EASA
European Union Aviation Safety Agency

9th Triennial Fire and Cabin Safety Research Conference

EASA participation to research projects on transportation of lithium batteries by air

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EASA Certification Directorate
30.10.2019

EASA participation to research projects on transportation of lithium batteries by air

- The SaBatAir project
- SaBatAir: Task 2
- SaBatAir: Task 4
- Upcoming EASA research on lithium batteries

Note: the information included in this presentation is privileged and provisional, as the research project is still on-going.

SaBatAir Project
(Safe Battery Transport by air)

- Research project funded by the European Union and supervised by EASA and DG MOVE with the support of a Scientific Committee.

- The Consortium:

vito vision on technology

ALGOLiON

AIRBUS

impact solutions independent plastic experts

DG SAFETY GROUP

grab it communication agency

Energy Ville

SaBatAir: scope of the project

- Assessment of the effectiveness of the test methods as described in draft SAE G27 AS6413 dated 12th November 2018

→ Give inputs and recommendations to the SAE G-27 committee

- Study and assess the effectiveness of potential mitigating measures against fire risk related to the transport of lithium metal and lithium ion batteries on Large Aeroplanes.

- Develop guidelines to support the production of a safety risk assessment for operators.

SaBatAir: schedule of the project

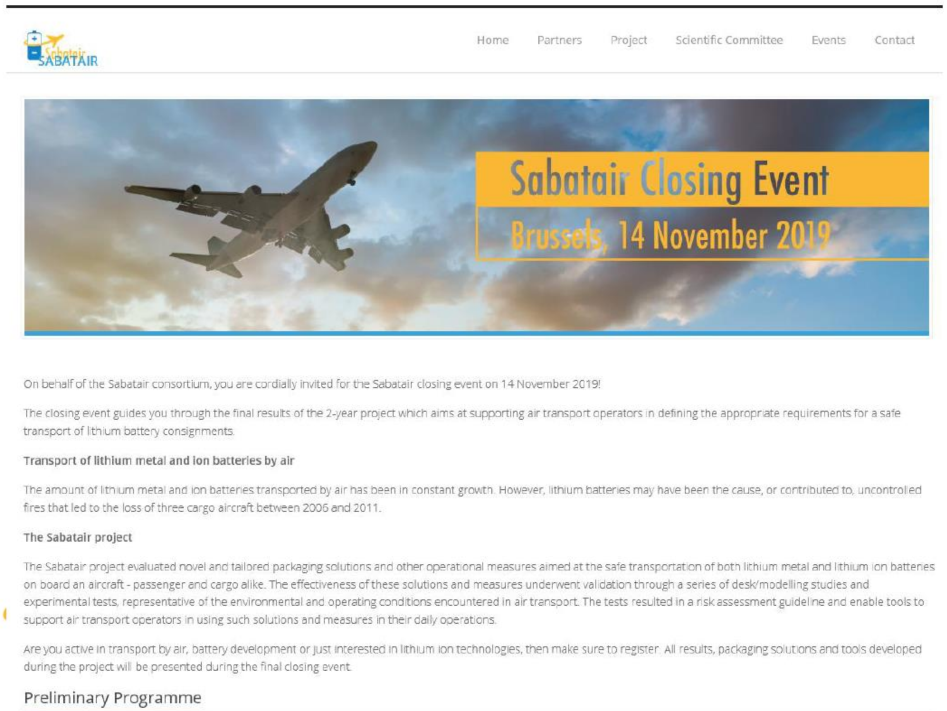
	2017	2018											2019												2020	
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Project plan UPDATE - 17.04.2018	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Month 13	Month 14	Month 15	Month 16	Month 17	Month 18	Month 19	Month 20	Month 21	Month 22	Month 23	Month 24	Month 25	Month 26	Month 27
Task 0 project management																											
Task 1																											
Task 2																											
Task 3																											
Task 4																											
Task 5																											
Task 6																											
Task 7																											
Deliverables				D1a, D1b	D1c	Draft D2a / D2a	D3a				Draft D2b / D2b		interim report	D3b	D5	D4		D6	D7			D8					D9
Deadline for delivery				31/mrt	27/apr	25/mei / 31/mei	30/jun				24/okt / 31/okt		21/dec	31/jan	28/feb	29/mrt		31/mei	28/jun			30/sep					28/feb
Meetings				Mlsne1 meeting				Mlsne 2 meeting				Mlsne 3 meeting			Mlsne 4 meeting			Mlsne 5 meeting				Mlsne 6 meeting			Mlsne 7 meeting		
Periodic meetings EASA				21/mrt				11/jul				15/nov			14/feb			28/mei				17/sep			17/dec		
Final presentation & Event																						18/sep					
For information: SAE International WG meeting dates							4-7/jun					5-9/nov															

SaBatAir: the main tasks

Task 1	Definition of Baseline - Review of State-of-the-Art and Hazard Identification
Task 2	The assessment of the definition and of the effectiveness of the test methods defined in the draft AS 6413
Task 3	Identification and assessment of additional mitigating measures related to packaging solutions or based on multi-layered approaches
Task 4	Evaluation of the effectiveness of the proposed mitigating measures through testing in an environment representative of a typical large aeroplane Class C cargo compartment
Task 5	Development of guidelines to support a safety risk assessment for the air transport of lithium batteries/cells

You're invited to attend the project closure event

November 14th, 2019 in Brussels (@ Atelier des Tanneurs)


SABATAIR

Home Partners Project Scientific Committee Events Contact

On behalf of the Sabatair consortium, you are cordially invited for the Sabatair closing event on 14 November 2019!

The closing event guides you through the final results of the 2-year project which aims at supporting air transport operators in defining the appropriate requirements for a safe transport of lithium battery consignments.

Transport of lithium metal and ion batteries by air

The amount of lithium metal and ion batteries transported by air has been in constant growth. However, lithium batteries may have been the cause, or contributed to, uncontrolled fires that led to the loss of three cargo aircraft between 2006 and 2011.

The Sabatair project

The Sabatair project evaluated novel and tailored packaging solutions and other operational measures aimed at the safe transportation of both lithium metal and lithium ion batteries on board an aircraft - passenger and cargo alike. The effectiveness of these solutions and measures underwent validation through a series of desk/modelling studies and experimental tests, representative of the environmental and operating conditions encountered in air transport. The tests resulted in a risk assessment guideline and enable tools to support air transport operators in using such solutions and measures in their daily operations.

Are you active in transport by air, battery development or just interested in lithium ion technologies, then make sure to register. All results, packaging solutions and tools developed during the project will be presented during the final closing event.

Preliminary Programme

https://sabatair.vito.be/sabatair-closing-event

SaBatAir contact persons

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Task 2: assessment of draft AS6413

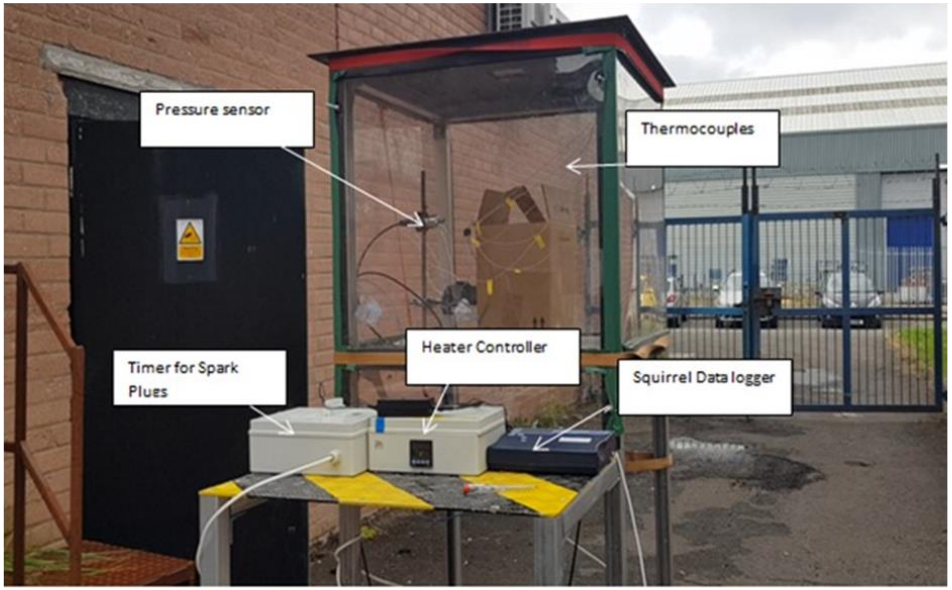
Initial objectives

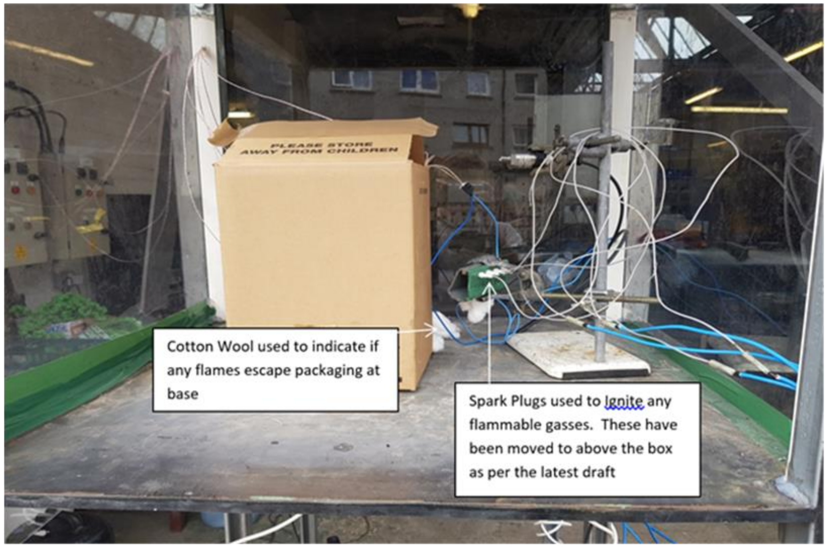
- Review of three test methods from the draft SAE AS6413 (Nov 2018 version):
  - Test(VIII) Reduced Cell configuration
  - Test (VII): Generic packaging
  - Test (I) Cells and/or batteries in specific packaging

→ Verify that reduced cell configuration test results match the results of Test(I) and Test (VII)

- Construction of test rig inline with draft SAE AS6413
- Review of available packaging and key failure modes
- Evaluation of repeatability of test results with focus on failures
- Recommendation of improvements

Test Setup





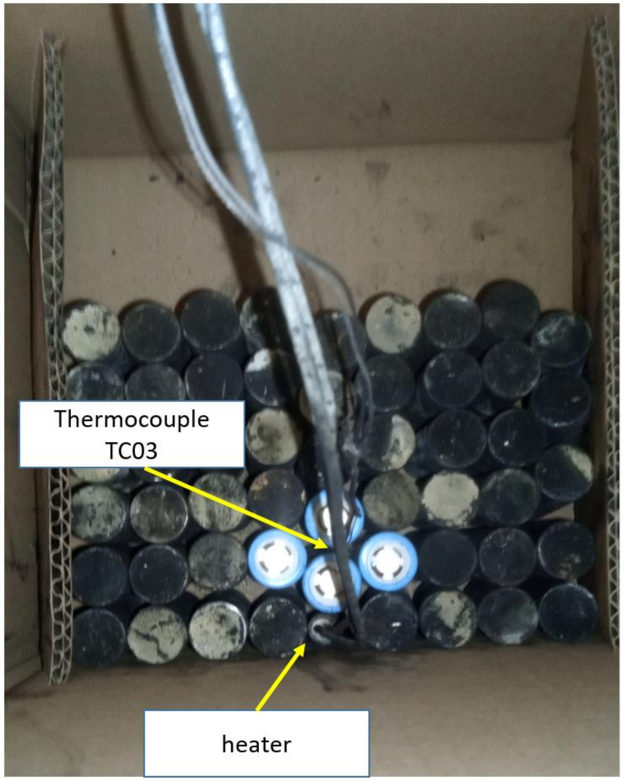
Setup of spark ignitors and cheesecloth

Item	Description	Calibration method
Chamber	Unistrut/Perspex design. Variable height floor to adjust air space as described in section 7 of the standard.	Chamber filled with CO_2 and verified that CO_2 level had not changed after 1 hour showing less than one air exchange.
Spark Ignitors	Motor vehicle spark ignitors x 4, sparking at 1HZ	N/A
Pressure sensor	642R-601 programmable pressure transmitter ranging from 0 – 6 Bar	Manufacturer calibrated with ISO17025 certificate
Thermocouples	7 K-type thermocouples	In house process against ISO 17025 traceable equipment @ 100°C and 200°C
Data Logger	Squirrel SQ2020 Data logger	N/A
Heater Cartridge	300W 10mm x 650mm heating cartridge	ISO 17025 certified methodology
PIC controller	Programmable controller for heating cartridge	N/A

All the tests were performed at Impact Solutions (Scotland)

Task 2: assessment of draft AS6413

- The test chamber functionalities were validated with some initial tests on some random cells.
- The tests were conducted on commercial 18650 cells 3,5Ah (NMC)
- Packaging: UN 4G Fibreboard



Task 2: assessment of draft AS6413

- Conclusion of the first set of tests with the reduced cell configuration

→ Limited repeatability of test results both at 30% and 100% SOC.

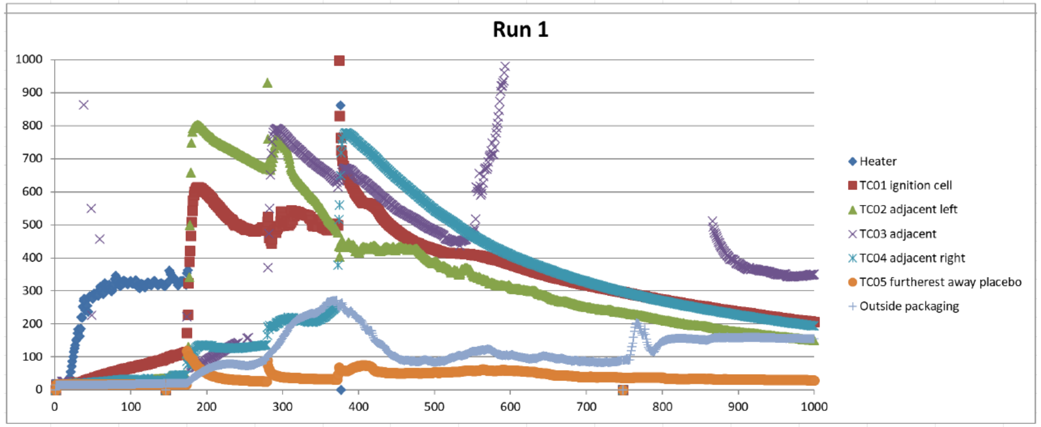
- Main identified cause: Control of the heater band from the other side of the cell leads to little control. Cells all went into thermal runaway well before the far side (TC03) had reached 200°C resulting with inconsistent results.

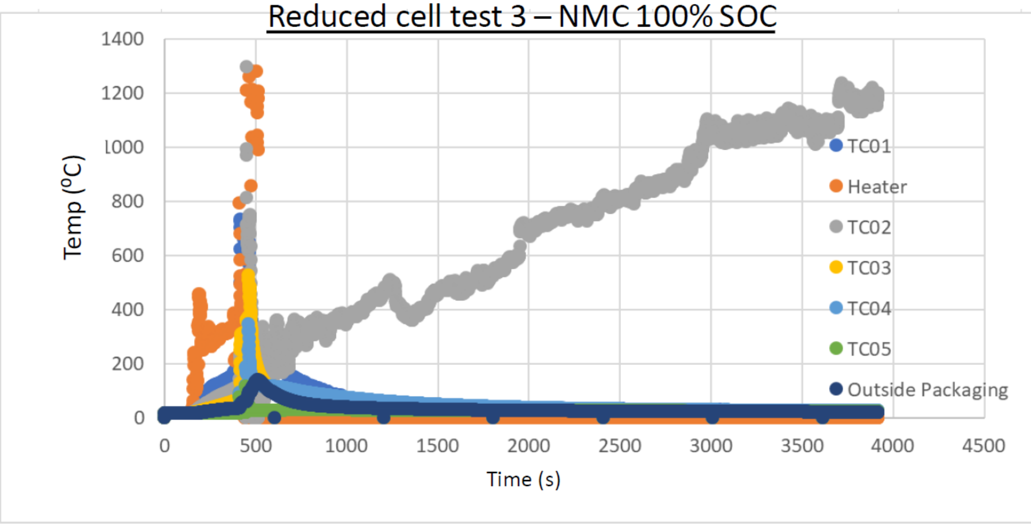
- Identified key variables:
  - Type, position and control of the heater
  - Amount of heat not directly transferred to the initiation cell

Task 2: assessment of draft AS6413

Repeatability assessment NMC-100%SOC

- Both 100% SOC have failed.
- Temp difference of ~ 300⁰C.
- Adjacent and right hand cell much lower reaction (less propagation between cells)





Task 2: improvement of draft AS6413

New objectives

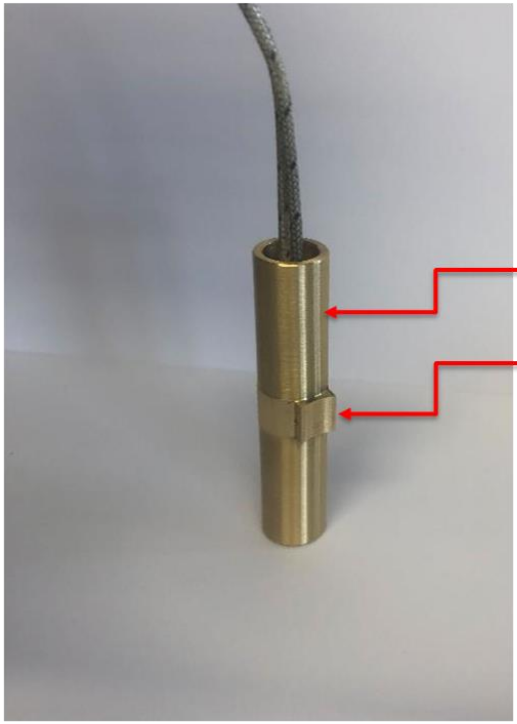
- Define type of heater, and position of a heater for both 18650 and pouch cells (type, shape, power rating etc).
- Define how to ensure the optimal amount of thermal energy is introduced to cause thermal runaway.
- Define how to prevent thermal energy being lost into the rest of the system, outside that of the initiation cell
- Determine the optimal method of controlling the heater (temperature ramp, or set temperature)

Task 2: improvement of draft AS6413

Proposed set up improvements

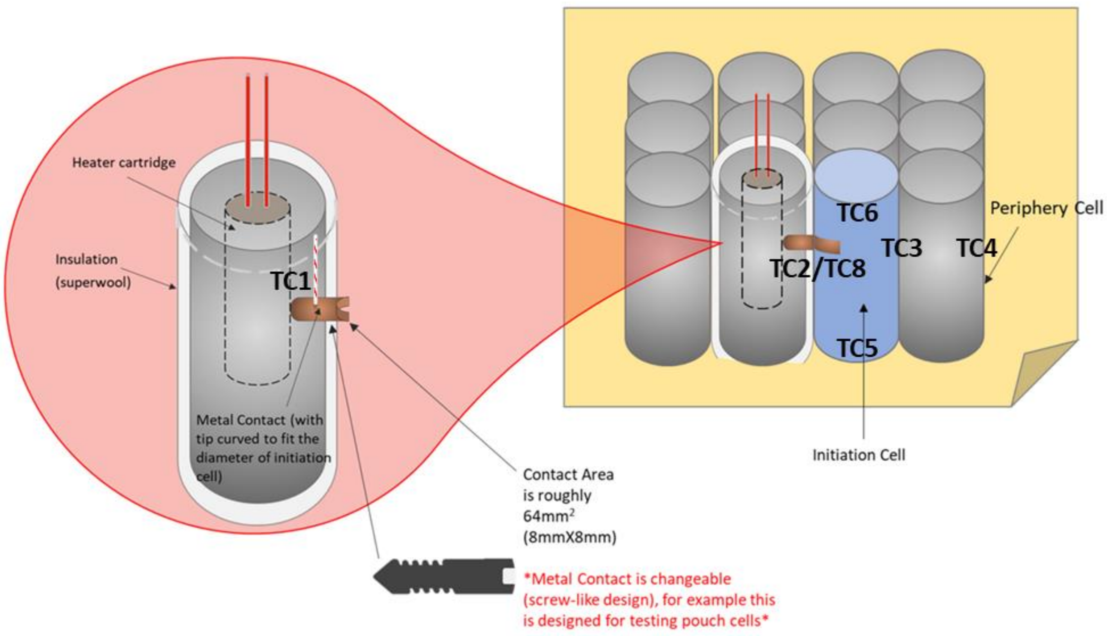
- Tighter control of the heat transfer to the initiation cell:
  - contact between the heater and the initiation cell is ensured by means of a metallic adapter of specified material and size;
  - the contact area between the adapter and the initiation cell is specified.
- Insulation should fully encapsulate the heater and the adapter except for the contact area with the initiation cell.
- No heat transfer from the heater to:
  - cells other than the initiation cell
  - the packaging.
- Temperature of the initiation cell monitored at the contact area and not at the backside.

Heater design



- Copper for high thermal conductivity
- Heater slots inside sleeve
- Concave contact point for cell contact
- Hole for placement of thermal couple and accurate temperature monitoring

Phase III



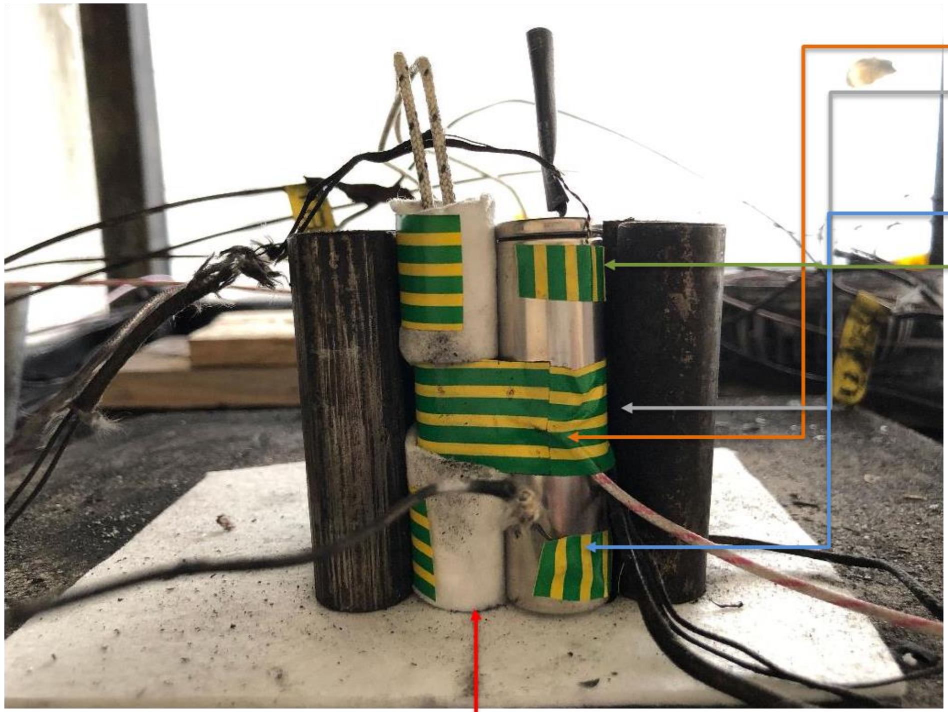
- Purpose: repeatability
- Use of 1 cell (initiation)
- Measure temperatures at points as indicated
- Temperature increase rate at T3: minimum 5°/C min.
- Hold TC3 at 200°C for 1 hour

TC1: Contact point
TC2: 5 mm away from contact area (at the same height)
TC3: Back of ignition cell
TC4: back of periphery cell
TC5: 10mm from base of initiation cell
TC6: 10mm from top of initiation cell
TC8: Mirror of TC2
Voltage

Task 2: improvement of draft AS6413

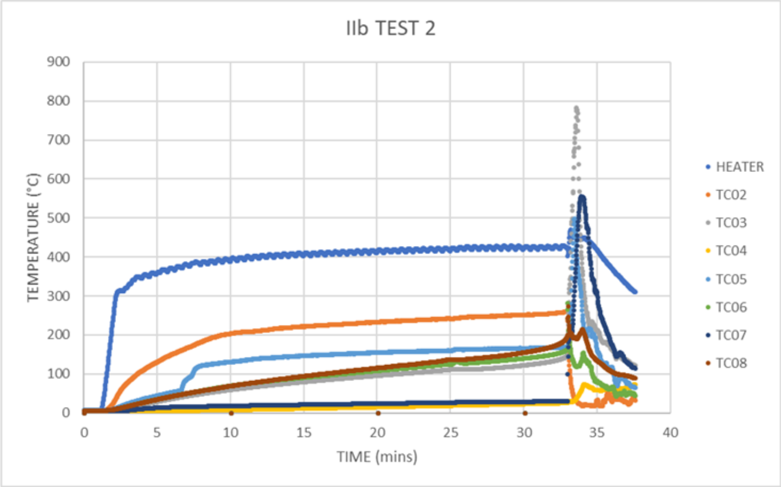
Objectives of Phase IIB

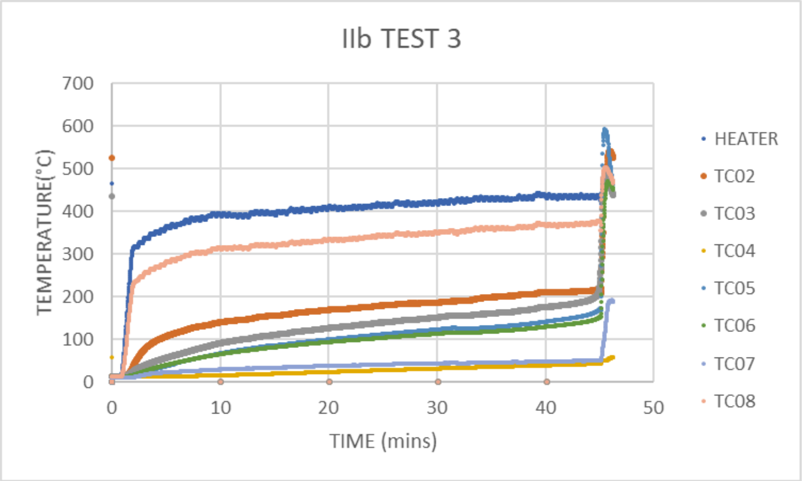
- Can consistent thermal runaway be achieved by applying heat to side of cell?
- Improve the design of heater/contact area



Task 2: improvement of draft AS6413

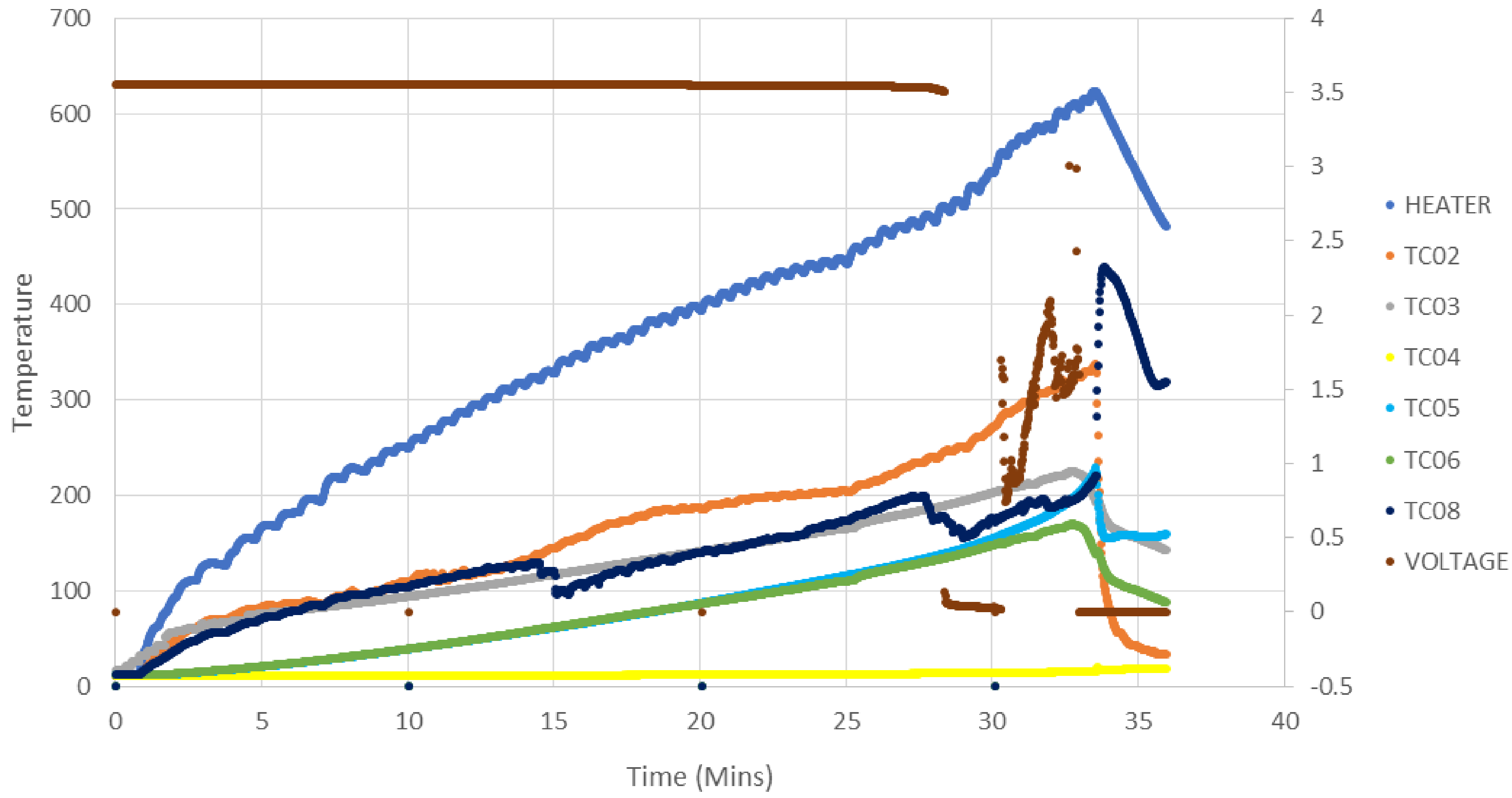
100%SOC results





- Thermal runaway observed after 35 and 45 minutes (circled in red)
- Consistent temperature peak around 600C

Task 2: improvement of draft AS6413



Task 2: improvement of draft AS6413

- Thermal runaway after 34 minutes. Voltage drop after 28 mins.
- 200°C reached after 30 minutes: ramp rate on TC3 (backside of the initiation cell) achieved at 6.6°C/min.
- Difficult to achieve a higher temperature increase rate on TC3
- Similar results obtained in subsequent tests with similar temperature increase rates

Task 2: improvement of draft AS6413

Conclusions

1) The proposed test setup ensures that:

- repeatable results (thermal runaway events) are generated using linear temperature increase;
- a thermocouple close to the contact surface with the heater can be used to monitor the temperature of the initiation cell;
- the amount of energy transferred by the heater to the packaging and to the cells adjacent to the initiation cell is minimized;
- a tighter range of the rate of temperature increase could be specified.

2) The area of the contact surface between the initiation cell/battery and the heater adapter may be function of the size/design of the cell/battery to be tested.

3) Monitoring voltage drop does not significantly help determining if thermal runaway of the initiation cell is on-going.

Next steps

- The final phase of Task 2 will consist in performing a series of tests using the reduced cell test method (test (VIII) of draft SAE AS6413.

- Tests will be run cells at 30% SOC and at 100% SOC.

- Further tests runs will be performed in November 2019 using cells at 100% SOC, implementing mitigating measures (packaging material change, individual cells/batteries isolation, etc.) as prototype solutions with the objective to reduce the severity of the fire event.

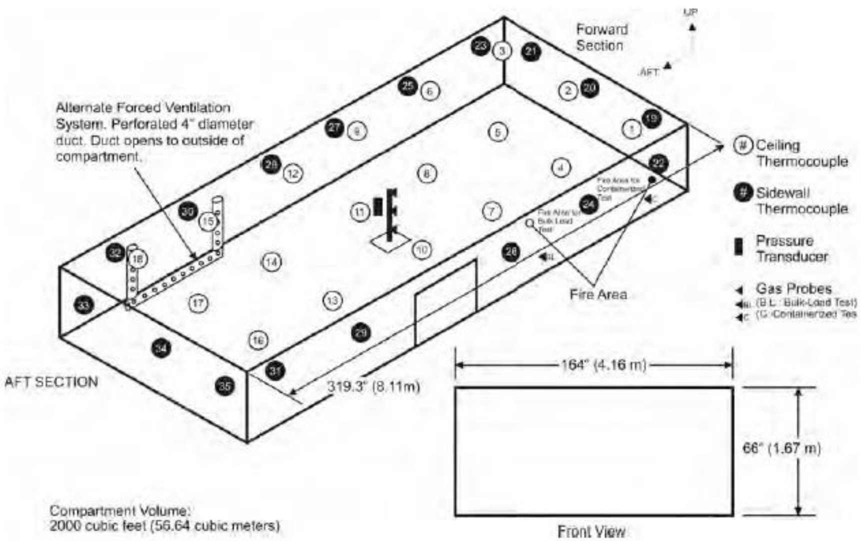
Task 4: the objectives

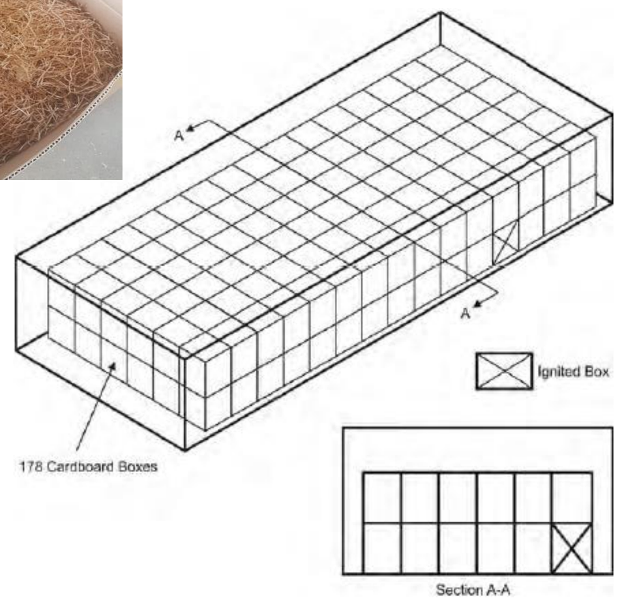
- Scope of Task 4: evaluation of the effectiveness of mitigating for lithium battery fires measures through testing in an environment representative of a typical large aeroplane Class C cargo compartment

- The fire scenario selected for Task 4 is the External Fire: to which extent 18650 cells (in UN 3840 packaging) transported in a Class C cargo compartment are affected by a cargo fire (not a battery fire) developing in their proximity.

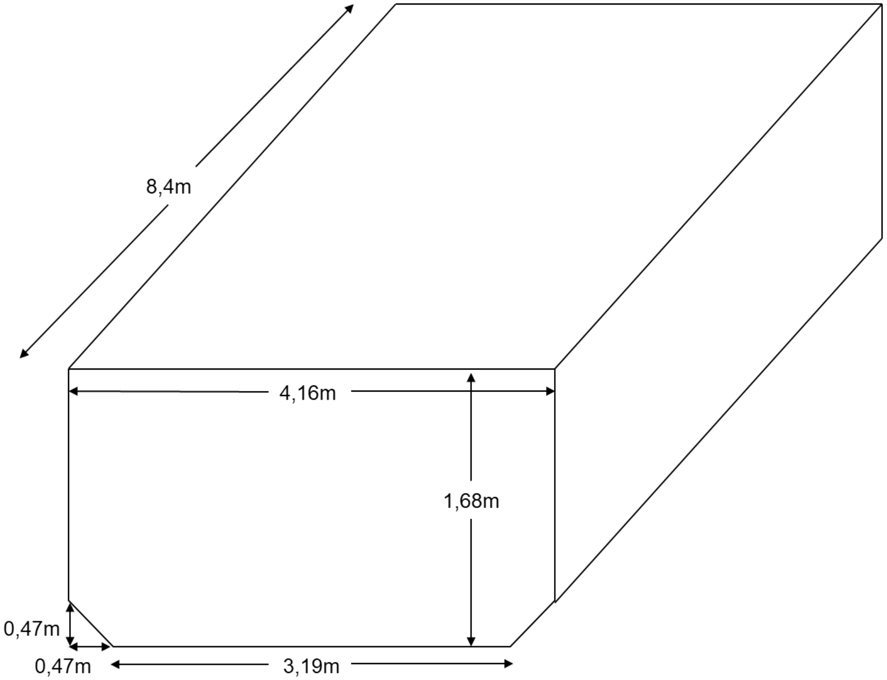
Cold Test: Proof that the Halon concentration is 3% at the location of the battery box	Fire initiation test: Place half amount of cells (400) next to the ignition box – do not use the Fire Suppression System	Halon baseline test 800 cells	FCC test 800 cells	FCC + thermal insulation test 800 cells

The reference for the development of the test setup was the bulk-load fire test as defined in DOT/FAA/TC-TN12/11 (Minimum Performance Standard for Aircraft Cargo Compartment Halon Replacement Fire Suppression System (2012 Update))

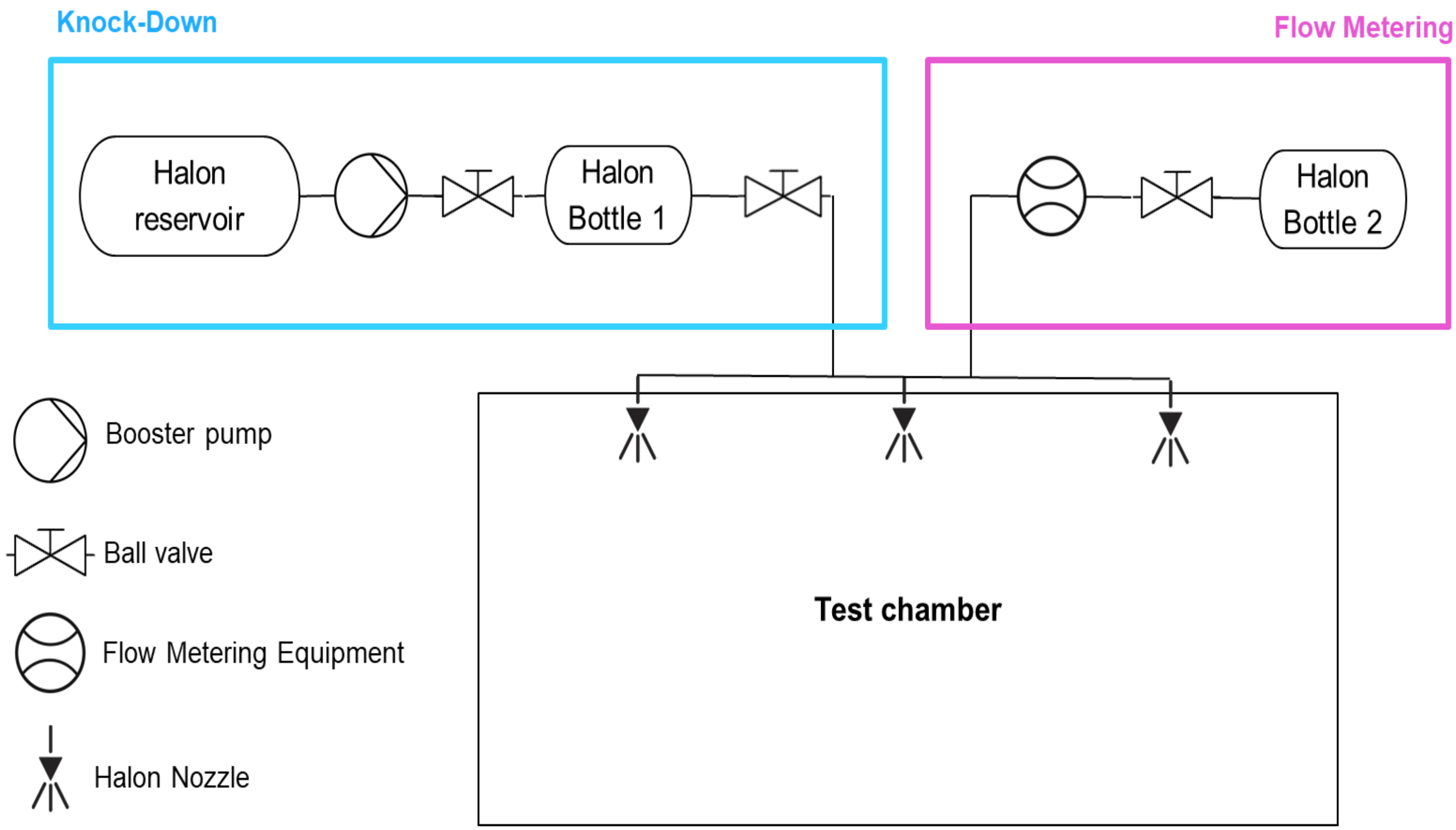




Tests were conducted in the cargo compartment Halon replacement MPS test chamber at DLR (Trauen, Germany)



Architecture of the fire suppression system

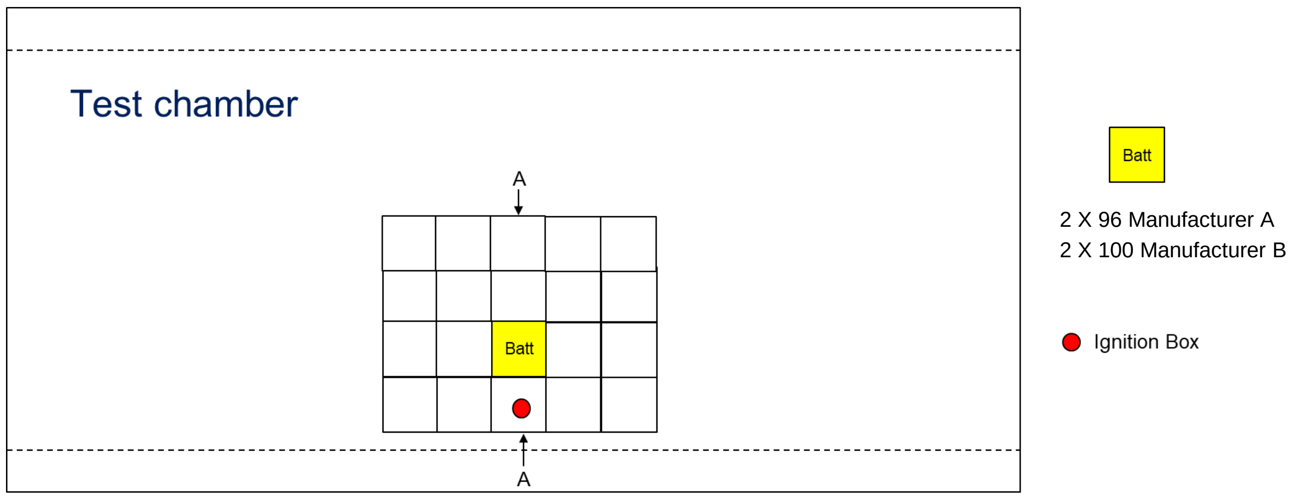


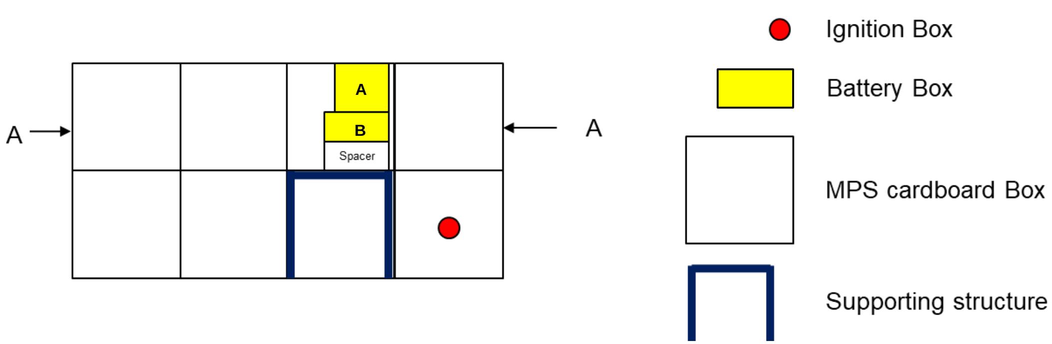
Task 4: test setup

Manufacturer A

Manufacturer B

Fire Initiation test





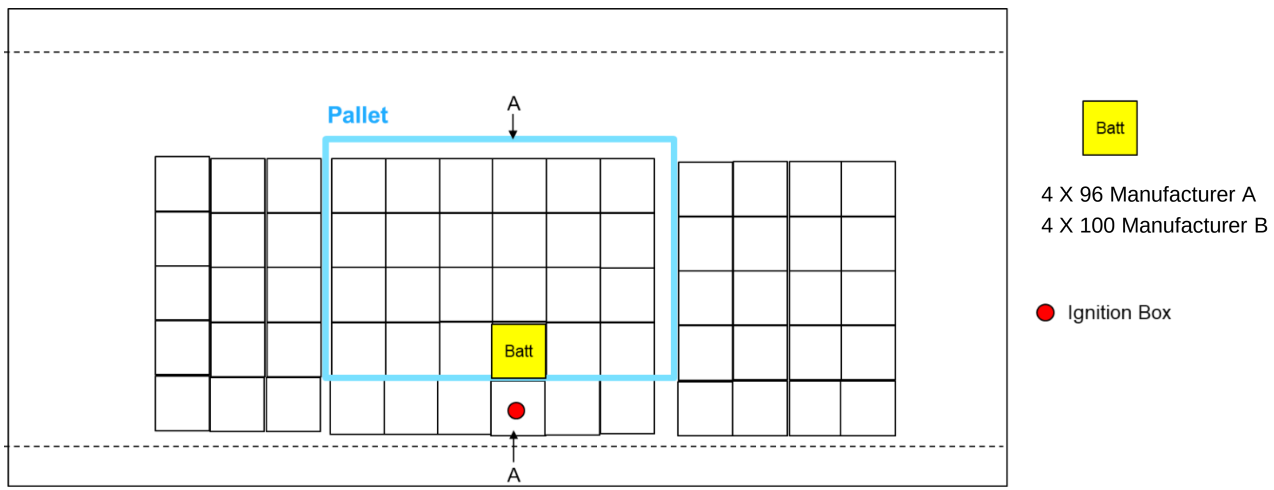
Task 4: test setup

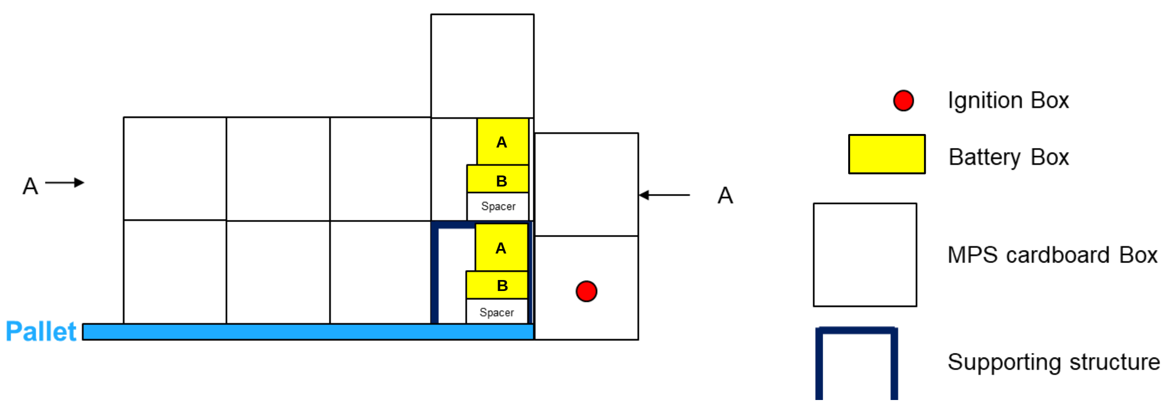
Test procedure

- Start the ventilation system (20 l/s)
- Ignite the ignition box
- Record the time when the temperature readings inside 2 different battery boxes exceed 80°C
- Stop the ventilation system
- Wait for 60sec
- Start the Halon Fire Suppression System
- Continue the test and record the data for another 180 minutes

Task 4: test setup

Halon baseline test



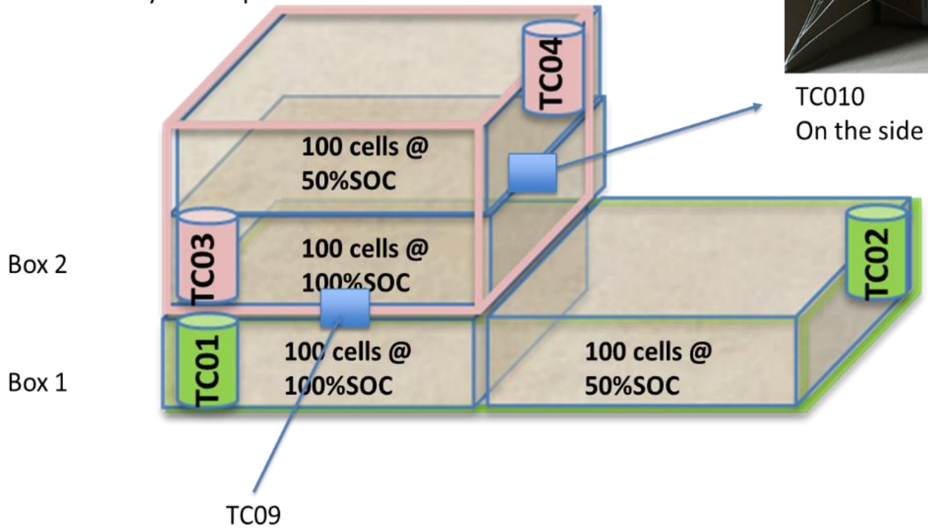


Task 4: test setup

FCC test

Battery boxes placed directly on the pallet

These boxes are placed directly on the pallet



TC010
On the side of the boxe

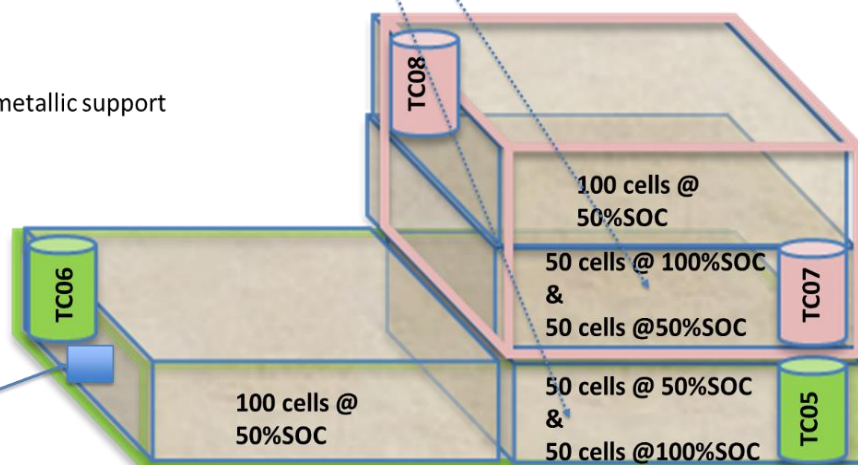
Front facing the flames

Battery boxes placed on the metallic support

The 50 cells @100%SOC are placed as shown in the picture.

These boxes are the metallic support

TC011 on the side of box 4



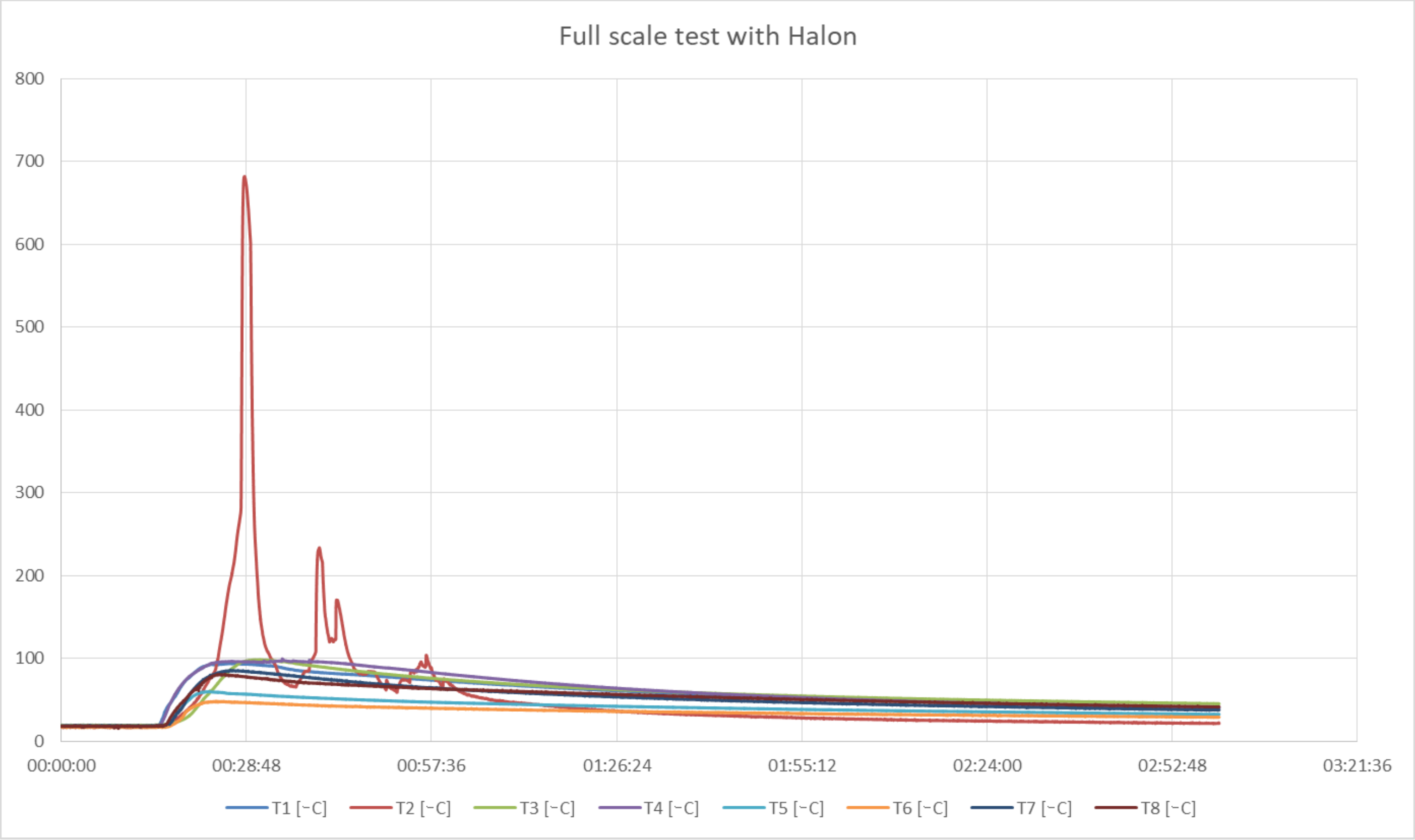
Box 4

Box 3

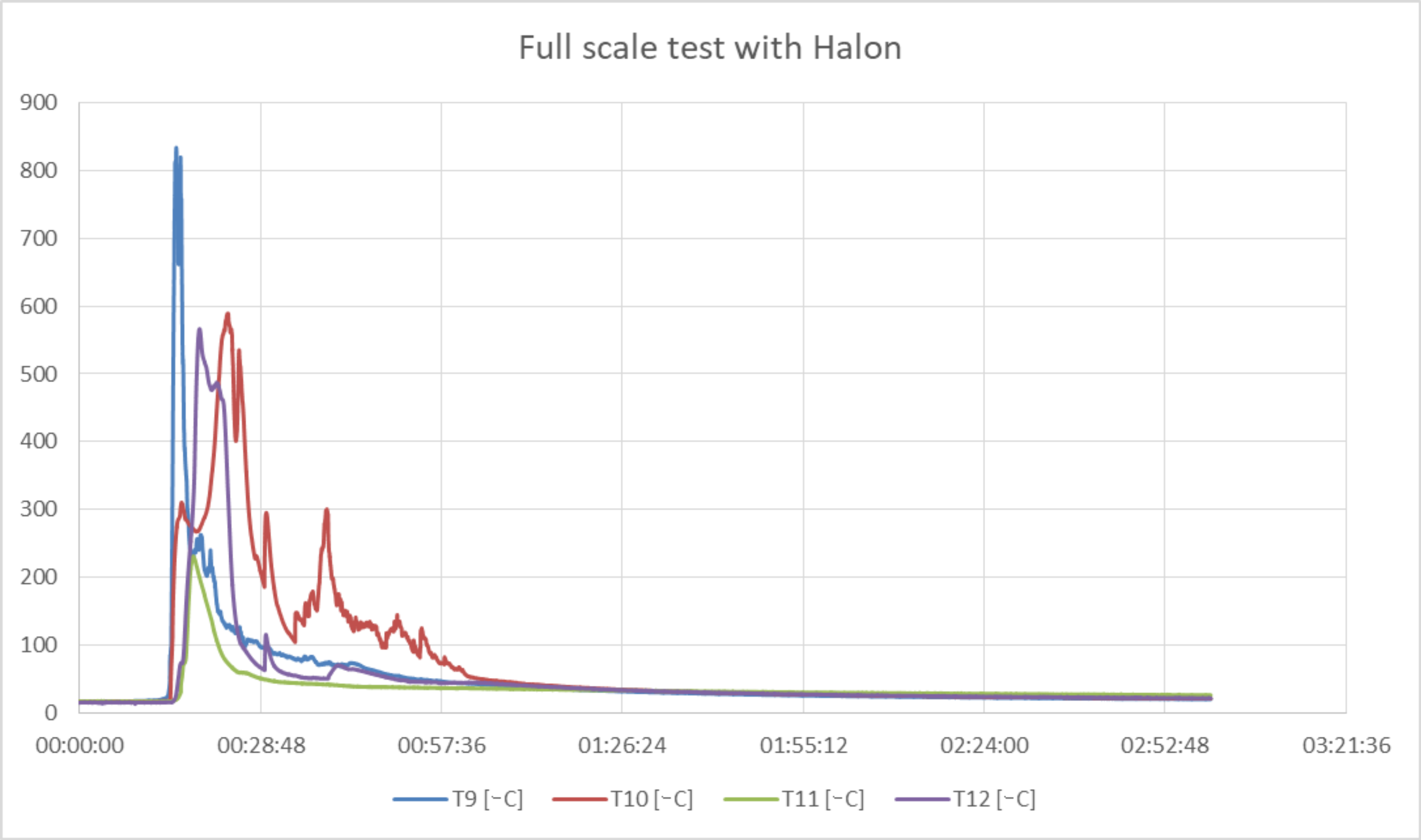
TC012 on the side of box 3

Front facing the flames

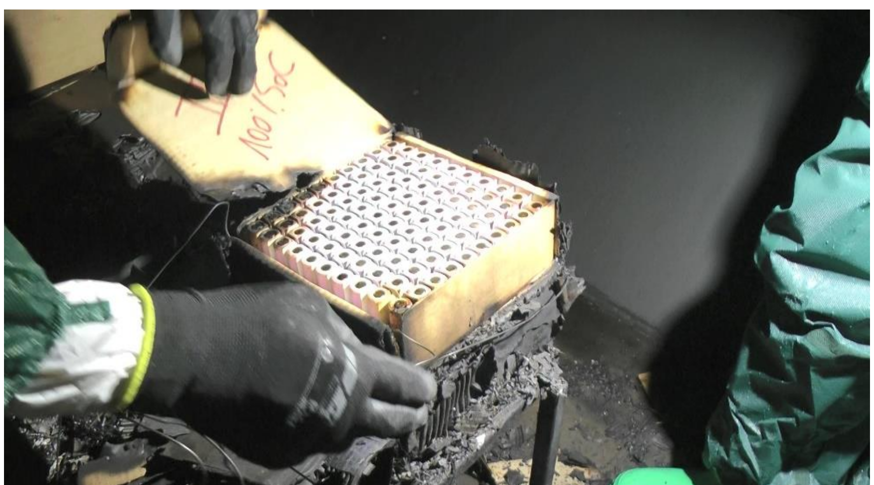
Halon baseline test



Halon baseline test



Halon baseline test

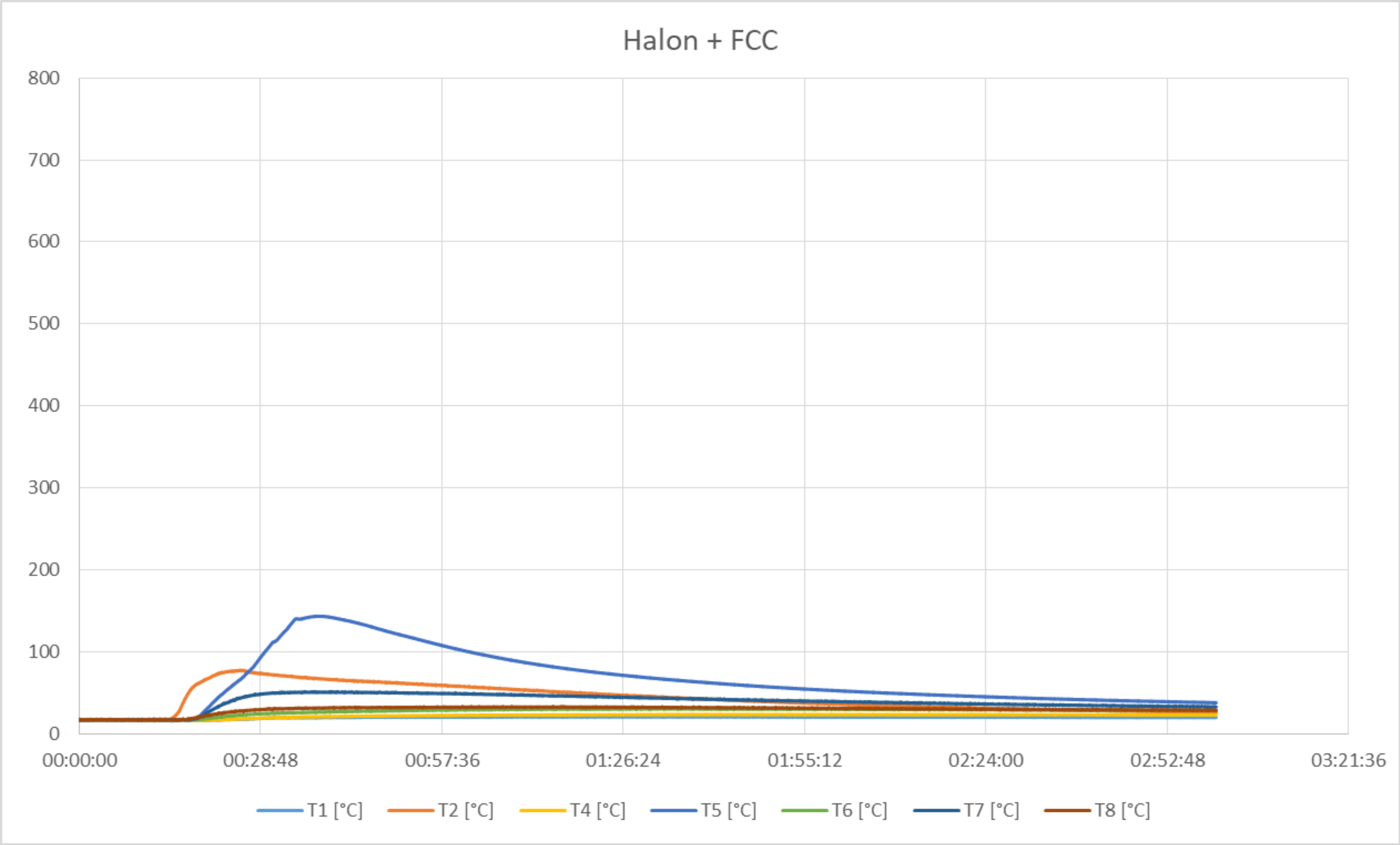


Task 4: test setup

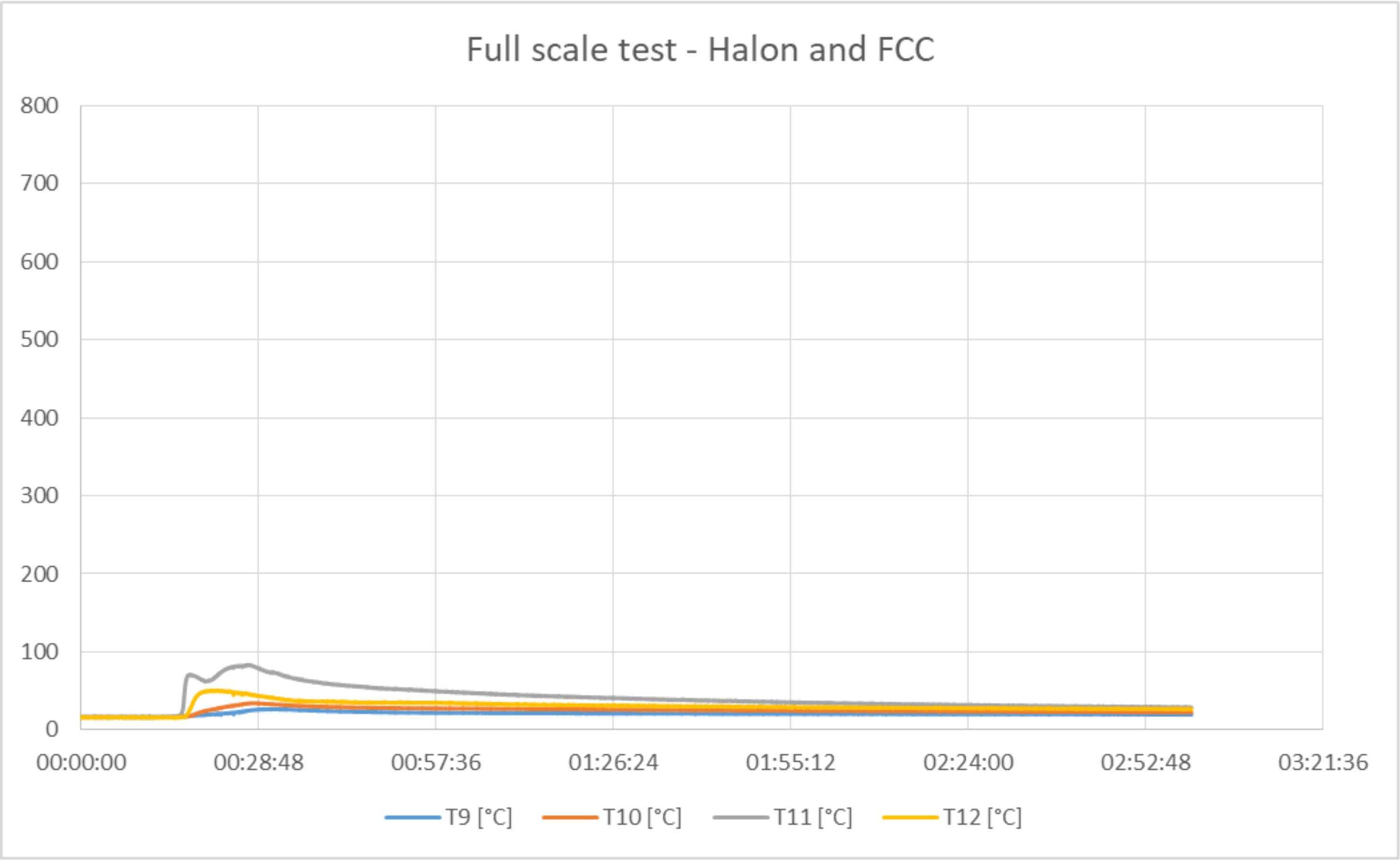
FCC Test procedure

- Start ventilation
- Start ignition
- Wait until any of the MPS-thermocouples reaches 93,3°C and start the stopwatch
- Switch ventilation off and start Halon discharge @ 13 minutes 24 seconds
- Continue the test and record the data for another 180 minutes

FCC test


Halon + FCC
800
700
600
500
400
300
200
100
0
00:00:00
00:28:48
00:57:36
01:26:24
01:55:12
02:24:00
02:52:48
03:21:36
T1 [°C]
T2 [°C]
T4 [°C]
T5 [°C]
T6 [°C]
T7 [°C]
T8 [°C]

FCC test


Full scale test - Halon and FCC
800
700
600
500
400
300
200
100
0
00:00:00
00:28:48
00:57:36
01:26:24
01:55:12
02:24:00
02:52:48
03:21:36
T9 [°C]
T10 [°C]
T11 [°C]
T12 [°C]

FCC test

Task 4: preliminary findings

- The Task 4 tests were conducted between 14th and 24th October 2019: the review of the test results is still on-going.
- The design of the setup required significant effort: it was difficult to involve the battery boxes in a simulated external fire scenario.
- Only 18650 cells from two manufacturers were tested: additional tests should be performed with different cell designs from different manufacturers.
- FCC provide significant mitigation to the severity of the event: no testing was conducted with additional mitigating measures (thermal acoustic insulation).

Upcoming EASA research on lithium batteries

- **Scope**: Fire risk(s) associated to the transport of lithium batteries on large aeroplanes.

- **Objectives**: evaluate the capability of Class C fire suppression systems in case of Lithium battery thermal runaway starting from a PED in checked baggage.

- **Budget: 500.000 Euros**

- **Planning:**
  - Call for tender: Nov 2019
  - Project Start: Q1 2020
  - Duration: 12 months

EASA
European Union Aviation Safety Agency

Any Questions?

Your safety is our mission.