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

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Vladimir Molkov, Dmitriy Makarov, Sergii Kashkarov

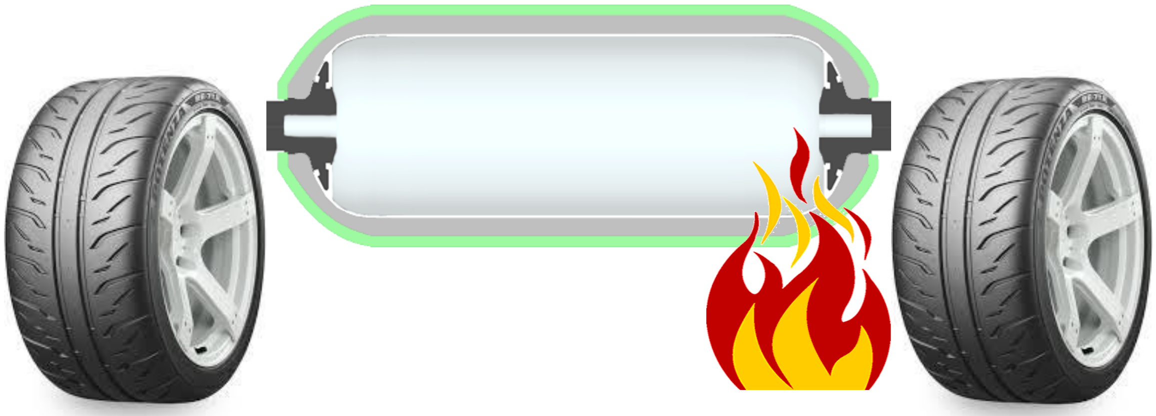
**Hydrogen Safety Engineering and Research Centre (HySAFER)**
**ulster.ac.uk**

# 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 |

# 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)

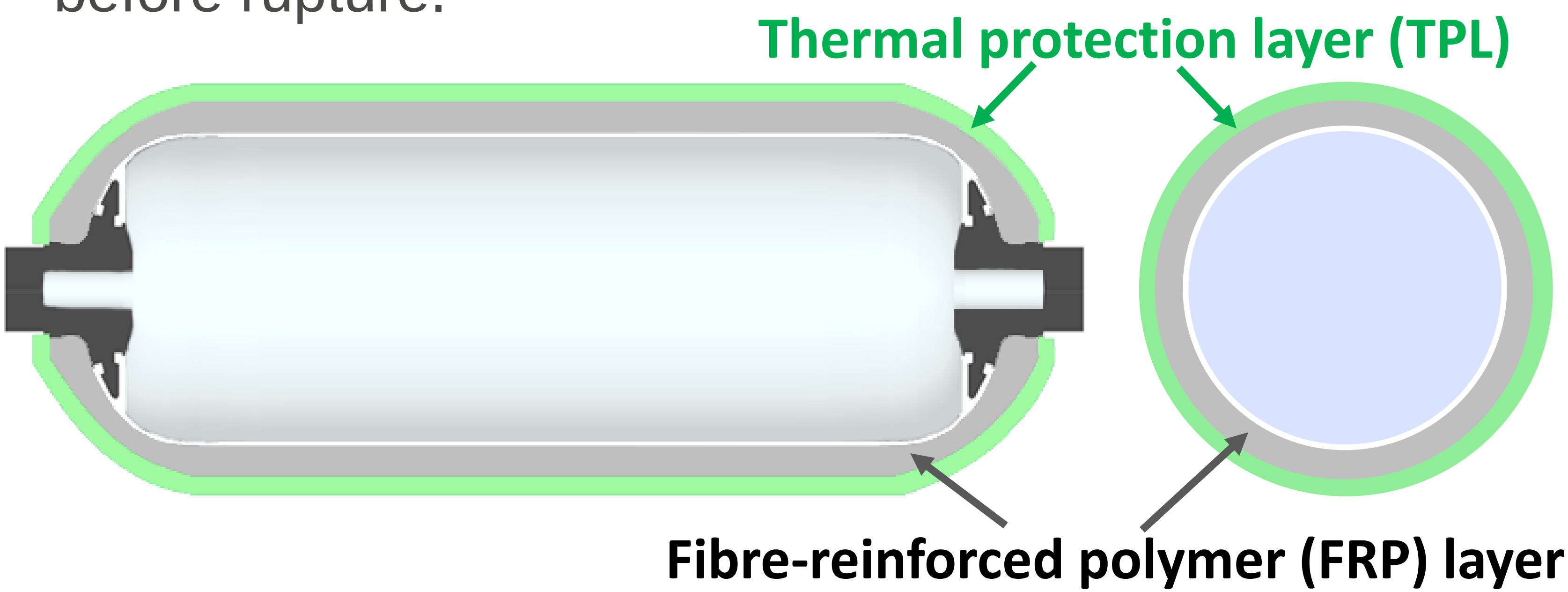
**Three leak-no-burst (LNB) technology strands:**

- Intumescent paint
- Boss design
- Hybrid composite

# 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**.

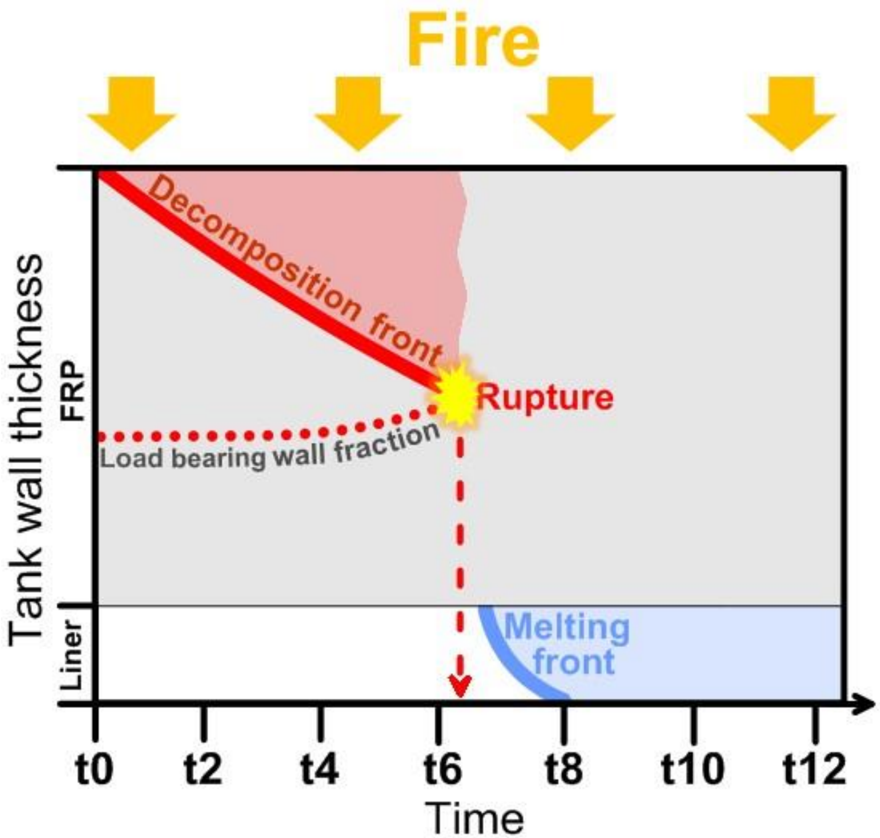
- The **TPL** thermal conductivity is below that of **FRP** to provide a failure of the liner, e.g. its melting, before a **load-bearing fraction of the FRP wall** is degraded to value:

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

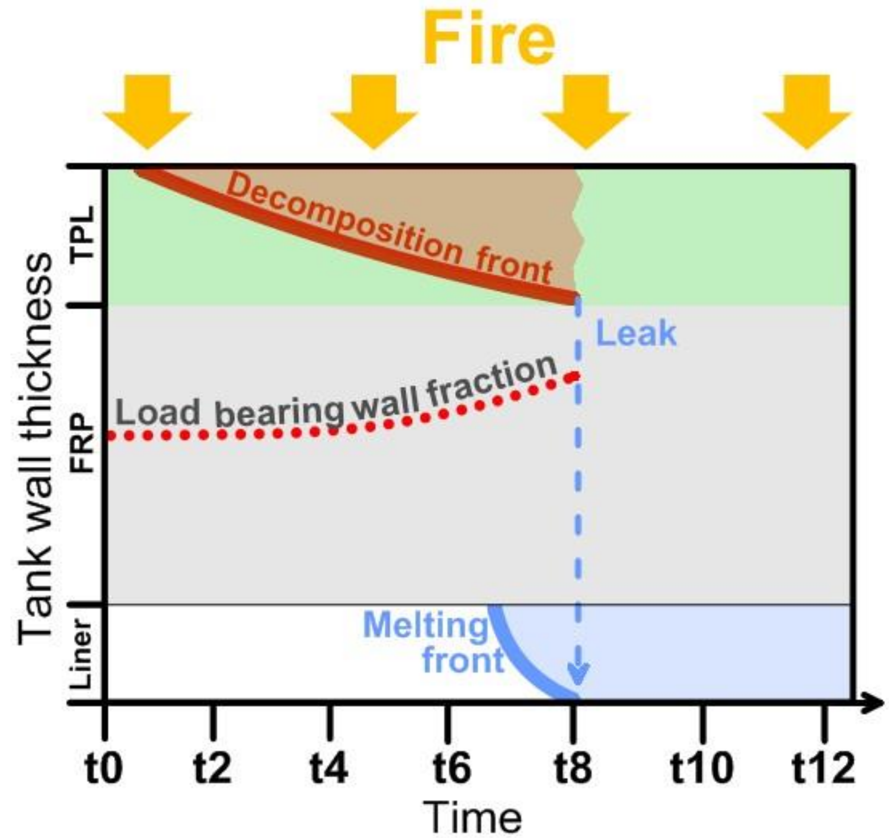
where $\alpha$ - coefficient of pressure increase above NWP.

# LNB safety technology
## Schematic description

Original tank: **rupture**




LNB tank: **no rupture!**

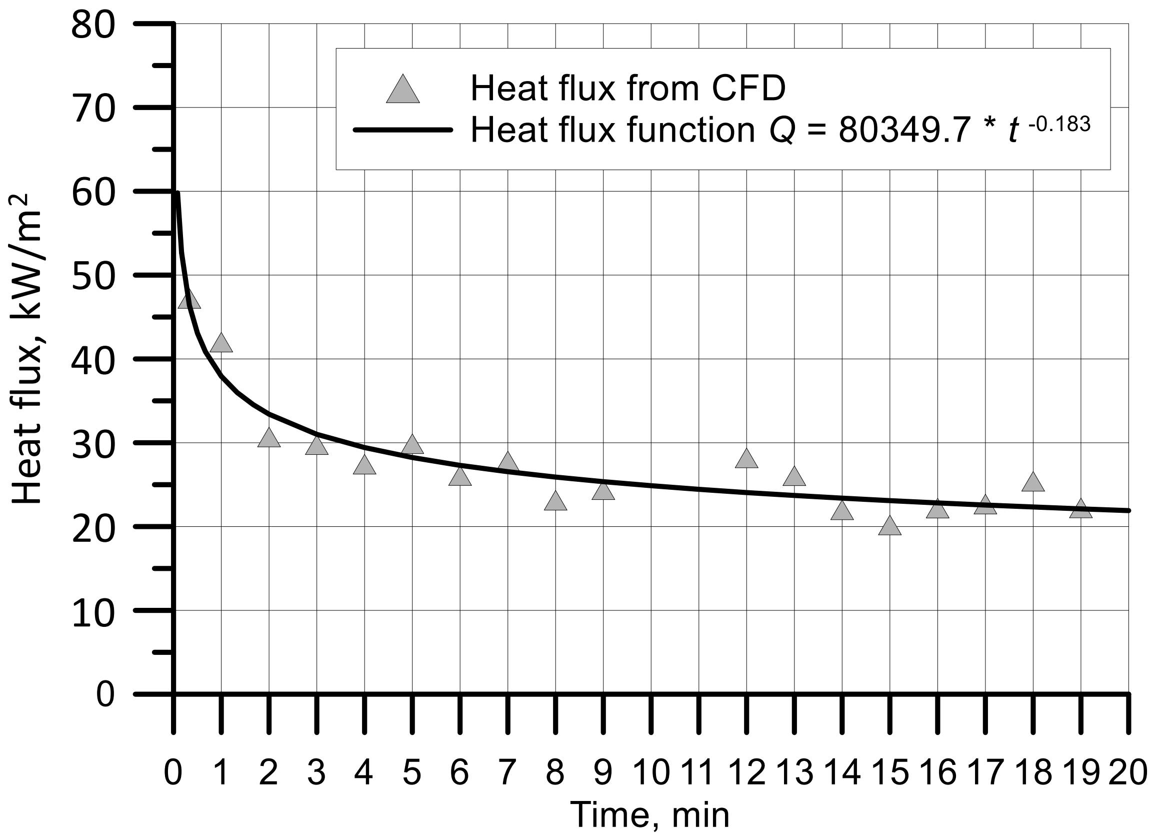



Prototype numerical testing results: LNB performance preserved for storage pressures up to 125% NWP and **any fire regimes (different HRR/A)**

# Prototyping: first trial

## Heat flux from 3D CFD simulations

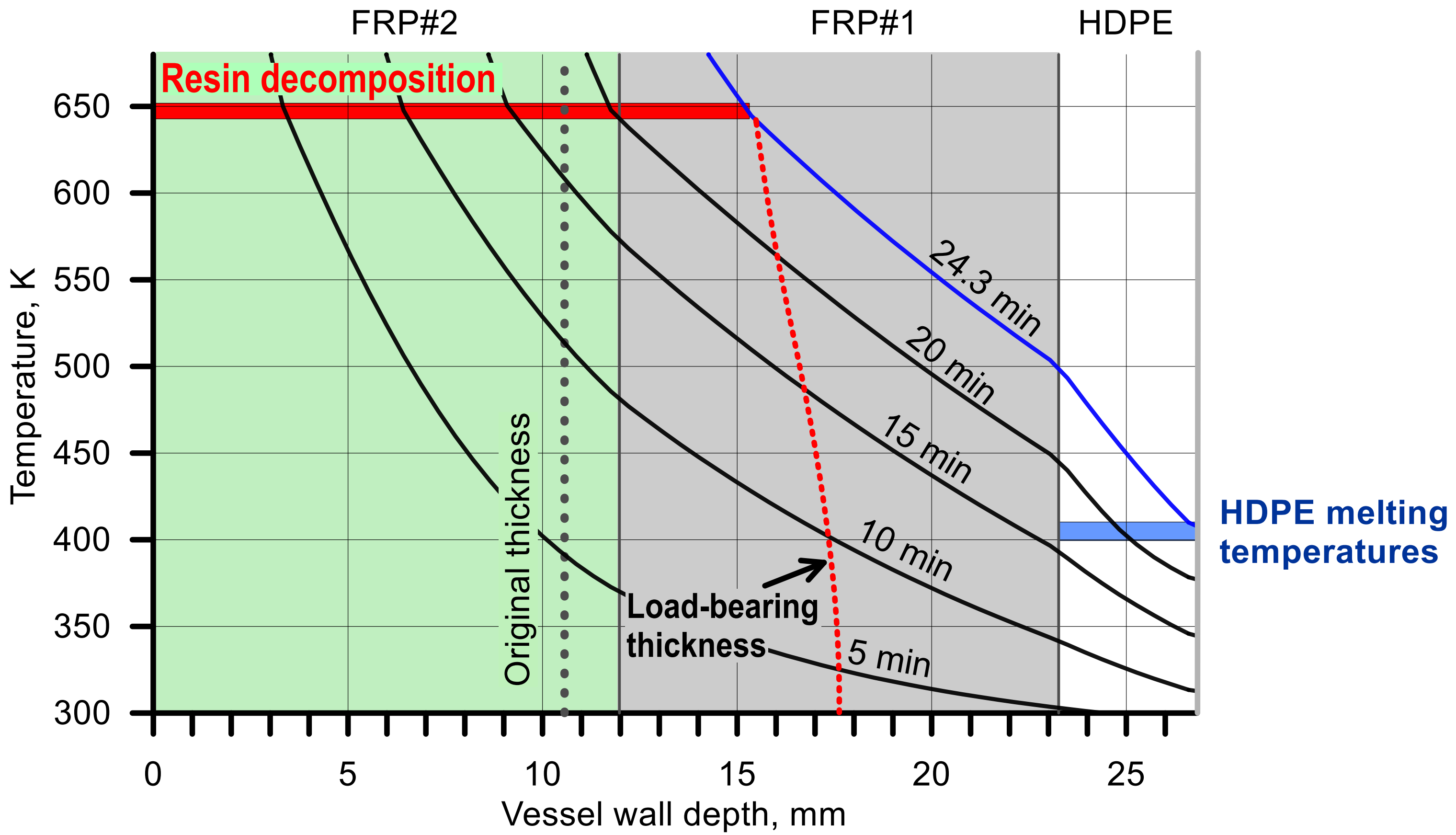
Maximum heat flux in 3D CFD numerical fire test (propane burner with specific heat release rate **HRR/A=1472 kW/m²** to provide reproducibility, HRR=500 kW).




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

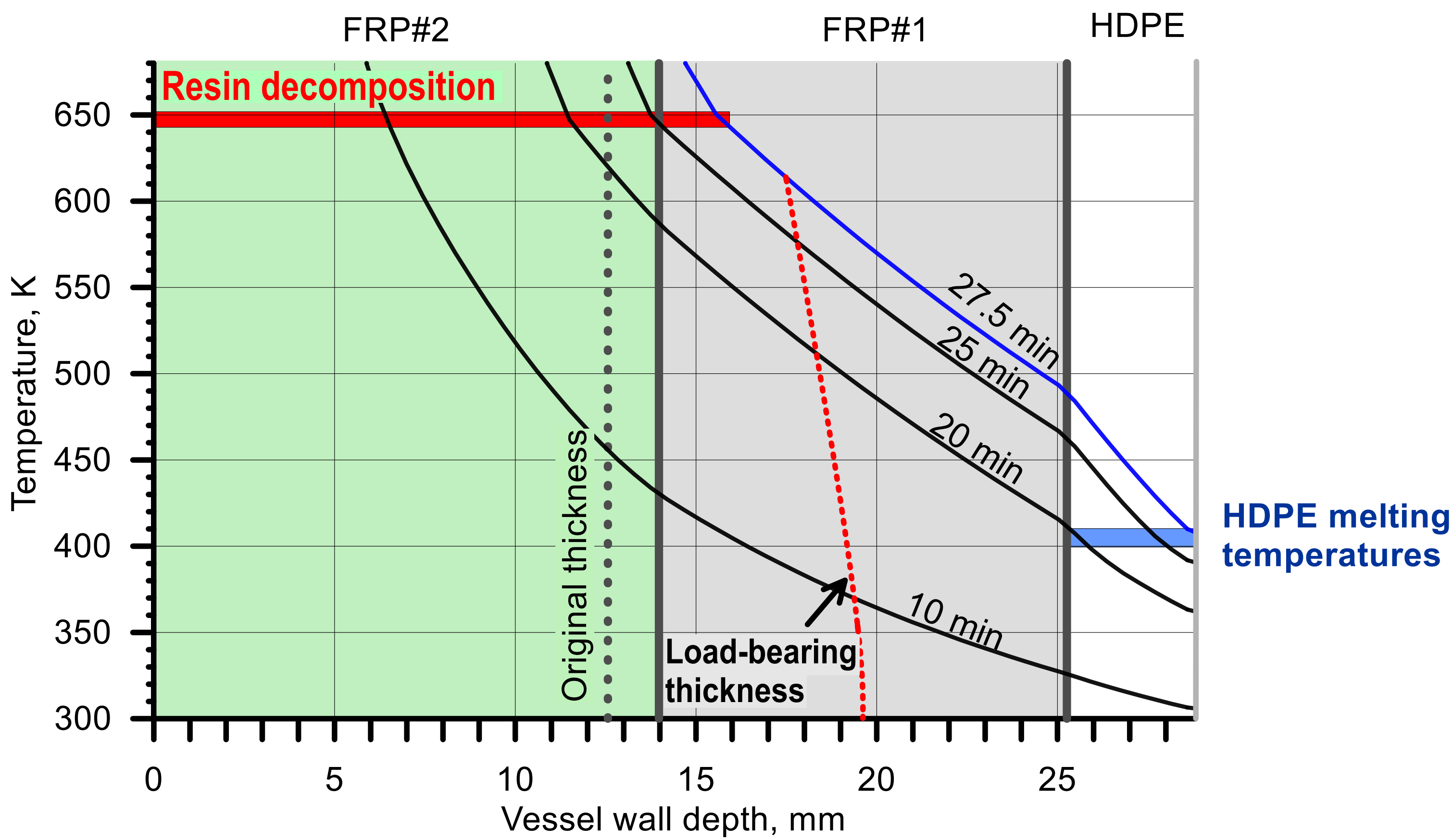
## Simulation by reduced model (1/3)




**Rupture**

# Prototyping: first trial

## Simulation by reduced model (2/3)

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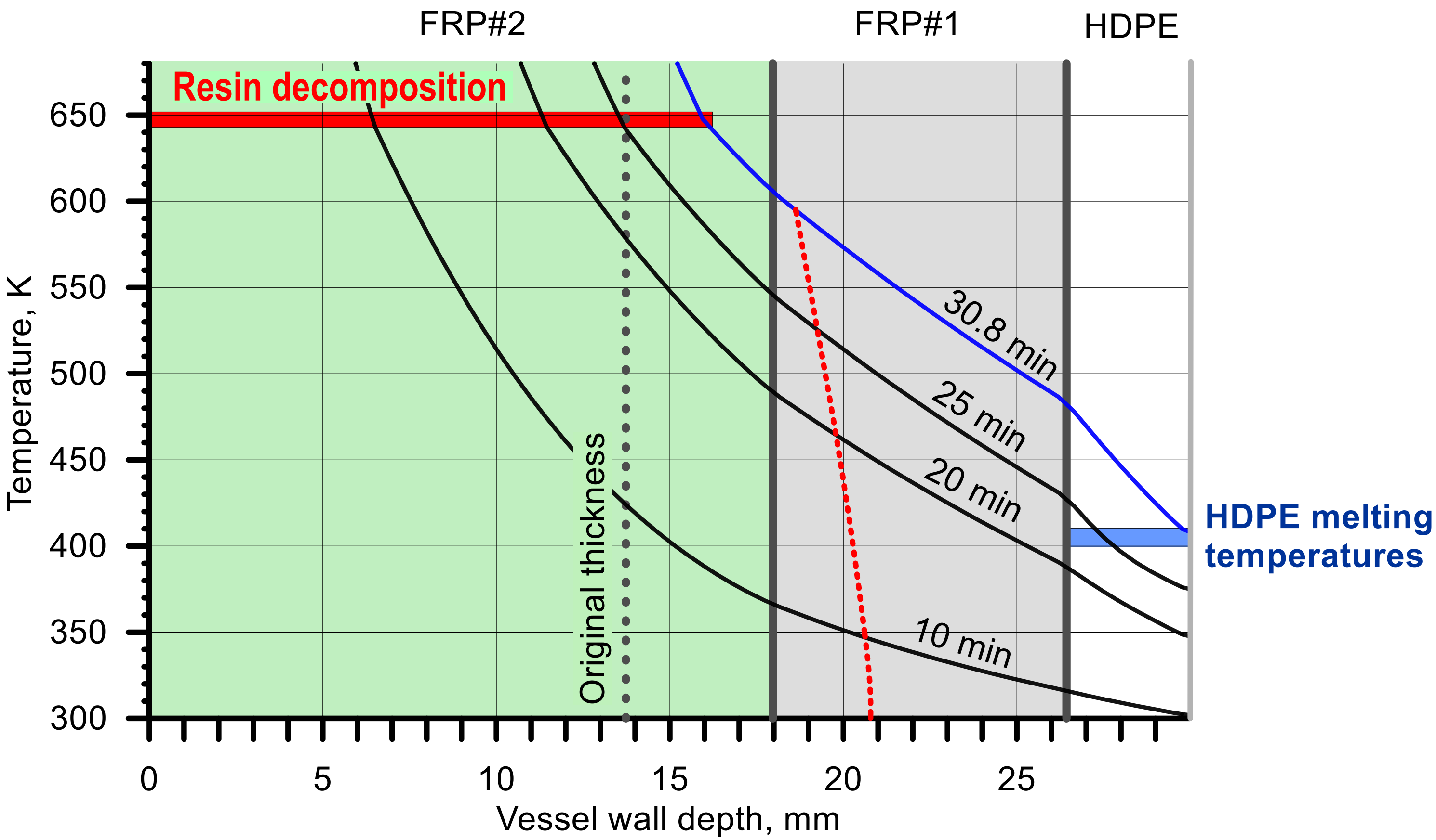
**Leak**

# 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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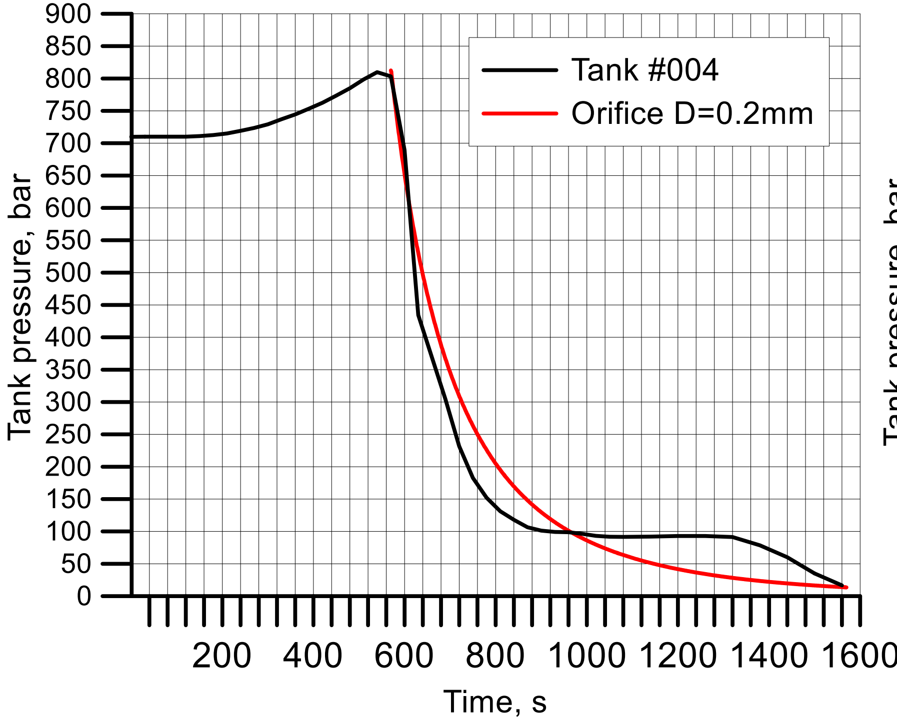
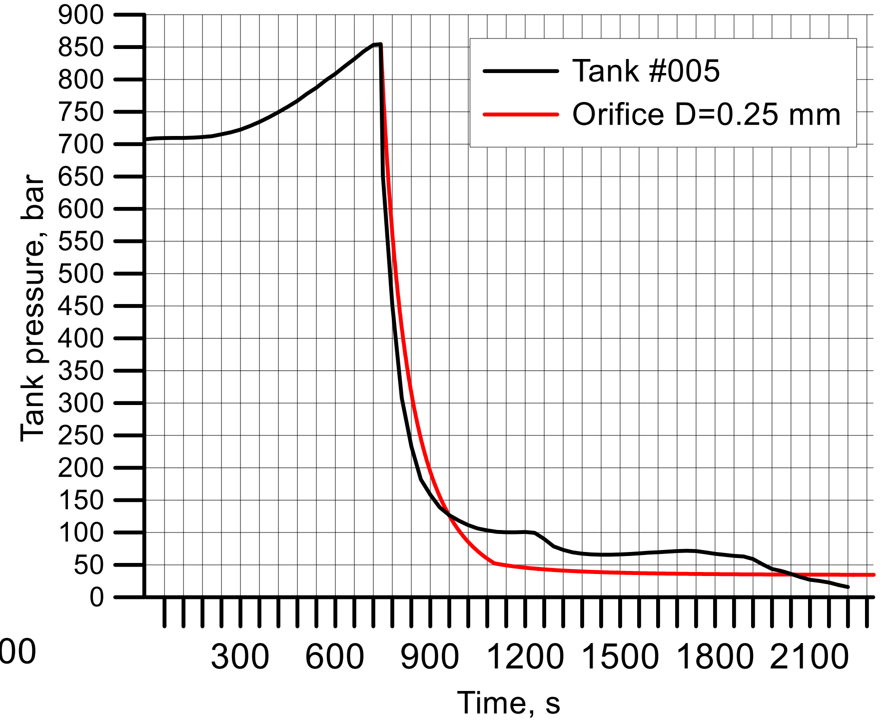
# First prototypes testing

## Blowdown equivalent diameter 0.20-0.25 mm

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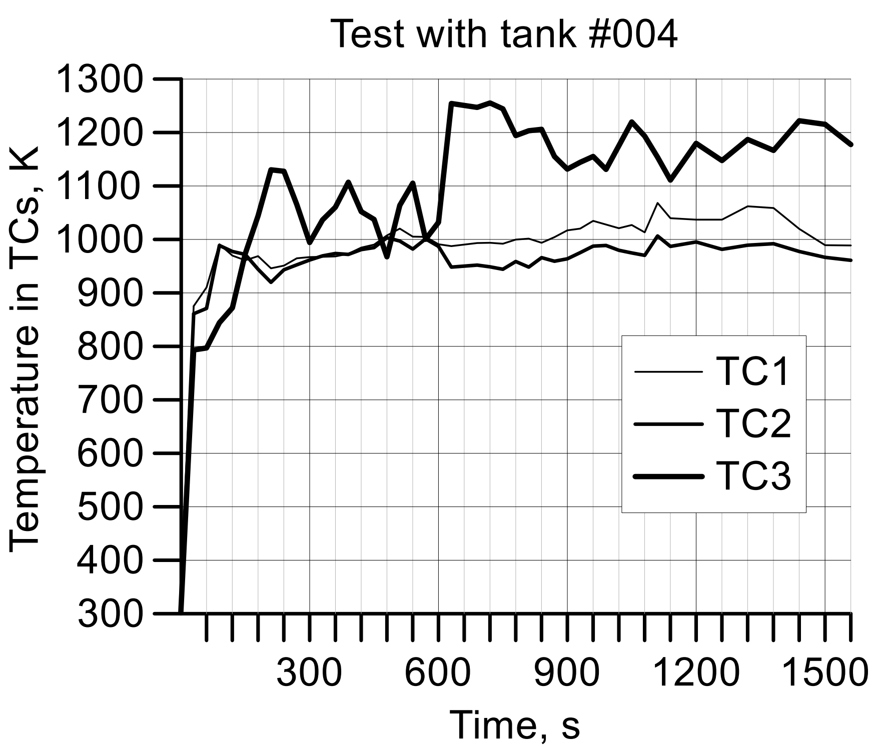
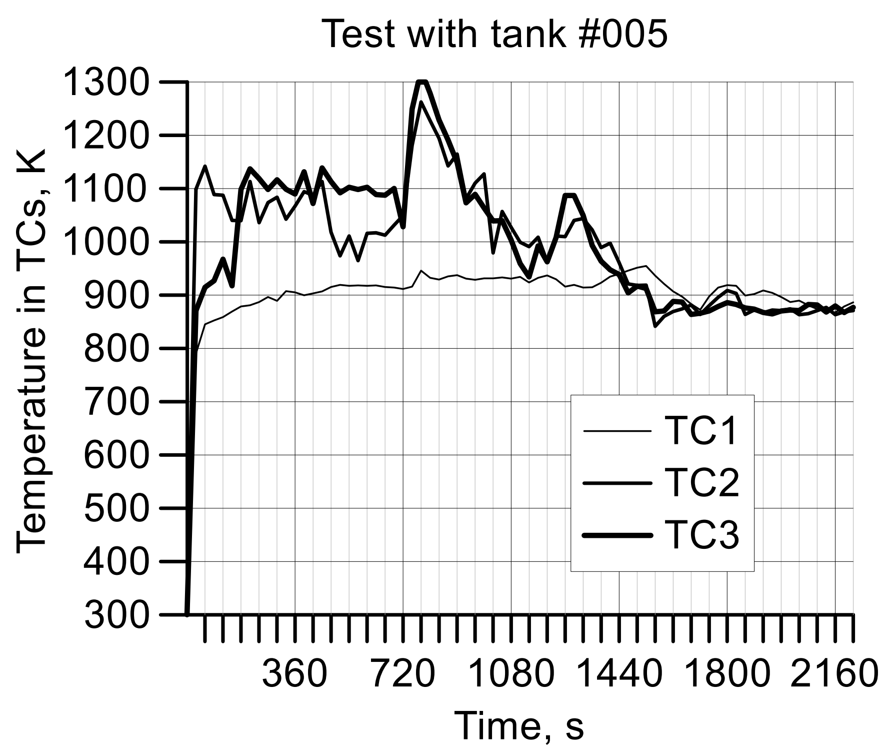
LNB resolves the issue of the destructive pressure peaking phenomenon in confined spaces like garage (**insignificant leak!**)

# GTR#13 engulfing fire test

## Test temperatures satisfy the regulation

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# Aftermath of first prototyping

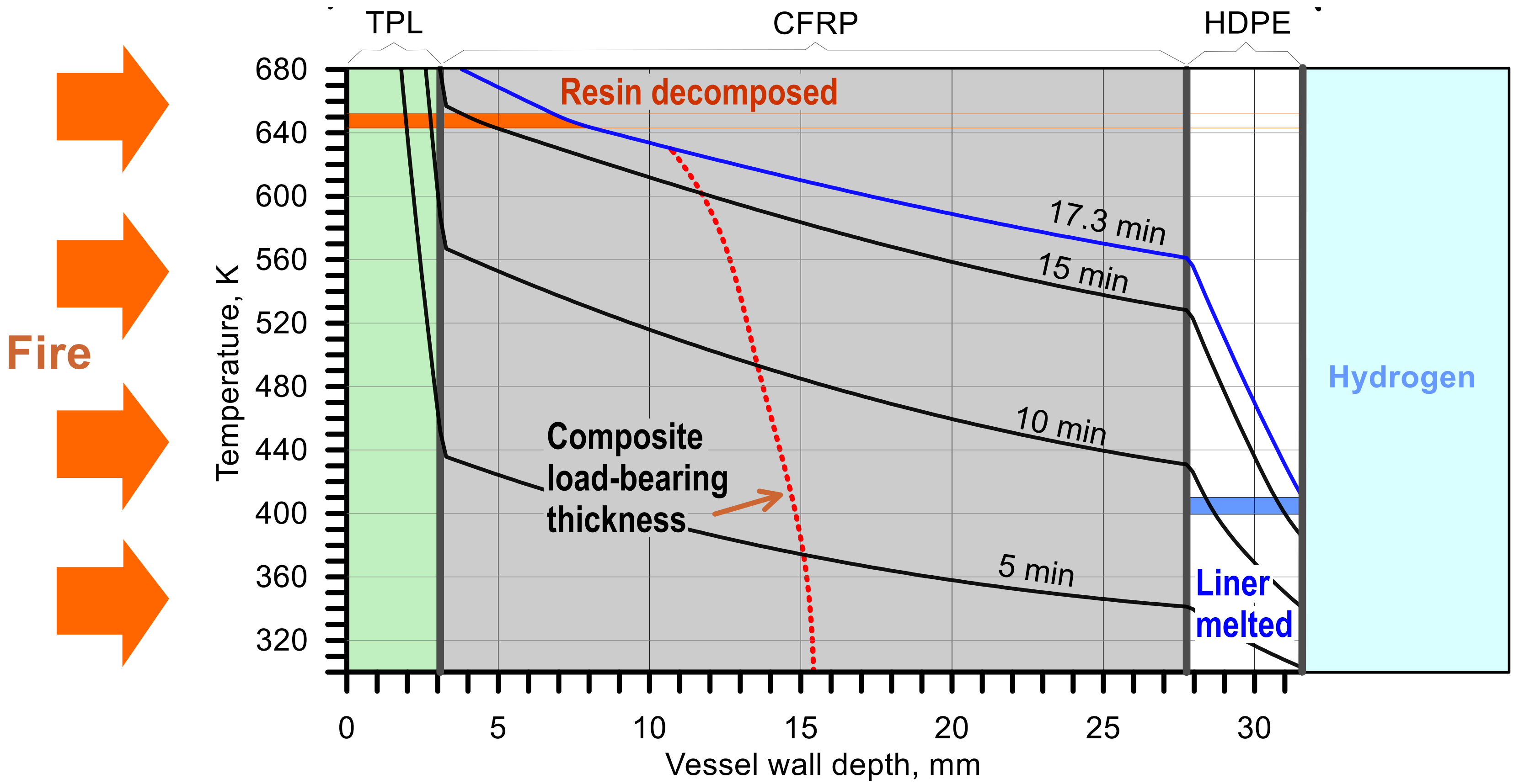
## Comments

- 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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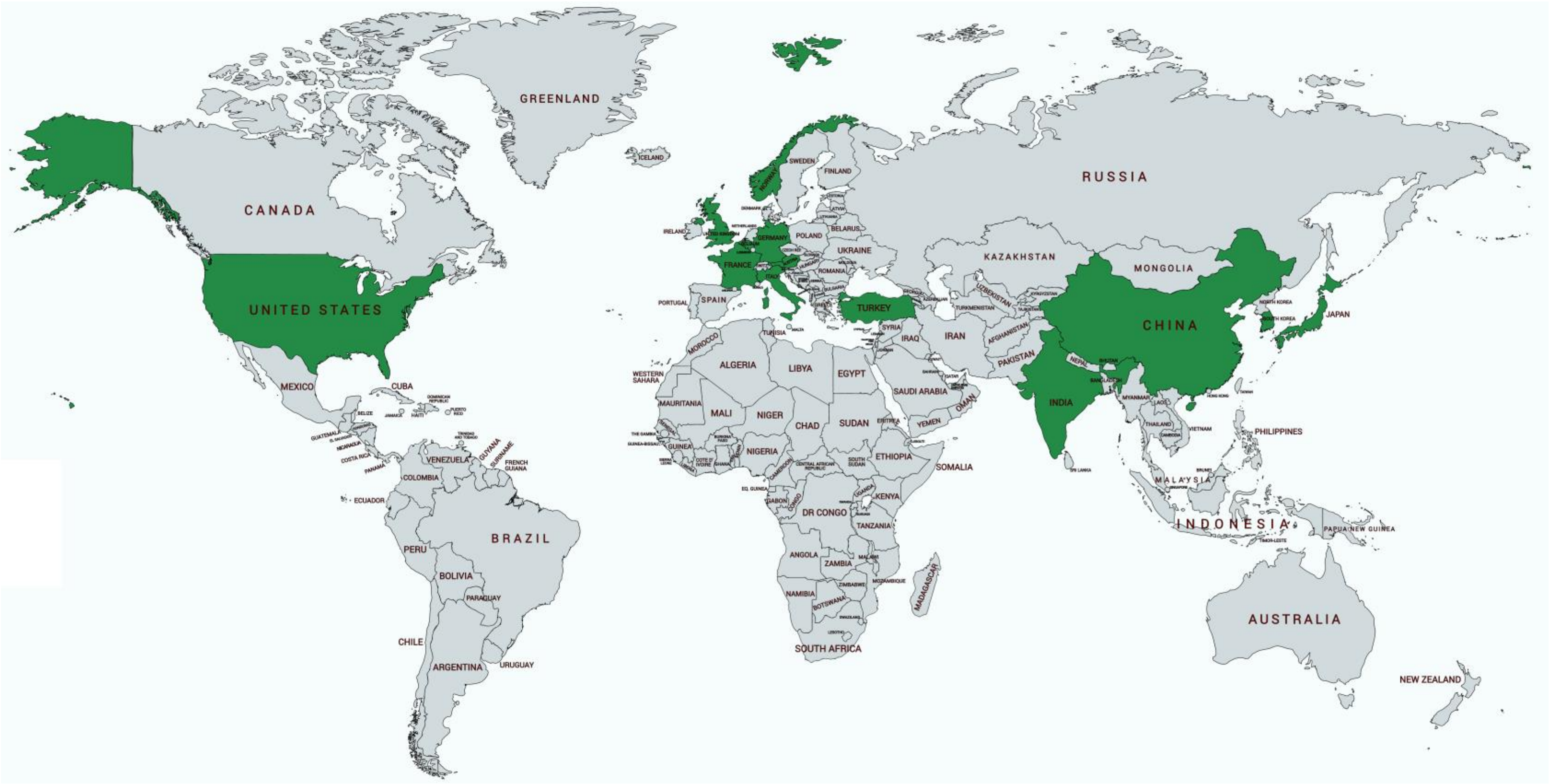
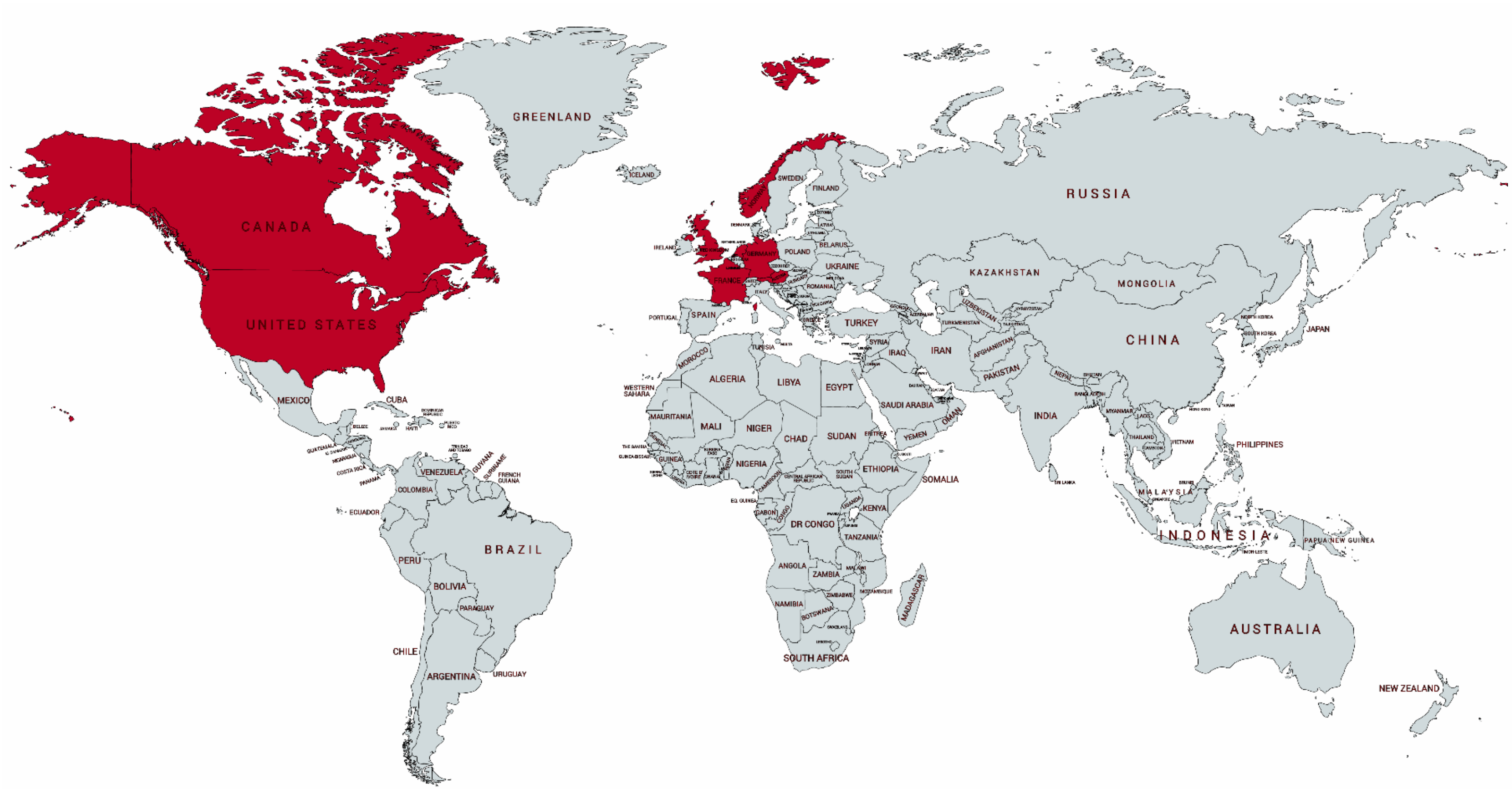
# Global partnership

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



# 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.