Assessment of hazards from loss of containment of LH2: Progress towards experimental tests on BLEVE with a shock-tube

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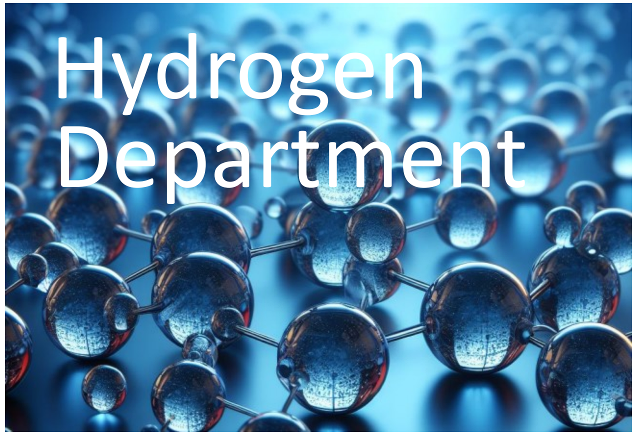

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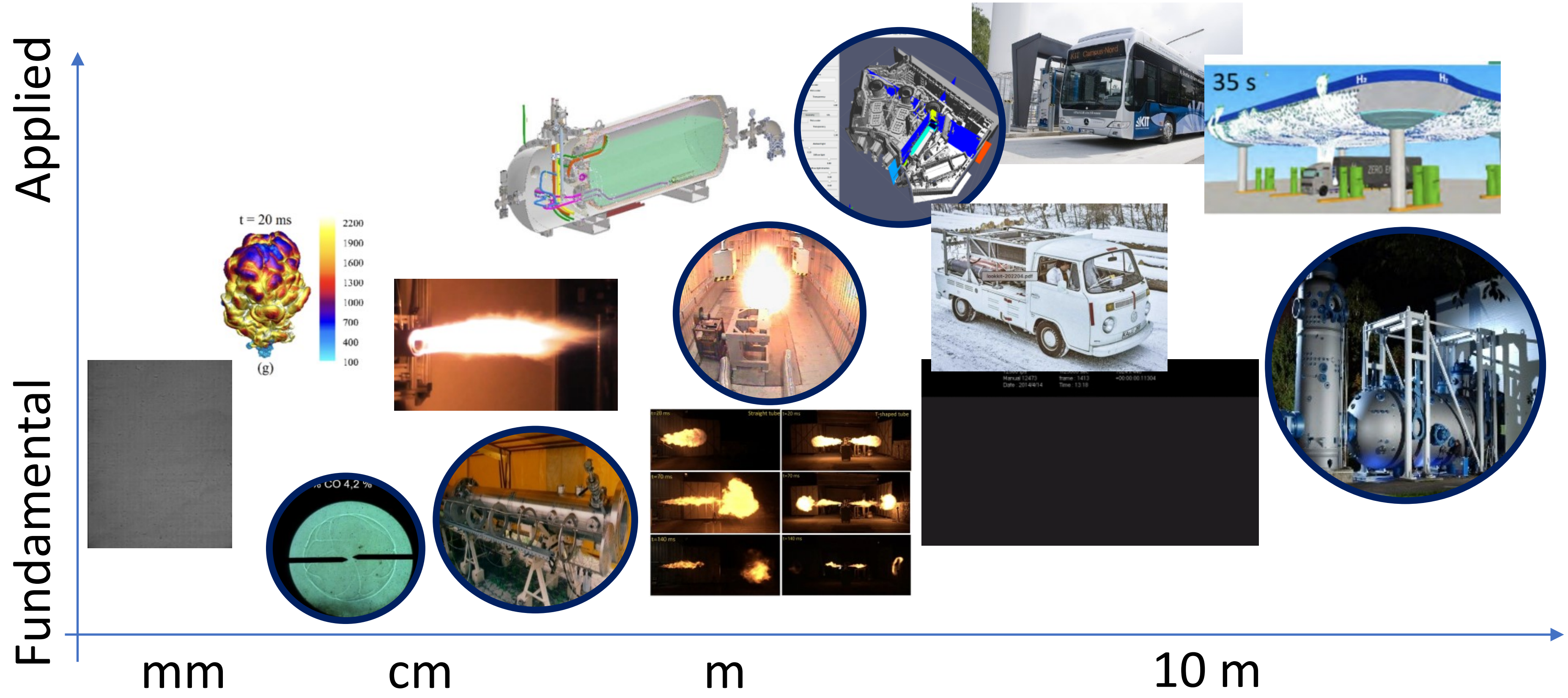
H2 Technology
Prof. Thomas Jordan



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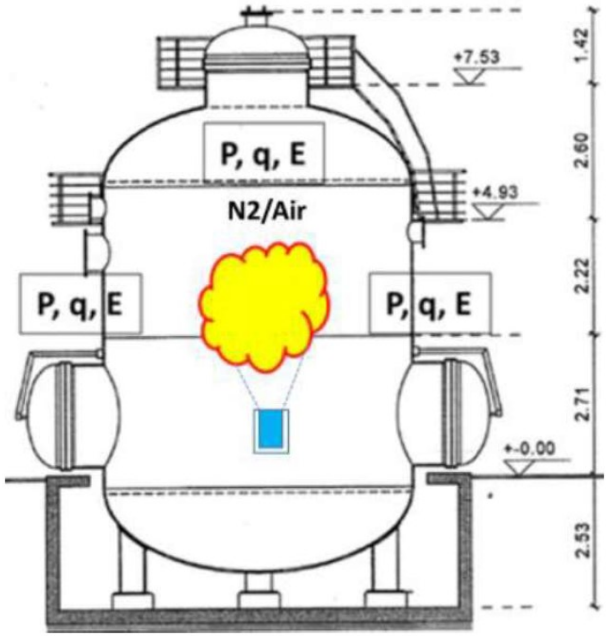
KIT Experimental Tasks 4.3.1

- Task 4.3 Performance of LH2 components and explosion consequences (Lead partner: **KIT**)

- Sub task 4.3.1 BLEVE tests with a shock tube filled with LH2 in an A2 vessel (Lead: KIT)



BLEVE : Boiling Liquid Expanding Vapor Explosion

The effect depends on a sudden phase change from liquid to vapor that might occur during a loss of containment.

We proposed to replicate this loss of containment using a shock tube, that consists in a tube with a calibrated rupture membrane.

Phenomena will be analyzed in inert atmosphere (rich in N2) and in air with ignition.

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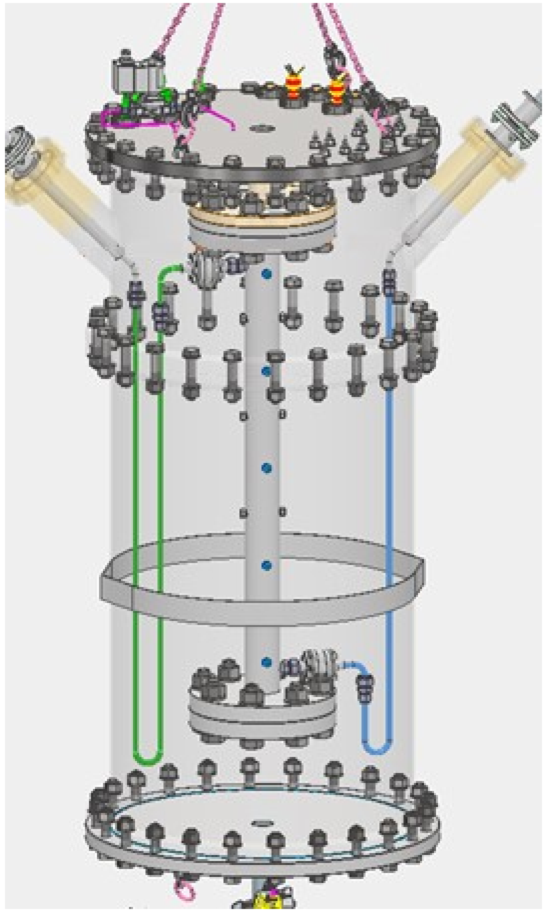
KIT Experimental Task 4.3.1

- Sub task 4.3.1 **BLEVE tests with a shock tube** filled with LH2 in an A2 vessel (Lead: KIT)

- Dimensions: L=1000 mm; D=50 mm
- Hydrogen inventory: 68 – 93 g (h≈750 mm)
- P = **5.3, 8.5, 11.6, 14.8, 18, 21.2, 24.4, 27.6** bar

(preliminary values, definitive pressures after tests, not all will be used)

- Ti = **20** K (only initial T known ->heating)



KIT Experimental Task 4.3.1

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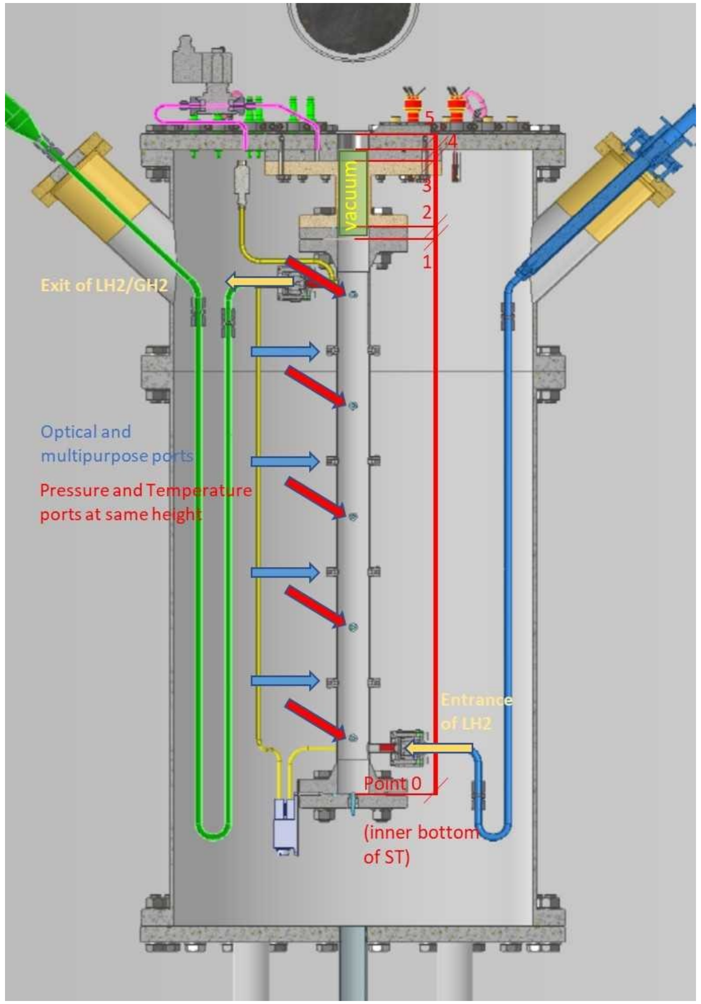

Internal measurements (cold):
- Dynamic pressure (5 positions along the tube)
- Static pressure (1 static in tee)
- Differential pressure (prototype to be tested)
- Temperature (5 positions along the tube: diodes & thermocouples type K)
- interface position (optical and thermos diodes)
- Optic sensor (prototype to be tested)

Procedure in Shock Tube
- Filling with LH2 up to exhaust level
- Heating up with wall heaters (outside)-> P rise
- Constant inventory, isochoric process
- Burst pressure regulated with burst membrane thickness
- Inventory sectioned with cryogenic check valves to minimized piping effect

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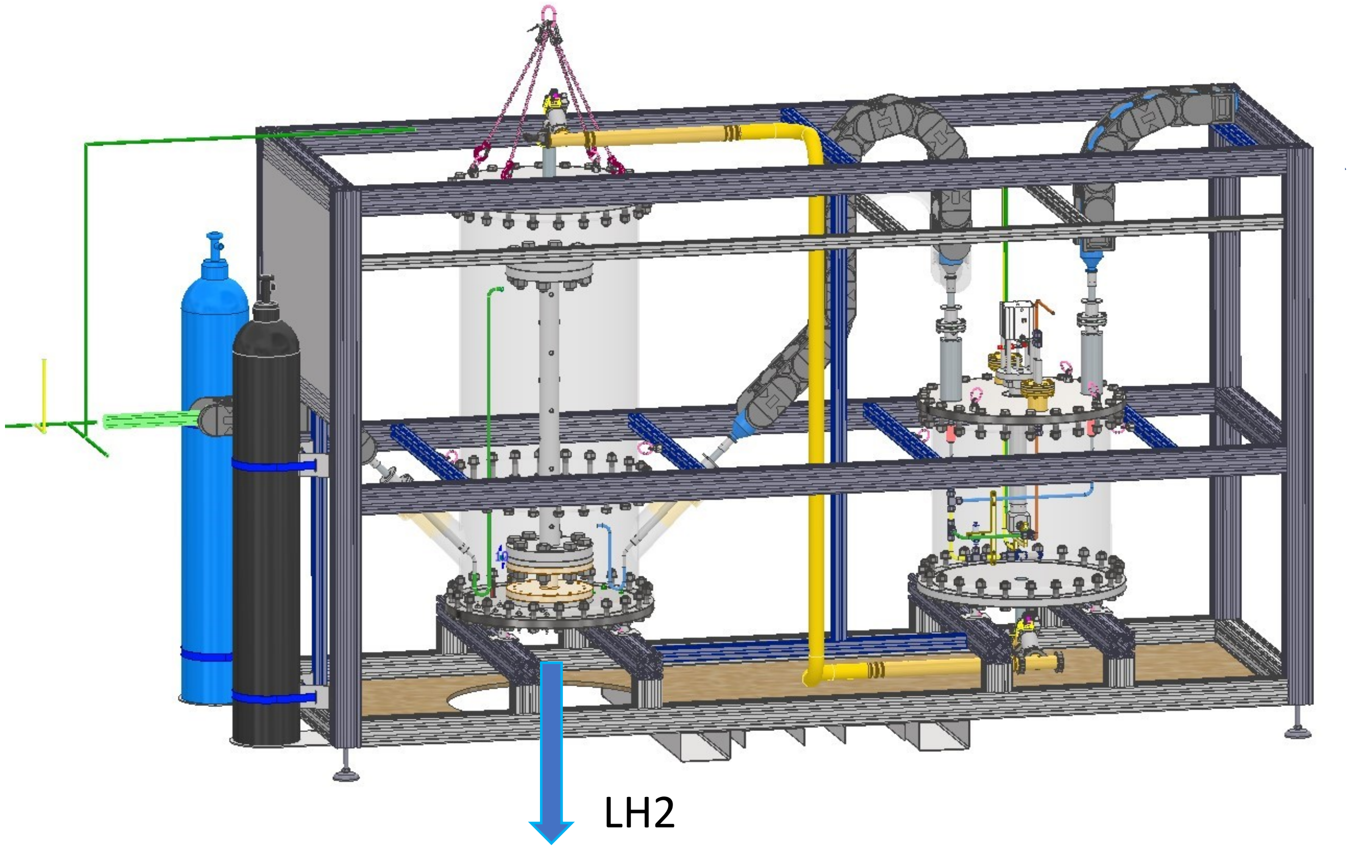

Observations:

- Vacuumized valve tank
- Two parts tank to put it upside down
- Angled insertions in/out
- Easy to manufacture
- Design 100% defined

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KIT Experimental Task 4.3.1

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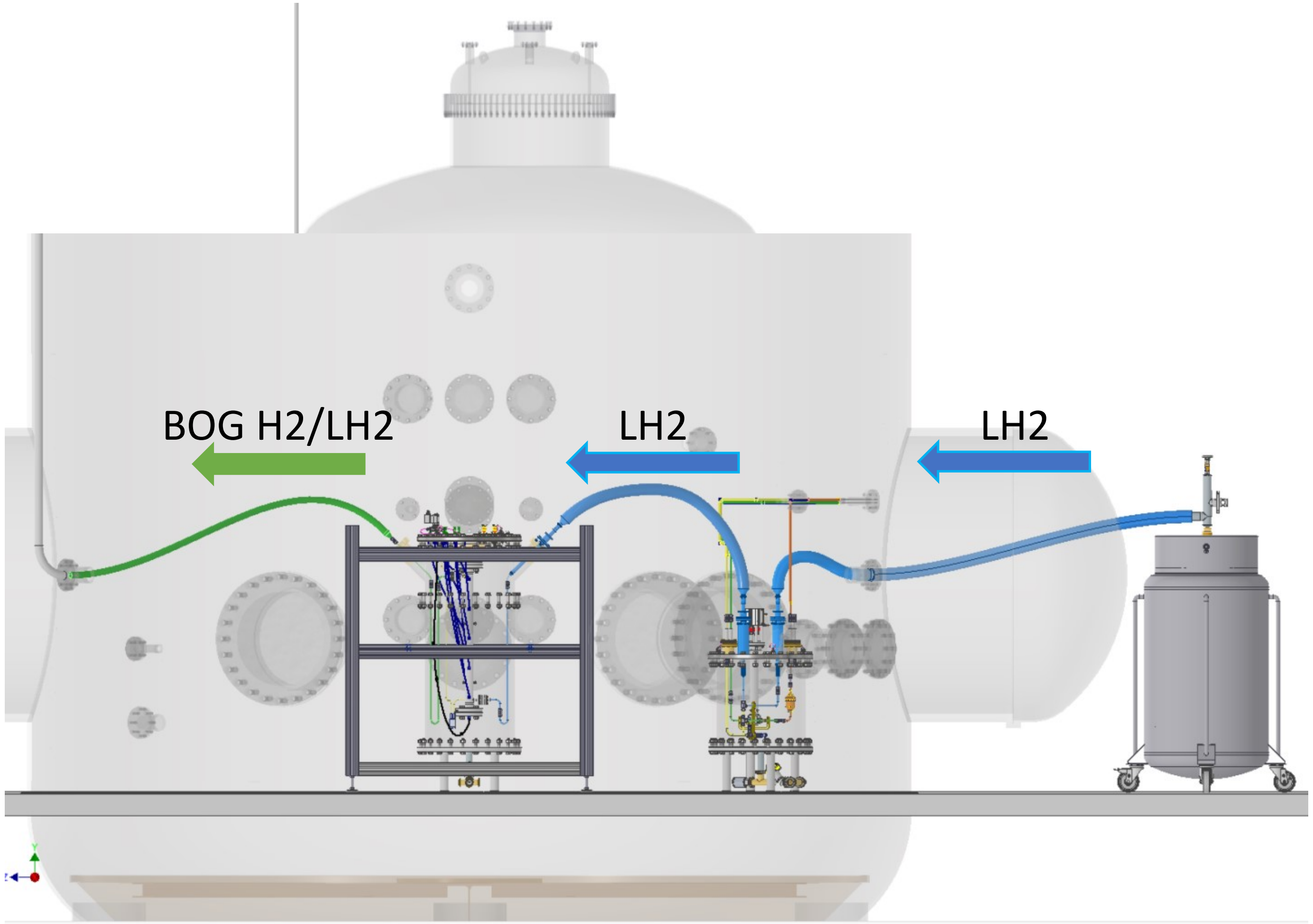

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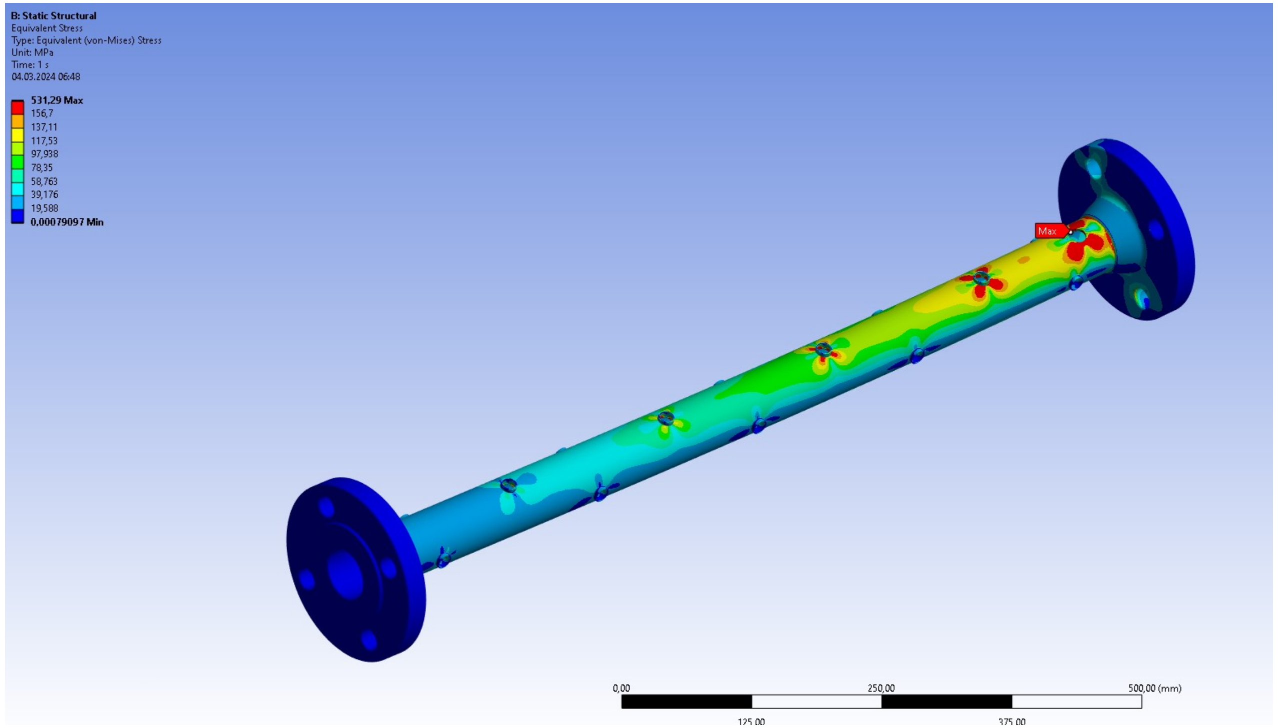

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- Two parts tank to put it upside down
- Angled insertions in/out
- Easy to manufacture.

Design 100% defined
Calculation of mechanical resistance of the shock's tube final design**. Iteration concluded (FEM)**
In construction in KIT Central Workshop
Procuring of periferics (cryogenic)

Some challenges:
-Sealings: Capton, Aluminium membrane, Helicoflex
-Glass fiber holder KIT R&D

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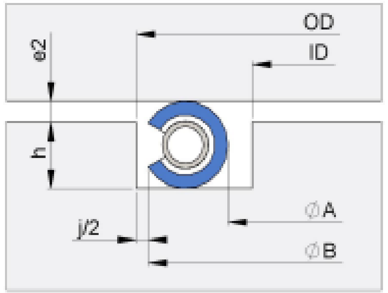
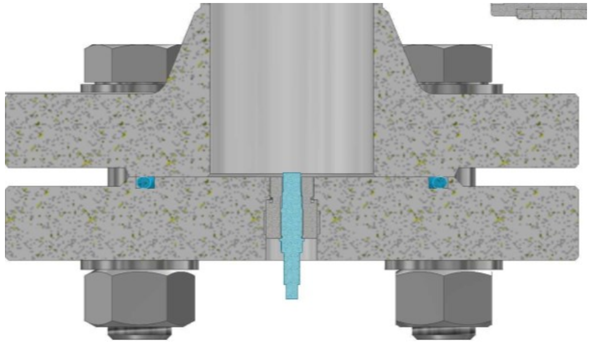
KIT Experimental Task 4.3.1

- Sub task 4.3.1 **BLEVE tests with a shock tube** filled with LH2 in an A2 vessel (Lead: KIT)

MS16 P&ID / design drawings and experimental set up photos





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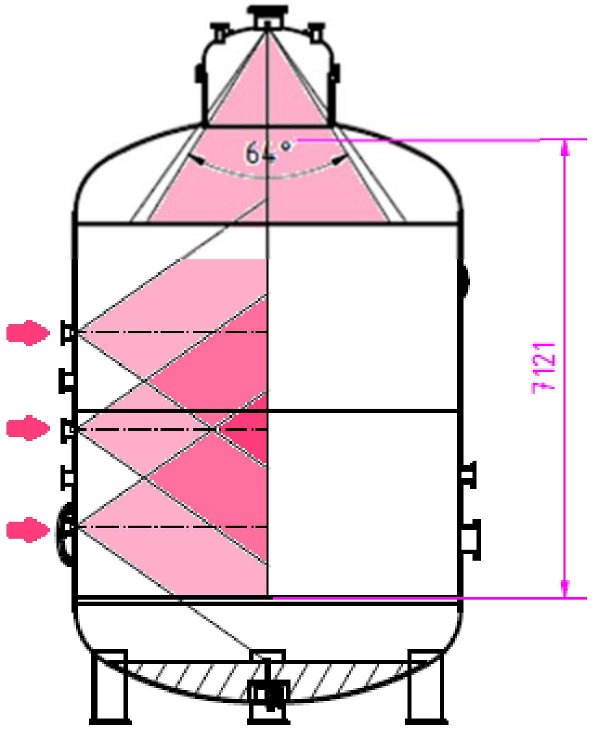
Left and upper right pictures taken from technetics.com

KIT Experimental Task 4.3.1

- Sub task 4.3.1 **BLEVE tests with a shock tube** filled with LH2 in an A2 vessel (Lead: KIT)

A2 and BOS



- **Outer measurements** inside A2 vessel (H=9 m, D= 6 m, V=220 m^3):

  - Dynamic pressure (5 positions)
  - Static pressure (1 position)
  - Temperature sensors (approx. 3 positions)

- **Outer video recording** (BOS +high-speed movie+ webcam)

  - 3 cameras 100 images per second covering the lateral side
  - 1 zenithal camera
  - 1 camera 10.000 images per second covering the region close to the membrane burst
  - 3 web cams for overall process

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KIT Experimental Task 4.3.1

- ❑ Sub task 4.3.1 **BLEVE tests with a shock tube** filled with LH2 in an A2 vessel (Lead: KIT)

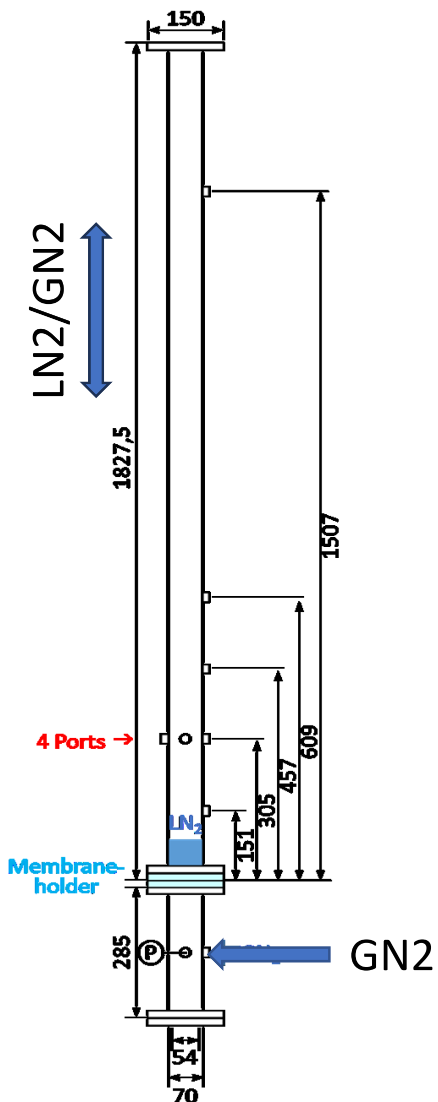
PRETESTS

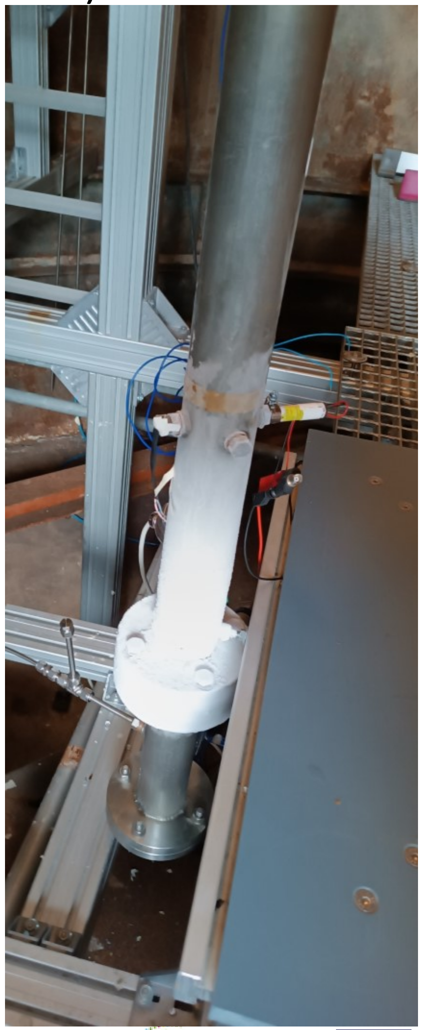
We selected pure Aluminium membranes 99,9% to be used as burst membranes:

- Already used in KIT H2 department
- Good repeatability
- Cheap and easy to manufacture in house

Pre tests necessary to check at low temperature and different configuration:

- Liquid N2
- Test different membrane providers
- Test P sensors
- Test T sensors
- Test of optical probes
- Test cameras setting





KIT Experimental Task 4.3.1

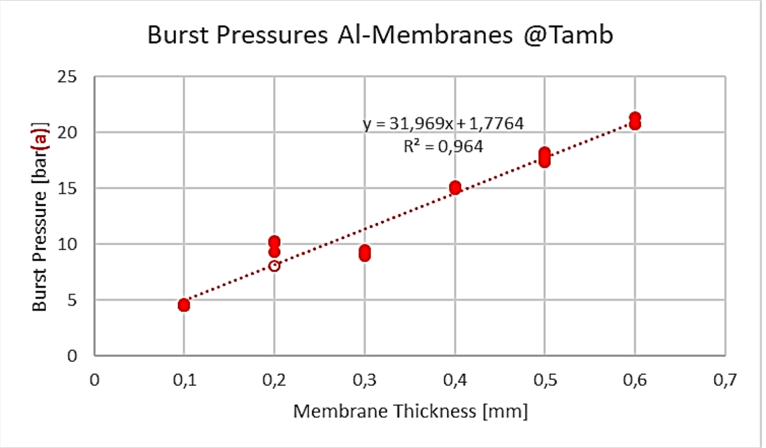
- Sub task 4.3.1 **BLEVE tests with a shock tube** filled with LH2 in an A2 vessel (Lead: KIT)

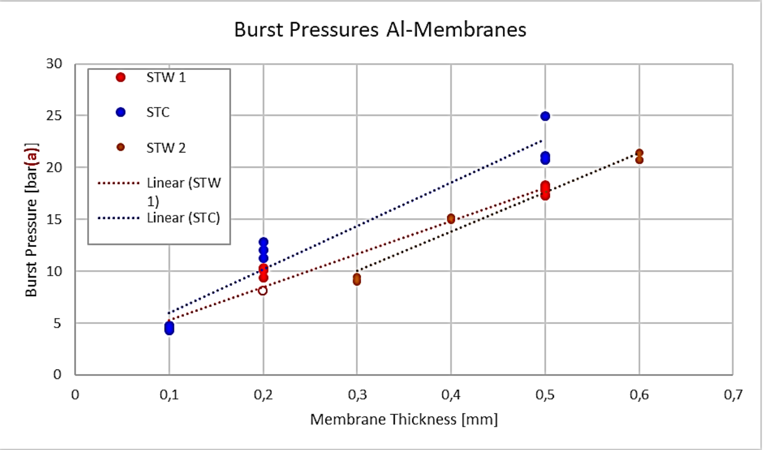
PRETESTS

Outcoming results:

- Plates with different thicknesses tested succesfully
- Manufacturer matters
- Repeatability is good
- Temperature affects less
- Fast camera and webcam setting and processing ready
- Optics photo gates showed preliminary good result

Thickness [mm]	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8
P [bar]	5,3	8,5	11,6	14,8	18,0	21,2	24,4	27,6





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KIT Experimental Task 4.3.1

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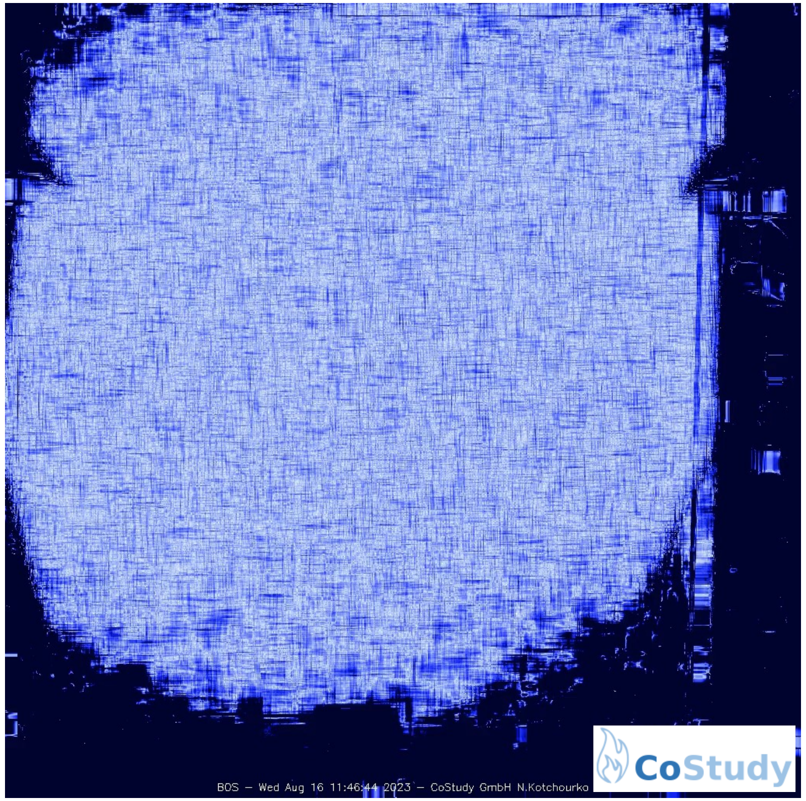
A2 and BOS (CoStudy processing)



Thank you for your attention

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