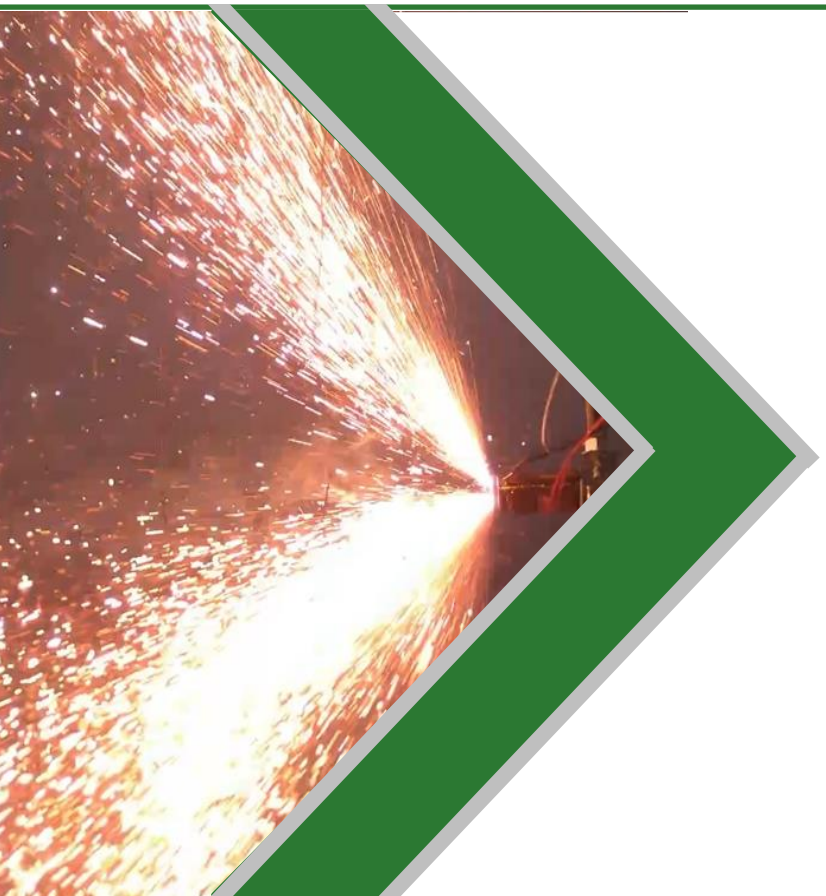


Experimental understanding of gas volumes and forces generated due to swelling during lithium-ion pouch cell failure

Gemma Howard

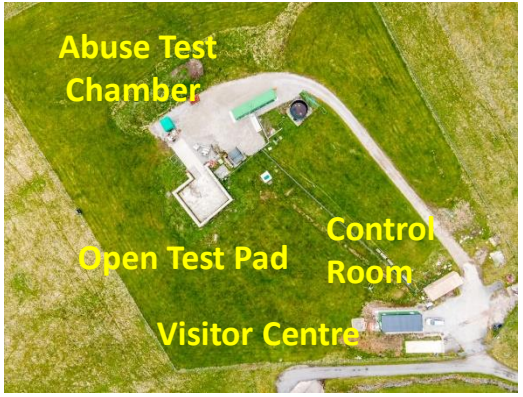
HSE Science and Research Centre, Buxton

About me

Test Facilities

BESPOKE RESEARCH AND CONSULTANCY FROM HSE

- Open Field Abuse Chambers
- Pressure Vessel
- Accelerated rate calorimetry (ARC)



Battery Testing Capability

BESPOKE RESEARCH AND CONSULTANCY FROM HSE

Over temperature

- External heat
- Flame impingement
- Accelerated rate calorimetry (ARC)

Electrical

- Overcharge
- Short circuit
- Cell cycling

Mechanical

- Nail penetration (open field or in a vessel)
- Water emersion
- Impact

Mitigation

- Passive and active fire protection testing
- Containment assessment

Gas and remnants analysis

- Real time gas analysis
- Gas quantity measurements
- Chemical and particle analysis

Pouch Cell Design, Advantages and Disadvantages

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Cylindrical Cell

Pouch Cell

+ Any size or shape
+ High capacity cells available
+ Lightweight
+ Compact
− Less protected than hard cased cell

Pouch Cell Failure Mechanism

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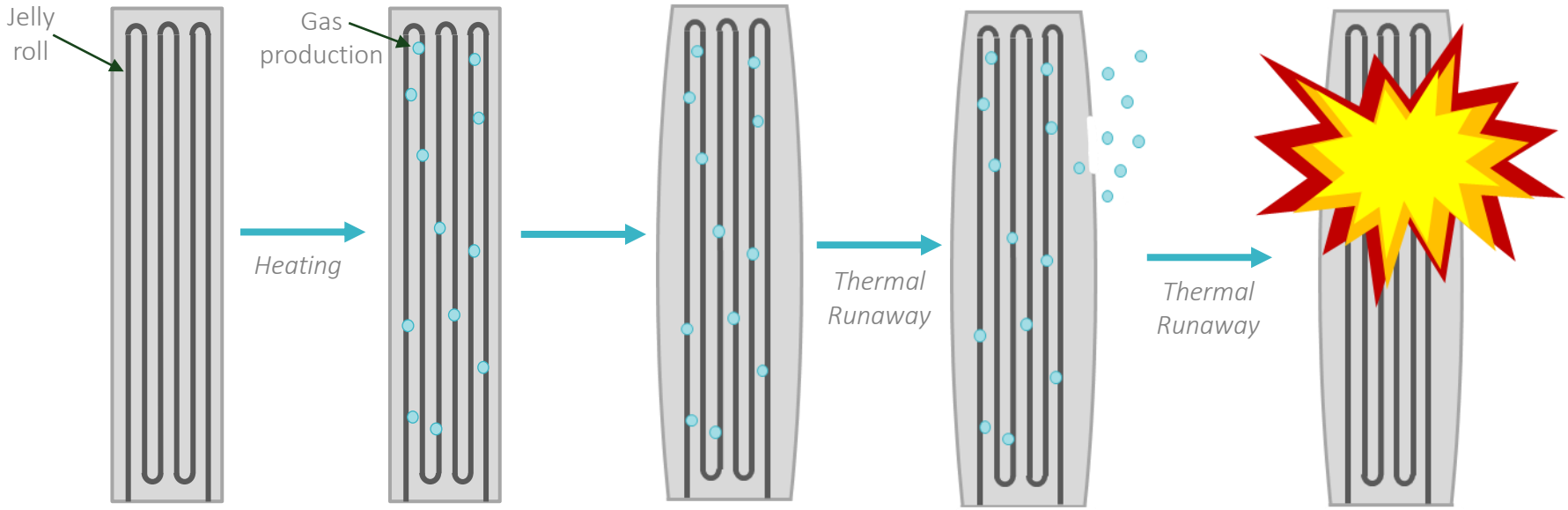

Pouch Cell Failure

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Pouch Cell Failure

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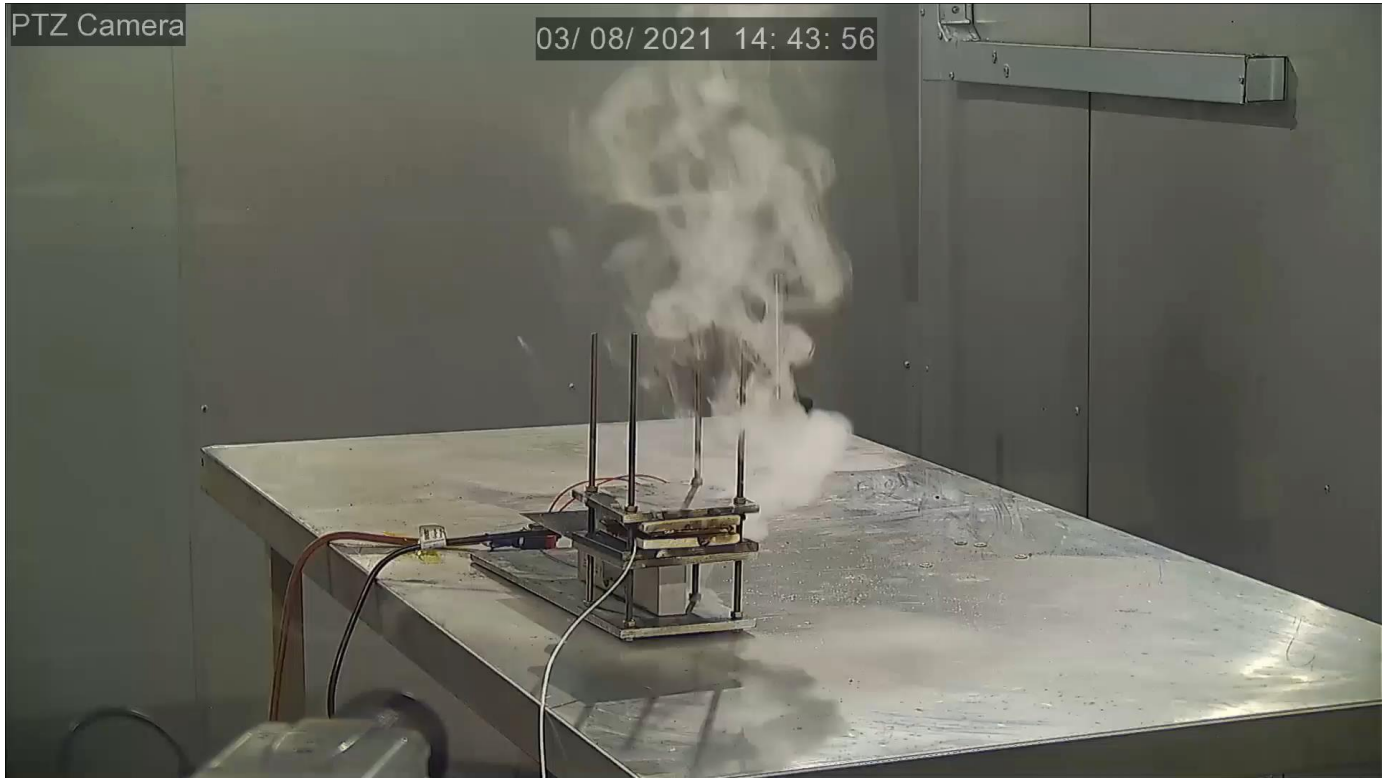

Pouch Cells Before and After Failure

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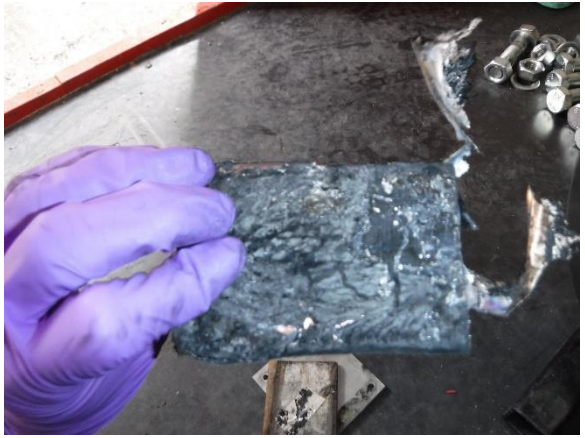
Before

During

After



Example of Failures

Samsung Galaxy Note 7

Reports of fires as a result of batteries overheating.

The overheating was due to manufacturing faults.

Experimental Aims

BESPOKE RESEARCH AND CONSULTANCY FROM HSE

Pouch Cell Pressure Measurement

- Measurement of maximum pressure generated as a result of swelling during an external heat test
- Gap above cell for expansion varied (none, 1mm and 2mm)

Gas Volumes and Analysis

- Gas volumes released during venting/ failure in single cell and cell block tests
- Gas % volume of select gases in nitrogen and air atmosphere

Pressure Measurements Test Design

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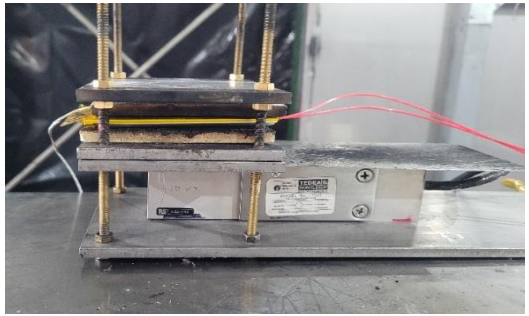
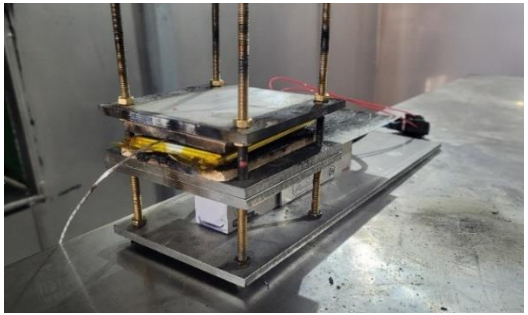
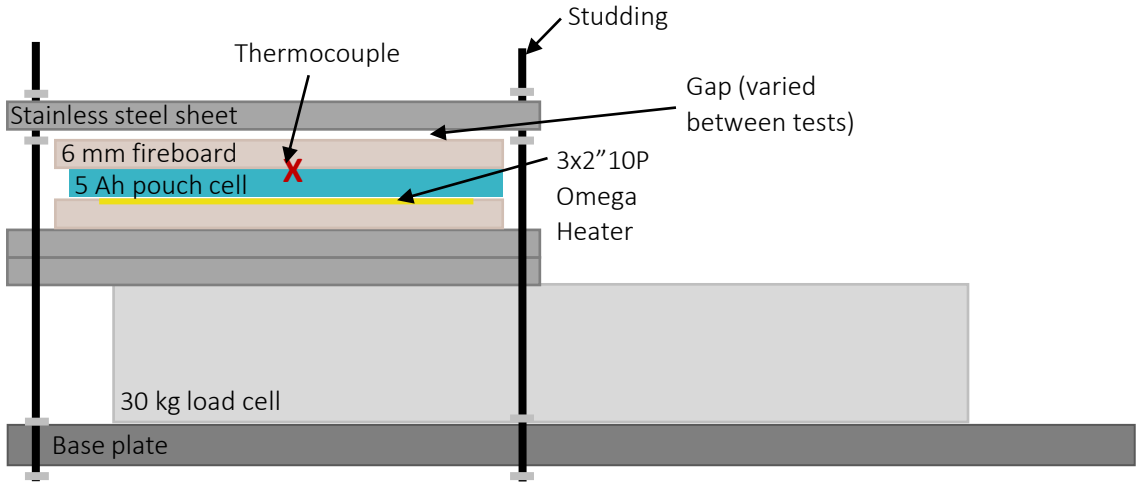
Abuse Method: External Heat **State of Charge:** 50% or 100% **Number of Cells:** 1







Pressure Measurement Calculations

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The internal pressure produced by the cell was calculated by:

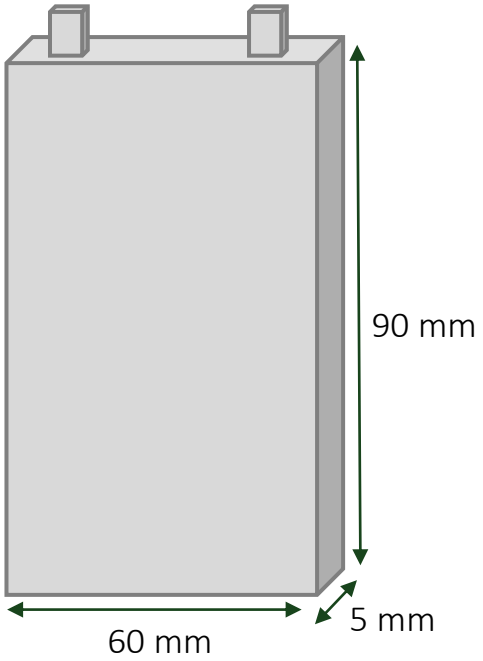
Converting the mass recorded to a force

Force (N) = Mass (kg) x Acceleration (gravity, 9.806 m/s^2)

Using the force to calculate the pressure

Pressure (Pa) = Force (N) / Area (0.0054 m^2)

Pressure (Pa) was converted to kPa



Pressure Measurement Results

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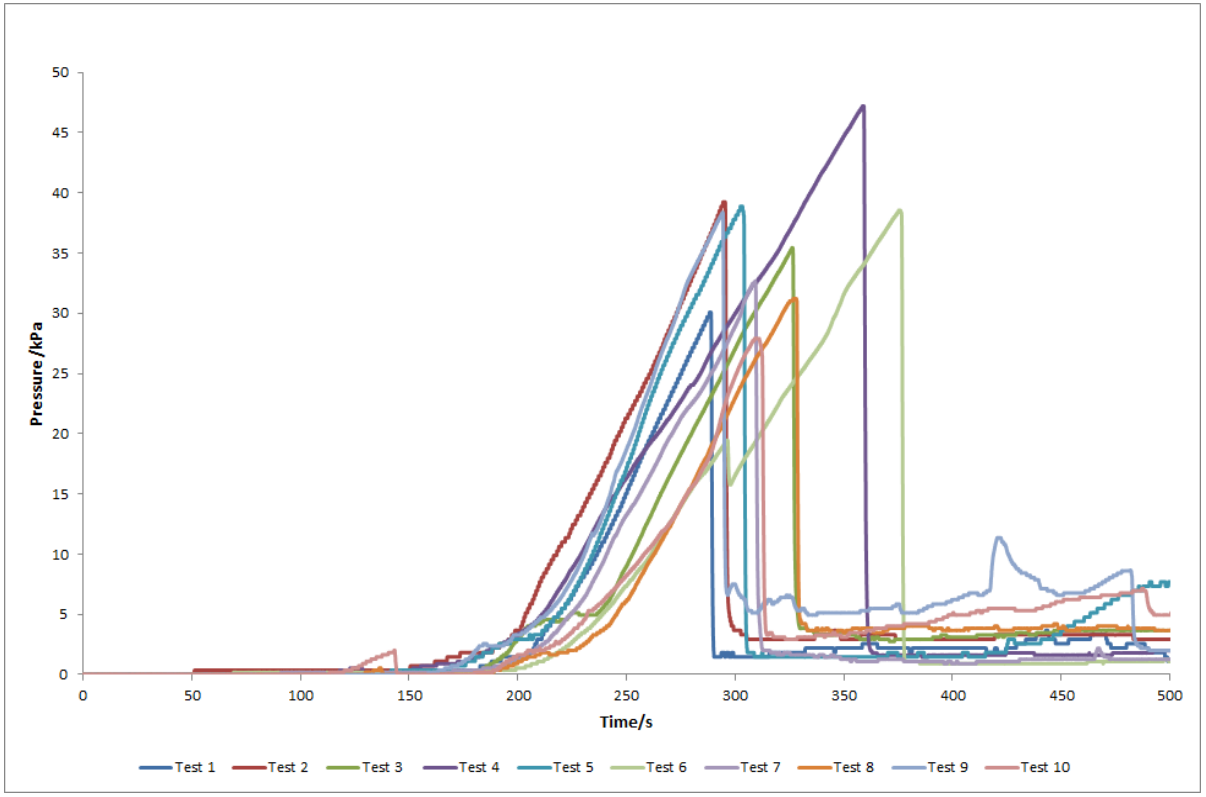


Pressure increase up to venting / failure

Test Conditions

Test 1-3: No gap , 100 %

Test 4-5: 1mm gap, 100 %

Test 6-7: 2mm gap, 100 %

Test 8-10: No gap, 50 %

Gas Volume and Analysis Test Design

BESPOKE RESEARCH AND CONSULTANCY FROM HSE

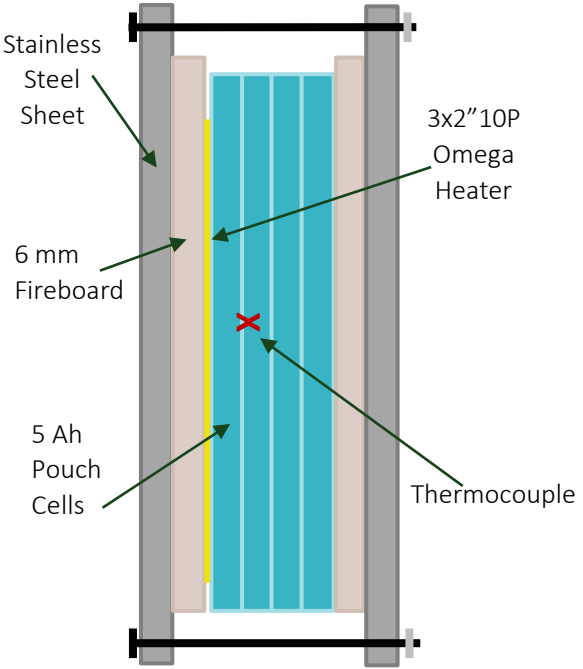
Abuse Method: External heat

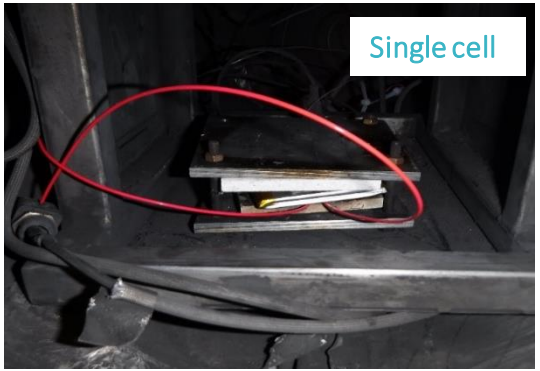
State of Charge: 100 %

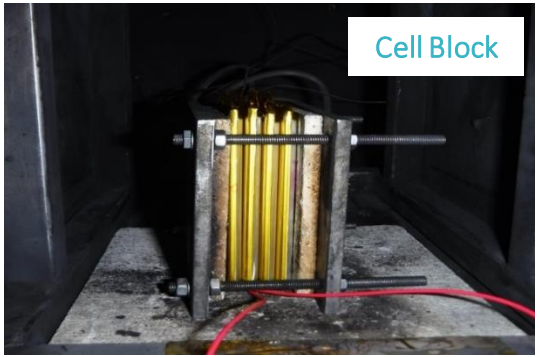
Number of Cells: 1 or 4

Atmosphere: Nitrogen or air

All test carried out in 46 L, 10 bar rated pressure vessel

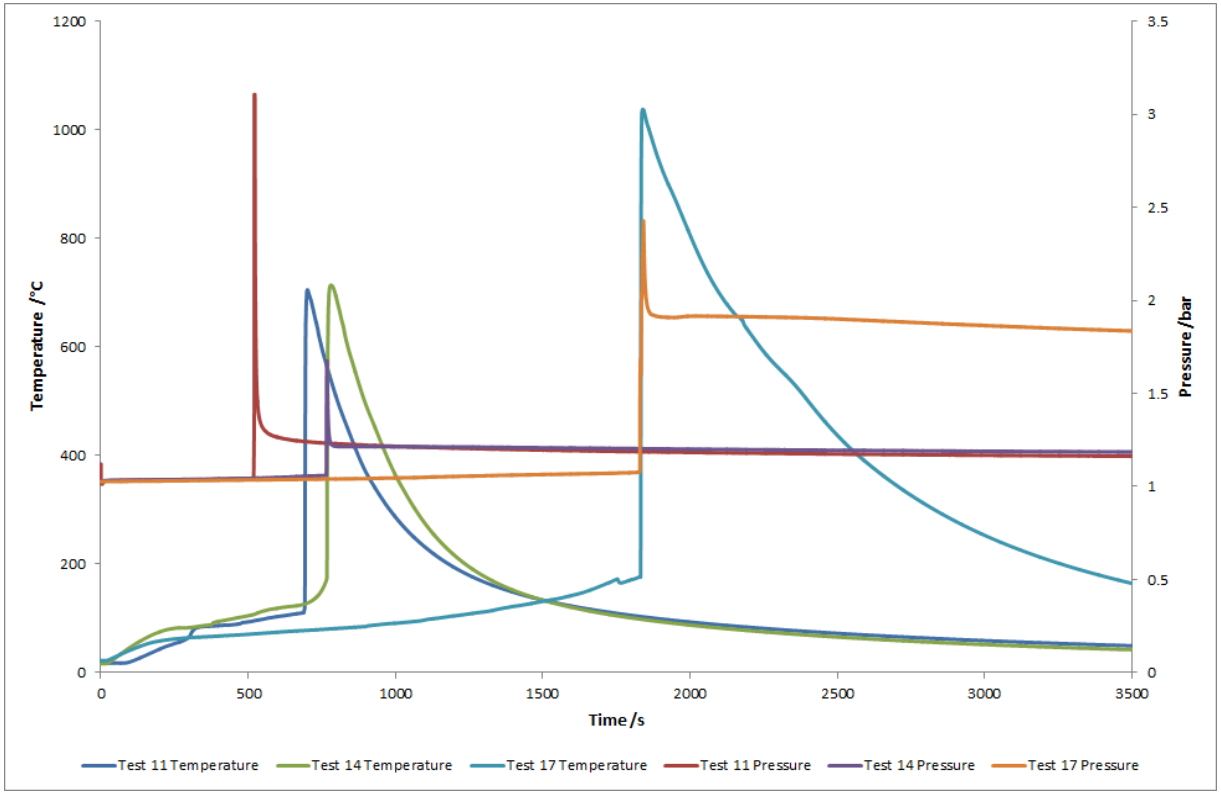






Cell Failure Nitrogen vs. Air Atmosphere

BESPOKE RESEARCH AND CONSULTANCY FROM HSE



Pressure and temperature

Test Conditions

Test 11: Single cell, Air, 100 %

Test 14: Single cell, N_2, 100 %

Test 17: 4 cell block, N_2, 100 %

Gas Volume Calculations

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Ambient temperature, pressure and pressure vessel volume used to calculate moles of gas:

$$\text{Moles of gas} = \frac{\text{Pressure (Pa)} \times \text{Volume of vessel (L)}}{\text{Ambient temperature (K)} \times 8.314}$$

Moles of gas used to calculate final gas volume under standard conditions (25 °C, 1 atm)

Gas Volume Results

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Test Number	Atmosphere	Number of Cells	Gas Volume (l)	Average Volume (l)
11	Air	1	4.7	4.3
12			4.9	
13			3.2	
14	Nitrogen		6.0	6.5
15			6.4	
16			7.1	
17		4	31.4	31.4

Gas Composition Single Cell

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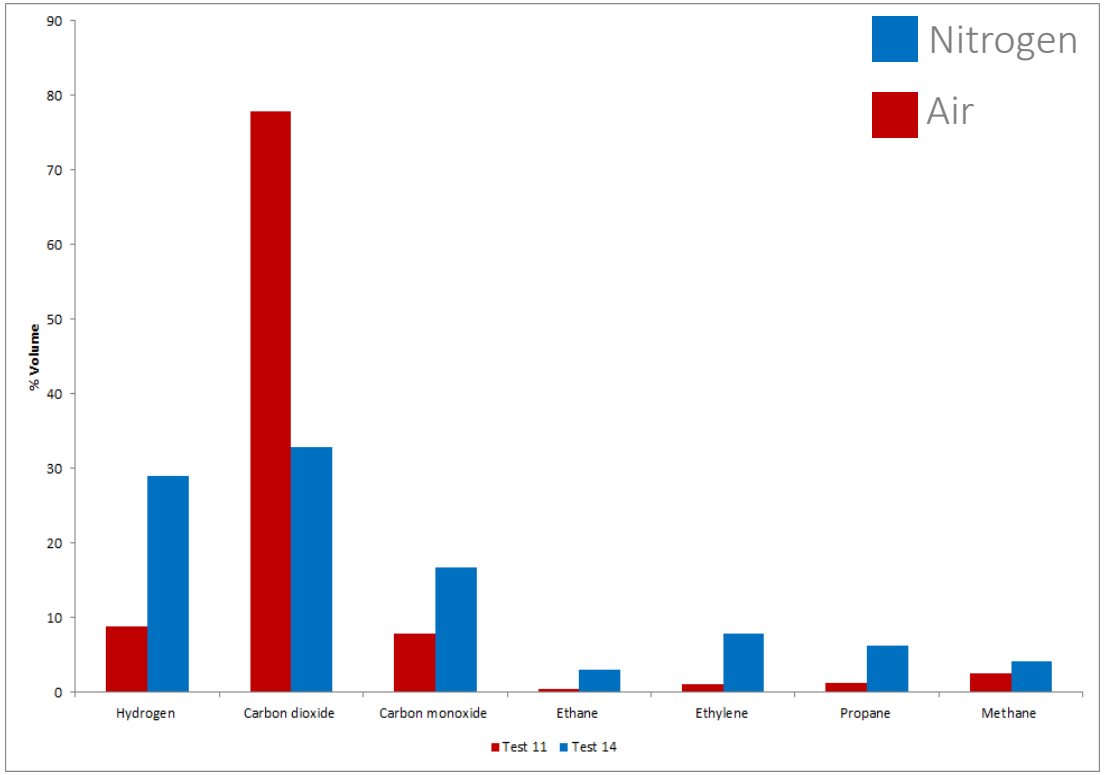

% Volumes for key gases

Key gases (analysed by mass spectrometry) :

- Hydrogen
- Carbon dioxide
- Carbon monoxide
- Ethane
- Ethylene
- Propane
- Methane

Gas Volume and Composition Differences

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- Air smaller volume of gas than nitrogen atmosphere
- Higher % volume of carbon dioxide produced in air atmosphere
- Higher % volume hydrogen in nitrogen atmosphere
- Higher % volume of small hydrocarbons in nitrogen atmosphere
- Approximately 5 times greater gas volume for cell block compared with single cell in nitrogen atmosphere

Conclusions

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- Considerable force exerted by swelling of cell
- Significant volumes of gas produced, mostly flammable

Any questions?

Gemma.howard@hse.gov.uk

Acknowledgements

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