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Accurate boundary conditions for LH2 storage tank modelling

ELVHYS Dissemination Conference

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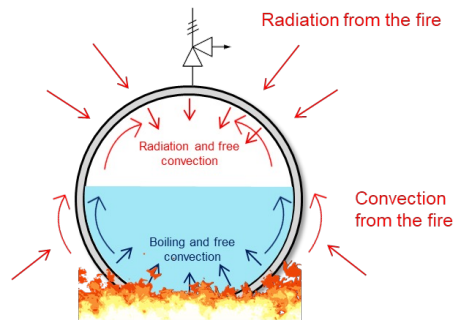
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Liquid hydrogen tanks exposed to fire

Inner perspective

*What happens **inside**?*

- ☐ Self-pressurization
- ☐ Temperature stratification
- ☐ Degradation of the insulation

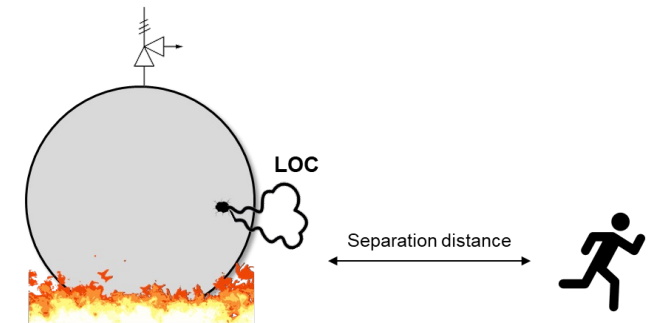


Video recorded during the SH2IFT project carried out at the BAM Test Site Technical Safety, Germany

Outer perspective

*What happens **outside**?*

- ☐ Loss of Containment (LOC)
- ☐ Tank failure
- ☐ Fires and explosions



Modelling of fire scenarios

Mathematical models, including lumped and CFD models, simplify the fire scenario defining **static full engulfing fires as boundary conditions**. However, this is often far from real case scenarios.

State-of-the-art approaches



 Fire

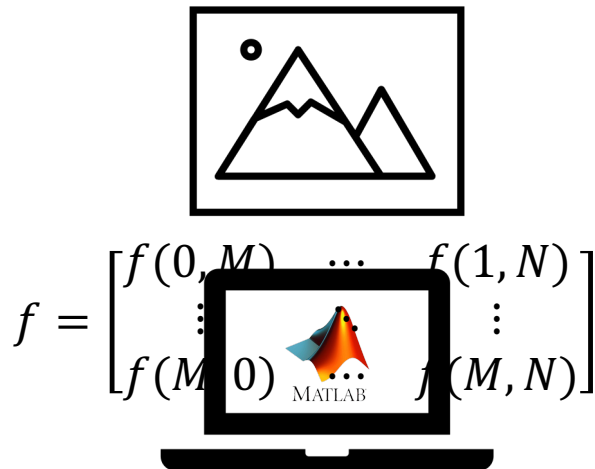
VS



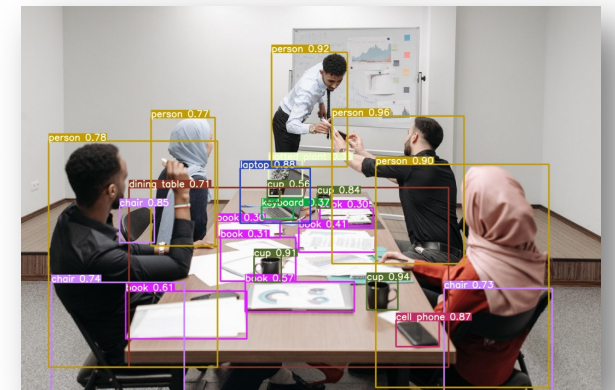
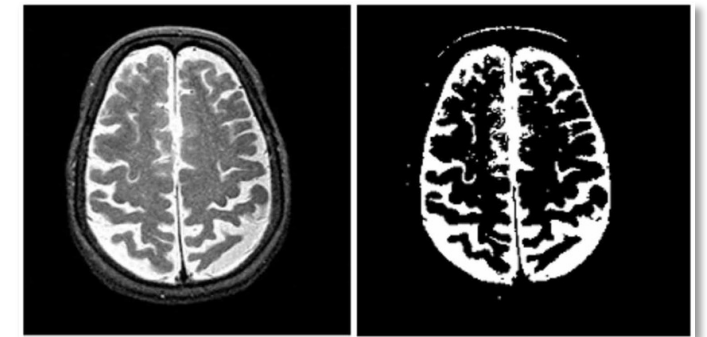
Partial engulfment scenarios
Dynamic variation of the flame distribution

Digital Image Processing

DIP: transforming a digital image, processing it by means of an algorithm and performing specific operations to extract information



- Image enhancement
- Image Restoration
- Color Image Processing
- Wavelets and Multiresolution Processing
- Compression
- Morphological processing
- Segmentation
- Representation and Description
- Object recognition



Reference fire tests



BAM Test Site Technical Safety, Germany



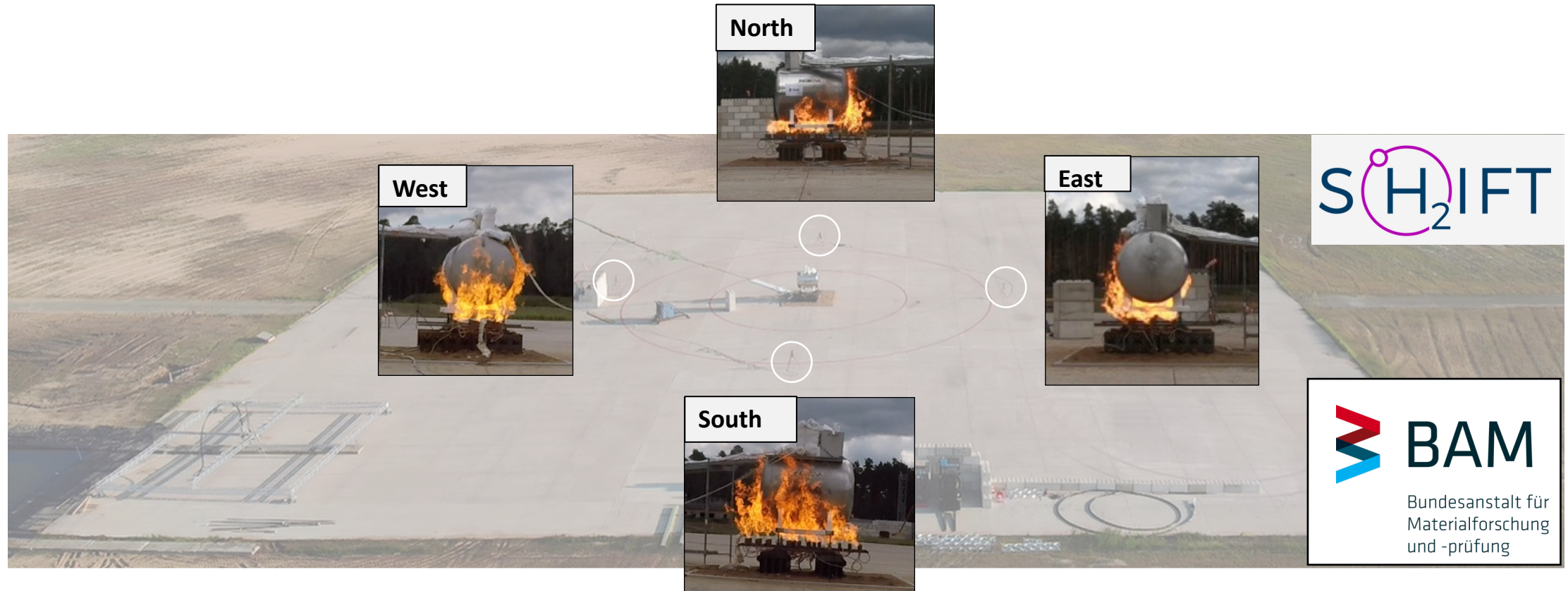
BLEVE01

BLEVE03

BLEVE02

Three fire tests involving **two horizontal** and a **vertical** cryogenic storage tanks

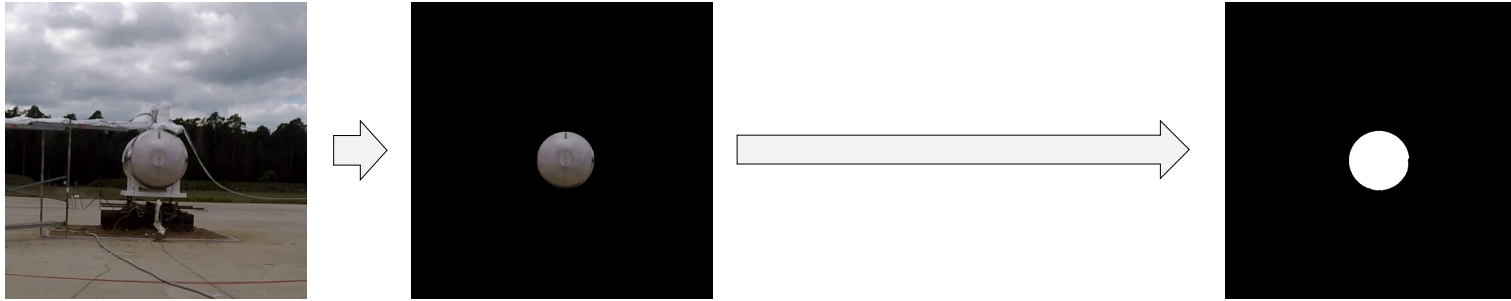
Reference fire tests



Experimental data

Recordings of the tests showing the tanks from **4 different views**

Methodology



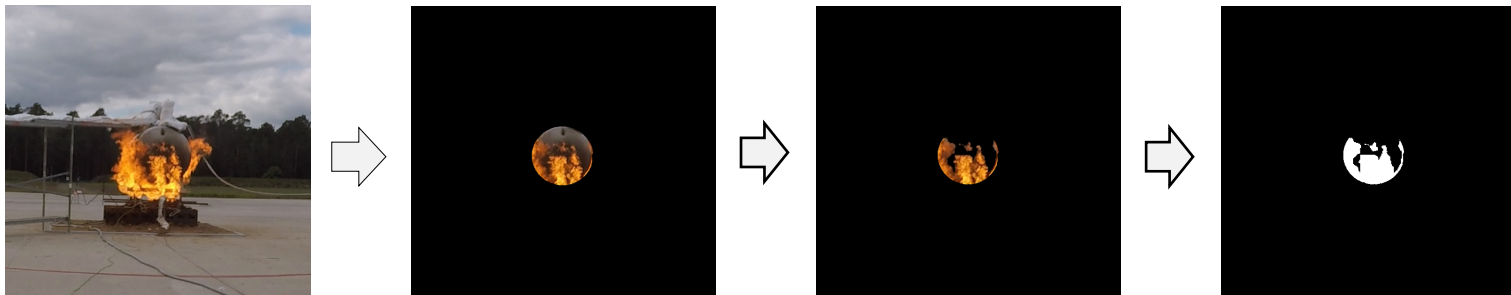
Output: *TANK MASK*

The surface of the tank showed in the frame is isolated from the other objects.



Before the fire start

After the fire start



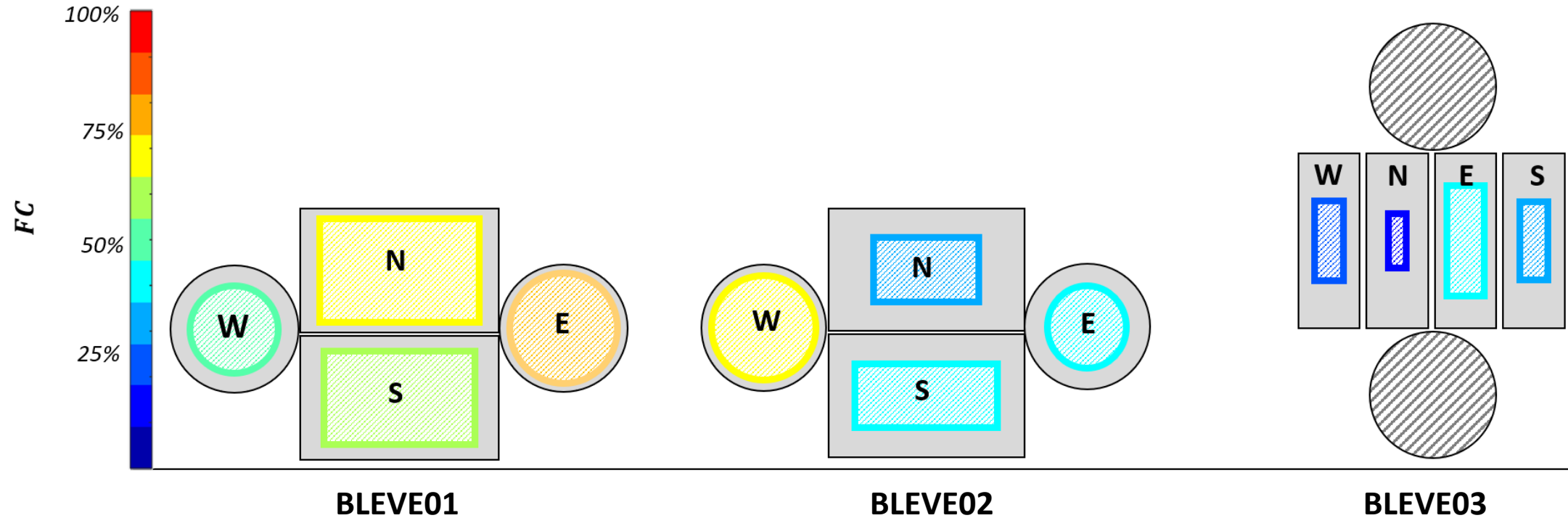
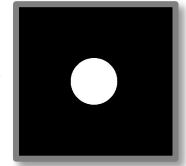
Output: *FLAME MASK*

The surface of the tank covered by the flames is isolated from the other objects

Methodology (2D)

Average flame coverage

$$FC = \sum_{t=0}^{t_{test}} \sum_{i=1}^{N_{view}} \frac{\text{N}^{\circ} \text{ of pixels in the flame mask}_i(t)}{\text{N}^{\circ} \text{ of pixels in the tank mask}}$$



Methodology

2D

average flame coverage for each tank surface and not exact flame location

projection of the 3D tank geometry



3D

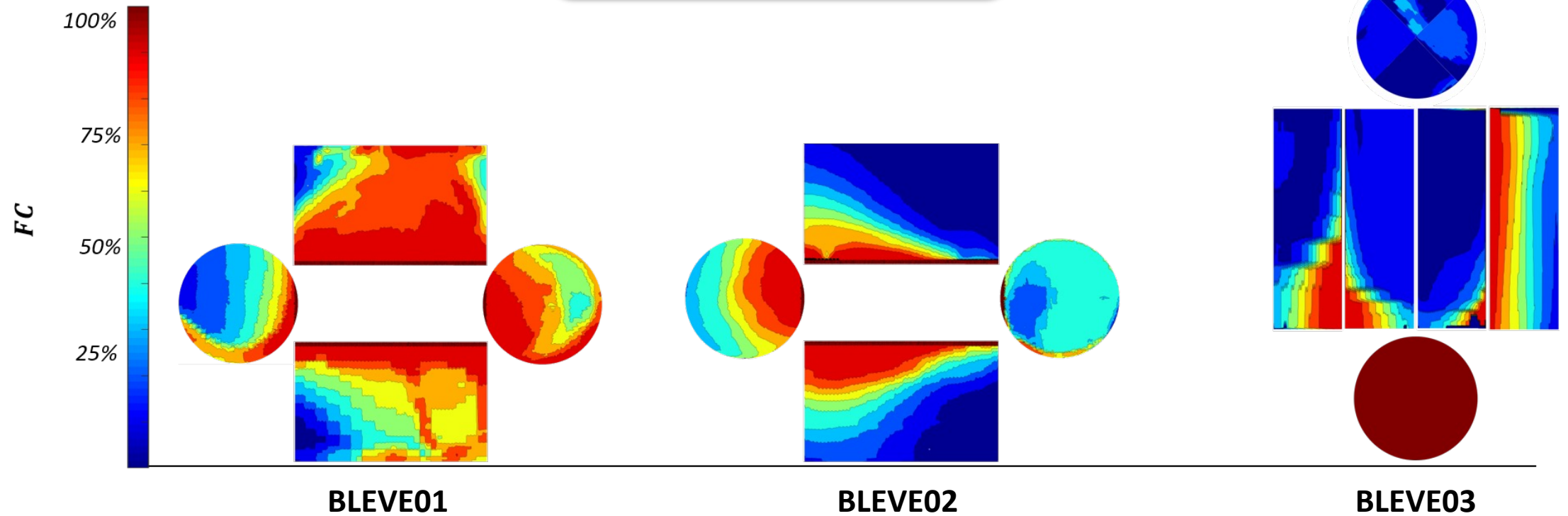
Time = 0.0 s



Methodology (3D)

Average flame coverage

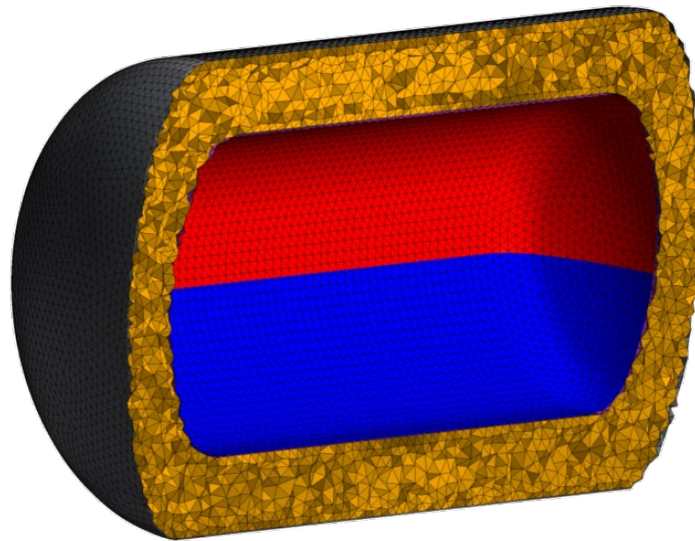
$$\varphi_f = \int_{t_{test}} \int_{A_{tank}} \phi_f(t) dA$$



Methodology (numerical simulation)

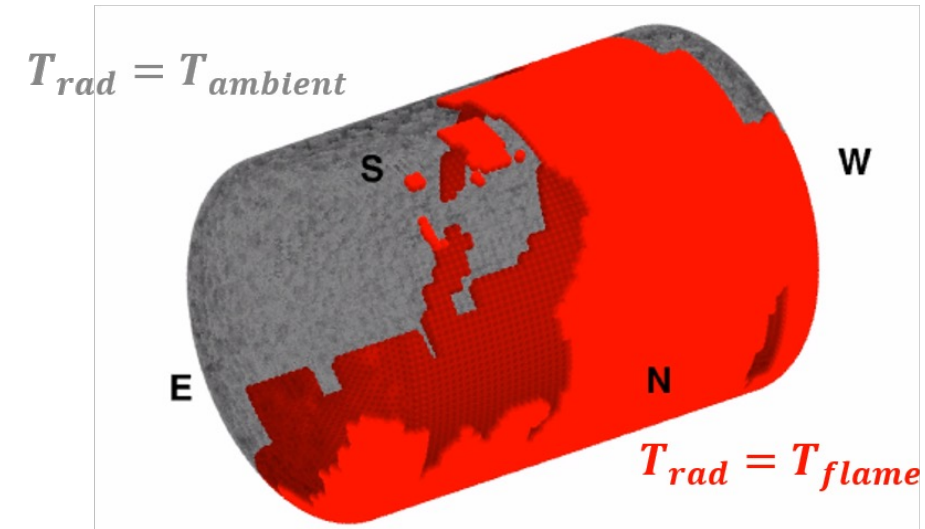
Thermal analysis

3D model to simulate the tank heating during the fire attack
(*radiation from the fire + convection with fluid*)



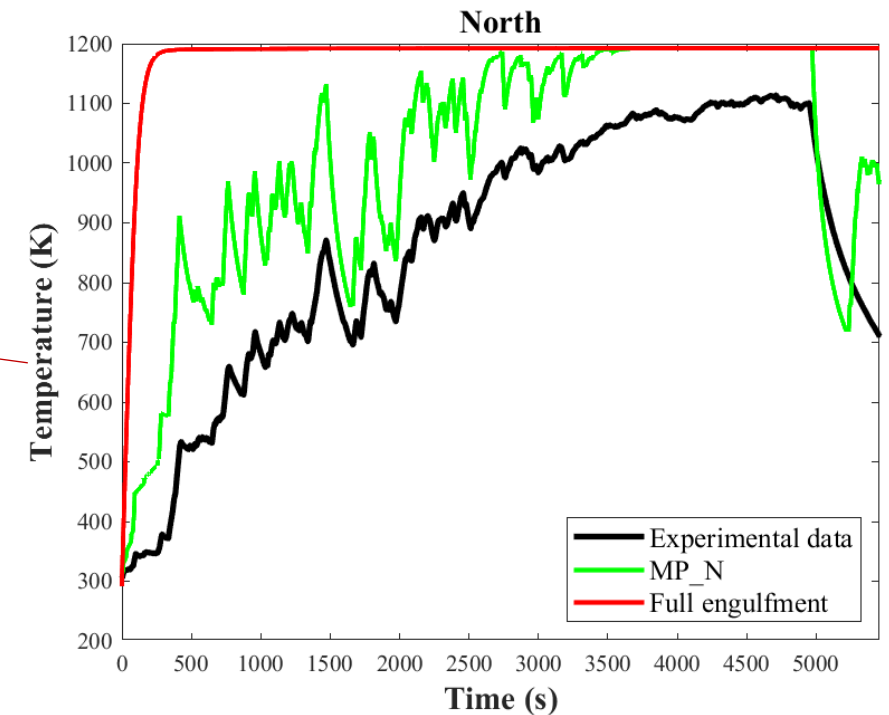
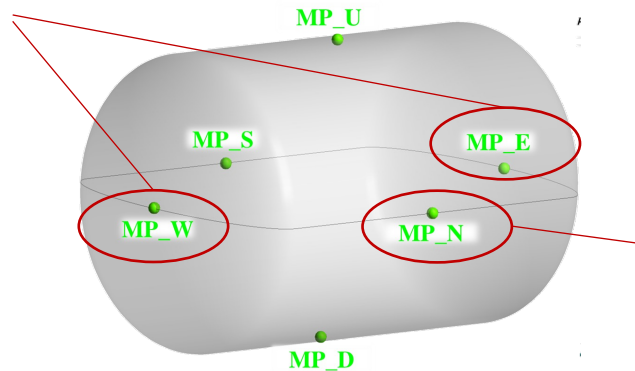
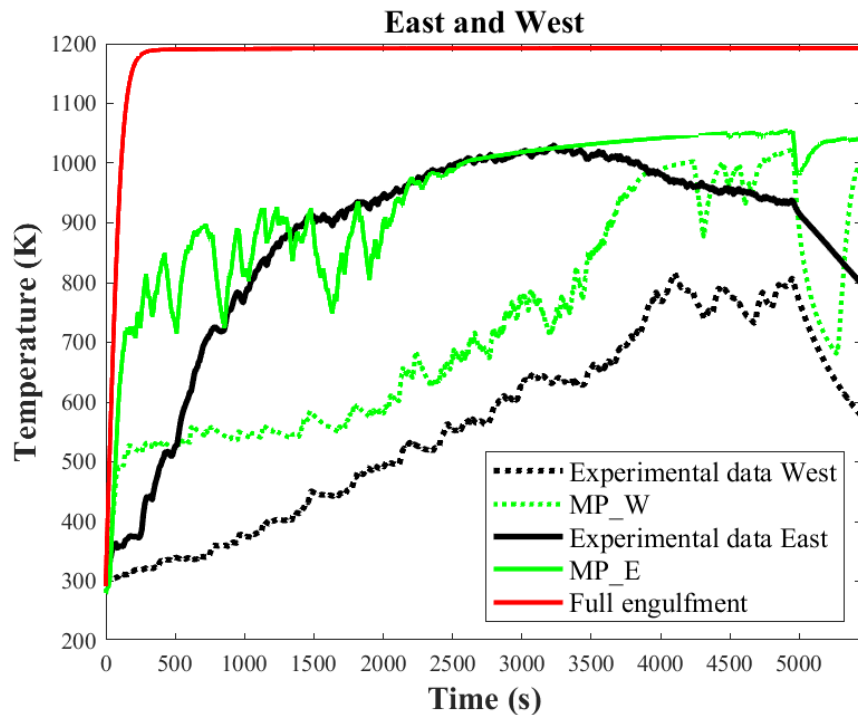
■ Vapour wetted wall ■ Liquid wetted wall
■ Insulation ■ Outer wall ■ Inner wall

+



Validation

Temperature calculated on the outer tank surface in correspondence of experimental thermocouples are compared with experimental measurements.



Method usages

- Correlation between fire engulfment and **wind velocity and direction**

Test	Tank orientation	Average wind direction	Average wind speed	Average flame coverage
BLEVE01	Horizontal	East	0.11	0.72
BLEVE02	Horizontal	West	0.89	0.46
BLEVE03	Vertical	West	1.00	0.41

- Detailed boundary conditions** for mathematical models for the prediction of the tank fire resistance (i.e., TTF)
- Quantitative assessment and verification of fire **test credibility** against established criteria

Conclusions

- The assumption of static **full engulfment** is often far from the real case scenario, especially for tests in open air
- Ambient conditions, especially **wind velocity and direction** play a significant role in determining the engulfment scenario
- **Tank orientation** also plays a role in defining how the fire engulfs the target
- **The use of the same experimental setup does not ensure the same exposure scenario**



Further analysis can focus on improved **fire temperature characterization** (e.g., exploiting recordings from thermocameras) and quantification of the **fire-target distance**



Thank you for your attention

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