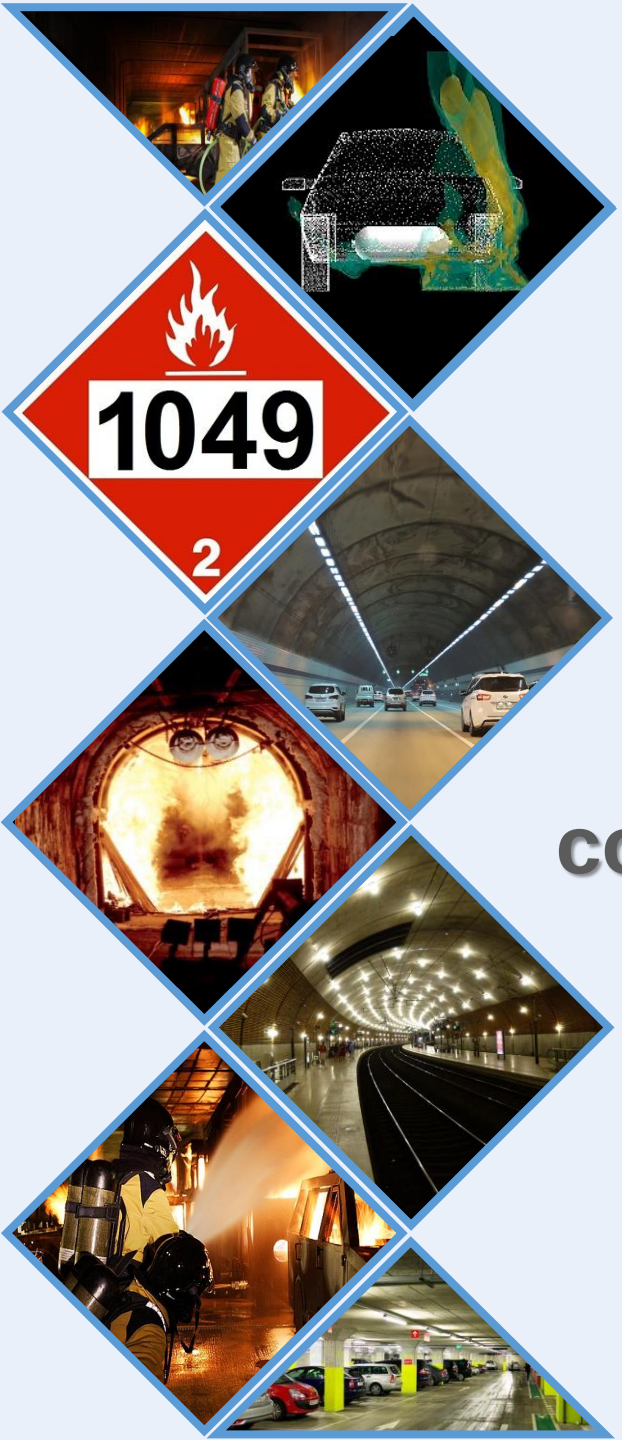


Dissemination Conference of HyTunnel-CS project
"PNR for safety of hydrogen driven vehicles and transport through tunnels and similar confined spaces"
14-15 July 2022, Brussels

Heat release rate, fire resistance rating and contribution of hydrogen released through TPRD to vehicle fire

Kashkarov S., Makarov D., Molkov V.

Abbreviations and definitions

FRR - Fire resistance rating: time from burner ignition until tank's rupture in a fire (without TPRD/failed TPRD or localised fire far from TPRD) [min]

HRR - Total heat release rate of a fire source [MW]

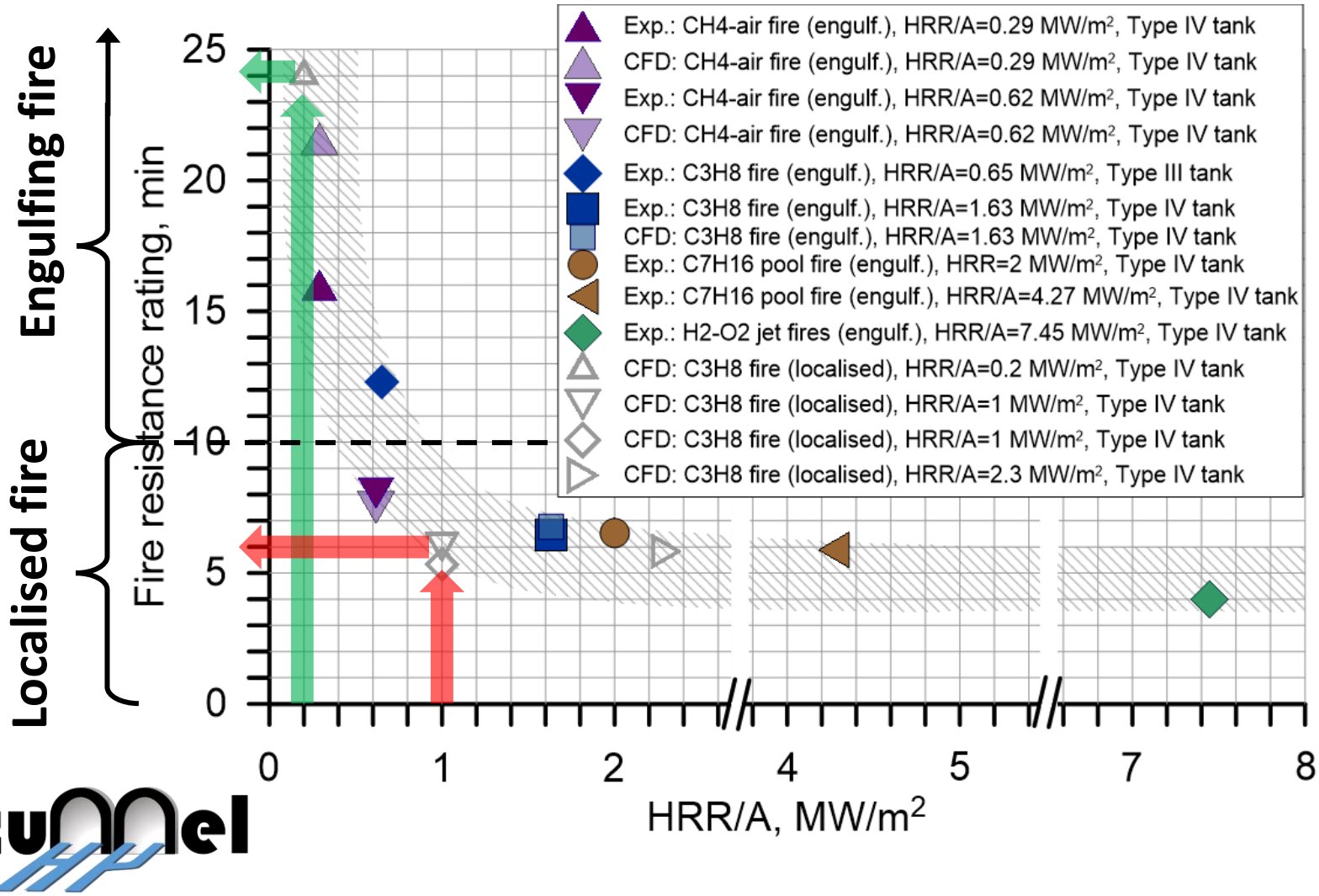
HRR/A - Specific HRR: total HRR produced by a fire source of the area A [MW/m^2]

LNB - Leak-no-burst safety technology, producing hydrogen micro-leaks from the tank in the event of a fire and releasing hydrogen safely

TPRD - Thermally activated pressure relief device.

Fire resistance vs fire HRR/A

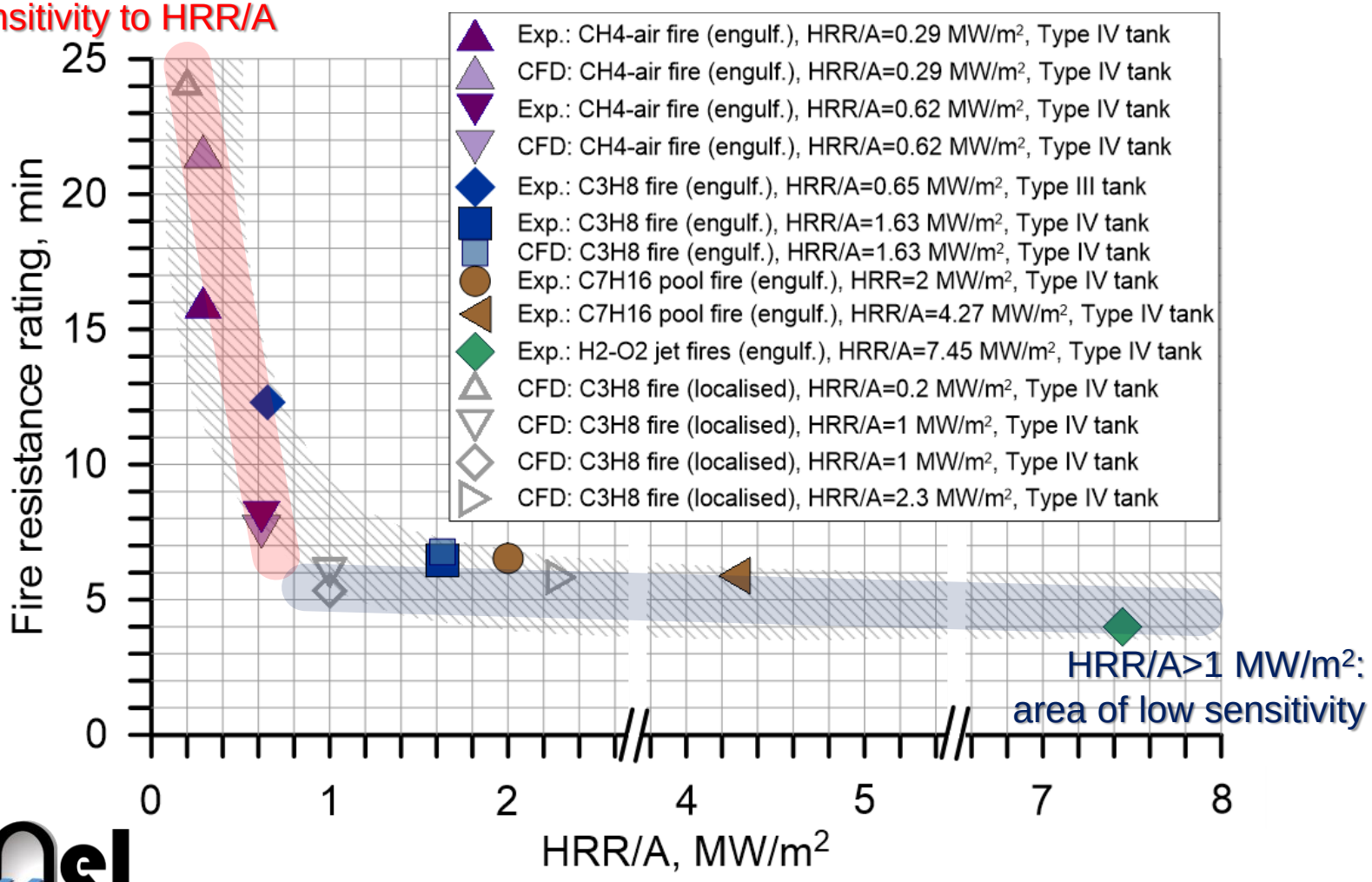
How can the fire test protocol be “cheated”?



Fire resistance vs fire HRR/A

High and low FRR sensitivity

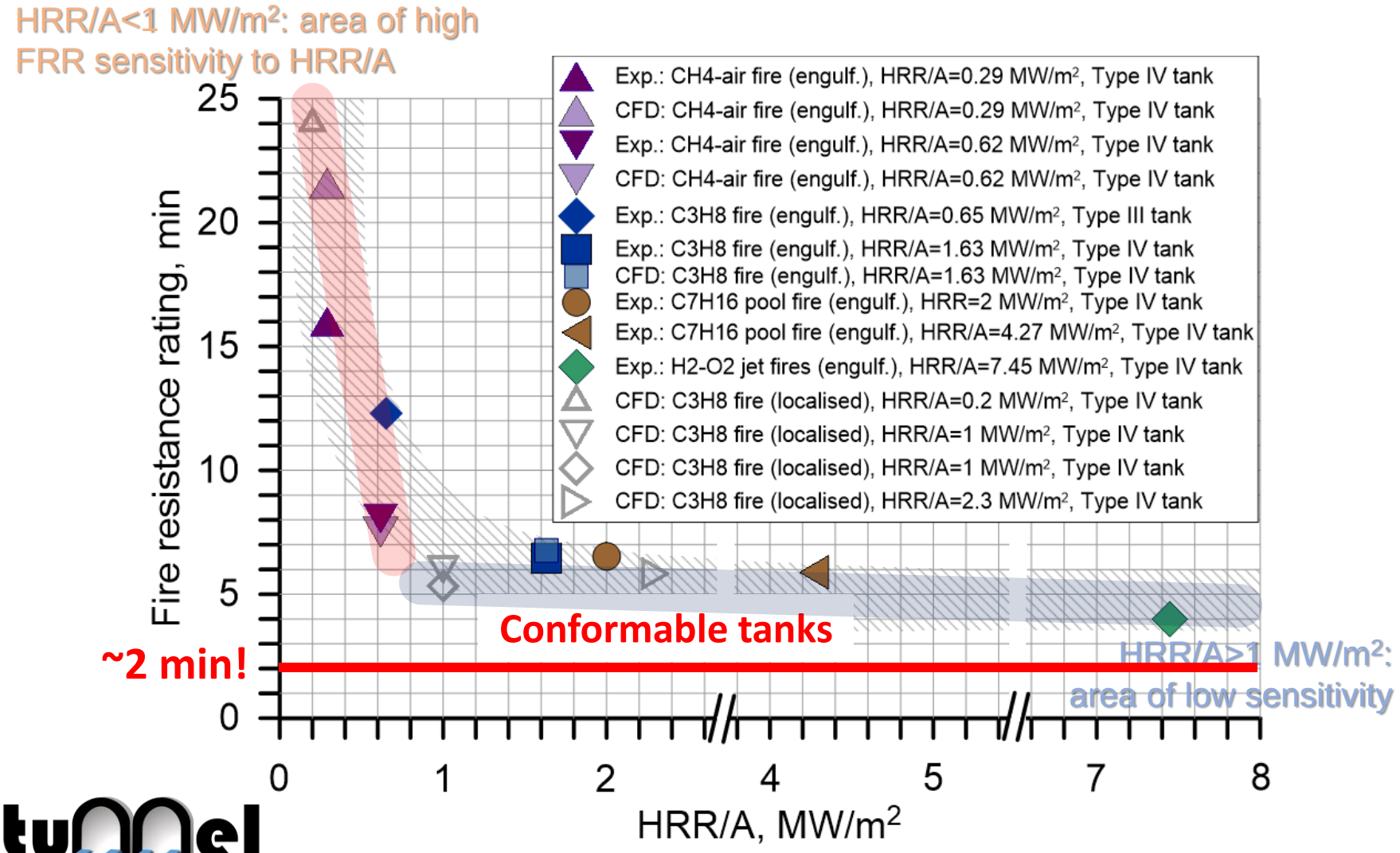
HRR/A<1 MW/m^2: area of high FRR sensitivity to HRR/A



HRR/A>1 MW/m^2: area of low sensitivity

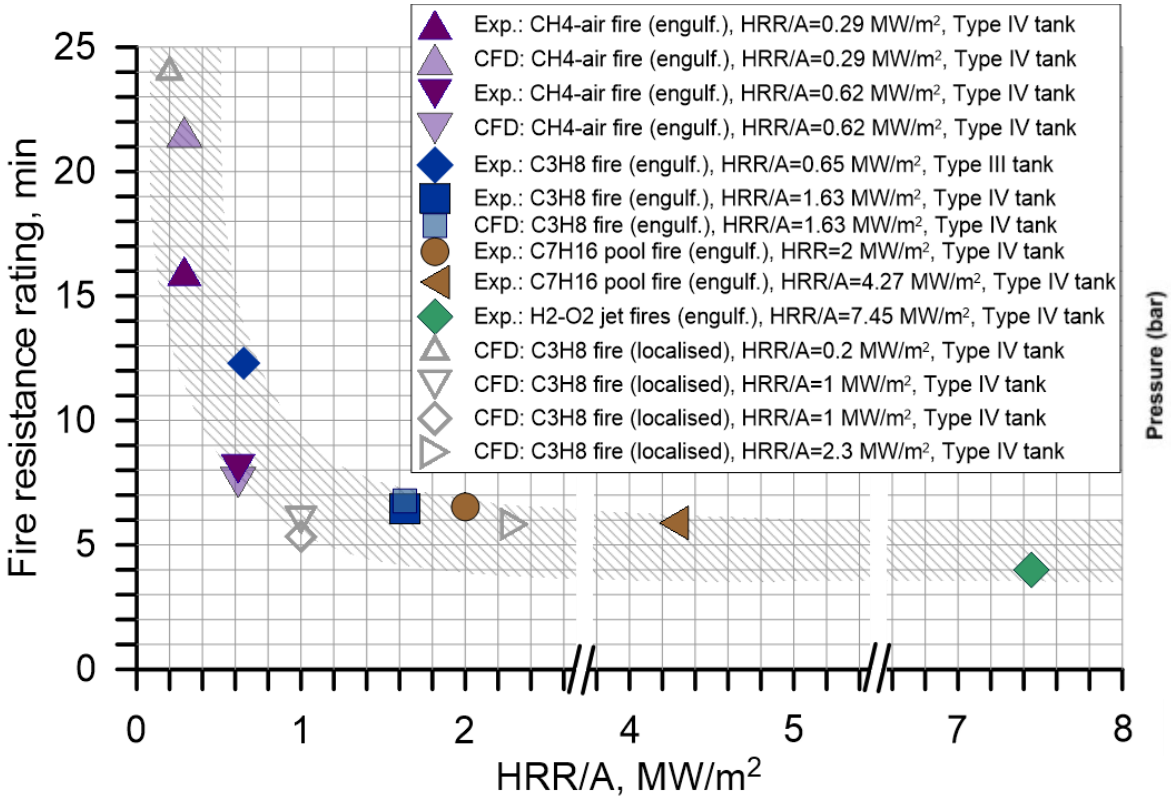
Fire resistance vs fire HRR/A

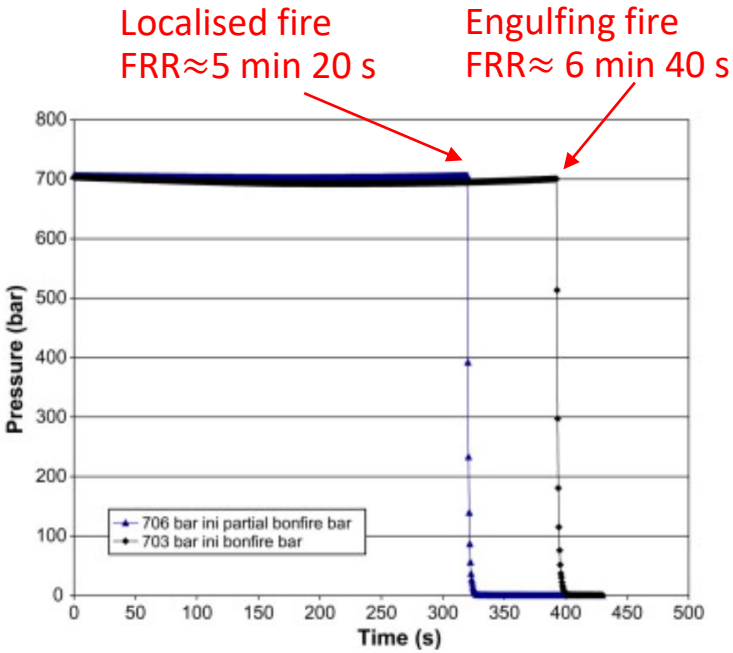
FRR is mush shorter for conformable tanks!



Fire resistance vs fire HRR/A

Liquid fuel fires and their HRR/A





References:

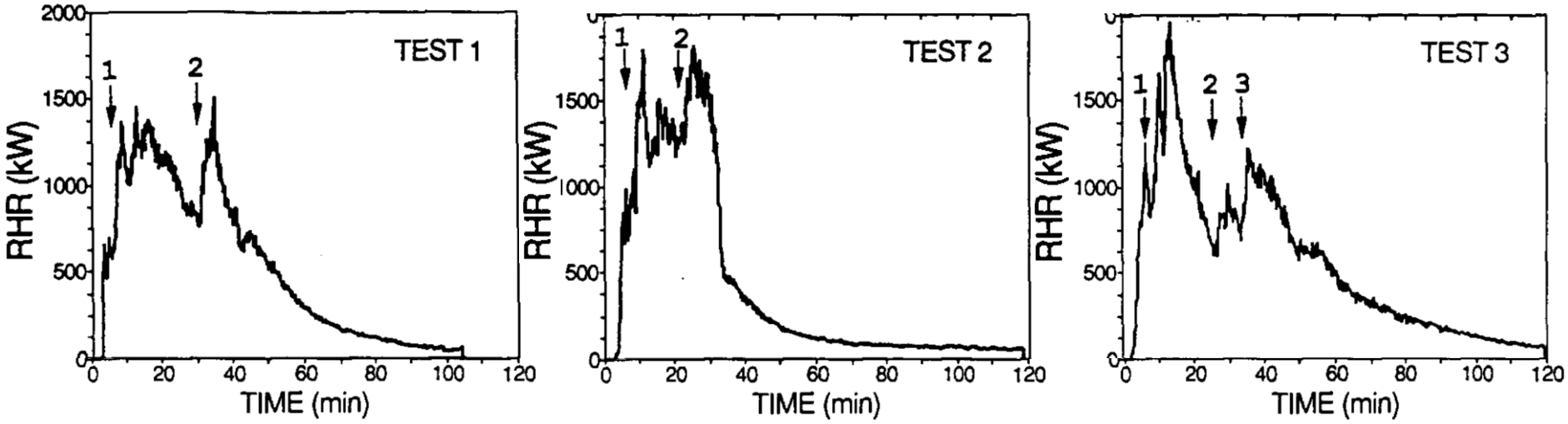
- *Heselden, Proceedings of the 2nd International Symposium on Aerodynamics and Ventilation of Vehicle Tunnels, Cambridge, UK, 23-25.03.1976*
- *H. Ingason, Y.Z. Li, Fire Safety Journal, 91, 2017, 399–406*
- *Baalisampang, T., Abbassi, R., Garaniya, V., Khan, F., Dadashzadeh, M., 2018. Review and analysis of fire and explosion accidents in maritime transportation. Ocean Eng.*
- *H. Ignason and Y. Z. Li. Spilled liquid fires in tunnels, FSJ, 2017.*
- *S. Ruban et.al. Fire risk on high-pressure full composite cylinders for automotive applications. Int. J. Hydrogen Energy 2012.*
- *V. Molkov et.al. Performance of hydrogen storage tank with TPRD in an engulfing fire, IJHE, 2021.*

Heat release rates (HRRs) in vehicle fires

HRR in vehicle fires

Example#1 – HRR per one passenger car

Test no.	*Car model*	*Mass before test without fuel (kg)*
1	Ford Taunus 1.6	990
2	Datsun 160J Sedan	918
3	Datsun 180B Sedan	1102

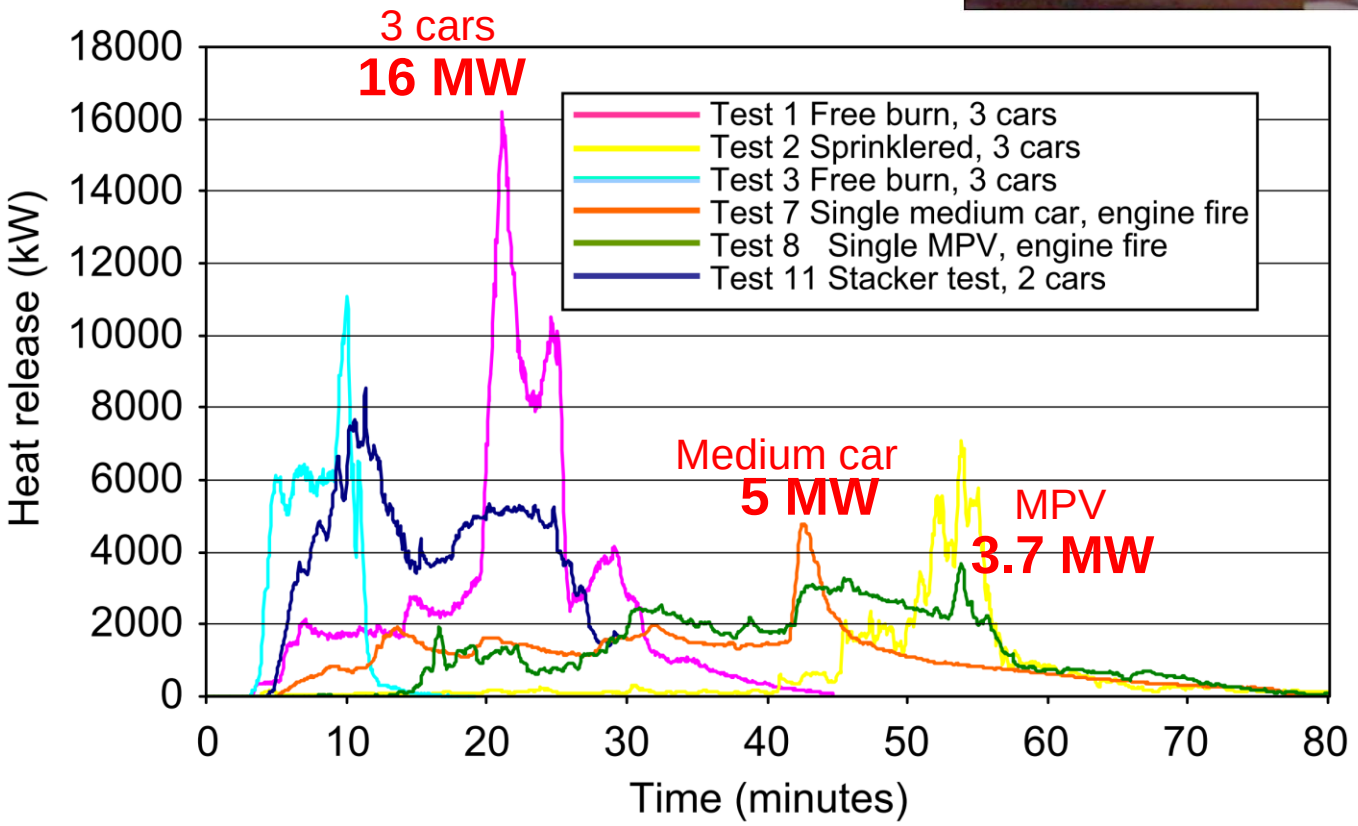


HRR≈1.5-1.9 MW

Reference: Mangs, J., Keski-Rahkonen, O., 1994. Characterization of the Fire Behaviour of a Burning Passenger Car. Part I: Car Fire Experiments. Fire Safety Journal 23, 17–35.

HRR in vehicle fires

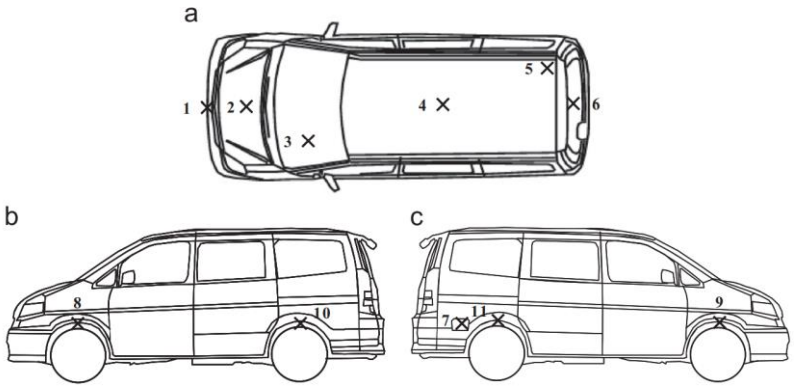
Example#2 – multiple cars

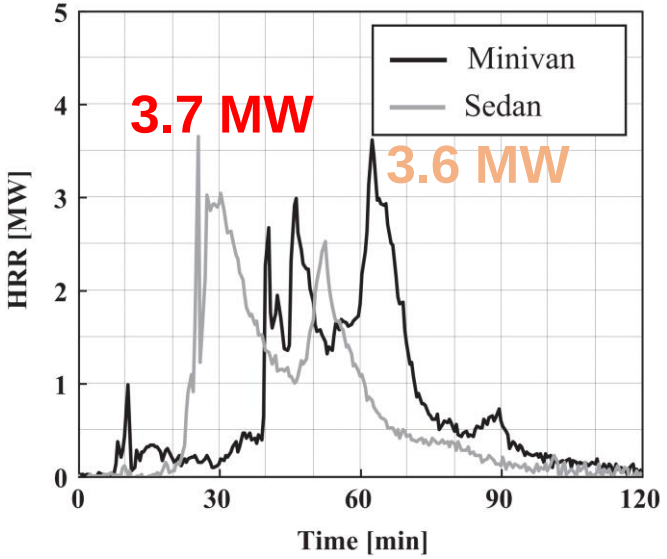


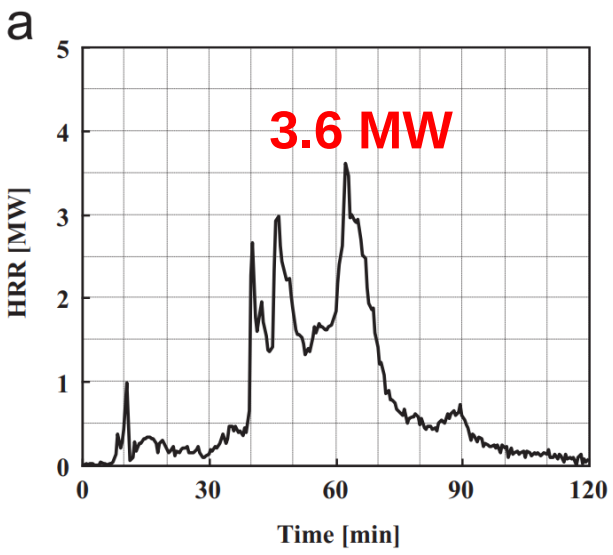
Reference: Merci B., Shipp M., 2013. Smoke and heat control for fires in large car parks: Lessons learnt from research?. Fire Safety Journal.

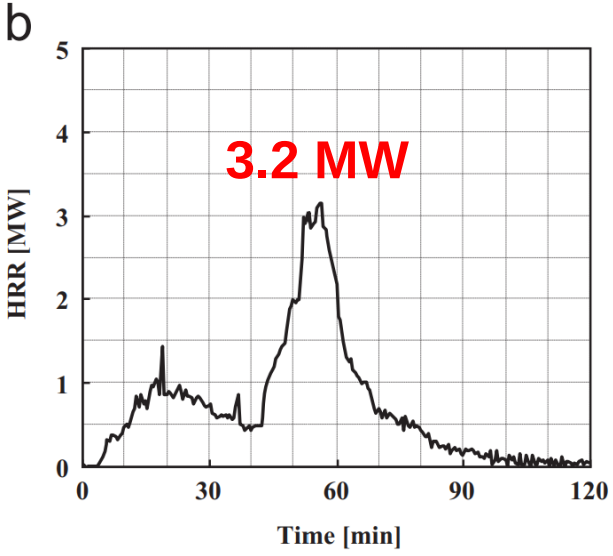
HRR in vehicle fires

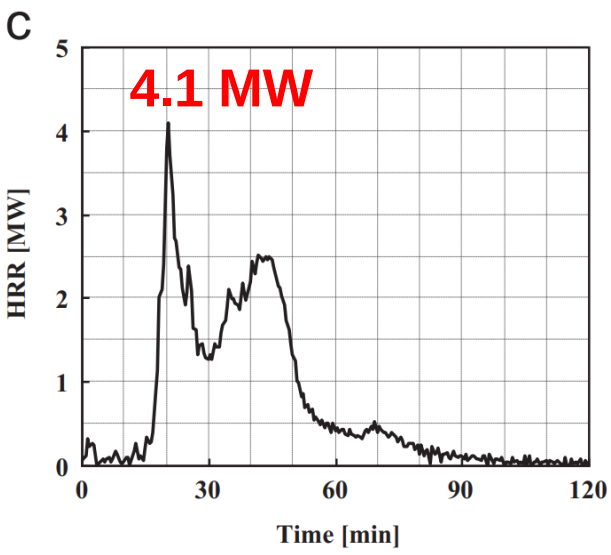
Example#3 - minivans







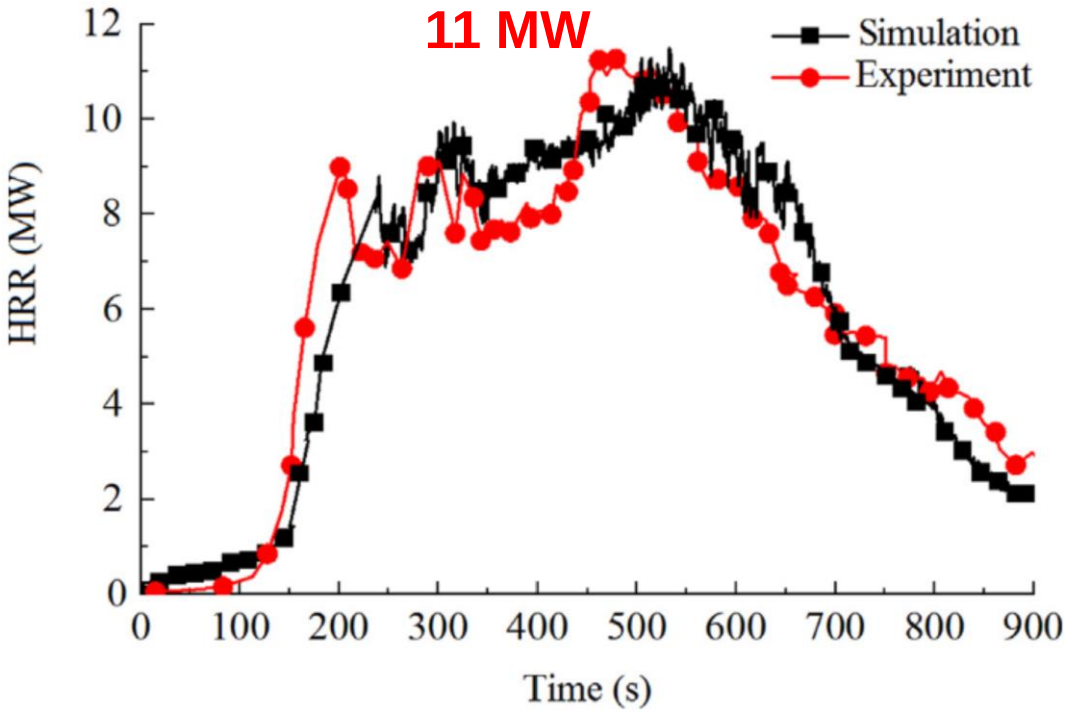


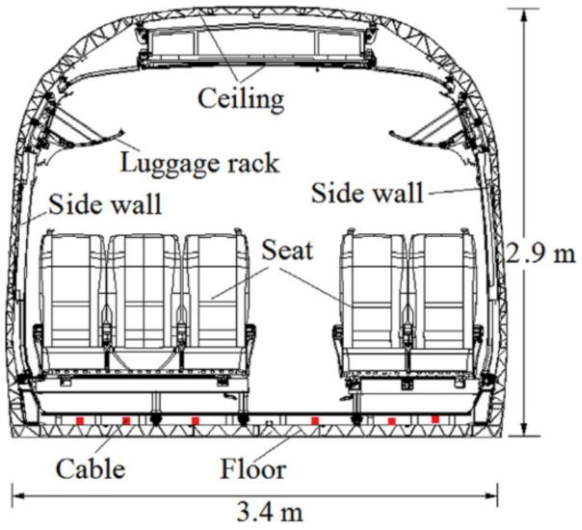


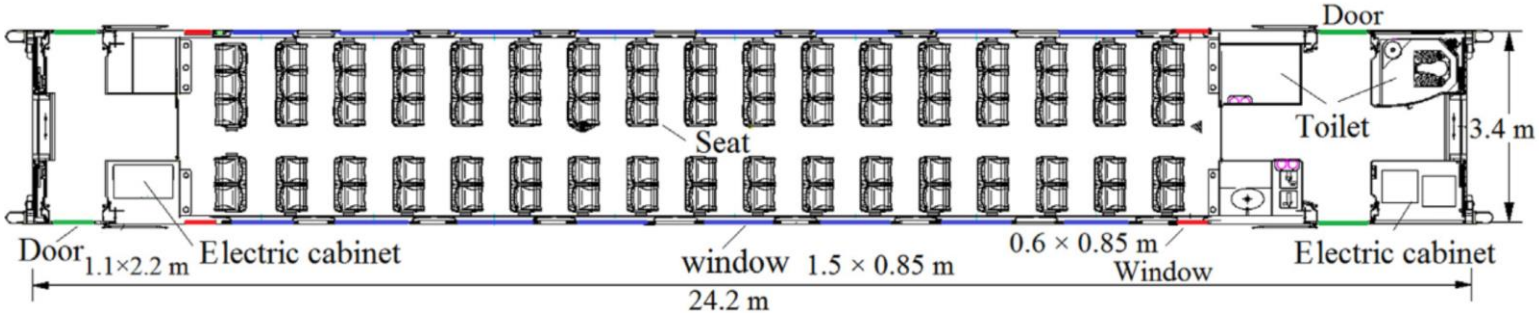
Reference: Okamoto, K., Otake, T., Miyamoto, H., Honma, M., Watanabe, N., 2013. Burning behavior of minivan passenger cars. Fire Safety Journal 62, 272–280.

HRR in vehicle fires

Example#4 - train







Reference: Zhou, Y., Wang, H., Bi, H., Liu, X., Gou, Q., 2020. Heat release rate of high-speed train fire in railway tunnels. Tunnelling and Underground Space Technology 105.

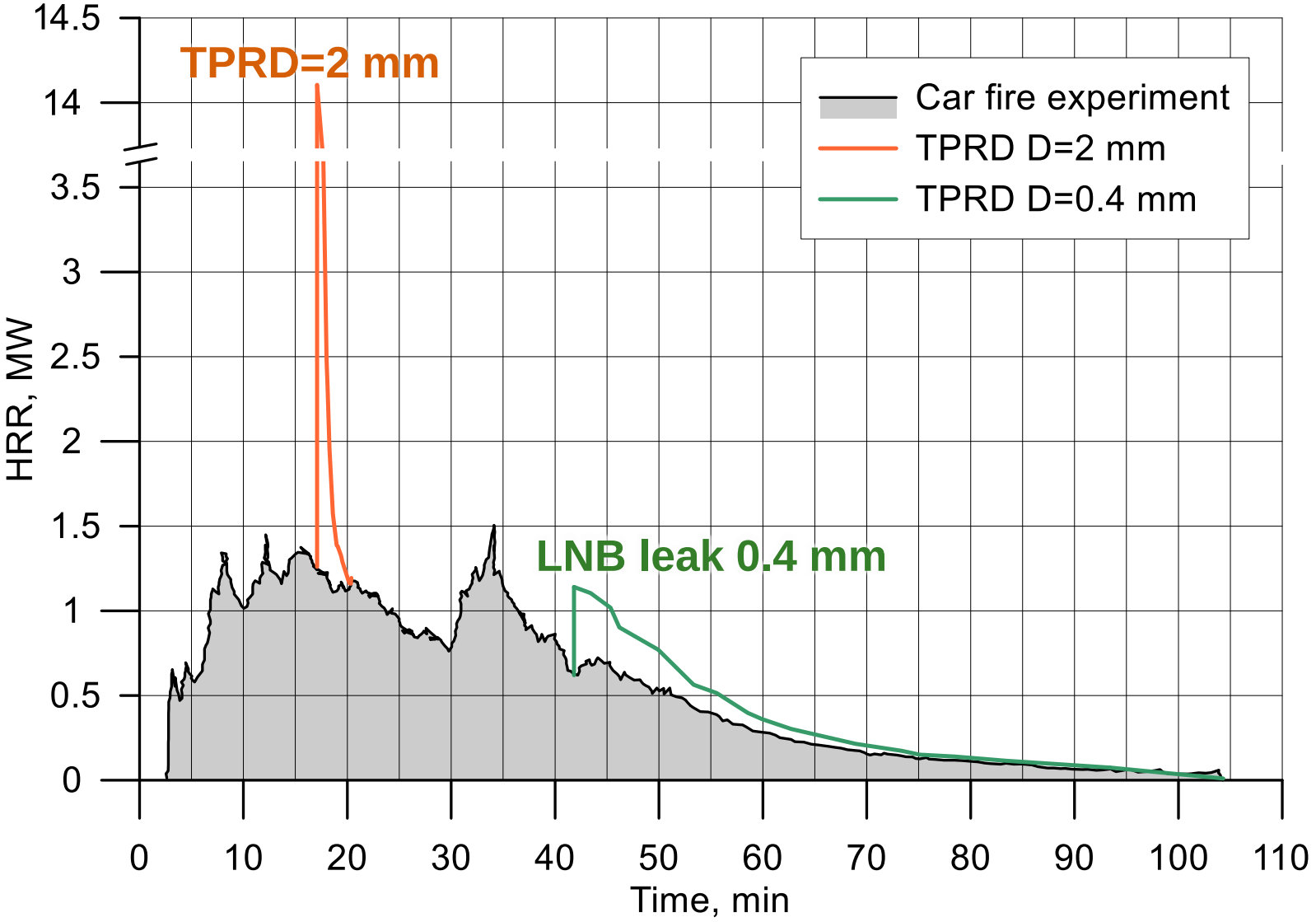
Hydrogen release contribution to the total vehicle fire HRR

TPRD orifice sizes

Hydrogen releases and HRRs

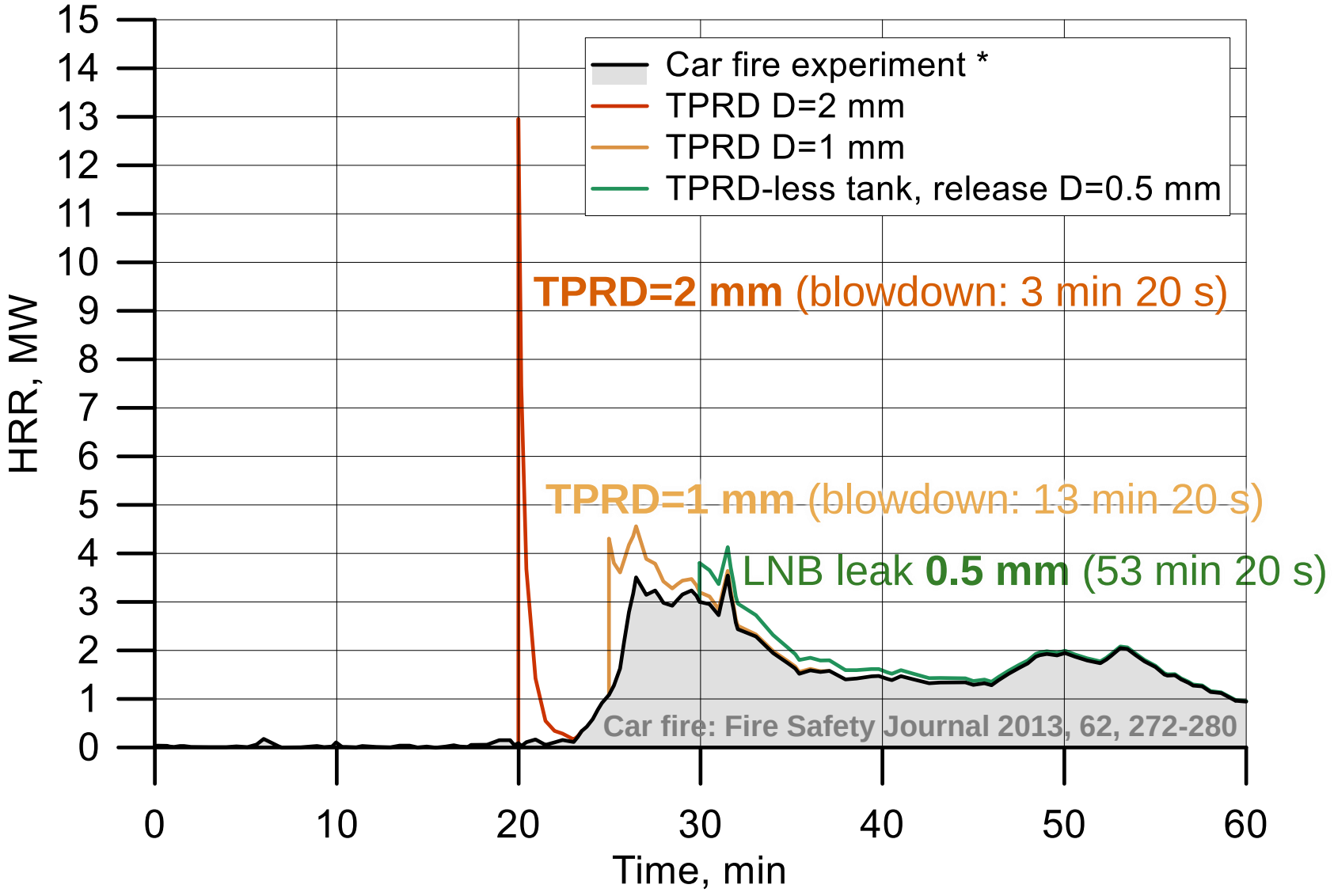
- Using experimental data from tests with micro LNB tanks at CEA, the estimated maximum orifice size equivalent to the cumulative size of the leaks is D=0.4 mm
- Used orifice sizes:
  - D=2 mm
  - D=0.4 mm

H2 release contribution to car fire HRR



Release from 62.4 L and 70 MPa tank

H2 release contribution to car fire HRR



Release from 62.4 L and 70 MPa tank

Conclusions

- The reduction of TPRD orifice size to below 0.5 mm and the use of explosion free in a fire tanks practically does not increase the contribution of the jet fire's HRR to the overall vehicle HRR
- This is unlike an ordinary TPRD orifice size, e.g. 2 mm, which increase HRR as much as 4-5 times (depending on a vehicle)
- GTR#13 fire test protocol should be updated, so that both, localised and engulfing portions include the gasoline/diesel fires – equivalent HRR/A
- Self-venting tanks should be introduced explicitly in GTR#13

Acknowledgements

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (JU) under grant agreement No 826193. The JU receives support from the European Union's Horizon 2020 research and innovation programme and United Kingdom, Germany, Greece, Denmark, Spain, Italy, Netherlands, Belgium, France, Norway, Switzerland.