ARSON FIRE IN TRAIN COMPARTMENT

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(Received 15 January 2004; Accepted 29 January 2004)

ABSTRACT

An arson fire happened in a train compartment in early January, 2004. Although the fire was started by burning thinner and newspapers with explosion of gas canisters, it did not grow up and very little damages were resulted. This has raised public concern on the safety of passengers while travelling on underground railways. Further, fire codes might be reviewed to see whether it is good enough on dealing with accidental fires as the number of arson fires appeared to be increasing. Points to be considered on fire safety provisions for train vehicles are discussed in this paper.

1. INTRODUCTION

An arson fire happened recently [e.g. 1] in an underground train compartment before the train entered the railway station on 5 January, 2004. The fire was set up by an arsonist using newspapers, a lighter, and one of the fire turpentine bottles in the front compartment near to the driver's cabin. Small LPG canisters were believed to be ignited. Nothing official in the fire investigation report has yet been announced to the public. However, it was reported [e.g. 1] that quite a big area on the wall of the train compartment was 'blackened'. Some explosions were heard in the incident. It is quite obvious that no active fire protection system was installed to control the fire.

In that incident, very little damages were resulted in comparing with the one in South Korea last year [2]. Therefore, either the emergency operation schemes of the local underground railway is acceptable; or the fire extinguished by itself, say due to insufficient air or not much combustibles to burn. However, this arson fire has raised public concern on the fire safety provisions in public transport. In fact, there had been three big fires happened in double-deck buses already [e.g. 3]. The whole bus was burnt out completely within 15 minutes, leaving only the engine chassis behind.

Further investigational works should be carried out and at least, the fire safety objectives [e.g. 4,5] for public transport have to be reviewed carefully. Note that most of the fire safety provisions are for protecting against accidental fires, not arson fires. Their differences might be in the heat release rate in burning the combustibles. For an accidental fire, the fire used to be started from a small size with low radiation heat flux. Materials assessed by only the ease of ignitability with a 'match' flame would give a good evaluation. In an arson fire, the fire might increase in size rapidly. In this train fire incident [1], fortunately only 20 % of the liquid fuel was burnt and not all the LPG canisters exploded. Otherwise, a big fire would be resulted in the 'sealed' train compartment. Other combustibles might be ignited by the high radiation heat flux. Even materials treated with fire retardants might not be 'safe' under the action of high heat flux. This has been confirmed by recent experimental data on polyurethane foam sofa where polyurethane samples treated with and without fire retardants were burnt under high heat radiative flux. Total fire safety [6] should be provided by passive fire protection, active fire system and fire safety management.

2. SEALED TRAIN COMPARTMENT

As reviewed before [7], many citizens travel on the several railway lines in Hong Kong everyday and might stay in the train compartment for up to an hour. Some of the railway lines are built underground and some have to travel through tunnels. The train compartments are constructed of metal without openable windows. Mechanical ventilation and air-conditioning systems are installed to supply fresh air and to provide a thermally-comfortable environment. This design is different from the train compartments thirty years ago, in which fresh air was supplied by openable windows and natural roof ventilators. Fire safety has to be watched even more carefully.

The consequences of the recent arson fire in a sealed train compartment can be very serious. Note that the traffic loading for the local railway lines is very heavy, one of them has to accommodate up to 3,000 passengers in each train (with one train every three minutes). There would be over 2,500 passengers per train during rush hours. As reported before on enclosure fire in a well-sealed structure, the pressure developed due to thermal expansion by a fire would be very high. Fortunately, that arson fire though started, was rather small for whatever unknown reasons.

3. FIRE SAFETY MANAGEMENT

Basically, four types of fires can be identified [8]:

- Accidental fires
- Arson fires
- Terrorist attack fires
- Fires due to natural disaster

Fire safety provisions for local buildings are basically provided for fighting against accidental fires. Dealing with an arson fire or a terrorist attack fire is a 'security' problem which would involve the police or military experts.

To ensure that all the fire safety provisions (hardware) work and people know what to do in a fire, there must be adequate fire safety management schemes (software). A fire safety plan [e.g. 5,9,10] including the following must be provided:

- Building maintenance plan
- Staff training plan
- Fire prevention plan
- Fire action plan

These schemes should be clearly laid down and include what should be done on the passive building design, active fire protection system and control of fire risk factors. There should be two modes of operation:

- Normal mode
- Emergency mode

Fire safety management schemes expressed mathematically as matrix elements should be worked out carefully. Some examples suggested for tunnels were reported [10].

4. IGNITION AND FIRE

In such crowded train compartments, the first target is to prevent the materials from ignition or to delay the ignition. Consequent to two recent fires in double-deck buses [3] which burnt away almost everything within 10 minutes, some citizens in Hong Kong had raised a question on whether they are safe while travelling on a bus. Key points for consideration in providing fire safety in local buses had been discussed. The possibility of flashover was analyzed with reference to materials fire safety. By using the tested results on a sandwich panel sample commonly used in the construction industry with a cone calorimeter, how incident thermal radiation heat flux would affect the fire behaviour of the materials was studied. It is recommended that tests on those sandwich panels with or without fire retardants treatment under higher external heat fluxes, say at least 20 kWm^{-2} for a flashover fire, should be developed to understand how the materials would behave in a fire. Before such tests are agreed by the interested parties, immediate actions to take on fire safety management are recommended. The desired fire protection goals for a bus had been outlined [11,12] and the following were suggested for a train compartment:

- Fire safety materials.
- Train fire scenarios.
- Smoke filling in the compartment.
- Brief review on the heat release rate in burning a train compartment with combustible luggage.

Note that burning samples of sandwich panels under 20 kWm^{-2} and 50 kWm^{-2} would be very different as reported before.

5. HEAT RELEASE RATE

As pointed out in U.S.A. for fire safe trains [13], a better understanding of the probable heat release rate [14] under flashover is strongly recommended. The 'design fire scenario' [15] is one of the primary uncertainties in fire safety engineering. A design fire in the train compartment depends on the materials used and carried by the passengers. It cannot be decided without understanding the combustibles present. The heat release rate has to be known and the results can be used as input parameters for fire models in studying the fire environment. Values up to 7 MW were used in terminal halls before for designing smoke management system.

With the possibility of having arson fires, in fact once in South Korea [2] and in Hong Kong [1], fire safety provisions for protection against arson fires have to be worked out. Rigs similar to an 'industry calorimeter' as in Sweden [16] should be developed to burn an actual train compartment for studying how much heat would be released. This is expensive but necessary.

There were some data on the total heat release rates for burning combustibles in retail shops, libraries and stores. For example, design fires deduced from large-scale fire tests in a sprinklered calorimeter [17] were reported. But these tests were started from a small fire such as an 'igniter' due to a short-circuited electrical appliance, a litter bin, or a gas burner as used in some standard fire tests. No radiation heat flux was applied to test the samples as in a cone calorimeter. The results are useful for understanding how a fire grows, develops to flashover and then spreads to adjacent areas. But this will not give the contribution of the materials, nor their assemblies, to a fire under flashover condition. The heat release rate measured would not be too high as only a small amount of the combustibles were ignited. And for most cases, fire suppression systems might be operated to reduce the resultant heat release rate. The tests then became a demonstration on how the system would act at the tested fire, but not for understanding the actual heat release rate and the possibility of igniting the combustibles under flashover condition. The situation should be reviewed as more fires other than due to accidents were reported.

The effect of high thermal radiation heat flux (such as 20 kWm^{-2} for flashover) on combustibles in a train compartment should be included in studying the possible heat release rate. This point had been raised before [18] and the consequences of missing it in assessing combustibles would be quite serious for retail shops.

Preliminary burning tests of several fire scenarios in small retail shops under flashover condition were reported in a new full-scale burning facility [18] with the Harbin Engineering University (HEU). In studying the heat release rates resulted from burning combustible items in a small room under flashover, the maximum heat release rate of some tests was up to 8 MW. The values were above 5 MW for over 400 s of burning time. The consequences of such a big fire in a transport terminal should be watched carefully.

Note that flashover would occur easily in a sealed train compartment. Upon ignition of any combustibles in a train compartment, much larger quantity of heat and smoke would be liberated and spread to the whole train crowded with people.

6. ASSESSMENT OF MATERIALS

Passengers might be carrying combustible luggage in the train compartments. For assessing the consequences of a fire, the possible heat release rates should be studied experimentally. Not only that, conducting full-scale burning tests for train compartments under flashover conditions is necessary.

As discussed in the literature [19], fire safe railway seatings for protecting against accidental fires or some arson fires must have the following properties:

- Materials difficult to ignite.
- Low surface flame spread.
- Low heat release.
- No ability to develop progressive smouldering fire.
- Low smoke production.
- Low smoke toxicity.

Arson fires as in the underground railway in Hong Kong and South Korea with explosion should be included.

Combustible materials should be assessed properly not just by the ease of ignition test with a small pilot flame. Igniting them by accident or on purpose will give a fire. The performance indicator PI of materials should be a function F of the following parameters: the ease of ignition measured by the time to ignite t_i, radiation heat flux R_f, peak heat release rate Q_p, time to achieve that t_p, smoke toxicity such as fractional effective exposure dose (or fractional effective dose) FED and the index assessing flame spreading such as time to flashover t_f in the room calorimeter test as:

$$PI = F\,(t_i, R_f, Q_p, t_p, FED, t_f) \qquad (1)$$

Assessment by a cone calorimeter and full-scale burning test is necessary to get PI.

7. CONCLUSION

There are many passengers during rush hours inside the train compartments. From the three accidental bus fires [3] and the recent arson underground train fire [1], it is obvious that fire safety should be further improved.

In-depth investigational works must be carried out on:

- Train structure and wall materials with and without fire retardants tested under high heat flux

  Ignition of the materials is a key point. Heat release rate, flame spreading and toxicity should be evaluated.

- Active fire protection system

  Water mist fire suppression system and clean agent gas protection system might be good choices. Smoke management system should be installed in both the train compartments [20] and the terminal. Fire vents in the train compartments such as quick releasing panels activated by heat sensors or manual means can be considered.

- Appropriate fire management system

  Evacuation from the tunnel or the terminal is another concern [e.g. 10] on life safety. The number of emergency exits provided is important with special consideration for train compartments. A good fire safety management scheme [10,20] including this point must be prepared. The only staff when the train is moving might be the driver, who, must be properly trained to take appropriate actions to evacuate the passengers in time.

Fire scenarios should be worked out together with the Authority and acceptable to the general public. Full-scale burning tests with train vehicles [18] are strongly recommended to assess the consequences of different fire scenarios.

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