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Leak-no-burst (LNB) safety technology for Type IV tanks

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Abbreviations

FRP	-	Fibre reinforced polymer
HDPE	-	High density polyethylene
IBP	-	Initial burst pressure
LNB	-	Leak-no-burst
NWP	-	Nominal working pressure
TPL	-	Thermal protection layer

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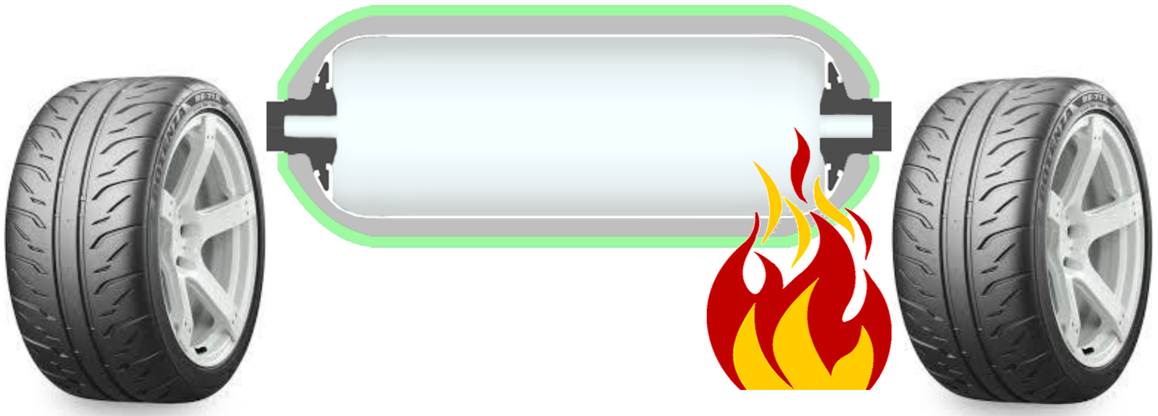
Localised fire or TPRD failure

Couple of scenarios



(i) Fire hits between chairs from saloon

(ii) Hydrocarbon spill fire under a vehicle or tire fire (opposite to TPRD location)

Solution:
Explosion-free in a fire tanks (LNB technology)

LNB safety technology
Ulster IP (1/3)

Three leak-no-burst (LNB) technology strands:

- Intumescent paint
- Boss design
- Hybrid composite

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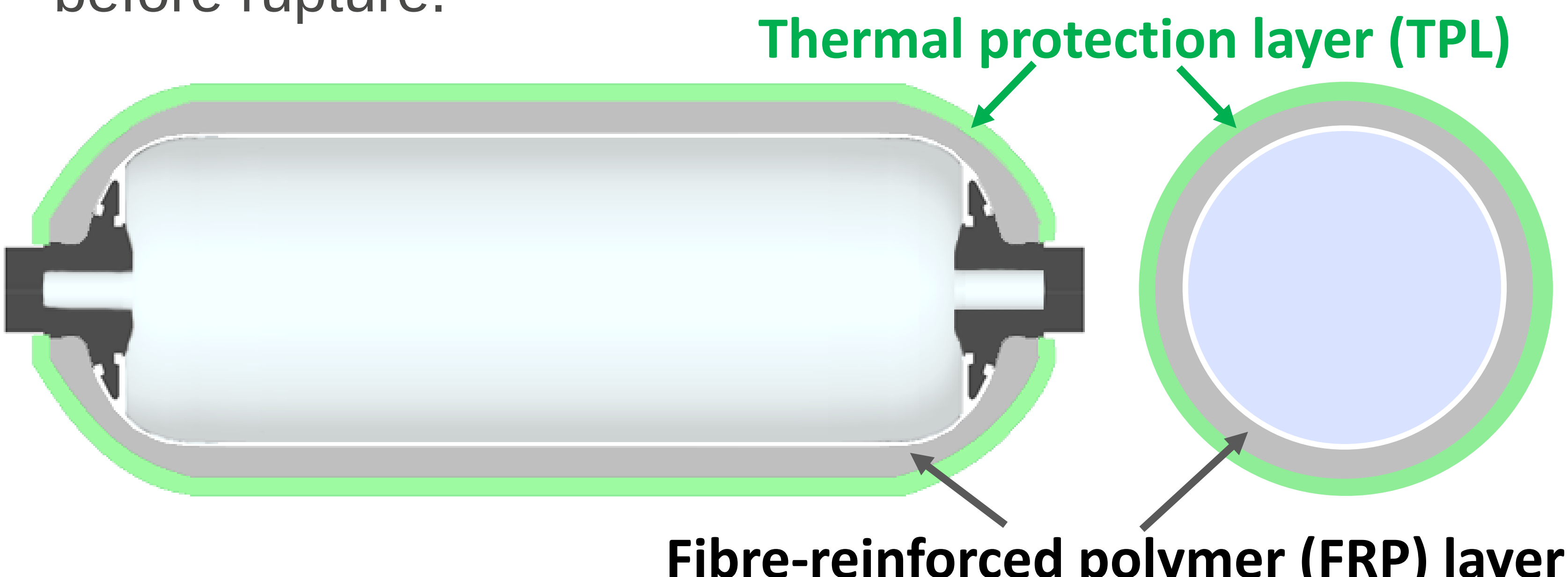
LNB safety technology
Ulster IP (2/3)

- A vessel comprises a load bearing **fibre-reinforced polymer (FRP)** layer, inner liner against gas permeation to the regulated level and outer **thermal protection layer (TPL)** that can be load bearing too.
- **Liner,** e.g. HDPE, melts to leak the gas through walls before rupture.



LNB safety technology

Ulster IP (3/3)

- The **TPL** thickness is a function of its thermal properties, the ratio of nominal working pressure (**NWP**) to initial burst pressure (**IBP**) in the vessel, and thermal properties of **FRP** and **TPL**.

- The **TPL** thermal conductivity is below that of **FRP** to provide a failure of the liner, e.g. its melting, before a **load-bearing fraction of the FRP wall** is degraded to value:

$$\alpha \cdot NWP/IBP,$$

where α - coefficient of pressure increase above NWP.

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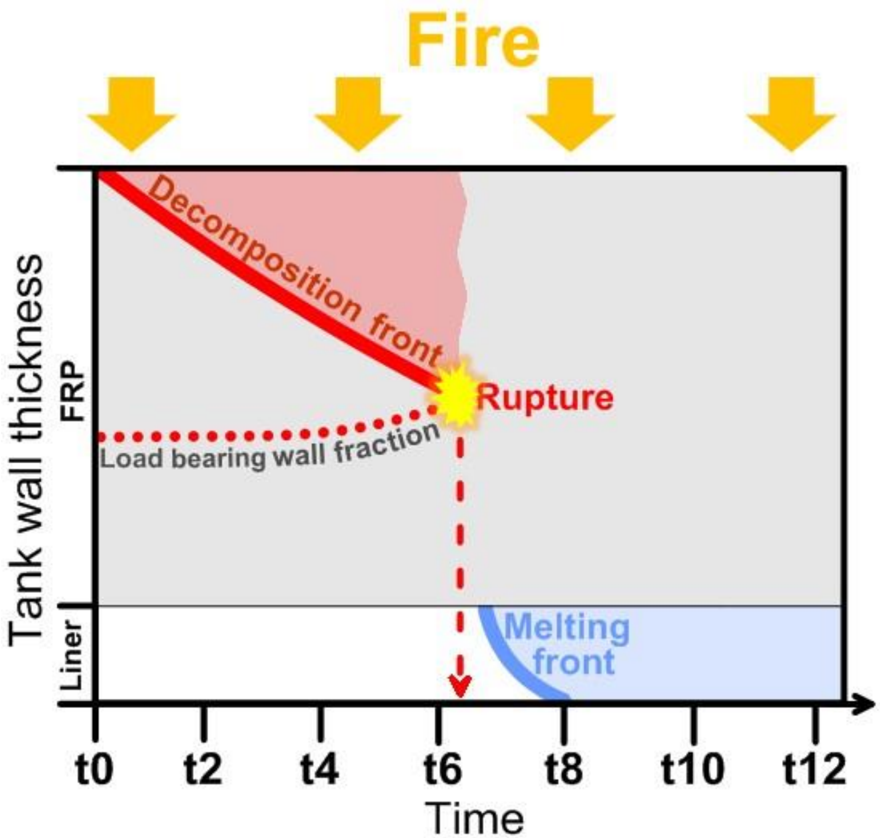
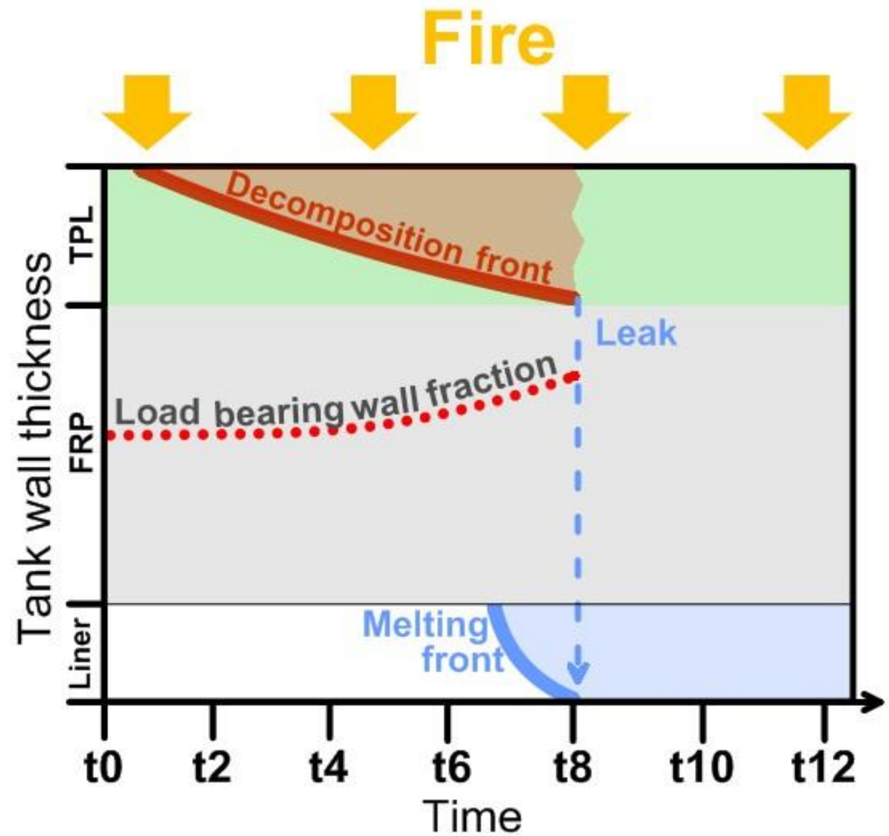
LNB safety technology
Schematic description

Original tank: **rupture**



LNB tank: **no rupture!**

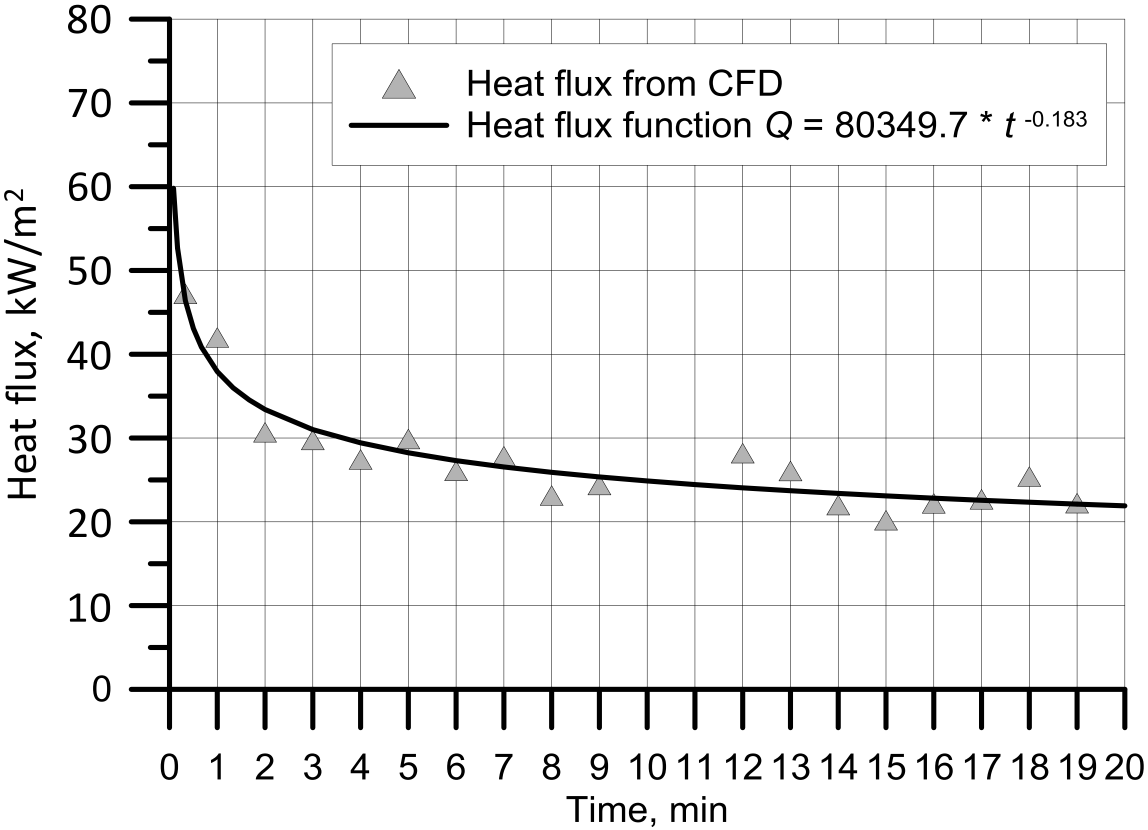


Prototype numerical testing results: LNB performance preserved for storage pressures up to 125% NWP and **any fire regimes (different HRR/A)**

Prototyping: first trial

Heat flux from 3D CFD simulations

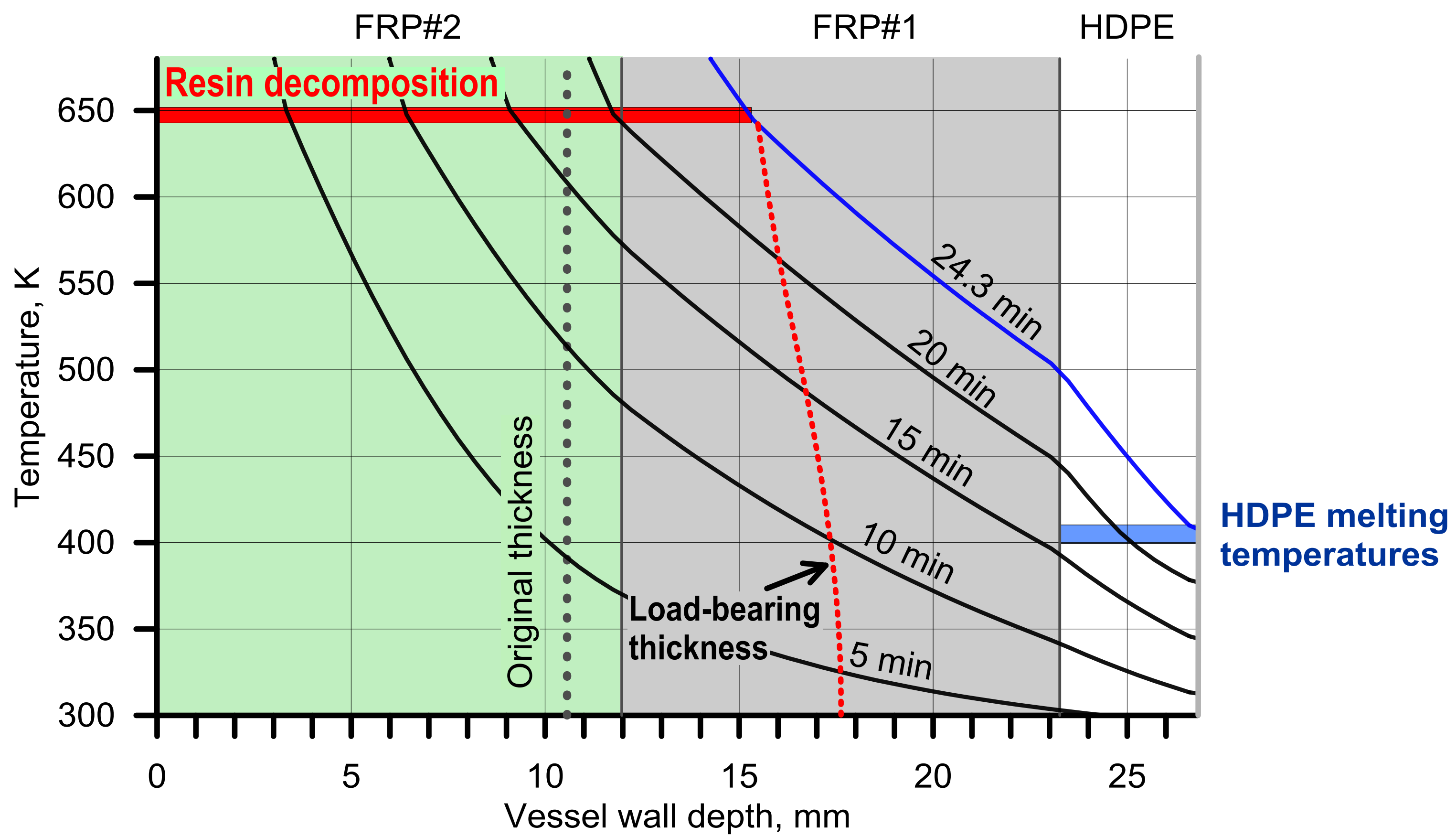
Maximum heat flux in 3D CFD numerical fire test (propane burner with specific heat release rate **HRR/A=1472 kW/m²** to provide reproducibility, HRR=500 kW).



Then simulated **heat flux** (not the same as HRR/A!) is applied in the reduced model as the input to design LNB tank prototype.

Prototyping: first trial

Simulation by reduced model (1/3)



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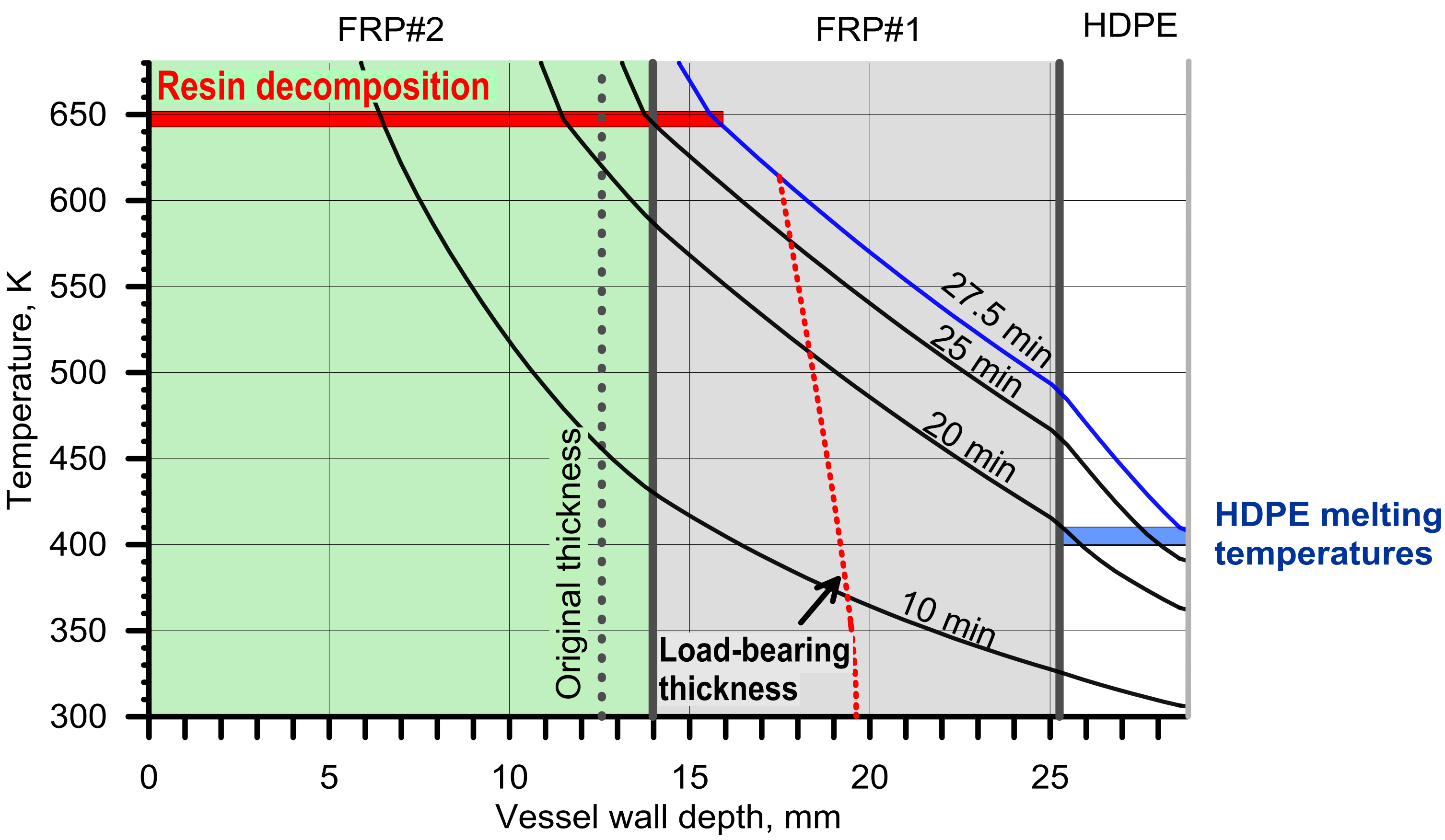
Rupture

Prototyping: first trial

Simulation by reduced model (2/3)



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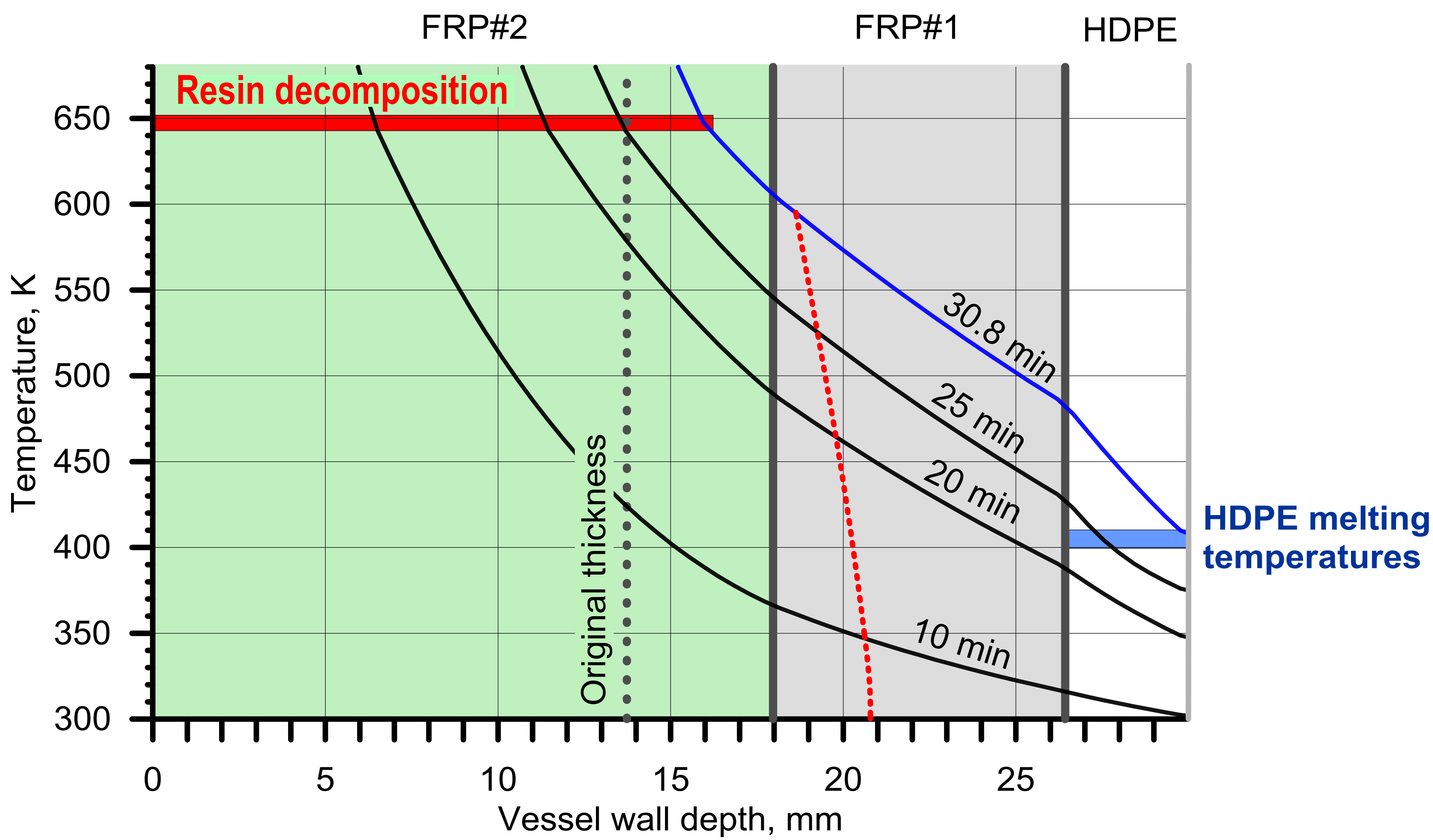
Leak

Prototyping: first trial

Simulation by reduced model (3/3)



Leak

First prototypes testing

Tanks parameters

Tank ID	OD of liner, in	OD of finished part, in	FRP#1 thickness, in	FRP#2 thickness, in	Weight, lb
#004	6.334	8.178	0.450	0.472	27.5
#005	6.336	8.465	0.366	0.699	32.3

Test results (LNB!)

Tank ID	Charge pressure, bar	Vent pressure, bar	Leak starts	Leak duration
#004	700	812.4	9m 27s	16m 29s
#005	700	854.5	12m 23s	14m 37s

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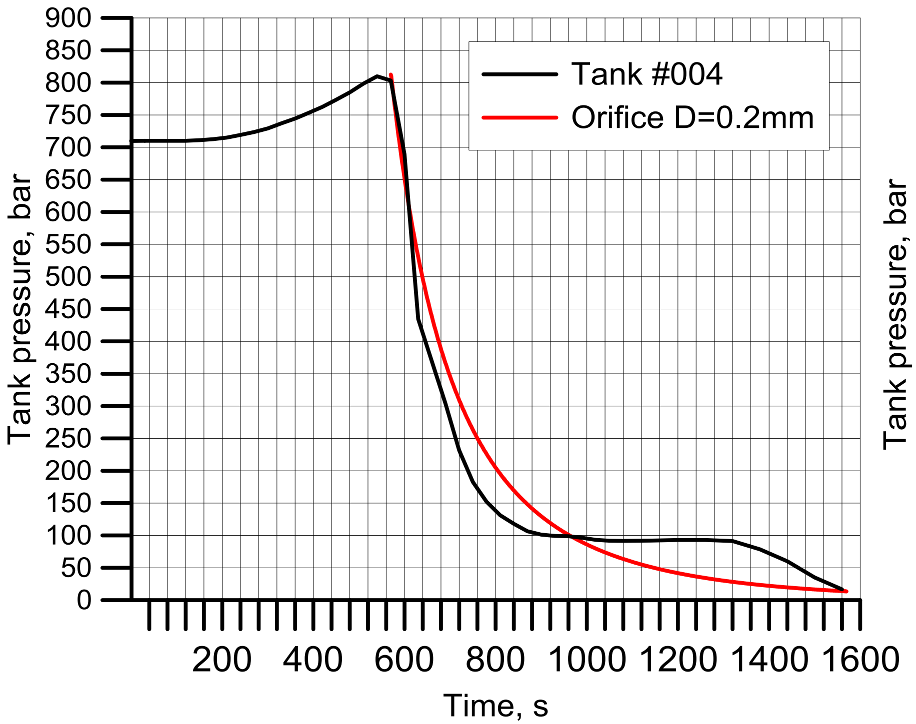
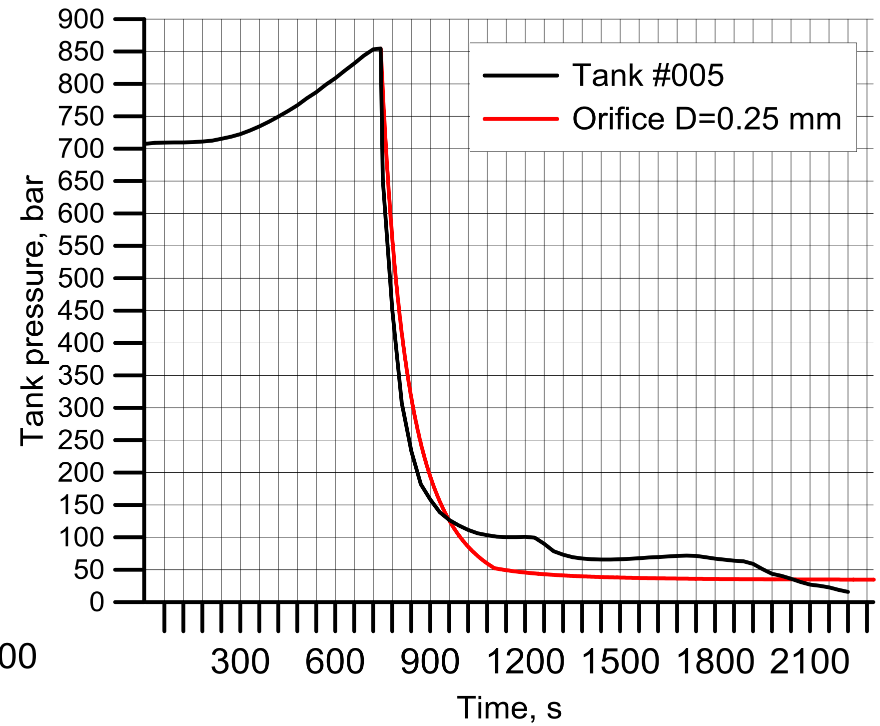
First prototypes testing

Blowdown equivalent diameter 0.20-0.25 mm





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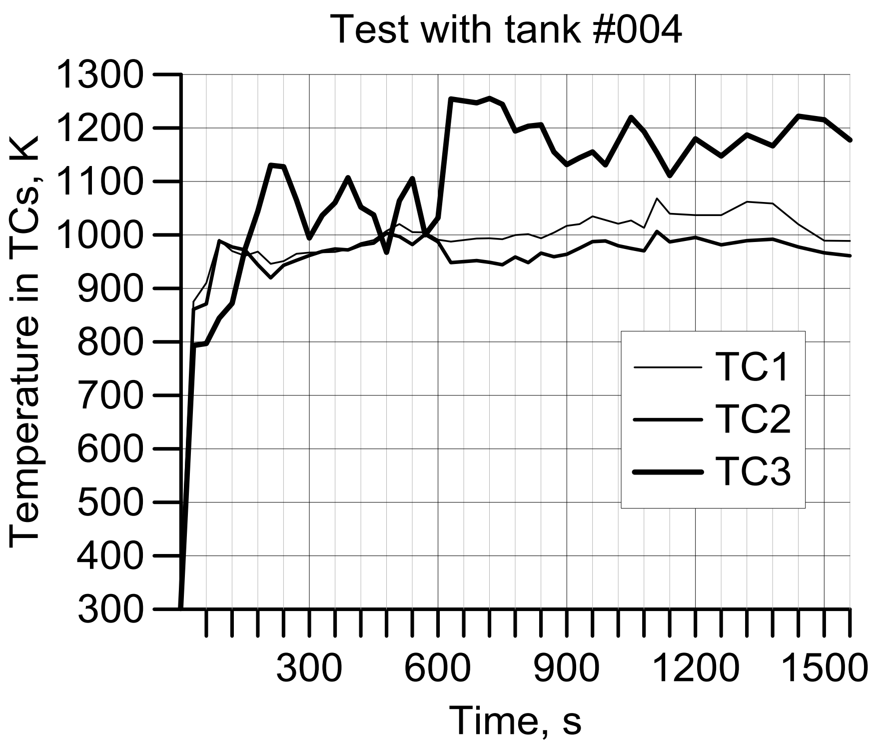
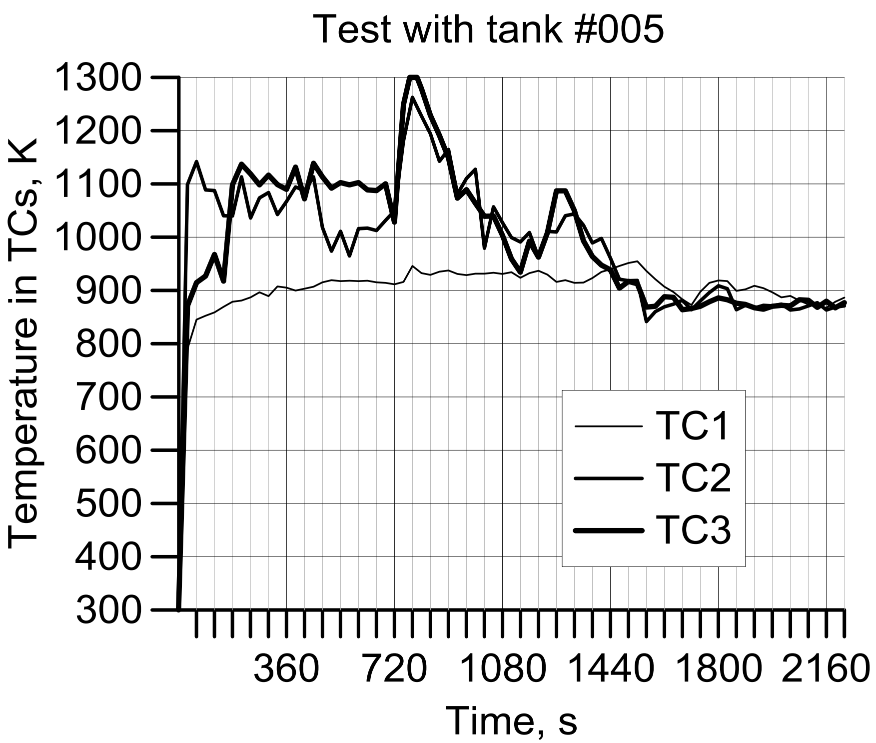
LNB resolves the issue of the destructive pressure peaking phenomenon in confined spaces like garage (**insignificant leak!**)

GTR#13 engulfing fire test

Test temperatures satisfy the regulation





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Aftermath of first prototyping

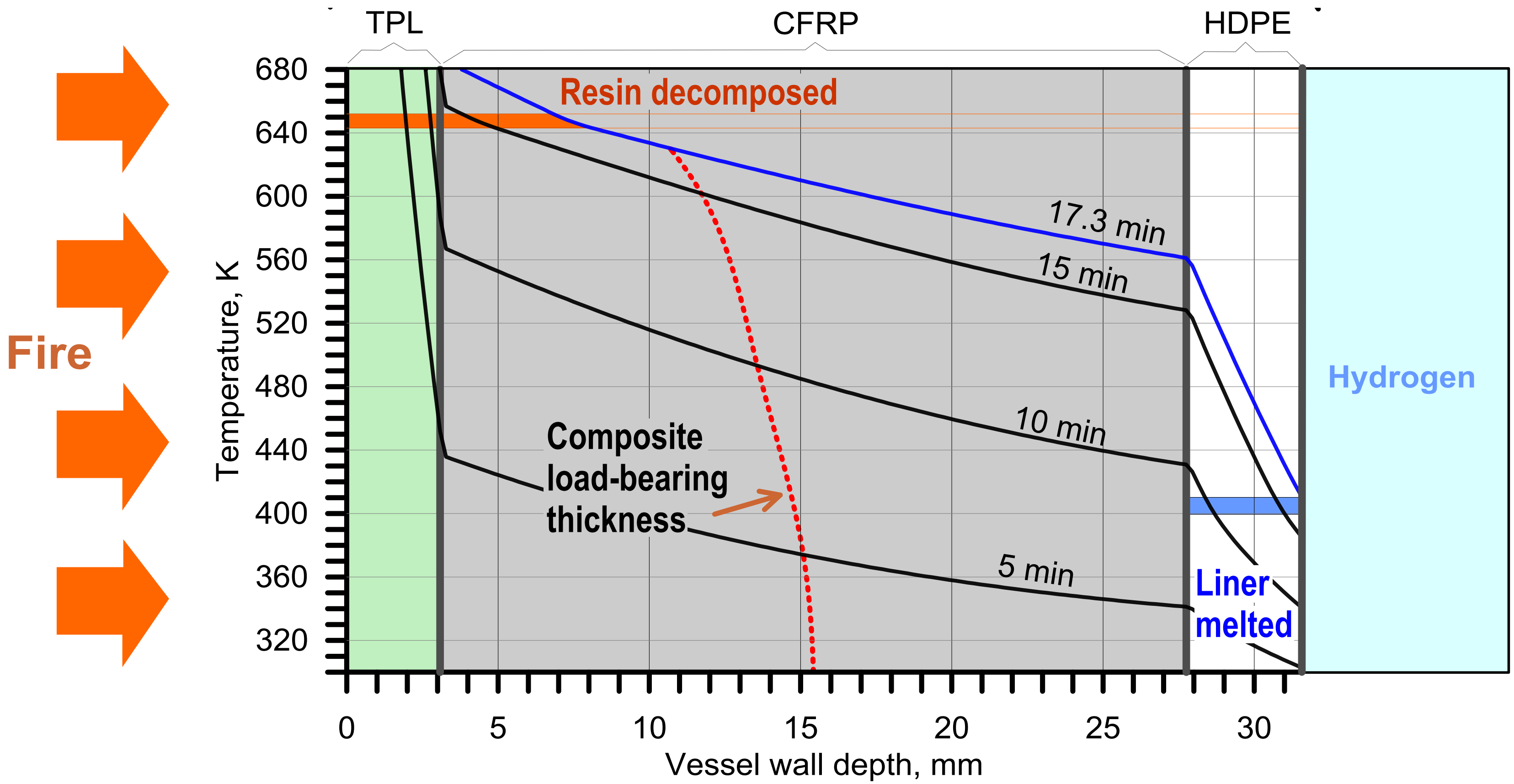
Comments

- No experimentally data available for thermal parameters of different fibre-resin composites (need to measure for prototype optimisation).
- “Conservative” values of parameters from literature were selected to provide LNB performance of the prototype (achieved).
- “Negative” consequence: first LNB tank prototype is thicker compared to the original 700 bar tank (criticism from OEM).
- Next steps in prototyping:
  - Measure thermal parameters of fibre-resin composites
  - Manufacturing LNB tank prototype of a larger volume with the same wall thickness as original tank (cheaper)

Aftermath of first prototyping

New prototype (size of original tank)

Original tank with partial change of carbon fibre to glass and different resins: *the same size but cheaper cost* ***and LNB***.



TPL of 3 mm only! No change of 2.25 – within production “scatter”.

Ulster intellectual investment to date

- EPSRC SUPERGEN Hydrogen and Fuel Cells Hub, EP/J016454/1, 2012-2017, **£219k**.
- EPSRC SUPERGEN Hydrogen and Fuel Cells Challenge: Safety Strategies for Onboard Hydrogen Storage Systems, EP/K021109/1, 2013-2017, **£1.2M**.
- Invest NI Proof of Concept “Composite tank prototype for onboard compressed hydrogen storage based on novel Ulster’s leak-no-burst safety technology”, **£106k**.
- Interreg Atlantic Area ERDF HYLANTIC “Atlantic network for renewable generation and supply of hydrogen to promote high energy efficiency EAPA_204/2016”, **€250k** of €2.5M.
- Forthcoming H2020 FCH 2 JU HyTunnel-CS “Pre-normative research for safety of hydrogen driven vehicles and transport through tunnels and similar confined spaces” project, 2019-2022, **€382k** of €2.5M.

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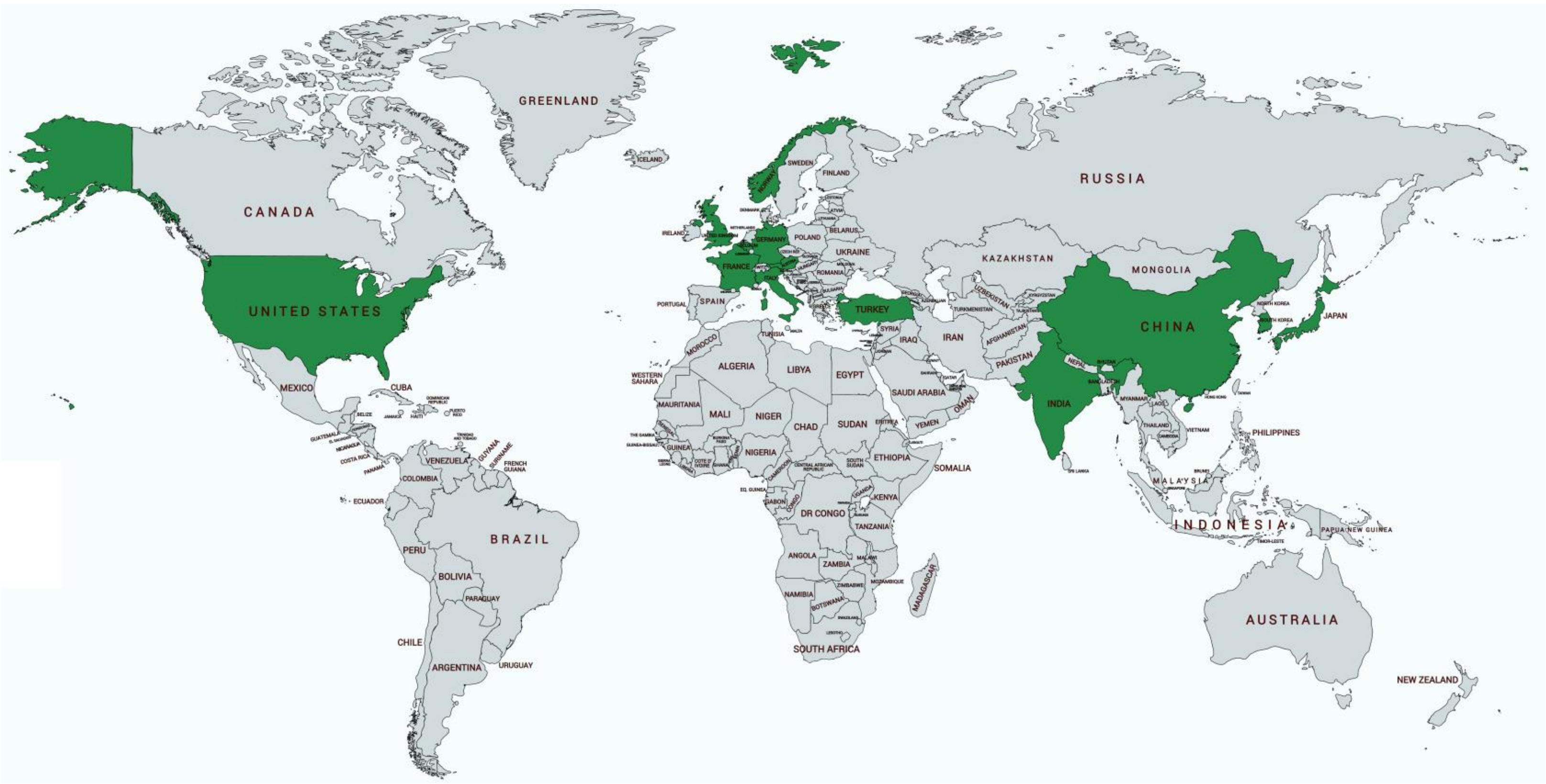
Global partnership

Ulster communicates with 43 tank and material suppliers from 15 countries.



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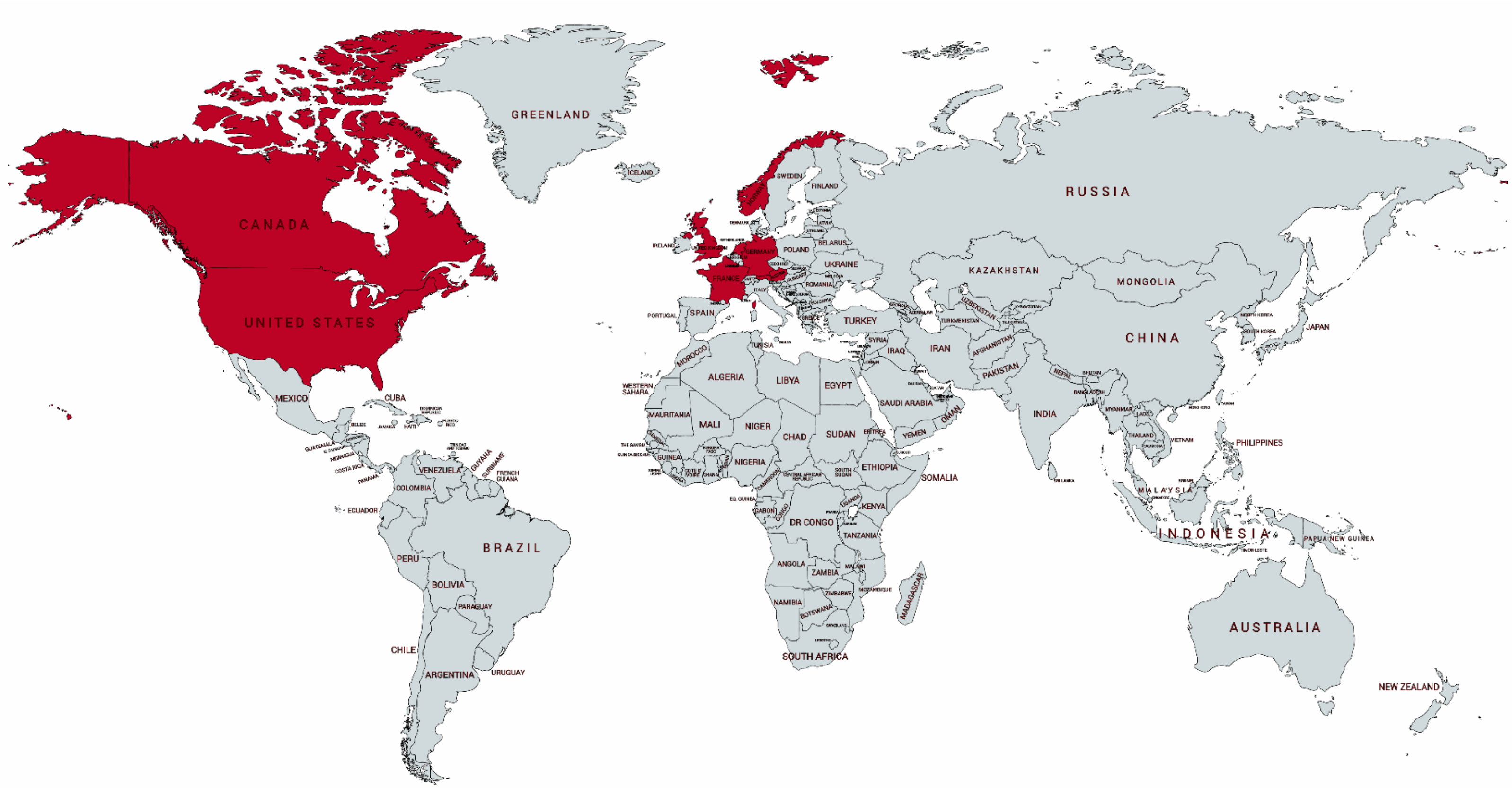
Global partnership

Ulster communicates with 10 testing laboratories from 6 countries.



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Concluding remarks

- First prototypes of LNB safety technology composite high pressure tanks are manufactured and successfully tested.
- Customers could have inherently safer hydrogen-powered vehicles with explosion-free in a fire onboard storage tanks.
- The hazards and associated risks of hydrogen vehicles could be eliminated or reduced drastically:
    - No blast wave!
    - No fireball!
    - No long flames!
    - No pressure peaking phenomenon in confined spaces!
- The requirement for onboard storage hydrogen tanks to be “explosion-free in a fire” should be included into GTR#13 regulation to further protect life and property.
- Ulster is open to expand collaboration with OEMs.