Fire Safety in Mass Transport Underground Systems

Anthony LAM, QFSM, CPM, JP, CFIFireE, FHKIE,
Director of Fire Services, Hong Kong Fire Services Department

Introduction

Thank you for the introduction.  Good Morning Ladies and Gentleman, before I begin my presentation, let me just show you the existing railway network in Hong Kong.  The red line is the oldest Kowloon Canton Railway that runs from the Kowloon peninsula to the Mainland.  The brown line is the Airport Railway that brings passengers to urban areas.  The purple one is the latest West Rail that is only completed and commissioned earlier this year.  The blue, green and dark blue lines comprise the underground commuter train network of the Mass Transit Railway Corporation or MTRC, which is the subject of my presentation today.

My presentation is about underground rail transport systems, with their high passenger capacity and low environmental impact, they are widely regarded as the backbone of urban transport.  They however present significant risks to emergency departments, because of their potential safety and security threats to passengers and the community, and it appears that they are becoming targets of attack by terrorists or aggrieved individuals.

Compared with other modes of transport, the frequency of railway disasters is not unduly high, although rescue work is often arduous.

Fortunately we have not experienced a serious railway accident in Hong Kong, but there was a near miss earlier this year, and I would like to share with you some of our observations, hopefully to receive your valuable input.

A Revealing Incident

The incident occurred at about 0900 hrs. on 5th January 2004.  An underground commuter train fully packed with passengers, was traveling through the submerged tube section and heading towards Admiralty Station.  A male passenger in the first train car was seen trying to ignite something with a cigarette lighter.  Other startled passengers tried to intervene, and the burning object fell on the floor,
and ignited a nylon bag also brought in by him.

A smoky fire quickly developed and brought chaos, panicky passengers jostled to the rear of the train. Some passengers operated the inter-com system to notify the train operator.

The operator immediately made a broadcast to advise all passengers to go to the rear of the train; he then reported the fire and continued to drive the train to the next station according to standing procedures.

On reaching Admiralty, the train operator opened all train doors and station screen doors to detrain passengers. Some of them suffered from smoke inhalation, some became hysteric, fortunately none of them were severely injured. The fire was put out and it was then discovered that the nylon bag which actually was partly burnt away, contained:

- Five LPG canisters;
- Four 2-litre plastic bottles containing toluene, and
- One 4.5-litre plastic drum also containing toluene.

2 of the LPG canisters had exploded and the other contents were partly burnt.

A Near Disaster

This incident has all the ingredients of a multiple-casualties disaster. Had the burning train stalled inside the tunnel, rescuers could have to work for days, and the impact upon the community would be unthinkable. We were extremely lucky this time, we considered this a test of preparedness and made a complete review of our safety provisions and procedures.

Partnership between the Transport Agency and the Authorities

We have learnt that safety in mass transport systems is built upon a partnership between the transport operators and the Authorities. Being a commercial enterprise, a transport operator’s prime concern is to maximize profits, although it also subscribes to the importance of safety and security, they would also consider costs versus benefits for any safety requirements imposed upon them.
From the Authorities’ viewpoint, safety requirements seemed never enough, and costs are of much lesser concern, so there is always a gap to bridge.

In order to address differences we have set up working groups to resolve conflicting issues. Two of the most important ones, which have been in place since the 70’s, are the Station and Transport Integration Committee (STIC); and the Safety and Security Co-ordination Committee (SSCC).

**STIC**

The STIC is chaired by a Chief Engineer of the Highways Department, and its members include the Fire Services, Police, Planning, Transport and Buildings Departments, the Hong Kong Railway Inspectorate, MTRC itself and other Departments on a need basis.

Its terms of reference is mainly to determine the number and location of station entrances having regard to passenger flow and their effects on roads, buildings and amenities; provision of transportation interchange facilities; location of ventilation shafts; the need for connecting walkways to nearby buildings; land use requirements etc.

**SSCC**

The SSCC is chaired by the Hong Kong Railway Inspectorate (HKRI) of the Transport Bureau, and its members include FSD, Police, Buildings Department, MTRC and again other departments, such as the Electrical and Mechanical Services Department and Department of Justice, etc.

The SSCC would offer safety advice on the design and layout of MTR facilities; the suitability of materials to be used; the emergency facilities to be incorporated; emergency and security procedures; preparation of draft instructions for laws and regulations, etc.

**Work Flow between Parties**

In terms of Workflow, the operator would submit an initial proposal to the respective member of the STIC and SSCC, who would offer their preliminary observations and comments to the Chairman. The Chairman would consolidate and
revert to the operator, who would take the matters up with respective departments before the formal submission. Meetings will be held both before and after the final submission, and when all issues have been adequately addressed, the Chairman will give his approval for the works to proceed.

Under the STIC and SSCC mechanism all works or activities in MTR stations, from as minor as adding an ATM machine to the introduction of a new station, will be closely monitored.

**Commercial Activities in MTR Premises**

As I mentioned before the Corporation is keen on maximizing commercial opportunities in stations. This however runs contrary to our policy, which is to avoid large number of people loitering in underground stations, or for stations to become a huge shopping mall. Through the SSCC process, we have agreed upon a list of trades and services with low fire hazards, including such things as mini-banks, courier services, cobblers, vendors for newspaper, drinks and confectionaries etc.

**Kiosks for Trades and Services**

These trades and services are housed in designed kiosks with a maximum size of 40m$^2$ and each separated from the other by no less than 1 hr. FRP construction. The fire load of each kiosk must not exceed 1135 MJ/ m$^2$ and they are normally sprinklered. For small kiosk not exceeding 20 m$^2$, sprinkler protection can be replaced by fixed gas suppression systems.

**Prescriptive Approach in the 1970’s**

Despite the fact that in the early 70’s, the adoption of fire engineering approach for the built environment was not a common practice, the formulation of safety requirements for MTR stations was very pragmatic. There were thorough discussions and references to international practices were often made.

**Fire Safety Provisions**

In determining fire safety measures for MTR premises, consideration was given to the low fire load, transient stay of passengers, and water being incompatible with high voltage systems; sprinklers were only required on a need basis.
The normal fire safety provisions include:

- Fire Detection System
- Emergency lighting
- Exit signs
- Fire hydrant/hose reel system
- Fire extinguishers
- Smoke control system
- Public address system
- Fireman access staircase

and requirements for rolling stock include:

- Fire extinguishers
- Emergency intercom system
- Detrainment ramp at both ends
- Automatic train operation
- Emergency lighting
- Batteries for power back-up (45 minutes)
- Non-combustible seats
- Materials for the wall and ceiling linings conforming to BS476 for surface spread of flame, and BS 6853 for Fire Precaution in Railway Rolling Stock

In retrospect, the insistence on the use of non-combustible seats and other materials inside train cars was a very important decision, as evident from the incident that I mentioned earlier on.

**Performance-based Approach for New MTR Developments**

At about 1992 when the planning of the new Airport Railway project was underway, we have agreed with designers that a risk-based, fire engineering approach should be taken. This approach is now applied to new railway developments in Hong Kong under the “Railway Development Strategy 2000 (or RDS 2000)”.

Fundamental to this approach is an assessment of the actual hazards in stations and the adoption of design fires that forms the basis of active protection systems. The major areas of assessment were *Compartmentation; Evacuation; Fire Size;* and *Smoke Control.*
**Compartmentation**

In terms of fire compartmentation, a station is generally divided into three parts, viz., public area, commercial area and back-of-house area. Public areas include concourses, platforms and circulation areas. They are not sprinklered and are separated from the back-of-house area (BOH) by 2 hours FRP separation. The BOH includes Station Control Room, offices, storages etc. which are fully sprinklered, except A/C plant rooms, transformer rooms etc.

A “Cabin Concept” is applied for the commercial or concession areas. Individual shops are separated into fire-rated cabins, each protected by sprinklers and smoke extraction system, with a smoke bulkhead provided over the opening. The cabin thus forms a loose compartment that inhibits heat and smoke from spilling into the public areas.

An MTR station as a whole is separated from adjacent developments (e.g. a department store) by 4 hours FRP. This is achieved by walls, floors and fire shutters. If the operation of a shutter would block an escape route, an alternative means of escape is provided, for instance through a by-pass lobby.

**Evacuation**

The evacuation strategy for MTR premises is rather unique. Since passengers are more familiar with the routes into and out of a station, it has been accepted that these will be used for normal evacuation, either horizontally to an adjacent zone, or via escalators and stairs to a zone at the next level.

As escalators could provide rapid movement of large numbers of people, it has been agreed that escalators that run in the direction of evacuation flow shall continue to run, and those that run counter to it shall be stopped and be used as stairs.

The evacuation time analysis is based on the evacuation load, the number and width of running escalators and stairs, and the travel distance. Generally, the evacuation time to a Place of Safe Passage should be less than 4.5 minutes.

As for ‘Track ways’, including tracks at grade, tunnels and viaducts, evacuation should be made whenever possible via the platform of a station. It could
also be made through cross passages to an unaffected tunnel or emergency access points to ground level.

Fire Size

For assessment of risks and smoke management purposes, design fires have been established. Design fires are expressed as steady rates of heat release, and in practice, fire sizes chosen are larger than would be expected, since fixtures and fittings in the stations are mainly non-combustible and passengers are only allowed to bring along small or medium sized baggages.

As far as the train cars are concerned, again as the body, linings and seats are non-combustible, and that only small or medium size baggage are carried on board, the incidence of an internal train fire is expected to be small.

Based upon available experimental data from documentation such as CIBSE Technical Guides and NFPA Handbook, the design fire sizes for different areas are shown in the following table:

<table>
<thead>
<tr>
<th>Area Under Consideration</th>
<th>Design Fire Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform/Concourse</td>
<td>2MW</td>
</tr>
<tr>
<td>Train Car</td>
<td>5MW to 17MW</td>
</tr>
<tr>
<td></td>
<td>depending upon the train type</td>
</tr>
<tr>
<td>Sprinklered Car Park</td>
<td>2MW</td>
</tr>
<tr>
<td>Sprinklered Retail Area (new station designs)</td>
<td>2MW to 3.5MW</td>
</tr>
<tr>
<td></td>
<td>depending upon the height of sprinkler</td>
</tr>
</tbody>
</table>

Smoke Control

Another area of concern is smoke control. The main objectives of smoke control in stations are two-fold, ie to maintain a Place of Safe Passage clear of smoke for a minimum of 30 minutes; and to contain smoke within concession areas by means
of the “Cabin Concept”

Smoke control is achieved by providing smoke reservoirs from which smoke is removed by static or dynamic means, and a smoke free clear height of not less than 2m is maintained. In the event of a fire in the platform, the screen doors would not necessarily be opened and the over-platform exhaust should be able to handle it independently.

In the event of a train fire at station, the platform screen doors will open to allow passengers to escape. The platform and the track will therefore form a combined smoke reservoir. Extraction shall be a combination of over-track and over-platform exhaust.

For a train fire between stations, the track ventilation system will be enhanced to act as a smoke extraction system, creating a push-pull effect, to facilitate evacuation against the direction of air flow.

As smoke and heat are exhausted to open air via smoke vents or ventilation buildings, location of these facilities are carefully chosen to ensure that they do not pose an exposure risks to adjacent developments.

Smoke Tests

While on the subject of smoke, I would like to digress a little and show you a short video clip. This is a full scale hot smoke test conducted by Professor K.H. YANG from Taiwan, in May 1999.

In this test, a 20 MW fire was set inside the tunnel, but the smoke extraction system was not brought into use. According to information supplied, the smoke created by the fire spanned more than 700 meters, ie some 350 m on either side, before the gas and smoke started to cool off and descend. The developed smoke layer was about 2 m deep, and a smoke free clear height of 4 m was maintained inside the tunnel for up to almost 15 minutes.

From the results of this test, Professor YANG came to the conclusion that this first 15 minutes would be critical for safe evacuation. He argued that if cross edit doors were provided at not more than 350 m intervals, and without activating the smoke extraction system to disturb the smoke layering, there should be ample time for
passengers to evacuate into an unaffected tunnel. After the first phase, the smoke extraction system could be brought into use as may be required to facilitate further evacuation.

You may have many questions on this test, as I do, and I’m afraid I’m not in a position to either defend or argue against the observations of the test. I have only found it a very interesting test and thought you might find it informative.

Prof. YANG has kindly agreed that should you have any questions on the rest results or the argument, he would be pleased to respond, and I shall let you have his e-mail address if you wished to.

**Operational Management**

So much for Smoke Control, I would like to continue with our discussion on operational management for underground mass transit systems. At the operational level, we have Operation Guidelines and Procedures (OGP) with respect to different scenarios for front-line members to follow. The OGP is kept by the Agencies as well as FSD, there are periodical reviews by the Corporation in consultation with FSD, and lessons learnt from incidents and practical exercises are always incorporated.

Exercises are conducted on a regional basis on various scenarios in order that front-line personnel are thoroughly drilled. Additionally, fire station personnel carry out monthly visits to MTR Stations within their respective station areas.

Regular meetings are held between railway operators and FSD to discuss issues of common interest, updating of information on major projects, experience-sharing from international railway incidents, etc.

A high degree of familiarization and alertness is thus maintained both at the operational and managerial level. The incident that occurred on 5 Jan 2004 clearly illustrated that the vigilance and preparedness have paid off.

**Lessons Learnt**

With over 20 years of operation, the MTRC boasts a very good safety record: not one passenger fatality has occurred due to operations, less than one
passenger was hospitalized per 10 million journeys and only minor injuries were sustained by staff. We are however by no means complacent and would make use of all opportunities to review our positions. That was exactly what we have done in the incident that I mentioned, and we have come up with some recommendations for improvements.

We feel that we should enhance public awareness of and participation in emergency procedures at MTR premises, and to assure the public that the procedures are sound. This could be done through publicity in the mass media and electronic bulletin boards in the train car, and we suggest that volunteers from the public be invited to participate in regular exercises.

In order to tighten up enforcement against carrying of dangerous substances in railway premises, we recommend the Corporation to deploy plain-clothes staff at strategic locations to observe the behaviour of suspected passengers. The public should be urged to report suspicious people or activities that may have come to their attention.

Other recommended measures include the installation of CCTV in train cars, enhancement of audio and visual devices to direct the flow of passengers for evacuation, and the enhancement of the ventilation system in trains to facilitate more effective smoke extraction.

The Way Forward

It is evident that the regular liaison between emergency departments and transport operators is an effective means of preparing for and dealing with mishaps as they occur. By working closely with the operators and maintaining an open-minded approach, we have maintained a high standard of safety in underground railway premises and rolling stock.

I am aware that despite of all these measures, possibilities exist for public transport systems to become targets of abuse and attack and we are still far from being absolutely safe from deliberate human actions. I am afraid that it is something that no community can fully prepare against, and it also raises another issue of public surveillance and intrusion into privacy, which is something outside this context.

As emergency response department, our role is to prepare ourselves not so
much as to prevent all possible accidents but to be able to take care of the aftermath of incidences. By continually reviewing and improving preparedness, maintaining the highest level of co-operation with railway operators, and by inviting public participation, we believe we are doing all we can to minimize the consequences of accidents. Thank you very much.