Fire Safety Engineering Workshop Session III B: Case Studies of Fire Safety of Underground Commercial Buildings

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Quality Fire Safety Management

Presented at the Fire Safety Engineering Workshop at Sichuan Fire Research Institute, May 26, 2015, Chengdu, China

Case Studies

- Case Study 1: Underground Pedestrian Street – China University of Mining & Technology
- Case Study 2: Larger-Scale Commercial Spaces in Underground Mass Rapid Transit Stations in Singapore

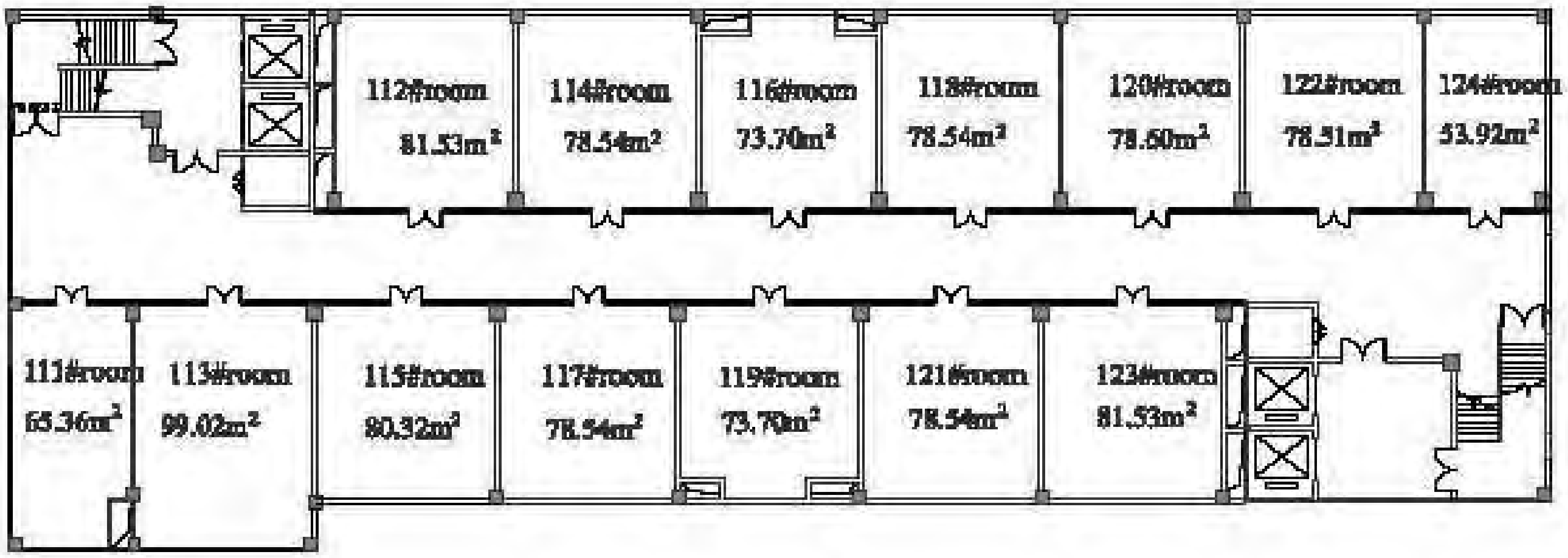
Goal

- Present case studies for underground commercial buildings
- Present issues & critique of case studies
- Discuss special considerations for fire safety of underground commercial building
- Recommendations to SCFRI for developing technology base for tall building fire safety

Case Study 1
Underground Pedestrian Street

- Need for underground commercial buildings:
  - City & population growth
  - Availability of urban land fro development
- Unique aspects of underground buildings
  - Large quantity of combustible materials
  - Fire loading
  - Evacuation population

Case Study I



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Project Overview

- 4 evacuation stairways
- Fire detection and alarm systems
- Pedestrian design capacity = 855
- 10 mechanical smoke exhausts in walkway

Evacuation Assessment

- Assumed occupant attributes
- Building-Exodus to calculate travel time
  - Complete evacuation in 183 s
- RSET = Td + Tpre + Tt = 454.6 s

Smoke Flow Analysis

- Assume water sprinkler in Room # 119 non-functional & room goes to flashover
- Maximum heat release rate = 3367 kW
- Assumed tolerance limits for:
  - Smoke temperature
  - CO
  - Visibility

Smoke Flow Analysis

- Used FDS to calculate the following conditions in 500 s:
  - Smoke temperature < 60 C
  - CO < 500 ppm
  - Smoke visibility > 10 m

Smoke Flow Analysis

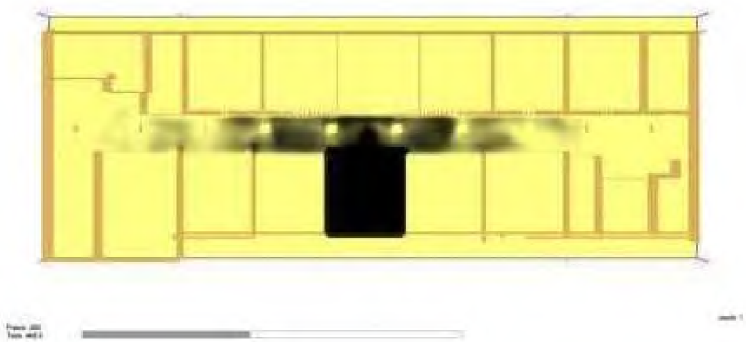

Fig.4 smoke distribution at 400 s

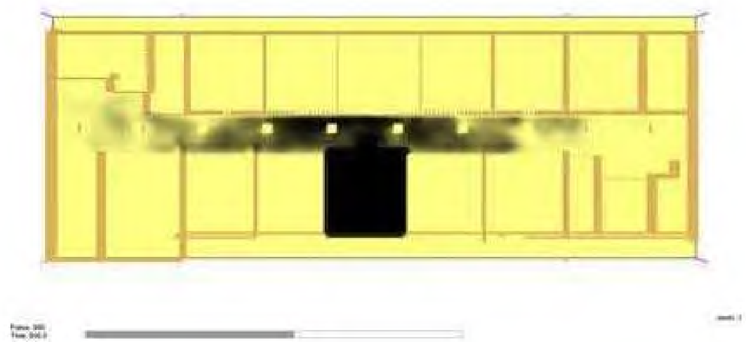

Fig.5 smoke distribution at 500 s

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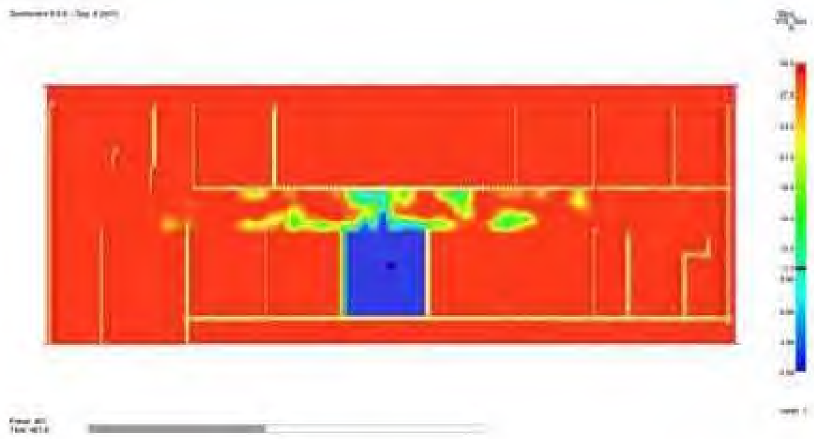


Fig.8 smoke visibility at 400 s

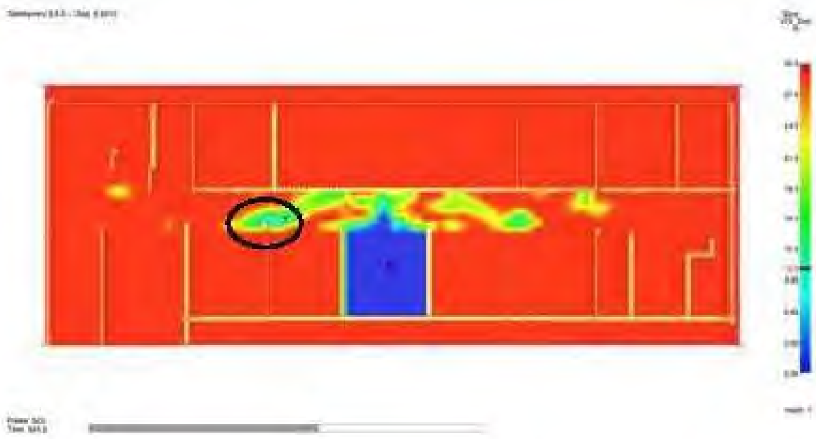


Fig.9 smoke visibility at 500 s

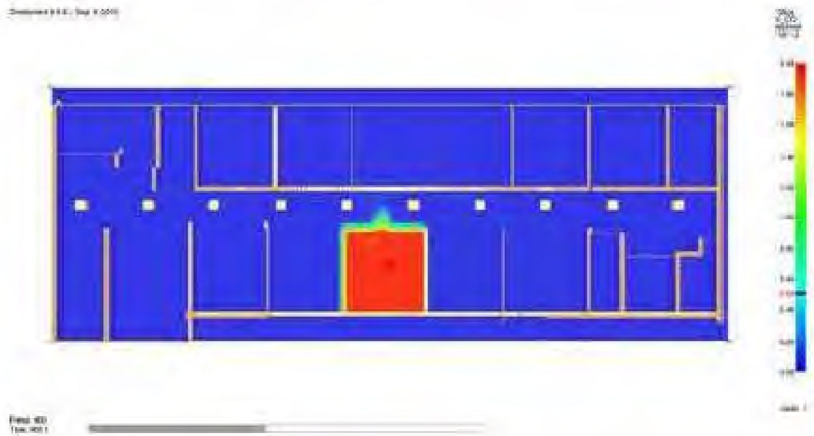


Fig.10 CO volume fraction at 400 s

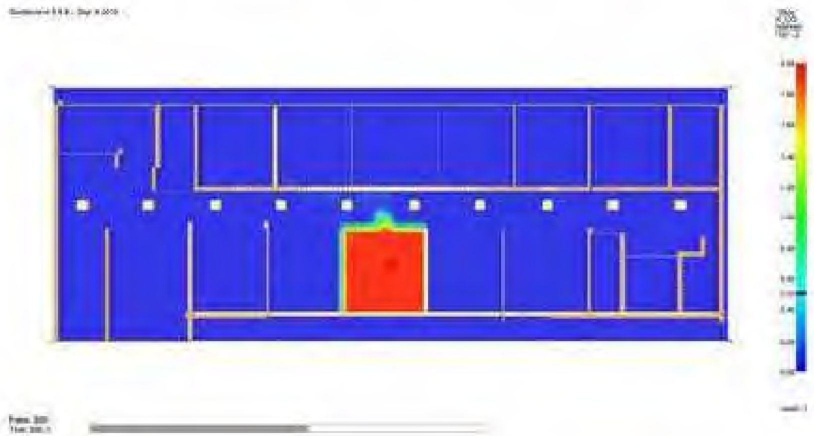


Fig.11 CO volume fraction at 500 s

Conclusions of Case Study

- T-aset (500s) > T-rset (454.6 s)
- Accurate prediction of:
  - Smoke movement
  - Evacuation of people
- Level of evacuation safety scientifically defined

Critique of Case Study

- Models used in study must be validated for all parameters predicted and used in safety analysis
- Blind validation pursuant to ISO 16730-1 highly recommended
- Movement of smoke and temperature generally accurate
- Prediction of CO and visibility difficult for under ventilated fires

Special Considerations for Commercial Underground Buildings

- Advanced sprinkler systems
- Advanced detection & alarm system
- Fire fighter access
- Life cycle management
- Inspection, testing, & maintenance

Special Considerations for Commercial Underground Buildings

- Integration of Systems
- Systems reliability
- Defense in depth
- Eliminate single point failures
- Information system

Recommendations to SCFRI

- Use ISO 23932 to develop safety requirements for underground buildings
  - Specific safety objectives, functional requirements & performance criteria for underground buildings
  - Special designs scenarios & design fires with ISO 16733-1
  - Special engineering analysis & assessment with performance criteria

Recommendations to SCFRI

- Benefit of ISO FSE standards is to address special features & requirements
- Need to validate calculation methods
- Special considerations must be overlaid over fire safety engineering analysis
- Fire safety engineering provides process to identify key hazards and engineering understanding

Case Study II – Underground Commercial Buildings

- Large scale commercial spaces in underground mass rapid transit stations
- Prescriptive requirements limit commercial spaces in stations
  - 100 m**2 for shop
  - 15 m**2 for kiosk

Case Study II

- Whole commercial floors allowed:
  - On floor above station floor
  - Fire separated from station floor
- Larger spaces in station studied using PB approach
- 3 stations evaluated by Task Force
- Planned to develop guide for similar commercial spaces in future

Case Study II

- Stakeholders involved:
  - Land Transport Authority (LTA)
  - Fire Safety Department (authority)
  - Private corporations in charge of spaces
- Fire safety objectives:
  - Safeguard people from injury or death due to fire in station
  - Safeguard occupants during evacuation

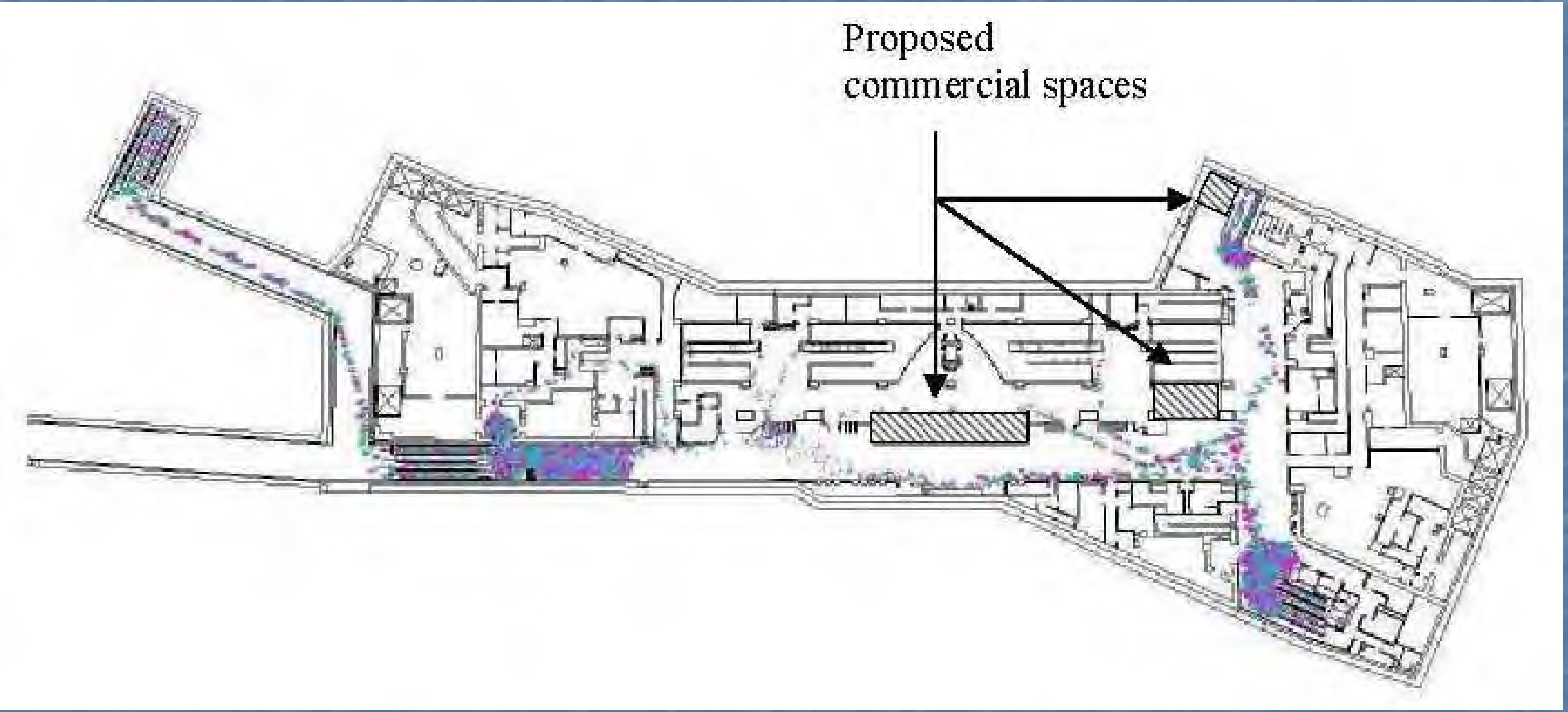
Case Study II

- Fire safety objectives:
  - Facilitate activities of emergency personnel
  - Prevent spread of fire to adjacent buildings
- Root & sub-objectives:
  - Occupants must reach safe place before untenable conditions
  - Provisions for adequate time for occupant escape

Case Study II

- Safety measures in original design:
  - Automatic sprinkler system in commercial spaces
  - Automatic fire detection in public areas
  - Smoke purging for public areas & corridors
  - Dry riser systems for fire brigade
- Design fire in one of added commercial spaces

Evacuation Modeling



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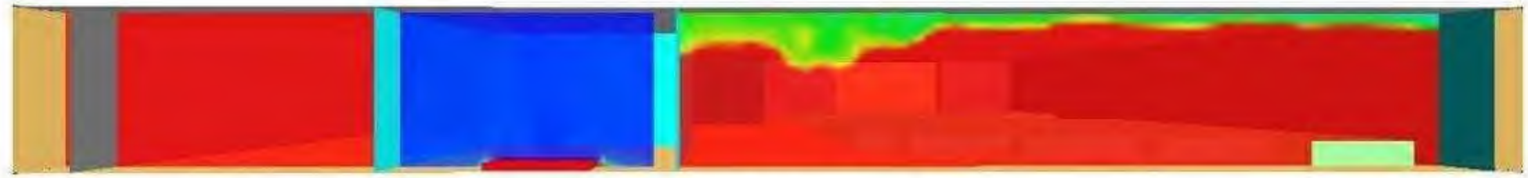
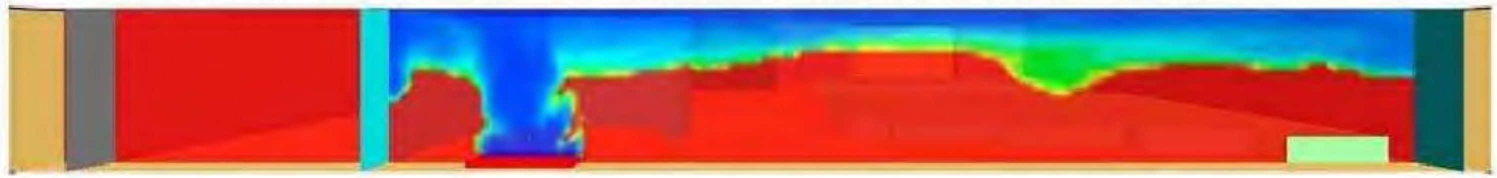
Case Study II

- STEPS evacuation model used for base & proposed design
  - Some change in flow pattern
  - Modeling showed evacuation times unaffected
- FDS used to study smoke flow
  - Low ceilings heights
  - Enclosed limited space
  - Difficult to maintain visibility for evacuation

Smoke Movement



Active fire separation activating successfully – Visibility slice taken at 3 minutes



Failure of active fire separation system – Visibility slice taken at 2.3 minutes when visibility required for way-finding is exceeded

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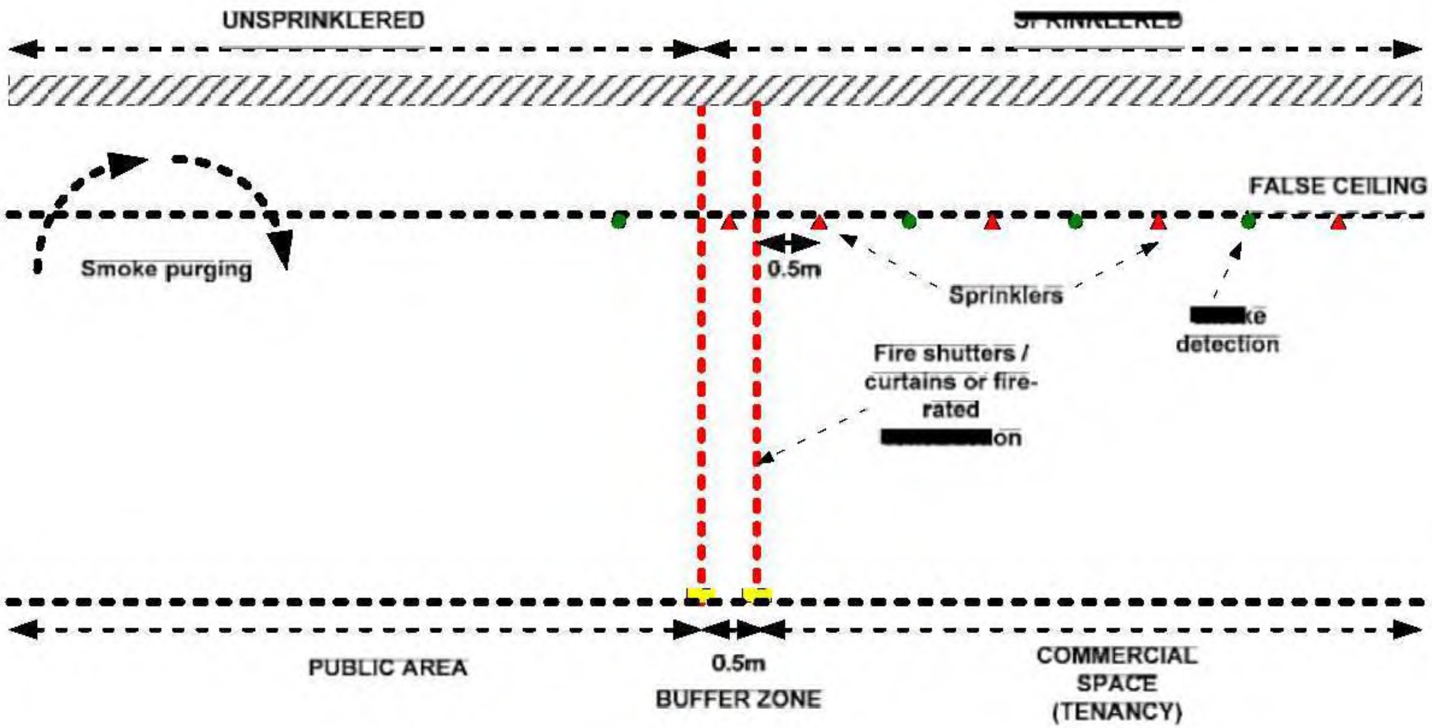
Design Features Implemented

- Implementation of smoke control difficult in already built stations
- Fire separation between commercial & public areas examined
- Failure scenarios examined to determine important features
  - Fire separation
  - Fire detection

Design Features Implemented

  - 50 % of shop open to outer space
  - Stacking of goods outside shop was concern
- Design decisions
  - 2^{nd} layer of fire separation
  - Increase maintenance & inspection
  - Prevent single failure of component that can have major impact

Final Design Concept



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Fire Safety Management

- No merchandise permitted beyond line of tenancy
- Line of tenancy clearly marked
- All trades & services limited to those in approved list
- 3-monthly testing & maintenance schedule
- Fire safety management procedure documented in O&M manual

For Future Stations

- Use engineered smoke control system
- Guideline developed for PB design
  - Size of commercial space
  - Location within station/impact on evacaution
  - Occupant load for evacuation analysis
  - Use of alternative systems to fire separation

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Questions

- Comments and discussion
- Thank you

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