Explosion Research for Emerging Fuels

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UKELG
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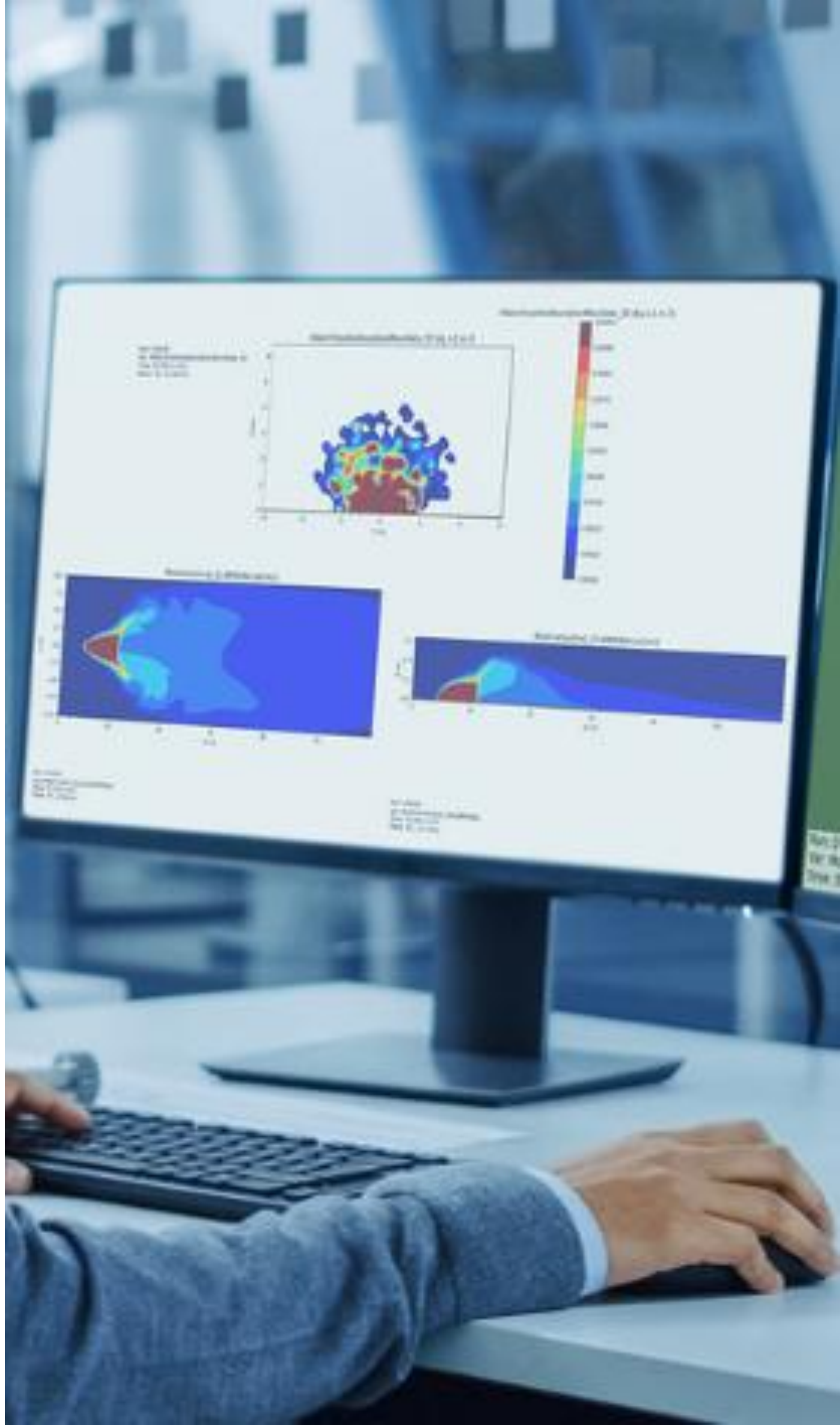
Outline

- Overview of Facilities
- Some Recent Projects
- Future Ideas



Test Facilities

GEXCON

Gexcon Fire & Explosion Testing Capabilities

Børnesskogen

- Located on the island of Sotra, just outside of Bergen, Norway
- Upper and lower bunkers, plus mobile bunker
- Fully stocked workshop, forklifts, storage containers, etc.
- Large open explosion test pad

Steinsland

- ~15 minutes away from explosion site.
- Upper and lower control rooms
- Fully stocked workshop, forklift, storage containers, etc.
- Open fire testing area as well as confined fire testing area
- Capable of testing a wide array of products, including lithium-ion batteries from the cell level all the way to the full installation level for industrial sized BESS units

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Gexcon Fire & Explosion Testing Capabilities

Using test results to enhance safety

Tests done in specialist facilities in Norway, from small to large scale under controlled, realistic conditions

- **Flammability testing of gases, vapours, and liquids** + **Combustible dust testing** to understand ignition behaviour and explosion risks
- **ATEX product testing and compliance services for mechanical equipment and protective systems** to help manufacturers meet EU regulations
- **Tests of passive fire protection equipment** to see how well they resist heat or pressure from jet fires or blasts
- **Custom experiments** on materials, equipment, components or systems to verify design performance, explosion properties, or modelling results.

Benefits of using test data

- Generates data to guide safety strategies or equipment design
- Reduces uncertainties with real-world test results
- Strengthens research outcomes with data from real tests
- Supports compliance & certification with verified data
- Enables the validation of software results

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Purpose-built facilities

Small-scale testing (Steinsland, Sotra, Norway)

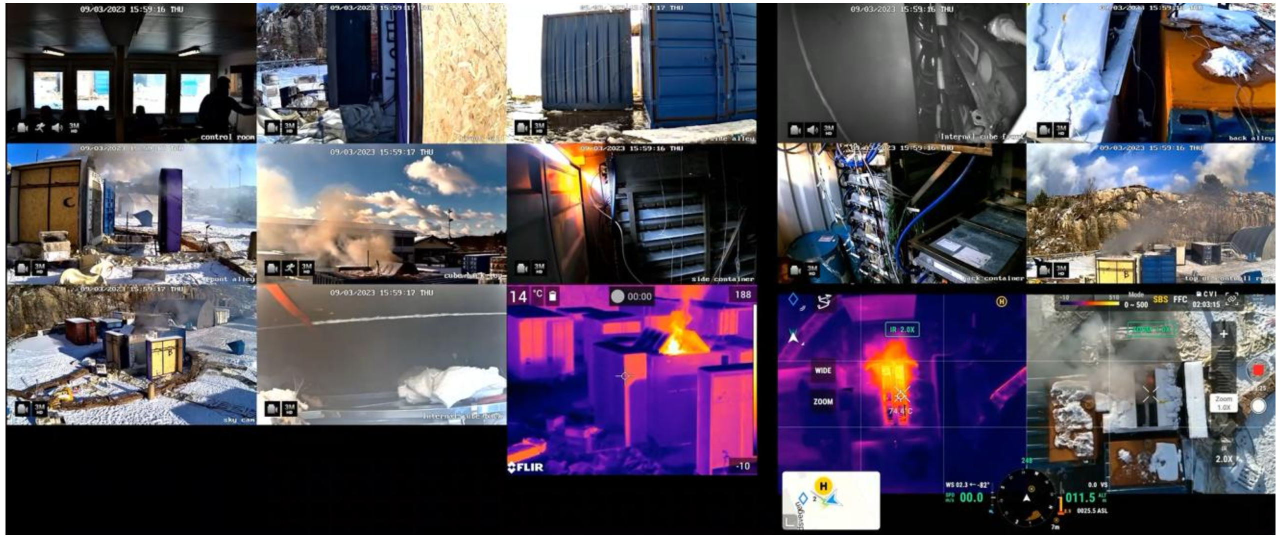
- Laboratory-scale testing for gas and dust explosions.
- Vessel sizes: <1 litre to ~2 m³.
- Closed, open, and vented vessels available for varied test scenarios.
- Supports equipment testing, research projects, and custom testing needs.

Mid- and large-scale testing (Børnesskogen & Steinsland, Sotra, Norway)

- Explosion testing using vessels from 0.5 m³ to 55 m³.
- Wide range of venting configurations and test scenarios.
- Includes equipment testing, gas and dust explosion research, and **customised testing projects, such as for BESS thermal runaway**

Gexcon BESS testing capabilities

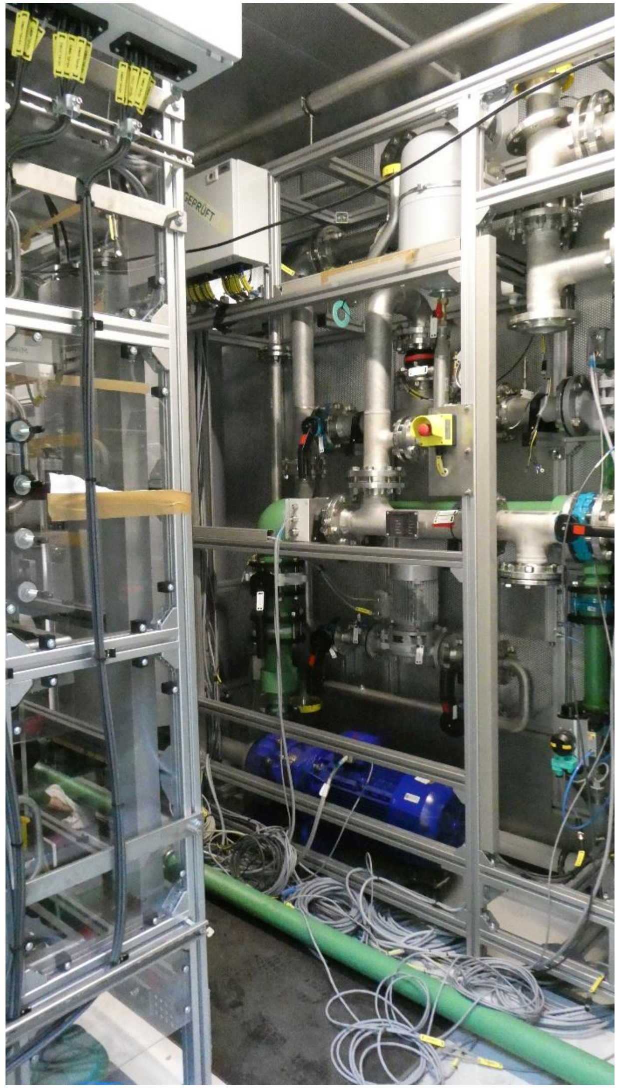
Critical for validating battery thermal runaway hazard models and for gaining a deeper understanding of the mechanisms driving battery thermal runaway through practical experimentation.



Recent / Ongoing Projects

Hydrogen and Oxygen Separator Explosion Tests

- **Aim:** Assess structural response and injury risk in an oxygen separator during hydrogen and oxygen explosions
- **Setup:** Full-scale mock separator with mixtures ignited under different water fill conditions
- **Process:** Ignition at flue exhaust with flame propagation into the separator
- **Findings:** Repeated detonations and pressure piling, pressure spikes above 100 barg



Hydrogen Jet Release and Static Ignition Tests

- **Aim:** Study whether hydrogen jets near sand or gravel can generate static and trigger ignition

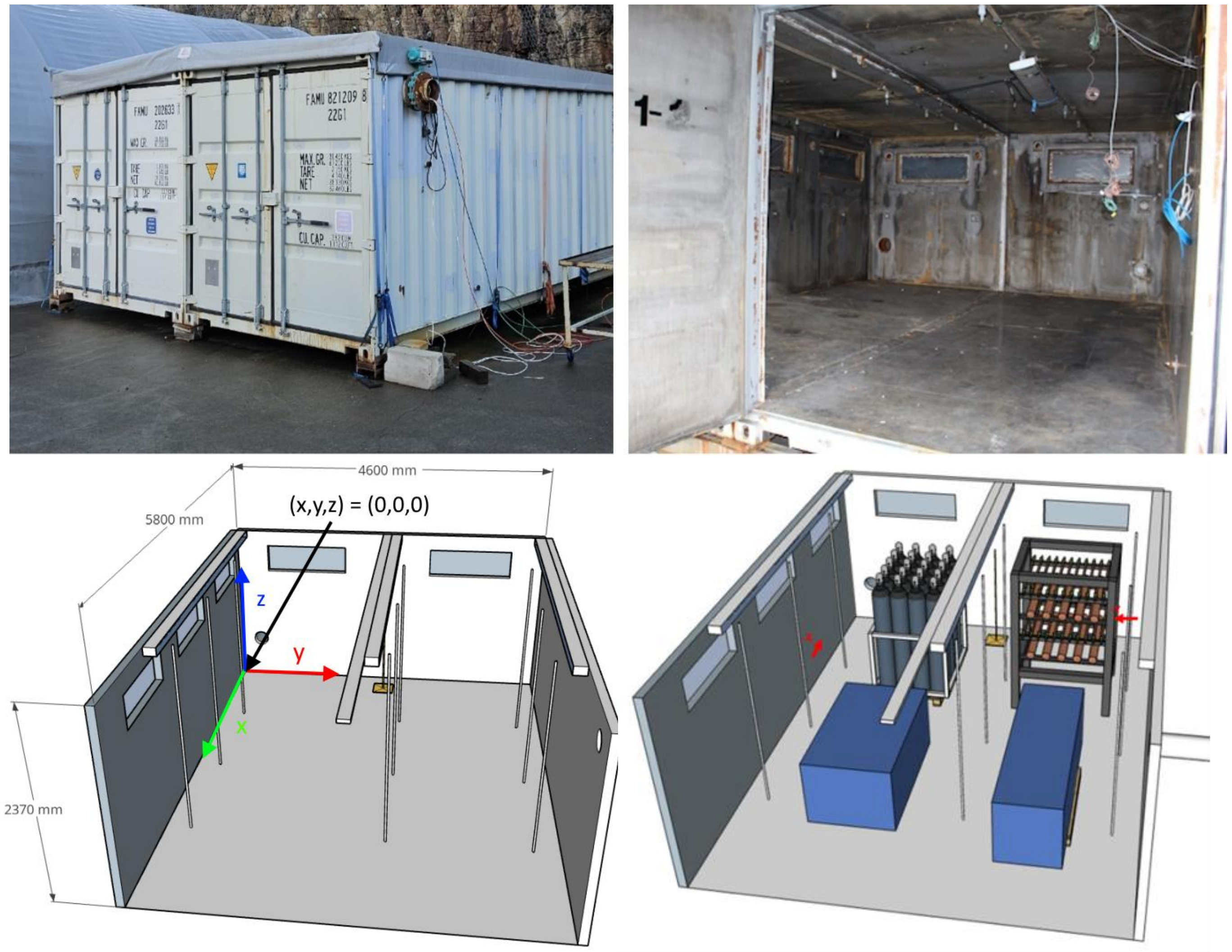
- **Setup:** Pressurised hydrogen jets aimed at an electrically isolated steel plate above sand or gravel

- **Parameters:** 1 to 3 mm nozzles, 1 to 5 m stand-off, 5 to 80 barg

- **Findings:** Static charge built up but voltage never reached the 1700 V needed for spark formation. No ignitions observed

Hydrogen and ammonia release in vented closed vessel

- **Aim:** Measure hydrogen and ammonia dispersion in a vented, congested 63 m³ container
- **Setup:** Twelve releases of each gas with active and passive ventilation
- **Instrumentation:** Forty-five sensors giving a detailed concentration map
- **Findings:** Ventilation keeps both gases below LEL, but ammonia remains above toxic limits without extreme airflow



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Explosion limits for hydrogen-oxygen mixtures at ambient and elevated temperatures and pressures

- **Aim:** Determine LEL and UEL of hydrogen and oxygen mixtures at 450–650 °C and up to 10 barg
- **Setup:** Lab-scale heated and pressurised vessel with controlled mixture preparation and ignition
- **Challenge:** Hydrogen reacted slowly without ignition, even below 1 percent at 550 °C. This hydrogen consumption limited the ability to define clear values at high temperature

Test Vessel (before and after insulation)

Ammonia - Water Spray Model Development

Large scale validation: NH3 release

Experiment: Dandrieux et al. J. Loss Prev. Process Ind. 14 (2001) 349–355

Table 1
Experimental conditions

Trial	1	2	3	4	5	6	7	A	B
Release rate (kg/min)	14.1	14.6	13.2	15.4	13.5	13.5	13.5	8.6	6.5
V (m/s)	0.8	3	1.9	0.3	2.8	2.8	4.4	2.0	6.0
Relative humidity (%)	65	50	60	65	50	50	60	30	60
Temperature (°C)	5	16	21	5	17	17	20	22	16
Source–curtain distance	no	no	no	6 m	6 m	6m	5 m	8 m	6 m

Key data

Ammonia Leak:

M = 0.25 kg/s = 15 kg/min

Water Curtain: peacock tail spray (Pons DSP65)

V = 730 l/min

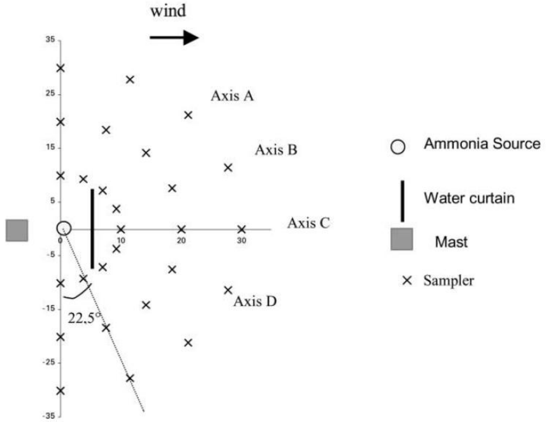
p = 8 bar

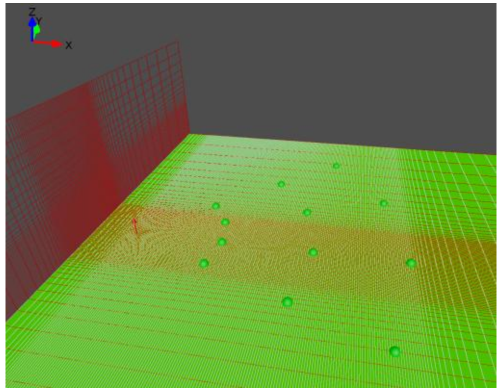
H=8 m, L=20 m

Domain size, X=30 m, Y=60 m, Z=15 m

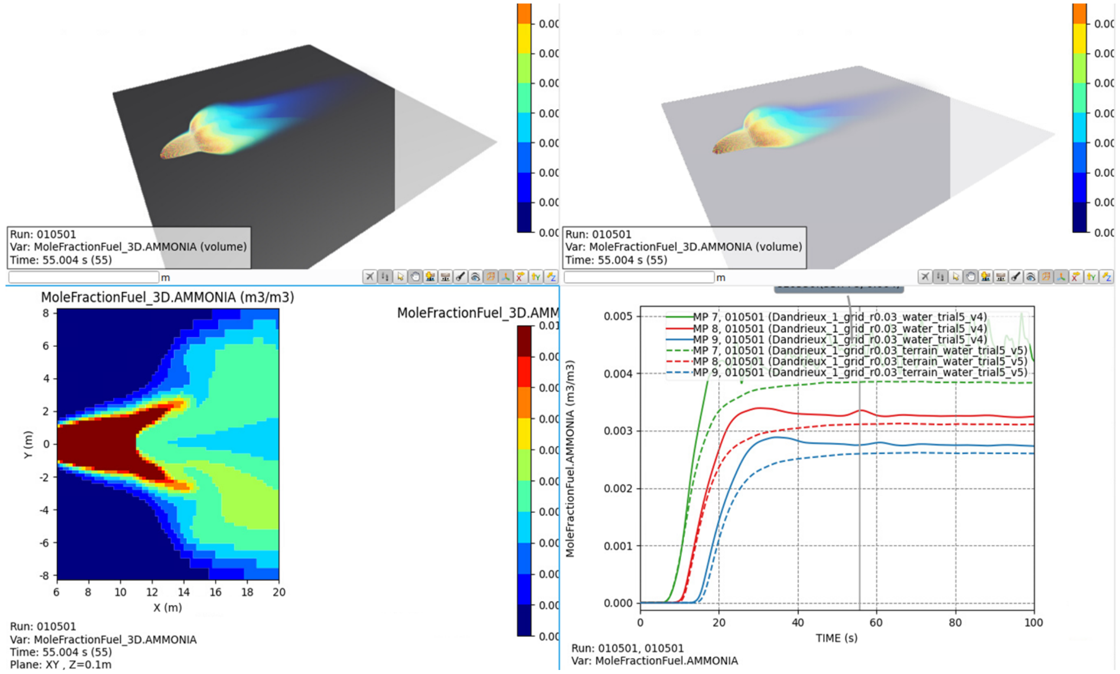
Sensors position: 10 m, 20 m, 30 m radially from the leak

Experimental configuration





FLACS simulations



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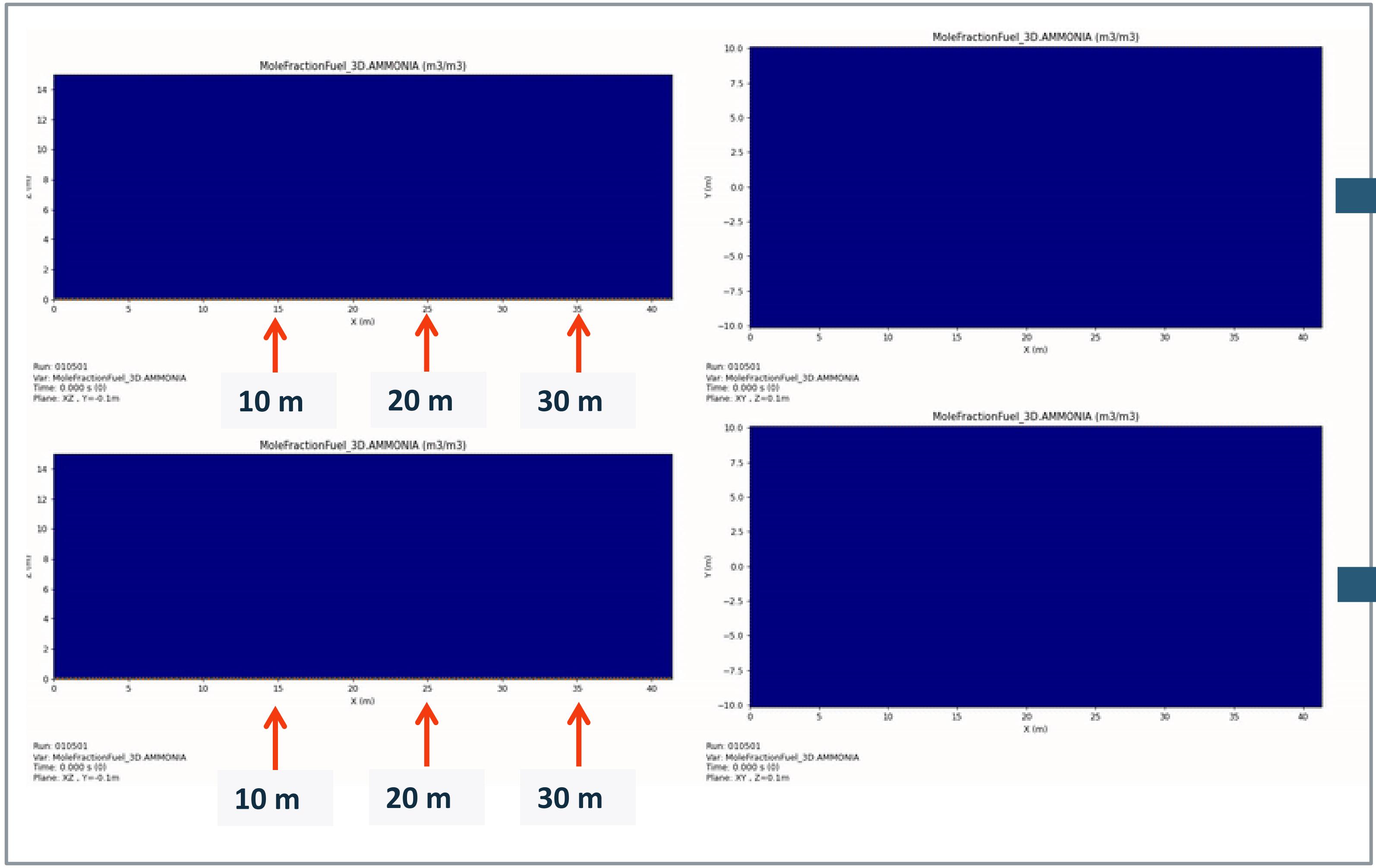
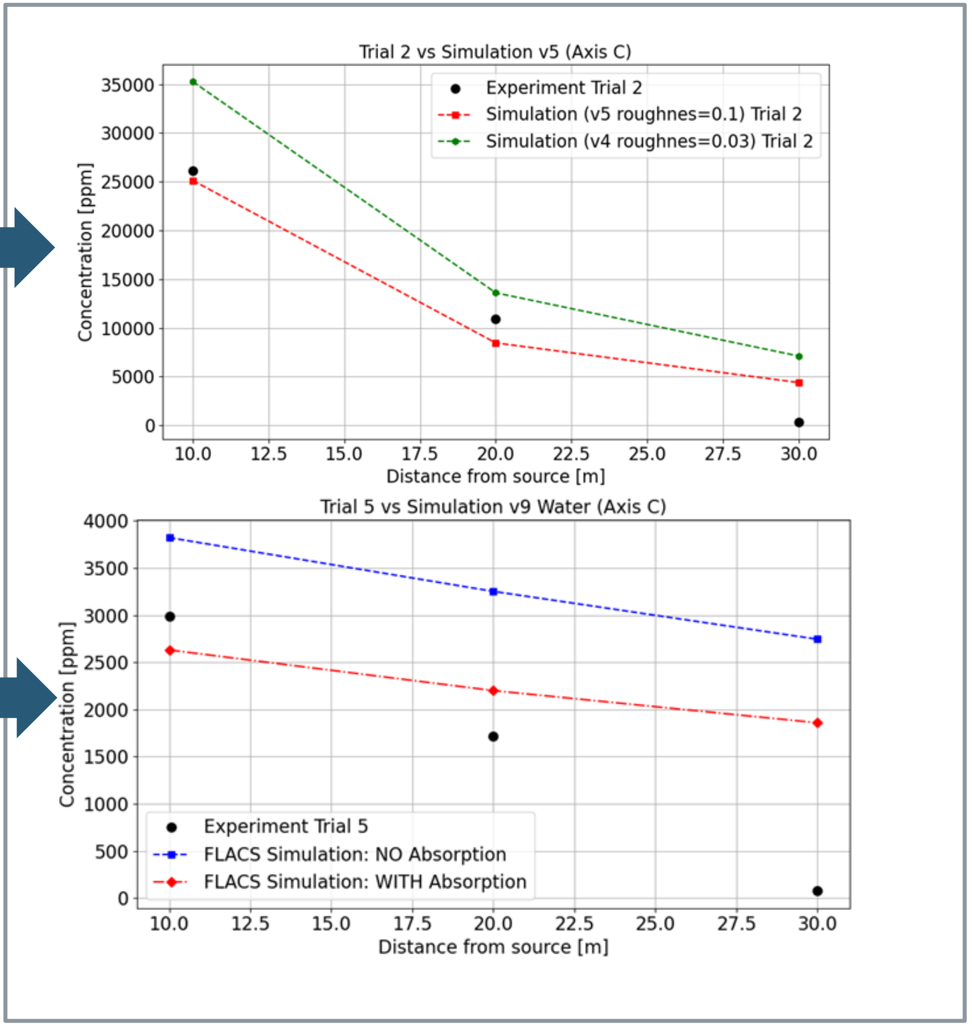
Ammonia - Water Spray Model Development





CFD Modelling

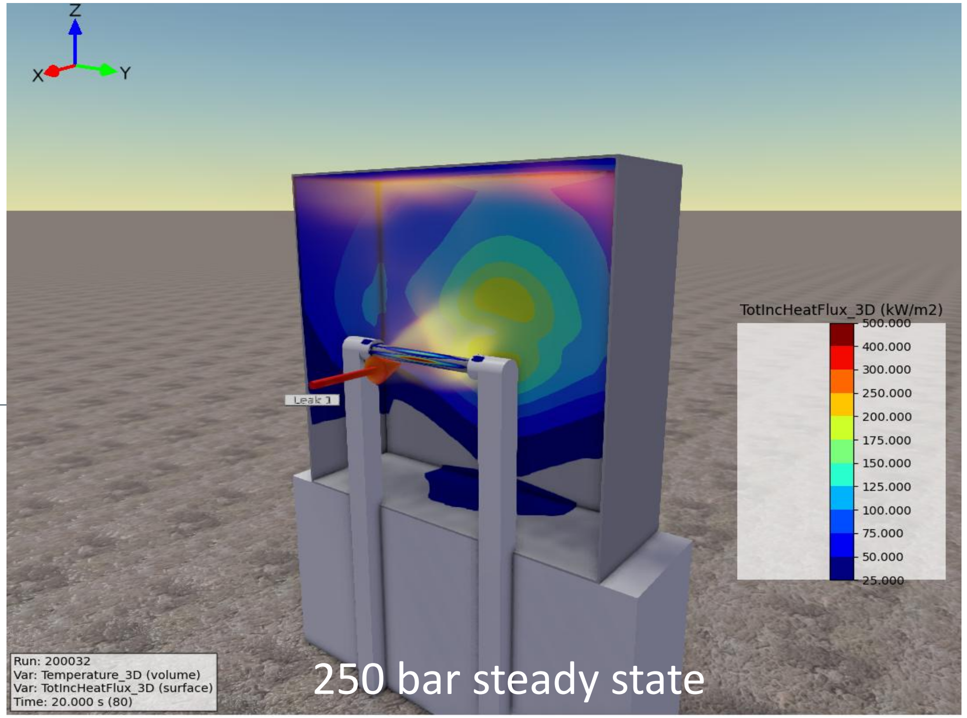
SH2IFT-2 Jet Fire modelling

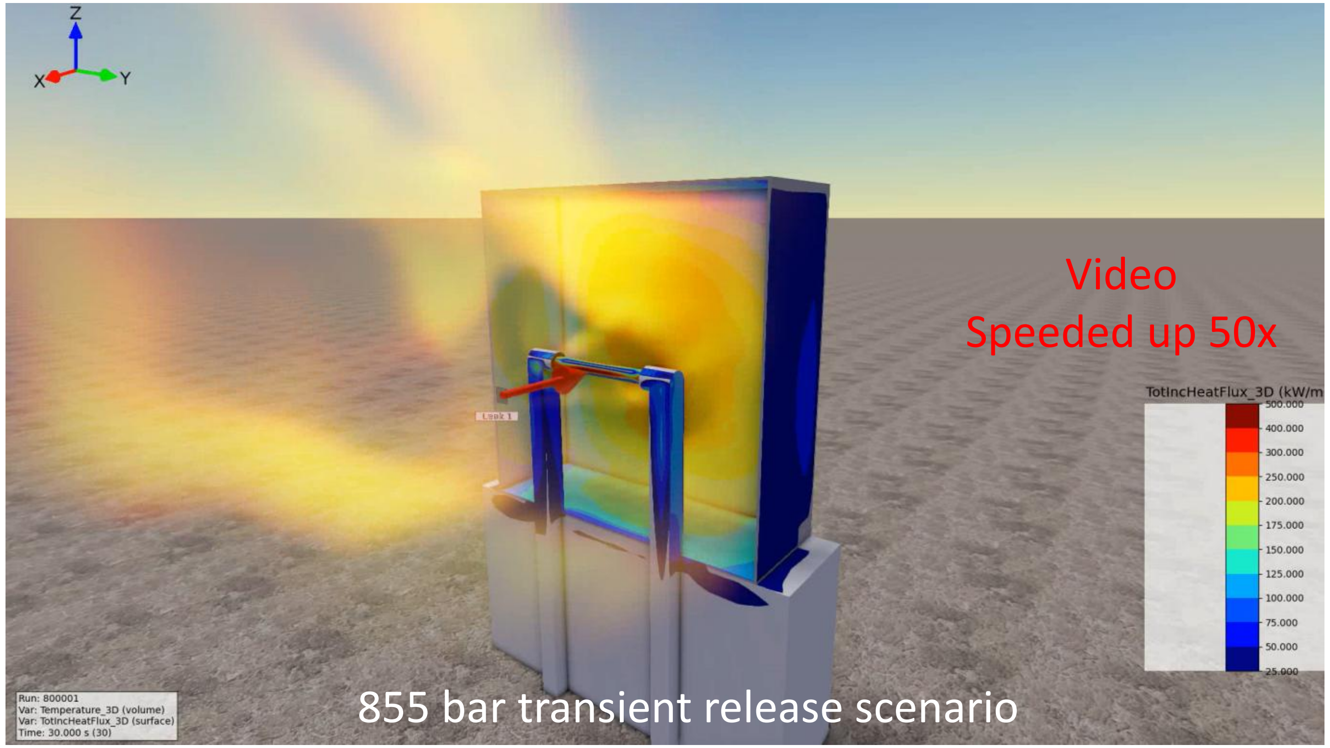
- **Aim**: Validate FLACS for HF (Total, Rad and Conv.) and use for estimating wall temperatures.

- **Setup and parameters:**

  250 bar steady state case
  - Reservoir pressure: 250 bar
  - Orifice size: 1 mm
  - Duration 55 minutes
  - 1x repeat (3min duration)
  - Naked steel pipe (6 cm diameter)

  855 bar transient case
  - (Initial) reservoir pressure 855 bar
  - Orifice size: 2 mm
  - Release duration: 8 minutes (480 s)
  - Naked steel pipe (6 cm diameter)



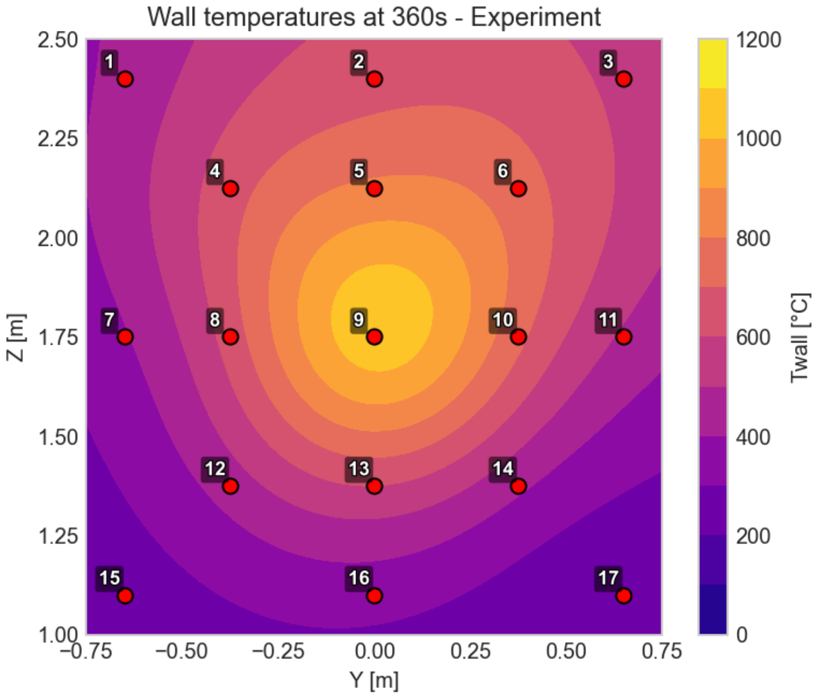


CFD Modelling - 250 bar scenario

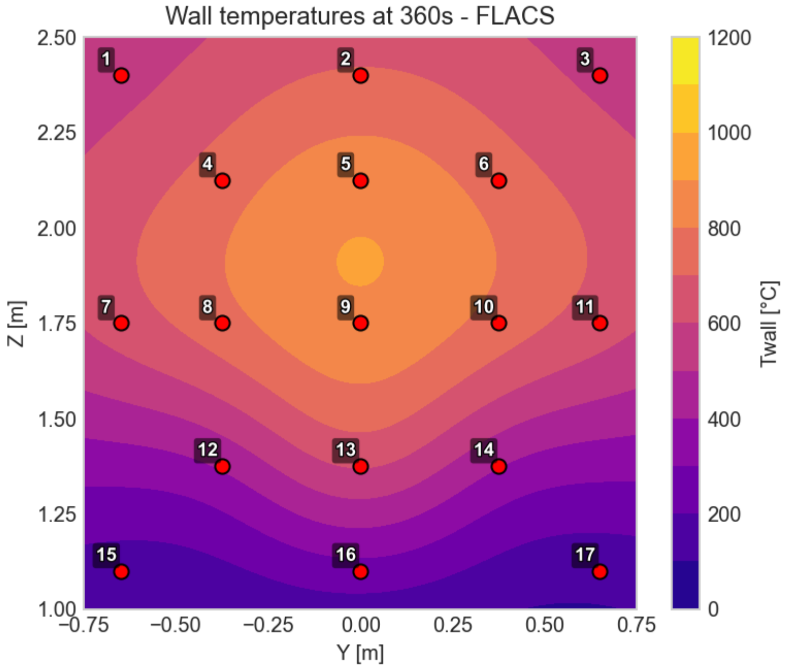
Validation against Wall temperature after 6min

- **Setup and parameters cont’d:**
  - Evaluation of wall temperatures (as surrogate for Total HF)
  - Uniform layer model used to calculate wall temperatures from FLACS results

- **Findings:**
  - Good agreement between experimental and wall temperatures calculated with FLACS
  - Good agreement for experimental and FLACS Incident RAD Heat Flux



Experiment



Calculated from FLACS results

Future Plans

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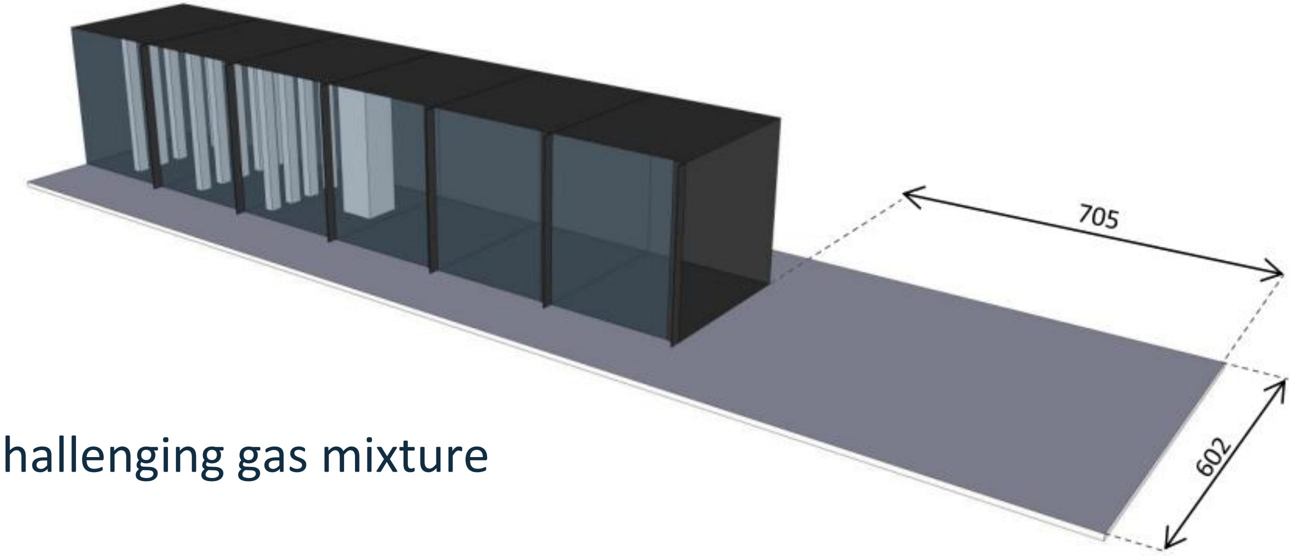
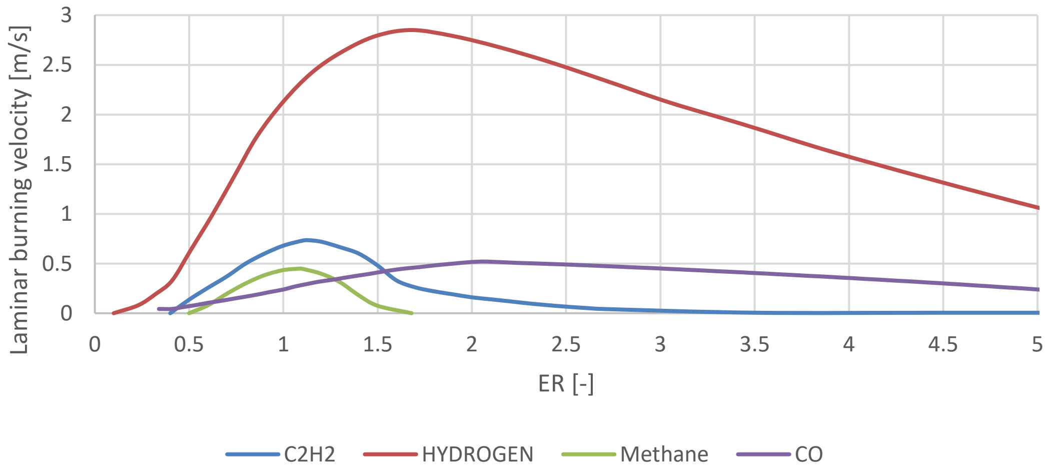
Planned experimental work

Hydrogen mixtures and BESS Off-gas experiments

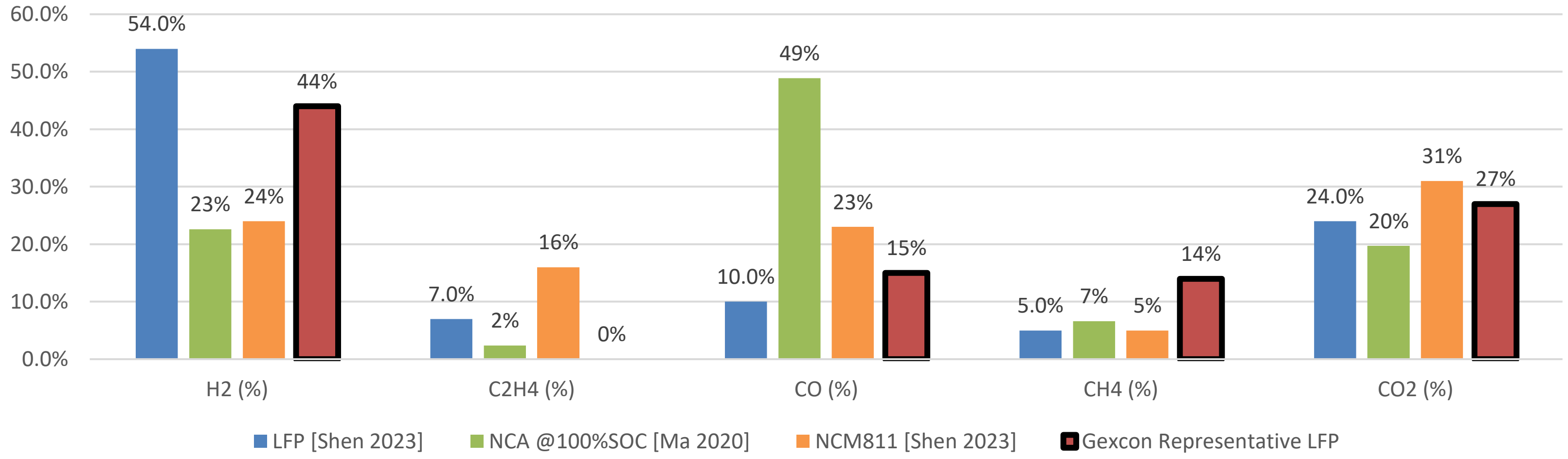


- **Aim**: Verify/validate FLACS for explosions of complex/challenging gas mixture relevant for Hydrogen/BESS industry
- **Setup**:
  - Small/medium scale vented explosion experiments in "Mogeleg" style channel
  - Two mixture types
    - Various Hydrogen-Propane mixes (representative for H_2 + Hydrocarbon mix)
    - Representative BESS Offgas (LFP@100% SOC)

Laminar burning velocities BESS offgas components



Offgas compositions different battery chemistries

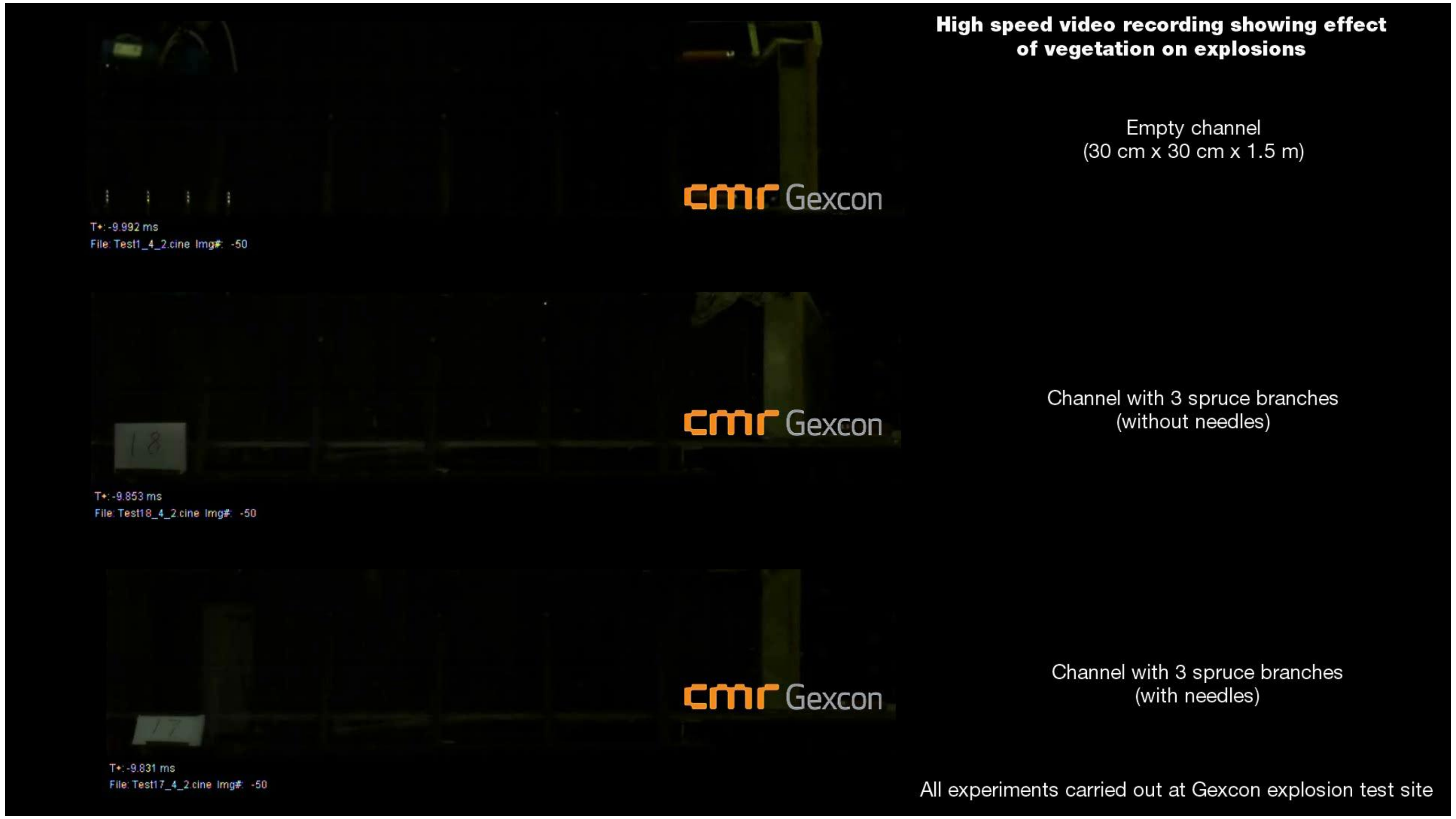


Planned experimental work

Hydrogen mixtures and BESS Off-gas experiments

- **Setup cont'd:**
- Benefits of using a small/medium sized channel:
  - Possible to do large experimental matrix including repeated in limited time
  - Possible to record flame progression in detail
- Can be followed up with larger scale experiments in future

- Video recording of previous explosion tests in the channel (Propane)



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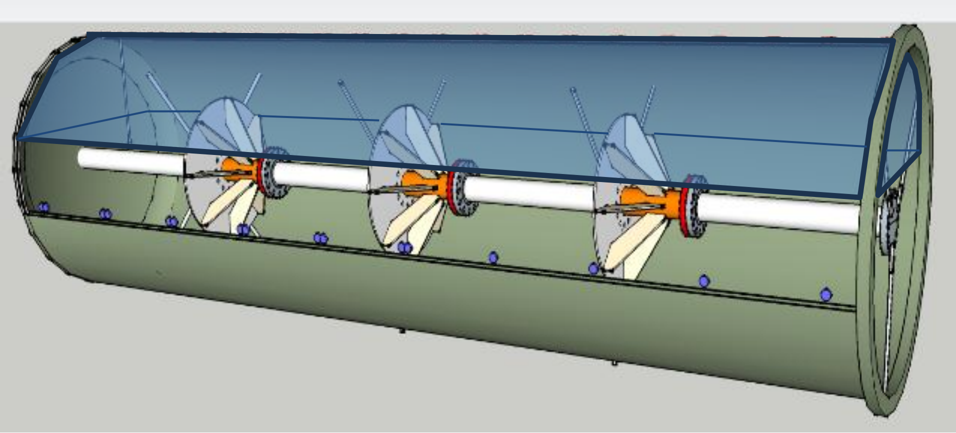


JIP-StratEx

Proposal

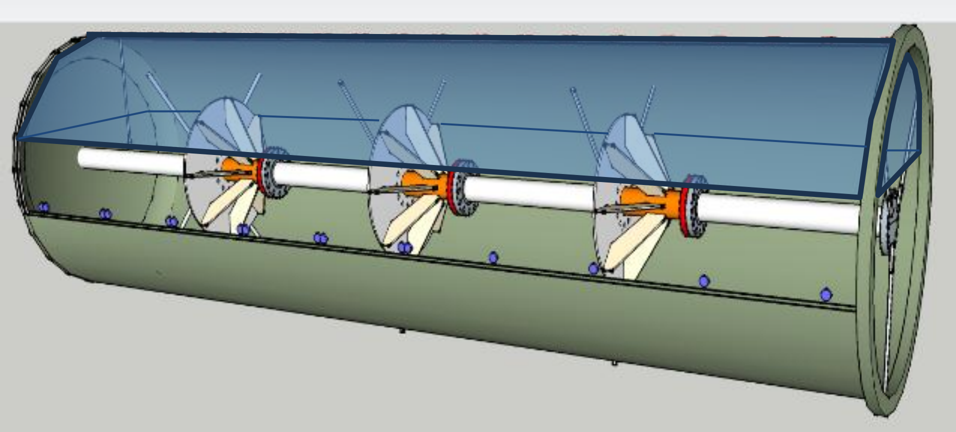
- **Aim**: Close knowledge gaps on stratified gas cloud explosions in confined/congested geometries
- **Phase**: Identifying potential sponsors and refining scope
- **Expected JIP timeline**: 2027-2029

- **Preliminary scope**:
  - 50 – 150 Medium/Large scale explosion tests
  - Light gasses such as: Hydrogen and/or (warm) BESS off-gas
  - Heavy gasses such as: Cryogenic Methane(LNG) gas
  - In a range of geometries such as:
    - 50 m³ cylindrical vessel
      (only vessel with sufficient pressure capacity for DDT scenarios)
    - 31 m³ 20ft ISO container
    - Gexcon module and/or
    - Representative BESS module geometry

Additional congestion will be included in tests (not shown)

JIP-StratEx

Proposal



- **Preliminary scope cont'd:**
  - Different congestion levels (incl. Medium/High)
  - Homogenous and/or non-homogenous (e.g. "real") stratified clouds
  - Potentially different explosion venting options and/or other mitigating measures
  - Potentially some scope for FLACS validation

- For more information, feedback and/or potential interest in participating in the JIP please contact:

  Djurre Siccama (Djurre.Siccama@gexcon.com)
  R&D Department manager

Additional congestion will be included in tests (not shown)

Thank you for your attention

For enquiries:
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