# Design and heat release rate test of freight carriage model

**H Weiping[1], L Yi [1], L Xin [1], J Lishuai[1], L Wanfu[2], Xu Zhisheng [3], Y Dongxing [1], T Liwei [1], Z Xianzhong[1], X Jianjun[1], H Guang[1], W Jianqiang[1]**

[1]Tianjin Fire Research Institute of MPS; [2]Tianjin University of Commerce; [3]Central South University

**Abstract.** The purpose of this paper was to ensure freight carriage's combustion time. Firstly, the freight carriage's fire load was obtained by reviewing papers. The freight carriage's HRR would be over 10 MW if burning time was enough. Secondly, the freight carriage model was designed referencing the real freight carriage's parameters. The standard combustible material cup boxes were used to simulate freight materials. Thirdly, the freight carriage model's HRR was tested using 10 MW cone calorimeter. Fitting curve was obtained based on t2 fire model. Further study should focus on freight carriage model's fire extinguishing experiment.

## 1. Introduction

Modern traffic had sped up passengers and freights' circulation effectively. There were still some fire risk in the high speed train. If the freight train with locomotives got fire in tunnel, economical loss and political influence were both serious [1]. For example, the 2008 Channel Tunnel fire occurred on 11 September. The fire spread to neighboring trucks on the train and destroyed six carriages and one locomotive. The high temperature reached 1000 °C and even destroyed the tunnel rooftop, which led to the Channel Tunnel's close for more than 2 days.

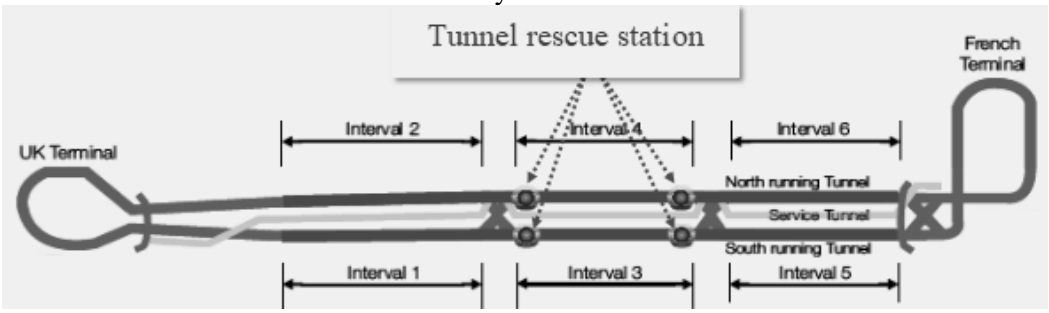


Fig. 1: Tunnel rescue station in Channel Tunnel fire

## 2. Freight carriage's hrr in reference papers

There were many types of freight carriage with different freight material [2]. Freight carriage types included boxcar, open wagon, flatcar, container car, ore car, heavy duty freight car, tankcar, isothermal car, poisoncar, lives tock car, cement car, special-purpose freight car and caboose. Freight materials included wood, clothing, wool, rubber tyre, straw and coal. The fire load was relative with the boxcar's capacity and freight material's type.

Table 1. Different types of freight carriages.

| Freight carriage | Definition | Comments |
|---|---|---|
| Boxcar | Enclosed with side doors. | Some with end doors and adjustable bulkheads. |
| Open wagon | Goods wagons for the transportation of bulk goods. | Tipped, dumped or shovelled. |
| Flatcar | Flat deck mounted on a pair of trucks or bogies. | Each end with four or six wheels. |
| Ore car | An open-topped rail vehicle used for transporting loose bulk materials. | With low side walls. |
| Caboose | Providing shelter for crew at the end of a freight train. | For switching and shunting. |

Take boxcar for example, this carriage with different freight materials had different fire loads. Compared with wood or straw, the rubber tyre had higher carbon content and bigger fire. In some papers and standard specification, the HRR could even reach 100 MW. In our study, our extinguishing target was 10 MW fire. So the combustion time of 10 MW should be ensured through this experiment.

Table 2. Different fire load of boxcar with different freight materials.

| Freight material | Boxcar and capacity | Fire load |
|---|---|---|
| Wood | P50 with 100 $m^3$ | 900000 MJ |
| Straw | P50 with 100 $m^3$ | 800000 MJ |
| Rubber tyre | P50 with 100 $m^3$ | 1600000 MJ |
| Wood | P60 with 120 $m^3$ | 1080000 MJ |
| Straw | P60 with 120 $m^3$ | 1920000 MJ |
| Rubber tyre | P60 with 120 $m^3$ | 960000 MJ |
| Wood | P70 with 145 $m^3$ | 1260000 MJ |
| Straw | P70 with 145 $m^3$ | 1120000 MJ |
| Rubber tyre | P70 with 145 $m^3$ | 2240000 MJ |

## 3. Freight carriage's HRR in experiment

### *3.1. Freight carriage model's design*

Freight carriage's general length was 11.3-13.4 m. Then the freight carriage model was half of the real length. The surrounding walls were made of galvanized steel sheet. The supporting columns were made of angle steel. The final designed carriage model was 6*3*2.5 m. The standard combustible material plastic cup box commodity was used as freight. There were 12 commodities in this freight carriage model while one commodity had 8 standard combustible material cup boxes.

Fig.2: Freight model with standard combustible material cup box commodities.


Fig.3: One standard combustible material cup box with 5*5*5 plastic cups.

*3.2. Freight carriage model's experiment*

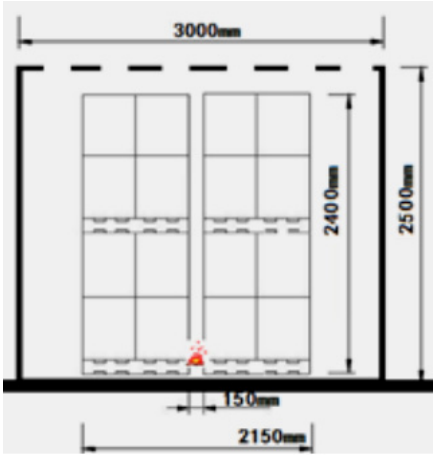


Fig. 4: The ignited point on the bottom layer.

There were four layers of standard combustible material cup boxes. Two wood bases were set below every two layers. Firstly, the ignited point was on the fourth layer in the bottom. Secondly, fire spread vertically because of the vertical gap air. Then, fire spread on the horizontal surface with the fire was growing gradually. Finally, the whole combustible material cup box commodities were in fire. During this process, the heat release rate was recorded using 10 MW cone calorimeter based on oxygen-consumption method [3].

Fig. 5: Combustion experiment using 10 MW cone calorimeter.

## 4. Analysis of experiment data

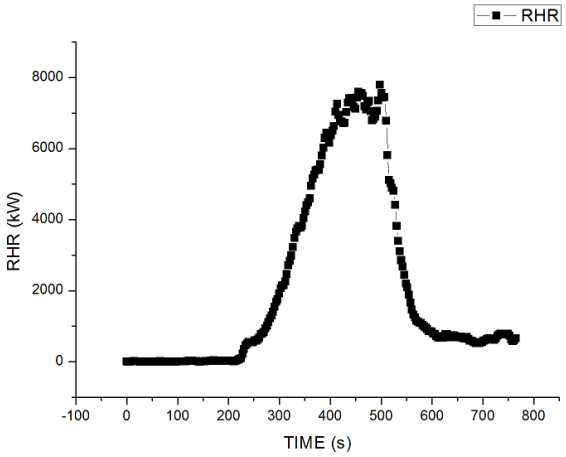


Fig. 6: Heat release rate curve of freight carriage's fire.

The heat release rate curve was obtained. To avoid fire scale's exceeding or cone calorimeter's breaking, the fire was put out when the HRR was over 7 MW. Then the HRR curve was obtained. The ignition point was 210 s. The highest HRR flat was 414 s, Then the fitting curve was obtained based on $t^2$ simulation fire curve. The fitting curve formula was below. When $t_0$=210 s and t=454 s, the HRR would be over 10 MW. Therefore, this freight fire's HRR would be over 10 MW 244 s after ignition.

$$HRR=0.1119(t-t_0)^2+14.3329(t-t_0)-166.3262$$

## 5. Conclusions

In this paper, the freight carriage's combust characteristics were studied. This freight carriage model with 92 standard combustible material cup boxes' HRR would be over 10 MW in 4 minutes [4,5]. If the extinguishing system could put out the fire less than 10 MW, the extinguishing system should response in 4 minutes to avoid fire's out of control. In the future, this freight carriage's extinguishing experiment should be carried out to improve special fire extinguishing design.

## Acknowledgments

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## References

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