanism</b>	<ul style="list-style-type: none"> <li>Wetting the fuel surface</li> </ul>	<ul style="list-style-type: none"> <li>Heat absorption</li> <li>Blocking fuel from oxygen</li> </ul>
<b>Water Flow Rate</b>	<ul style="list-style-type: none"> <li>Higher (3-5 times of Water Mist System)</li> </ul>	<ul style="list-style-type: none"> <li>Lower</li> </ul>
<b>Installation Cost</b>	<ul style="list-style-type: none"> <li>Lower</li> </ul>	<ul style="list-style-type: none"> <li>Higher</li> </ul>
<b>Operation and Maintenance Cost</b>	<ul style="list-style-type: none"> <li>Lower</li> </ul>	<ul style="list-style-type: none"> <li>Higher</li> </ul>
<b>Impact to Operation when Falsely Activated</b>	<ul style="list-style-type: none"> <li>Only area near faulty head affected</li> </ul>	<ul style="list-style-type: none"> <li>Only area near faulty head affected</li> </ul>
<b>Tank Size</b>	<ul style="list-style-type: none"> <li>Larger</li> </ul>	<ul style="list-style-type: none"> <li>Smaller</li> </ul>



# 3. Metro Tunnels

## Current Practice

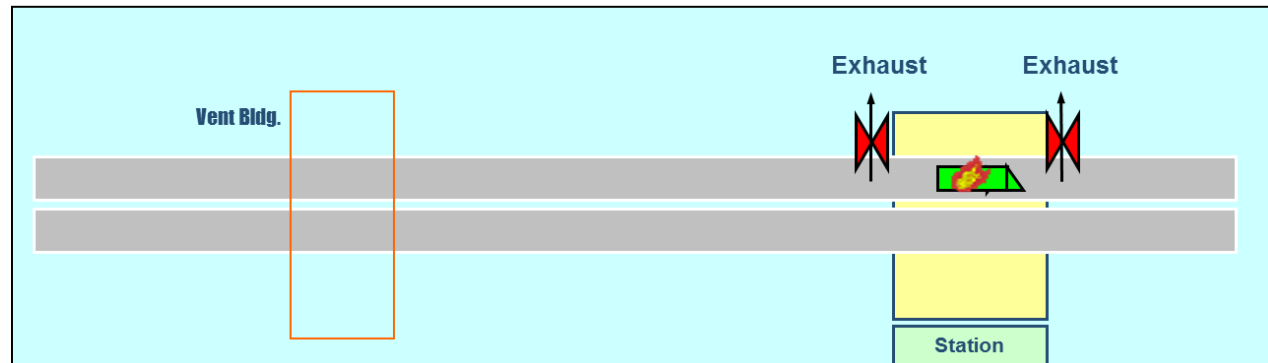
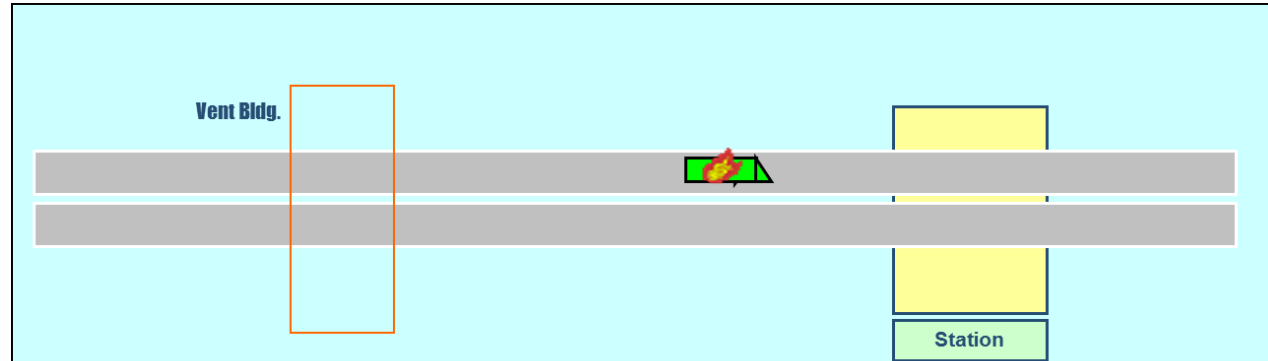
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Source of reference: [sh.people.com.cn](http://sh.people.com.cn)  
(20<sup>th</sup> Sep 2009)

# Current Provision

- “Drive Through Concept”



# Current Provision

- Fire Services Provision in Metro System

	Train	Tunnel
Fire Detection	<ul style="list-style-type: none"> <li>• Smoke Detector</li> <li>• CCTV</li> </ul>	<ul style="list-style-type: none"> <li>• Aspirating Smoke Detector</li> <li>• Linear Heat Detector</li> </ul>
Warning	<ul style="list-style-type: none"> <li>• Train communication systems such as break glass, intercom phone, and public address system</li> </ul>	
Manual Fire Suppression	<ul style="list-style-type: none"> <li>• Potable Fire Extinguishers</li> </ul>	<ul style="list-style-type: none"> <li>• Fire Hydrant</li> </ul>
Smoke Control	<ul style="list-style-type: none"> <li>• Close the intake of the train air-conditioning unit</li> </ul>	<ul style="list-style-type: none"> <li>• Tunnel Ventilation System</li> </ul>
Egress Path	<ul style="list-style-type: none"> <li>• Side Door</li> <li>• Detrainment Device at Front / Rear Car (optional)</li> </ul>	<ul style="list-style-type: none"> <li>• Cross Passage between tunnels</li> <li>• Escape Staircases</li> </ul>
Fireman Access		<ul style="list-style-type: none"> <li>• Fireman Staircases</li> <li>• Special Vehicle (long tunnel)</li> </ul>

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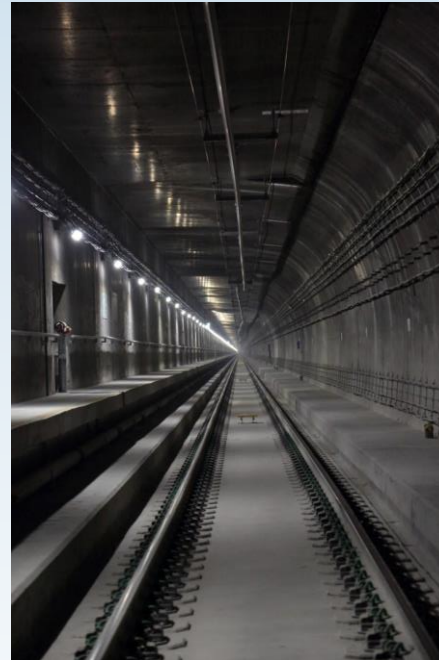




# 3. Metro Tunnels

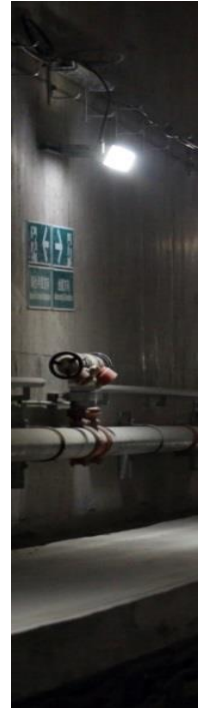
## Use of Water Based FFFS

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# Use of Water Based FFFS

- Road Tunnels
  - Fire Hydrant
  - Hose Reel
  - Other Water Based FFFS provision varies
    - Deluge System
    - Drencher System
    - ....
  
- Current practices (Metro Tunnels)
  - Only Fire Hydrant



	Hong Kong	Singapore	Mainland China	NFPA
Road Tunnel	20 – 100 MW	100 – 300 MW	20 – 100 MW	5 – 300 MW
Metro Tunnel	5 – 22 MW	10 – 15.2 MW	5 – 10.5 MW	Full Scale Test: 13 – 52.5 MW





# Purpose of Water Based FFFS in Metro Tunnels

- Assisting in fire department intervention
- Protect the asset in tunnels, especially tunnel structure
- Protect the fireman

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# Purpose of Water Based FFFS in Metro Tunnels

- Water Based FFFS in Road Tunnels
  - Early suppression
  - Retard fire growth rate
  - Remove heat from environment
  - Limit the fire spread
  - Extend the available escape time
  - Lower the possible damage
- How about Metro Tunnels?





# Concerns related to Water Based FFFS

Shielded Fire

Steam

Maintenance  
Cost and  
Access

Tunnel  
Ventilation  
System

Electrocution  
and Short  
Circuit

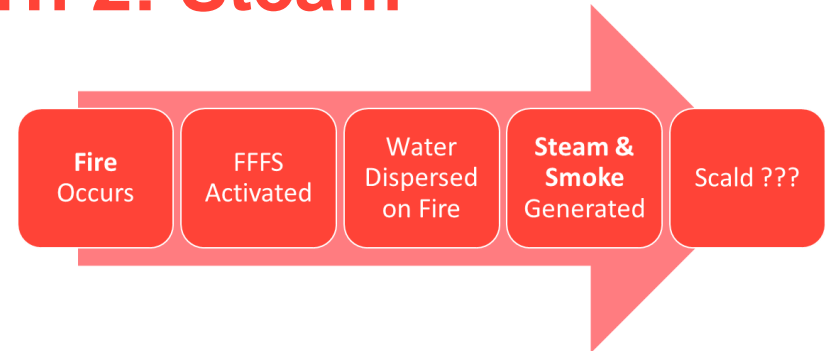
False  
Activation



# Concern 1: Shielded Fire

- Fire within or under a Train
  - Water cannot reach the fire
- Water Based FFFS
  - Prevent **Fire Spread**
  - Lower **Heat Release Rate**
  - Lower **Tunnel Ceiling Temperature**
  - Not able to **Extinguish the Fire**

## Concern 2: Steam



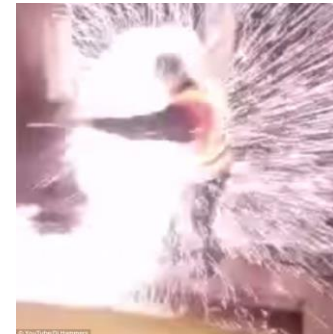
- Tunnel fire has higher fire heat release rate than station fire
- **Road Tunnels**
  - ❑ Experiments prove that Water Mist System
    - Reduce **Heat Flux**
    - Reduce **Tunnel Air Temperature**
  - ❑ Sprinkler System would have similar effect
- **Metro Tunnels**
  - ❑ Small Cross Section Area (~25 m<sup>2</sup>)
    - **May not able to cool down the hot steam quickly**
  - ❑ Further research and development (R&D)

## Concern 3: Maintenance Cost and Access

- Water based FFFS installed at high level (Tunnel height: ~5m)
  - Access to high level**
  - Work at height**
  - Avoid damage to overhead line during maintenance**
- Difficult to detect water leakage in metro operation
- Off Power: Avoid electrocution

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### Electrocution of Worker in New York Subway



Source of Reference: UK Daily Mail on 05<sup>th</sup> May 2015



## Concern 4: Electrocution

- Power supply for Metro Tunnels
  - ❑ **Overhead Lines near tunnel ceiling**
  - ❑ **Third Rail near rail level**
- Water → Electrified environment
- May need power isolation BEFORE activation of water based FFFS
- Long Response Time → Effectiveness of FFFS *reduced*

## Concern 5 Combined Effect with Tunnel Ventilation System (TVS)

- TVS will activate during fire
- Impact to water based FFFS due to TVS
  - Strong wind from TVS**
  - Water dispersion affected**
  - Effectiveness of Water Based FFFS may be reduced**
- Fire heat release rate lowered by water based FFFS
  - Effectiveness of TVS increased**

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## Concern 6: False Activation

- In Road Tunnels
  - Service interruption**
  - Risk of collision**
- In Metro Tunnels
  - Traction power supply system DOWN due to system interlock**
  - Metro service partially/totally terminated**
- Time needed for recovery of traction power supply

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Source of Reference: Singapore The Straits Times (17<sup>th</sup> May 2017)  
<http://www.straitstimes.com/singapore/mce-sprinklers-activated-by-accident-expressway-not-closed>



# 4. Conclusion

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# Underground Stations Public Area

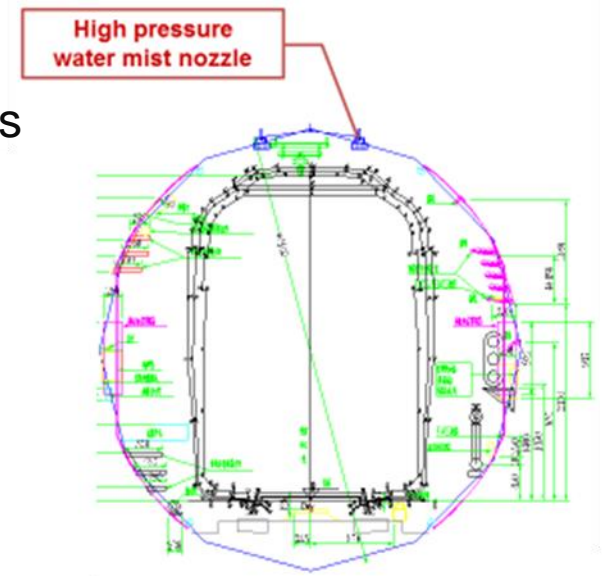
- Current
  - Fire Hydrant + Hose Reel
  - Additional Water Based FFFS
    - **NFPA 130: Not required**
    - **Sprinkler in some cities**
    - **Water Mist?**
  
- Way forward
  - More R&D to address the concerns related to Water Based FFFS
  - Conduct QRA for justification on the use of Water Based FFFS

# Metro Tunnels

- Current
  - ❑ Fire Hydrant
  - ❑ Additional Water Based FFFS
    - **NFPA 130: Not required**
- Way forward
  - ❑ More R&D to address the concerns related to Water Based FFFS



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# Thank you!

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