

# PRE-SLHY

## Status of the PS-Experiments on WP3 and 4

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Pre-normative REsearch for Safe use of Liquid HYdrogen

223  
1966



# Introduction WP3-Experiments

- In the Description of Work two experimental series' for WP3 to be performed by Pro-Science in the HYKA-facilities at KIT are described:

E3.1 Jet-Experiments (unignited DisCha-Experiments)

E3.4 (Unignited) Pool-Experiments (in same facility as E4.4 (ignited)).

- The execution of the experiments was initially planned as follows:

Today

|         | 20 18 |   |   |   |   |   |   |   |   |    |    |    | 20 19 |    |    |    |    |    |    |    |    |    |    |    | 20 20 |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---------|-------|---|---|---|---|---|---|---|---|----|----|----|-------|----|----|----|----|----|----|----|----|----|----|----|-------|----|----|----|----|----|----|----|----|----|----|----|--|--|--|--|--|--|--|--|--|--|--|--|--|
|         | J     | F | M | A | M | J | J | A | S | O  | N  | D  | J     | F  | M  | A  | M  | J  | J  | A  | S  | O  | N  | D  | J     | F  | M  | A  | M  | J  | J  | A  | S  | O  | N  | D  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| PRESLHY | 1     | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13    | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25    | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| WP3     |       |   |   |   |   |   |   |   |   |    |    |    |       |    |    |    |    |    |    |    |    |    |    |    |       |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E3.1    |       |   |   |   |   |   |   |   |   |    |    |    |       |    |    |    |    |    |    |    |    |    |    |    |       |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |
| E3.4    |       |   |   |   |   |   |   |   |   |    |    |    |       |    |    |    |    |    |    |    |    |    |    |    |       |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |

# Update WP3-Experiments

- Updated Time Schedule WP3-Experiments by PS/KIT:

E3.1a Jet-Experiments (unignited DisCha-Experiments) done & reported

E3.1b Kryostat-Experiments

E3.4 (Unignited) Pool-Experiments (same facility as E4.4 (see there)).

|         | 20 18 |   |   |   |   |   |   |   |   |    |    |    | 20 19 |    |    |    |    |    |    |    |    |    |    |    | 20 20 |    |    |    |    |    |    |    |    |      |    |    |  |   |  |  |  |  |  |  |  |  |
|---------|-------|---|---|---|---|---|---|---|---|----|----|----|-------|----|----|----|----|----|----|----|----|----|----|----|-------|----|----|----|----|----|----|----|----|------|----|----|--|---|--|--|--|--|--|--|--|--|
|         | J     | F | M | A | M | J | J | A | S | O  | N  | D  | J     | F  | M  | A  | M  | J  | J  | A  | S  | O  | N  | D  | J     | F  | M  | A  | M  | J  | J  | A  | S  | O    | N  | D  |  |   |  |  |  |  |  |  |  |  |
| PRESLHY | 1     | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13    | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25    | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34   | 35 | 36 |  |   |  |  |  |  |  |  |  |  |
| WP3     |       |   |   |   |   |   |   |   |   |    |    |    |       |    |    |    |    |    |    |    |    |    |    |    |       |    |    |    |    |    |    |    |    |      |    |    |  |   |  |  |  |  |  |  |  |  |
| E3.1    |       |   |   |   |   |   |   |   |   |    |    |    | 3.1a  |    |    |    |    |    |    |    |    |    |    |    | D     |    |    |    |    |    |    |    |    | 3.1b |    |    |  | D |  |  |  |  |  |  |  |  |
| E3.4    |       |   |   |   |   |   |   |   |   |    |    |    |       |    |    |    |    |    |    |    |    |    |    |    |       |    |    |    |    |    |    | D  |    |      |    |    |  |   |  |  |  |  |  |  |  |  |

Today

# E3.1b Small Scale Multiphase Release (Cryostat-Facility)

- No release of LH<sub>2</sub> possible from DisCha-facility,
- Therefore the Cryostat-Facility will be used to achieve LH<sub>2</sub>-releases,

## Details of the facility



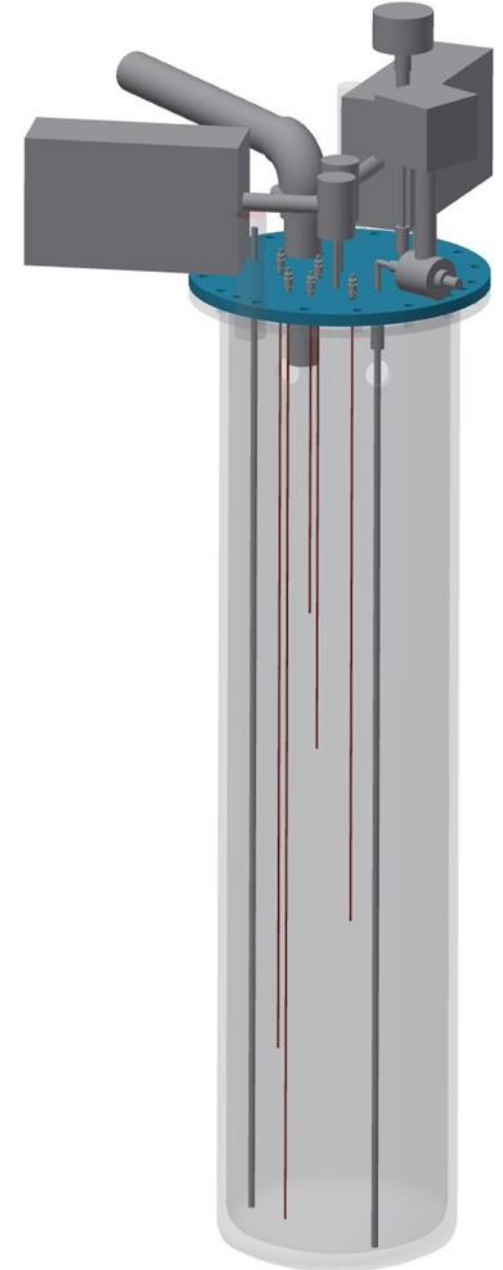
- Properties

- $P_{\max}$ : 6 bar →  $P_{\max}(\text{Exp})$ : 5 bar
- Volume: 225 l  
(will be reduced via Styrofoam rings),
- Long, uncooled neck further reduces available volume,
- Loaned from other Institute  
→ Revision in progress:
  - Top flange with pipework, controls and instruments was missing and is currently fabricated,
  - old safety valves are replaced,
  - security check (TÜV) is compulsory.

# E3.1b Small Scale Multiphase Release (Cryostat-Facility)



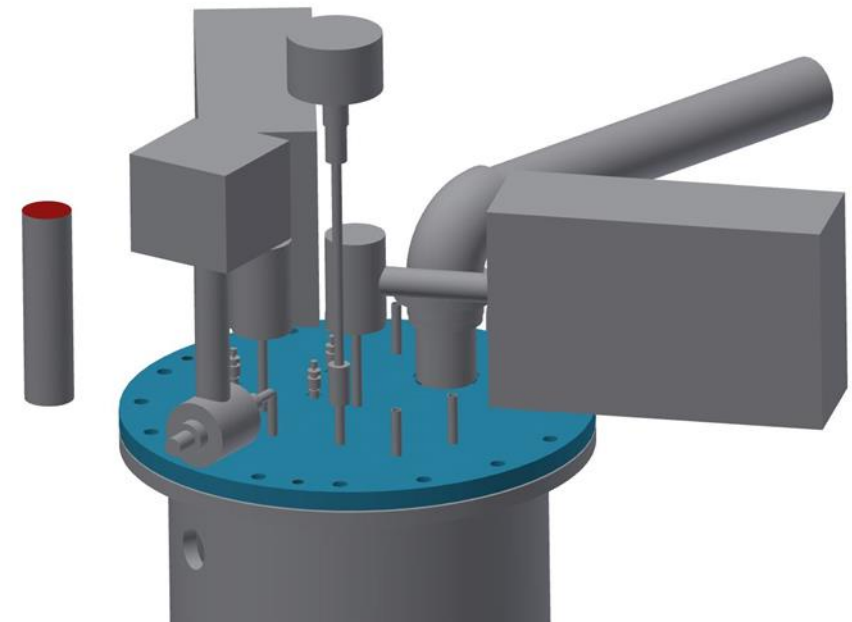
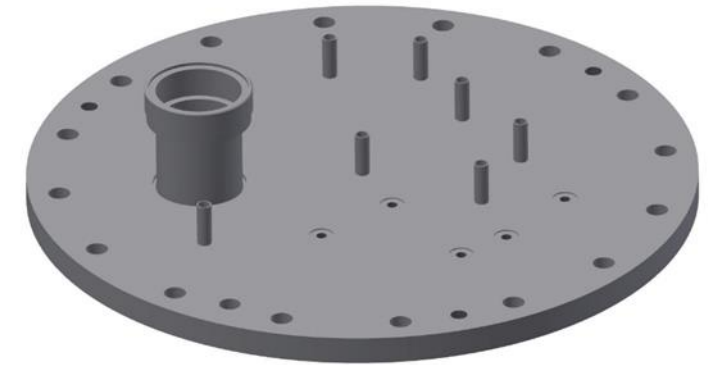
- Instrumentation (mostly similar to DisCha):
  - P in vessel and close to nozzle,
  - T close to and in nozzle-aperture,
  - 3x T and 3x CH2 in jet  
(long sampling lines necessary, gas must be warmed prior to concentration measurement),
  - Flow measurement (New)
    - No flowmeter with low pressure loss available for LH<sub>2</sub>-temperature,
    - Flow will be determined using scales to measure weight of complete assembly (special scales purchased and already delivered).
- Experimental Program:
  - 4 Reservoir-pressures (e.g. 2, 3, 4, 5 bar),
  - At least 2 nozzles (e.g. 1 and 4 mm).



# E3.1b Small Scale Multiphase Release (Cryostat-Facility)

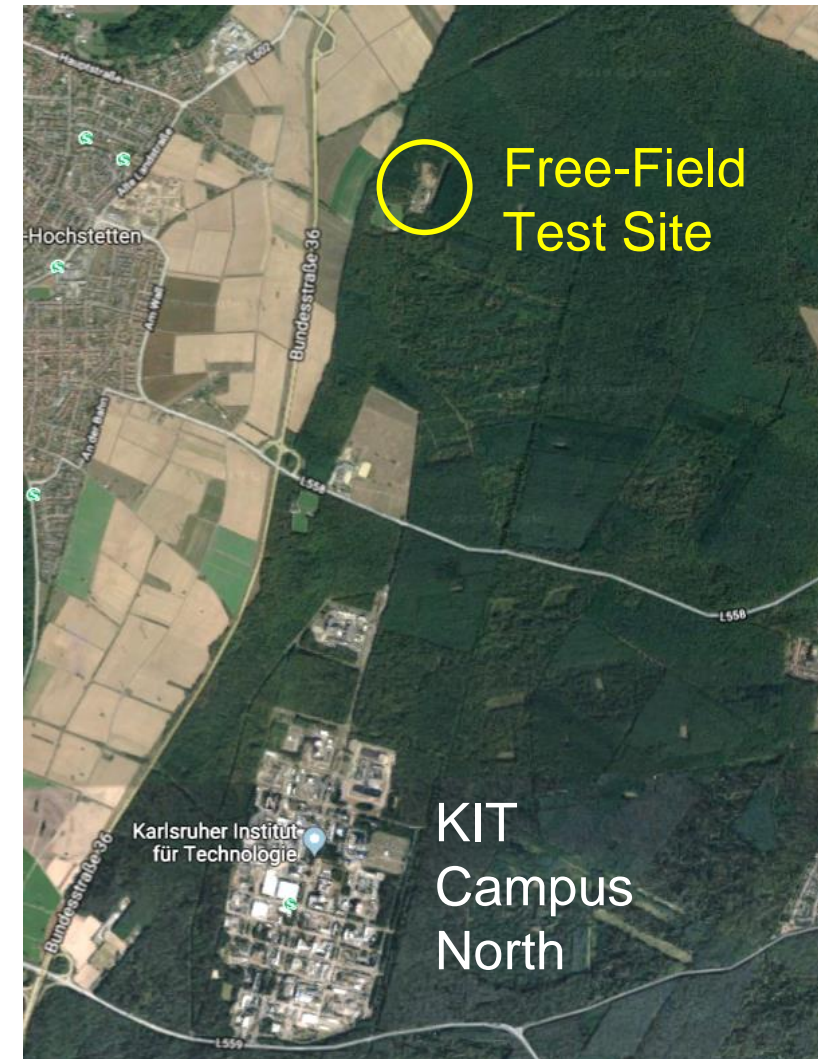


- Main problem was missing lid of the cryostat which had to be constructed and fabricated at KIT-workshop,
- Since the connection to the LH2-trailer is now clarified the construction of the lid was completed,
- Most of fabrication work (e.g. holes for bolts to connect the lid with the vessel) was done already earlier, lid is currently finalized in workshop,
- As soon as lid is available assembly will be started,
- Experiments will be carried out in Free-Field Test-Site after completion of Ignited Pool Tests.



## E3.4 Spill of LH<sub>2</sub> (Pool-Facility)

- General aim:
  - Generation and characterization of a LH<sub>2</sub>-pool above different substrates like concrete, gravel and sand (Task E3.4, Step 1)
  - Ignition of the pool (Task E4.4, Step 2)
- Both steps will be performed subsequently in same facility.
- Work strongly delayed to initial time schedule due to problems with:
  - Energy of ignited spills possibly too high for HyKA at KIT, so a more remote test site had to be found  
➔ Free-Field Test Site north of KIT
  - Problems with purchasing LH<sub>2</sub>  
Many thanks to Simon Jallais and AirLiquide for delivery of LH<sub>2</sub> with trailer and hose!
  - Uncertainties on pipework for LH<sub>2</sub>-release  
Many thanks to colleagues from HSL for fast and extensive help!



## E3.4 Spill of LH<sub>2</sub> (Pool-Facility)



- Work slightly delayed to updated time schedule due to problems with:
  - Delivery of LH<sub>2</sub> delayed due to several reasons (preparation of facility, contractual details, Corona/COVID19),
  - Uncertainties on pipework for LH<sub>2</sub>-release:  
Unfortunately none of the adapters provided by HSE/HSL really matched to the hose provided by AirLiquide with the trailer (nevertheless it was very helpful to have physical examples at hand!)
  - So distance from trailer to pool is shorter than initially planned  
→ additional protection of trailer necessary
- Most problems solved, experiments on unignited pool (E3.4) have started,
- Experiments on ignited pools (E4.4) will be conducted after completion of E3.4.



# E3.4 Spill of LH<sub>2</sub> (Pool-Facility)

- Free-Field-Test-Site:

Trailer was delivered, ... (March 12)



... protected and ...  
(March 13/16)



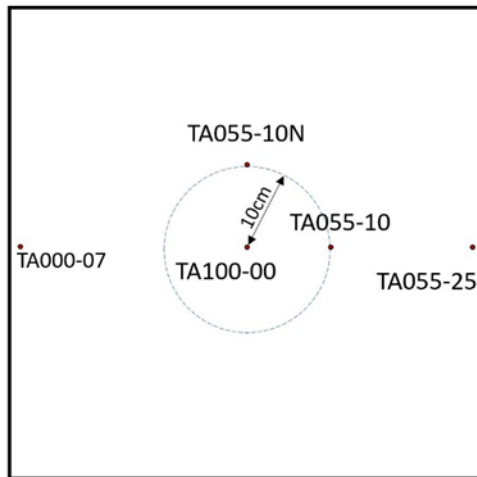
... facility completed. (March 20)



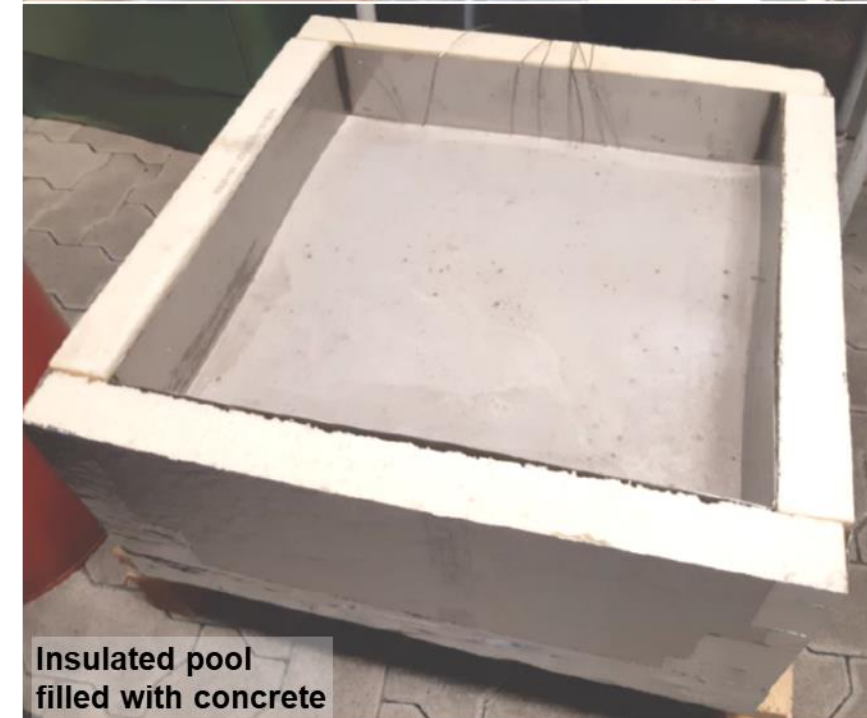
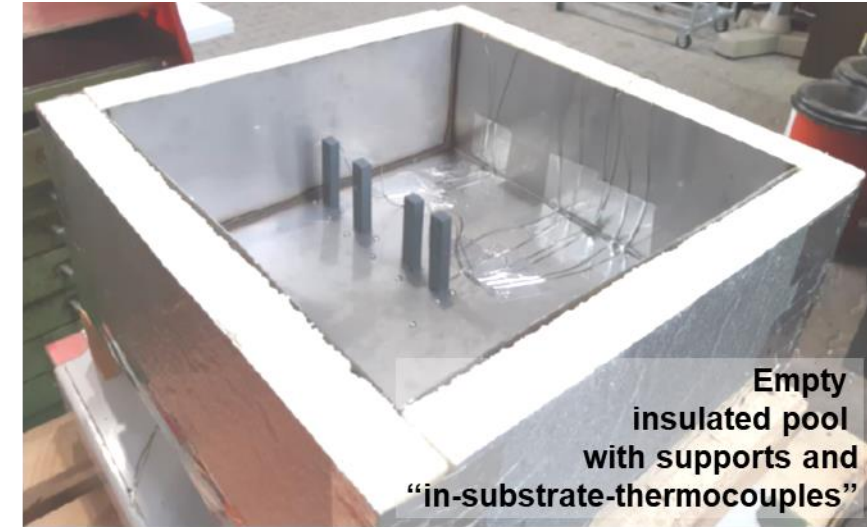
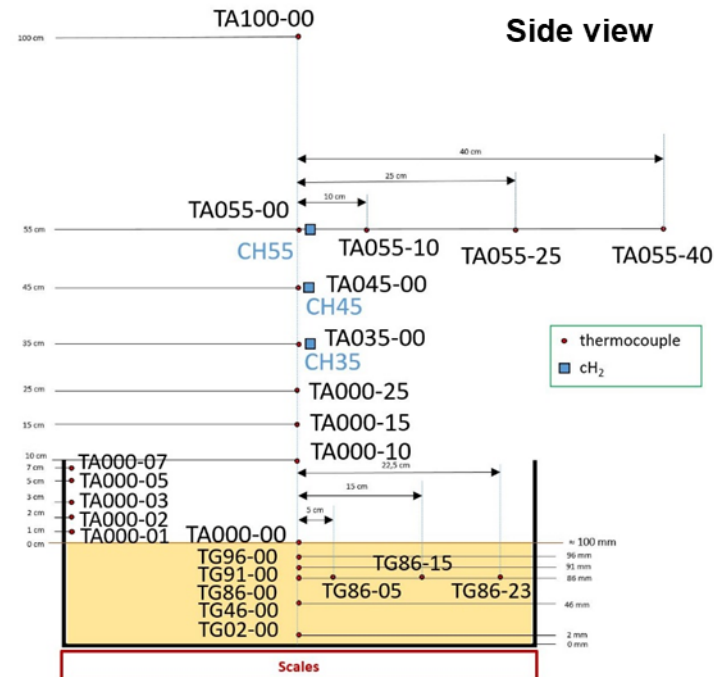
# E3.4 Spill of LH<sub>2</sub> (Pool-Facility)

- Pool Instrumentation:
  - 8 Thermocouples in substrate (5 on center line),
  - 7 Thermocouples in pool above substrate (located at pool wall),
  - 11 Thermocouples above pool (7 on center line),
  - 3 positions for continuous H<sub>2</sub>-concentration measurement,
  - Scales for weight-measurement of LH<sub>2</sub>-pool.

Sketch of thermocouple and CH<sub>2</sub>-sensing positions



Top view of pool



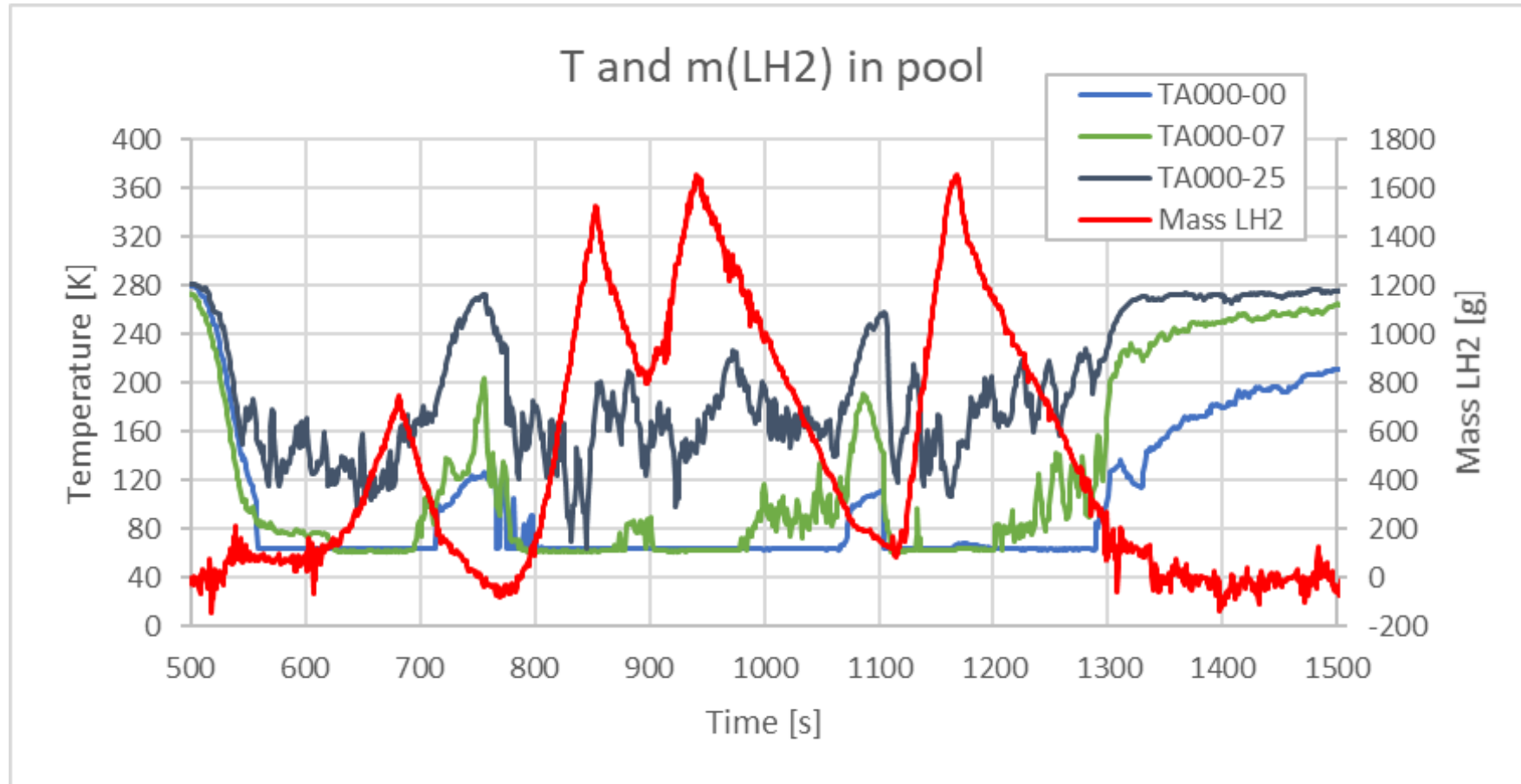
## E3.4 Spill of LH<sub>2</sub> (Pool-Facility)



- Control software and instrumentation of pools is completed,
- One pre-test and a first test series (without artificial wind) was performed with the concrete pool,
- Pool formation was observed and can be clearly monitored in the signals of the thermocouples in different heights inside the pool and also in the signal of the scales.
- Despite promising first results concerns arose on the amount of H<sub>2</sub> that is present during and after the pool formation,
- In combination with the small hose length (4 m) changes in control and procedure of the experiments are necessary, especially in the presence of adverse natural wind conditions (natural wind in direction of trailer),
- Facility and procedure has to be reworked prior to continuation of experiments.

# E3.4 Spill of LH<sub>2</sub> (Pool-Facility)

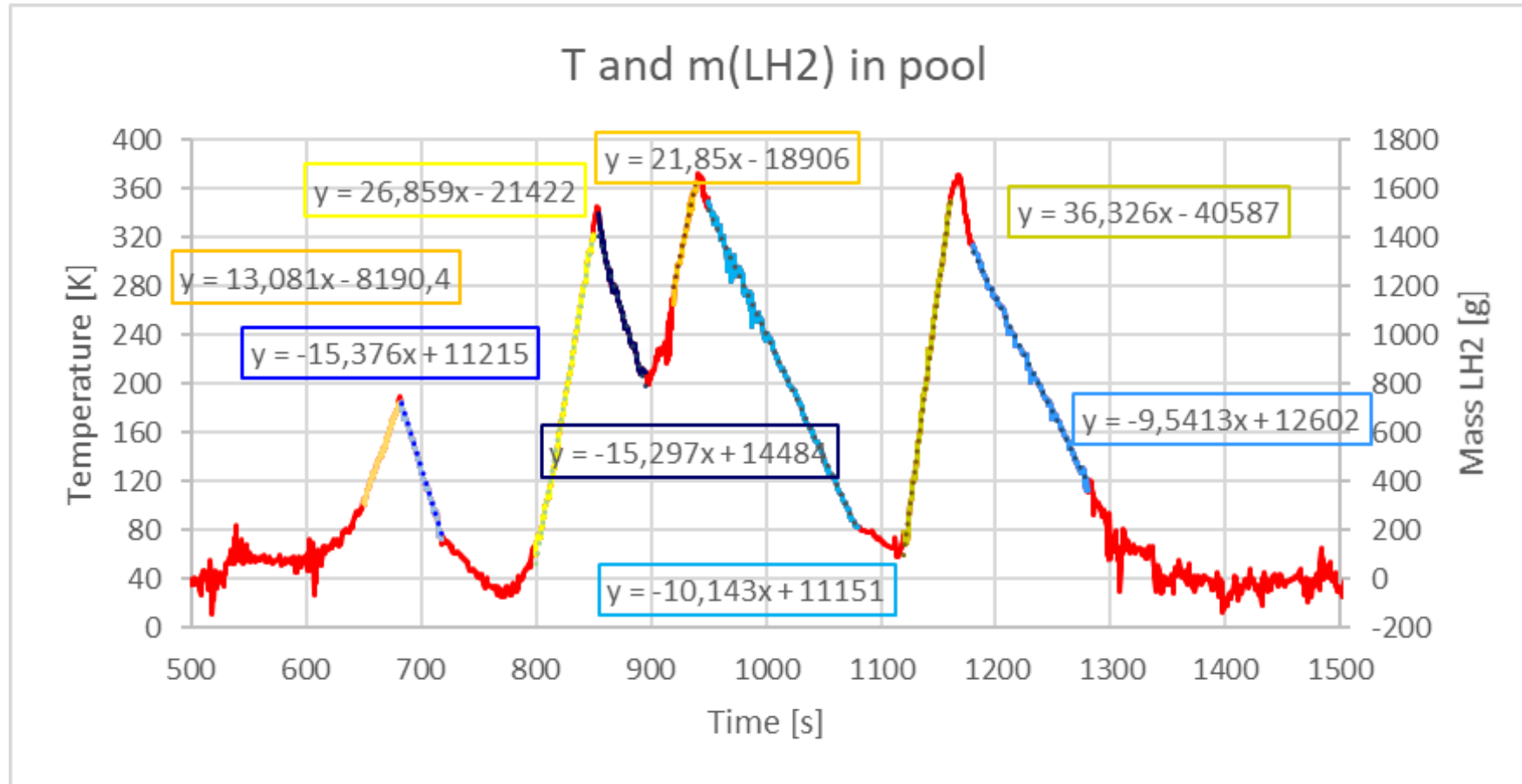
- Preliminary results of 1<sup>st</sup> test series



- Pool was filled and evaporated four times,
- Filling was stopped when pool started to overflow

# E3.4 Spill of LH<sub>2</sub> (Pool-Facility)

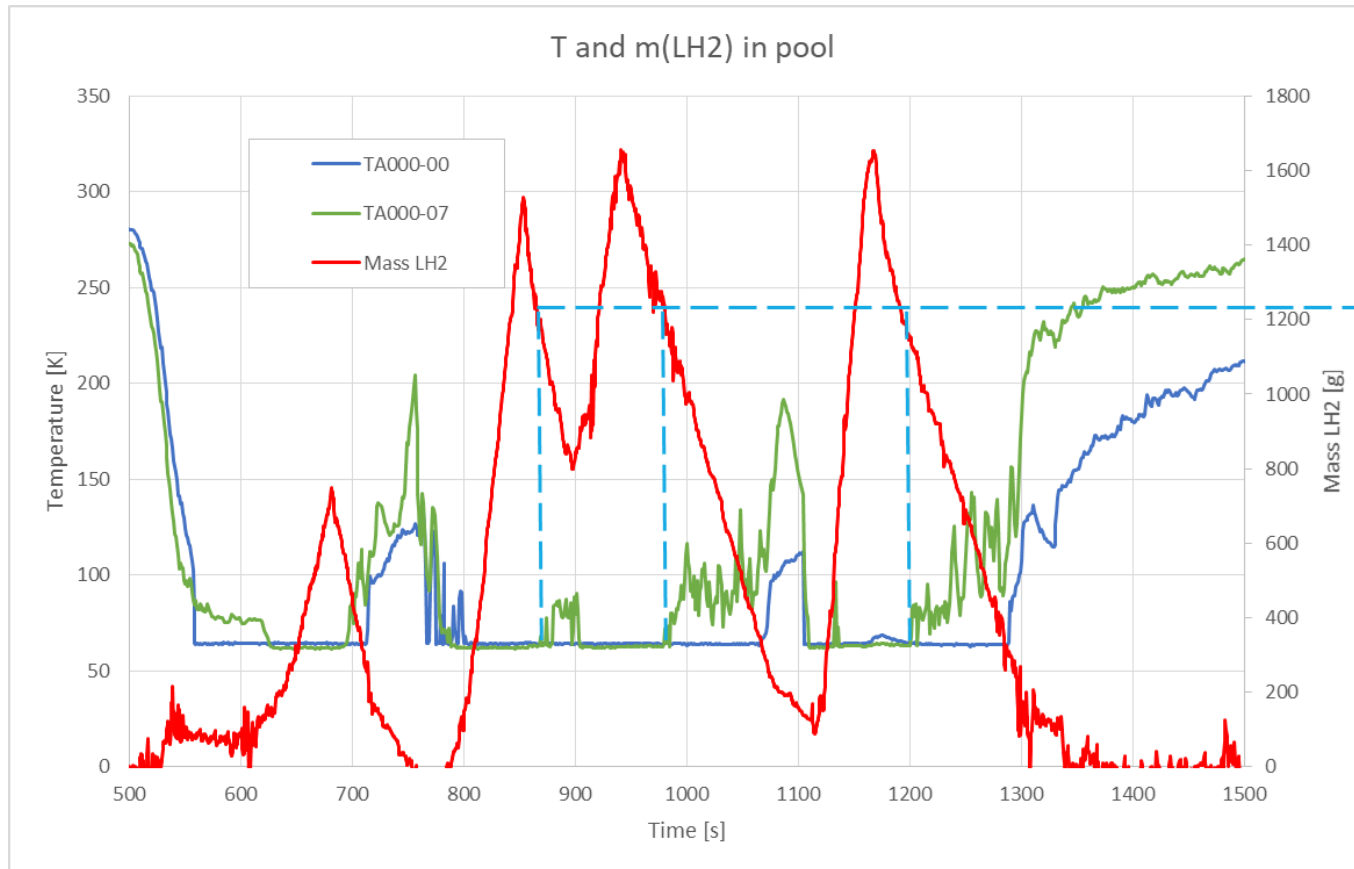
- Preliminary results of 1<sup>st</sup> test series



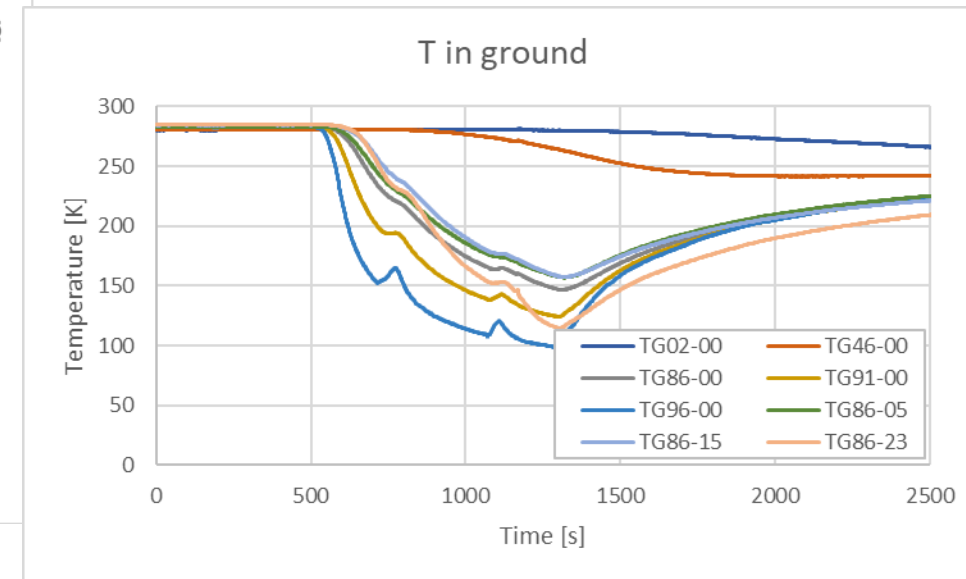
- Pool formation and evaporation rates can be determined from signal of scales

# E3.4 Spill of LH<sub>2</sub> (Pool-Facility)

- Measured temperatures and LH2 masses
  - TA0000-00 is positioned in the pool at the sidewall on the ground surface
  - TA000-07 (in pool 7 cm above concrete surface), reacts as soon as pool depth < 7 cm



LH2 mass for 7 cm pool depth



- Pool height is  $h_{\text{pool}} = m_{\text{LH}_2} / (\rho_{\text{LH}_2} L^2)$
- Results in  $h_{\text{pool}} \text{ in cm} = 5.65 \times 10^{-3} m_{\text{LH}_2} \text{ in g}$
- LH2 mass for 7 cm pool depth (= position of TA000-07) is 1238 g

# E3.4 Spill of LH<sub>2</sub> (Pool-Facility)

- Preliminary results of 1<sup>st</sup> test series

