Progress in GTR#13 fire test protocol improvement

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Two items for discussion

- HRR approach versus specific HRR (HRR/A) approach
- HRR/A approach versus heat flux approach

Definitions

Heat release rate (HRR)	Heat release rate in a fire [kW]
Specific heat release rate (HRR/A)	Heat release rate in a fire per fire area = heat release rate per unit area [kW/m^2]
Fire resistance rating (FRR)	Time from the start of a fire until tank rupture in a fire

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HRR approach versus specific HRR (HRR/A) approach

Expanded validation domain: 6 tests

Is FRR saturation still applicable?

Test burner	Tank parameters			Fire source (burner) parameters			
	Tank type, *V* and *P*	Tank sizes: *L*×*W*, m	Tank FRR, min	HRR, kW	Burner sizes: *L*×*W*, m	A, m^2	HRR/A, kW/m^2
CH4-air premixed [1]	Type IV, 36 L, 700 bar	0.91×0.325	16	79	0.849×0.32	0.272	290.8
			8	165	0.835×0.32	0.267	617.5
C3H8 [2,3]	Type III, 88 L, 350 bar*	0.84×0.41	12.3	265	0.889×0.457	0.406	652
	Type IV, 72.4 L, 350 bar		6.45	370	0.838×0.3	0.251	1471.4
Heptane, pool fire [4,5]	Type IV, 36 L, 700 bar*	N/A	6.5	1500	0.8×1.2	0.96	1562.5
	Type IV, 100 L, 700 bar	N/A	6	4100	0.8×1.2	0.96	4270.8

Note: * 2 newly added experiments.

Sources:

[1] D. Makarov, Y. Kim, S. Kashkarov, and V. Molkov, ISFEH8, Hefei, China, 2016.

[2] N. Weyandt, Southwest Research Institute report for the MVFRI, 2006.

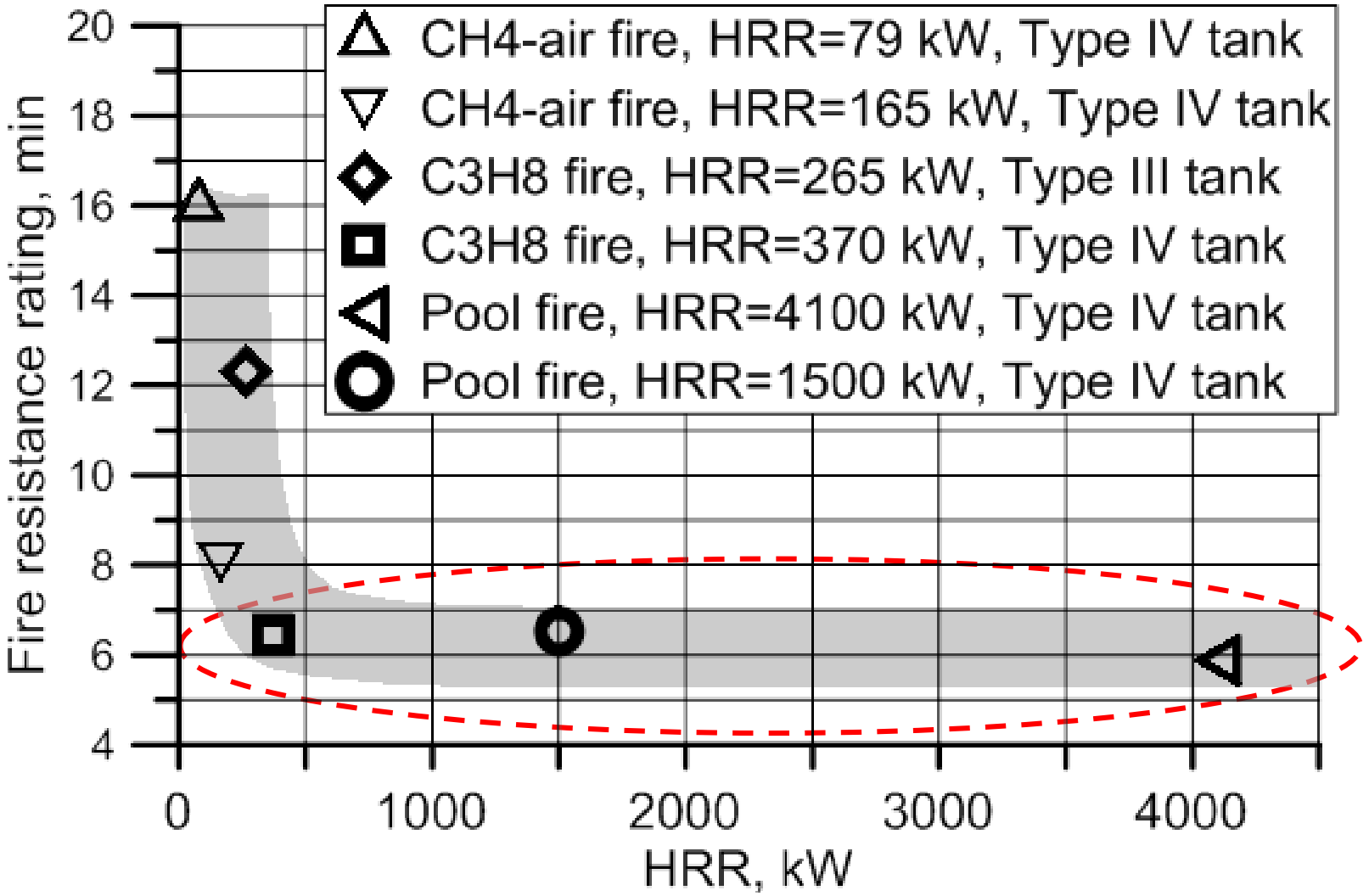
[3] N. Weyandt, Southwest Research Institute report for the MVFRI, 01.06939.01.001, 2005.

[4] S. Ruban et al., IJHE, 2012.

[5] L. Bustamante Valencia, P. Blanc-Vannet, L. Heudier, and D. Jamois, Fire Technology, 2016.

FRR saturation with HRR still works

Reproducibility criteria: HRR>350 kW



HRR approach

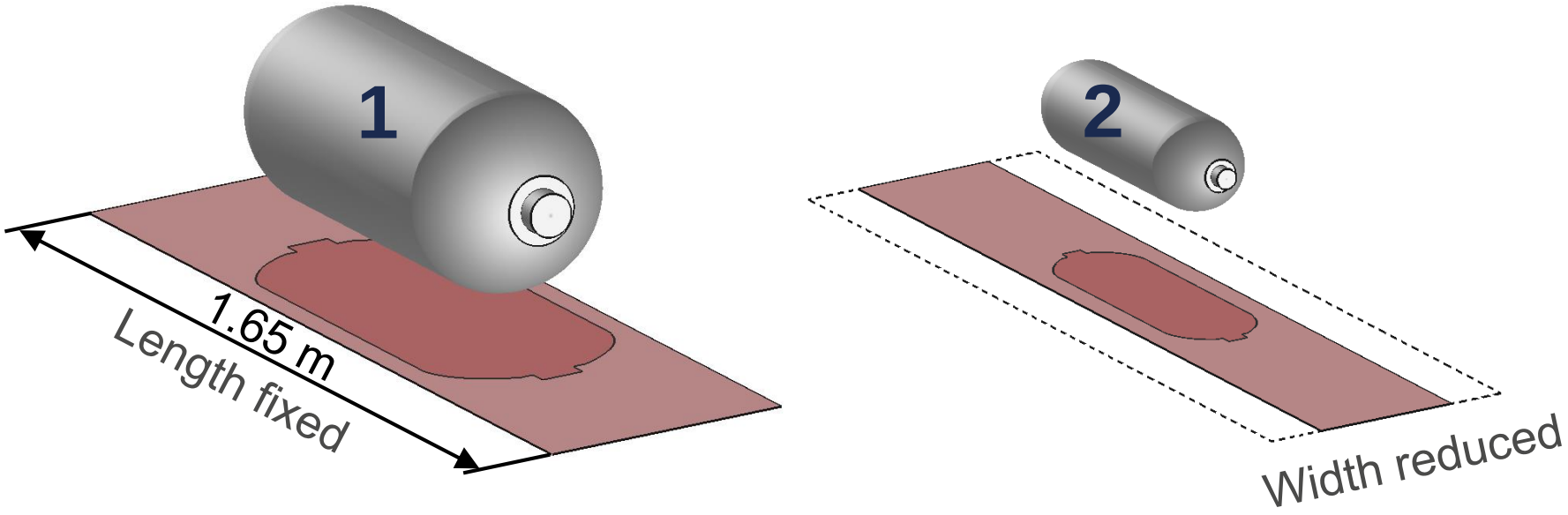
Three weak points

- Only limited number of fire tests with burst are available for validation (please contribute).
- If we fix HRR but change burner size (only width can be changed, because the length of 1.65 m is fixed) then HRR per unit area of tank projection will change with tank size.
- Tanks with length above 1.65 m would be a subject of only “localised” fire.

Benefits of HRR/A approach

The same heat flux to different size tanks

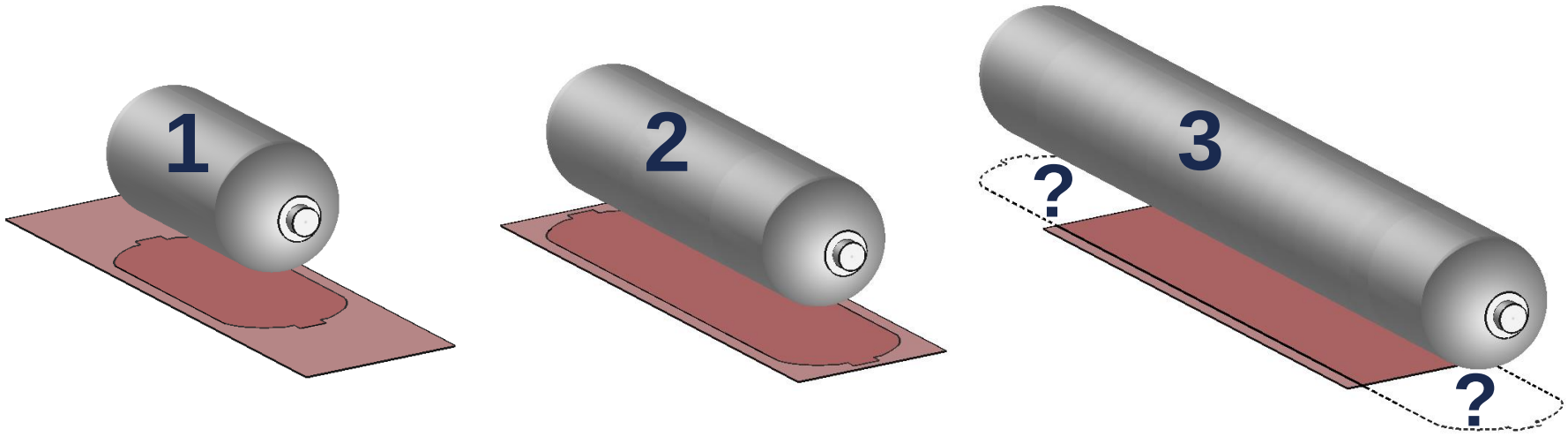
GTR#13: *"The width of the fire source encompasses the entire diameter (width) of the storage system".*



- **HRR approach: $HRR_1 = HRR_2$ then $HRR/A_1 \neq HRR/A_2$**
- **HRR/A approach: $HRR/A_1 = HRR/A_2$ thus the change of burner size doesn't change HRR/A and thus heat flux to tank**

Benefits of HRR/A approach

The same heat flux to different size tanks



The same heat flux to different size tanks should be provided: there is a need to relax requirement of 1.65 m length

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HRR/A approach

Is there saturation of FRR with HRR/A?

- HRR per unit area of a tank projection doesn't depend on a tank size (if the tank projection is within the burner borders).
- GTR#13 requirement of the burner length 1.65 m should be relaxed (changed to the condition of tank projection to be within the burner borders).

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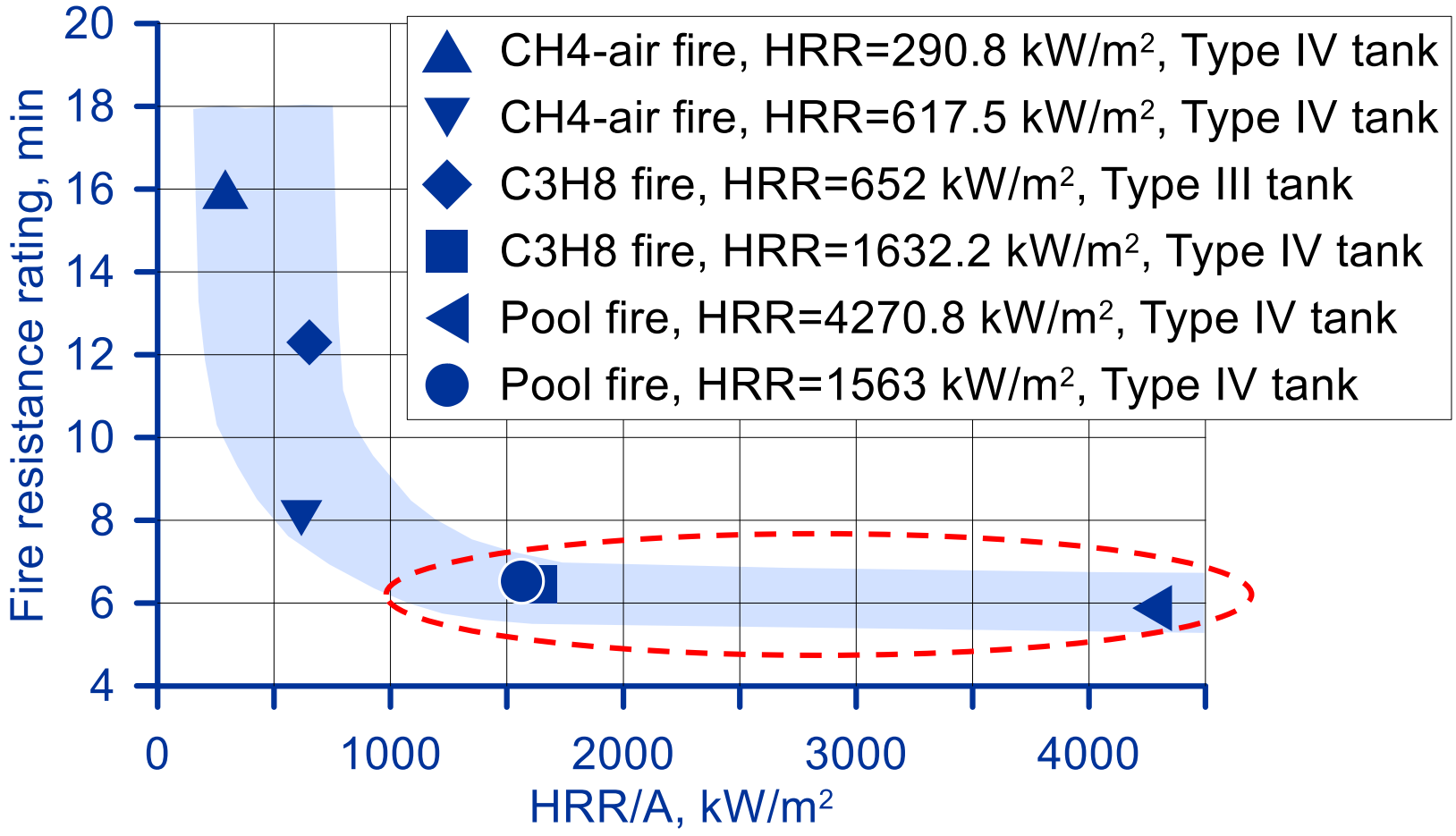
HRR/A approach

Saturation at HRR/A > 1000 kW/m²



Specific HRR saturation at about HRR/A>1000 kW/m²

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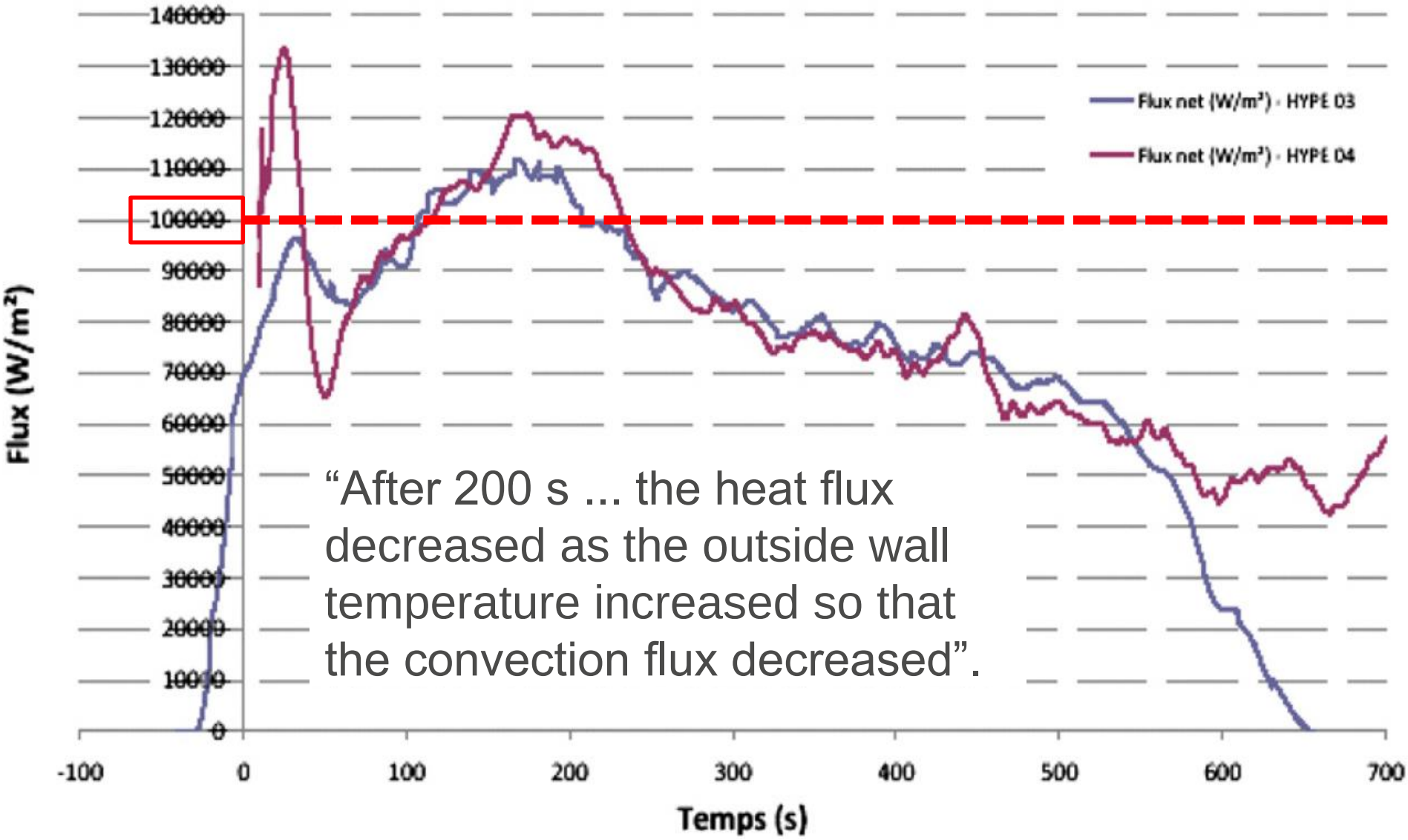
HRR approach versus heat flux approach

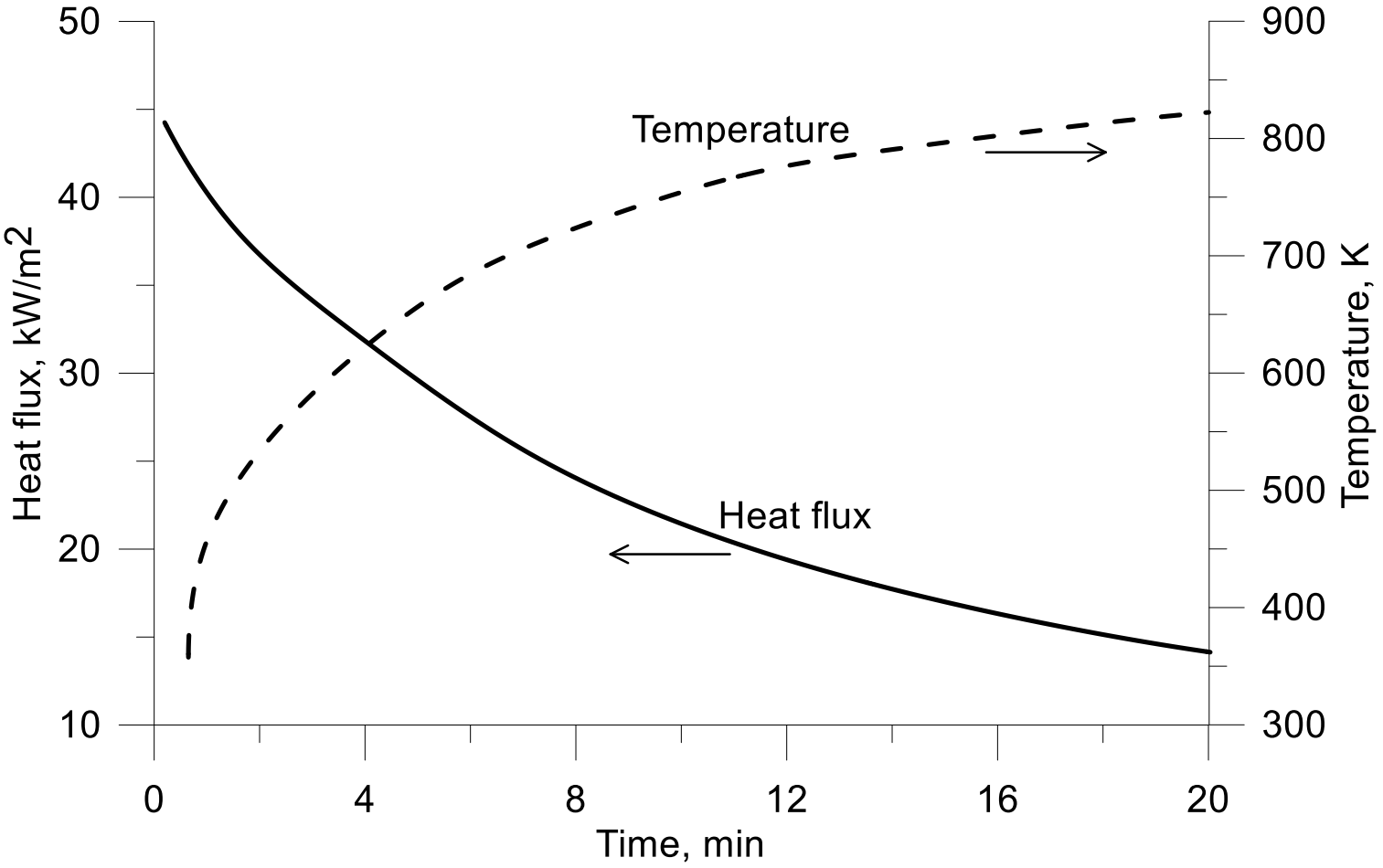
Experimental heat flux on tank mock-up



Source: *S. Ruban et al., 'Fire risk on high-pressure full composite cylinders for automotive applications', IJHE, 2012.*

Heat flux (CFD): decrease confirmed

Constant heat flux is not possible



Source: *Y. Kim, D. Makarov, S. Kashkarov, P. Joseph, and V. Molkov, 'Modelling heat transfer in an intumescent paint and its effect on fire resistance of on-board hydrogen storage', International Journal of Hydrogen Energy, 2017*

Concluding remarks

- Previously suggested FRR saturation limit for HRR above 350 kW is changed to more controlled FRR saturation limit for specific heat release rate HRR/A above 1 MW/m^2.
- The new HRR/A approach will allow to exclude effect of tank size on FRR (as it is in the previously suggested HRR approach).
- The length of the burner 1.65 m should be relaxed. Tank projection should be within a burner border and the burner should provide HRR/A to ensure FRR saturation level (HRR/A should be above 1 MW/m^2)
- Experimental and numerical studies demonstrate that the heat flux on a tank surface is changing in time and it's impractical to keep it always above 100 kW/m^2.
- The use of easily controllable in fire test specific heat release rate (HRR/A) seems preferable compared to the use of heat flux (changing in time and changes with the change of tank material) sensors to provide fire test protocol reproducibility.

THANK YOU

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