UN GTR#13 IWG SGS meeting

Tianjin, 18-20 June 2019

GTR#13 fire test: suggested amendments

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Outline

- Definitions, abbreviations, GTR#13 text marking
- Engulfing fire: fire resistance rating (first responders request)
- Engulfing fire: effect of burner type (no wind)
    - GTR#13 text amendment No.1 (Engulfing fire)
- Engulfing fire: effect of wind (remarks on burner's type)
- Localised fire. Part 1/2: do we need "localised portion…"?
- Localised fire. Part 2/2: new localised (smouldering) fire test
    - GTR#13 text amendment No.2 (Localised smouldering fire)
- TPRD and other proven means of controlled release
    - GTR#13 text amendment No.3 (TPRD and other proven means)
- Concluding remarks

Definitions and abbreviations

Heat release rate (HRR)	-	Heat release rate in a fire [kW] (can easily be measured by propane flow rate to a burner).
Specific heat release rate (HRR/A)	-	Heat release rate in a fire, HRR, divided by area of fire source, A, [kW/m^2]
Heat flux, $\dot{q}''$	-	Heat flux on tank surface [kW/m^2] (not the same as HRR/A even dimension is the same!).
Fire resistance rating (FRR) required by firemen (EU HyResponse project)	-	Time from burner ignition until container's rupture in a fire (without TPRD or failed TPRD or localised fire far from TPRD, e.g. smouldering fire)

Abbreviations

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

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GTR#13 text amendments marking

The GTR#13 current text is corrected as follows:

- **New added** text – <u>underlined green font</u>
- **Removed current** text – ~~crossed out red font~~

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Engulfing fire: fire resistance rating (FRR) for first responders

Low probability high consequences event

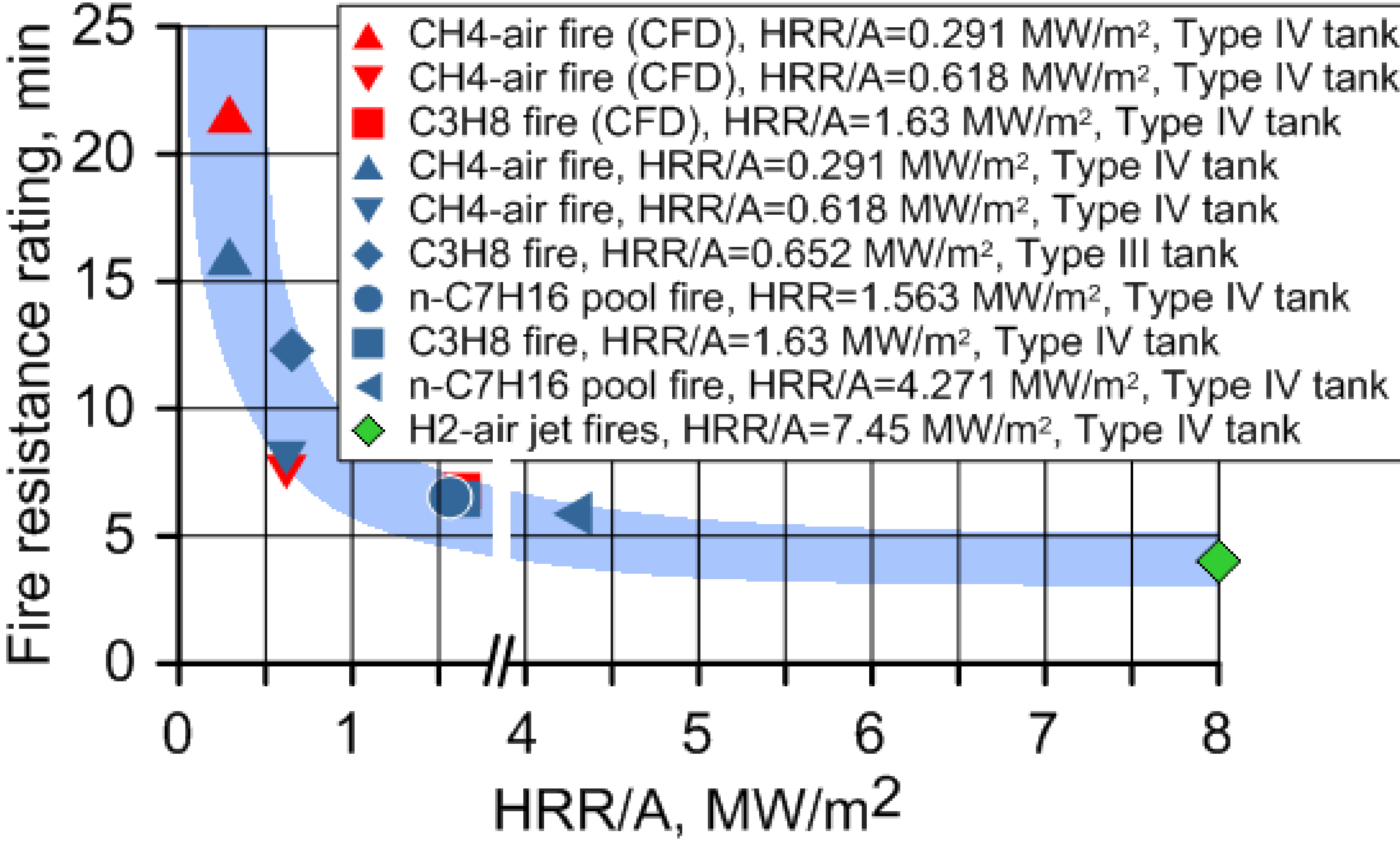
Failed to be initiated or blocked TPRD

Fire brigades need to know time to tank rupture in a fire (FRR):

- London fire brigades: first responders arrival time is 5 min 34 s.
- This is comparable to FRR (see next slide).
- Firemen need to know FRR and parameters of blast wave and fireball to develop intervention strategy and tactics.

Tank FRR drops with burner's HRR/A!

Reproducibility of FRR at HRR/A ≥1 MW/m²

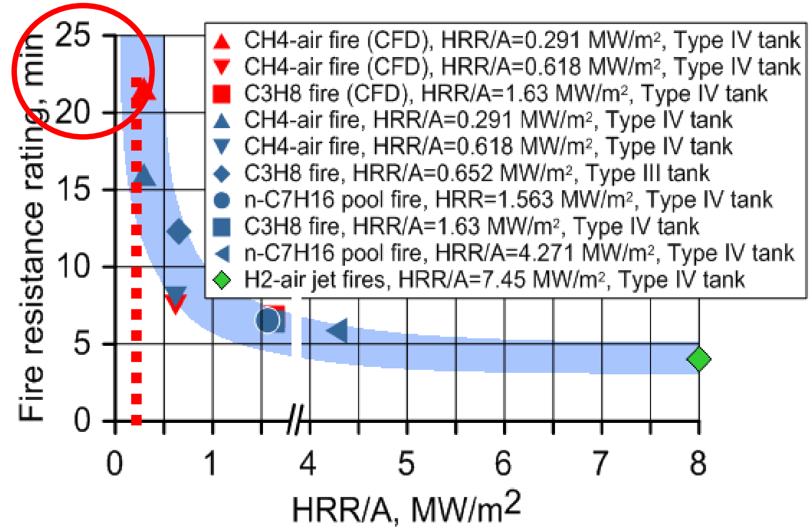


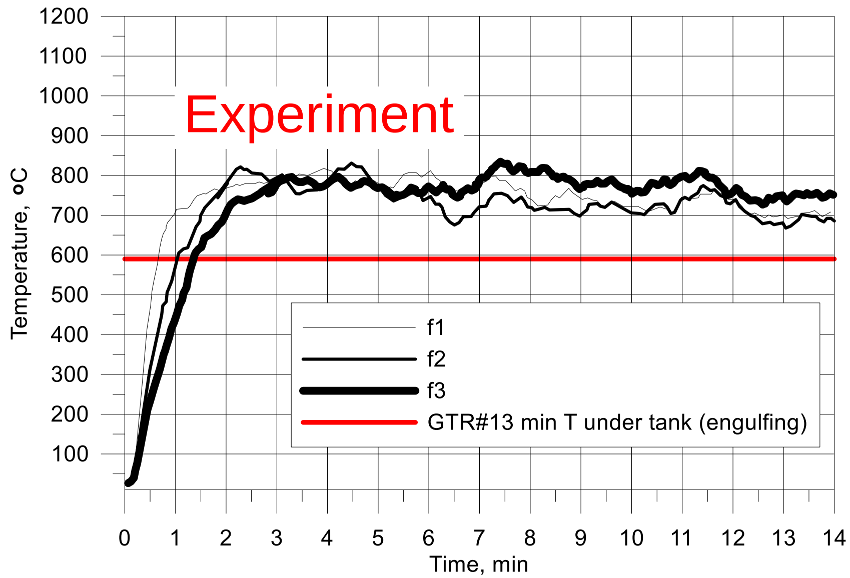
Containers must be tested at severe (not mild!) realistic conditions.

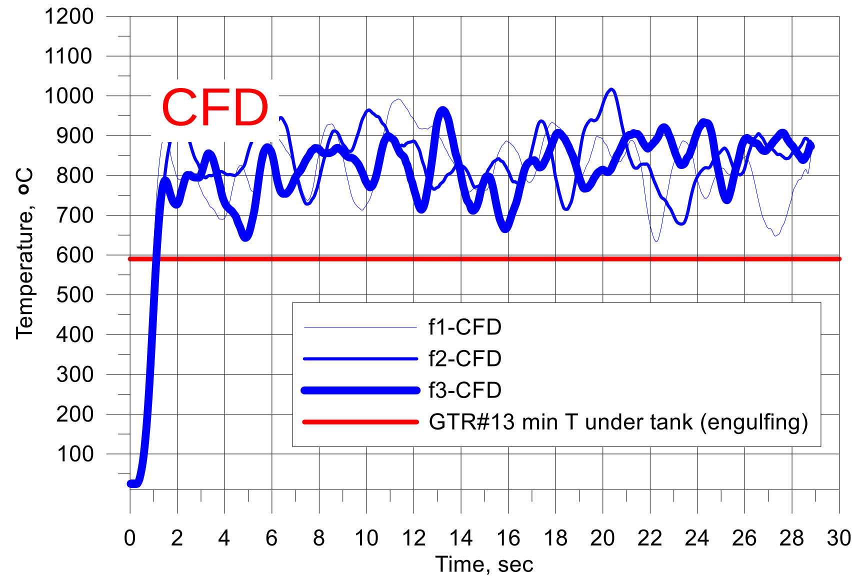
Engulfing fire: effect of burner type (no wind)

Blanket burner

Low HRR/A=0.228 MW/m²





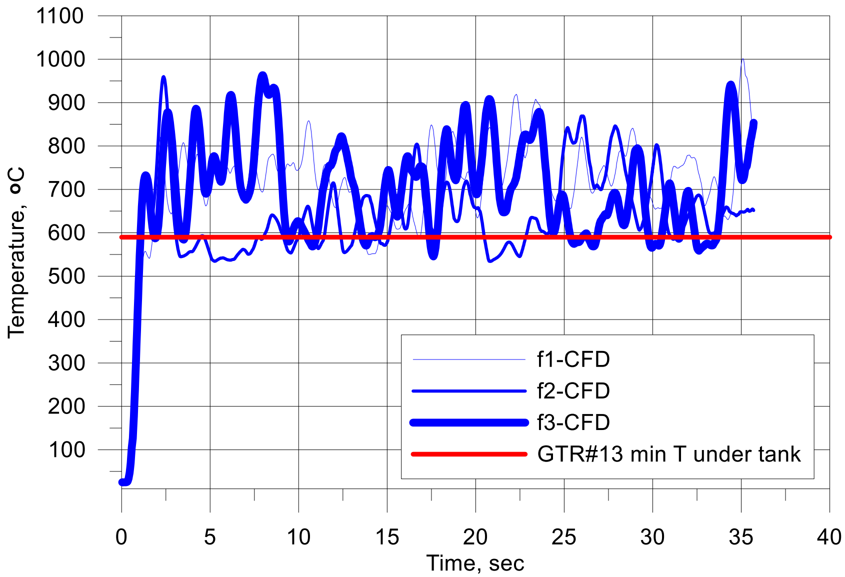


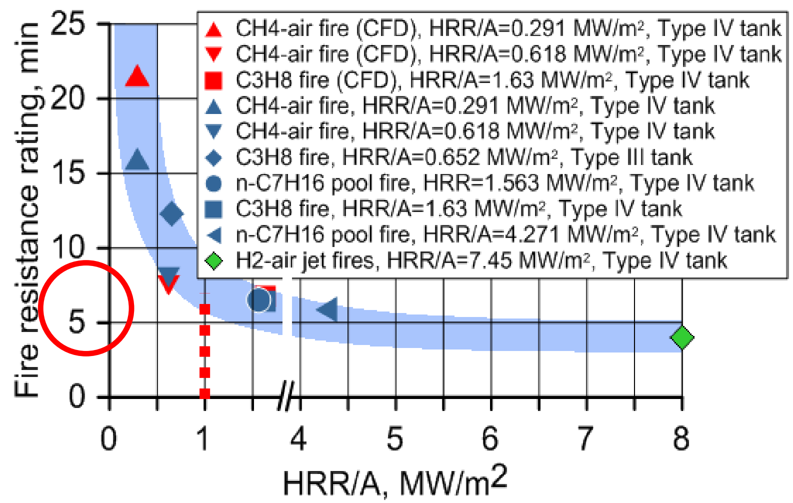
Temperature under the tank is GTR#13 compliant.

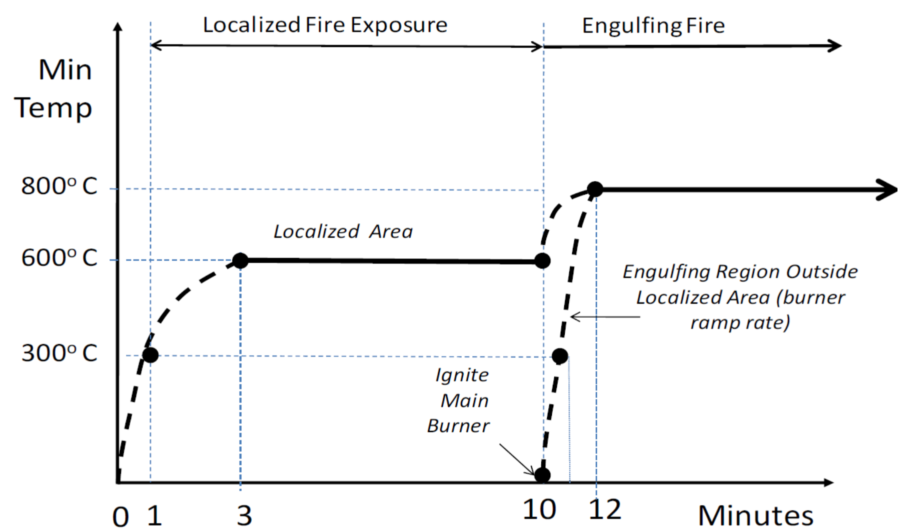
Fire resistant rating (FRR) is artificially high (15-25 min).

Blanket burner

Required HRR/A=1 MW/m²





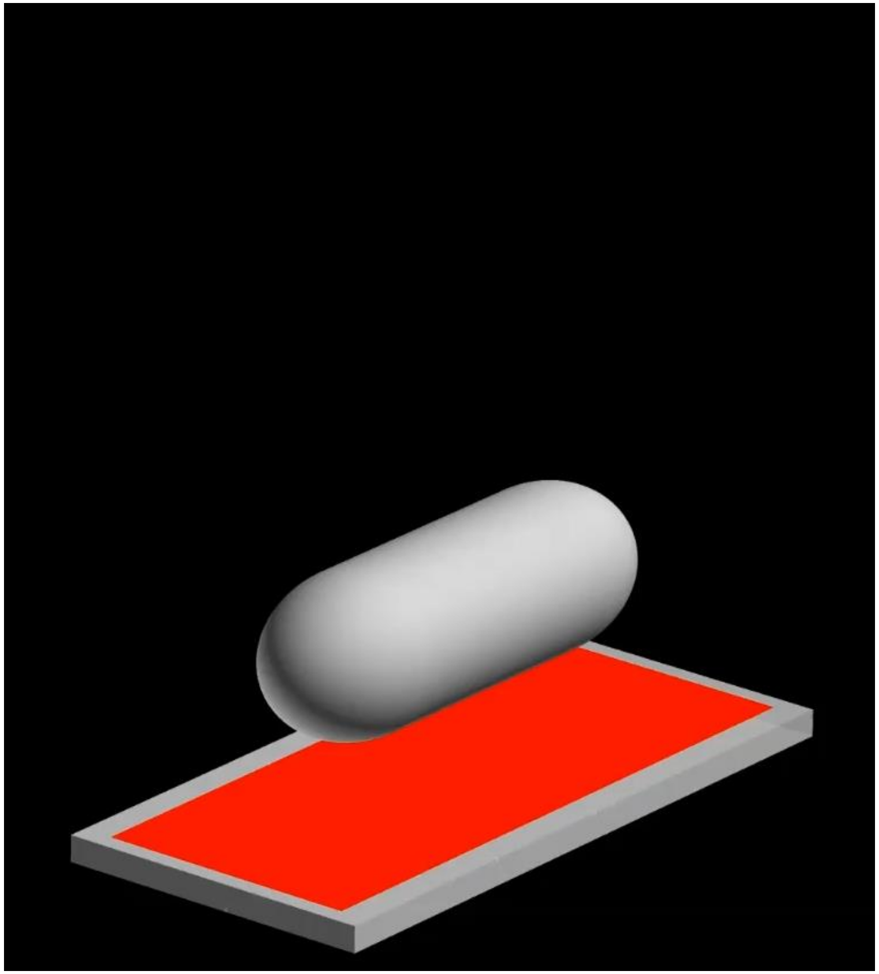


Temperature under the tank is GTR#13 compliant.

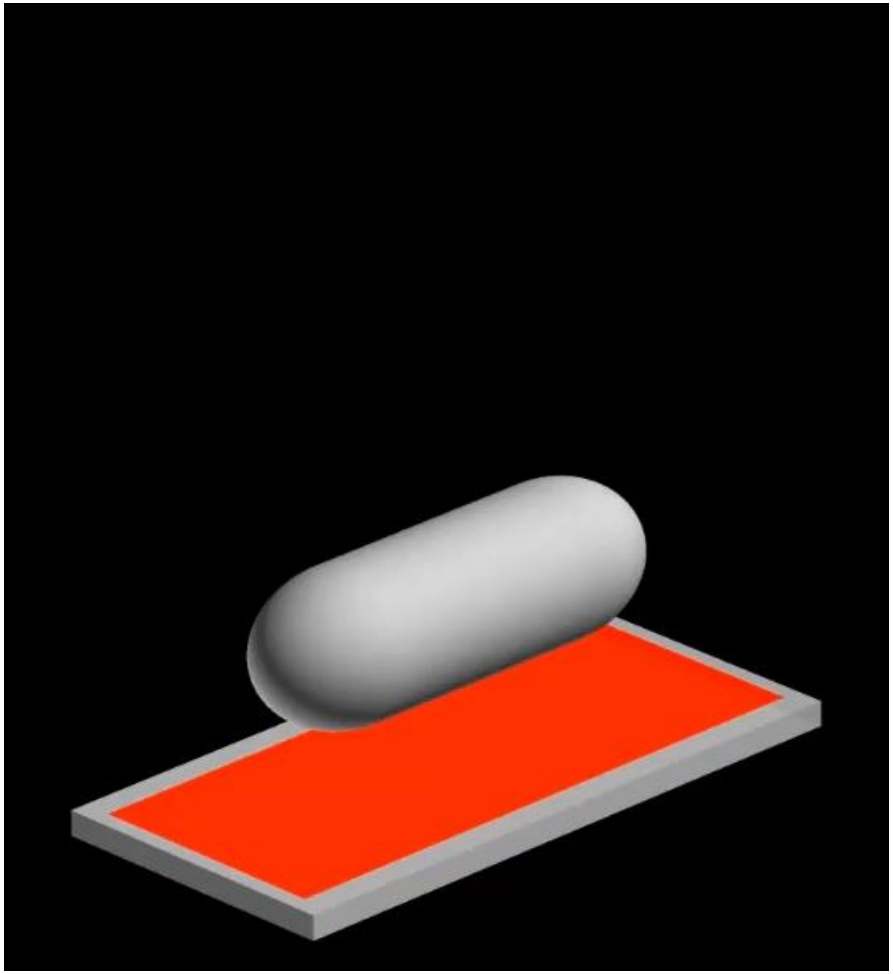
Fire resistant rating (FRR) is realistic (below 7 min, i.e. less than duration of “localised fire exposure” of 10 min!).

Blanket burner: two different HRR/A

HRR/A=0.228 MW/m^2



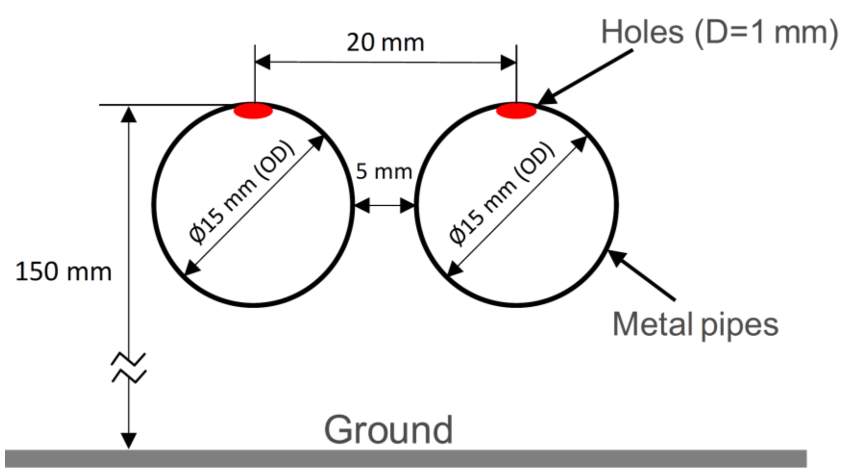
HRR/A=1 MW/m^2

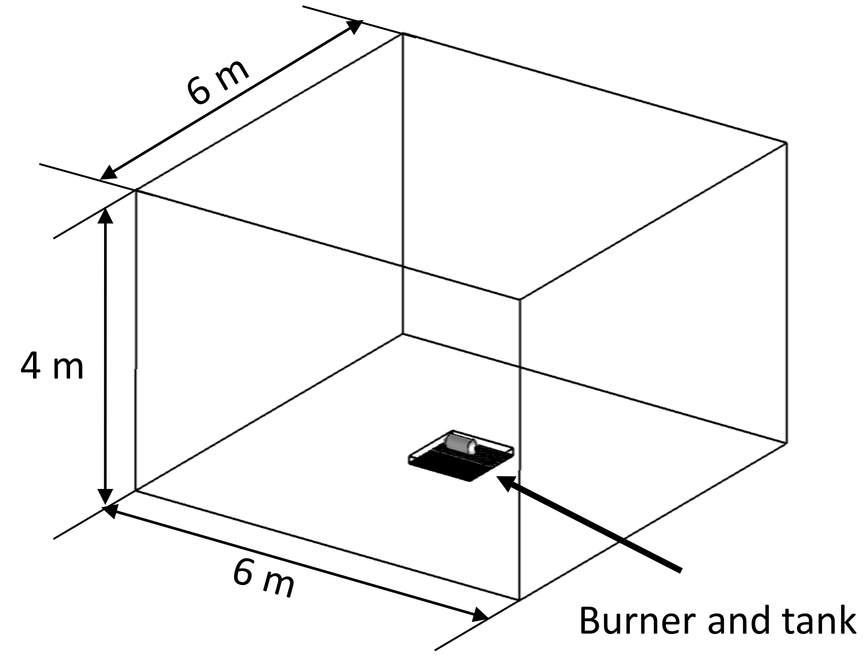


590°C (GTR#13 min required) | 1030°C | 1230 °C

Pipe burner
Details of numerical experiments

- 5600 holes spaced uniformly at 20 mm. Hole D=1 mm.
- Propane injection velocities: 5.3 m/s (HRR/A=1 MW/m^2), 1.2 m/s (HRR/A=0.228 MW/m^2).
- Burner positioned at 0.15 m above the ground.
- Calculation domain: 6x6x4 m.
- Conjugate heat transfer to Type 3 tank (0.9x0.3 m).

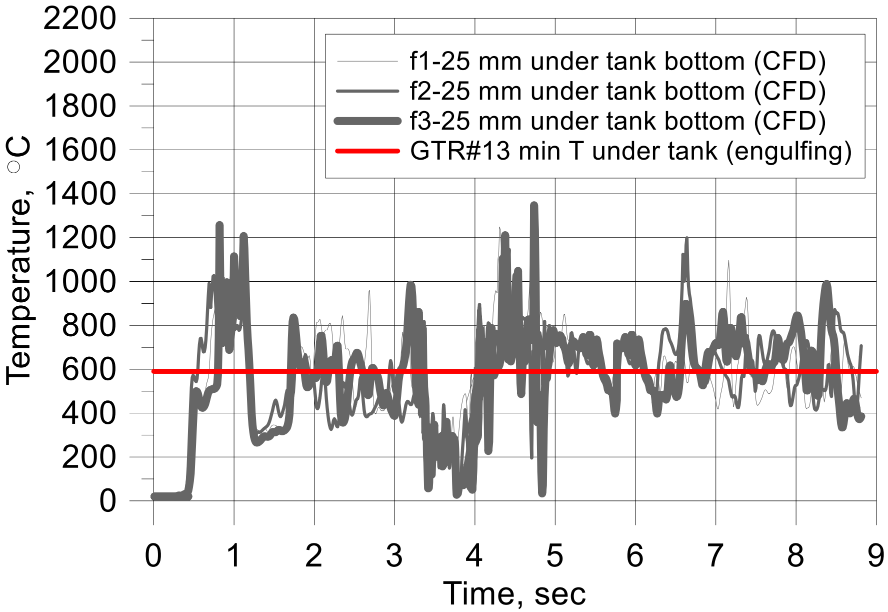




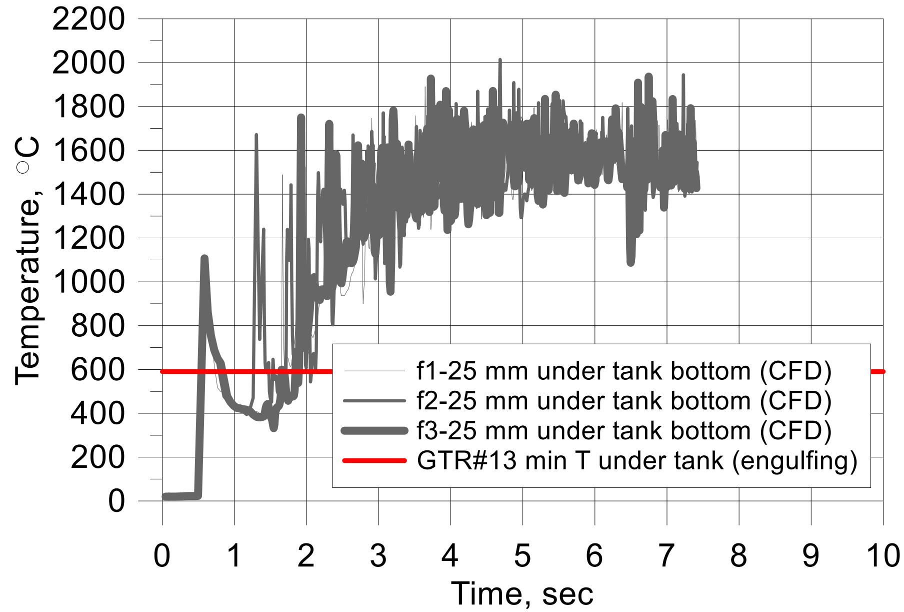
Pipe burner

Temperatures under the tank

Case1: HRR/A=0.228 MW/m^2



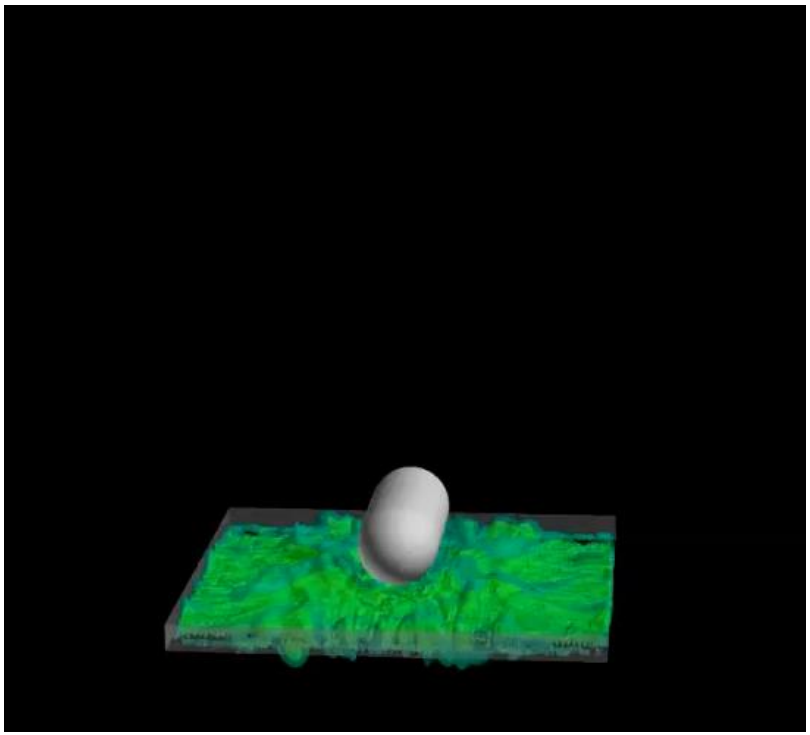
Case 2: HRR/A=1 MW/m^2



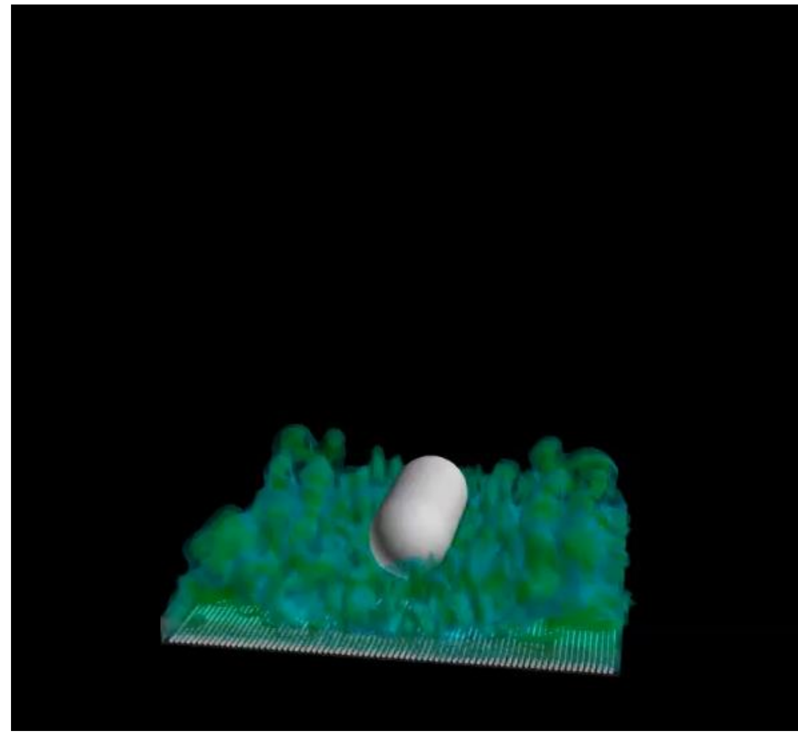
Temperature under the tank is GTR#13 compliant for HRR/A=1 MW/m2 and either not compliant or at the limit for HRR/A=0.228 MW/m^2!

Pipe burner
Temperature iso-surfaces

Case1: HRR/A=0.228 MW/m^2



Case 2: HRR/A=1 MW/m^2



Temperatures:

590°C (GTR#13 min required)

1030°C

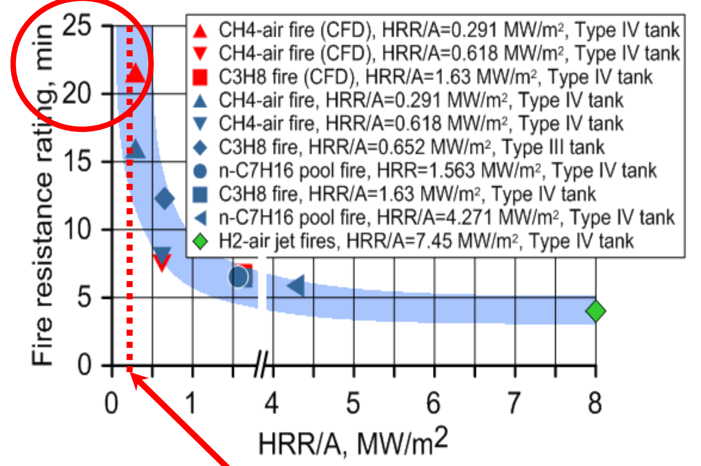
Burner's HRR/A

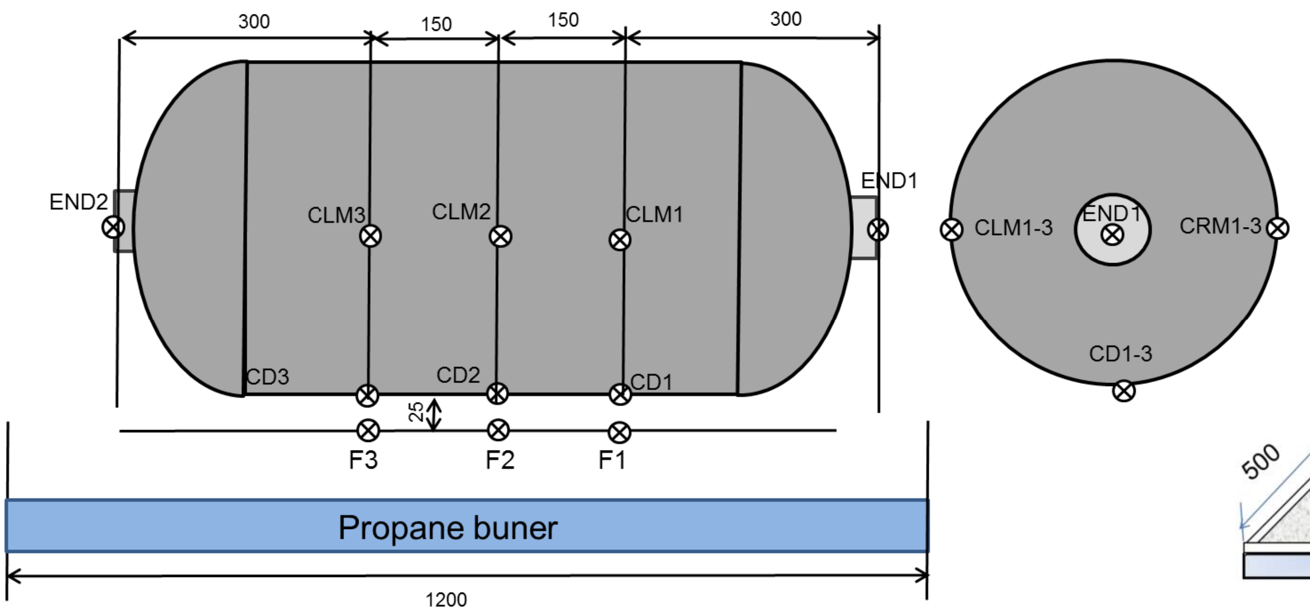
Case 1: HRR/A=0.228 MW/m²

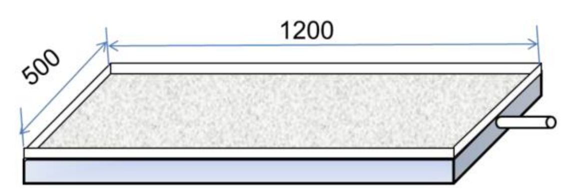
Propane rate $\dot{V}$=100 NL/min ($\dot{m}$=3 g/s).

Blanket burner test: A=0.6 m², HRR=0.137 MW.

Thus, low specific heat release rate of **HRR/A=0.228 MW/m²**.







Favourable conditions to pass fire test at lower HRR/A.
Not conservative approach with hidden higher risk of tank rupture.

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Text amendment No.1: Engulfing fire

6. Test conditions and procedures
6.2. Test procedures…for hydrogen storage

6.2.5. Test procedures for service terminating performance in fire

6.2.5.1. Fire test

Localized portion of the fire test

"(c) The fire source consists of ~~LPG~~ gas burners or a pool fire configured to produce the specific heat release rate, HRR/A, not less than 1 MW/m^2 and a uniform minimum temperature on the test article measured with a minimum 5 thermocouples covering the length of the test article ~~up to 1.65 m maximum~~ …"

Rationale: To ensure fire test reproducibility, to inform first responders about conservative value of time to rupture, and dismiss limit for burner and vessel size.

6. Test conditions and procedures
6.2. Test procedures…for hydrogen storage

6.2.5. Test procedures for service terminating performance in fire

6.2.5.1. Fire test

Localized portion of the fire test

“(f) As shown in Figure 7 the temperature of the thermocouples in the localized fire area has increased continuously to at least 300°C within 1 minute of ignition, to at least 600°C within 3 minutes of ignition, and a temperature of at least 600°C is maintained for the next 7 minutes. ~~The temperature in the localized fire area shall not exceed 900°C during this period.~~”

Rationale: The upper temperature limit in the localised fire should be relaxed, as the maximum temperature in a fire may easily exceed 900ºC and vary depending on fuel and burner HRR/A. This limitation “helps” to pass current GTR#13 fire test but could create a problem for customers and firemen in real life (fire).

6. Test conditions and procedures
6.2. Test procedures…for hydrogen storage

6.2.5. Test procedures for service terminating performance in fire

6.2.5.1. Fire test

Engulfing portion of the fire test

"… The minimum temperature is held at 800°C~~, and the maximum temperature shall not exceed 1100 °C~~."

Rationale: The upper temperature limit in the engulfing fire should be relaxed, as the maximum temperature in a fire may exceed 1100ºC and vary depending on fuel and burner HRR/A. This limitation "helps" to pass GTR#13 fire test but could create a problem in real life (fire).

6. Test conditions and procedures
6.2. Test procedures…for hydrogen storage

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Table 2
Summary of fire test protocol

	Localized fire region	*Time period*	*Engulfing fire region (Outside the localized fire region)*
Action	Ignite Burners	0-1 minute	No Burner Operation
Minimum temperature	Not specified		Not specified
~~Maximum temperature~~	~~Less than 900°C~~		~~Not specified~~
Action	Increase temperature and stabilize fire for start of localized fire exposure	1-3 minutes	No Burner Operation
Minimum temperature	Greater than 300°C		Not specified
~~Maximum temperature~~	~~Less than 900°C~~		~~Not specified~~
Action	Localized fire exposure continues	3-10 minutes	No Burner Operation
Minimum temperature	1-minute rolling average greater than 600°C		Not specified
~~Maximum temperature~~	~~1-minute rolling average less than 900°C~~		~~Not specified~~
Action	Increase temperature	10-11 minutes	Main Burner Ignited at 10 minutes
Minimum Temperature	1-minute rolling average greater than 600°C		Not specified
~~Maximum temperature~~	~~1-minute rolling average less than 1,100°C~~		~~Less than 1,100°C~~
Action	Increase temperature and stabilize fire for start of engulfing fire exposure	11-12 minutes	Increase temperature and stabilize fire for start of engulfing fire exposure
Minimum temperature	1-minute rolling average greater than 600°C		Greater than 300°C
~~Maximum temperature~~	~~1 minute rolling average less than 1,100°C~~		~~Less than 1,100°C~~
Action	Engulfing fire exposure continues	12 minutes - end of test	Engulfing fire exposure continues
Minimum temperature	1-minute rolling average greater than 800°C		1-minute rolling average greater than 800°C
~~Maximum temperature~~	~~1 minute rolling average less than 1,100°C~~		~~1-minute rolling average less than 1,100°C~~

6. Test conditions and procedures
6.2. Test procedures…for hydrogen storage

6.2.5. Test procedures for service terminating performance in fire

6.2.5.1. Fire test

Engulfing portion of the fire test

“The test article is held at temperature (engulfing fire condition) until the system vents through the TPRD and the pressure falls to less than 1 MPa. In a separate fire test **without TPRD** the **fire resistance rating** of a tank (**elapsed time from ignition of the fire to the tank rupture**) should be documented to inform first responders’ intervention strategy and tactics (the specific heat release rate, HRR/A, of the fire source should be documented as well).”

Rationale: request of first responders (EU HyResponse project).

6. Test conditions and procedures
6.2. Test procedures…for hydrogen storage

6.2.5. Test procedures for service terminating performance in fire

6.2.5.2. Engulfing fire test:

“A uniform fire source ~~of 1.65 m length~~ provides direct flame impingement on the container surface across its entire diameter. The specific heat release rate of a fire source, HRR/A, should not be less than 1 MW/m^2.”

Rationale: To dismiss limit for burner and vessel size, and ensure fire test reproducibility in different laboratories.

6. Test conditions and procedures
6.2. Test procedures…for hydrogen storage

6.2.5. Test procedures for service terminating performance in fire

6.2.5.2. Engulfing fire test:

“The container shall vent through a pressure relief device without bursting. In a separate engulfing fire test without TPRD the fire resistance rating of a tank (elapsed time from ignition of the fire to the tank rupture) should be documented to inform fire fighters and first responders, along with specific heat release rate, HRR/A, of the fire source.”

Rationale: request of first responders (EU HyResponse project).

Engulfing fire: effect of wind

Table of wind velocities

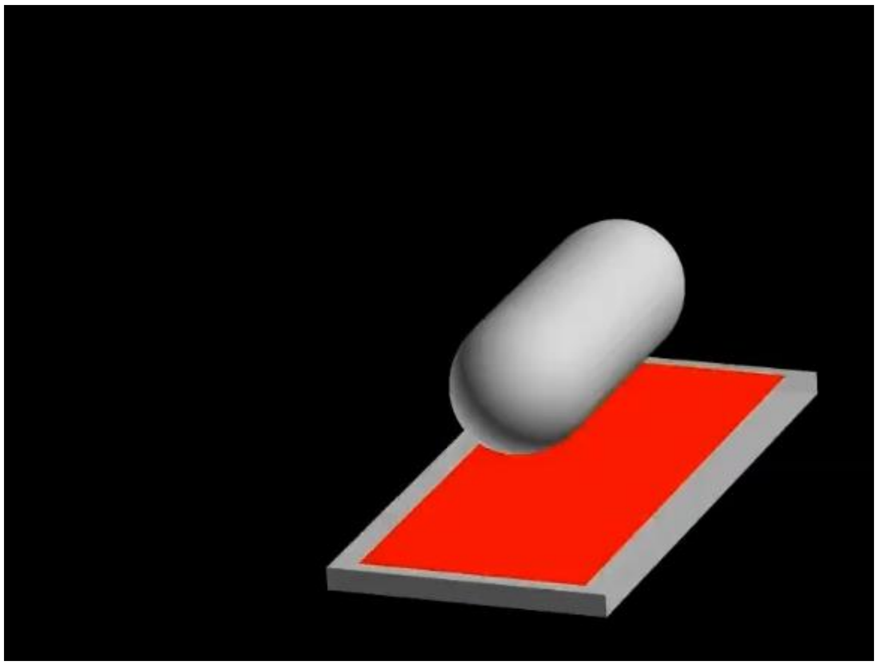
Wind speed	Description
< 1 mph < 0.5 m/s	Calm
1–3 mph 0.5–1.5 m/s	Light air
4–7 mph **1.6–3.3 m/s**	**Light breeze (HSL test, Case 1). Wind felt on face; leaves rustle; wind vane moved by wind.**
8–12 mph **3.4–5.5 m/s**	**Gentle breeze (Case 2). Leaves and small twigs in constant motion; light flags extended.**
13–18 mph 5.5–7.9 m/s	Moderate breeze
19–24 mph **8–10.7 m/s**	**Fresh breeze (Case 3). Small trees in leaf begin to sway; crested wavelets form on inland waters.**
25–31 mph 10.8–13.8 m/s	Strong breeze
32–38 mph 13.9–17.1 m/s	High wind, moderate gale, near gale
39–46 mph 17.2–20.7 m/s	Gale, fresh gale

Source: https://en.wikipedia.org/wiki/Beaufort_scale

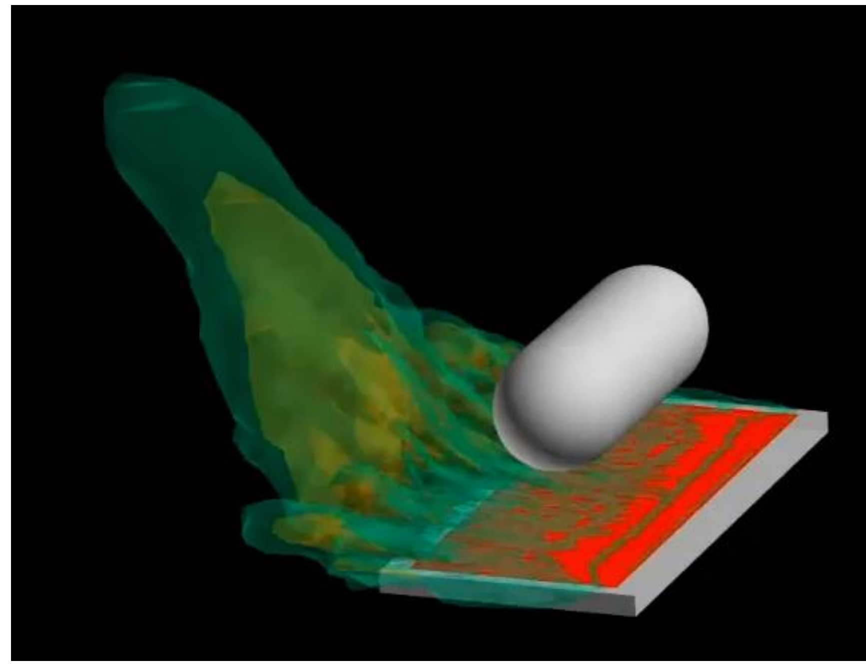
Blanket burner: wind 1.8 m/s

Temperature iso-surfaces (values – next slide)

HRR/A=0.228 MW/m^2



HRR/A=1 MW/m^2



Temperatures:

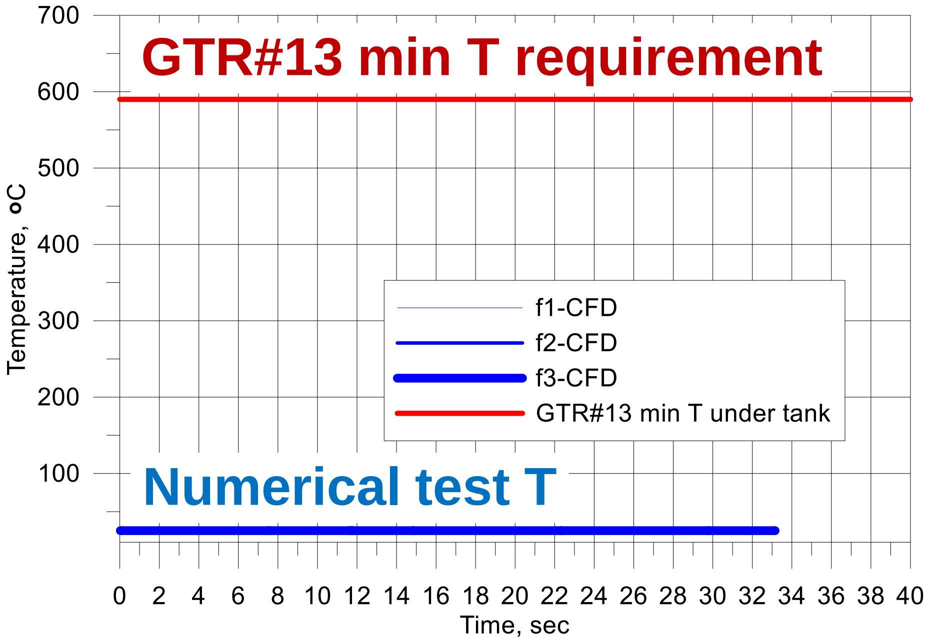
590°C (GTR#13 min required)

1030°C

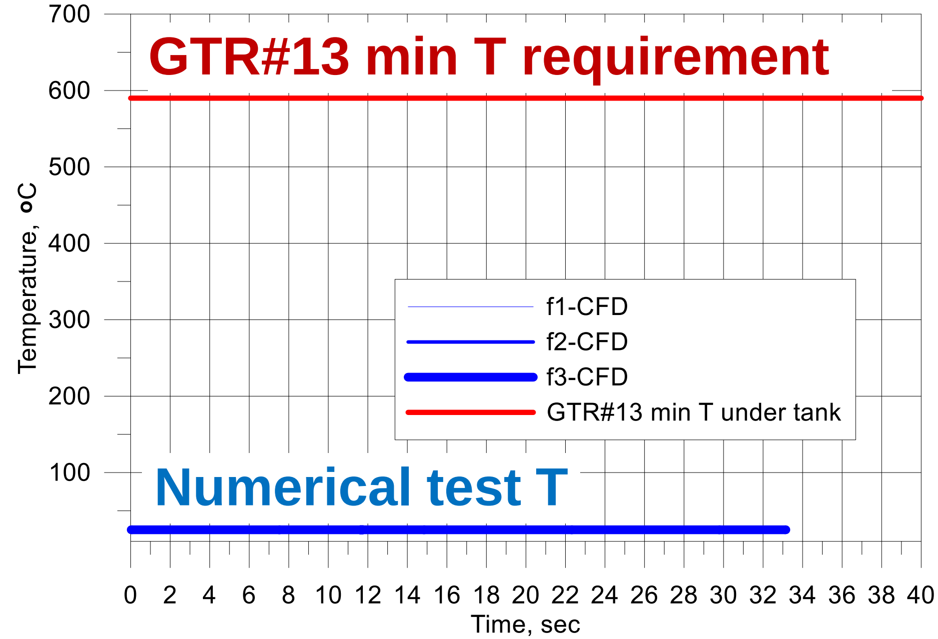
Blanket burner: wind 1.8 m/s

Temperatures under tank (GTR#13 non-compliant)

HRR/A=0.228 MW/m^2



HRR/A=1 MW/m^2



In wind conditions (<1.8> m/s, Buxton, UK) GTR#13 minimum temperature requirements **are not satisfied: temperatures under the tank are close to ambient 20°C!**

Blanket burner: performance in wind

Remarks

- Blanket burner of investigated size 500x1200 mm performance in a wind of order 1.8 m/s doesn’t comply to minimum GTR#13 temperature requirements (even with HRR/A≥1 MW/m^2).
- Only “no wind” facilities could use blanket burner to satisfy GTR#13 temperature requirements.

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Pipe burner: performance in wind

Three different wind speeds

- **Wind 1**: Propane flow rate $\dot{V}$=1589 NL/min, $\dot{m}$=48.54 g/s, HRR=2.25 MW. **HRR/A=1 MW/m²**. **Wind speed 1.8 m/s**.
- **Wind 2**: Propane flow rate $\dot{V}$=1589 NL/min, $\dot{m}$=48.54 g/s, HRR=2.25 MW. **HRR/A=1 MW/m²**. **Wind speed 5 m/s**.
- **Wind 3:** Propane flow rate $\dot{V}$=1589 NL/min, $\dot{m}$=48.54 g/s, HRR=2.25 MW. **HRR/A=1 MW/m²**. **Wind speed 10 m/s**.

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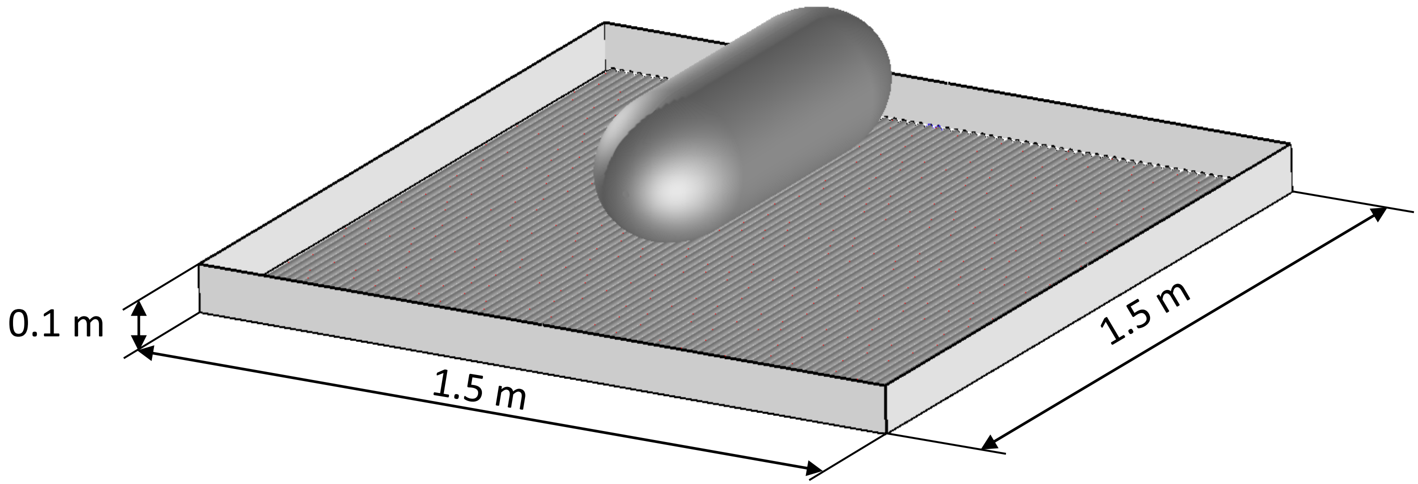
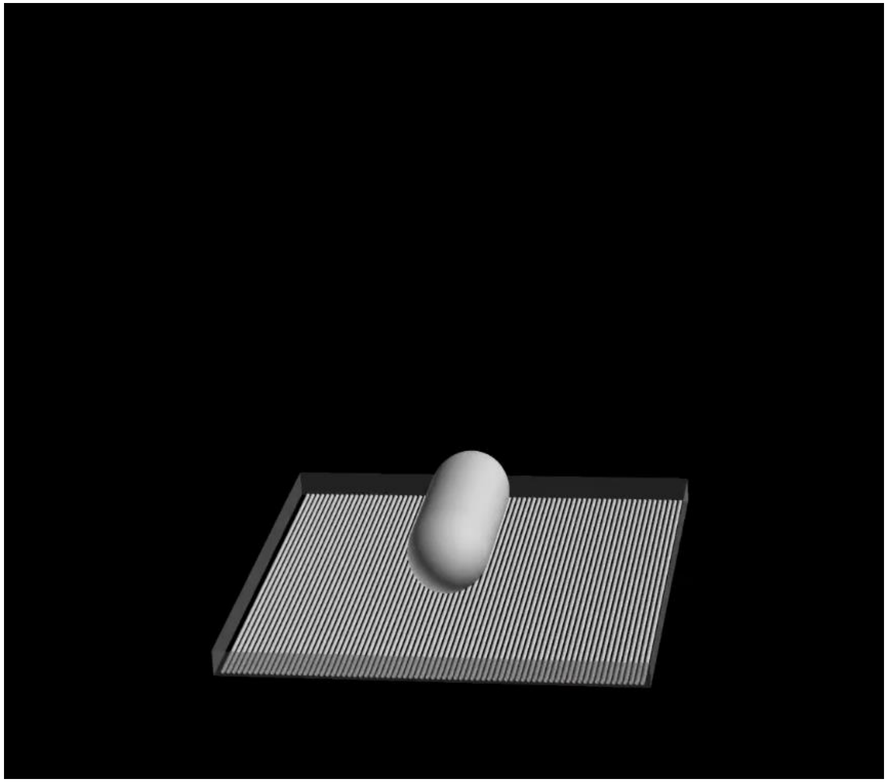


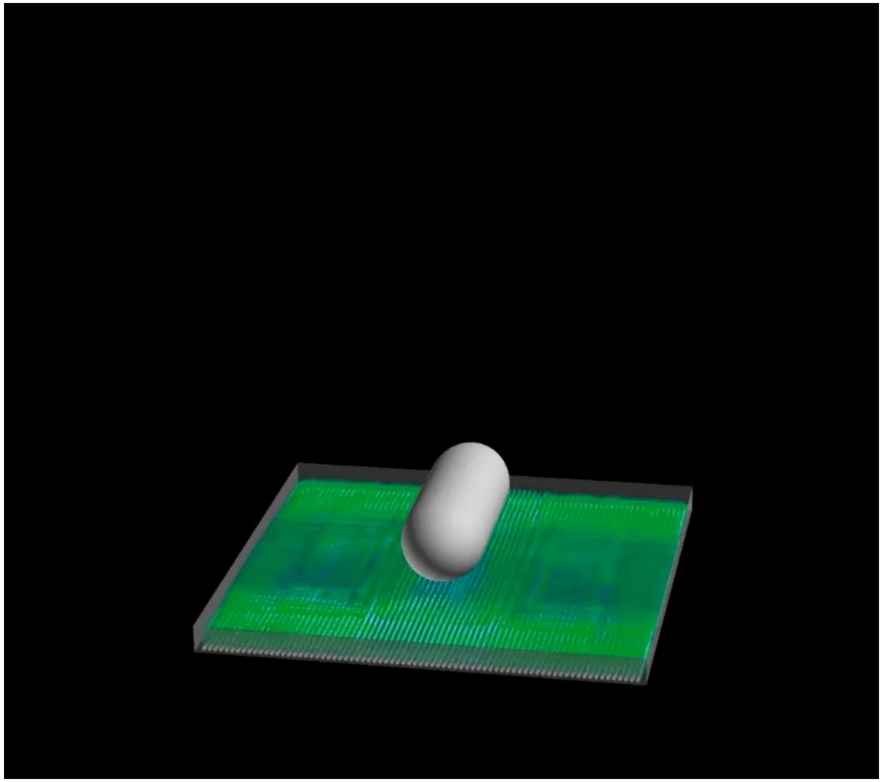
Pipe burner: wind 1.8 m/s (Wind 1)

Temperature iso-surfaces (values – next slide)

HRR/A=0.228 MW/m^2



HRR/A=1 MW/m^2



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Temperatures:

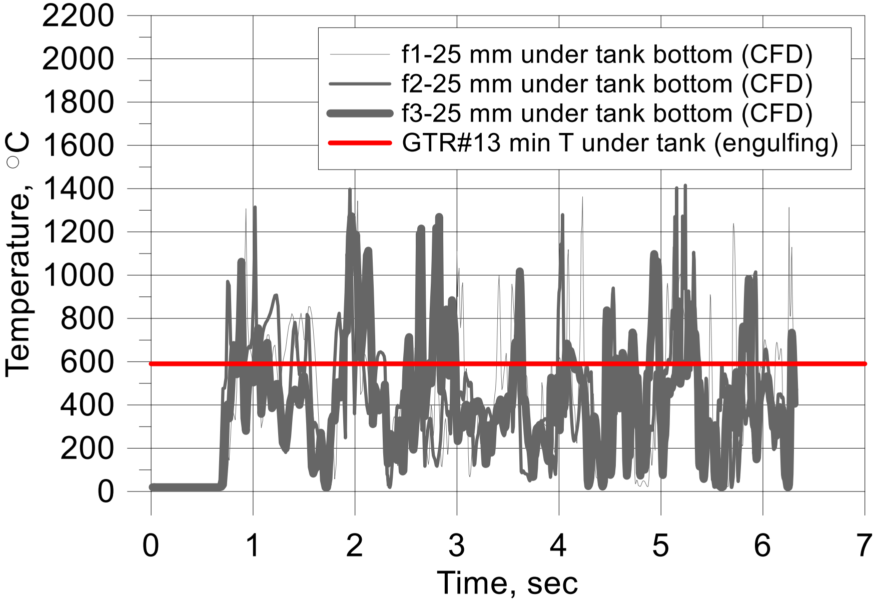
590°C (GTR#13 min required)

1030°C

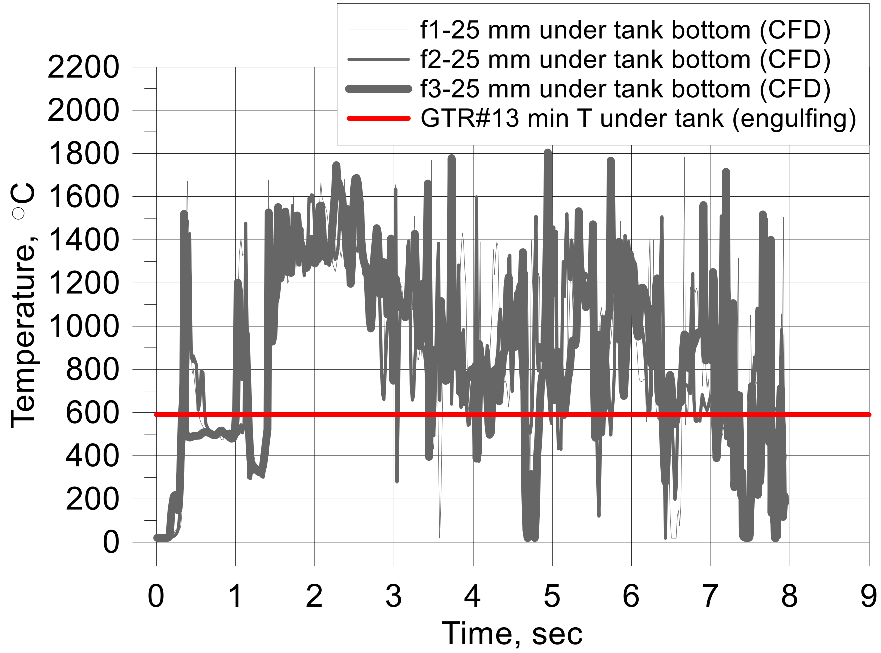
Pipe burner: wind 1.8 m/s (Wind 1)

Temperatures under tank (simulation)

HRR/A=0.228 MW/m^2



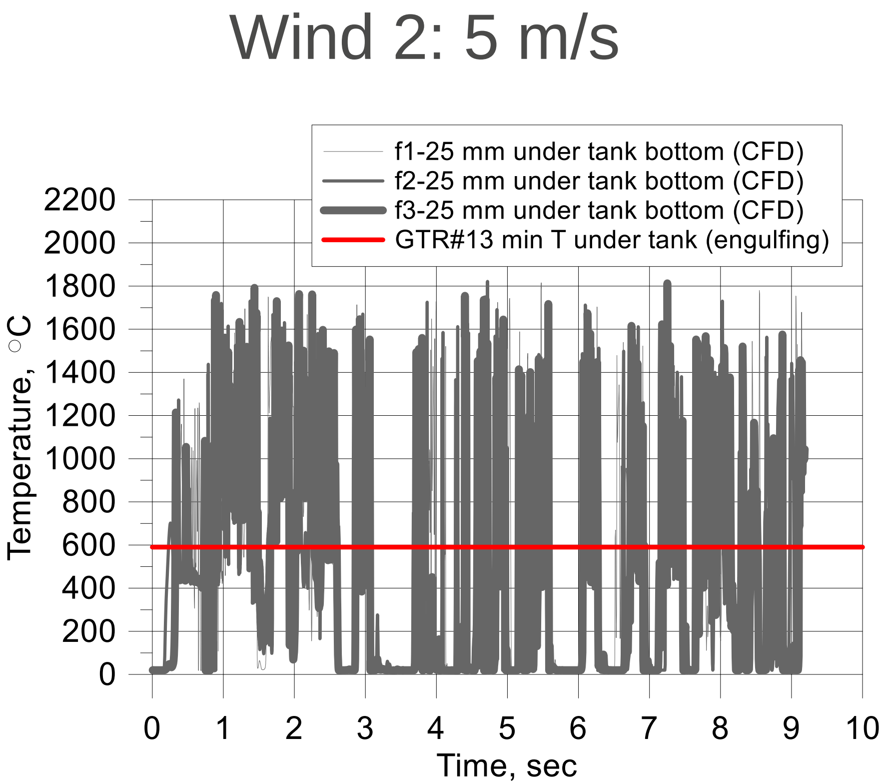
HRR/A=1 MW/m^2

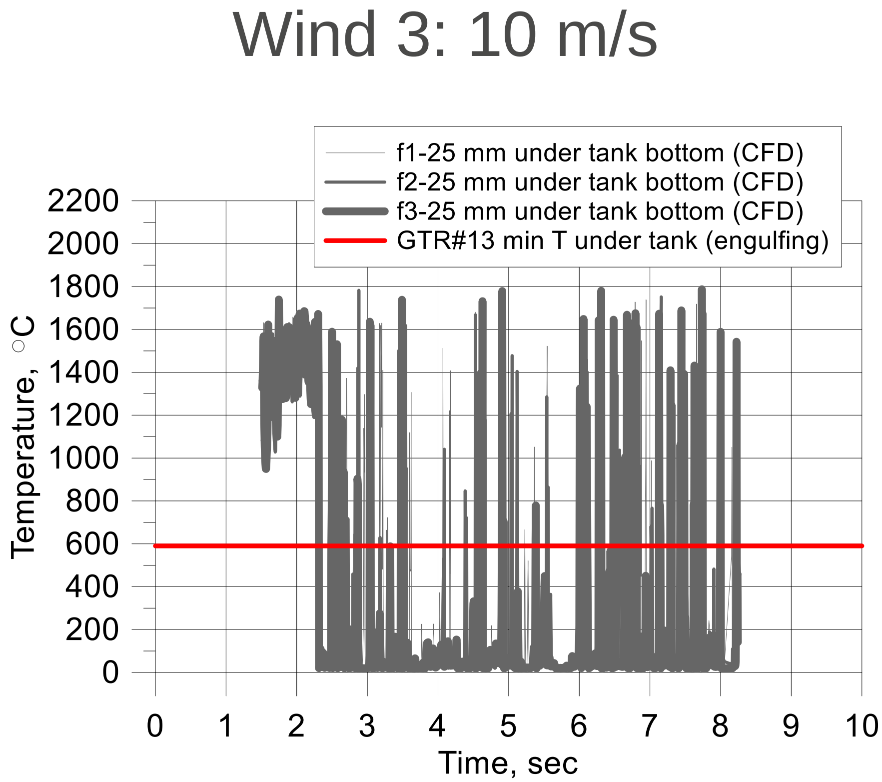


- **GTR#13 T are not always satisfied for HRR/A=0.228 MW/m2 (initial test stage).**
- **GTR#13 T are satisfied for HRR/A=1 MW/m^2 (concluded from initial test stage).**

Pipe burner: wind 5 m/s and 10 m/s

Temperatures under tank (simulations)



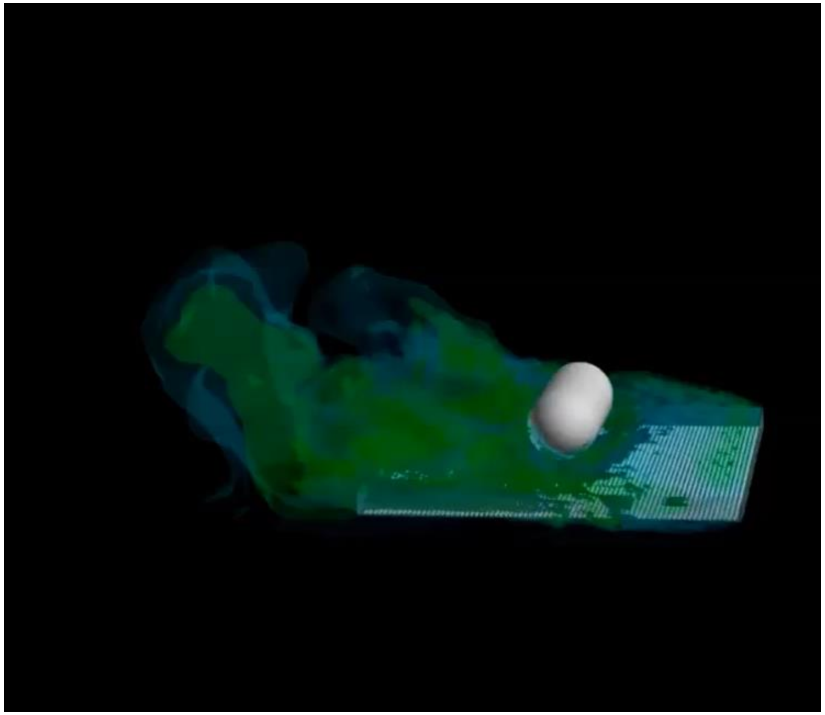


- **GTR#13 T are satisfied for wind 5 m/s (concluded from initial test stage).**
- **GTR#13 T are not satisfied for wind 10 m/s (concluded from initial test stage).**

Pipe burner: wind 5 m/s and 10 m/s

Temperature iso-surfaces

Wind 2: 5 m/s



Wind 3: 10 m/s

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Temperatures:

590°C (GTR#13 min required) 1030°C

The pipe burner with wind
Remarks

- The pipe burner reproduces GTR#13 minimum temperatures requirements with HRR/A=1 MW/m^2 and wind velocity 1.8 m/s ("light breeze"), and 5 m/s ("gentle breeze"), however does not reproduce required temperatures at wind velocity 10 m/s ("fresh breeze").
- To satisfy GTR#13 minimum temperature requirements for engulfing fire test the pipe burner can be used for velocities no more than 5 m/s.

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Localised fire.
Part 1/2: do we need “localised portion”?

Four localised fires under a vehicle

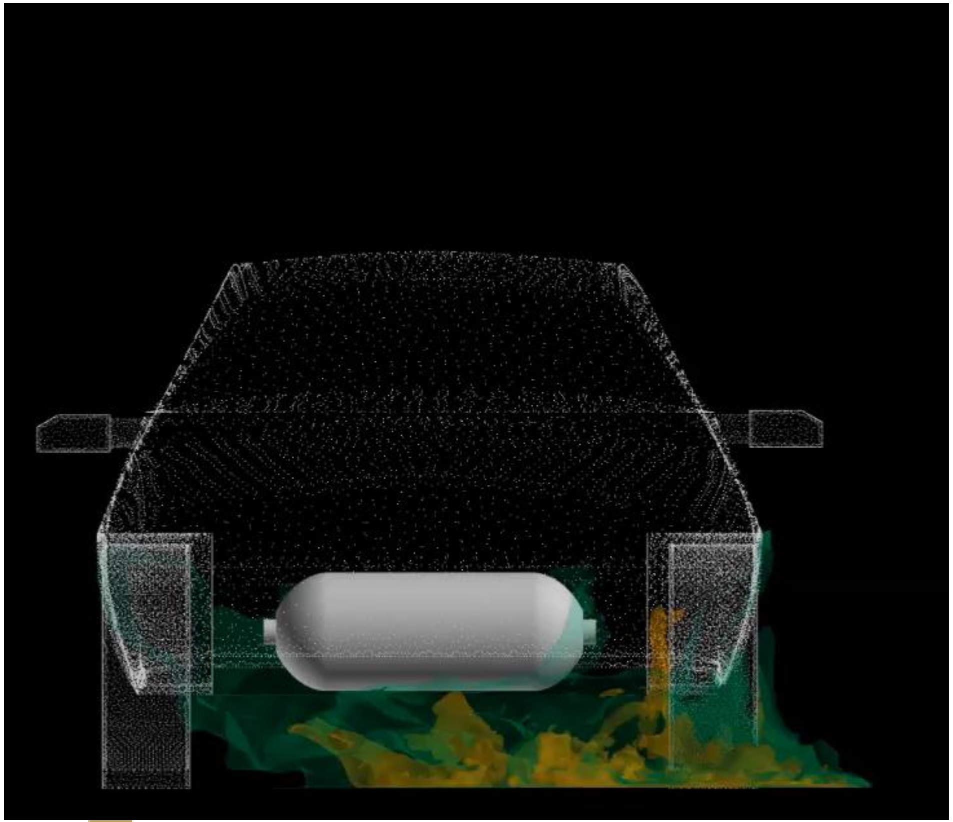
Range: A=0.2-1.9 m^2, HRR/A=0.2-2.3 MW/m^2

- **Fire 1:** *surrogate fuel*, C3H8 equivalent $\dot{m}$=8.2 g/s.
  Burner A=1.9 m^2, HRR=0.38 MW: **HRR/A=0.2 MW/m^2**.
- **Fire 2:** *surrogate fuel*, C3H8 $\dot{m}$=41 g/s.
  Burner **A=1.9 m^2**, HRR=1.9 MW: **HRR/A=1 MW/m^2**.
- **Fire 3:** *diesel* $\dot{m}$=4.72 g/s(*), C3H8 $\dot{m}$=4.31 g/s.
  Burner **A=0.2 m^2**, HRR=0.2 MW: **HRR/A=1 MW/m^2**.
- **Fire 4:** *diesel* $\dot{m}$=103 g/s(*), C3H8 $\dot{m}$=94.5 g/s.
  Burner A=1.9 m^2, HRR= 4.38 MW: **HRR/A=2.3 MW/m^2**.

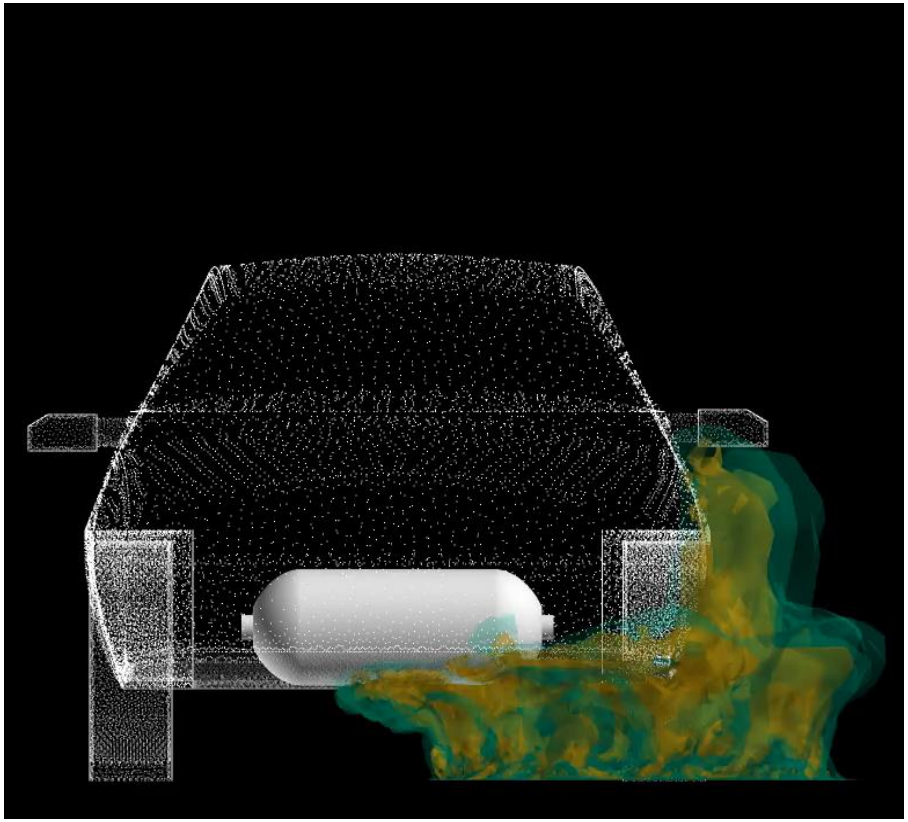
(*) **Obtained using** D. Drysdale, An introduction to fire dynamics, 3rd ed., 2011.

In-situ fire dynamics: Fire 1 and Fire 2
Temperature iso-surfaces

Fire 1: HRR/A=0.2 MW/m^2



Fire 2: HRR/A=1 MW/m^2



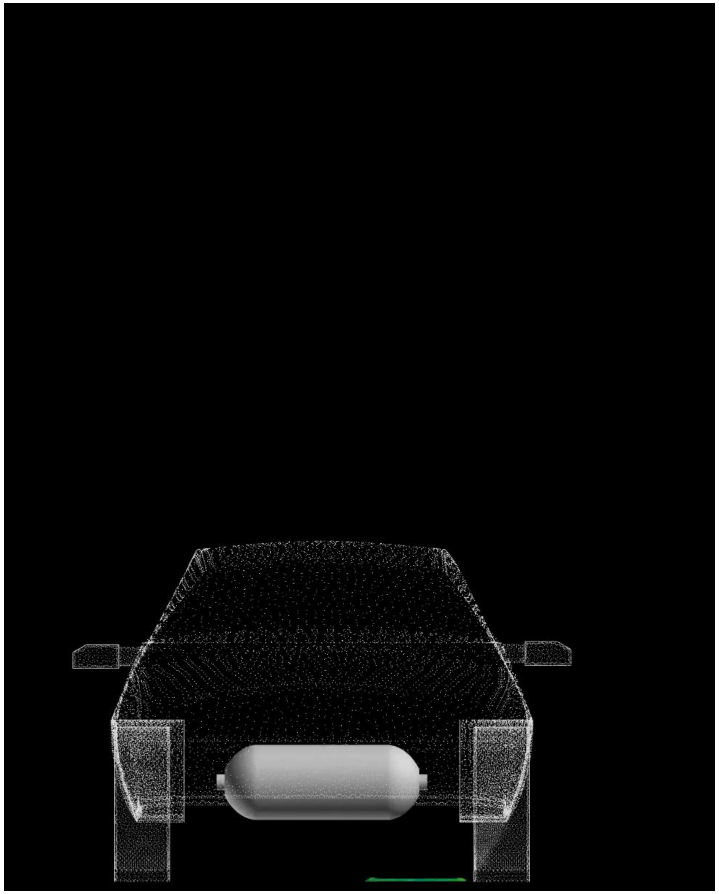
600°C (GTR#13 min required)

1030°C

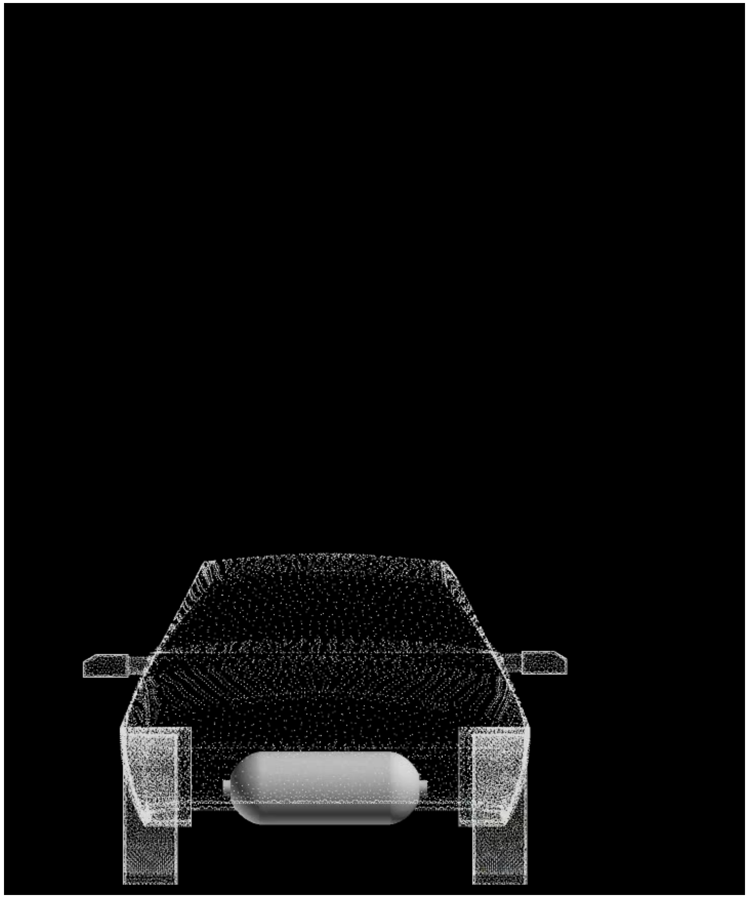
In-situ fire dynamics: Fire 3 and Fire 4

Temperature iso-surfaces

Fire 3: HRR/A=1 MW/m^2



Fire 4: HRR/A=2.3 MW/m^2



600°C (GTR#13 min required) 1030°C

In-situ localised fires: Qs & As

- Would localised fires with specific heat release rate, HRR/A, in the range 0.2-2.3 MW/m^2 provide agreement with GTR#13 temperature requirements?
  Answer: Yes for only HRR/A > 1 MW/m^2.
- How different will be heat flux to a tank from a fire for different HRR/A?
  Answer: $\dot{q}''$=50 kW/m^2 (HRR/A=0.2 MW/m^2); $\dot{q}''$=90 kW/m^2 (HRR/A>1 MW/m^2)
- If GTR#13 fire test temperature requirements are fulfilled, but the heat flux to the tank is different – would this affect the fire resistance rating of a tank?
  Answer: Yes.
  FRR=19 min (HRR/A=0.2 MW/m^2).
  FRR=5.3-6.0 min (HRR/A=1.0-2.3 MW/m^2).

Conclusions

- In-situ localised fire test satisfies GTR#13 temperature requirements only for HRR/A > 1 MW/m^2.
- TPRD location area is affected immediately in case of in-situ localised test making it unnecessary.
- Consider cancelling current “Localized portion of the fire test” for stand-alone tank as current localised fire conditions are different from localised fire conditions for in-situ tank fire test.

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Localised fire.
Part 2/2: new localised (smouldering) fire test

Smouldering fire – not addressed issue

CNG truck explosions in USA

"…**natural-gas powered garbage truck began** **smouldering**… neighbour was recording just as the **truck exploded**",

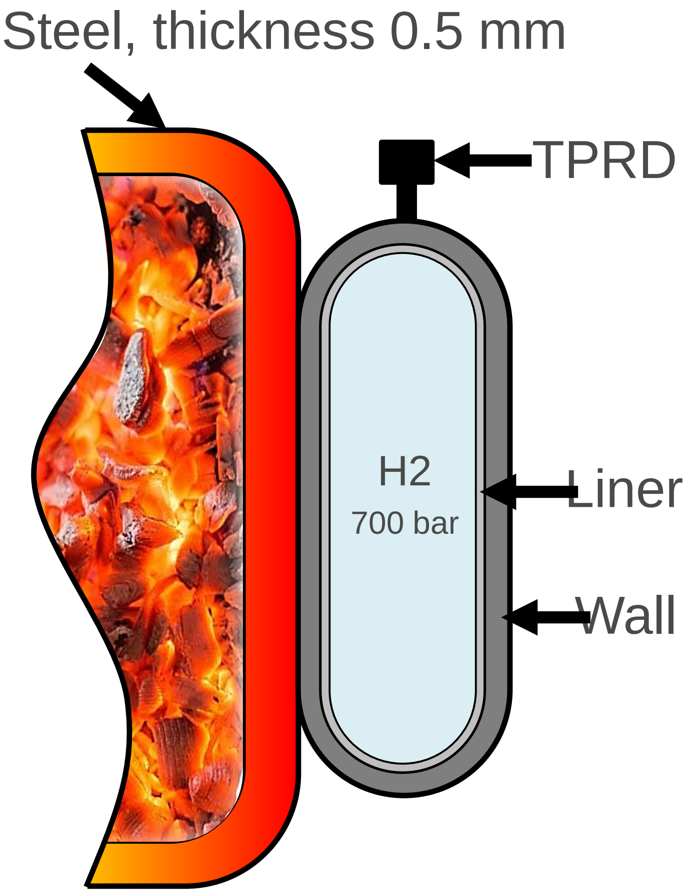
"…garbage truck exploded after catching fire … and **blasted a hole in the front of a nearby house**". "A total of **four houses were damaged** in the explosion".

Sources:
https://www.today.com/video/caught-on-camera-natural-gas-powered-garbage-truck-explodes-609780803613
https://www.nj.com/mercer/2016/01/garbage_truck_explosion_damages_hamilton_house.html

Smouldering fire is localised fire type

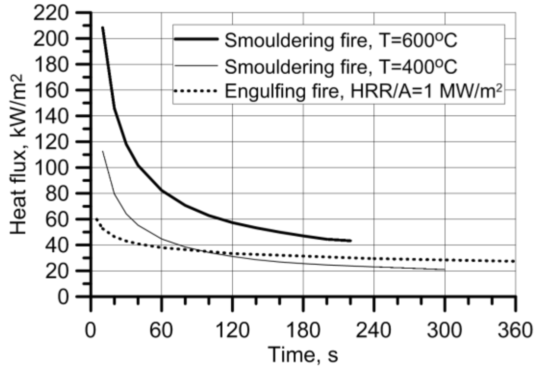
Numerical tests formulation (simplified)

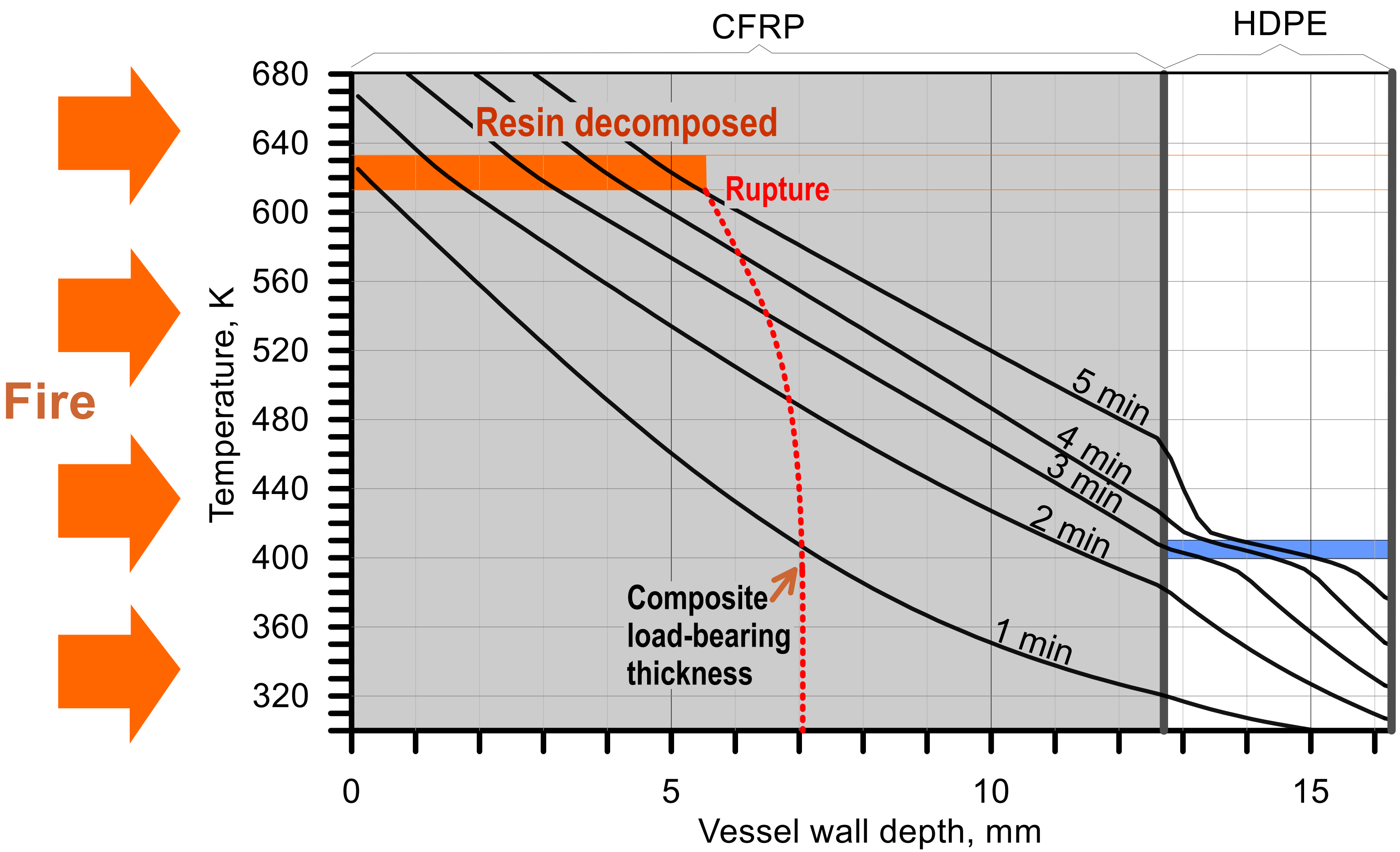
- Temperature range of smouldering: 250-600ºC (temperatures in the range about 250-350ºC, i.e. below the temperature of resin degradation of 350ºC, cannot cause tank rupture).
- Two numerical experiments: T_s=400ºC and T_s=600ºC .



Original tank: engulfing fire

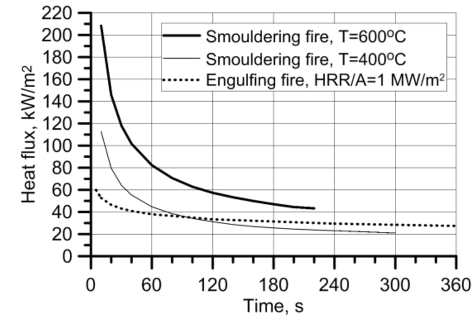
Rupture in 5 min!

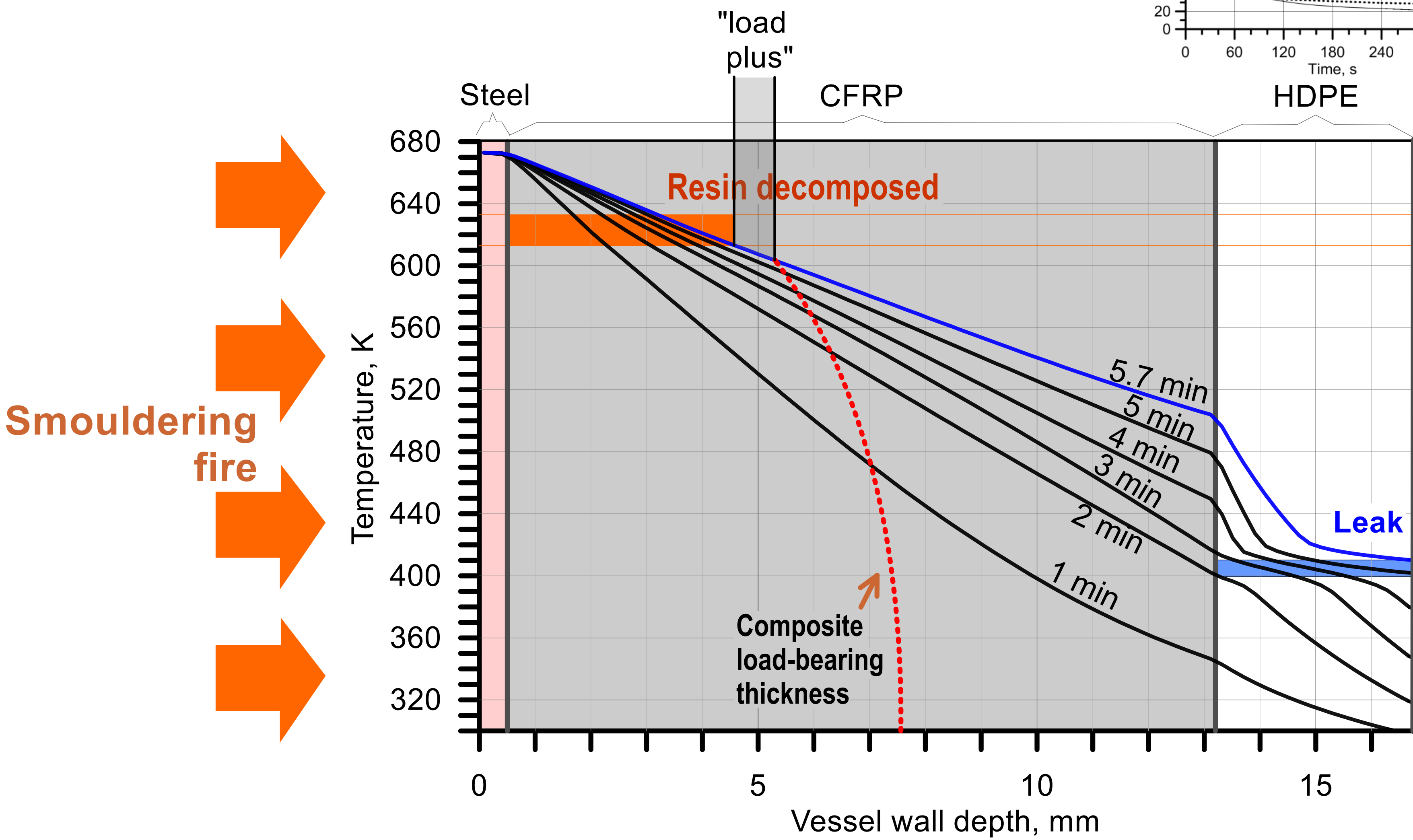




Original tank: smouldering fire (400°C)

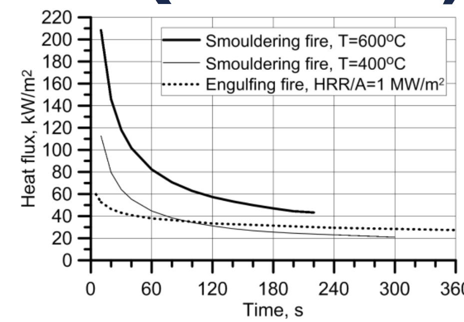
Leak in 5.7 min … (see next slide)

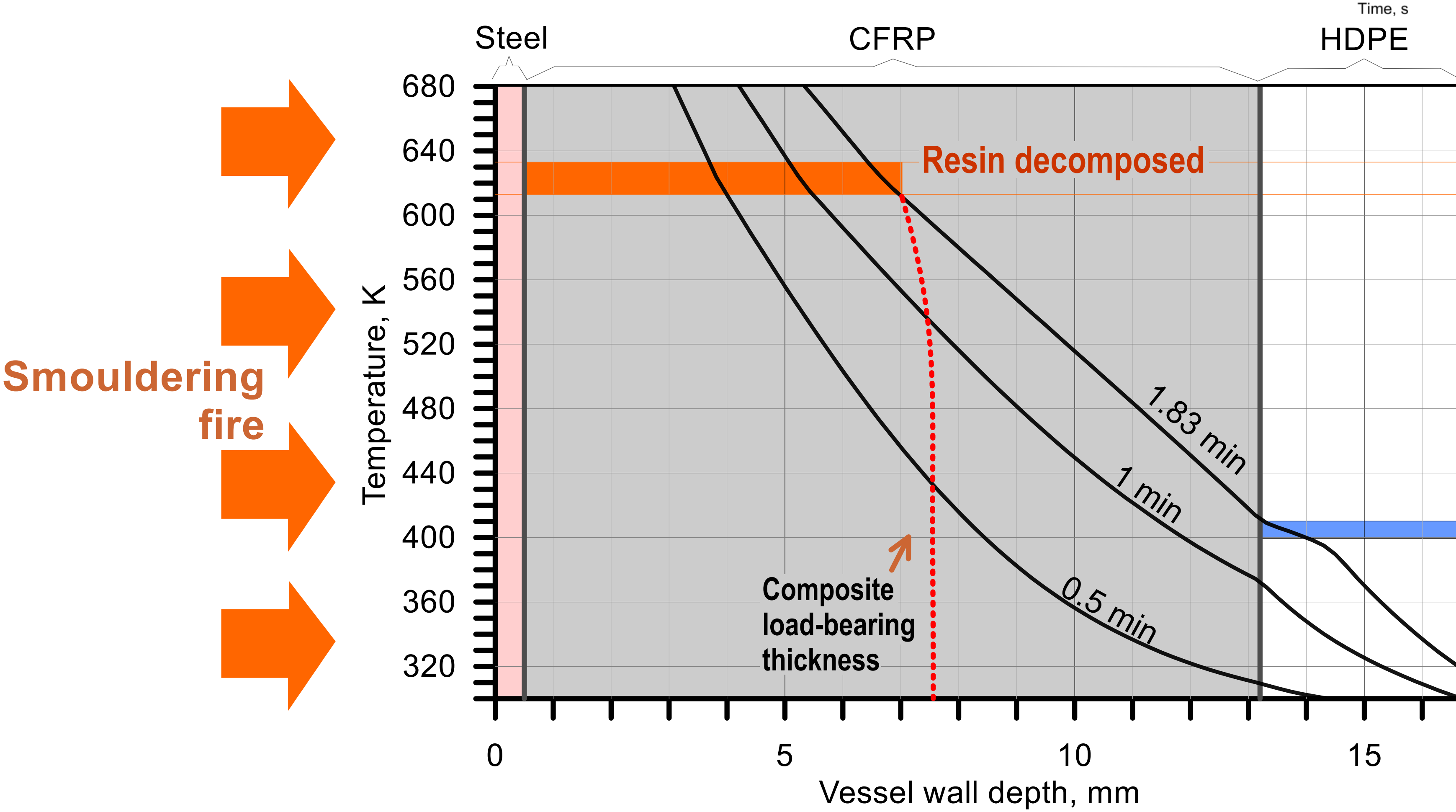




Original tank: smouldering fire (600°C)

Rupture in 1.83 min!





Conclusions

- The smouldering fire is a type of localised fire that caused tank rupture on CNG trucks (equipped with TPRD!).
- There is no fire test protocol for reaction of hydrogen tank on smouldering fire.
- The localised (smouldering) fire test should be developed and included into GTR#13 to address a real issue (smouldering fires) for high-pressure composite tanks for gas storage.

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Text amendment No.2: Localised (smouldering) fire

6.2.5. Test procedures for service terminating performance in fire

6.2.5.3. Localised (smouldering) fire test:

“The test unit is the compressed hydrogen storage system. The storage system is filled with compressed hydrogen gas at 100 per cent NWP. The container is positioned in direct contact with a hot metal plate mimicking temperature of a smouldering material (depends on material). The hot plate sizes should be at least of the length and width of the test article.

The hot plate surface temperatures shall be monitored by at least three thermocouples. Thermocouples temperature and the container pressure shall be recorded at least every 30 seconds during the test.”… **(continued on next page)**

…

“In the smouldering fire test without TPRD the fire resistance rating of a tank (the elapsed time from ignition of the fire to the tank rupture) should be documented.”

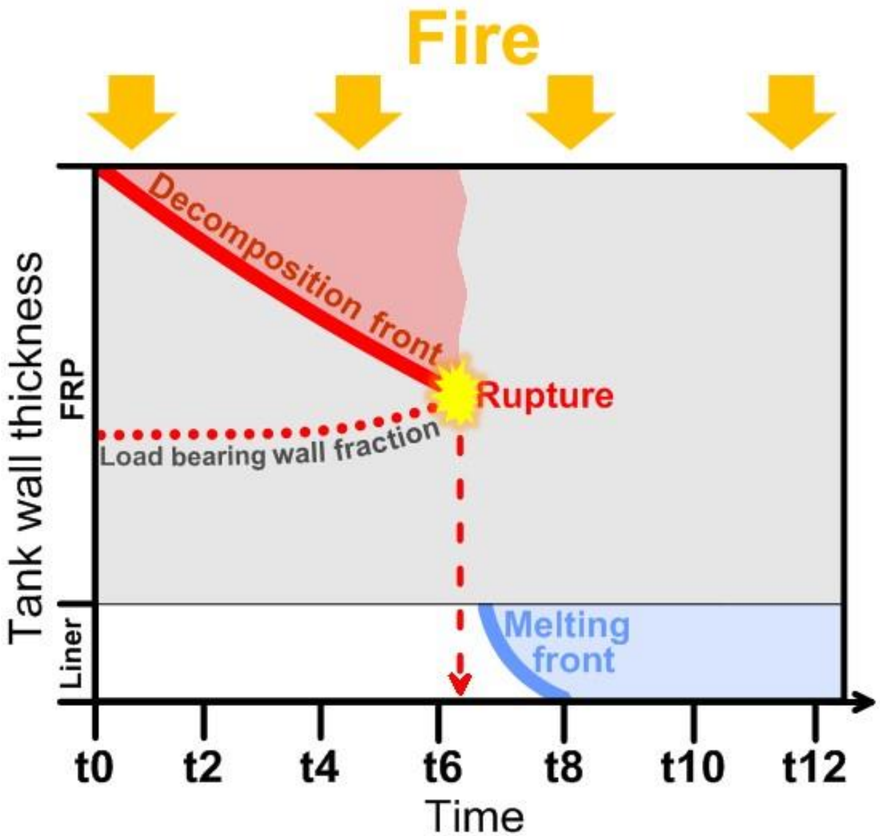
This is an initial proposal for localised smouldering fire test.

TPRD and other proven means of controlled release (GTR#13 should not stop innovations)

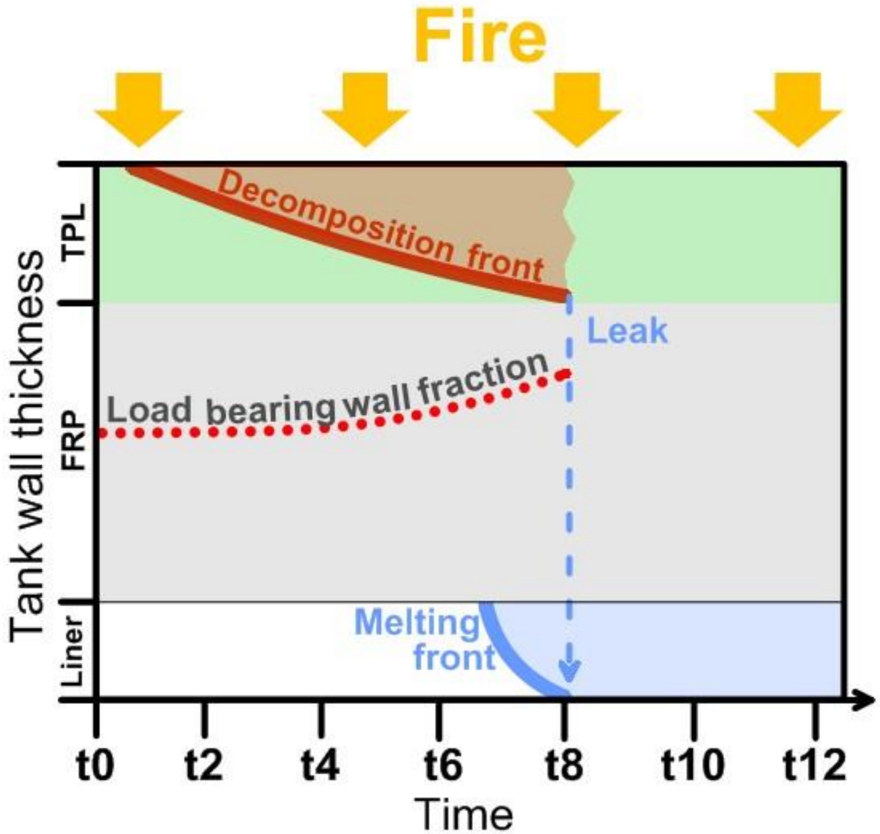
Leak-no-burst (LNB) in fire technology

Ordinary tank (left) and LBN tank (right)

Original tank: **rupture**



LNB tank: **no rupture!**



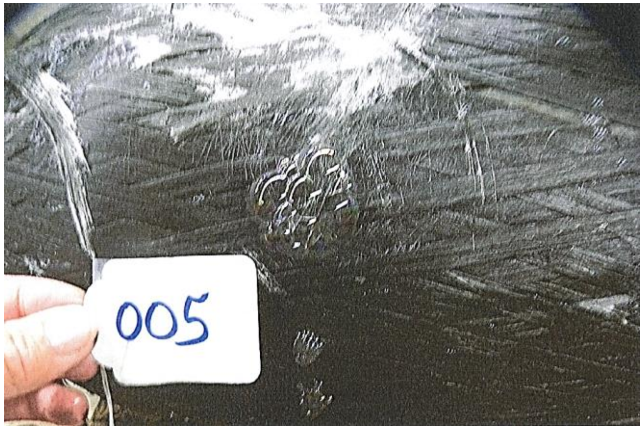
The first LNB tank prototypes

Tanks parameters (made in USA)

ID	OD of liner, in	OD of finished part, in	FRP#1 thickness, in	FRP#2 thickness, in	Weight, lb
#4	6.334	8.178	0.450	0.472	27.5
#5	6.336	8.465	0.366	0.699	32.3

Fire test results (tested in USA)

ID	Charge pressure	Vent pressure	Leak starts	Leak duration
#4	700 bar	812.4 bar	9m 27s	16m 29s
#5	700 bar	854.5 bar	12m 23s	14m 37s

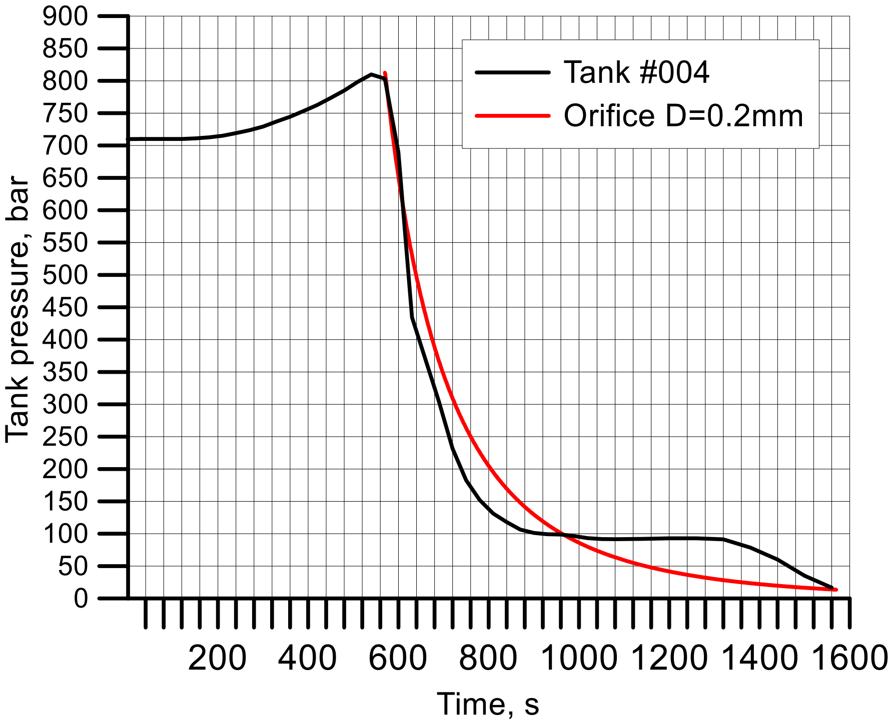


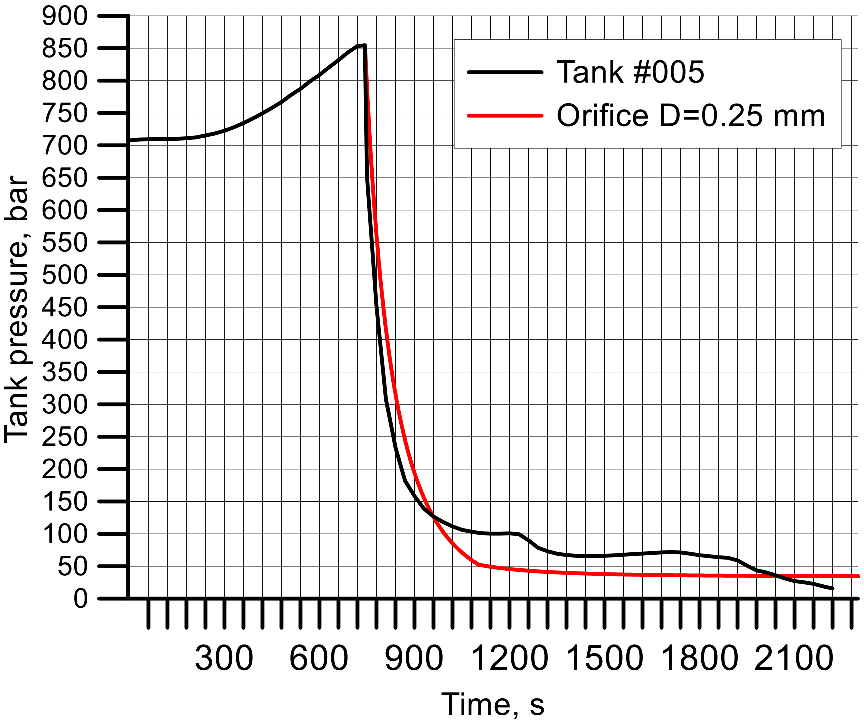
These hazards are eliminated:

- No blast wave!
- No fireball!
- No projectiles (including vehicle)!
- No long flames!
- No pressure peaking phenomenon!

The first LNB tank prototypes testing

Blowdown equivalent diameter 0.20-0.25 mm





LNB safety technology closes safety issues of hydrogen vehicles in confined spaces like garage, tunnel, underground parking, in “isolated” marine and aviation conditions, etc.

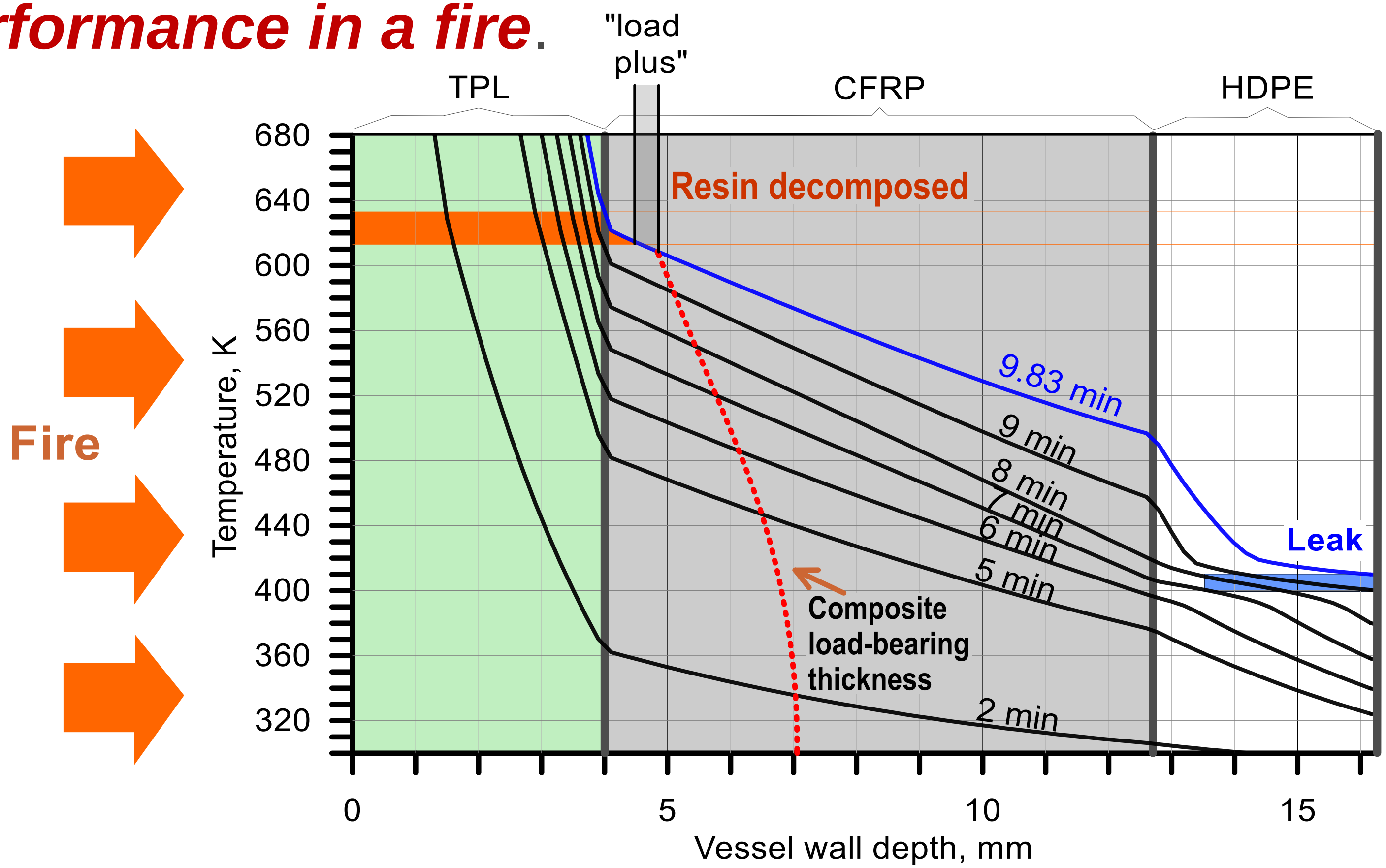
Aftermath the first prototypes testing

- No experimental data available for thermal parameters of different fibre-resin composites. “Conservative” values were selected from literature to provide first LNB prototype design.
- Question from OEMs: the first LNB tank prototype wall thickness is thicker compared to the original tank. Can LNB tank be of the same wall thickness (and be explosion-free)?
- Steps in development of the second prototype tanks:
  - Measure different fibre-resin composites thermal properties.
  - Manufacturing of the second LNB tank prototypes of the same wall thickness as original tank (but cheaper!).
  - Testing of the second LNB tank prototypes is planned for Autumn 2019.

Example of the second prototypes

Wall thickness of the original tank

Partial change of carbon fibre to different (cheaper) fibre and change of resin at TPL (keeping IBP >200% of NWP): *the same wall size but cheaper* ***and new feature: explosion-free performance in a fire***.

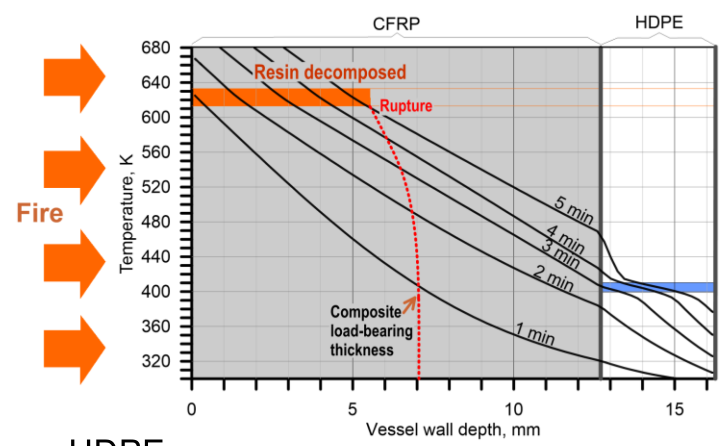


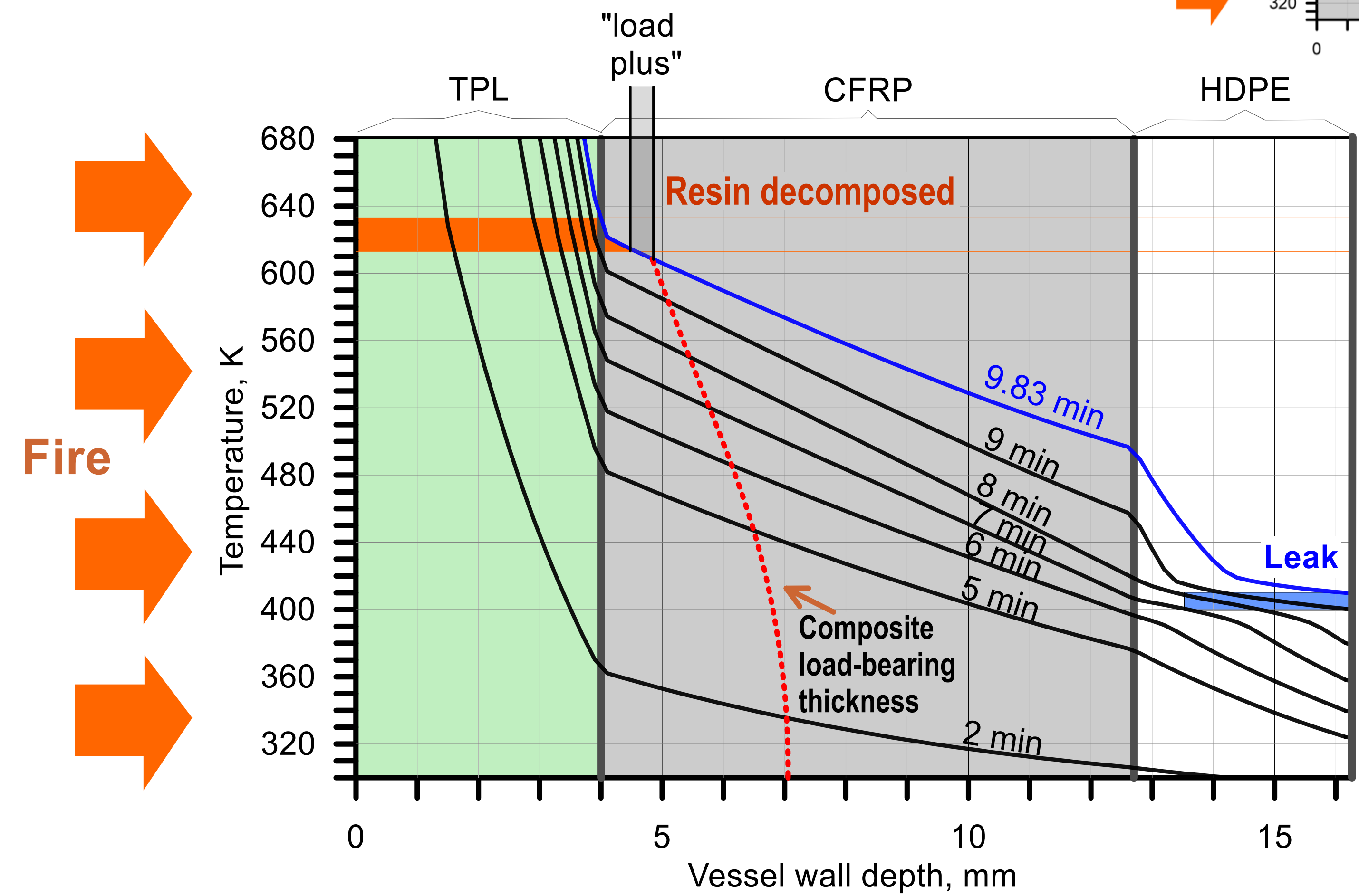
LNB tank (“TPRD-free”)

Engulfing fire: leak in 9.83 min (70 MPa, 7.5 L)!

Original tank in engulfing fire

Rupture in 5 min!



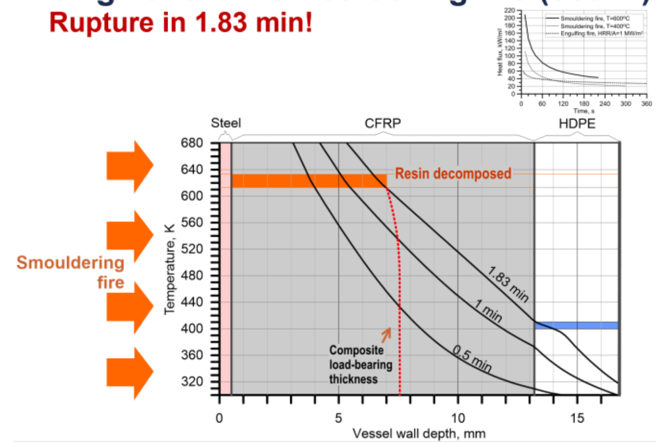


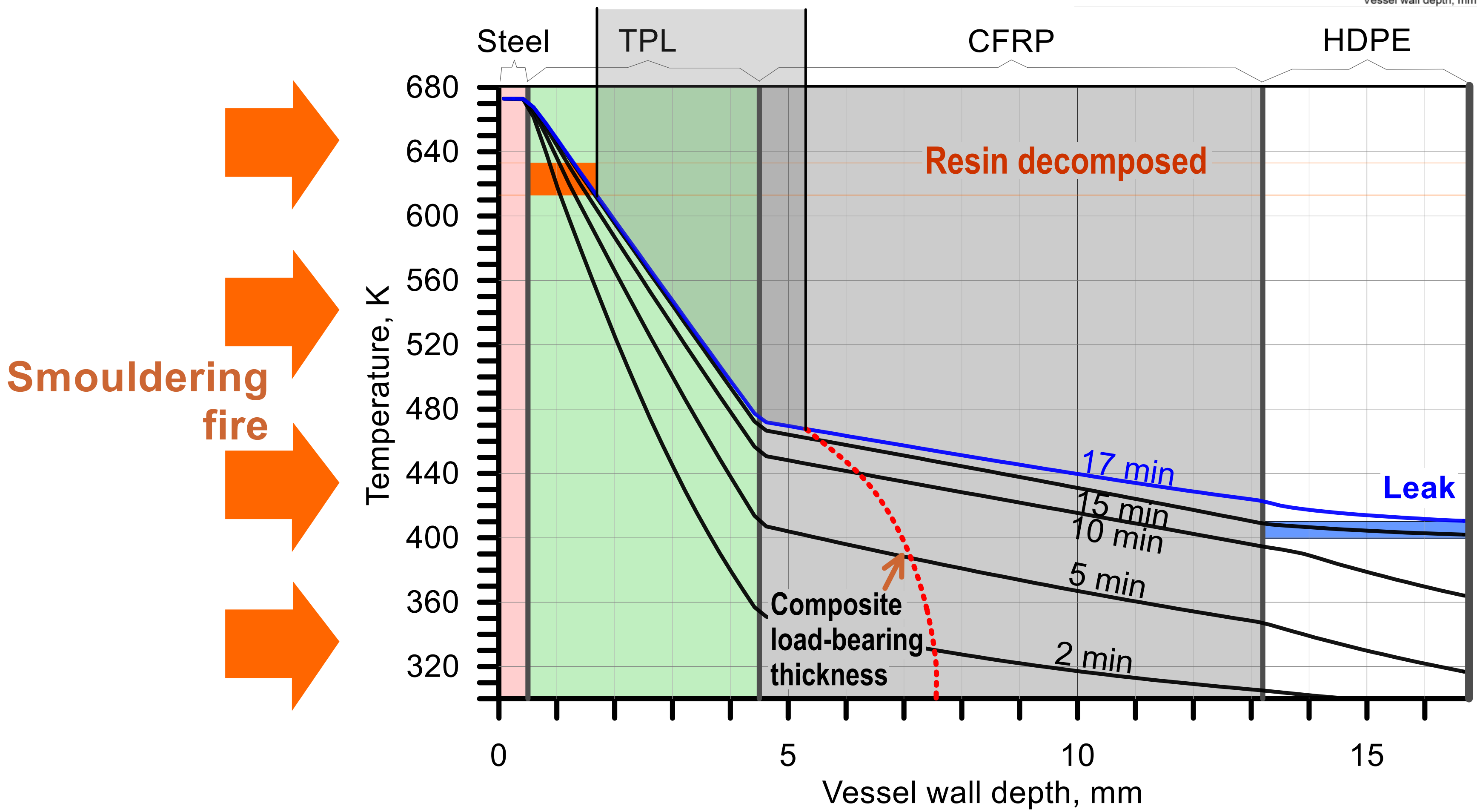
LNB tank (“TPRD-free”)

Smouldering fire: leak in 17 min (70 MPa, 7.5 L)!

Original tank: smouldering fire (600°C)

Rupture in 1.83 min!





Remarks on “other proven means”

- The first prototypes of LNB composite tanks are manufactured and successfully tested.
- Testing confirmed that the customers could have hydrogen 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 projectiles!
  - No long flames!
  - No pressure peaking phenomenon!
- The LNB safety technology allows safe use of hydrogen vehicles in confines space like garage, tunnel, underground parking, in “isolated” marine and aviation conditions, etc.
- The second prototypes with wall thickness as original tank will be tested in autumn 2019!

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Text amendment No.3:
TPRD and other proven means

C. Description of typical HFCVs
3. Hydrogen storage system

(a) Compressed hydrogen storage system

"19. ...Most high pressure hydrogen storage containers used in fuel cell vehicles consist of two layers: an inner liner that prevents gas leakage/permeation (usually made of metal or thermoplastic polymer), and an outer layer that provides structural integrity (usually made of metal or thermoset resin-impregnated fibre-reinforced composite wrapped over the gas-sealing inner liner)." In a fire test an insignificant leak through tank wall is allowed if it is a part of a tank safety design.

Rationale: GTR#13 should be open to innovations and further improvement in provision of life safety and property protection. Hence, other than TPRD (or in addition to TPRD) proven means for safe release of hydrogen in a fire to exclude tank's rupture should be allowed.

C. Description of typical HFCVs
3. Hydrogen storage system

(a) Compressed hydrogen storage system

“22. In the event of a fire, thermally activated pressure relief devices (TPRDs) or/and other proven means provide a controlled release of the gas from the compressed hydrogen storage containers before the high temperatures in the fire weaken the containers and cause a hazardous rupture. TPRDs ~~are~~ should be designed to vent the entire contents of the container ~~rapidly.~~” excluding its rupture during blowdown. TPRD design should exclude the pressure peaking phenomenon in confined spaces like garages, etc.

Rationale: GTR#13 should be open to innovations and further improvement in provision of life safety and property protection. Hence, other than TPRD (or in addition to TPRD) proven means for safe release of hydrogen in a fire to exclude tank’s rupture should be allowed.

E. Rationale for paragraph 5…
2. Vehicle fuel system requirements…

(a) In-Use Requirements

(viii) Recommended features for design of a hydrogen fuel system

"(a) The hydrogen fuel system should function in a safe and proper manner and be designed to minimize the potential for hydrogen leaks, (e.g. minimize line connections to the extent possible). The leaks through TPRD or other proven means to control release in conditions of a fire should be minimised too (at condition of tank rupture exclusion);"

Rationale: GTR#13 should be open to innovations and further improvement in provision of life safety and property protection. Hence, other than TPRD (or in addition to TPRD) proven means for safe release of hydrogen in a fire to exclude tank's rupture should be allowed.

5. Performance requirements

5.1. Vehicle fuel system

5.1.4. Verification test for service terminating performance in fire

A hydrogen storage system is pressurized to NWP and exposed to fire (para. 6.2.5.1. test procedure).

“A ~~temperature~~ thermally-activated pressure relief device or other proven means shall release the contained gases in a controlled manner without rupture” and accounting for the pressure peaking phenomenon in confined spaces like garages.

Rationale: GTR#13 should be open to innovations and further improvement in provision of life safety and property protection. Hence, other than TPRD (or in addition to TPRD) proven means for safe release of hydrogen in a fire to exclude tank’s rupture should be allowed.

5. Performance requirements

5.2. Vehicle fuel system

5.2.1.3. Hydrogen discharge systems

5.2.1.3.1. Pressure relief systems…

…

“(b) Storage system TPRDs…

(c) Other pressure relief devices (such as a burst disk)…”

(d) Other proven safety means for pressure relief from a storage container.

Rationale: GTR#13 should be open to innovations and further improvement in provision of life safety and property protection. Hence, other than TPRD (or in addition to TPRD) proven means for safe release of hydrogen in a fire to exclude tank’s rupture should be allowed.

6. Test conditions and procedures
6.2. Test procedures…for hydrogen storage

6.2.5. Test procedures for service terminating performance in fire

6.2.5.1. Fire test

“The test article is held at temperature (engulfing fire condition) until the system vents through the TPRD or other proven safety means and the pressure falls to less than 1 MPa… the storage system shall not rupture”. The design of TPRD or other proven safety means should exclude confined structure demolition by the pressure peaking phenomenon.

Rationale: GTR#13 should be open to innovations and further improvement in provision of life safety and property protection. Hence, other than TPRD (or in addition to TPRD) proven means for safe release of hydrogen in a fire to exclude tank’s rupture should be allowed.

6. Test conditions and procedures
6.2. Test procedures…for hydrogen storage

6.2.5. Test procedures for service terminating performance in fire

6.2.5.1. Fire test

Documenting results of the fire test

“The results include the elapsed time from ignition of the fire to the start of venting through the TPRD(s) or other proven safety means, and the maximum pressure and time of evacuation until a pressure of less than 1 MPa is reached.”

The fire resistance rating of a tank (elapsed time from ignition of fire to tank rupture) should be defined in a test without TRPD and documented, along with the specific heat release rate, HRR/A, of a fire source.

Rationale: Fire test protocol should include requirement for determination of fire resistance rating (FRR) of the container to inform first responders for development of their intervention strategies and tactics.

Concluding remarks

- The amendments to GTR#13 sections "6. Test conditions and procedures", "C. Description of typical HFCVs", and "E. Rationale for paragraph 5…" are developed based on performed experimental, theoretical and numerical studies.
- GTR#13 text is amended by requirement to the **specific heat release rate** in a burner to be above **HRR/A>1 MW/m^2** to provide fire test reproducibility in different laboratories around the world and exclude "favorable" conditions to pass regulated fire test, which would have little relation to real vehicle fires.
- GRT#13 text is amended to account for **innovations in hydrogen safety technologies** for storage systems, e.g. explosion-free in a fire tanks following LNB safety technology and other means (e.g. presented at the UN GTR#13 IWG SGS meeting in Brussels on 17-19 October 2017).
- GTR#13 text amended to account for the **pressure peaking phenomenon** (following requirements of ISO 19882 "Gaseous hydrogen – Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers").
- GTR#13 text is amended by requirement to measure **fire resistance rating** (FRR) of high-pressure tanks (test without TPRD) to inform fire fighters and first responders for them to develop intervention strategies and tactics.
- To reflect on real accidents with garbage tracks it is suggested to introduce **new localised (smouldering) fire test**. Based on in-situ localised fire analysis it is suggested to cancel "localised portion" of fire test.
- The fire source should be "wind-resistant" for test performed in the open.

THANK YOU

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