

Several Points to Watch on Fire Hazards of Railway Systems

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(30 mins total)



Topics Covered

- 1. Introduction**
- 2. Tilted Tunnel Smoke Spread**
- 3. Water-based Fixed Firefighting WFFS for Tunnels**
- 4. Heat Collector Plates for Sprinklers in Tall Halls**
- 5. Battery Fire or Explosion of Phone in Train Car**
- 6. Smoke Extraction: Static Vs Dynamic**
- 7. Bridge Access to Terminals**
- 8. Arson Fires**
- 9. Conclusions**



1. Introduction



W.K. Chow, L. Qu and Edgar C.L. Pang, “Incidents on fire and ventilation provision in subway systems in Hong Kong”, International Journal on Engineering Performance-Based Fire Codes, Vol. 10, No. 3, p.41-47 (2011).

W.K. Chow, “Concerns on fire and ventilation provision in subway system” (2012)
http://www.bse.polyu.edu.hk/researchCentre/Fire_Engineering/Hot_Issues.html

- ★ Fire Safety
 - ★ Ventilation
- } 2 concerns identified before.

Difficulties in firefighting at:

- Deep underground stations
- Long tunnels with longer EEP.



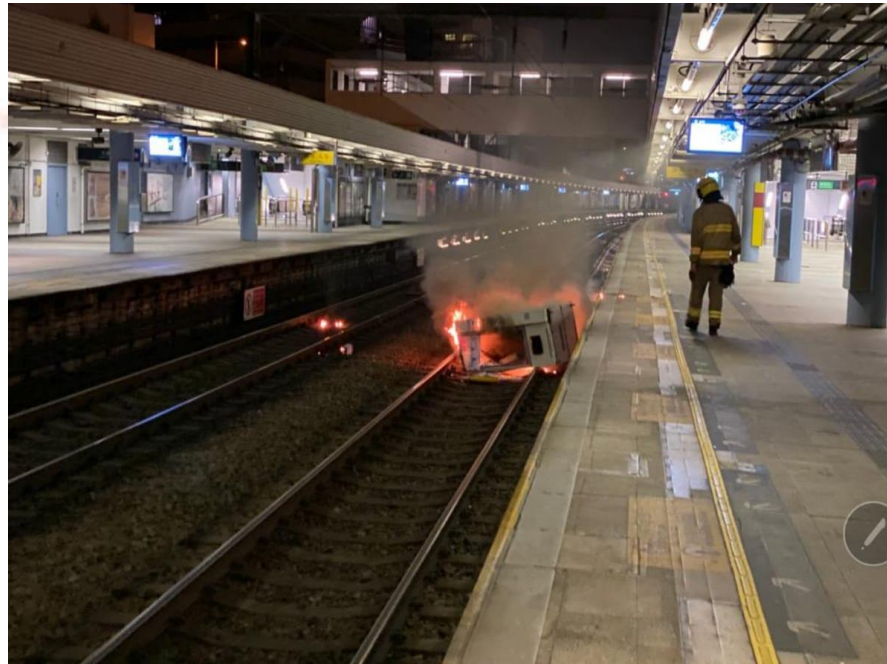
Arson Fires



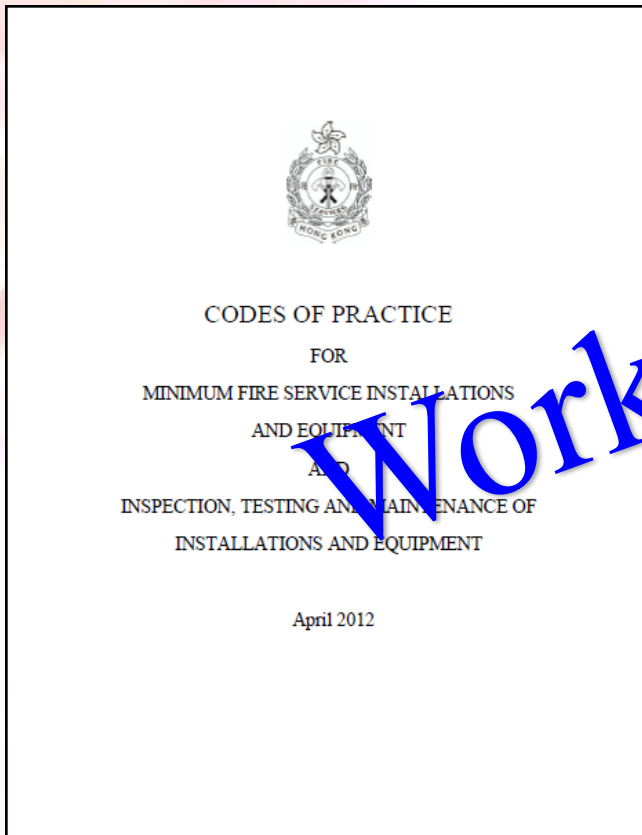
**MTR Train
Compartment
Arson Fire,
January 2004 and
March 2017**



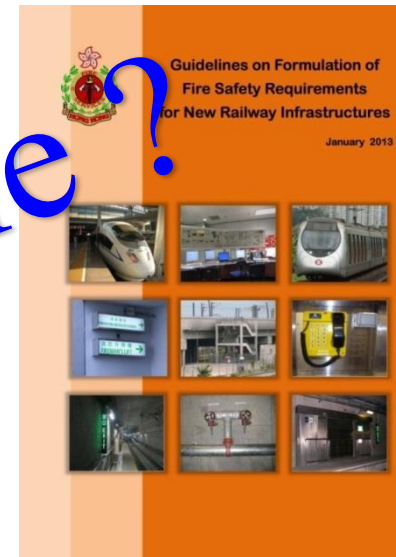
- ★ 2 only in 2004 and 2017.
- ★ Many arson fires since late 2019.



Active



FSI Codes



Guidelines on Formulation of Fire Safety Requirements for New Railway Infrastructures, January 2013



Fire safety problems identified in large public terminals built in the past three decades are:

- ★ Extended travel distance.
- ★ Crowded during peak seasons or after suspension.
- ★ Firefighting and rescue strategy in large terminal halls to work out carefully.



Signal faults: Big Railway Interchange, October 2018



What Happens if there is a fire or explosion?



South China Morning Post, 16 October 2018



Fire Safety Management

- ★ A good fire safety management should be carried out carefully to ensure assumptions made in PBD are met.

Must keep the design fire scenario assessed in FEA report !

- ★ A fire safety plan should be worked out with four parts:

- maintenance plan;
- staff training plan;
- fire action plan; and
- fire prevention plan.

**Very Expensive!
Difficult to Control by
Responsible Officers!**



Fire Risk Factors:



Hong Kong MTR staff spent more than an ho...
scmp.com



Influx of tourists will put MTR trains under st...
scmp.com



13 Bad Habits People Do at the MTR | HK Ex...
expats.hk

October 2018

Heavy passenger loading



Parallel traders
(Oriental Daily, 13 Oct 2012)

High fire load density



Key points: (funded by TBRS 2014-2019)

Tunnel Fire

- Tilted tunnel
- Critical velocity of smoke control
- Water-based fixed firefighting WFFF

Train Car Fire

- Heat release rate of High Speed Rail System train car
- Flame characteristics
- Lithium-ion battery fire of smart phone in train car

Crowded Terminals

- Protecting tall terminals by Heat Collector Plate (HCP) above sprinkler
- Smoke extraction: static Vs dynamic
- Arson fire

Would talk on some topics above

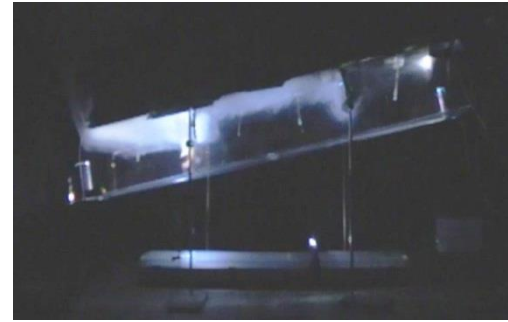


2. Tilted Tunnel Smoke Spread





(a) Stage 1: Blocked by the screen at the fire zone



(b) Stage 2: Moving down along the screen

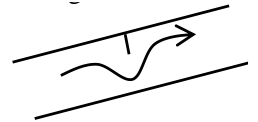


(c) Stage 3: Passing through the screen to the protected zone B



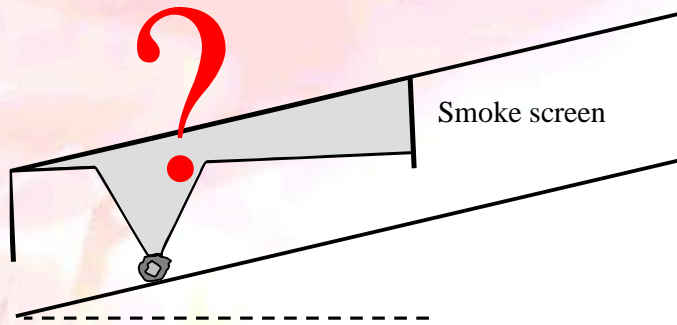
(d) Stage 4 : Spread up to the protected zone B above

Smoke spread up at higher level

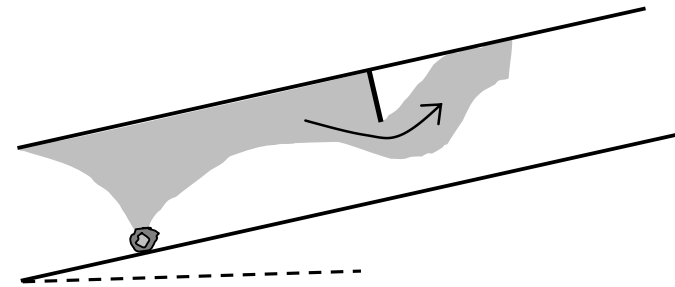


Smoke movements in SM1 tilted at 10° to horizontal with smoke screen

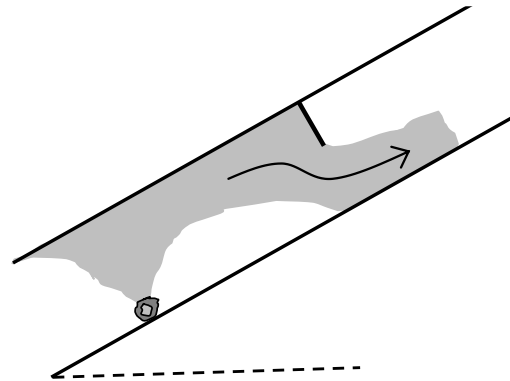




(a) Assumed smoke reservoir in a local project (Ip and Luo 2005)

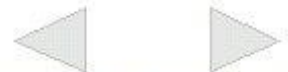


(b) Small angle

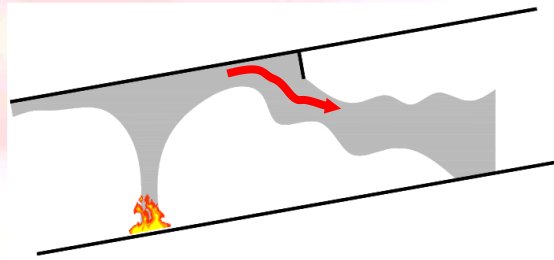


(c) Large angle

Smoke movement

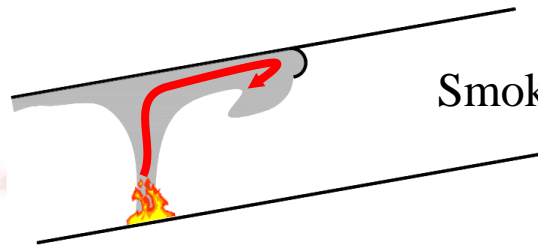


Smoke moves along the barrier surface



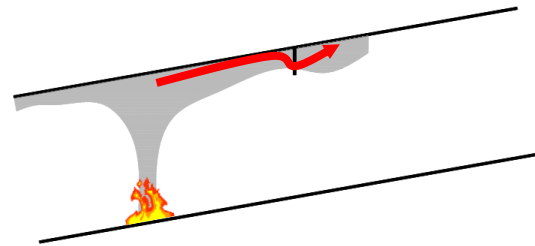
(a) Rectangular smoke barrier

Traditional Smoke Screen !



Smoke recirculates

(b) Modified for recirculation

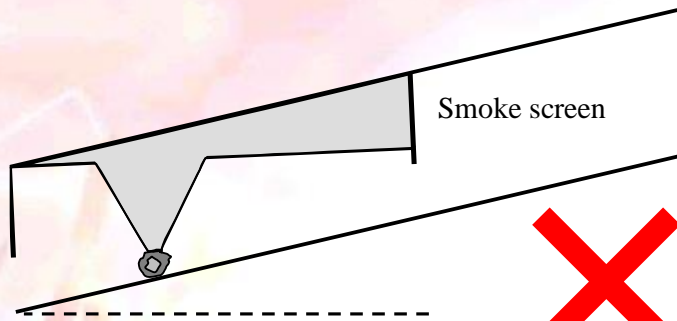


Holes allow smoke to pass through the barrier to avoid falling down

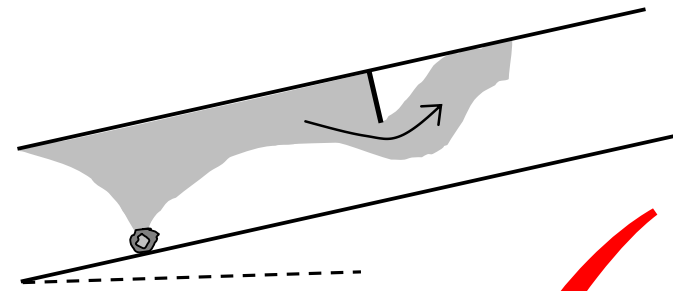
(c) Modified for keeping buoyancy

Smoke barriers in tilted tunnel

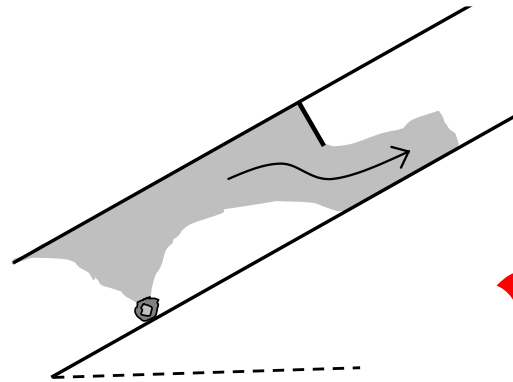




(a) Assumed smoke reservoir in a local project (Ip and Luo 2005)



(b) Small angle



(c) Large angle

Smoke movement



3. Water-based Fixed Firefighting WFFS for Tunnels



★ **With Beijing University of Technology**

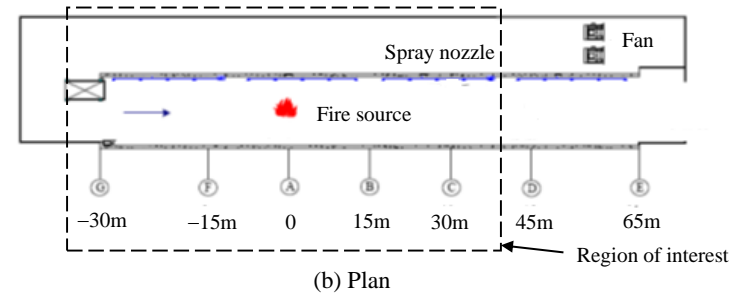
★ **Experiment at Shanghai Tongtai 上海同泰**



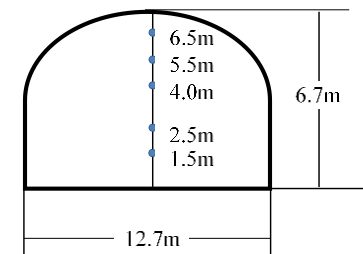
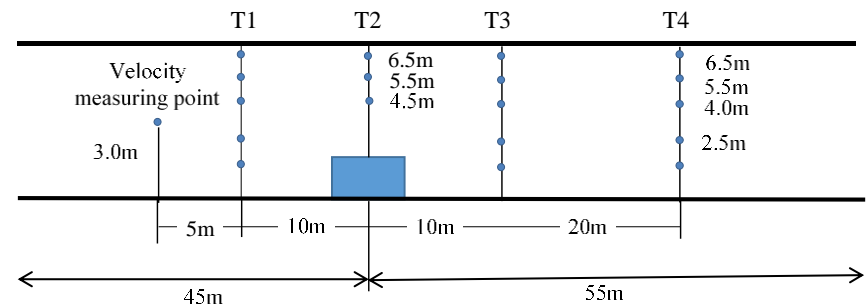
Outside the Tunnel



(a) Inside view



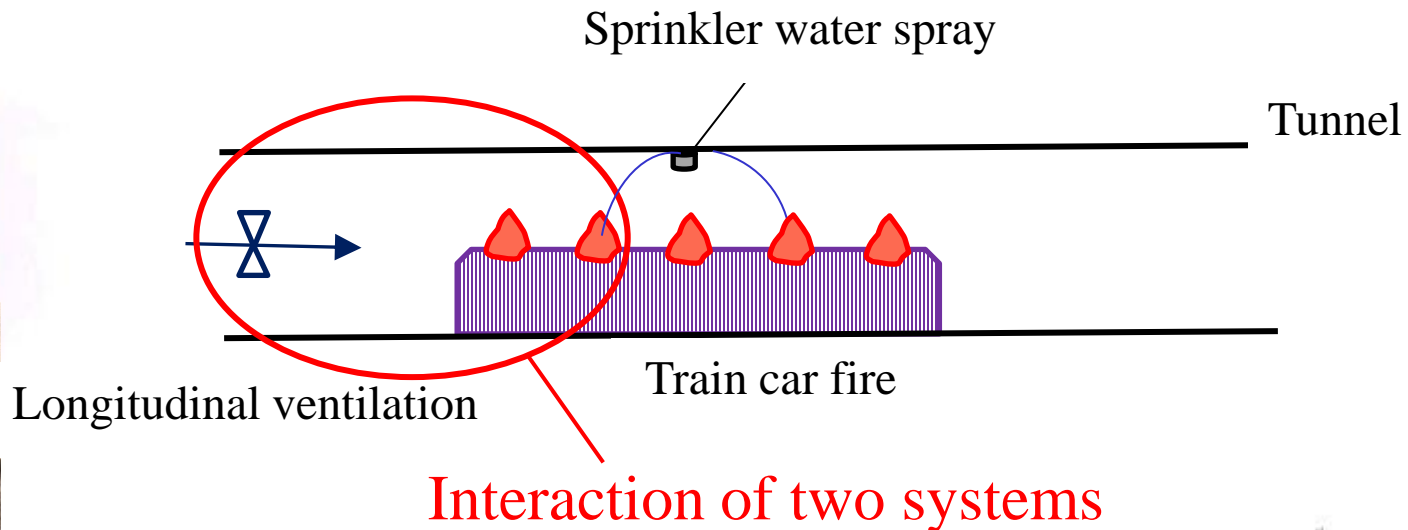
Inside the Tunnel

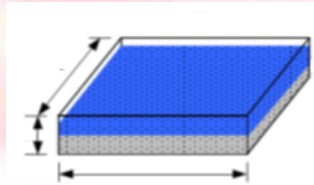


The tunnel for full-scale burning tests



- ★ **Full-scale burning tests on the suppression effects of WFFS and ventilation systems on wood pallet fire and diesel pool fire were carried out in a tunnel burning facility.**
- ★ **Factors affecting the suppression efficiency of WFFS and its interaction with ventilation system.**





1.5m



Diesel fuel pan



Wood pallet

Steel plate →



Simulate burning inside a car

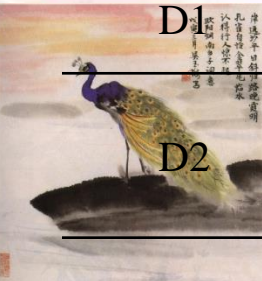
Fire Sources



Testing scenarios

W: Wood D: Diesel

Experiment scenarios	Fire source	Ventilation condition	Activation of the ventilation system	Suppression agent
W1	Wood pallet stack fire	No ventilation	-	Foam-water spray
W2	Wood pallet stack fire	3 m/s	Fan activated after fire ignition	Water spray
W3	Wood pallet stack fire with a top shield plate	3 m/s	Fan activated after fire ignition	Water spray
W4	Wood pallet stack fire with a top shield plate	3 m/s	Fan started 90 s later than the WFFFS	Water spray
D1	Diesel pool fire	No ventilation	-	Foam-water spray
D2	Diesel pool fire	3 m/s	Fan activated after fire ignition	Foam-water spray





(a) WFFF system activated



(b) 60 s after activating WFFF system



(c) 120 s after activating WFFF system



(d) 180 s after activating WFFF system



(e) 240 s after activating WFFF system



(f) 300 s after activating WFFF system



Fire suppression events in Scenario W1





(a) Flame blown to the downwind side



(b) WFFF system activated



(c) 60 s after activating WFFF system



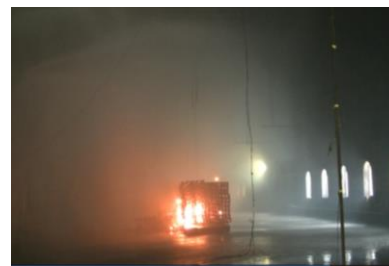
(d) 120 s after activating WFFF system



(e) 180 s after activating WFFF system



(f) 240 s after activating WFFF system



(g) 300 s after activating WFFF system



Fire suppression events in Scenario W2





(a) Wood pallet burning with the top shield



(b) WFFF system activated



(c) 60 s after activating WFFF system



(d) 120 s after activating WFFF system



(e) 180 s after activating WFFF system



(f) 240 s after activating WFFF system



Fire suppression events in Scenario W3





(a) WFFF system activated



(b) 60 s after activating WFFF system



(c) Ventilation system activated at 90 s



(d) 120 s after activating WFFF system



(e) 240 s after activating WFFF system



(f) 300 s after activating WFFF system



Fire suppression events in Scenario W4





(a) Smoke layer formed



(b) WFFF system activated



(c) 8 s after activating WFFF system



(d) Fire extinguished at 10 s after activating WFFF system



Fire suppression process in Scenario D1





(a) Smoke backlayering prevented



(b) Flame blown downward



(c) WFFF system activated



(d) Fire extinguished at 10 s after activating WFFF system



Fire suppression process in Scenario D2



- ★ **Activating the water spray zone would have better control on the fire upon operating the longitudinal ventilation system.**
- ★ **For fire occurring inside vehicles, the extinguishing effect of the WFFS would be affected, and more time is needed to control the fire under this condition.**
- ★ **Foam-water spray system appears to be more efficient in suppressing liquid fires.**



- ★ **Stability of the smoke layer in the tunnel might be affected or even destroyed after discharging water spray.**
- ★ **Longitudinal ventilation operating with a higher critical air speed can improve the visibility in tunnel.**
- ★ **Ventilation system should be operated earlier than the WFFS when a fire occurs in the tunnel for better fire control.**



4. Heat Collector Plates for Sprinklers in Tall Halls





(a) In platform



HCP



Taiwan HSRS station

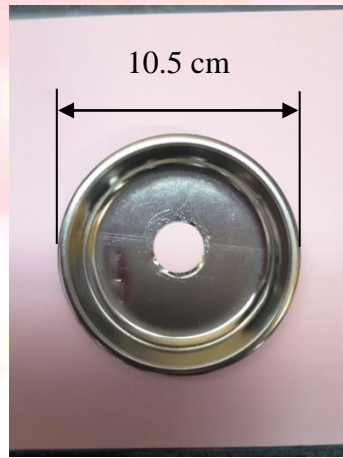


(b) In station hall



HCP





Top

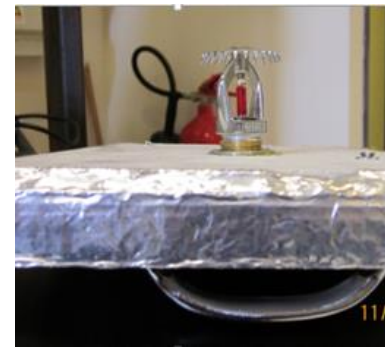


Bottom

The HCP



With sprinkler head

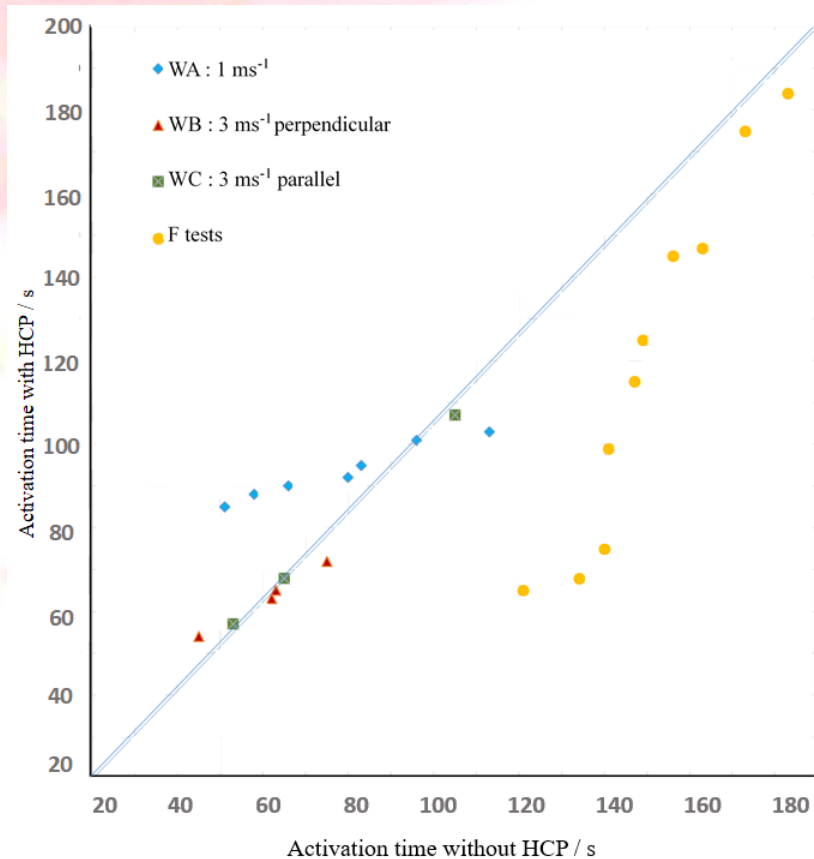


In wind tunnel



Heat collector plate





Sprinkler activation times with and without HCP

S.L. Lin, W.K. Chow, Y.K. Woo, D.F. Szeto, Chung HweiSu, “Effect of heat collector plate on thermal sensitivity of sprinkler heads in large terminal Halls”, *Journal of Building Engineering*, Vol. 25, September 2019. Appeared online first 26 April 2019.



5. Battery Fire or Explosion of Phone in Train Car





Samsung Galaxy S4



Sony Z3+

Jessie H.Y. Kwok, C.H. Cheng and W.K. Chow “An experimental study on possible thermal hazards of cellular phones” Third International Fire Safety Symposium (IFireSS 2019), 5-7 June 2019, Ottawa, Ontario, Canada.



- ★ **The thermal hazards of cellular phones leading to fire and explosion should be watched carefully.**
- ★ **The consequences could be very hazardous if explosion occurs in a crowded space like the train car.**
- ★ **The passenger loading could be very high and each person might carry more than one cellular phone while travelling in high-speed railway system across cities.**
- ★ **Having phone explosion accident as experienced in 2013 in an empty train would give very different consequences.**



Explosion of battery at Airport Express 17 January 2015



Sing Tao Daily, “山寨充電器機鐵車廂內爆炸”, 18 January 2015



★ **Using 2 phones with fire and explosion reported before:**

- **Samsung Galaxy S4**

- **Sony Z3+**

(Names hidden in paper)

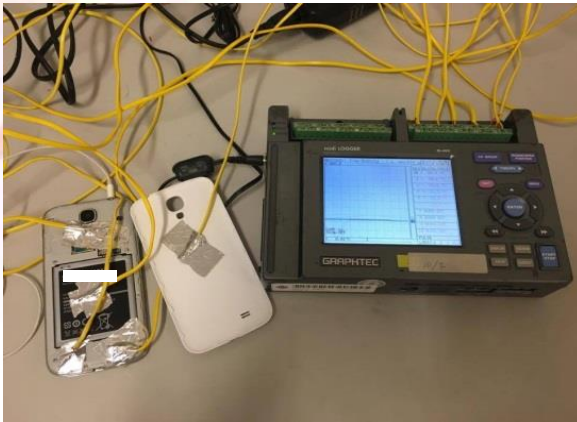
★ **Experiment 1 on thermal hazards of the two phone samples**

- **Part I: Not Charging**

- **Part II: Charging**

★ **Experiment 2 on limiting heat dissipation by thermal insulation**





(a) Outlook



(b) Thermocouples at different components

Experiment 1 for Phone A





(a) Experimental setup



(b) Cover removed to see thermocouples at different components

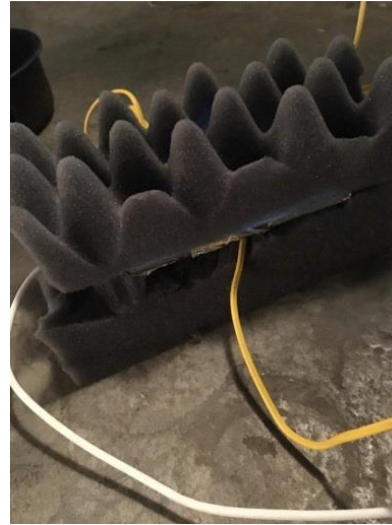


Experiment 1 for Phone B





(a) Experiment setup



(b) Thermal insulation materials

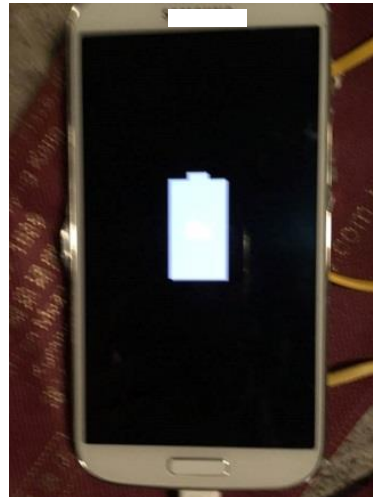


Experiment 2 for Phone A





(b) Warning signal 1



(c) Warning signal 2



(d) Back of phone

Results for Phone A in Experiment 2



- ★ **The above experiment shows that using cellular phone while charging it, the phone can be heated up to high temperatures.**
- ★ **When the temperature of the battery exceeds the limit, the internal protection device would be activated to provide safety precautions.**
- ★ **The tested cellular phones should be safe if one is not using non-genuine batteries, or the battery protection can cut off the current when heated up to a high temperature.**

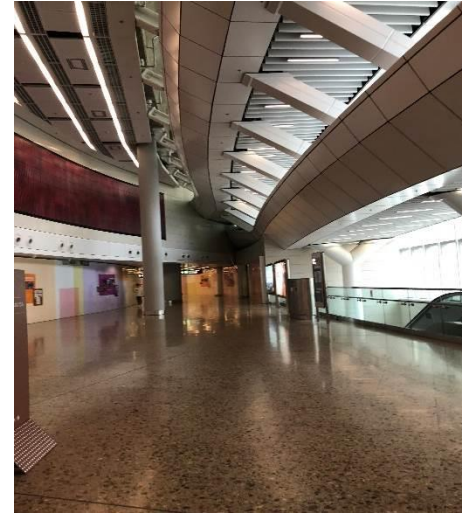


- ★ Nevertheless, the use of non-genuine batteries is quite common, and thermal hazards, even when not involving explosion, could be dangerous when it occurs in a crowded enclosure like the train.
- ★ This could trigger panic among the passengers, and over-reactions could be much more dangerous than the thermal hazard itself.



6. Smoke Extraction: Static Vs Dynamic

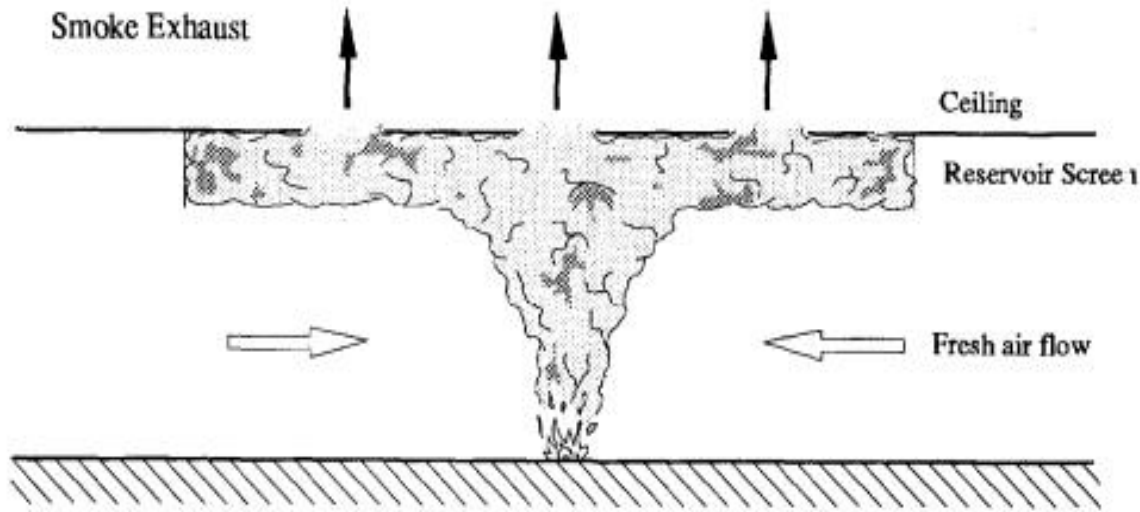




W. Peng, Q. Wang and W.K. Chow “Numerical simulation on atrium smoke extraction system”, Under preparation (2019).



Static: Buoyancy
Dynamic: Fan flow rate



- ★ **Static Smoke Extraction: Big fire**
- ★ **Dynamic Smoke Extraction: Small fire**



Case Study: High speed railway station, such as Hong Kong West Kowloon Station.

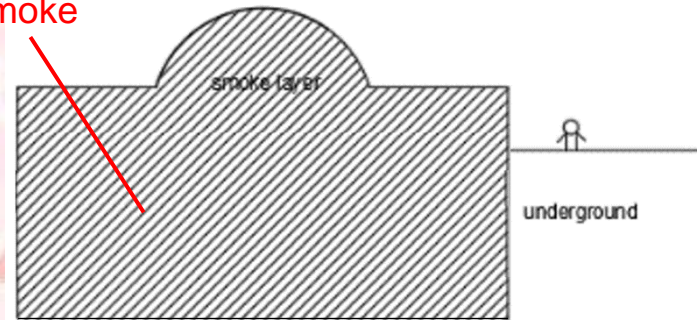


High-speed railway station

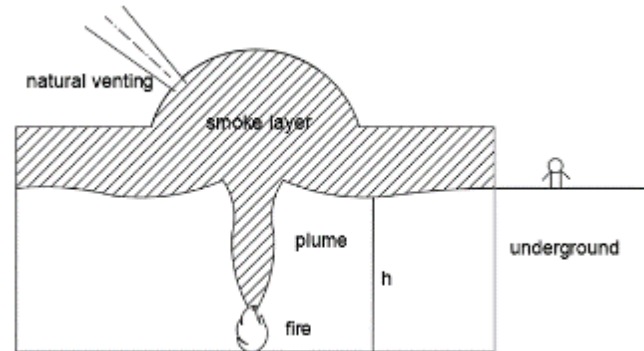


Case 1 -- No Smoke Exhaust System

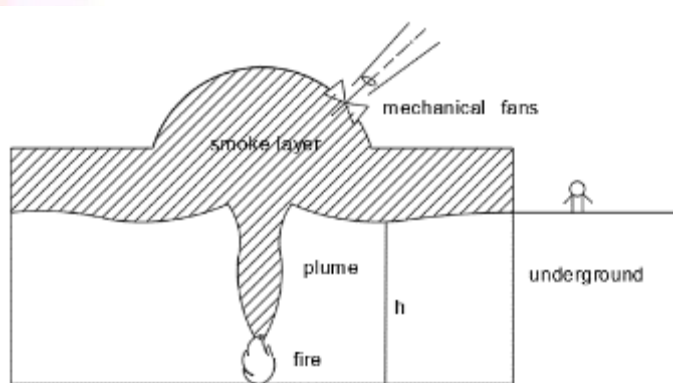
Full of smoke



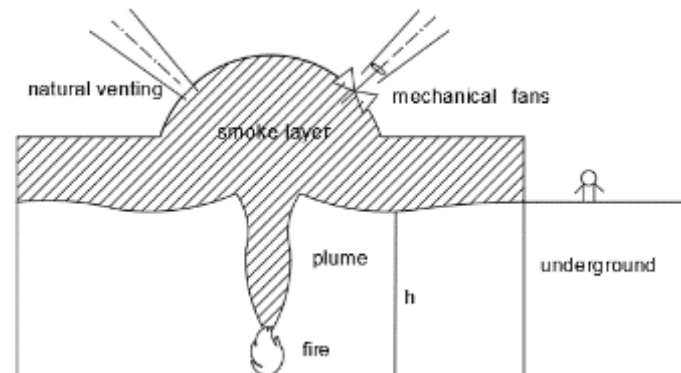
Case 2 -- Static smoke extract system

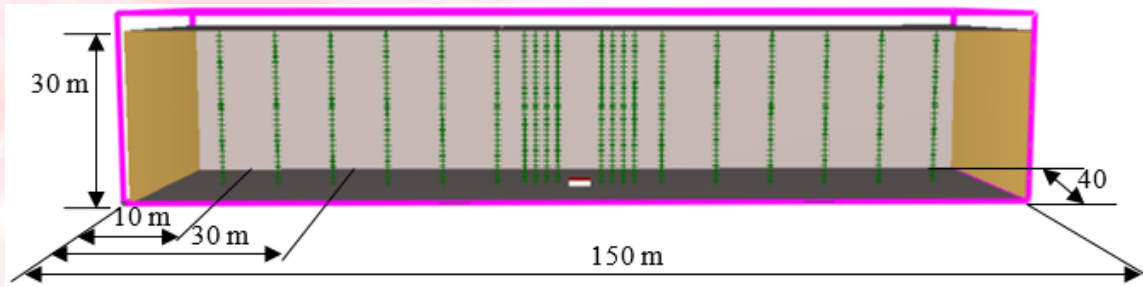


Case 3 -- Dynamic smoke extract system

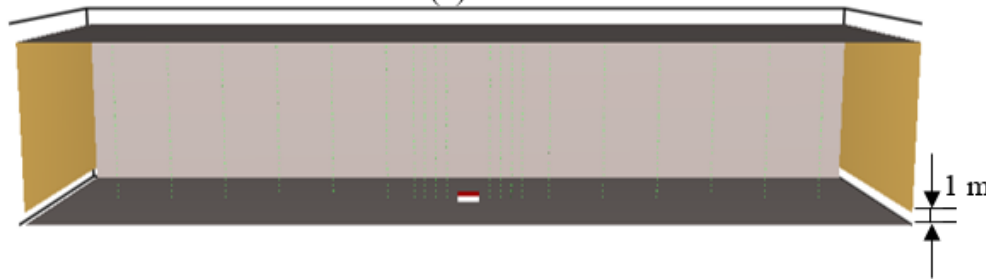


Case 4 -- Hybrid





(a) The atrium

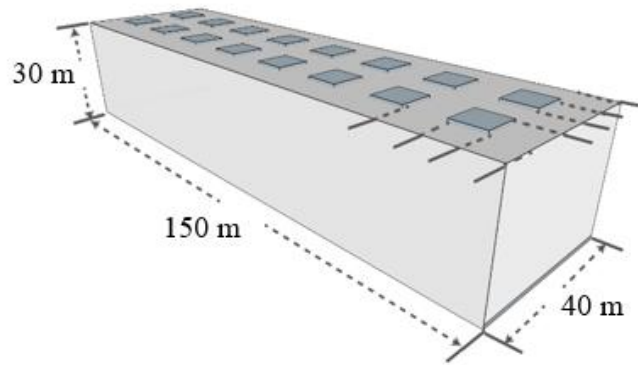


(b) With two 1 m gaps at the bottom

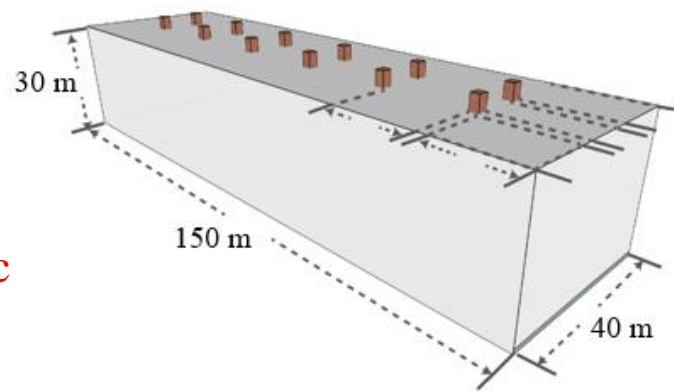
HSRS Kowloon West Terminal



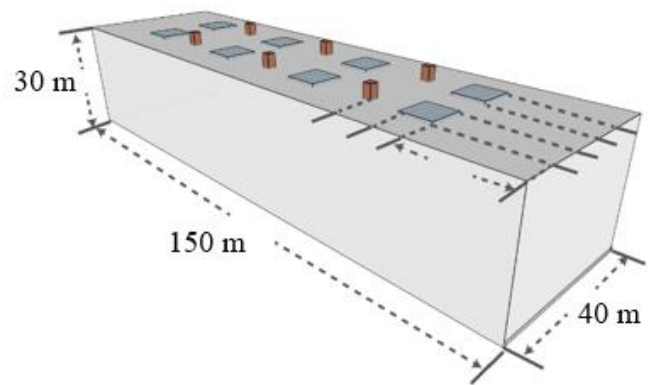
Static



Dynamic

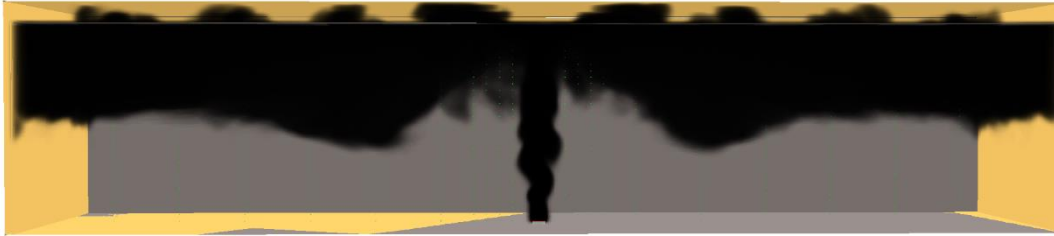


Hybrid

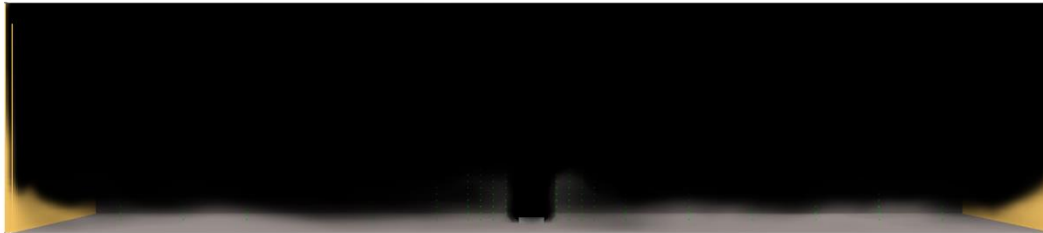


Different smoke extraction designs



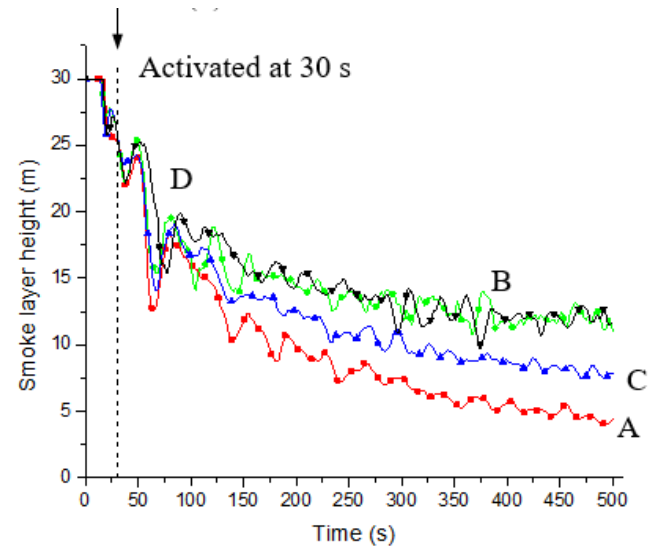
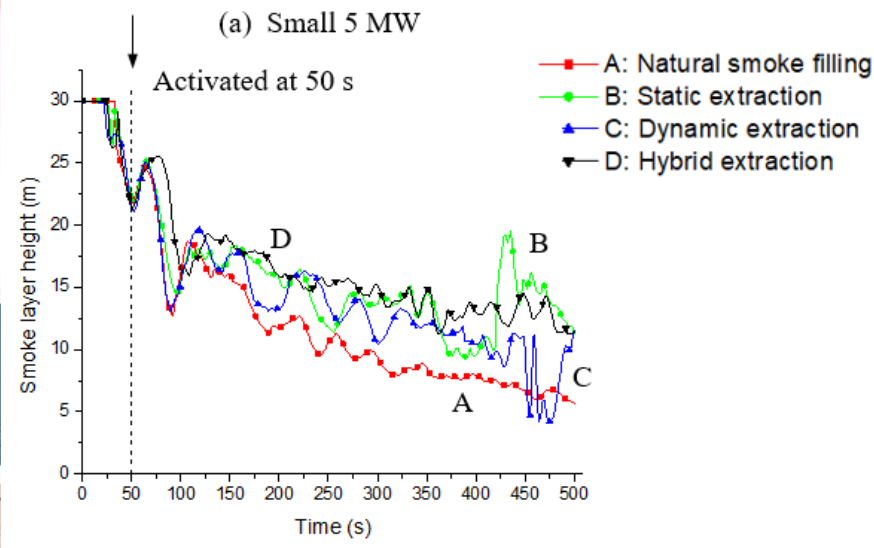
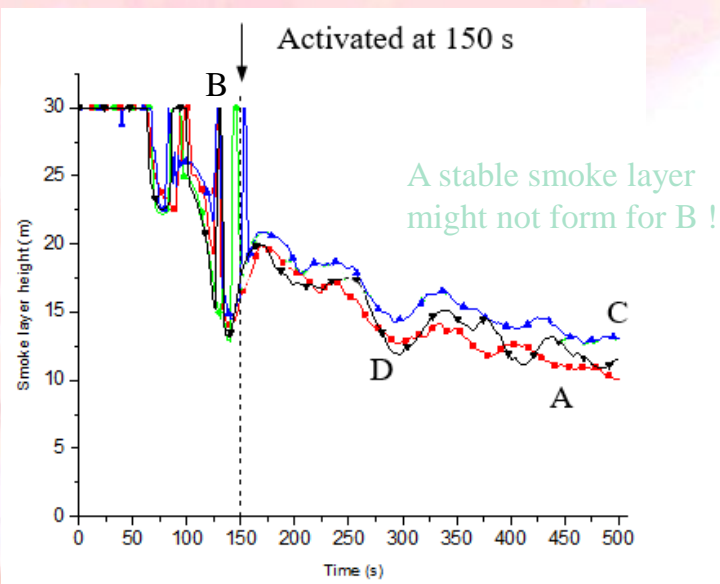


Smoke with stable layer interface



Smoke without stable layer interface





(b) Medium 20 MW fire

(c) Big fire 50 MW

Smoke layer interface height



- ★ **FDS applied to justify smoke movement and control.**
- ★ **Natural smoke exhaust system is more appropriate for a big fire.**
- ★ **Mechanical smoke exhaust system is more appropriate for a small fire.**
- ★ **Hybrid system can be better.**



Any experiments ?



7. Bridge Access to Terminals



A New Hazard: Fire to bridges linking terminal

- Passenger bridges
 - Vehicle bridges
 - Train bridges
- All connected to terminal !**

★ Linking among platforms.



Some are having bridges for passengers, vehicles or trains.

Passengers

Vehicles



Seoul Incheon Airport



Atlanta Highway Bridge Fire 2017



<https://www.youtube.com/watch?v=Z3n15chVJWo>



Another example ?



Burning 2 HGV : Possible > 200 MW



Burning footbridge !

Any fire resistance ?



Double-deck bus fire below a footbridge

https://orientaldaily.on.cc/cnt/news/20190512/00176_064.html



Very dangerous to footbridges

Above scenarios arranged burning under bridges will be terrible. Both heat and smoke to crowd above should be watched! Owner must have good fire safety management, even with adequate fire resistance and sprinkler in the footbridges !
(photo: 東網)



8. Arson Fire

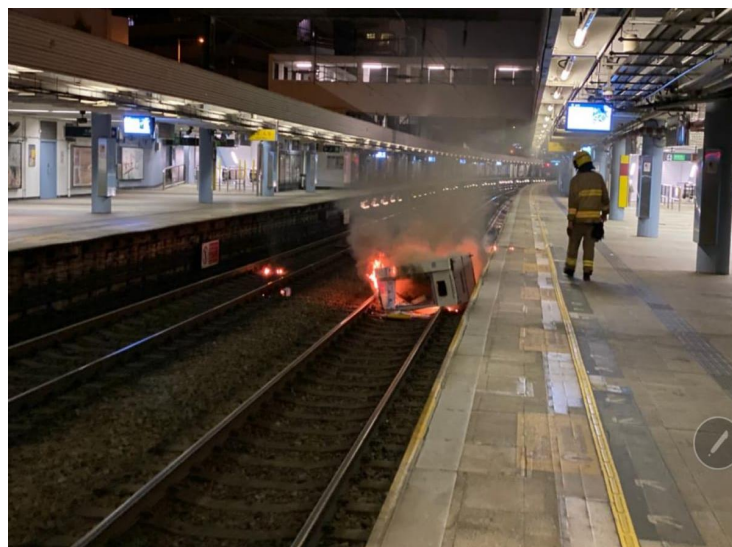


- ★ **Two arson fire incidents occurred in railway systems in Hong Kong before 2019.**
- ★ **Arson fire in 2004 took place in the subway between two stations and 10 passengers were injured.**
- ★ **For 2017, an arsonist inside the first compartment of the train car threw a lit petrol bomb when the train was about to reach the station platform. 18 injuries were recorded and the arsonist died several months later.**



- ★ **A series of terrorist activities in Hong Kong has emerged since late June 2019, with frequent arson attack on the railway system.**
- ★ **Leading to damage and service suspension in a number of incidents.**
- ★ **There are now reviews on whether arson fire should be included in the safety strategy of subway systems.**





- ★ **Protection against arson fires is normally not required in many places including Hong Kong.**
- ★ **However, situations have changed in many countries as there have been arson fires in railway systems including subway stations and tunnels.**
- ★ **A serious fire in subway occurred in Manhattan, New York, on the early morning of March 27, 2020.**
- ★ **The fire killed the operator, injured at least 16 others, and severely damaged the north part of the station and the train cars.**



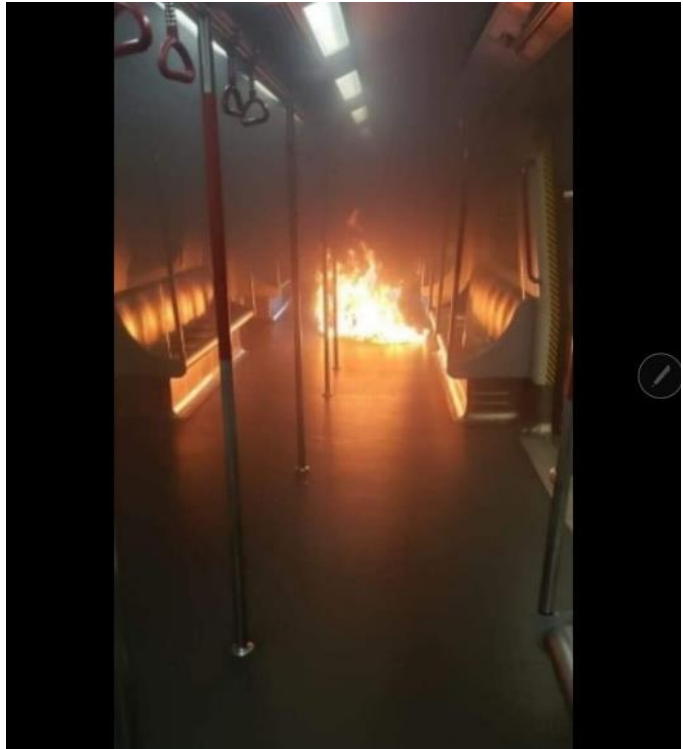
- ★ When a tunnel is occupied by a train stopping inside as fire occurs, the smoke movement inside the tunnel is affected and is determined by the degree of blockage.
- ★ When fire occurs near a train stopping inside a tunnel, the train body and hence the air inside the train compartments will be heated up rapidly.
- ★ Another possible fire scenario was taken after seeing so many arson fires in subway system.



- ★ **On the arson fires in the subway system occurring since 2019:**
- ★ **The arsonist brought liquid fuel and gas canisters and set fire inside more than 20 stations.**
- ★ **Small arson fires were even set up in the tunnel near the subway platform during the riot incidents.**
- ★ **Different fuels, both liquid gasoline, gas canisters and even solid powder with them, blocking up tracks, burning train cars and setting up fires at the tunnel by covering themselves by masks and umbrellas.**



風



- ★ **There are challenges on not studying such arson fires by some citizens.**
- ★ **FSM to use ?**



9. Conclusions



- ★ **Many new challenges.**
- ★ **Designed under low design fires and low occupant load.**
- ★ **No arson fires.**



Crowded Stations, October 2018

⇒ Evacuation ?



Trains take the strain as Hong Kong commut...
scmp.com



Hong Kong MTR staff spent more than an ho...
scmp.com



Fines for disruptions on MTR need review | S...
scmp.com

MTR - 我地感謝乘客唔今朝觀塘綠列車服務受阻...
zh-hk.facebook.com



Influx of tourists will put MTR trains under st...
scmp.com



Stock video of shanghai, china - 2 november ...
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drinkyourcarbs.com



13 Bad Habits People Do at the MTR | HK Ex...
expats.hk

Rush hour commuter chaos as MTR battles ...
hongkongfp.com



Green Fire Safety :

★ Fire Safety Provisions:

- **Passive Building Construction (PBD): Green design on fire resistance**
- **Fire Service Installations (FSI) : Active green agent e.g. FM-200**
- **Green detection technology**

★ Fire Safety Management: Evacuation in crowded areas

★ Green Fire Safety Provisions – FSI, PBD, FSM

- **Clean but not effective: Not useful ?**

★ Green Firefighting:

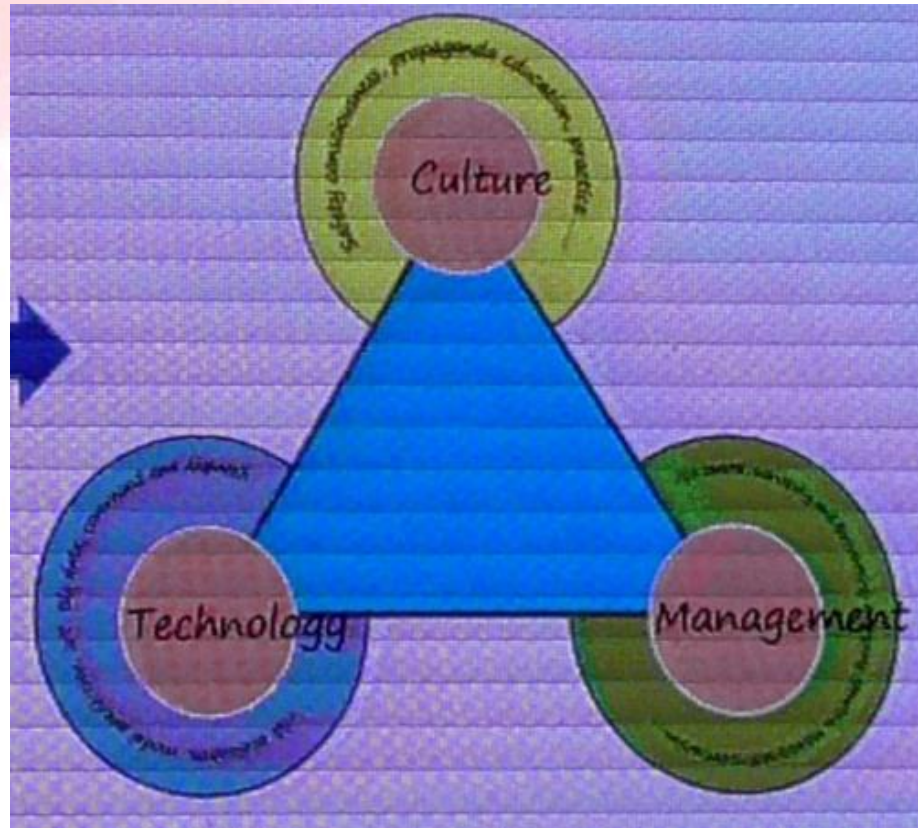
- **None track records**
- **Taking over 10 years to build up data**
- **Quick Response: 電光火石間**



Deep Concern !

- ★ Fire is not green, how can effective firefighting be green to save life ?
- ★ Halon is effective in fire extinguishment, but not green !
- ★ Killing many brave firemen if the technology and management does not work ?





Three legs stand



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