# Experimental investigation of the HRR of light commercial vehicles

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**ABSTRACT**
This paper focuses on the experimental measurement of the heat release rate obtained during the combustion of Light Commercial Vehicles. Two tests were performed on Light Commercial Vehicles loaded either with solids (wooden and plastic pallets) or solids mixed with liquids (painting). The Heat Release Rate was measured with a Large Scale Heat Release rate apparatus and four load cells were used to record the mass loss during the test. In addition to the HRR and mass loss measurements, temperatures and radiative heat fluxes were also measured around the vehicles. These tests showed that, even if the overall fuel load is more important for LCV than a passenger car, the peak HRRs are limited by the incoming air and are finally comparable to those of passenger cars.

**INTRODUCTION**
In France, the fire resistance of car park structures is verified by fire safety engineering studies. The recommended method is based on the use of real fire scenarios. Currently, two types of vehicles are involved, passenger vehicle and light commercial vehicle (LCV). A series of experiments on Internal Combustion Engine (ICE) vehicles in the late 1990s led to the development of fire scenarios for passenger vehicles [1]. These data are used in the calculation method dealing with vehicle fires in the case of open car parks (thermal actions) [2]. However, the Heat Released Rate used for LCV is an extrapolation from measurements performed on passenger vehicles based on an expert analysis and appears to be highly unfavourable to the stability of car park structures. This test campaign lead by the CTICM involved many partners (ArcelorMittal and LCPP), with the support of Renault Group for the supply of the investigated vehicles.

**MATERIAL AND METHOD**
This experimental campaign consists in the combustion test of four vehicles, two Light Commercial Vehicles and two passenger vehicles. In this paper, only the combustion of the LCVs is presented (Figure 1). Two load types of combustible and incombustible materials were used (Table 1). For the first test, solid materials were loaded inside the vehicle. Liquid combustible, painting in this case, was added in the second test. These additional amounts of combustible aim at representing the common loading of a craftsman. It should be emphasis that the LCV used in the first test had extra windows on the rear (Figure 1) while the one used in the second test has none which is closer to a craftsman's vehicle (Figure 2). The ignition was performed under the passenger seat and along the dashboard in order to obtain conditions similar to those of fire scenarios.

*Table 1 : Solid and liquid loads characteristics*

| Load | Materials | Total weight [kg] | Theoretical total heat released [MJ] |
|---|---|---|---|
| Solid | Wood, Polyethylene, concrete, steel, white spirit | 372,7 | 4 200 |
| Liquid | Acrylic paint, solvent paint, epoxy paint, white spirit | 331,4 | 3442 |

*Figure 1 : LCV (left) and solid load (right) tested during the first test*

*Figure 2 : LCV (left) and liquid load (right) tested during the second test*

Tests were carried out under a 7.7 m x 5.3 m Large Scale Heat Release apparatus (LSHR) (Figure 2) settled in Efectis large scale fire test and training platform, in order to measure the HRR over time. Temperatures and radiative heat fluxes around the vehicles were measured to evaluate the eventual thermal stress received by ~~structure~~ structural elements as well as other vehicles parked next to the LCV. Finally, the mass was also recorded during the experiments to deduce an effective heat of combustion. Only the measured HRR are presented in the following sections.

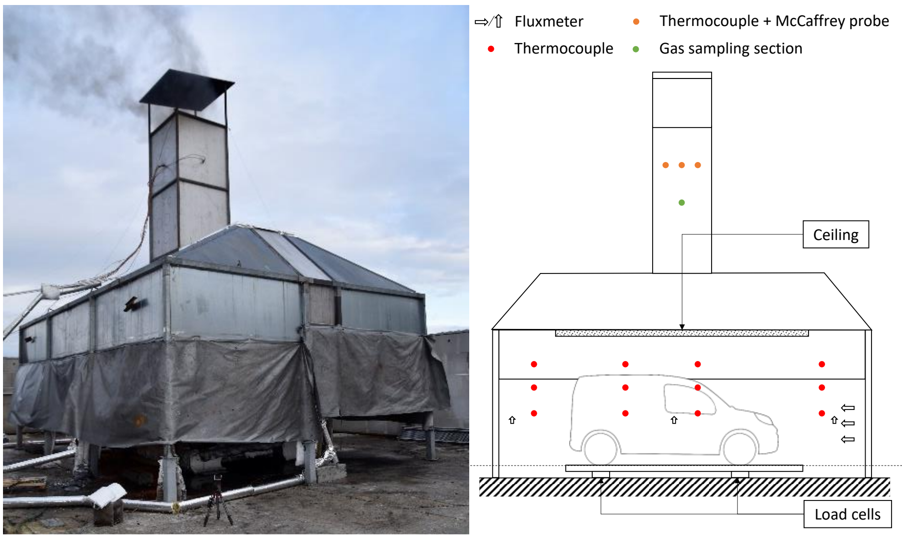


*Figure 3 : Large Scale Heat Release apparatus*

## MAIN HRR RESULTS

HRR measured during the two tests are presented Figure 4. Two types of events are identified on the figures, breakage of windows and propagations to bumper elements. Concerning the first test (Figure 4a), a single HRR peak of 7.35 MW is obtained at 34 minutes and 30 seconds after the ignition. Various successive increases in HRR, followed by a short plateau, are visible during the fire growth. Most of these increases are following a window breakage or a propagation to a bumper part. It should be noticed that the fire spread to the rear bumper before reaching the maximum HRR value. Thus, this value corresponds to a slight overlap of front and rear combustions. However, the rear combustion is only weakly developed and has little influence on the peak value. Its full development can be observed at 40 minutes with a lower peak HRR of 6.45 MW.

A different development was observed for the second test (Figure 4b). The fire grow quickly in the cabin and was followed by a plateau. The effect of the lack of additional windows in the second vehicle can be observed on the HRR curve (Figure 4 right) as a plateau appears after the ignition. The main increase in HRR appears after the propagation to the front bumper at 14 minutes and to the rear one at 22 minutes 30 seconds. Two HRR peaks are visible, the first of 5.6 MW and a second one of 4.4 MW. This phenomenon is due to the lack of ~~VUL~~ LCV rear combustion during the first peak. Rear bumper propagation occurred during a decay phase.

The presence of additional windows can cause the difference in fire spread rate and peak HRR value. Indeed, a shorter delay between front and rear bumper propagation was observed during the first test. These delays were 2 min 30 s and 11 min for the first and second tests, respectively. A better air supply at the additional load level may have facilitated the fire spread to the ~~VUL~~ LCV rear and increased the HRR value. Nevertheless, load configuration also played an important role in this phenomenon, allowing a next to next propagation.

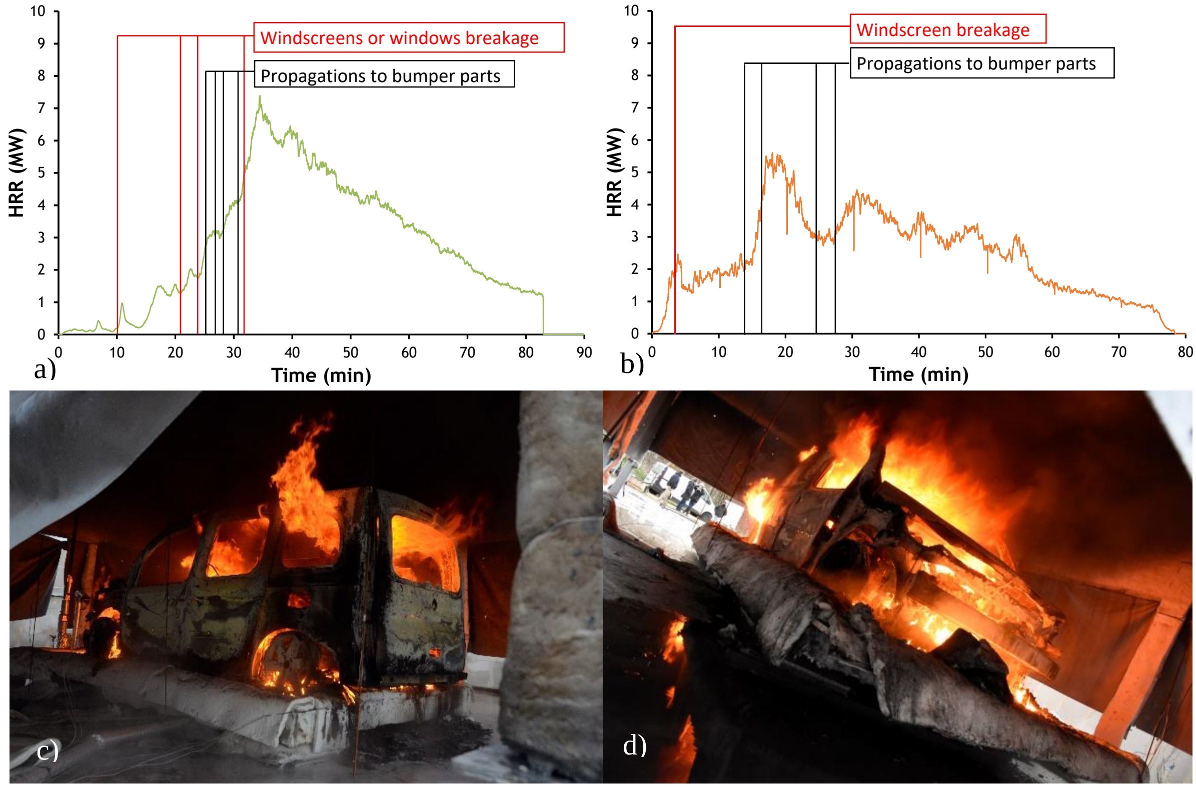


*Figure 4 : HRR over time measured during and combustion observed during the first test (a and c) and the second test (b and d)*

Figure 5 shows the HRR measured during this test campaign compared to those measured for a passenger vehicle [1] and the French theoretical curve for a loaded LCV [2]. The curve obtained in the first test was shifted by 13 minutes 30 seconds in order to compare the curves more easily.

During combustion in the passenger (front) compartment, the measured HRR are close, up to the opening of the side window in the first test. Compared to the Class 3 vehicle fire, the duration of the ignition plateau is close to that observed in the second test. The increase following the plateau is similar to that of the first test. However, a greater increase appears for the conventional vehicle with a peak HRR greater than 8 MW. Nevertheless, the peak is less wide and the power is lower than 1 MW rapidly with an earlier extinction of the fire. This suggests that the additional load increases the duration of the fire and not its peak.

Finally, it should be noted that the maximum HRR is strongly overestimated with the French theoretical curve for loaded LCV. With this curve, the total heat released is 19 500 MJ. The additional load represents 10 000 MJ. In this test campaign, 14 857 MJ and 11 953 MJ have been released during the first and the second tests, respectively. Additional fuel loads were estimated at 4 200 and 3 442 MJ. Thus, differences of 5 800 and 6560 MJ were determined between the two tests and the French theoretical fuel load. Based on the results presented above, it is unlikely that this difference in fuel load is the cause of a maximum HRR value of 18 MW during 10 minutes. Therefore, this theoretical curve seems very unrealistic and penalizing with respect to reality.

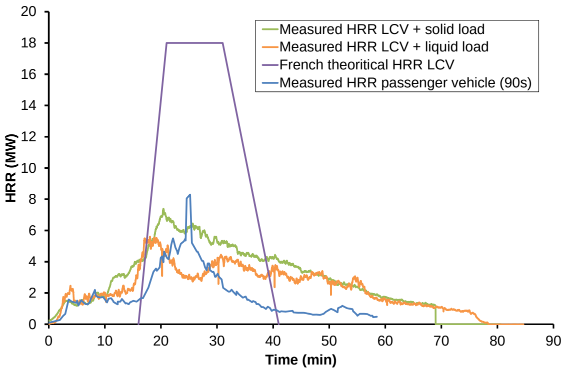


*Figure 5 : Confrontation between the HRR of a passenger car [1], the theoretical LCV HRR [2] and the two measured LCV HRR over time*

## CONCLUSIONS

The tests performed confirmed that the maximum HRR for LCV is not so far from standard vehicles, this is due to the effect of the ventilation on the control of the heat release rate. Indeed, although a large quantity of combustible is present, the HRR is limited by the incoming airflow. Thus the maximum HRR ~~registered~~ measured is comparable to the one of standard of standard light vehicles, as observed. These tests provide a valuable set of data for engineering studies.

A second step to this work will concern the heat released by new passenger vehicles. Indeed, data used today in fire scenarios for open cark park fire engineering studies are still based on the experimental campaign of 2001. These new tests would allow us to validate or update these data.

## REFERENCES

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