FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

HyTunnel-CS:
Pre-normative research for safety of hydrogen driven vehicles and transport through tunnels and similar confined spaces

Online workshop on
Safe Storage of Compressed Gas Hydrogen
in road transport applications
and related infrastructure

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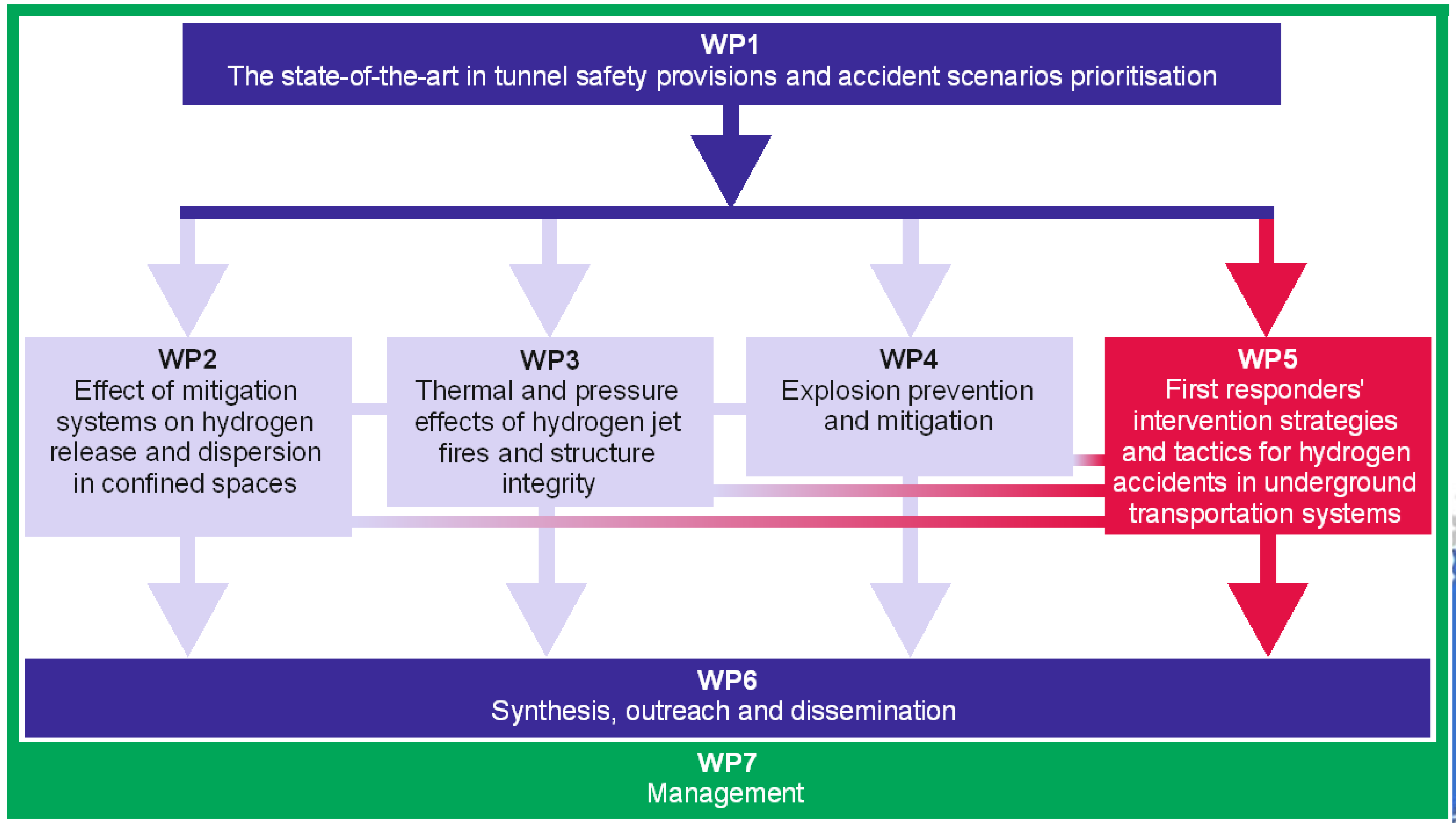
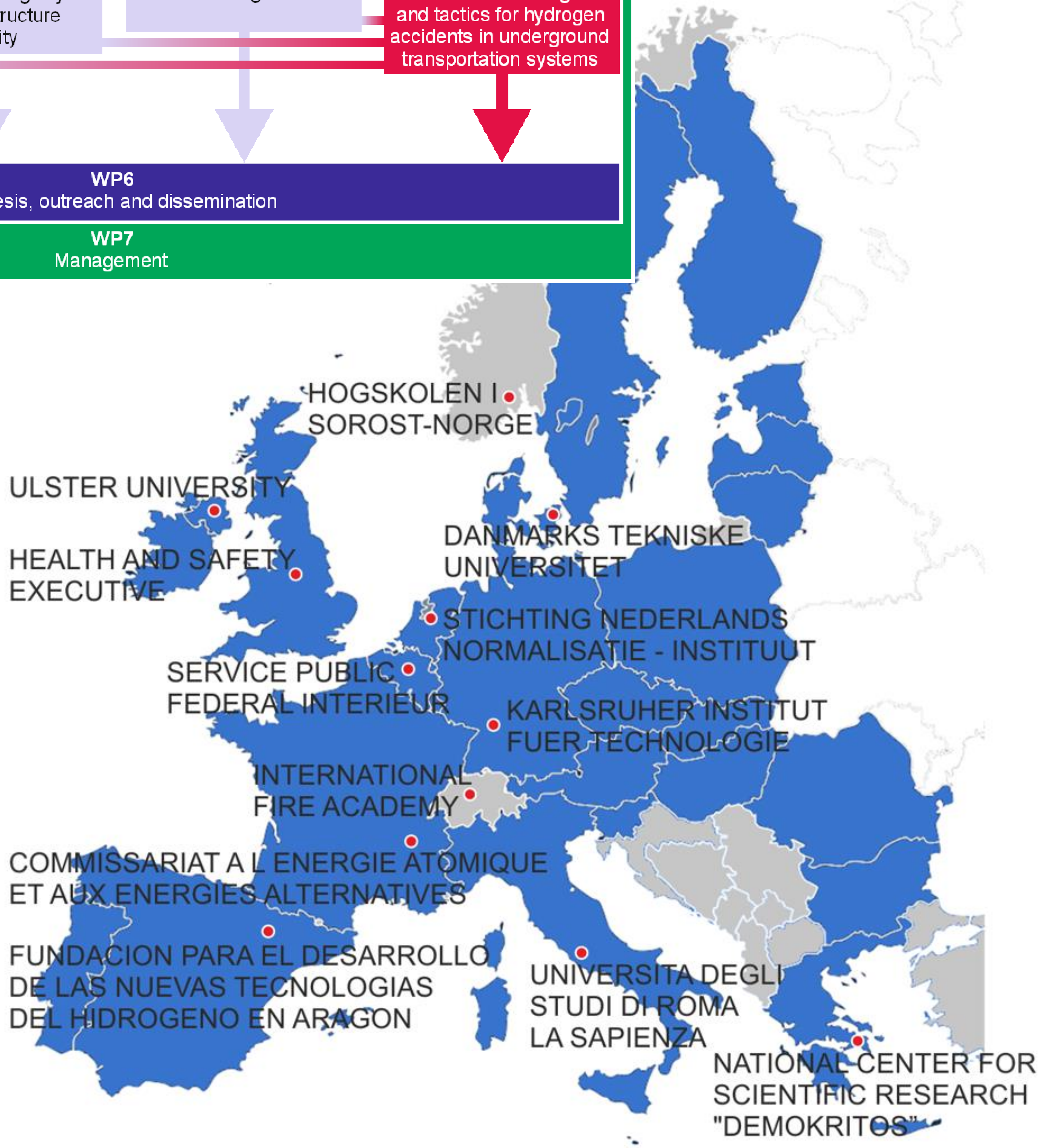
IMPORTANCE OF PRE-NORMATIVE RESEARCH



Project Brief

- 13 partners from 11 countries (all safety experts)
- Safety responsible person: a team from each partner
- Description of Work: includes testing of self-venting tanks
- Max inventory, physical state (p,T): N/A to theoretical and CFD studies.
- Location (see map), operational domain (academia and R&D, SDO)
- **HyTunnel-CS ambition:** Allow hydrogen-powered vehicles enter underground traffic infrastructure.
- **HyTunnel-CS aim:** Conduct PNR to close knowledge gaps and technological bottlenecks in the provision of safety in the use of hydrogen-powered vehicles in underground transportation systems.
- **The importance of pre-normative research (PNR):** develops generic knowledge that can be used for inherently safer deployment of hydrogen systems and infrastructure, e.g. in demonstration projects which are lacking relevant RCS to progress faster and safer.
- **This presentation – only about onboard storage.**



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REMARK ON REGULATIONS, CODES AND STANDARDS: ESSENTIAL AMENDMENTS ARE NEEDED

- **No RCS on underground parking** of hydrogen-powered vehicles. HyTunnel-CS recommends how to avoid flammable cloud and hot products (T>300 C) under the ceiling, thus **allowing underground parking.**
- **No RCS for design of tank-TPRD system** to withstand any engulfing fire. HyTunnel-CS for the first time developed and validated the model to calculate TPRD diameter to withstand any engulfing fire.
- **No RCS for self-venting tanks**. HyTunnel-CS will report the use of breakthrough safety technology of self-venting storage container without TPRD following IP protected microleak-no-burst technology and prototype testing by three partners.
- ISO 19882:2018 “Gaseous hydrogen – Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers” requires account for the pressure peaking phenomenon. HyTunnel-CS will recommend validated reduced and CFD **models and tools for mitigation of the pressure peaking phenomena in garages and storage rooms in trains, marine vessels, aircrafts, etc**.
- UN ECE GTR#13 “Global Technical Regulation on Hydrogen and Fuel Cell Vehicles” includes the **fire test protocol**. HyTunnel-CS will recommend the update accounting for **fires of different intensity** to achieve the goal **“onboard storage should withstand any fire”**.

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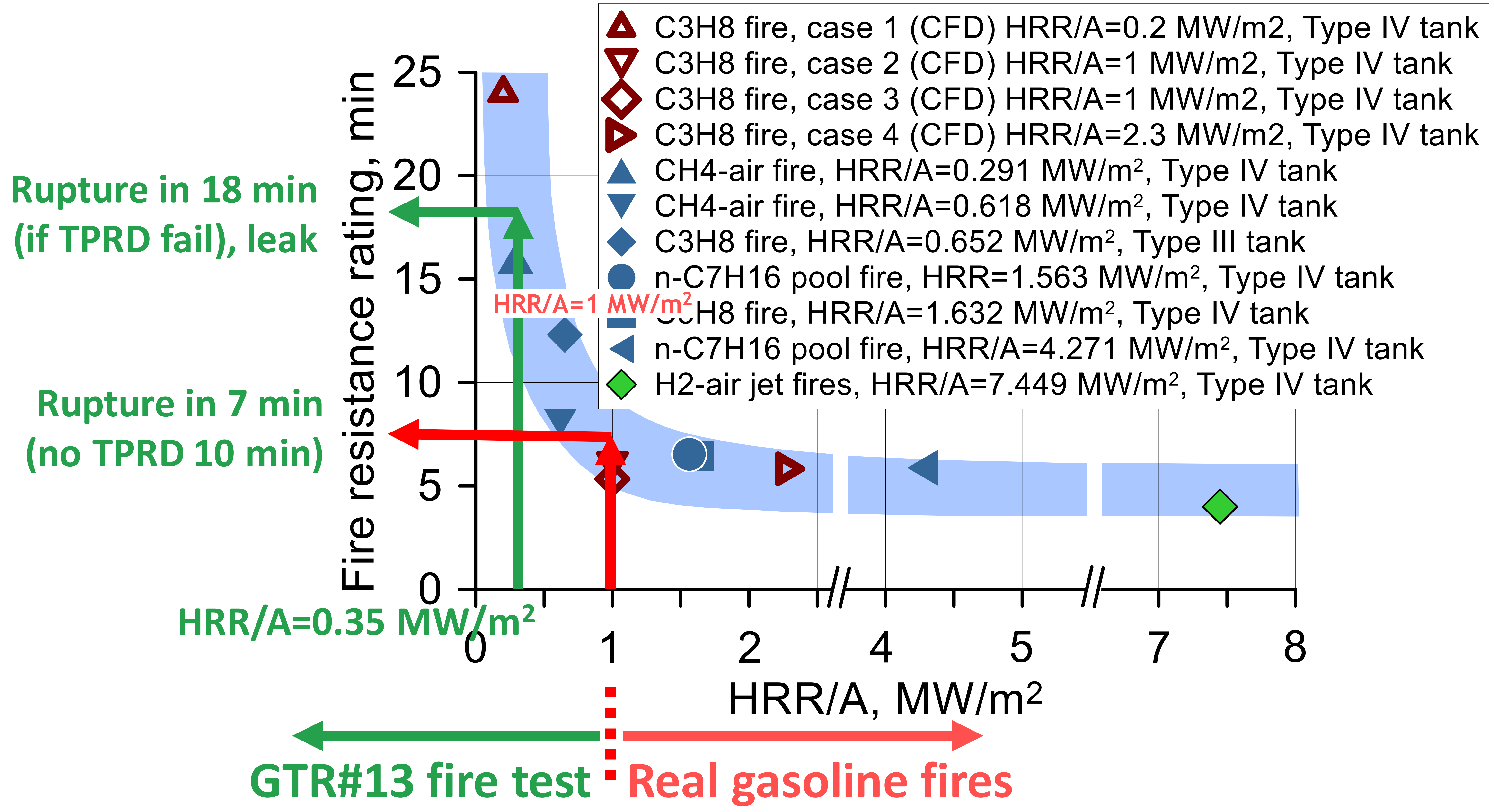
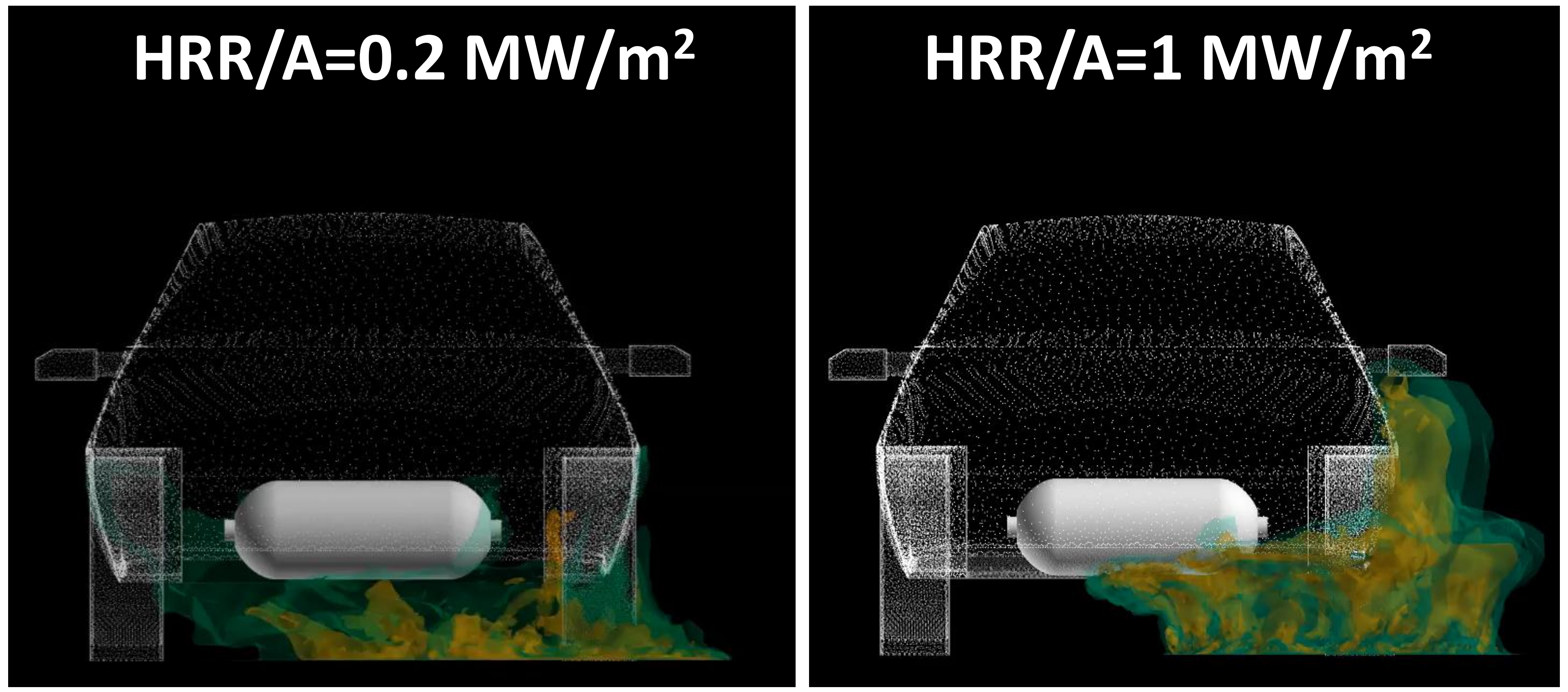
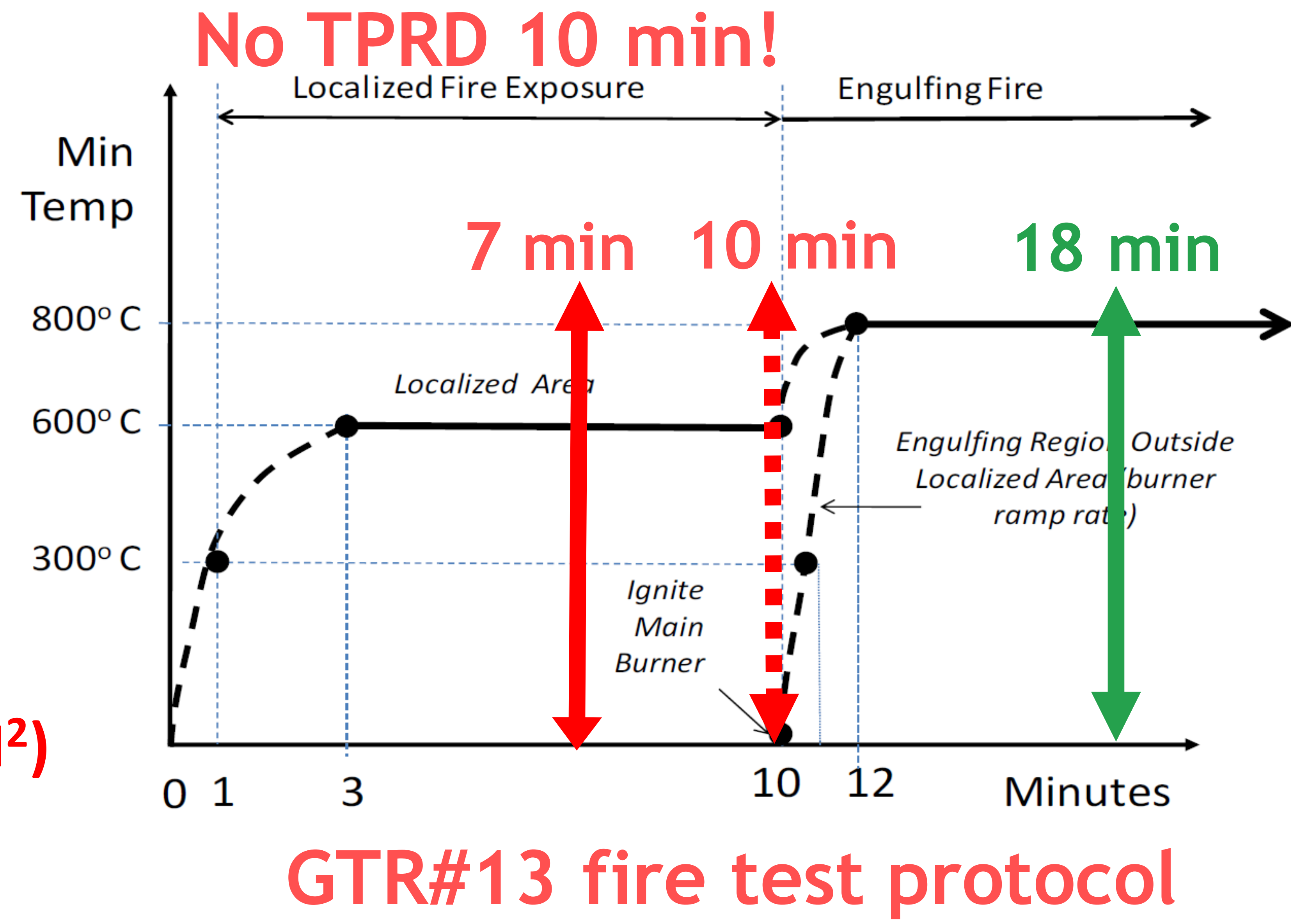
GTR#13 FIRE TEST PROTOCOL TO BE AMENDED







CONCLUDING REMARKS:

- REAL GASOLINE/DIESEL FIRES HAVE SPECIFIC HEAT RELEASE RATE HRR/A=1-2 MW/M²
- TANKS MUST WITHSTAND ANY FIRE (NOT REDUCED GTR#13 HRR/A=0.20-0.76 MW/M²)
- PASSING GTR#13 FIRE TEST DOES NOT PROTECT FROM RUPTURE IN REAL FIRES

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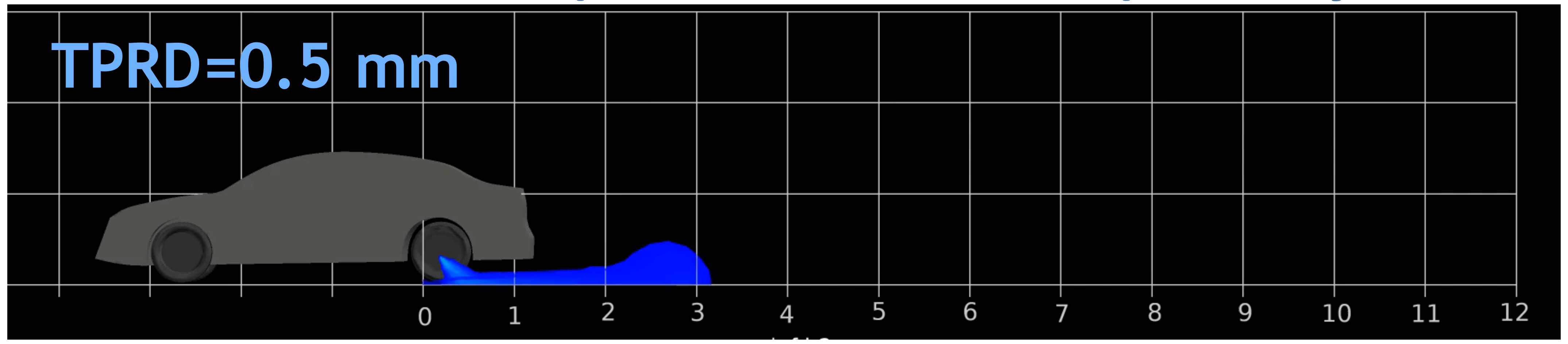
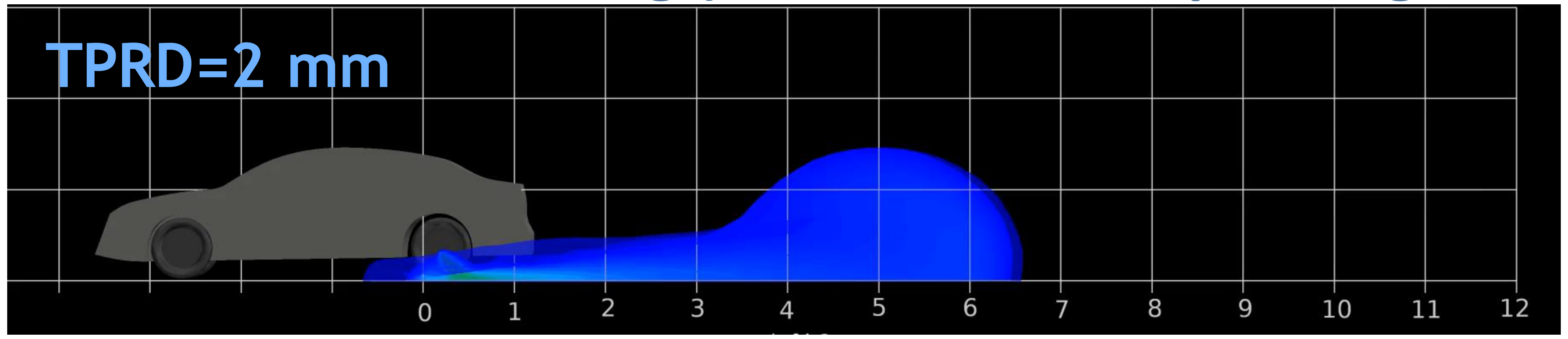
DESIGN OF TPRD PARAMETERS FOR UNDERGROUND PARKING OF CARS

Example of CFD study for underground parking (23.5x3x45 m) with ceiling height 2.1-3.0 m and ACH=0-10:

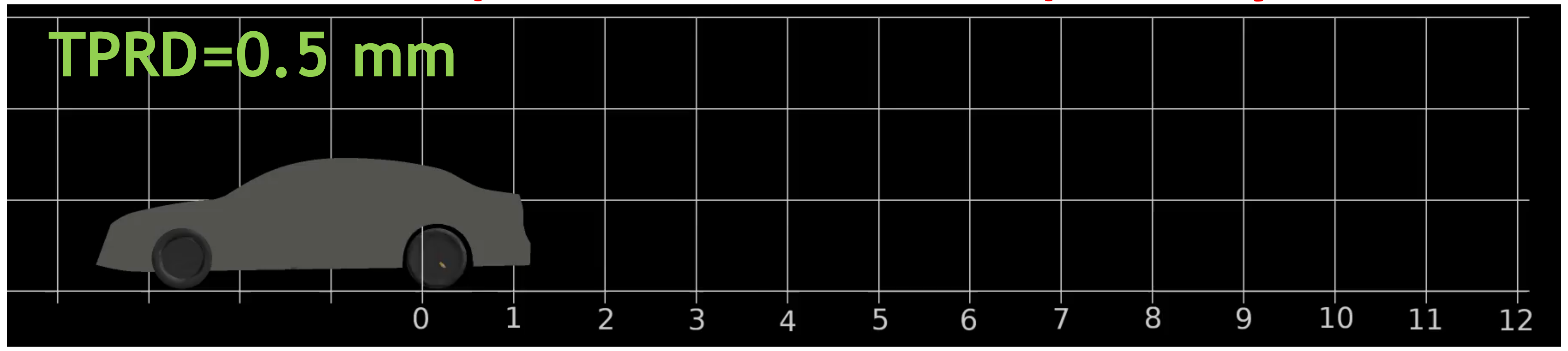
- TPRD=0.5-2.0 mm
- Tank (62.4 L, NWP=70 MPa)
- Angle 45°

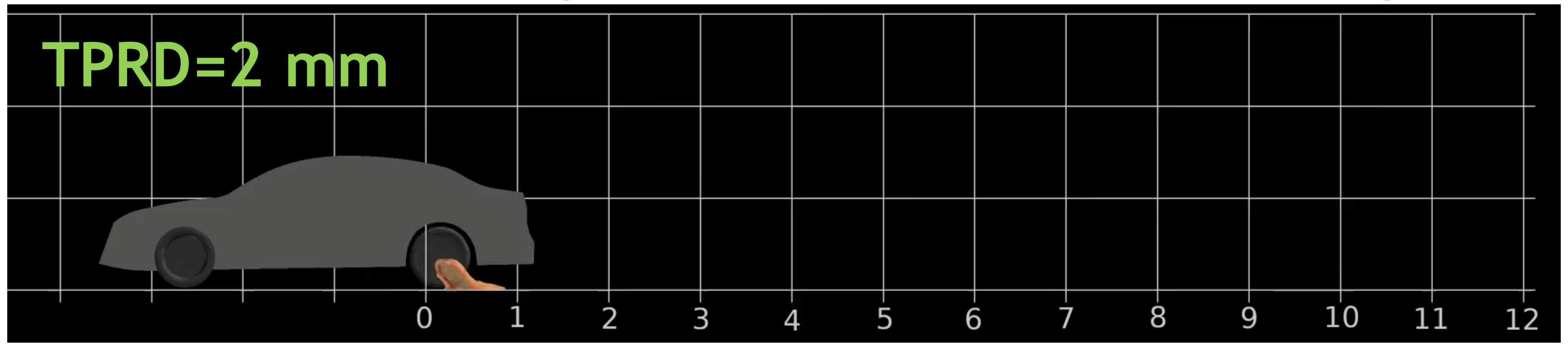
Release from TPRD (contour of LFL=4%). Safety criterion: no cloud under the ceiling (thus no follow-up deflagration!).





Fire from TPRD (contour of T>300°C). Safety criterion: T<300°C under the ceiling (no ventilation ducts damage).





CONCLUDING REMARKS:

- TPRD=0.5 MM EXCLUDES FORMATION OF FLAMMABLE CLOUD UNDER THE CEILING (NO DEFLAGRATION!)
- TPRD=0.5 MM EXCLUDES HOT PRODUCTS AT T>300°C TO REACH VENTILATION DUCTS
- PLUS TPRD=0.5 MM EXCLUDES DEMOLITION OF GARAGE BY THE PRESSURE PEAKING PHENOMENON
- WOULD TPRD=0.5 MM EXCLUDE TANK RUPTURE IN A FIRE (see answer on the next slide)?

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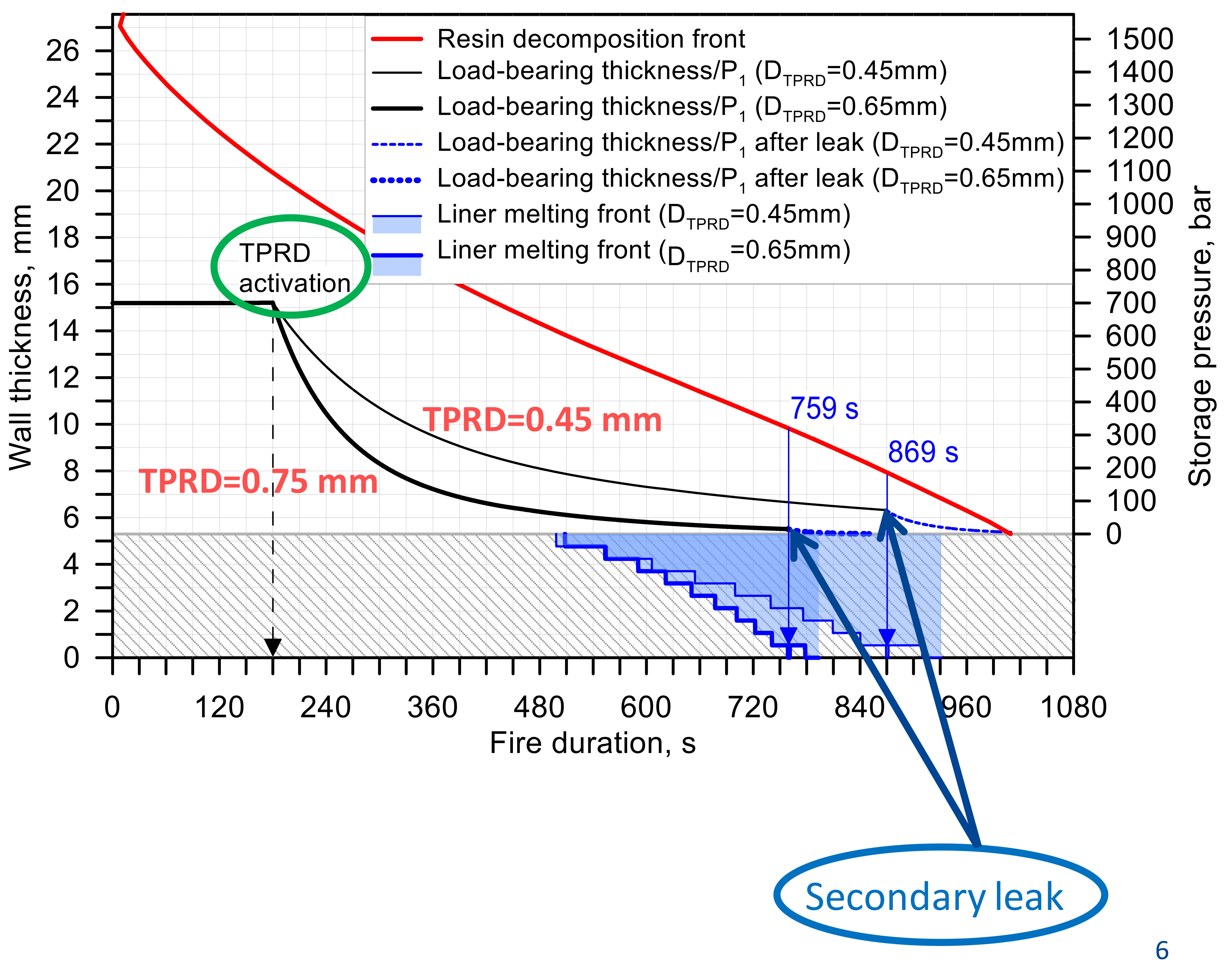
DESIGN OF TANK-TPRD SYSTEM: ENGULFING FIRE

- **Tank:** 70 MPa, 36 litres, Type IV (HDPE)
- **Gasoline fire:** HRR/A=1 MW/m^2.
- **TPRD response time:** 3 min.
- **Question:**
  What TPRD diameter would exclude:
  (a) tank rupture,
  (b) the pressure peaking phenomenon,
  (c) formation of flammable cloud under the underground parking ceiling
  (d) formation of products with T>300^{o}C under the ceiling of underground parking.
- **Answer:**
  for selected tank parameters (!) it is
  TPRD=0.45 mm (36 L tank)
  TPRD=0.75 mm (244 L tank)



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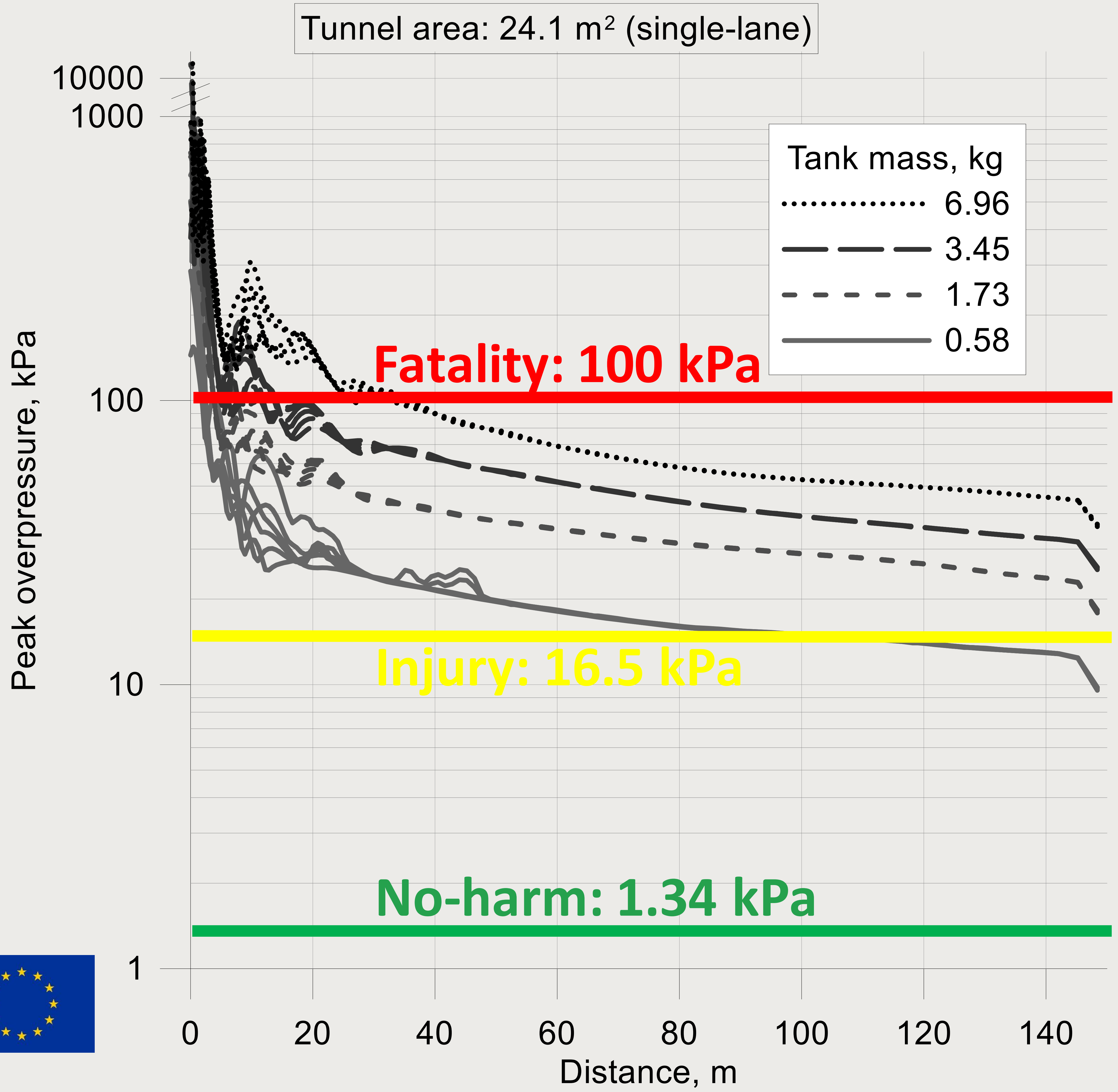
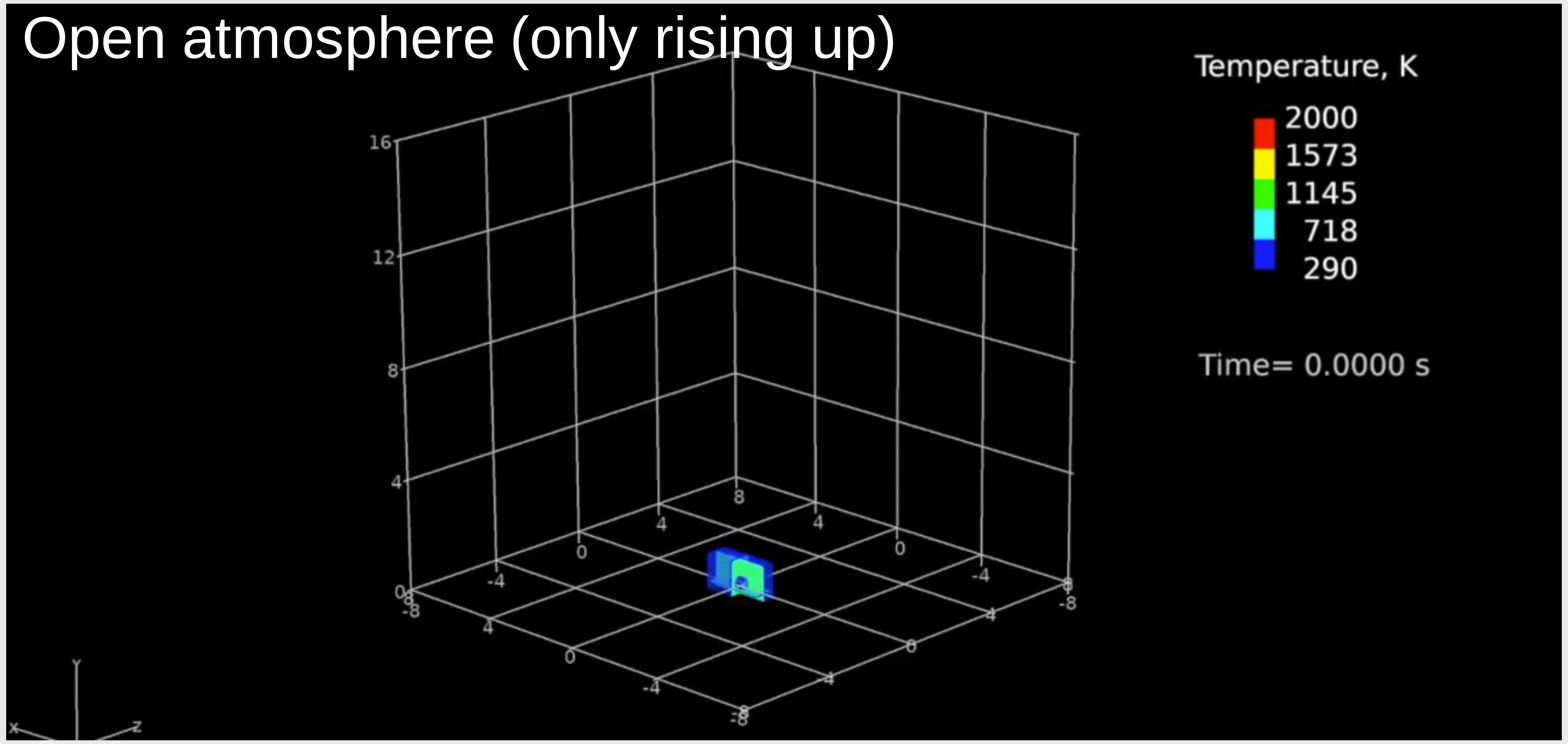
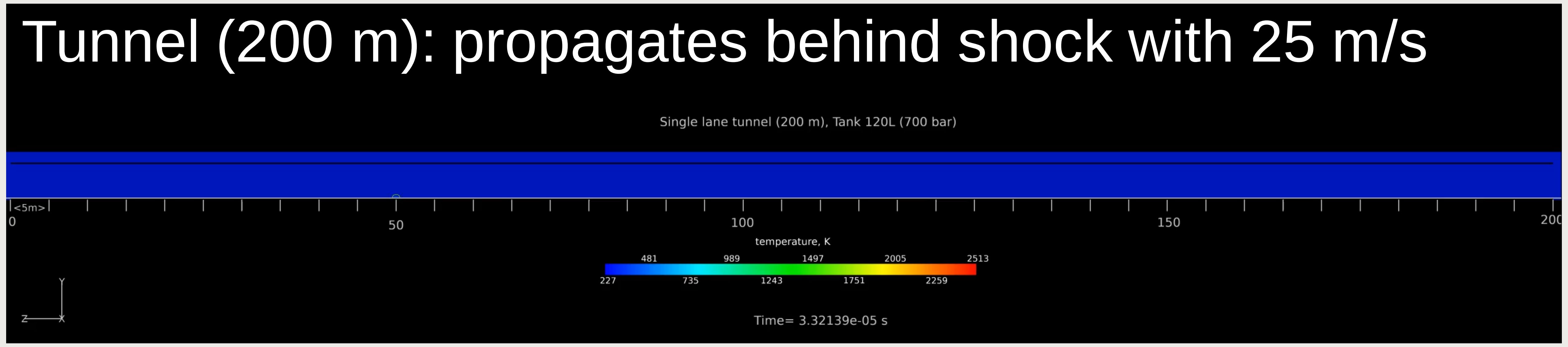
MAIN SAFETY CONCERN: BLAST WAVE AND FIREBALL AFTER TANK RUPTURE IN CONFINED SPACE

BLAST WAVE: LITTLE DECAY



FIREBALL





CAN BE TANK RUPTURE EXCLUDED IF TPRD FAILS?

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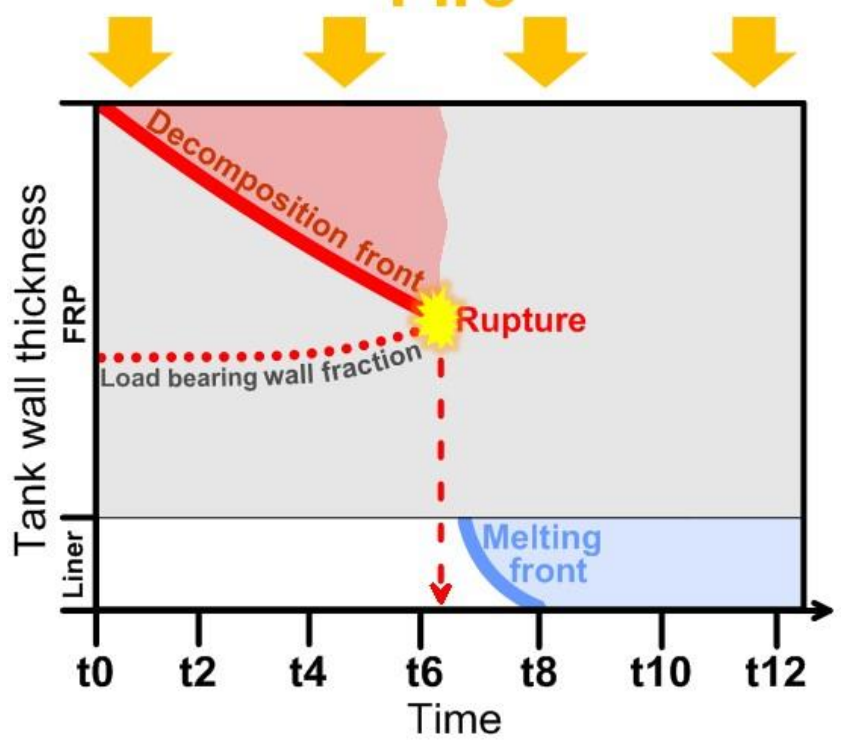
BREAKTHROUGH SAFETY TECHNOLOGY FOR STORAGE TANKS (BACKGROUND IP)

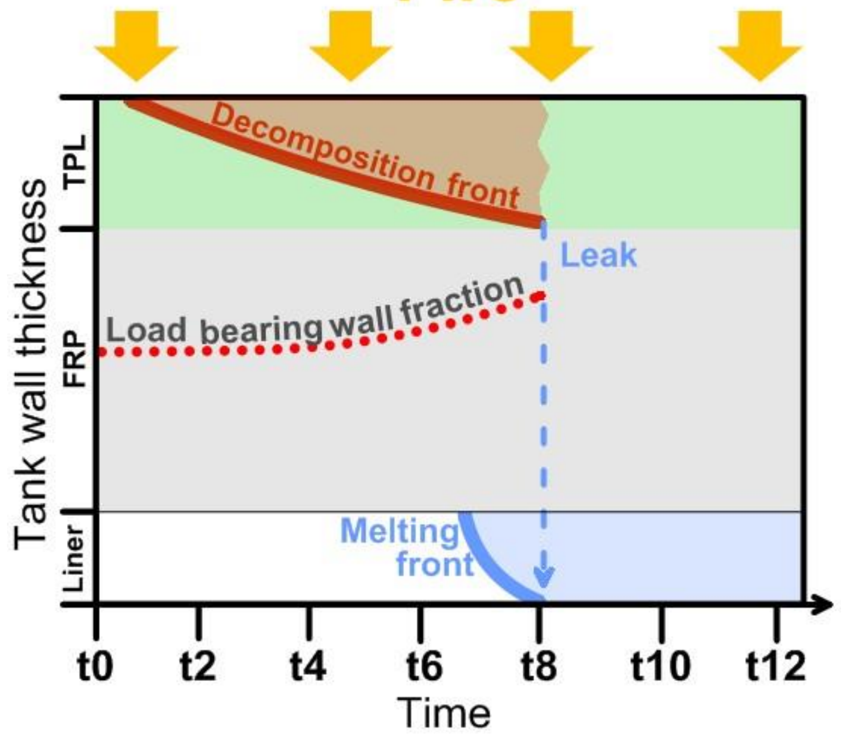
Explosion free in a fire self-venting (TPRD-less) tanks are successfully tested (microleaks-no-burst, μLNB, safety technology):

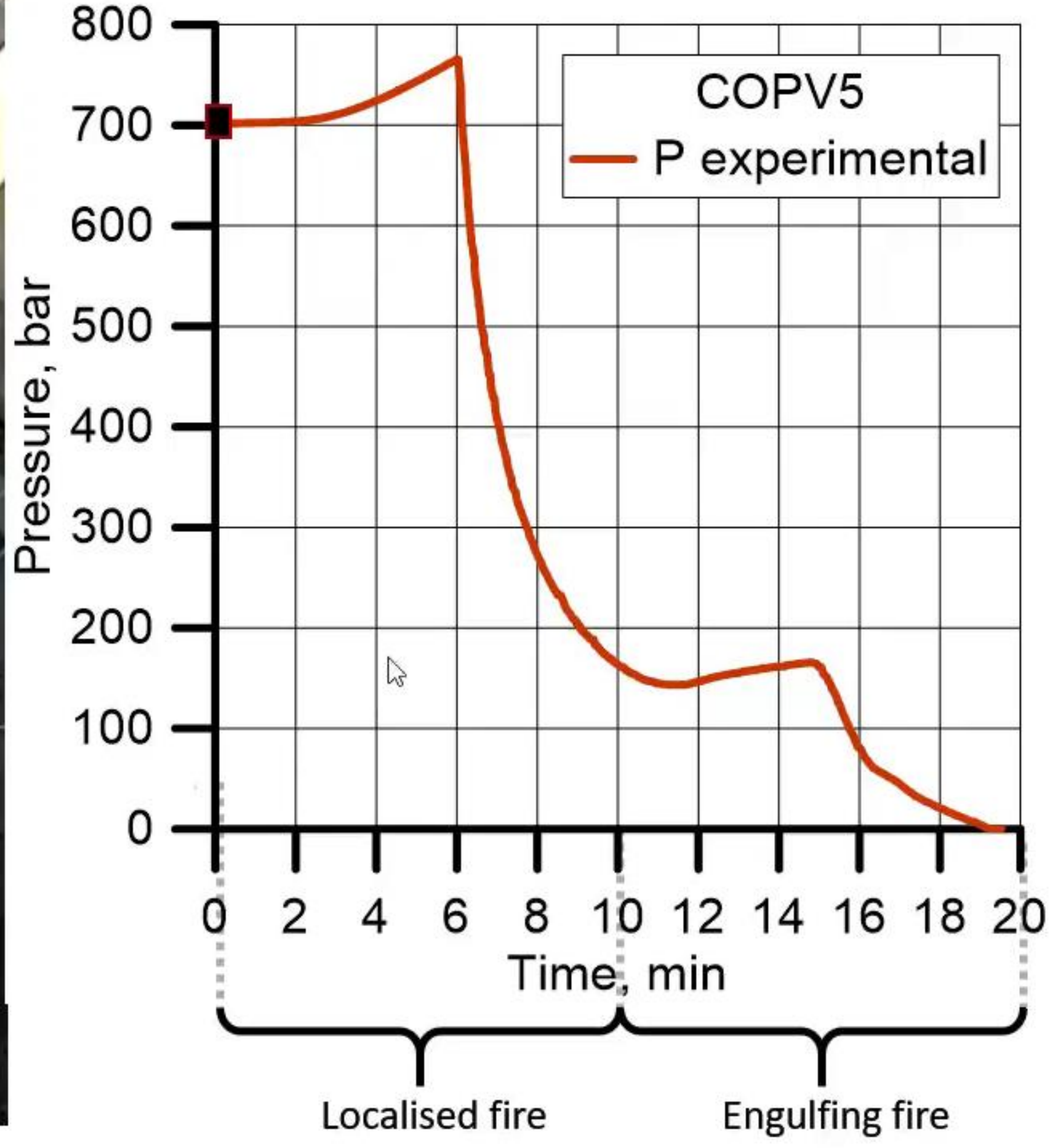
- **Allows** hydrogen-powered vehicles enter and park in any confined space.
- **Excludes** tank rupture (tested at fire with realistic HRR/A=1 MW/m^2, i.e. beyond reduced HRR/A=0.20 MW/m^2 in localised and HRR/A=0.76 MW/m^2 in engulfing fire test of GTR#13):
  - **No blast wave!**
  - **No fireball!**
  - **No projectiles!**
  - **No long flames (microflames)!**
  - **No formation of flammable cloud!**
  - **No pressure peaking phenomenon!**
  - **No life and property loss!**

Original tank



TPRD-less tank





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EXPECTED IMPACT (INCLUDING FOR STORAGE TANKS)

- **Stakeholders, including OEMs:**
  Recommendations for inherently safer use of hydrogen vehicles in underground transportation systems,
- **First responders:**
  Harmonised recommendations for intervention strategies and tactics for first responders providing conditions for their life safety and property protection
- **Industry (HE and beyond):**
  Recommendations for the update of relevant RCS, including through partner NEN (secretariate of CEN/CENELEC/JTC6 Hydrogen in energy systems)
- **Research, including academia (HER and beyond):**
  Closed knowledge gaps, addressed technological bottlenecks, shared beyond the state-of-the-art in hydrogen safety

Acknowledgements

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