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Progress on effect of hydrogen jet fire on mechanical ventilation system in underground parking

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Aim of the research

- The study aims at the development of a model to assess the effect of a hydrogen jet fire on mechanical ventilation system in an underground parking.
- Focus is posed on resolving the questions:
  - Are current ventilation requirements applicable?
  - Which is the maximum mass flow rate through a vehicle TPRD to fulfil current ventilation requirements?
- The study analyses the heat release rate from the jet fire through the TPRD of an on-board storage tank, as it may aggravate the vehicle fire consequences.

Ventilation in underground parking

BS 7346-7:2013

Requirements for mechanical ventilation in the event of fire:

- Clear the smoke produced by the fire to facilitate the occupants escape and the first responders intervention.
- Provide at least **10 ACH.**

Performance recommendations for equipment:

*"All fans intended to exhaust hot gases used within a car park ventilation system should be tested in accordance with BS EN 12101-3 to verify their suitability for operating at **300 °C** for a period not less than **60 minutes** (class F300)."*

Details of the study

Assumptions and scenarios

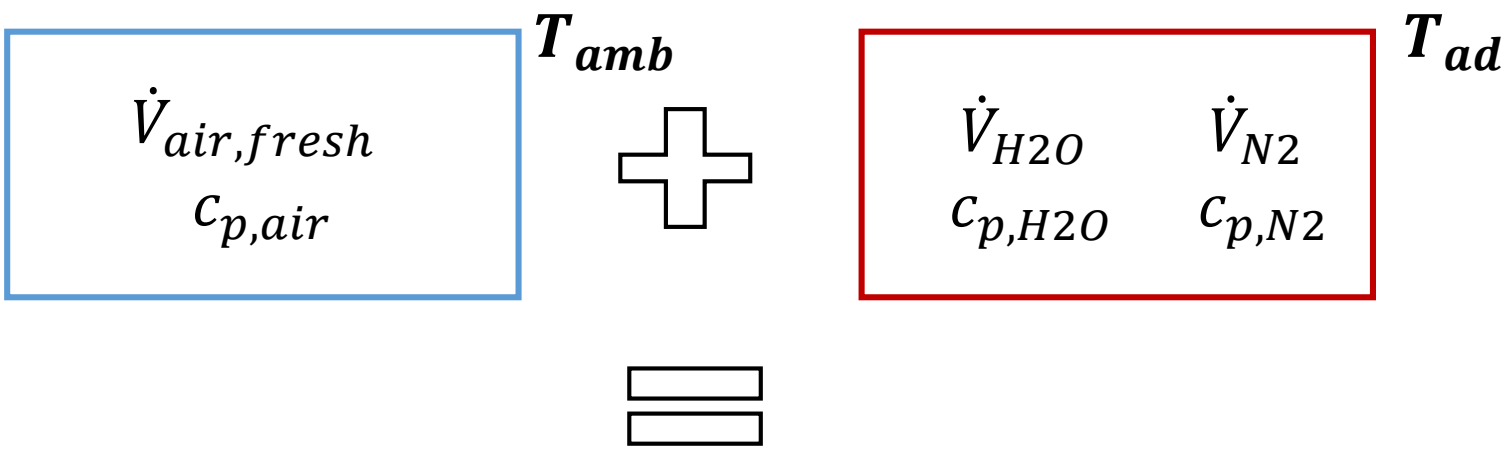
- Steady state releases.
- Ventilation: 10 ACH of fresh air as reference case.
- The model assumes one extraction vent.
- Five TPRD release scenarios are considered.

Diameter, mm	Storage pressure, bar	Mass flow rate, kg/s
0.5	700	0.007
1	700	0.027
2	700	0.11
5	700	0.67
5	350	0.38

Perfect mixing model

Model description and assumptions

- Isobaric combustion.
- Adiabatic and **perfect mixing** of total fresh air given by mechanical ventilation and combustion products produced by the hydrogen jet fire.

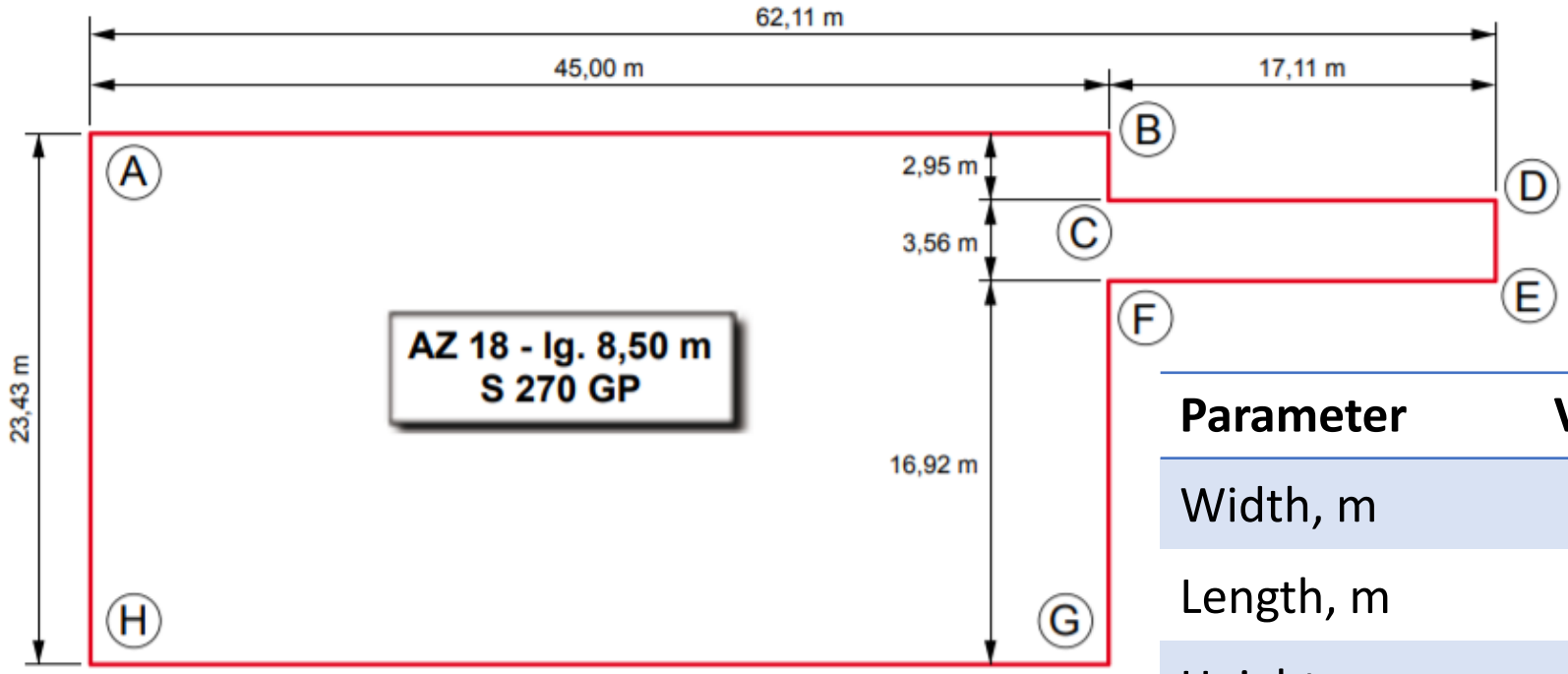


$$T_{final} = \frac{\dot{m}_{H2O} c_{p,H2O} T_{ad} + \dot{m}_{N2} c_{p,N2} T_{ad} + \dot{m}_{air} c_{p,air} T_{amb}}{\dot{m}_{H2O} c_{p,H2O} + \dot{m}_{N2} c_{p,N2} + \dot{m}_{air} c_{p,air}}$$

Case study A

Layout of the underground car park

Real underground car park in St. Martnes Latem (Gent, Belgium)



Parameter	Value
Width, m	23.4
Length, m	45
Height, m	3

Results

Case study A: 23x45x3 m park (one extraction vent)

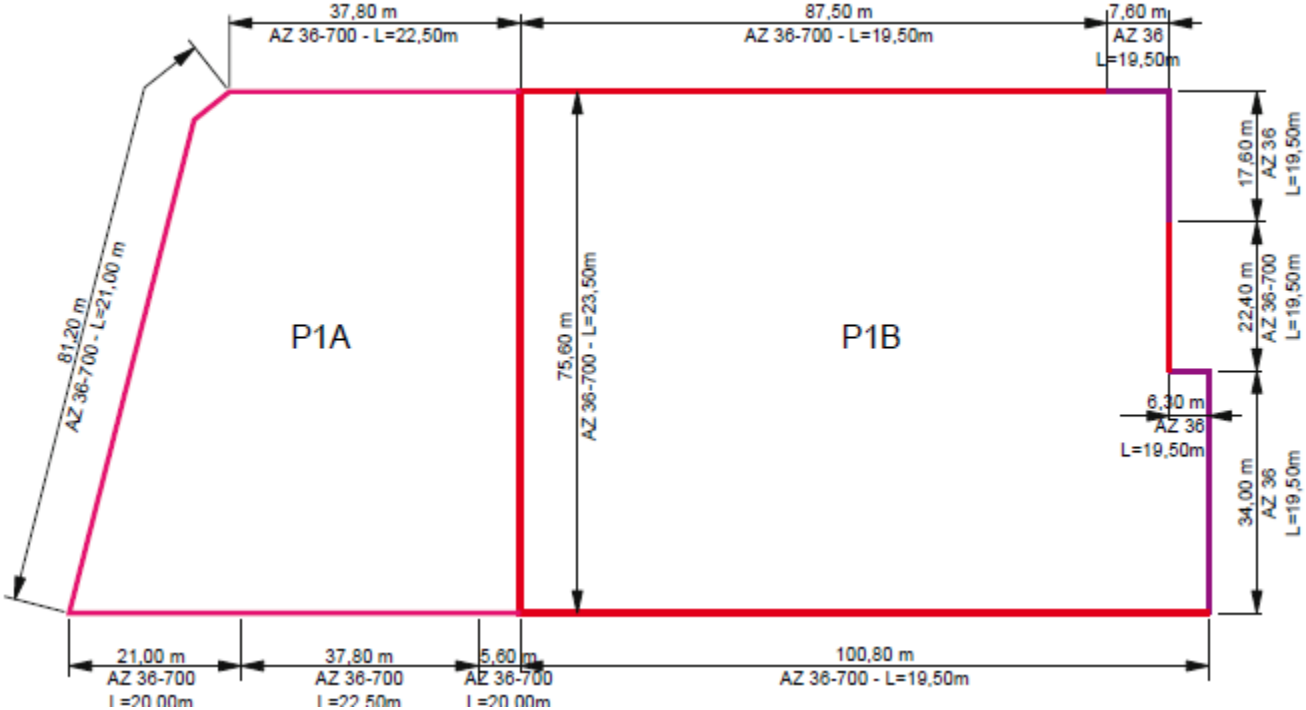
TPRD diameter, mm	Storage pressure, bar	Temperature at the entrance of the extraction duct, °C	
		15 ACH	10 ACH
0.5	700	65.4	90.3
1	700	210.6	302.0
2	700	706.4	977.3
5	700	Not acceptable	
5	350	Not acceptable	

Regulations “limit” = 300 °C

Case study B

Layout of the underground car park

Real underground 3 storeys car park in Haarlem (The Netherlands).



P1B car park

Parameter	Value
Width, m	75.6
Length, m	100.8
Height, m	2.6

Results

Case study B: 76x100x2.6 m park (one extraction vent)

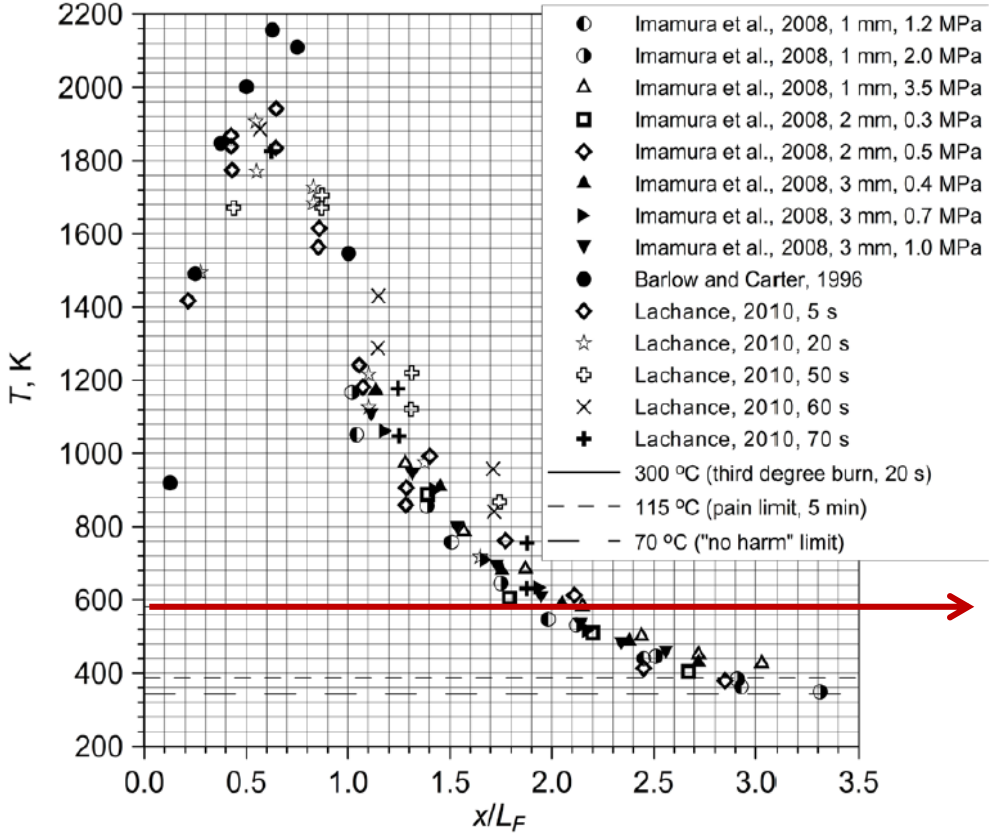
TPRD diameter, mm	Storage pressure, bar	Temperature at the entrance of the extraction duct, °C	
		15 ACH	10 ACH
0.5	700	23.3	27.5
1	700	48.5	65.1
2	700	146.4	209.3
5	700	726.6	1003.4
5	350	445.1	630.7

Regulations “limit” = 300 °C

Temperature decay in the jet

Hydrogen jet fires

- Distribution of temperature along the axis of a hydrogen jet fire as function of distance from the nozzle, x, normalized by the flame length, Lf (Molkov, 2012).



<u>Additional approach</u>

Recommending a minimum distance between a hydrogen powered vehicle parking slot and a vent to satisfy regulations

Regulation recommendation on maximum temperature in the ventilation ducts (300 °C) is reached at x≈2Lf

Results

Minimum distance to TPRD location

- Assumption: hydrogen jet fires directed towards the vent.
- Recommended distance between a parked hydrogen powered vehicle and a ventilation extraction duct:

TPRD diameter, mm	Storage pressure, bar	Minimum distance to TPRD, m
0.5	700	3.3
1	700	6.6
2	700	13.2
5	700	33.0
5	350	26.0

- CFD modelling may be needed for exact calculations of downwards jets.

Car fire: heat release rate (HRR)

BS 7346-7:2013

❖ Steady-state design fires

"The design fire should either use the appropriate value of heat release rate and other parameters from Table 1 or an alternative appropriate in the circumstances of the particular design…"

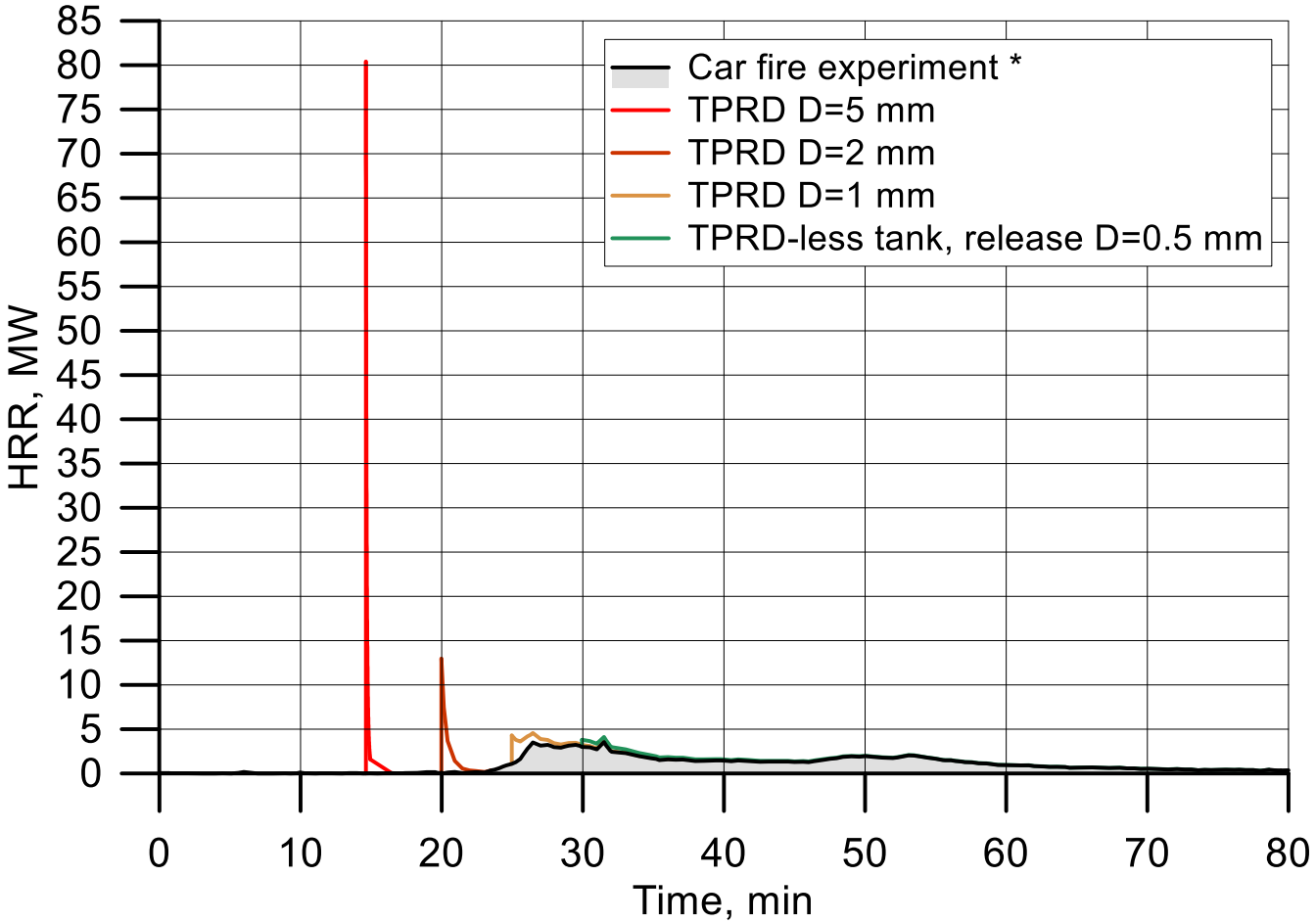
Fire parameters	Indoor car park without sprinkler system	Indoor car park with sprinkler system	2 car stacker with sprinklers
Dimensions	5 m × 5 m	2 m × 5 m	2 m × 5 m
Perimeter	20 m	14 m	14 m
Heat release rate	8 MW	4 MW	6 MW

❖ Time-dependent design fires

"The design fires should be based on an experimental test fire, …"

HRR in hydrogen vehicle fire (1/2)

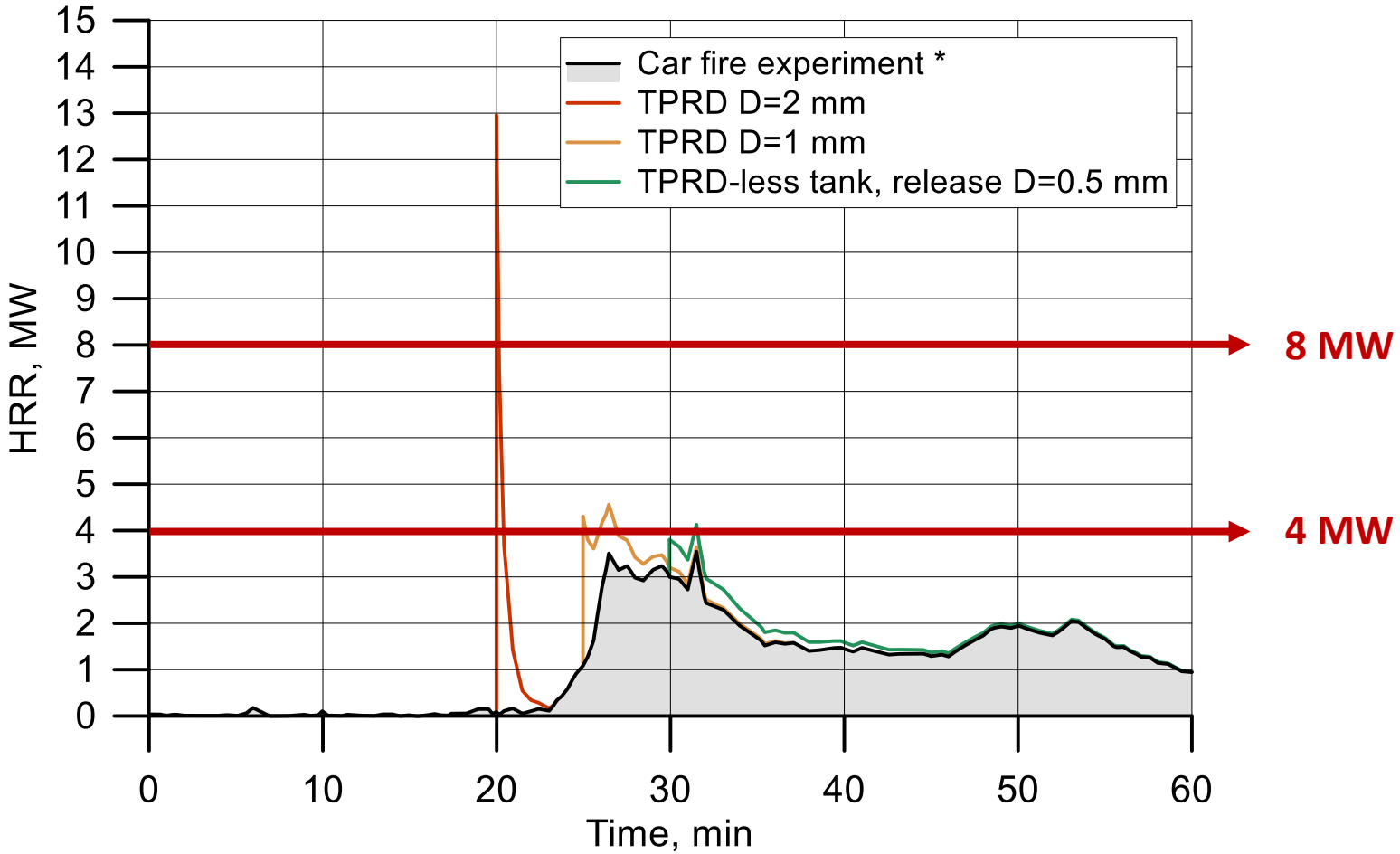
Car fire: Fire Safety Journal 2013, 62, 272-280



- **5 mm** release: 32 s.

HRR in hydrogen vehicle fire (2/2)

Car fire: Fire Safety Journal 2013, 62, 272-280



- **2 mm** release: 3 min 20 s, **1 mm** release: 13 min 20 s.
  - **0.5 mm** release: 53 min 20 s (TPRD-less tank).

Concluding remarks

… and future works

- The simplified engineering model can be employed to assess effect of a hydrogen jet fire on mechanical ventilation system.
- The model performance will be assessed against experimental test planned by USN.
- The model evaluates the maximum TPRD size allowable in a certain underground car park to fulfil ventilation requirements.
- The model should be further refined to consider multiple extraction ducts and blowdown of a storage tank.
- CFD modelling may be required beyond the applicability range of the developed model.
- The effect of a hydrogen jet fire on a design HRR of a vehicle was found to be negligible for TPRD<1mm.

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