PRESLHY WP4 – electrostatics / ignition experiments

PRESLHY Athens meeting 30-03-2020

Pre-normative REsearch for Safe use of Liquid HYdrogen

Experimental Programme

- WP3: Unignited releases focussing on dispersion / source term
- WP4: Ignition phenomena focussing on electrostatics / condensed phase initiation / rapid phase transition
- WP5: Combustion characteristics including semiconfined / congested regions

Contents

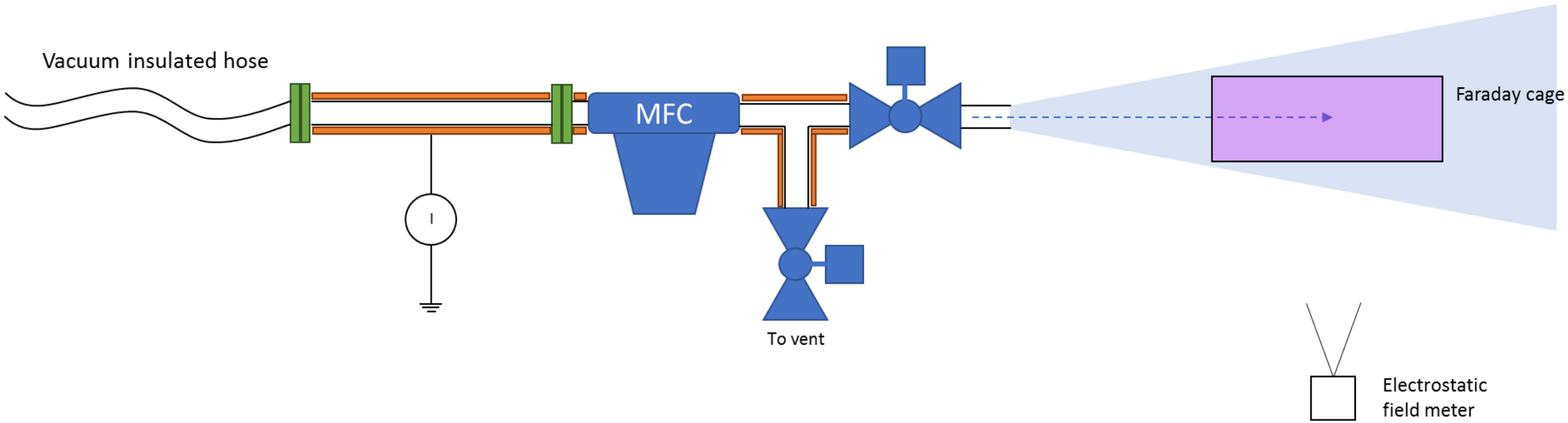
- E4.3 Electrostatic experiments summary
  - Setup
  - Plume measurements
  - Wall current measurements
  - Initial conclusions
- E4.5 Condensed phase summary
  - Setup
  - Rapid phase transition experiments
  - Initial conclusions
- Deliverables and other activities

Contents

- E4.3 Electrostatic experiments summary
  - Setup
  - Plume measurements
  - Wall current measurements
  - Initial conclusions
- E4.5 Condensed phase summary
  - Setup
  - Rapid phase transition experiments
  - Initial conclusions
- Deliverables and other activities

Electrostatics experiments setup

- Wall current measured with WP3 dispersion trials.
- Plume measurements made during separate releases.

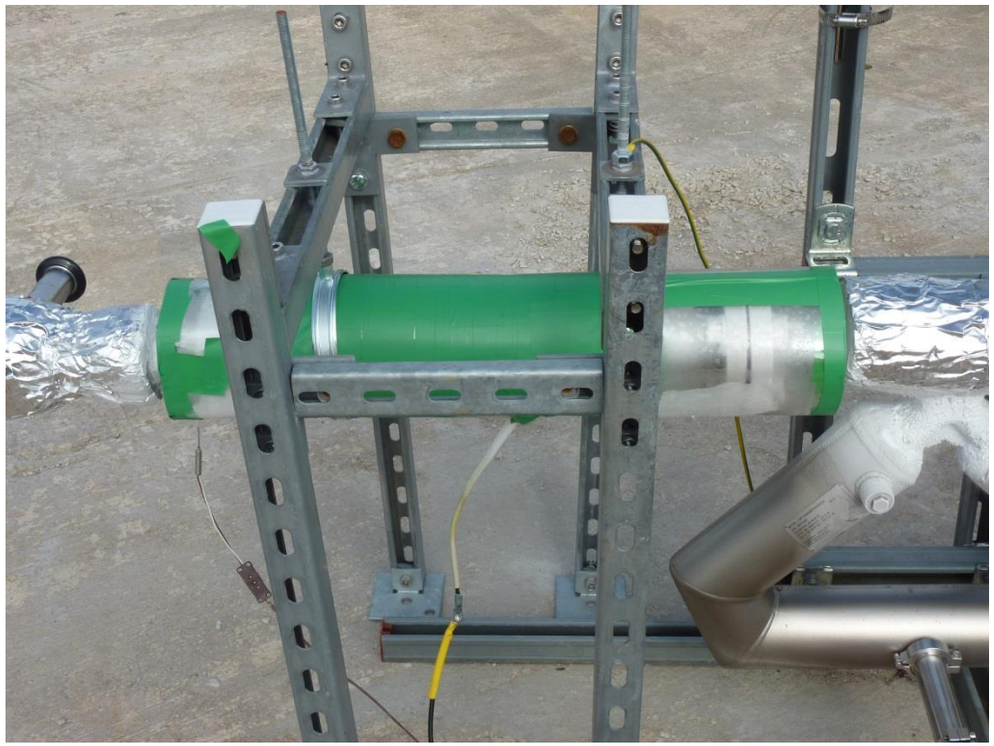


Release station sketch

Instrumentation

- Plume measurement:
  - Field meter, faraday cage.
- Wall current:
  - Isolated pipe section, electrometer.

Faraday cage and field meter



Isolated pipework

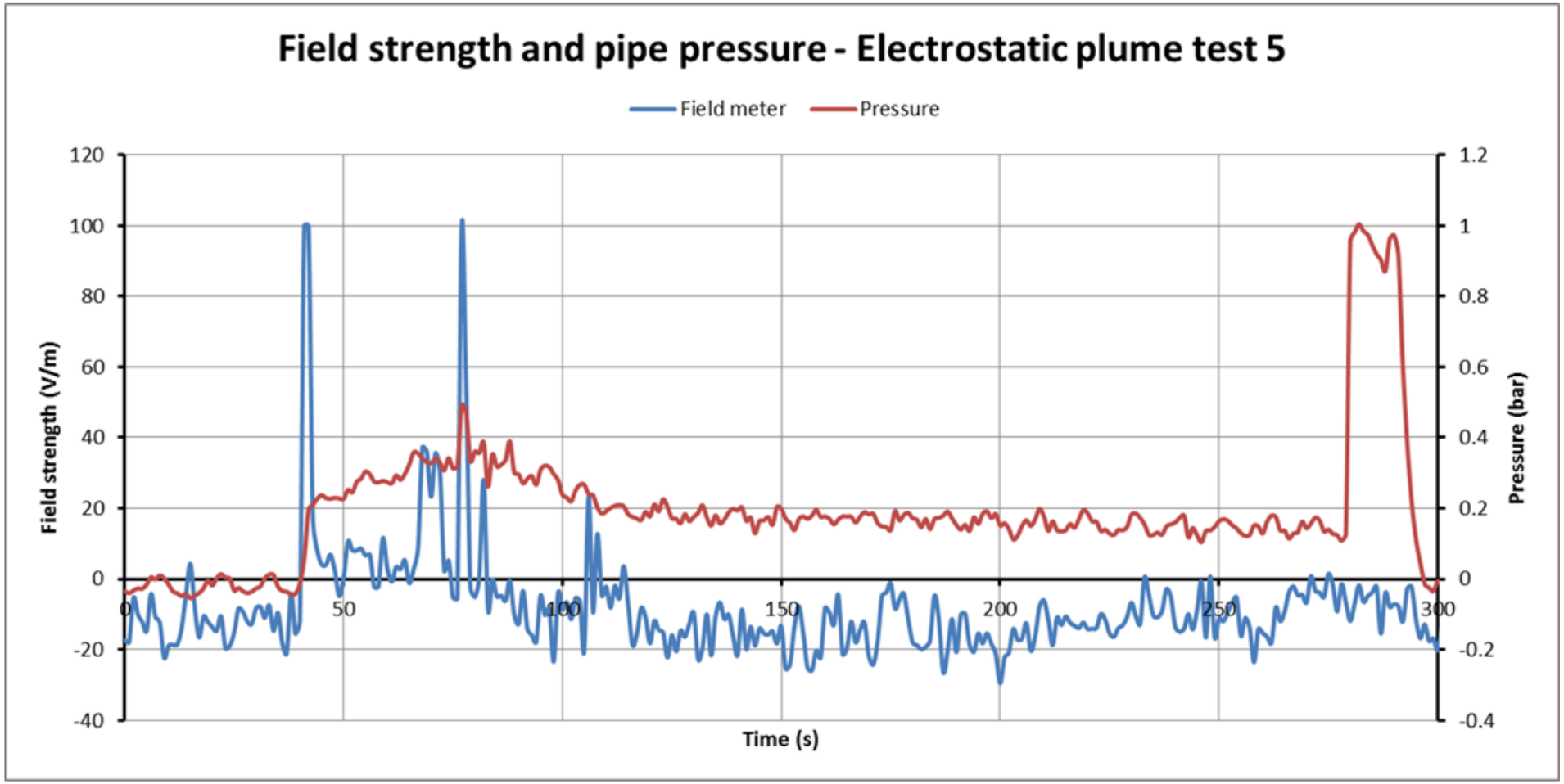
Results – Plume measurements

- 7 trials in total.
- No positive results on the majority of trials.

Trial No	Test No	Field meter configuration	Orifice Diameter	Pressure	Results
1	4.3.2	Free-field layout 1	6 mm	5 Bar	No significant plume measurements.
2	4.3.2	Free-field layout 1	6 mm	5 Bar	No significant plume measurements.
3	4.3.2	Free-field layout 2	6 mm	1 bar	No significant plume measurements.
4	4.3.4	Free-field layout 2	12 mm	1 bar	No significant plume measurements.
5	4.3.6	Free-field layout 2	25.4 mm	1 bar	Initial & mid-flow peaks.
6	4.3.3	Faraday cage	12 mm	1 bar	No significant plume measurements.
7	4.3.5	Faraday cage	6 mm	5 bar	Initial peak.

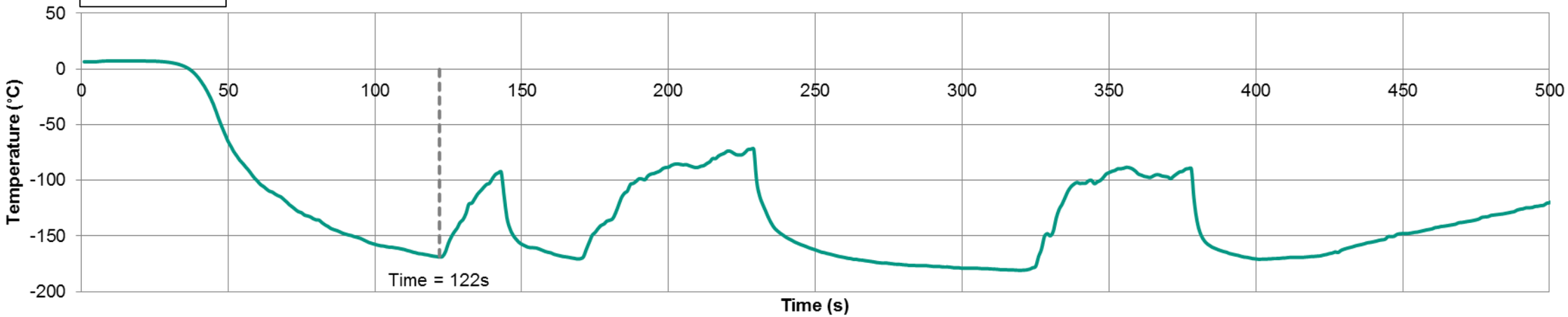
Results – Plume measurements (no cage)

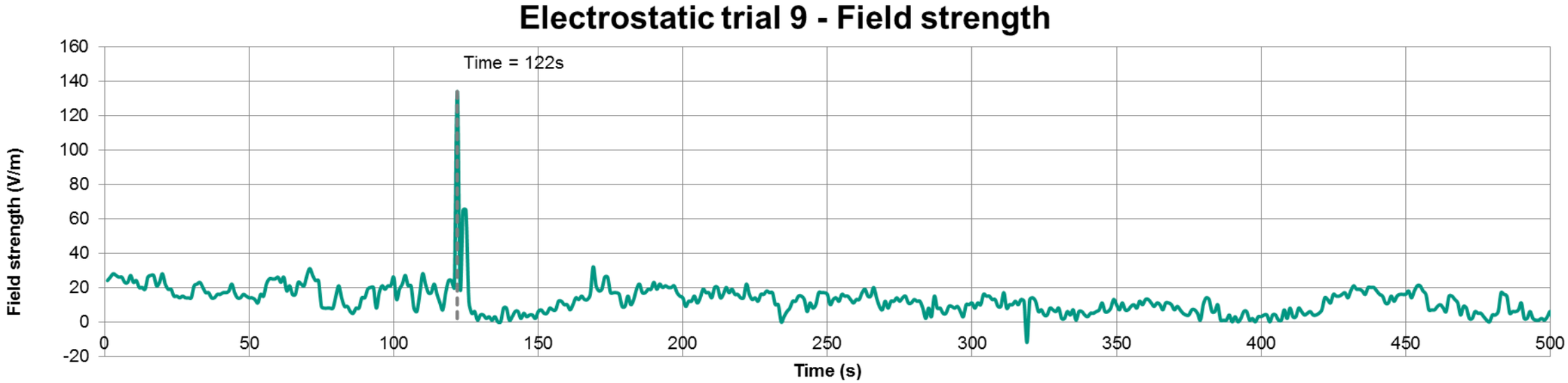
$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$



Results – Plume measurements (with cage)

$$E = \frac{\sigma R}{2\varepsilon_0}$$





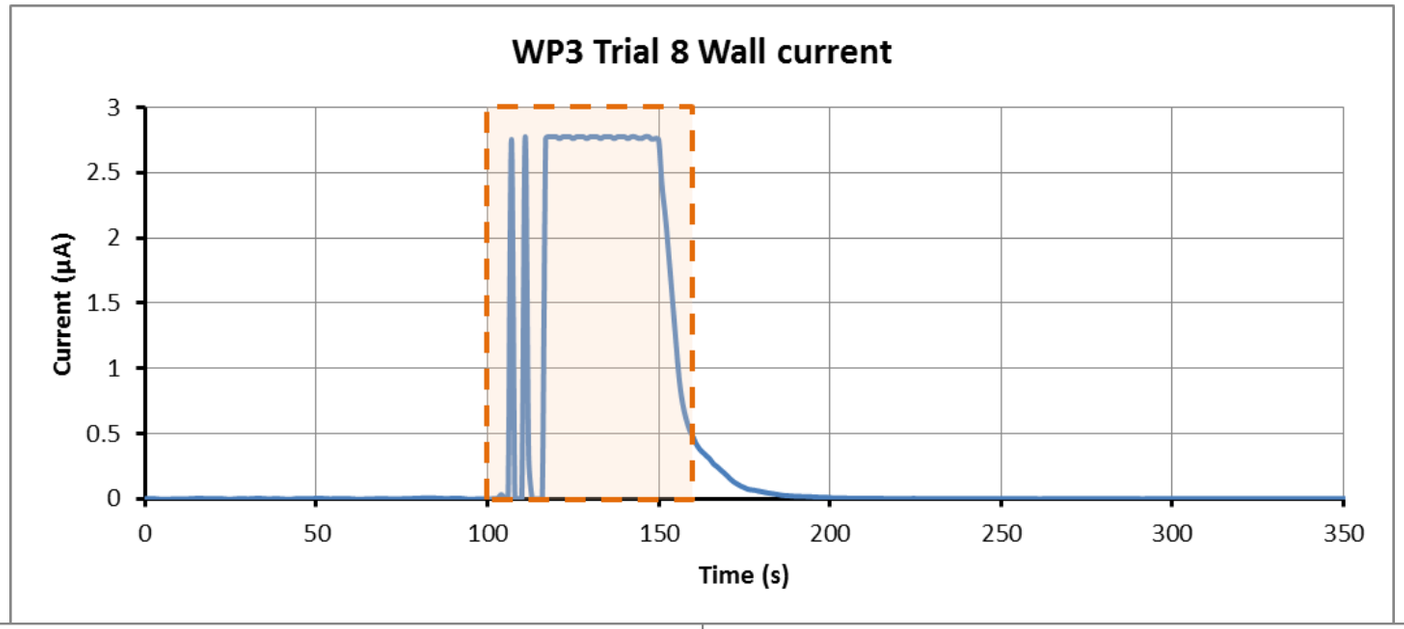
Results – Isolated pipe

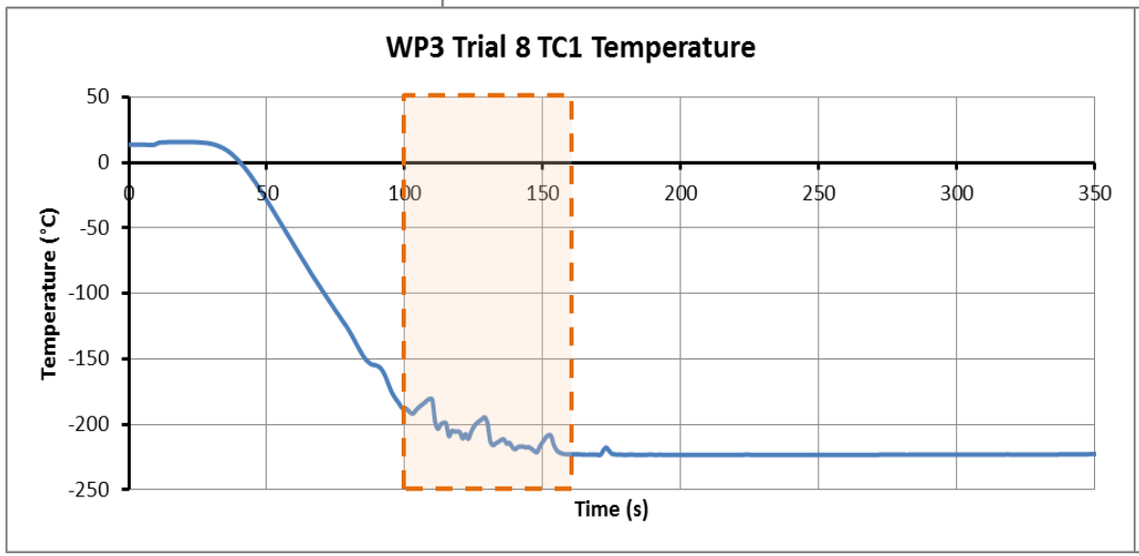
- Wall current measurements taken in a total of 30 trials.
- Positive results on 12 trials, shown below.

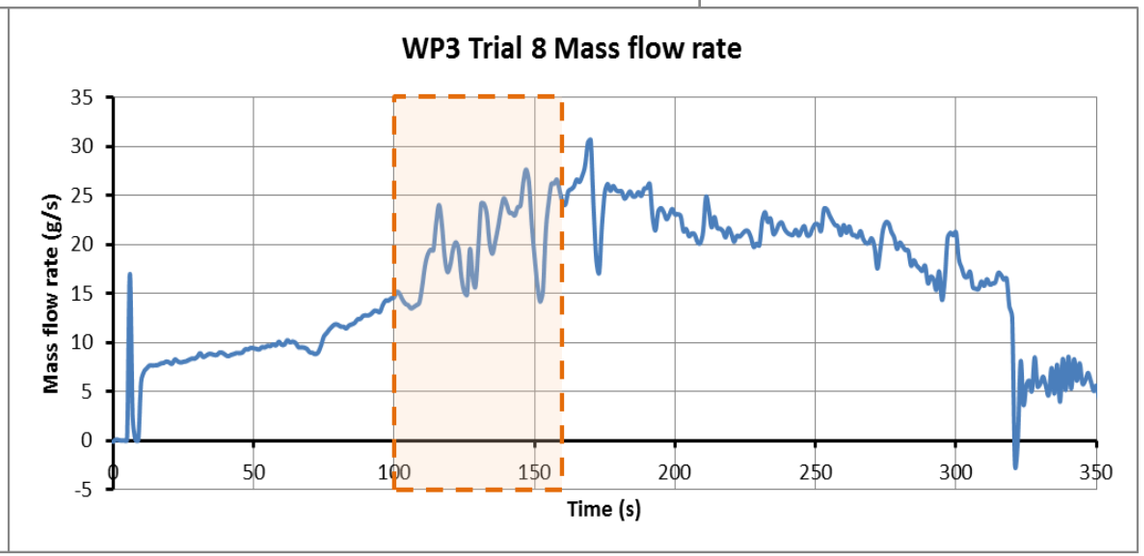
Package	No.	Size (mm)	(bar)	peak	Range	(Ω^2)
3.5	2	25.4	1	3.8 (nA)*	-2 to 2 nA	1.06×10^7
3.5	**3**	**25.4**	**1**	**230 (nA)***	**-200 to 200 nA**	**1.02×10^6**
3.5	**5**	**6**	**1**	**240 (nA)***	**-200 to 200 nA**	**2.48×10^6**
3.5	6	12	1	-9.6 (nA)	-2 to 2 µA	
3.5	7	12	1	-9.6 (nA)	-2 to 2 µA	
3.5	**8**	**12**	**1**	**2.8 (µA)***	**-2 to 2 µA**	**2.07×10^7**
3.5	**10**	**25.4**	**5**	**0.16 (µA)**	**-200 to 200 µA**	**2.67×10^4**
3.5	18	6	1	-0.27 (nA)	-200 to 200 nA	
3.5	23	12	4.5	-0.25 (nA)	-200 to 200 nA	
3.5	25	25.4	4.5	-0.99 (nA)	-200 to 200 nA	1.03×10^7
4.3	**3**	**6**	**1**	**0.20 (µA)**	**-200 to 200 µA**	**6.06×10^4**
4.3	5	25.4	1	-0.35 (nA)	-200 to 200 nA	

Note: Input impedance of electrometer << 1 Ω

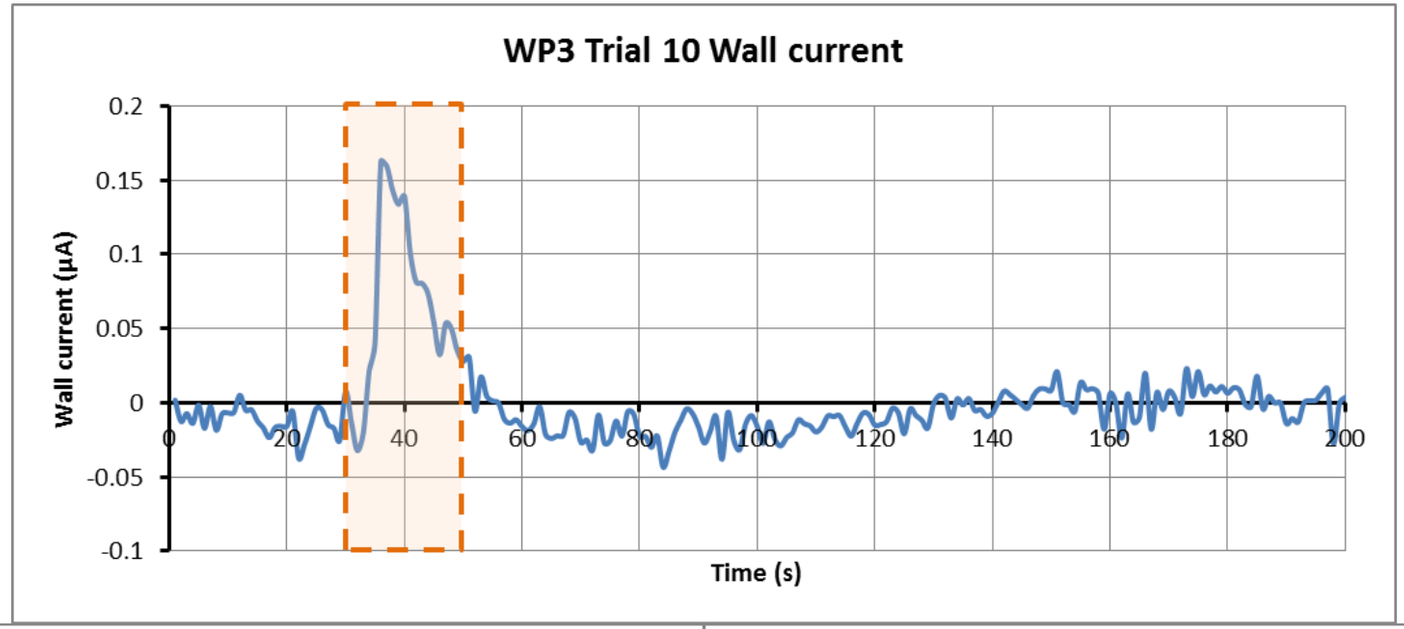
Results – Isolated pipe

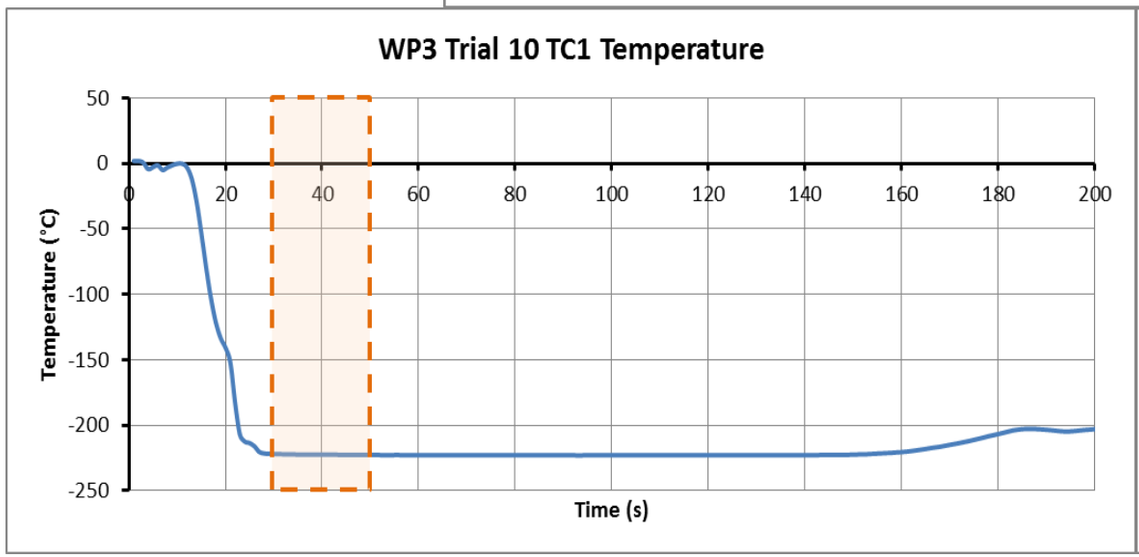


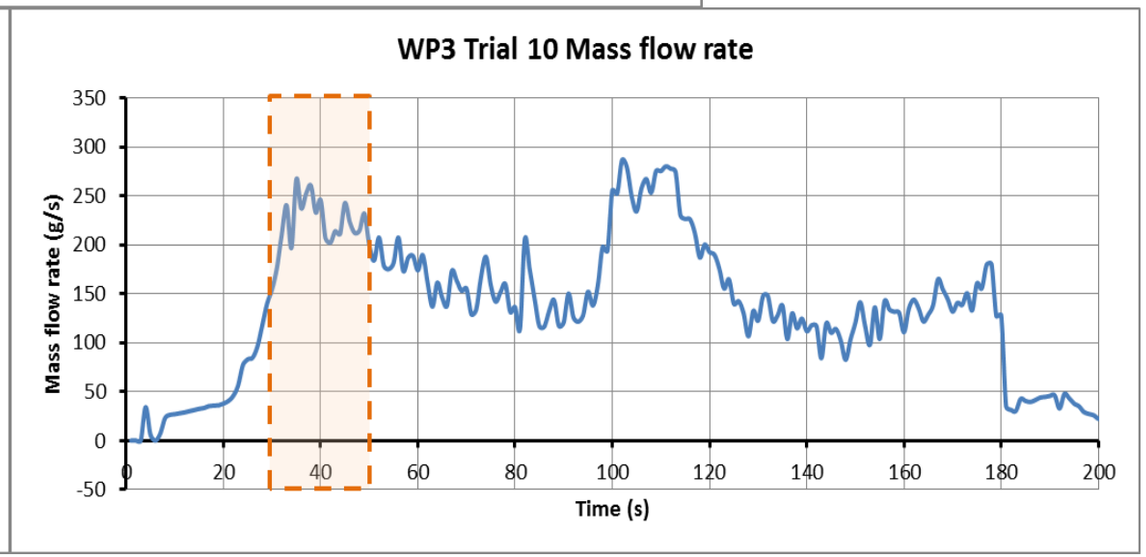




Results – Isolated pipe







Results – Isolated pipe

- Frost formation compromised the electrical isolation.

Frost on electrical isolation joint

Electrostatics initial conclusions

- Hydrogen did not hold a significant charge.
- Multiphase hydrogen flow can generate a current in isolated steel pipework.
- Occasional charge spikes have been identified, possibly caused by ice breaking off the nozzle or air being ejected from un-purged pipework.

Contents

- E4.3 Electrostatic experiments summary
  - Setup
  - Plume measurements
  - Wall current measurements
  - Initial conclusions
- E4.5 Condensed phase summary
  - Setup
  - Rapid phase transition experiments
  - Initial conclusions
- Deliverables and other activities

RPT setup

- Simplified release station.
- Tanker pressure below 300 mbar.
- 800 x 800 x 100 mm trough.

Setup of RTP experiments

RPT setup

- Water delivery system with sprinkler and hose attachments.
- Thermocouple rake to measure pool depth.
- Pressure transducers to capture any overpressures.

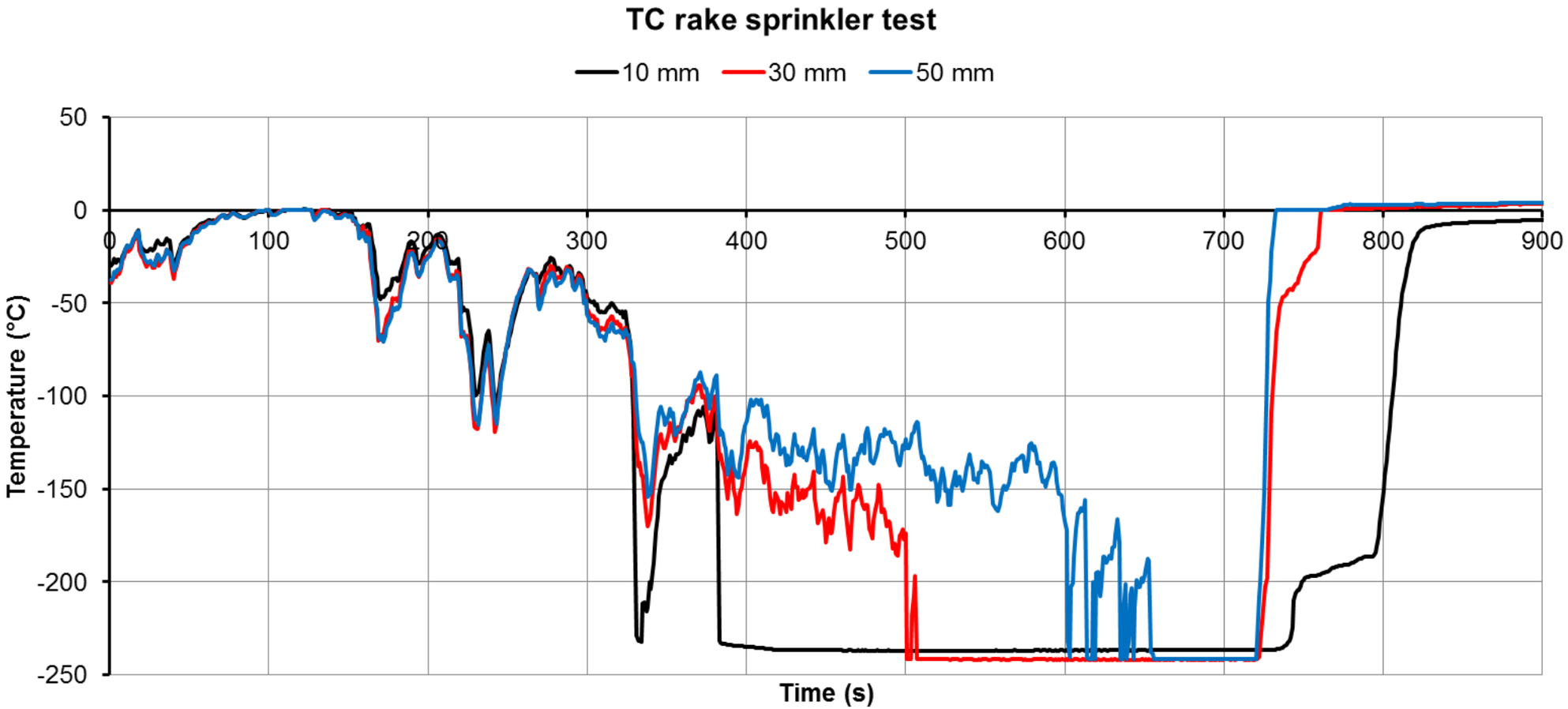
Sprinkler system

Hose system

Results – RPT sprinkler

Results – RPT sprinkler

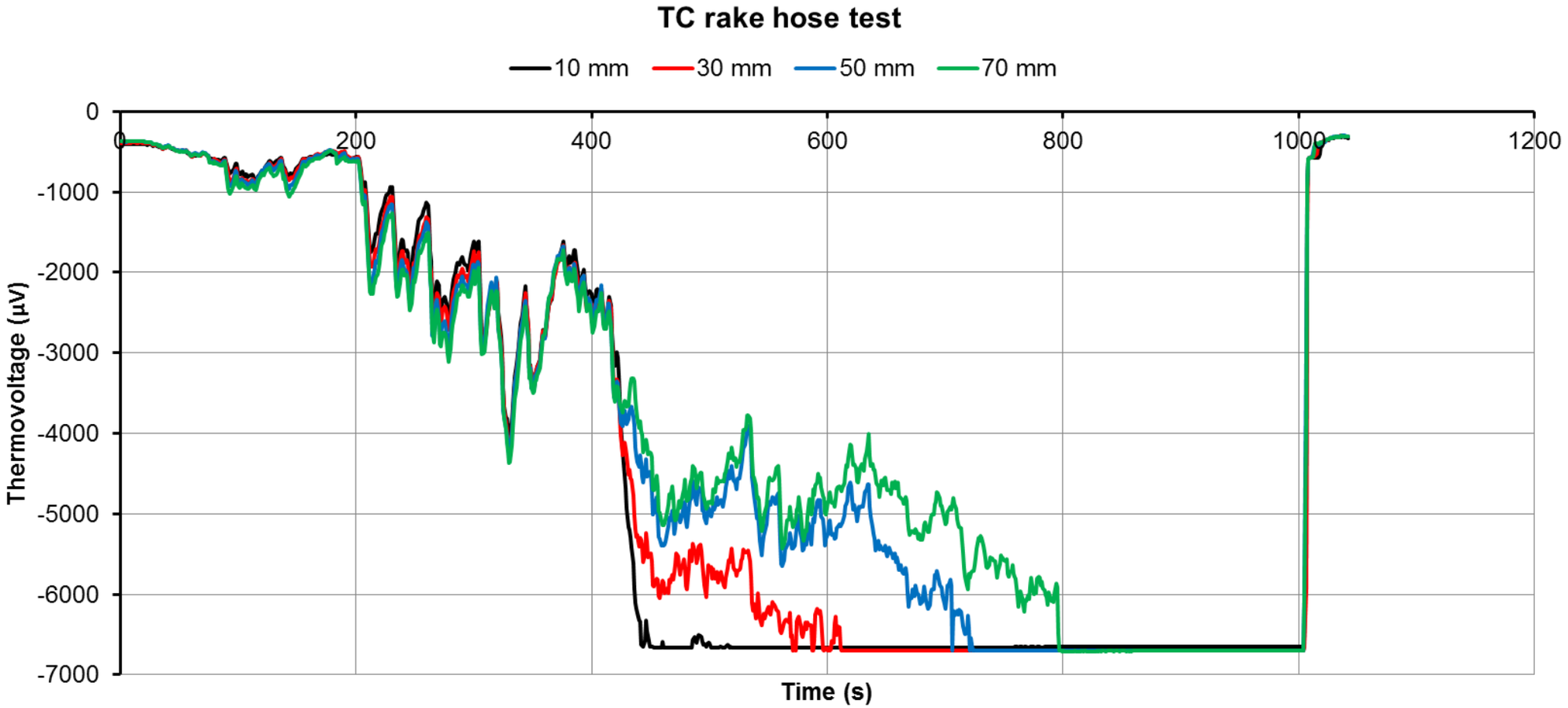
- No overpressures recorded.
- Vapour production complete in approximately 30 s.
- Ice formation in trough.



Results – RPT hose

Results – RPT hose

- No overpressures recorded.
- Vapour production complete in approximately 10 s.
- No ice formation in trough.



RPT initial conclusions

- During these tests, contact between water and liquid hydrogen did not cause an RPT.
- These tests suggested that sprinklers and monitors can be used to control the flow or accumulation of liquid hydrogen without risking the occurrence of RPT.
- The rate of vaporisation of LH_2 is enhanced and if ignited could result in more severe consequences.

Contents

- E4.3 Electrostatic experiments summary
  - Setup
  - Plume measurements
  - Wall current measurements
  - Initial conclusions
- E4.5 Condensed phase summary
  - Setup
  - Rapid phase transition experiments
  - Conclusions
- Deliverables and other activities

Deliverables

- Deliverable D4.1 “Theory and analysis of ignition with specific conditions related to cryogenic hydrogen” issued.
- D4.6 and D4.8, experimental summaries, are in draft with HSE.
- D4.2 and D4.3 due later in 2020.

Other WP4 activities

- INERIS –
  - Hot surface ignition tests complete
  - MIE tests done at ambient temperature, cryogenic temperatures in progress due to experimental challenges
- KIT –
  - Electrostatic measurements in a cold jet complete
  - Pool experiments in preparation (LH_2) supply

Acknowledgements

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 779613. The HSE work programme acknowledges funding from its sponsors Shell, Lloyd's and Equinor.