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Design of tank-TPRD system to exclude rupture in a fire and the pressure peaking phenomenon

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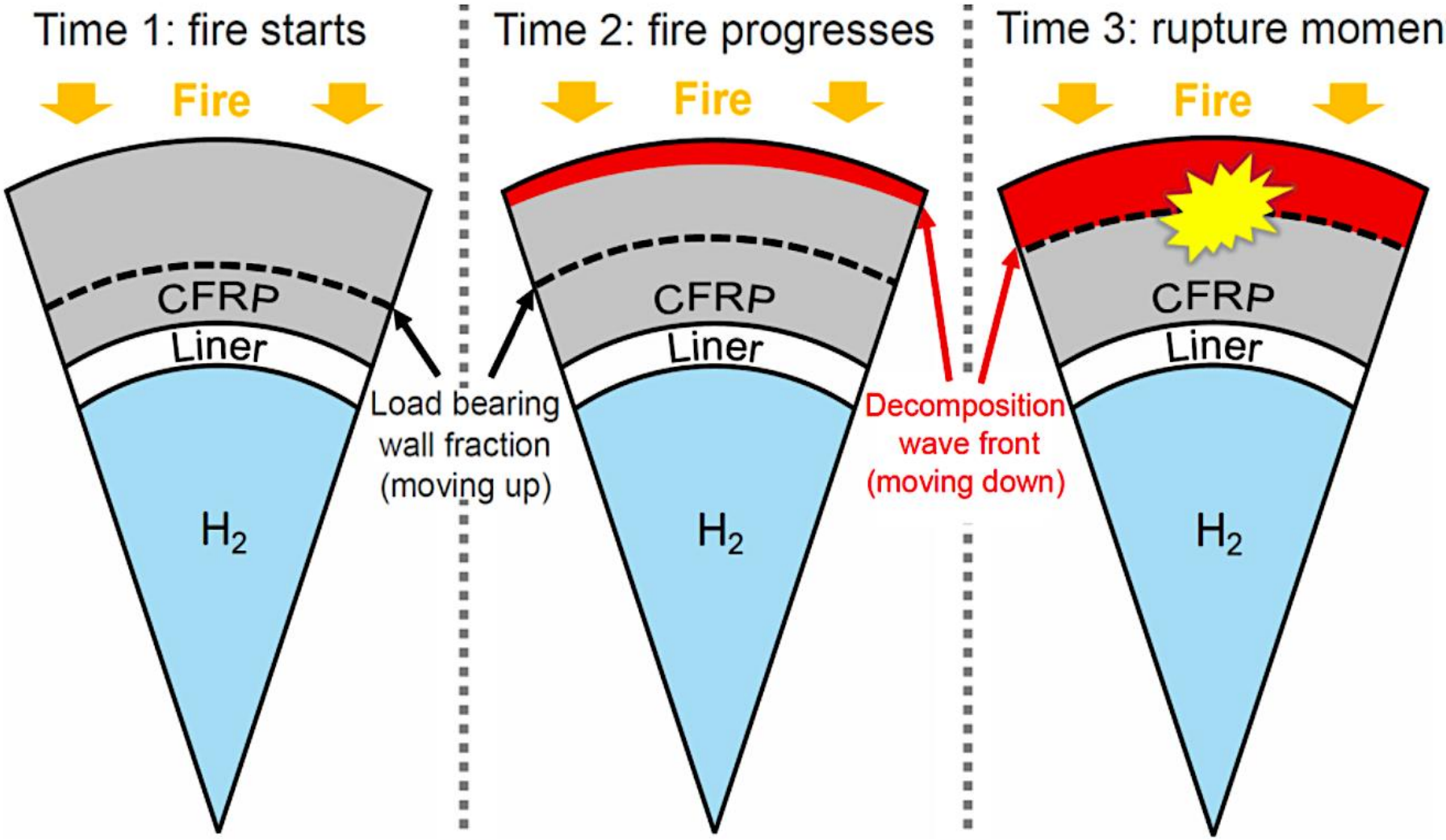
Abbreviations and definitions

FRR	-	Fire resistance rating: time from burner ignition until tank's rupture in a fire (without TPRD or failed TPRD or localised fire far from TPRD, e.g. in a smouldering fire)
IR	-	Individual Risk
LNB	-	Leak-no-burst safety technology, producing hydrogen micro-leaks from the tank in the event of a fire and releasing hydrogen safely
NWP	-	Nominal Working Pressure
SoC	-	State of Charge; SAE J2601: "ratio of CHSS hydrogen density to the density at NWP rated at the standard temperature 15 ºC"
TPRD	-	Thermally activated pressure relief device

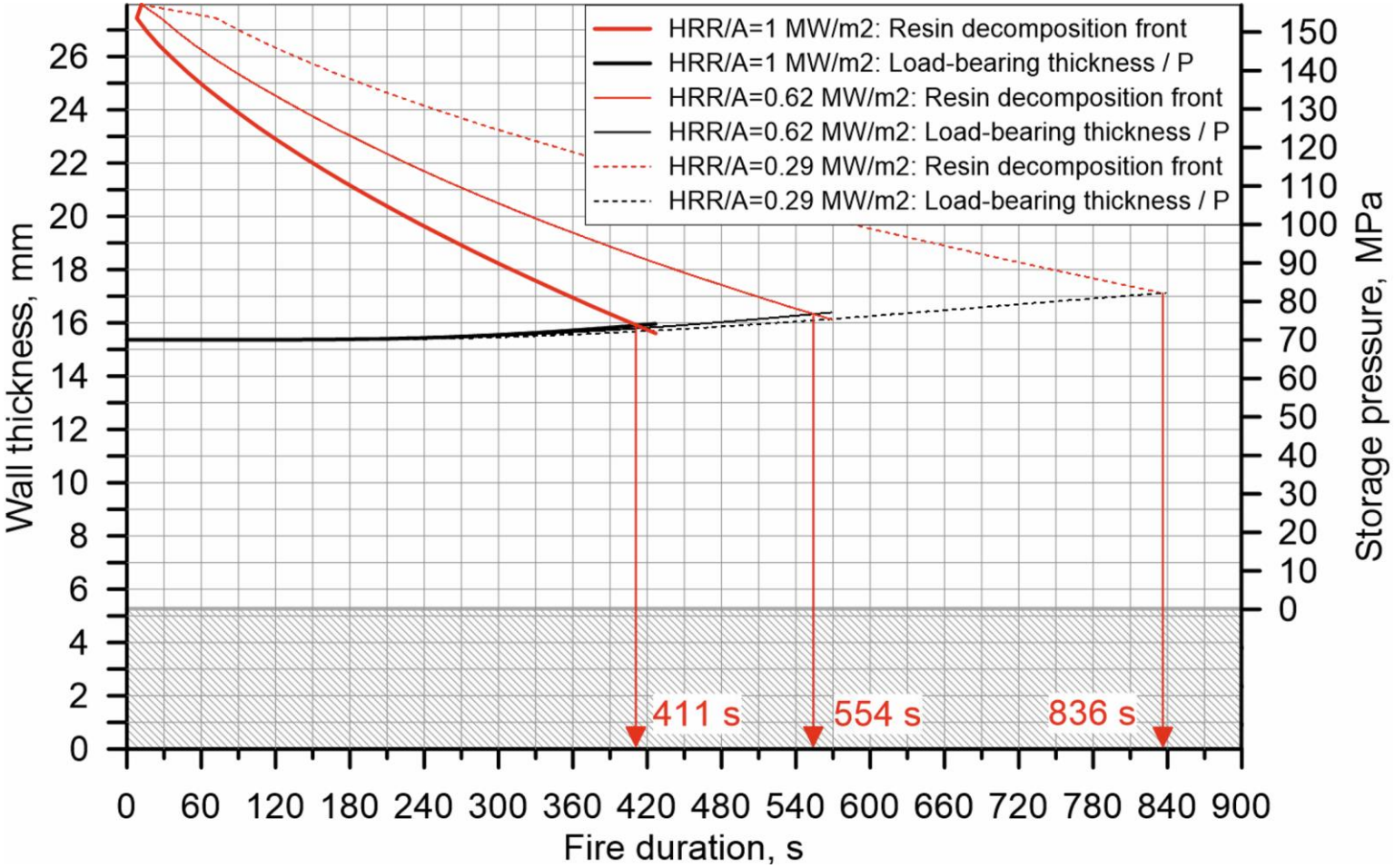
Mechanism of hydrogen tank failure in a fire

Composite tank failure mechanism



Tank with failed/blocked TPRD

Effect of HRR/A on tank FRR (36 L, 70 MPa)

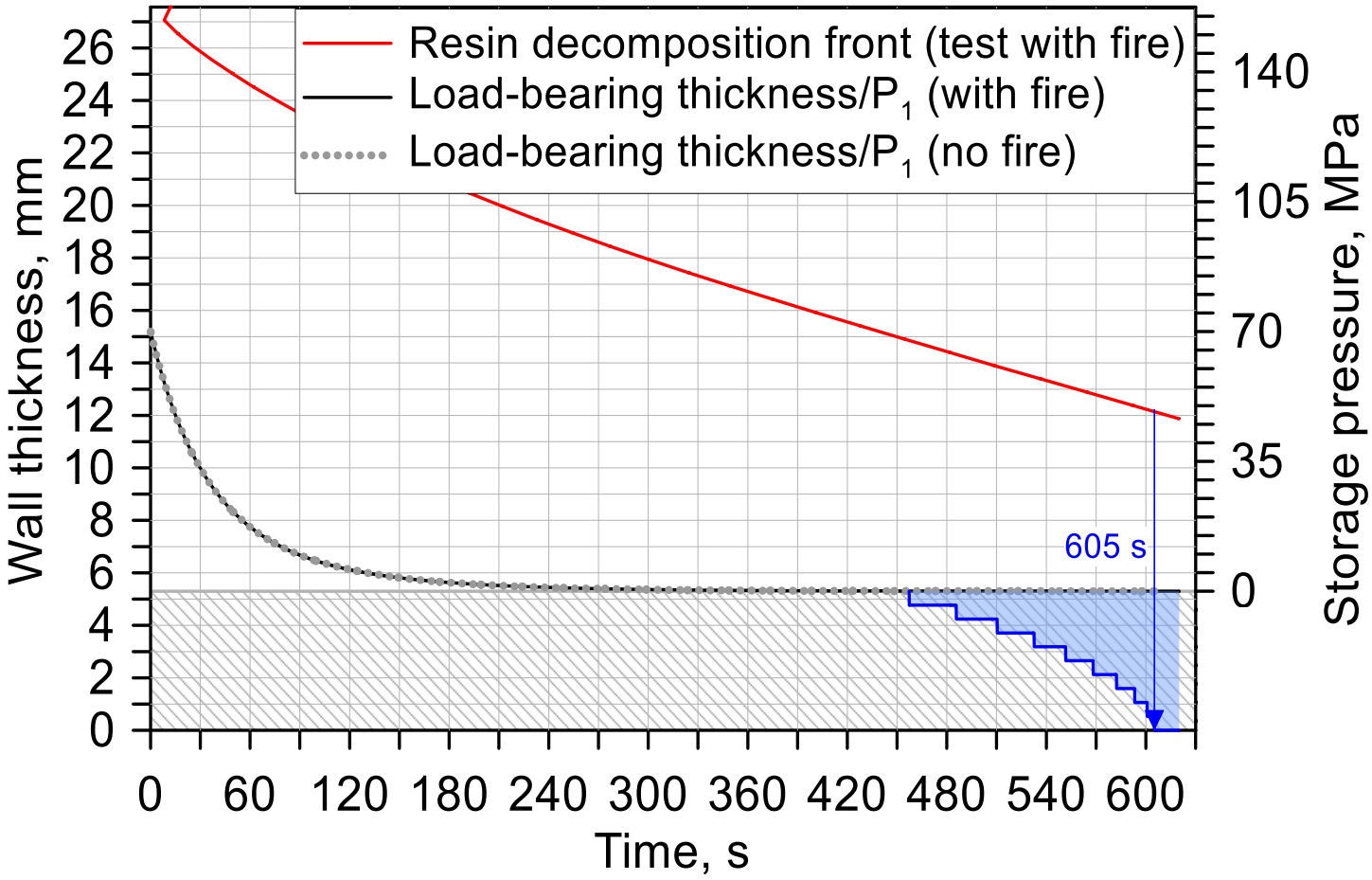


The increase in fire intensity (HRR/A) significantly increases the rate of resin decomposition and thus reduces the time to rupture (FRR)

Tank-TPRD system in a fire

Tank-TPRD system

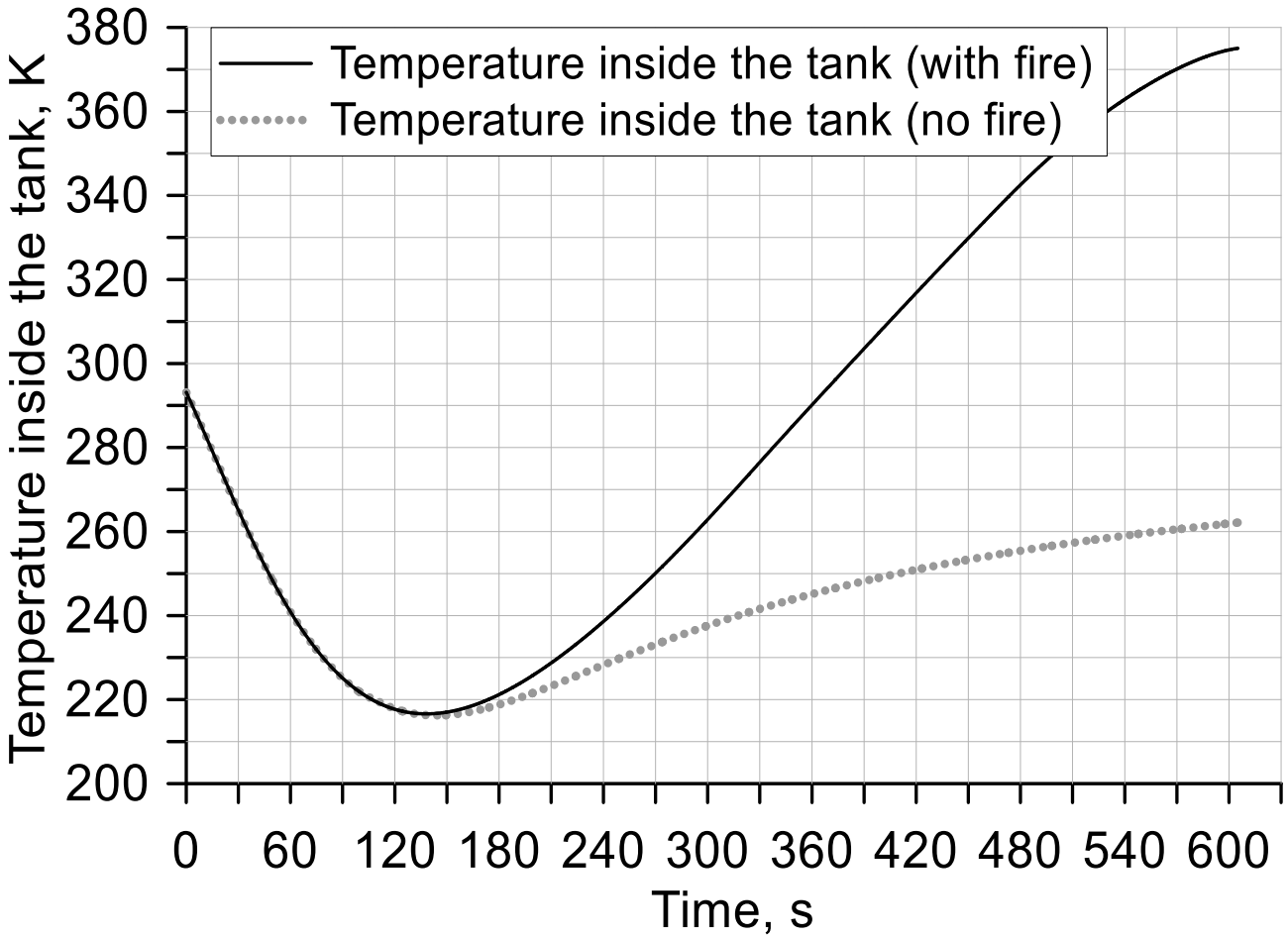
Effect of a fire on tank blow-down (36 L, 70 MPa)



Storage pressure/wall load-bearing thickness

Tank-TPRD system

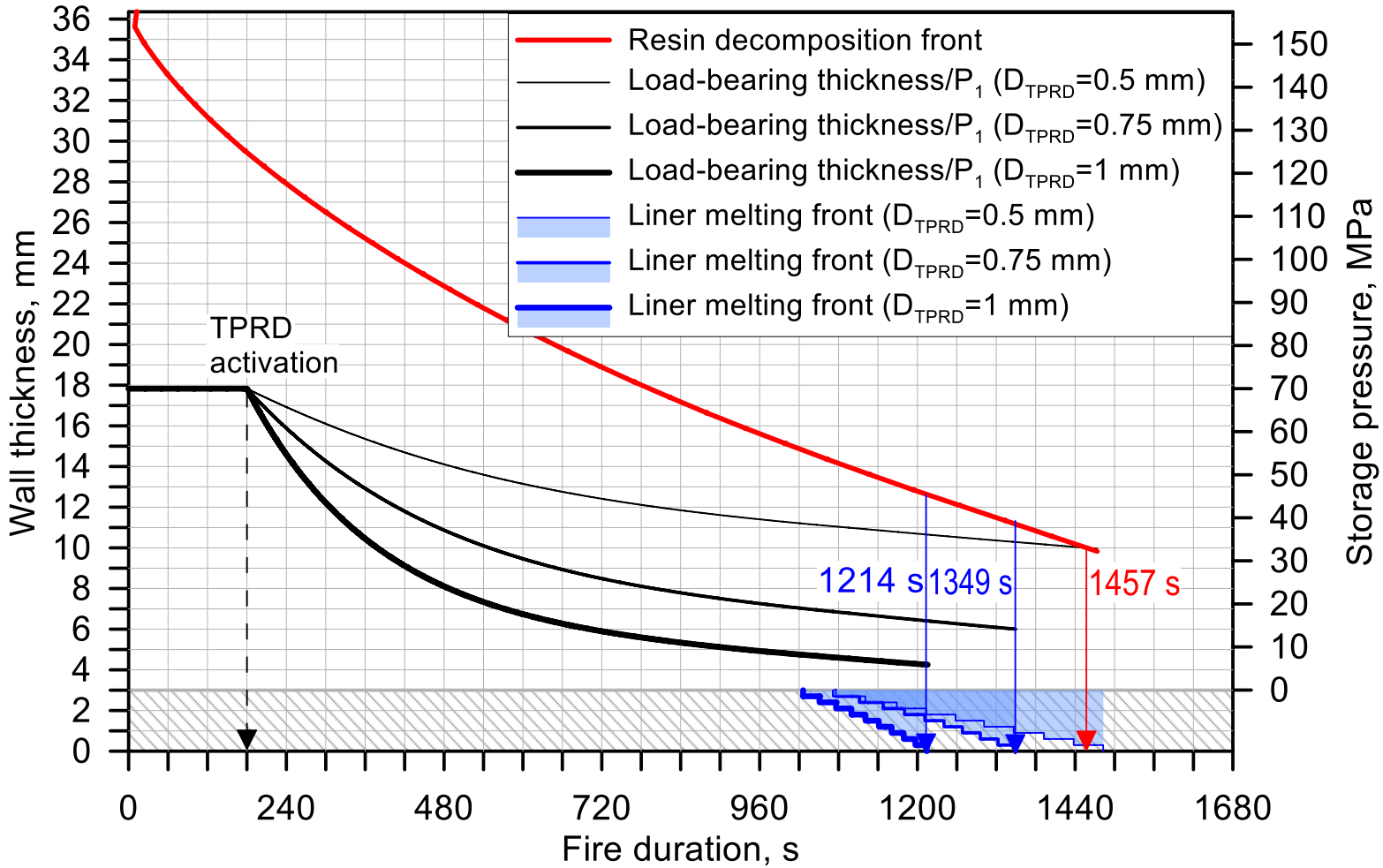
Effect of a fire on tank blow-down (36 L, 70 MPa)



Temperature histories in the tank

Tank-TPRD system

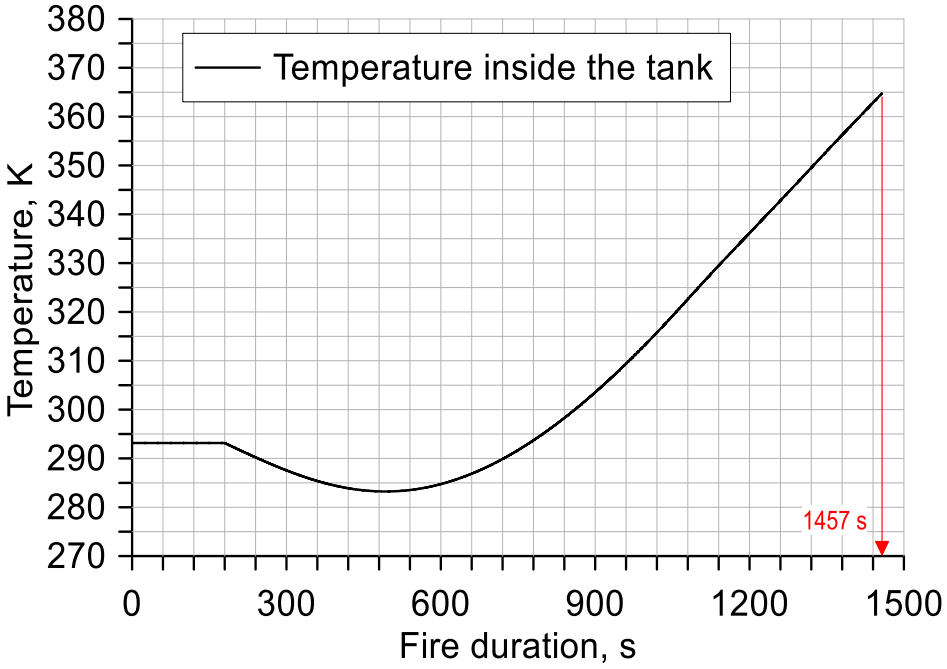
Hydrogen tank blow-down (244 L, 70 MPa)

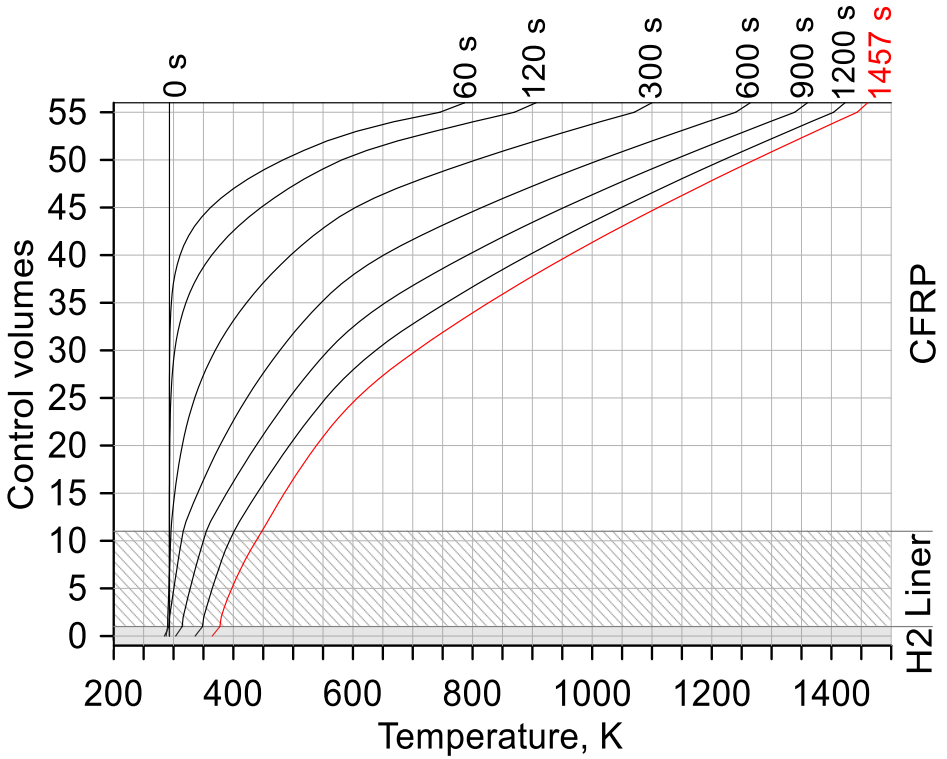


TPRD D=0.75 mm is sufficient to blow-down 244 L tank in a fire of HRR/A=1 MW/m^2

Tank-TPRD system

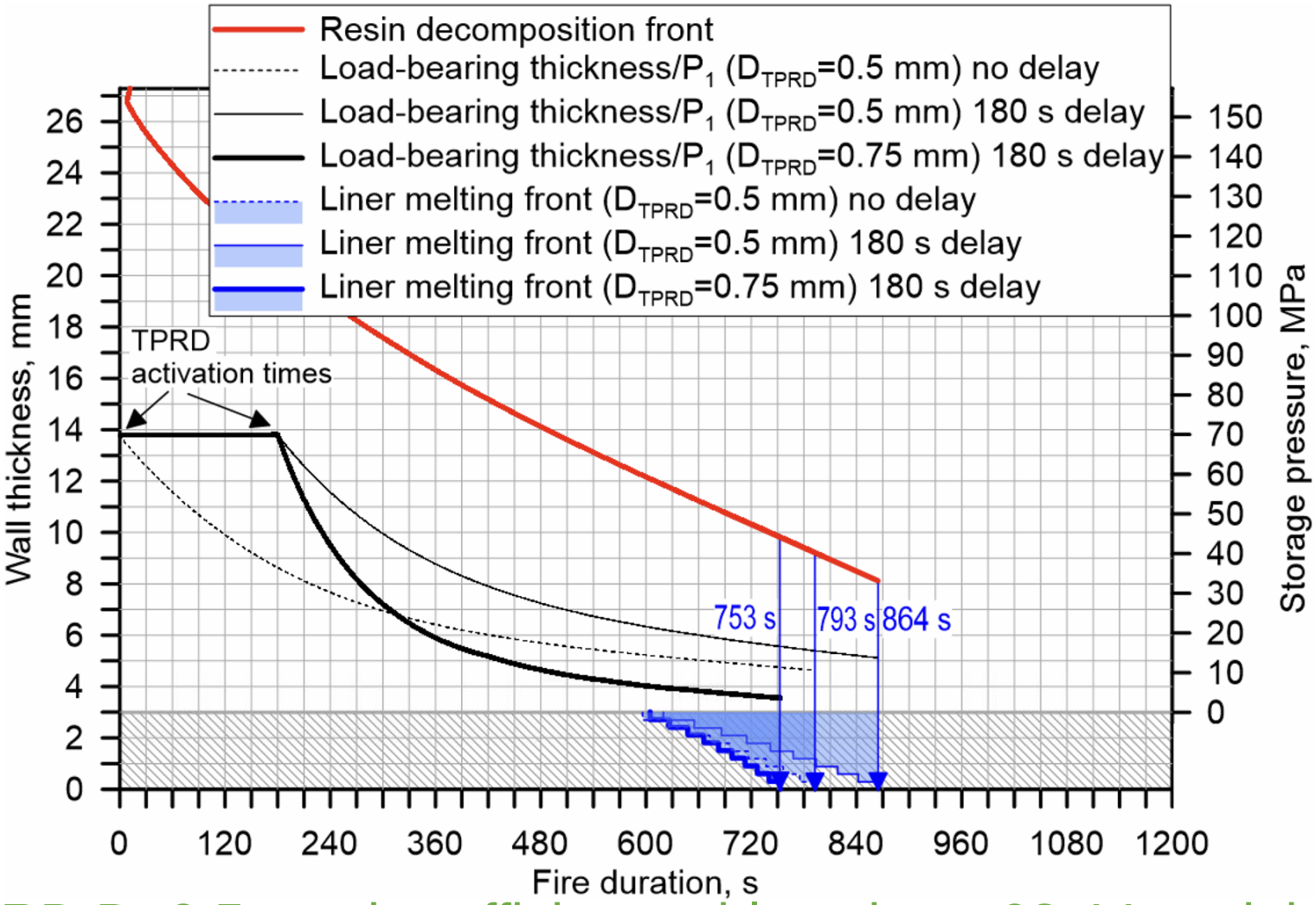
Hydrogen tank blow-down (244 L, 70 MPa)





Tank-TPRD system

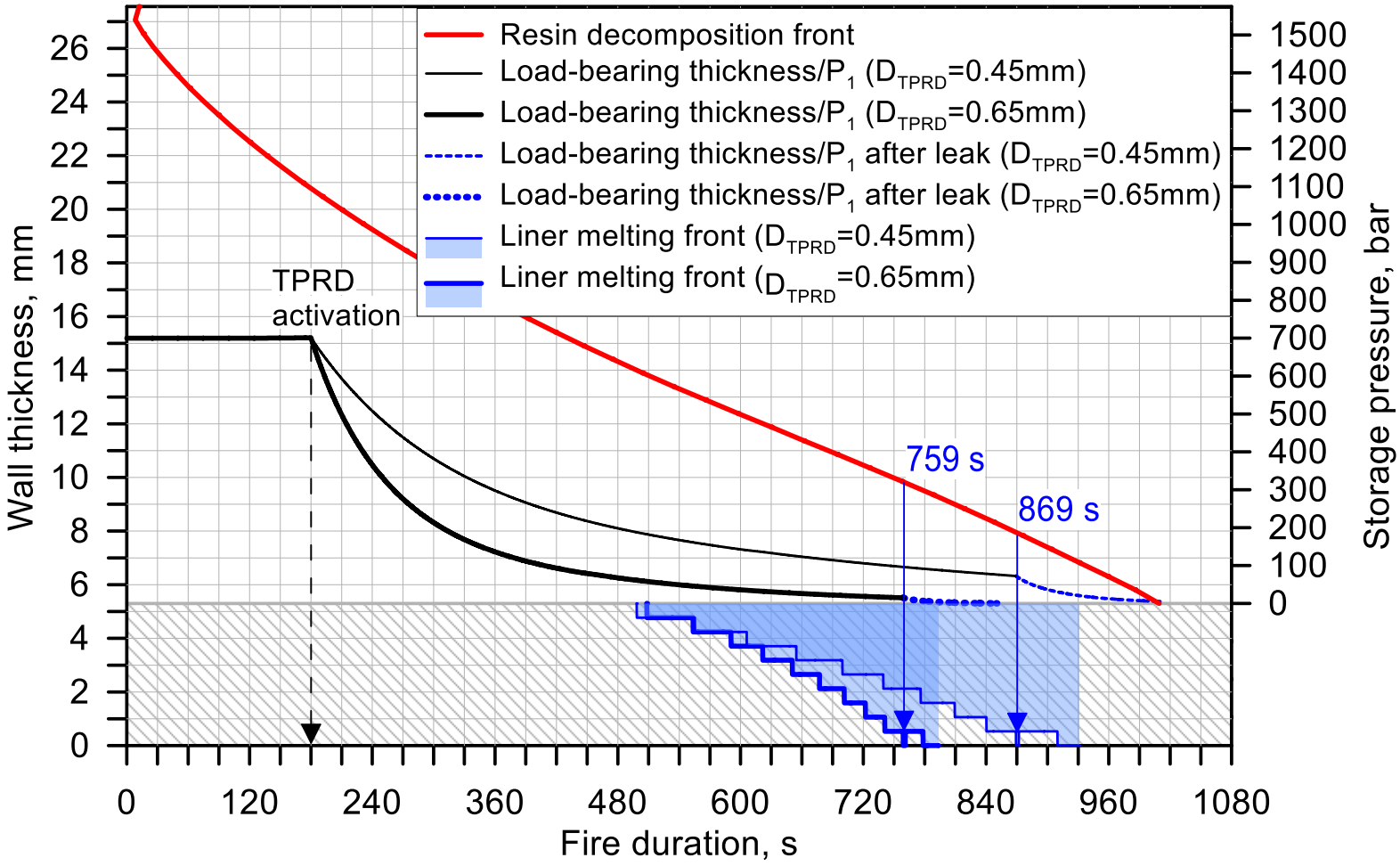
Hydrogen tank blow-down (62.4 L, 70 MPa)



TPRD D=0.5 mm is sufficient to blow-down 62.4 L tank in a fire of HRR/A=1 MW/m^2

Tank-TPRD system

Hydrogen tank blow-down (36 L, 70 MPa)

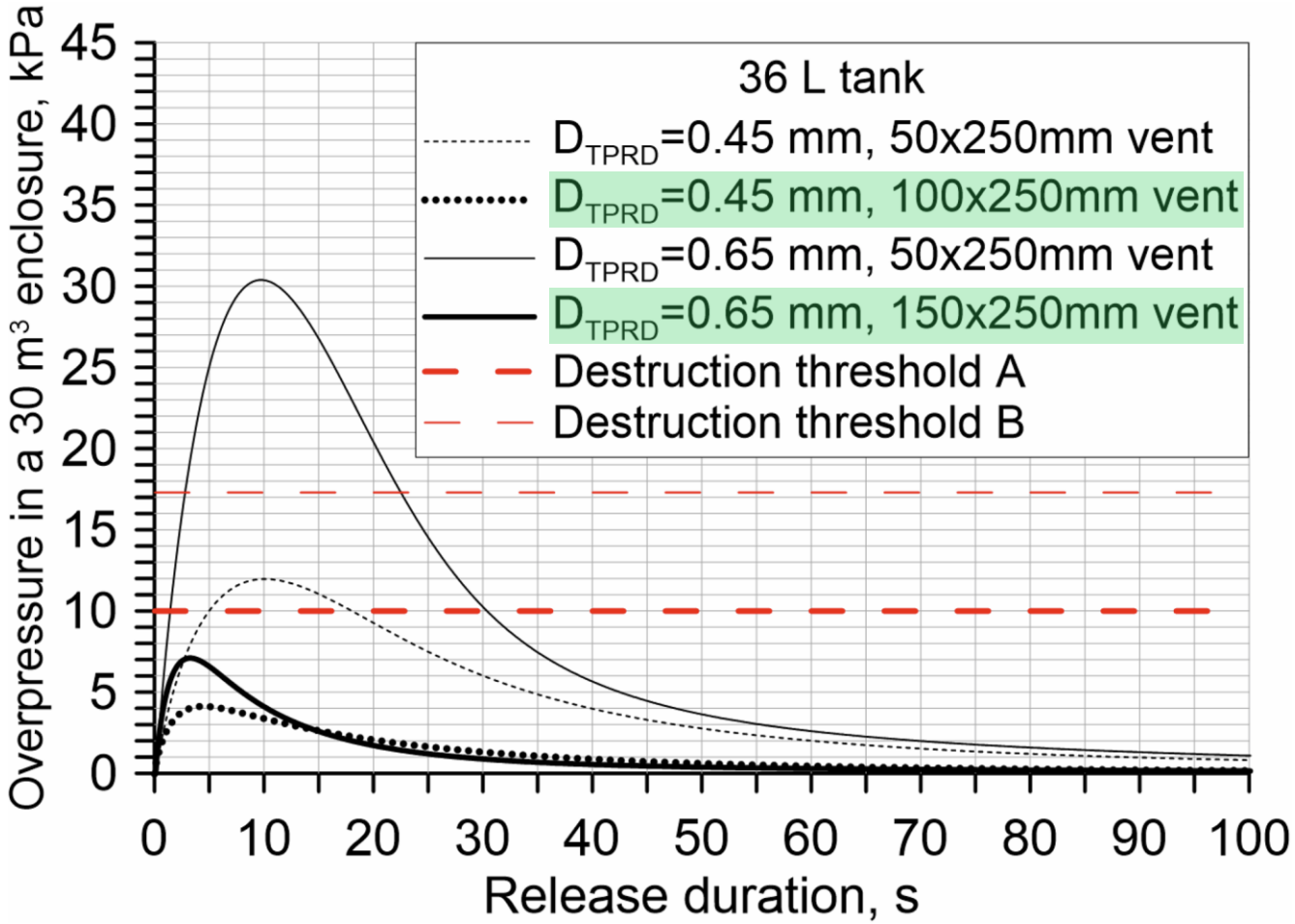


TPRD D=0.45 mm is sufficient to blow-down 62.4 L tank in a fire of HRR/A=1 MW/m^2

TPRD orifice diameter and the pressure peaking phenomenon (PPP)

PPP overpressure dynamics

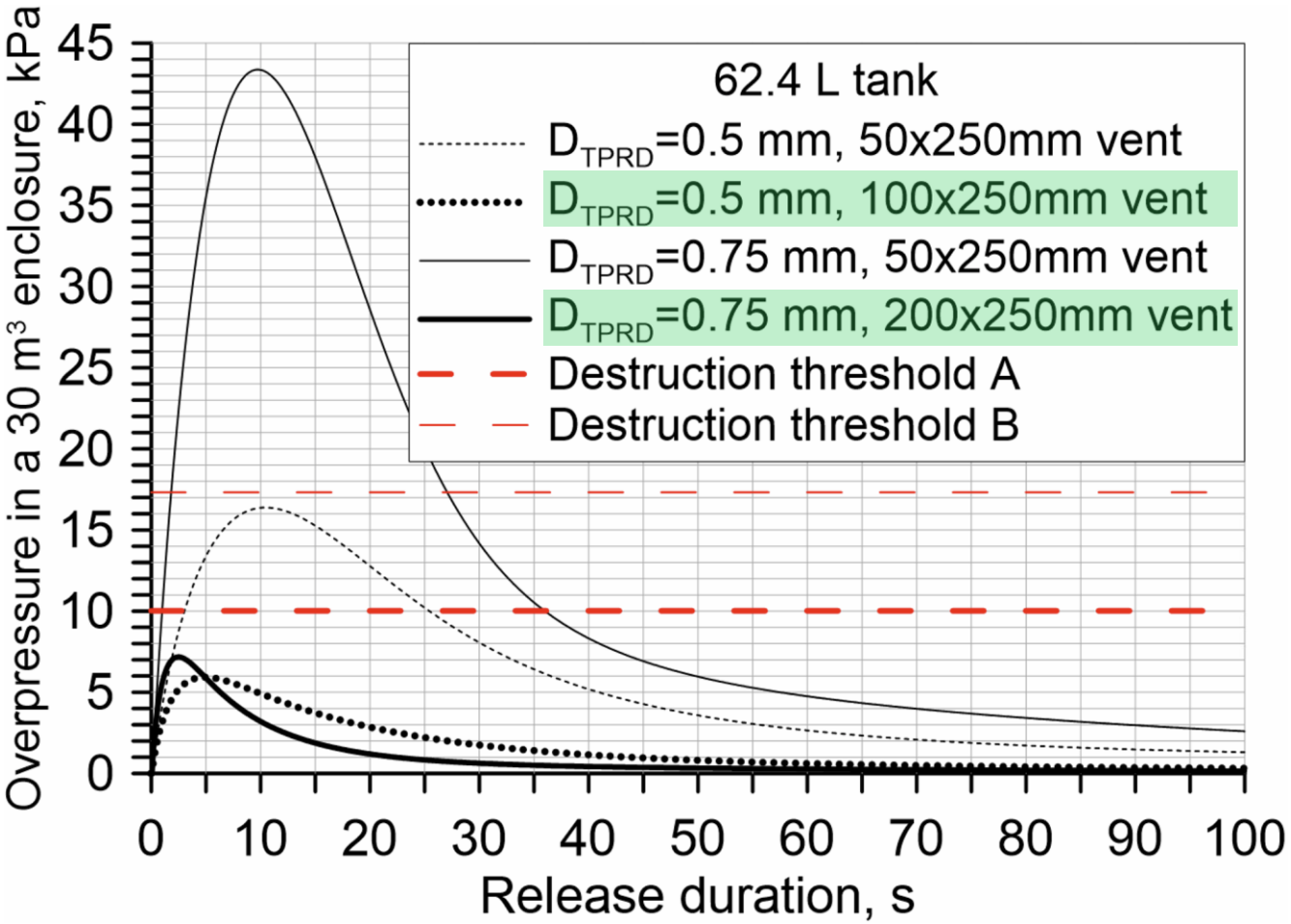
Hydrogen release in 30 m³ garage (36 L, 70 MPa)



Destruction threshold A: *P=10 kPa*, threshold B: P=*17.3 kPa*

PPP overpressure dynamics

Hydrogen release in 30 m³ garage (36 L, 70 MPa)

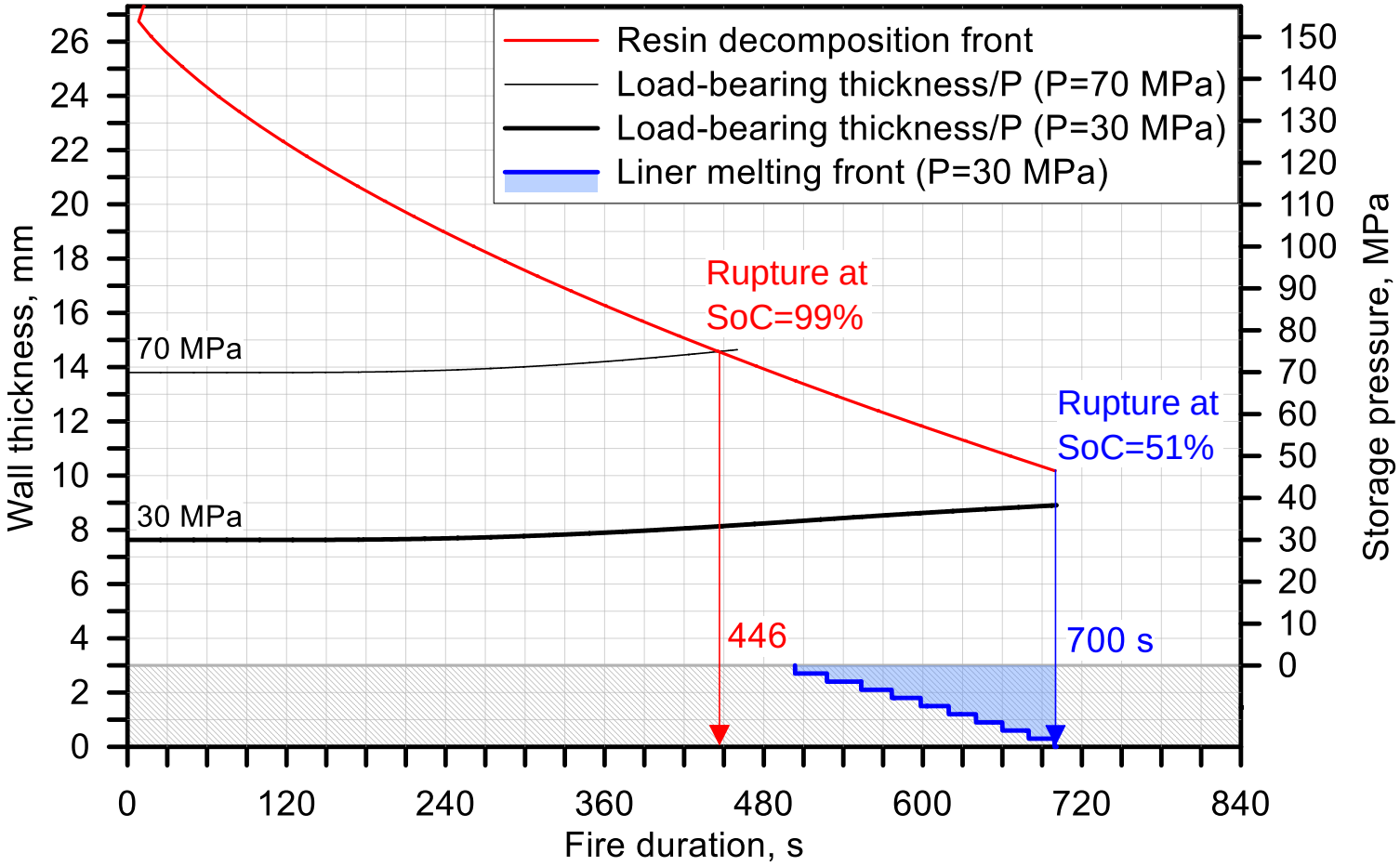


Destruction threshold A: *P=10 kPa*, threshold B: P=*17.3 kPa*

Effect of state of charge (SoC) on tank fire resistance rating

Tank with failed/blocked TPRD

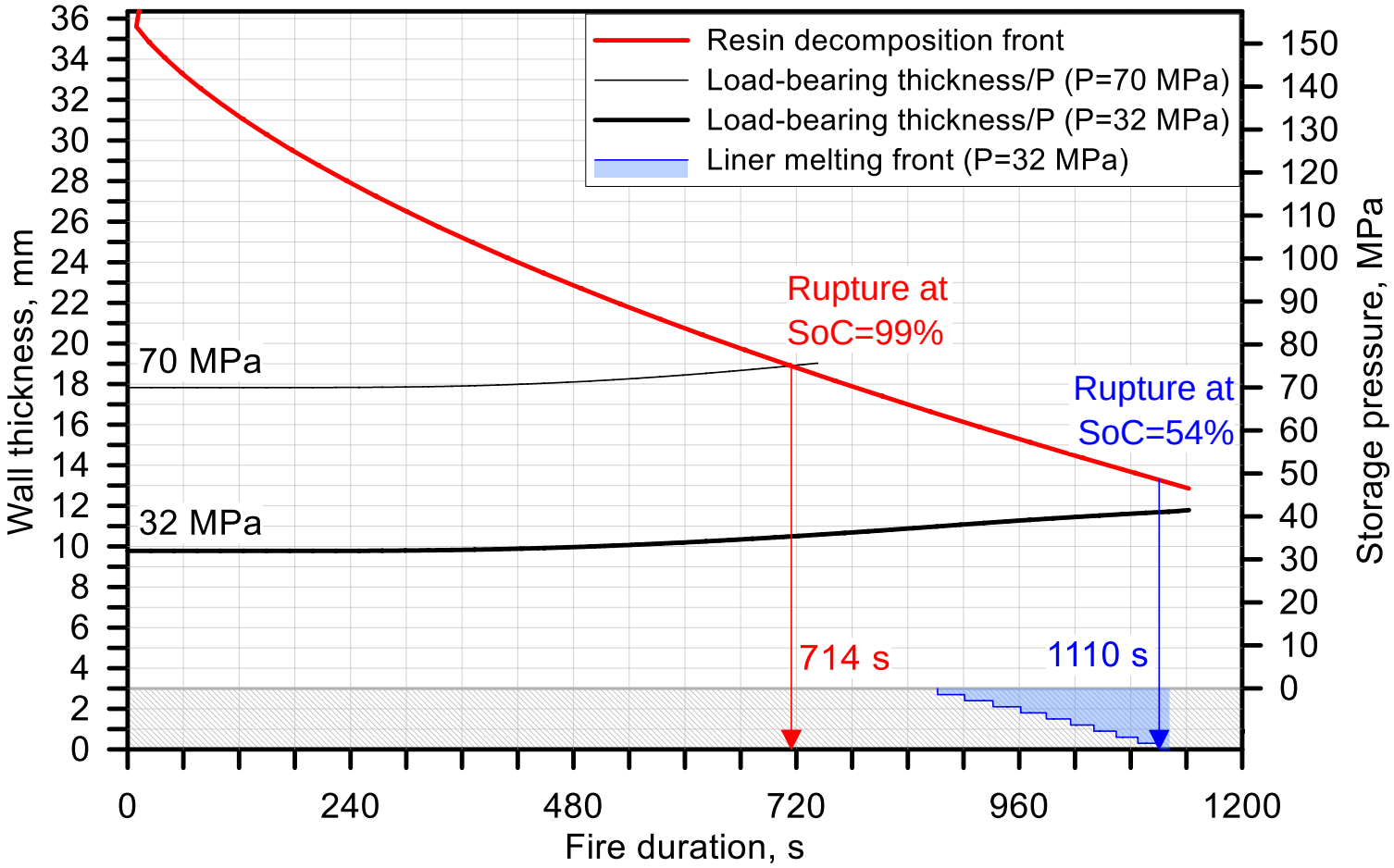
Effect of SoC on tank FRR (62.4 L, 70 MPa)



The decrease of tank's SoC to 51% for such tank will result in hydrogen leak and exclude tank rupture.

Tank with failed/blocked TPRD

Effect of SoC on tank FRR (244 L, 70 MPa)



The decrease of tank's SoC to 54% for such tank will result in hydrogen leak and exclude tank rupture.

Conclusions

- The exclusion of rupture of the studied Type IV tanks with NWP=70 MPa can be provided using a TPRD diameter of 0.75 mm for 244 L tank, 0.5 mm for 62.4 L tank, and 0.45 mm for 36 L tank
- For releases in a garage from a passenger car (from onboard storage tanks 62.4 L and 36 L), at least two bricks total size vent area (100x250 mm) is needed to prevent the destructive consequences of the PPP on a structure
- The reduction of SoC may allow for avoiding of tank rupture in a fire, i.e. decrease of SoC to 51% and 54% for 62.4 L and 244 L tanks respectively (both 70 MPa) resulted in hydrogen leak and exclusion tank rupture

Acknowledgements

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