European Union Aviation Safety Agency

EASA update on AIRPED research project

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EASA research

AirPED

Research project EASA.2020.HVP.12
based on the Horizon 2020 Work Programme Societal Challenge 4
'Smart, green and integrated transport'

- Lithium battery fires in cargo compartments:
  - PEDs in checked baggage
  - Bulk shipment of lithium batteries
- Budget: 600.000 €
- Project started in September 2021
- Report to be published in Q4 2024

AirPED

Objectives

- To evaluate the effectiveness of cargo fire suppression systems (Halon-based and Halon-free) in case of thermal runaway events originating from battery-powered devices in checked baggage
- To generate data to support the revision of the MPS for Aircraft Cargo Compartment Halon Replacement Fire Suppression Systems : validation of the definition of a new cargo fire test scenario involving lithium batteries
- To perform additional tests with the same setup as Task 4 of the Sabatair project (external fire scenario, with FCCs protecting the batteries/cells)

TASK 1 – EVALUATE THE BASELINE PERFORMANCES OF THE SELECTED FIRE TEST CHAMBER FOR MPS TESTS

- The test chamber should meet the definition given in DOT/FAA/TC-TN12/11 (Minimum Performance Standard for Aircraft Cargo Compartment Halon Replacement Fire Suppression Systems (May 2012 Update)), considering the changes currently under development by the IASFPF Cargo MPS Task Group.
- Compliance in volume and shape, materials and, as one of the most important performance influencing parameters, the leakage and the way it is imposed.
- Perform full-scale fire tests to prove the performance of the chamber.
- Introduce any design change necessary to ensure that the test chamber is suitable to perform testing as per the MPS.

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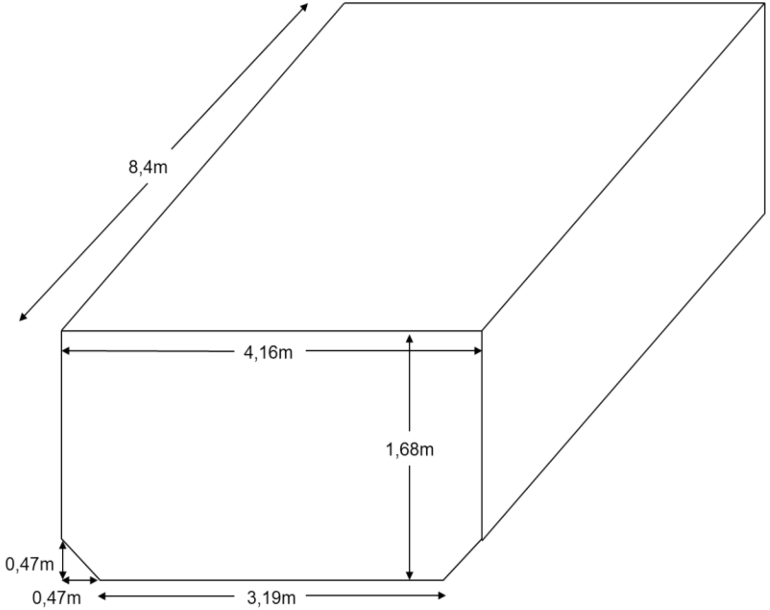
The tests are conducted in the cargo compartment Halon replacement MPS test chamber at DLR (Trauen, Germany)



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TASK 2 – DEVELOP THE TEST PLAN AND PROTOCOLS

TASK 3 – PERFORMANCE OF FIRE TESTS

Test Scenario
Unsuppressed Surface Burning
Unsuppressed Bulk Load
Unsuppressed Containerized
Unsuppressed Multiple Fire Test

Test Scenario
Surface burning & Halon 1301
Bulk Load & Halon 1301
Containerized & Halon 1301
Multiple Fire Test & Halon 1301
Multiple Fire Test & Halon replacement agent
Surface Burning & Halon replacement agent
Bulk Load & Halon replacement agent
Containerized & Halon replacement agent

Test Scenario
Calibration of baggage
Compartment floor
Compartment ceiling
ULD container
Involvement of a bulk shipment of cells/batteries in an external fire event

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TASK 4 – ASSESSMENT OF TEST RESULTS AND AIRCRAFT FIRE PROTECTION EFFECTIVENESS

TASK 5 – PROJECT CONCLUSIONS, RECOMMENDATIONS AND PRESENTATION TO AVIATION STAKEHOLDERS

- The objective of Task 4 and Task is the assessment of the effectiveness of a state-of-the-art fire protection means of a Class C cargo compartment in suppressing a fire involving lithium batteries. This assessment will be done based on test data from the different test scenarios carried in the previous tasks and will include:
  - the evaluation of the level of performance of the tested aircraft fire protection systems in the tested cargo fire scenarios
  - recommendations for improvements of the MPS test protocols, with particular reference to the definition of the new Multiple Fuel Fire scenario involving lithium batteries.
- The final project report will also identify recommendations and further work on open issues that were not deeply investigated during this project.

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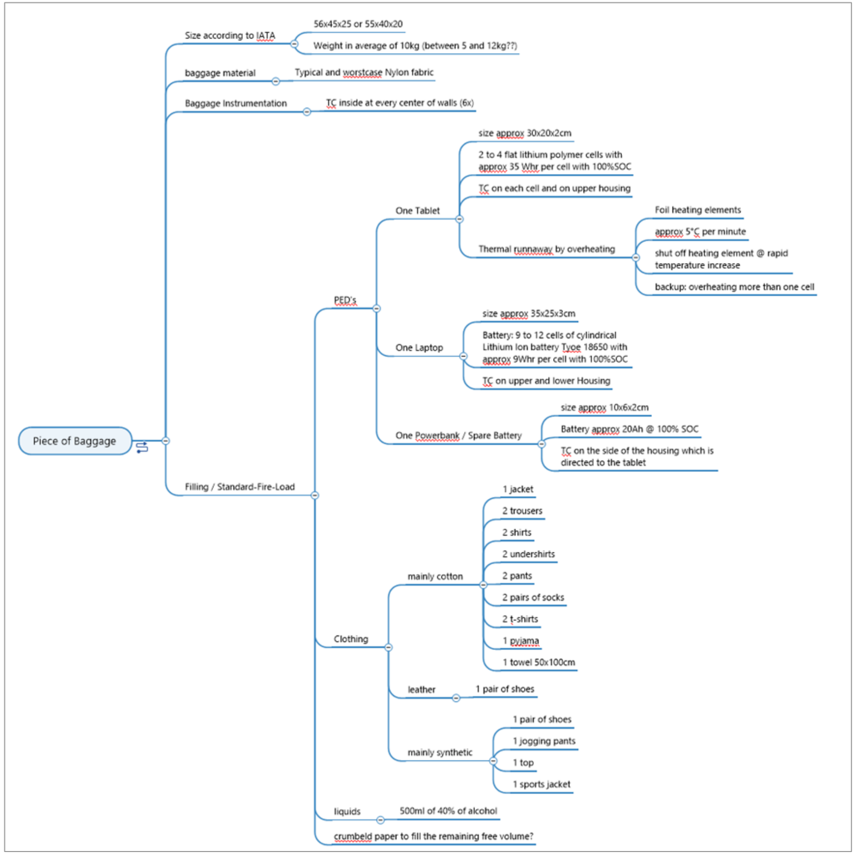
SCENARIO 1: Baseline – Calibration of baggage

→ The objective of this test is to define a representative single baggage configuration to be used for the thermal runaway test scenarios that will address possible fire events in representative check-in baggage of passenger aircrafts.

→ Different baggage configurations including PEDs, power banks and/or spare batteries, together with other representative checked-in baggage content (e.g. clothes, permissible liquids and/or aerosol cans) will be tested until PEDs in thermal runaway are able to create a sustained internal fire that may propagate outside the baggage



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SCENARIO 2: Compartment floor

- The objective of this test is to investigate the scenario in which fire starts from a piece of baggage that is not directly exposed to the extinguishing agent discharged in the compartment.
- The thermal runaway occurs inside the baggage located on the floor in the middle of the compartment and which is fully hidden below other baggage items with similar PED battery loadings.
- The extinguishing agent shall be released inside the compartment after a timeframe that is established with the objective to simulate the sequence of events that would occur in an actual cargo fire scenario, from the time at which fire detection occurs and a warning is provided to flight crew to the implementation of the cargo fire emergency procedure.

SCENARIO 3: Compartment ceiling

→ The objective of this test is to evaluate the scenario in which the fire starts in a point as close as possible to the ceiling level and as far as possible from the fire suppression system nozzle(s). This scenario is critical for the effectiveness of the fire suppression system considering the stratification of Halon 1301.

→ The thermal runaway occurs inside a baggage located in one corner of the mock-up as close as possible to the ceiling considering the typical limitations to the maximum loading height for cargo compartments of large aeroplane (ref. paragraph 12 of AMC 25.851(b)).

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SCENARIO 4: ULD (container)

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- The objective of this test is to investigate the scenario in which fire starts from a piece of baggage that is not directly exposed to the extinguishing agent because it is placed inside a standard ULD container.

- Three LD-3 containers will be used for this test and arranged like the containerized scenario in the MPS. A minimum set of 6 baggage units having the configuration determined in scenario 1 will be placed inside the middle container. Dummy load will be used to fill up the whole container.

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SCENARIO 5: Multiple Fuel Fire Scenario

- The intent of these tests is to ensure that Class C cargo compartment fire suppression systems can address a fire event developing from a complex fire load.

- The fire load for the Multiple Fuel Fire scenario consists of materials that when combusted produces a complex fire (i.e., after ignition, the resulting fire consists of Class A surface burning, Class B flammable liquid fire, and thermal runaway of some lithium cells).

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SCENARIO 6: Halon Replacement

→ Show that a candidate replacement agent can pass the cargo MPS, including the Multiple Fuel Fire scenario.

Only MFF with Nitrogen

Test Scenario
Surface burning & Halon 1301
Bulk load & Halon 1301
Containerized & Halon 1301
Multiple Fire Test & Halon 1301
Multiple Fire Test & Halon replacement agent
Surface Burning & Halon replacement agent
Bulk Load & Halon replacement agent
Containerized & Halon replacement agent

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SCENARIO 7: Involvement of a bulk shipment of cells/batteries in an external fire event

CANCELLED

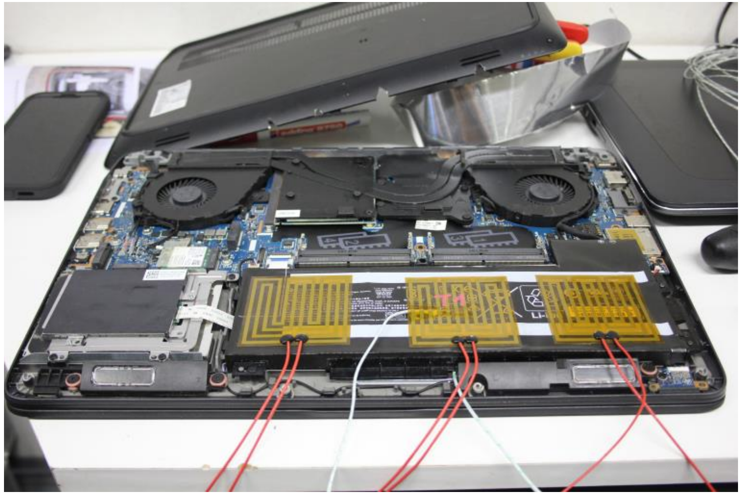
- The objective is to perform a series of tests to assess the external fire threat on the packaging solution used for the transport as cargo of lithium cells/batteries (other than 18650 cells).
- Assess fire suppression and non-propagation aspects with and without additional mitigating measures (e.g. FCCs) protecting the cell/batteries.

Timeline

- → September 2021 : project start
- → October 2022: interruption of testing activities at DLR
- → June 2023: restart of communication with DLR
  - → Maintenance on the test chamber and test equipment
- → June 2024: restart of testing activities at DLR:
  - → Unsuppressed MFF tests (fire scenario 5)
  - → Baggage calibration test (fire scenario 1)

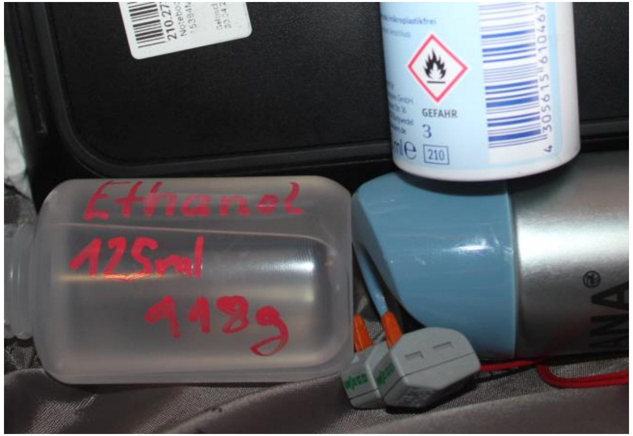
Baggage Calibration (Fire Scenario 1)

→ The objective of this test is to define a representative single baggage configuration to be used for the thermal runaway test scenarios that will address possible fire events in representative check-in baggage of passenger aircrafts.

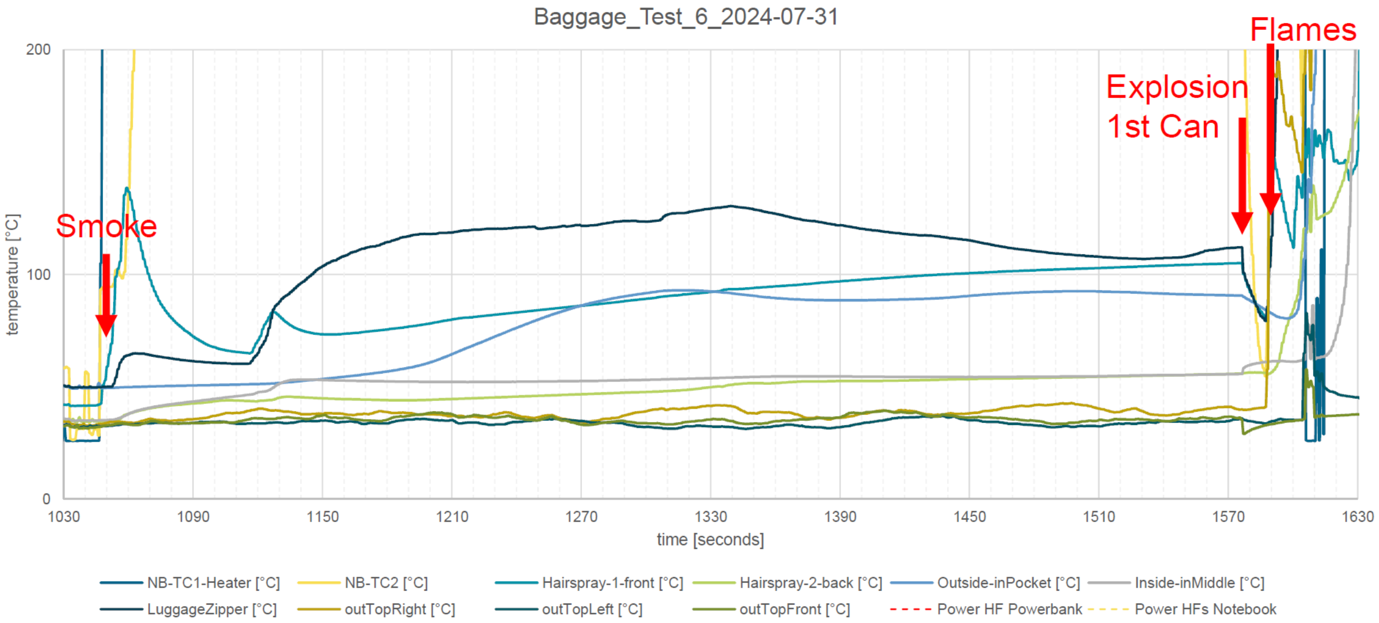


Baggage Calibration (Fire Scenario 1)

- 6 calibration tests already performed
- Thermal runaway initiated on a laptop battery (pouch cells, 100 Wh) not sufficient to achieve propagation outside the box
- Flame propagation outside the baggage was achieved only when aerosol cans (containing flammable gases) were placed adjacent to the laptop battery
- Aerosol can testing in the MPS chamber resulted in an explosion that damaged the chamber door



Baggage Calibration (Fire Scenario 1)



Baggage Calibration (Fire Scenario 1)

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Baggage Calibration (Fire Scenario 1)

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Baggage Calibration (Fire Scenario 1)

- New calibration tests will be performed using an artificial fire source based on the UL5800 definition
- No aerosol cans in the initiation baggage
- Fire Scenarios 2 and 3 will be run with aerosol cans and power banks inside bags located in the periphery of the fire load.
- The objective of the tests will be to demonstrate that Halon 1301 can stop fire propagation from the initiation baggage

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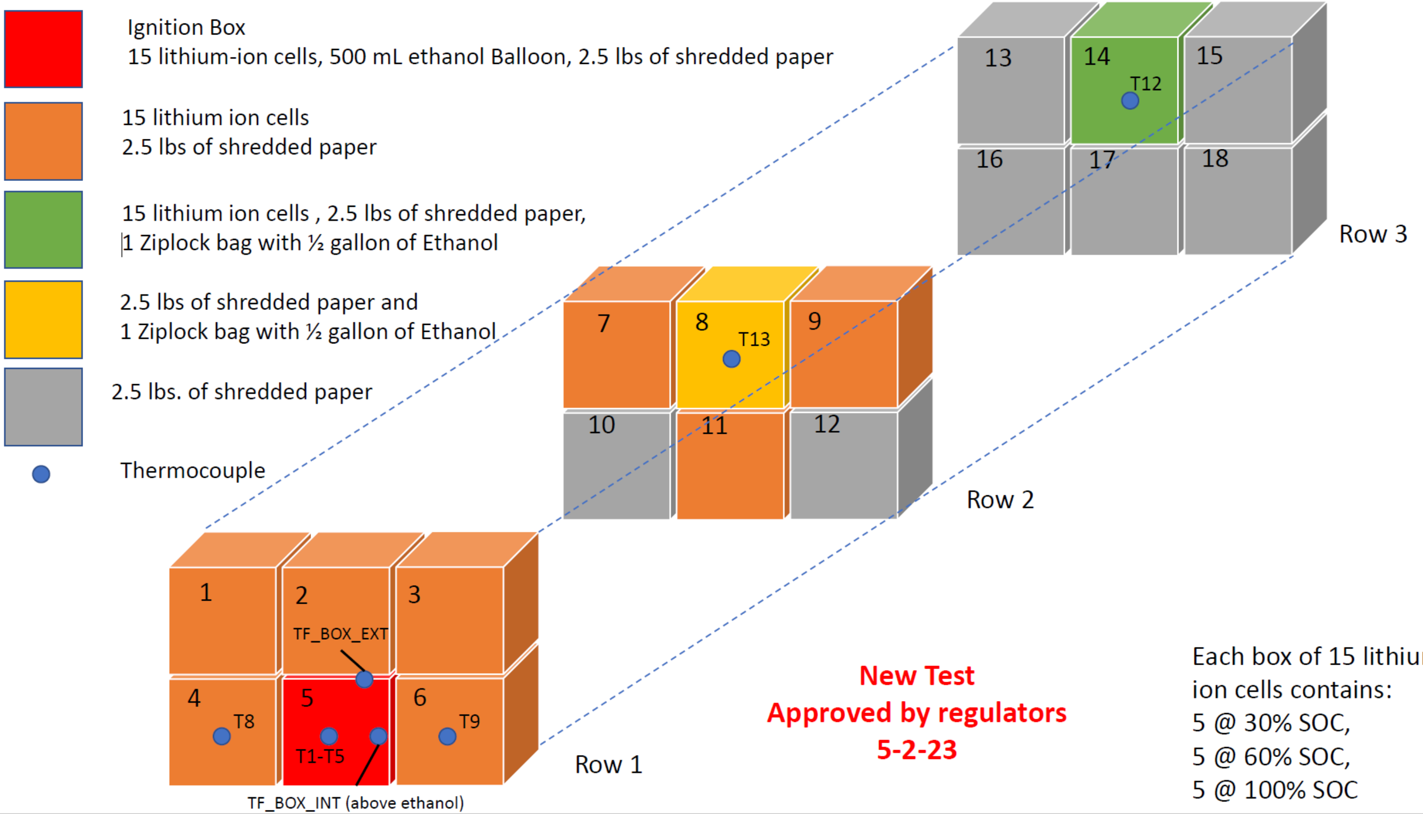
Multiple Fuel Fire (MFF) Test

SCENARIO 5: Multiple Fuel Fire Scenario



New Test
Approved by regulators
5-2-23

Each box of 15 lithium ion cells contains:
5 @ 30% SOC,
5 @ 60% SOC,
5 @ 100% SOC

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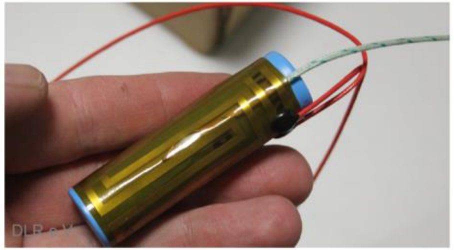
Unsuppressed MFF Test

Test Set-Up

18650 Cells

Heating foils and TCs on two cells with 60 % SoC	Cells held together with tape and free space filled with cardboard	Cells placed in cardboard box with 2 additional TCs (red dots)



- In each box 5x 100 % SoC, 5x 60 % SoC, 5x 30 % SoC as in Halon Handbook Draft 3
- Polymide foil heaters 60 x 60 mm, 48 Watts
- TC1 and TC2 attached beneath film heaters, TC3 and TC4 attached to adjacent cells

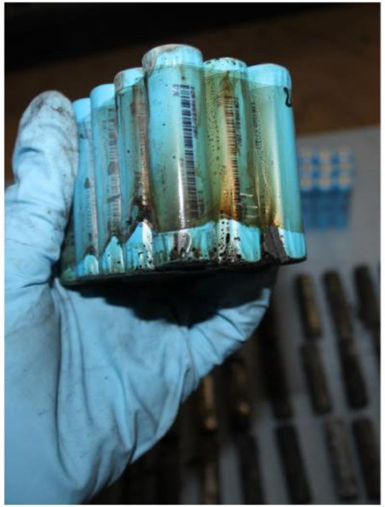
Unsuppressed MFF Test

Inspection of fire damage

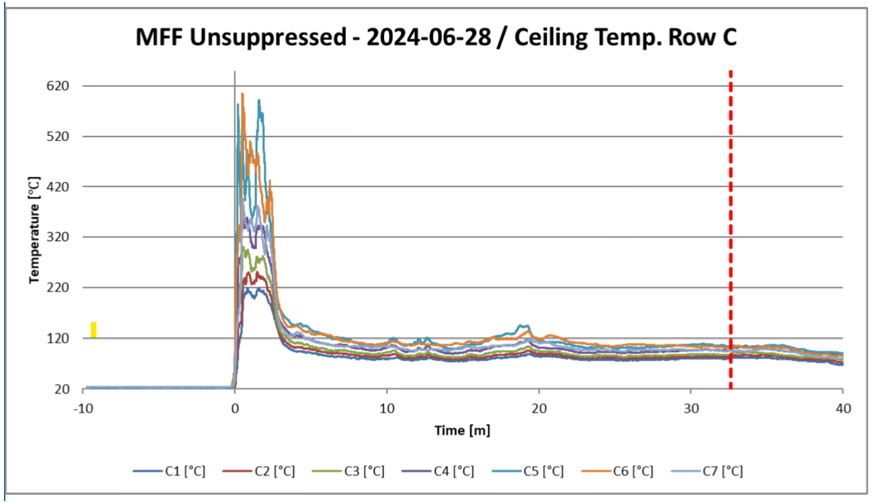
Unsuppressed MFF Test

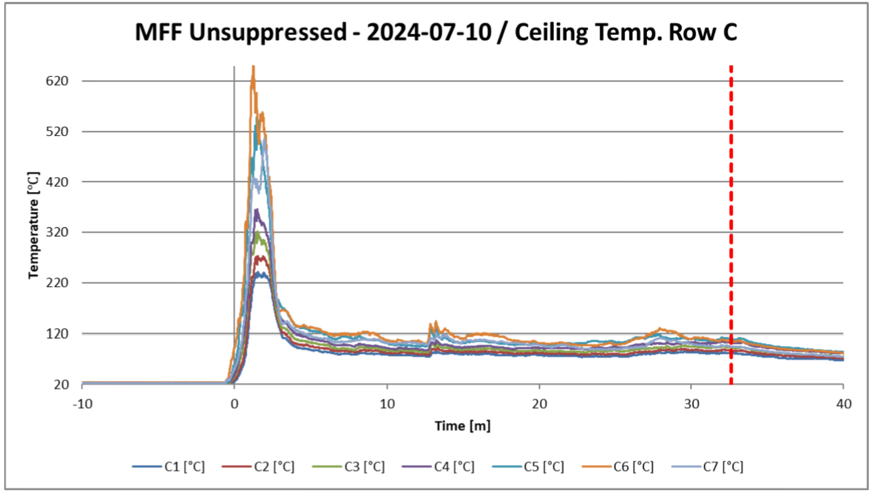
Inspection of fire damage

- 4 cells missing
- 3 small boxes (from box 14, 7 and one unknown) with each 15 cells unburned

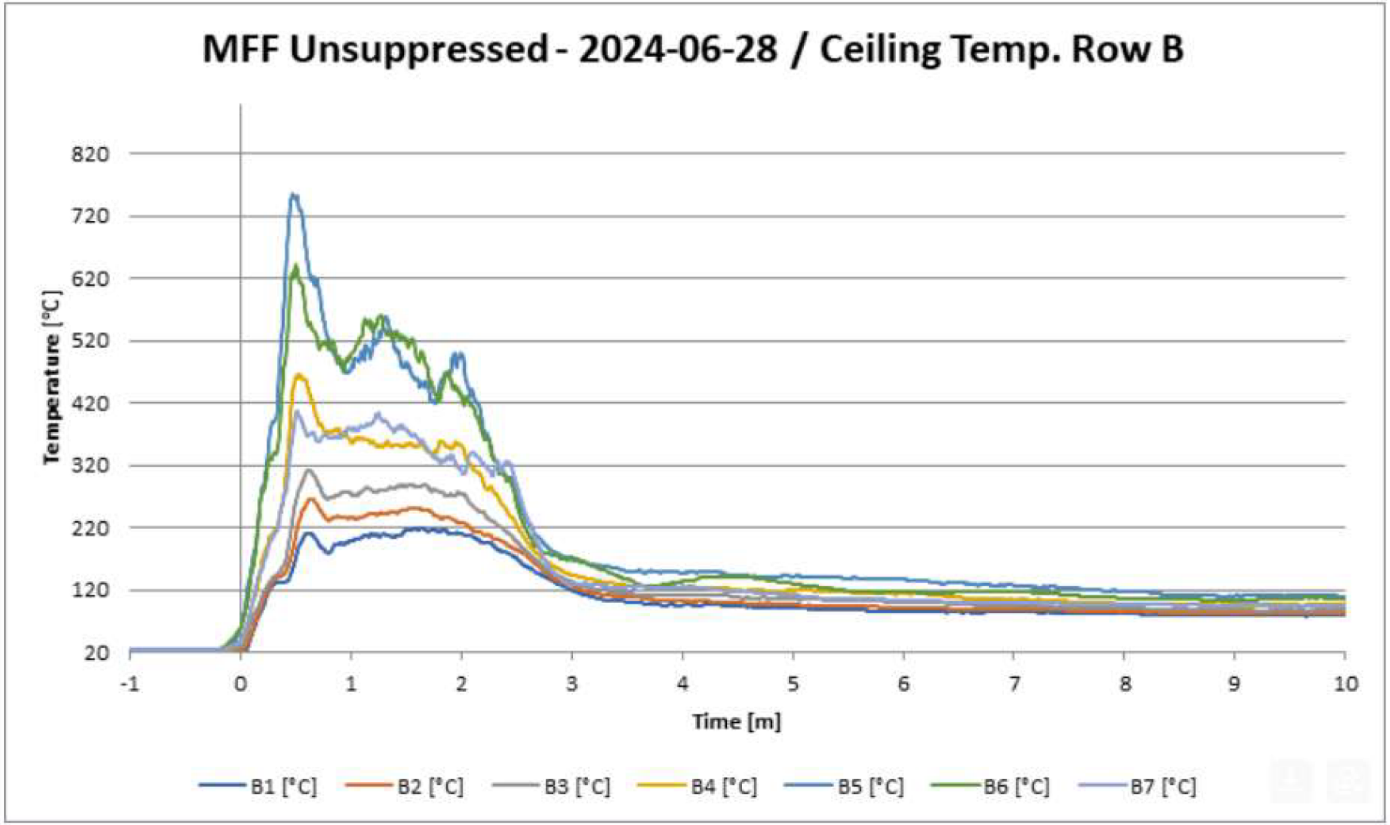


Unsuppressed MFF Test





Unsuppressed MFF Test



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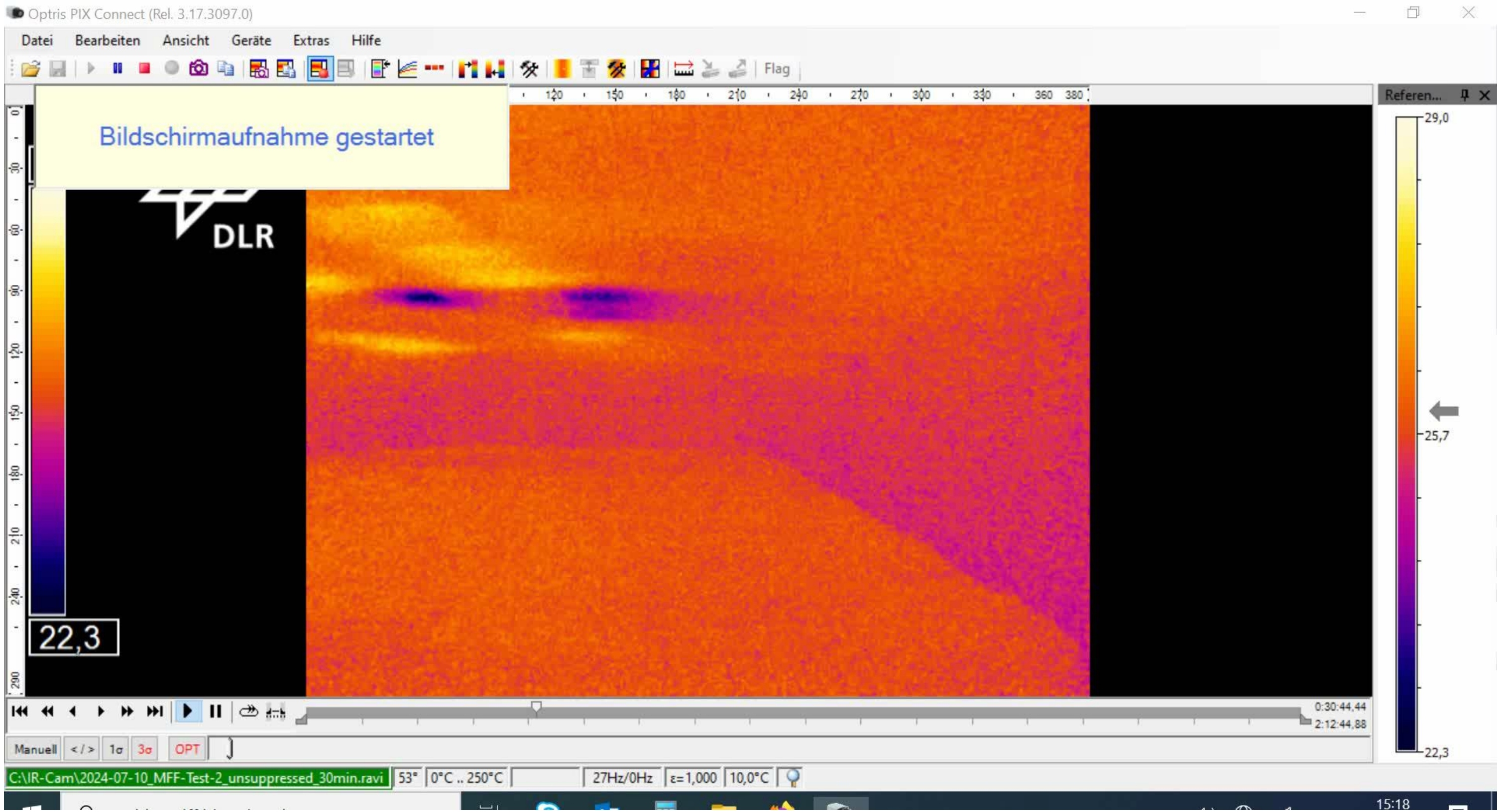
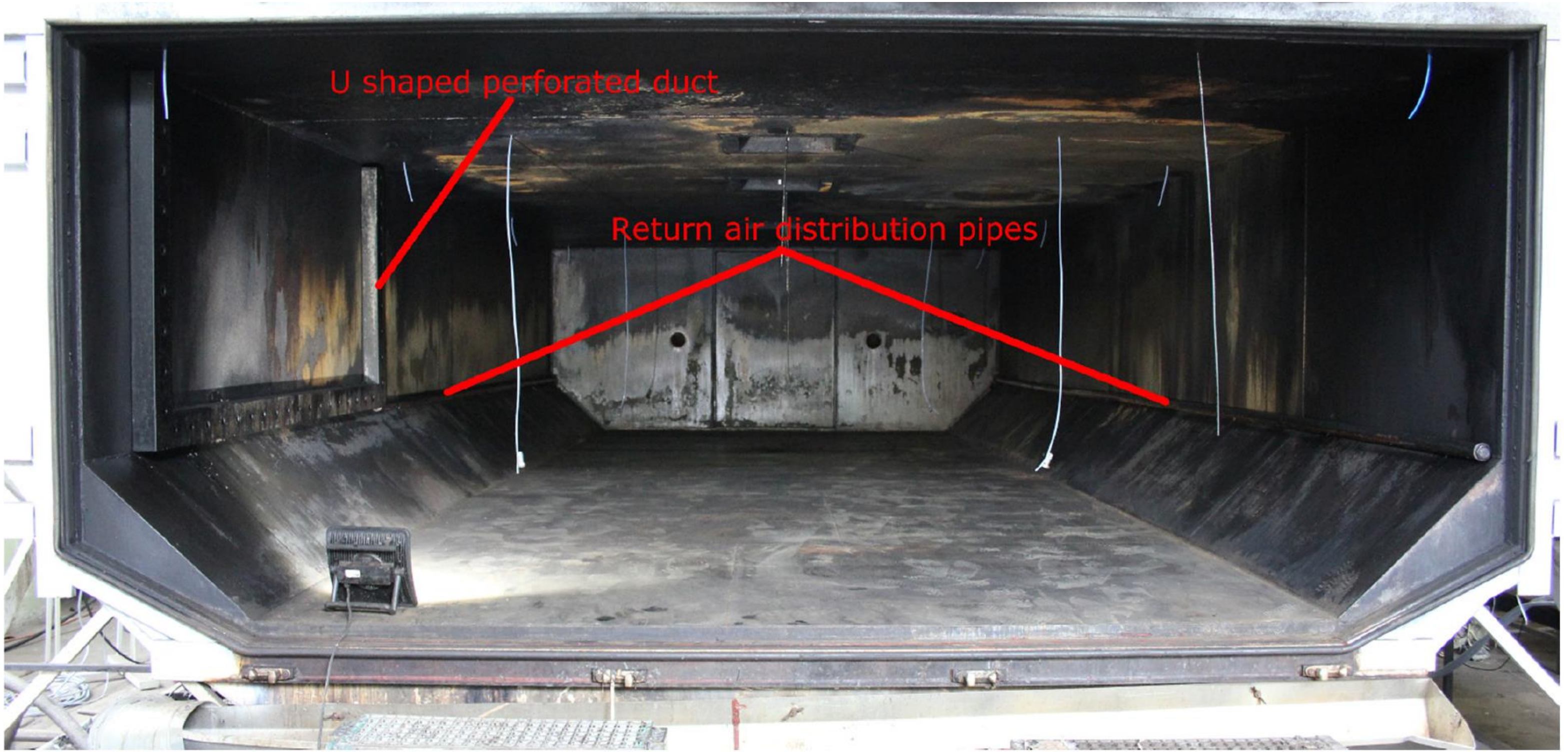
Unsuppressed MFF Test



Test Chamber Ventilation System



AirPED Test Chamber Ventilation System

This procedure is based on the test data recovered from the fire test performed within the AirPED project in 2022.

1. Close cargo compartment access doors.
2. Close return air valve for fresh air distribution.
3. Switch on gas analyzing pumps.
4. Blow in compressed air with a total mass flow of 1400 slpm (~23.3 slps).
5. Start and adjust leakage pump settings to compensate the overpressure build up inside the test cell. The pressure in the cargo bay should now be the same as the ambient pressure.
6. Open inlet air valve of the return air ducting. Ideally this shall be draft free during leakage calibration with correct pump settings.
7. Stop compressed air flow into the test cell. A negative pressure will establish itself due to the airflow resistance of the return air ducting.
8. The leakage rate is now calibrated.

Test Chamber Ventilation System

180-Minutes Bulk-Load with Halon (30th May)

AirPED Test Chamber Ventilation System

- Blocking was found, because leakage calibration for the last 30-minutes BL test with Halon failed (4th June)
- Leakage pipes were not cleaned before end of 180-minutes test (one containerized and one bulk load tets, both with halon, were conducted before)
- As a leassons learned, pipe are now investigated cleaned after each test
- Clogging seems to be worse with Halon tests (A cooling effect of smoke gases?)

MFF Tests results

- The first two Unsuppressed MFF tests were not considered sufficiently severe to allow the assessment of the performance of an agent
- Leakage tests using N2 did not reveal any issue with meeting the leakage levels specified in the MPS
- Two options were considered:
  - Increasing airflow into the chamber during the test
  - Increasing the criticality of the fire load (e.g. increased SOC of the lithium cells)

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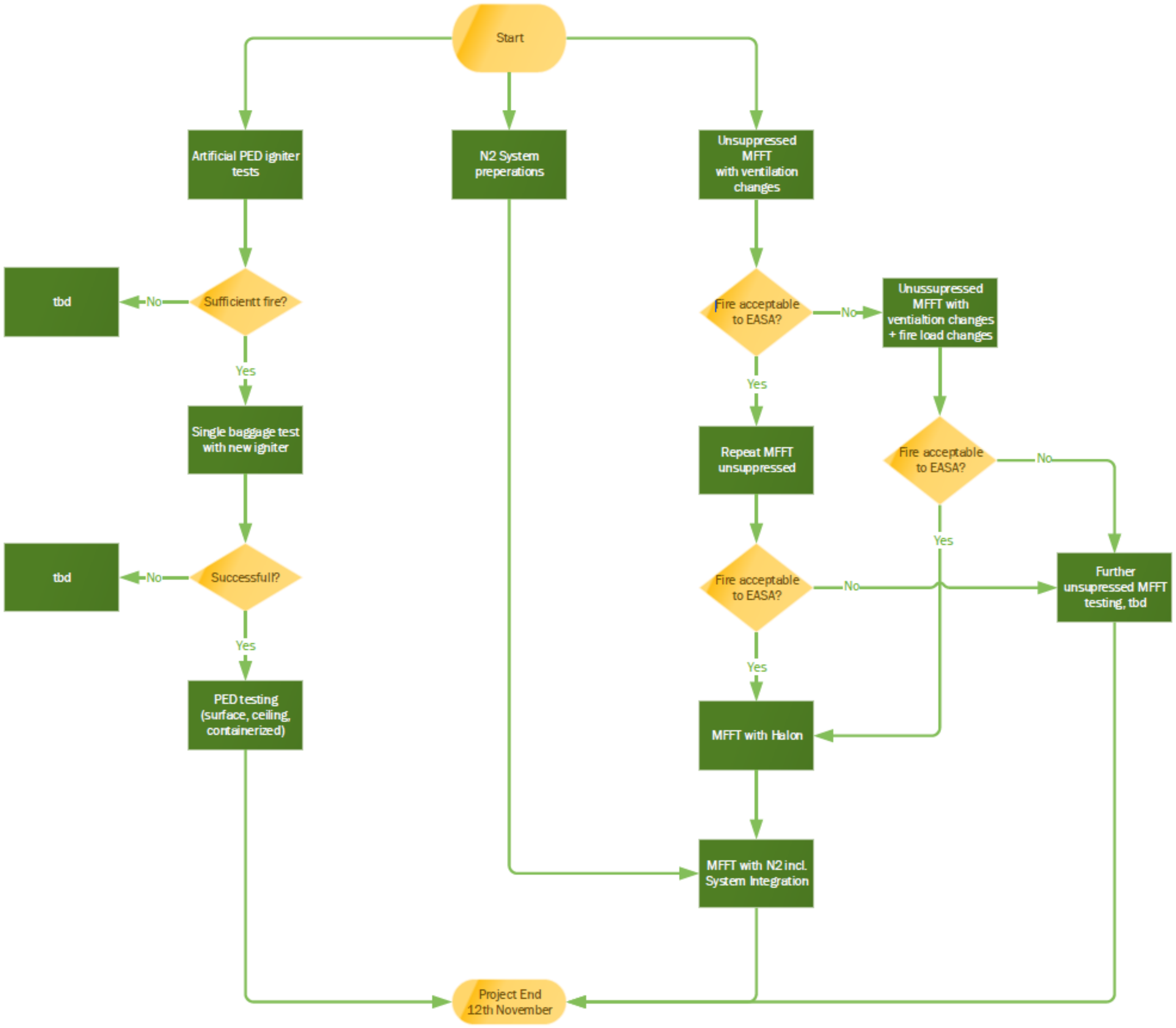

Start
Artificial PED igniter tests
N2 System preperations
Unsuppressed MFFT with ventilation changes
tbd
No
Sufficientt fire?
Yes
Single baggage test with new igniter
tbd
No
Successfull?
Yes
PED testing (surface, ceiling, containerized)
Fire acceptable to EASA?
No
Unussupressed MFFT with ventialtion changes + fire load changes
Yes
Repeat MFFT unsuppressed
Fire acceptable to EASA?
No
Yes
Further unsupressed MFFT testing, tbd
Fire acceptable to EASA?
No
Yes
MFFT with Halon
MFFT with N2 incl. System Integration
Project End 12th November

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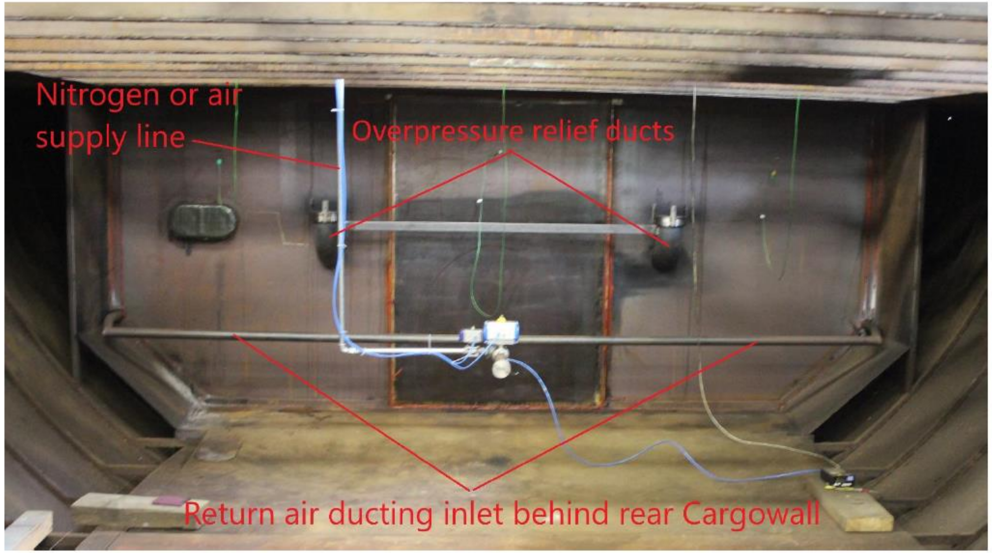
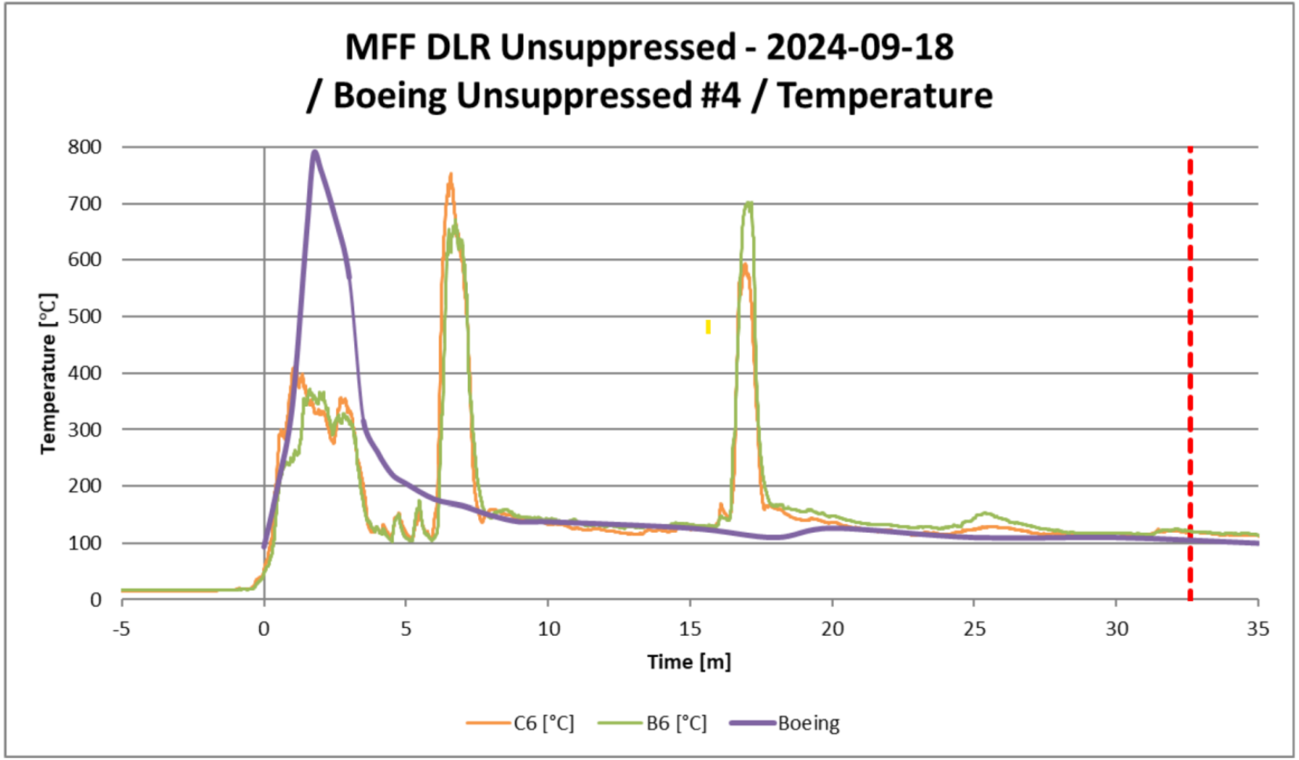
New calibration procedure



1. Close cargo compartment access doors.
2. Close return air valve for fresh air distribution.
3. Open air supply line valve.
4. Switch on gas analyzing pumps.
5. Introduce compressed air with a total mass flow of 1400 slpm (~23.3 slps) over the injection line into the return air ducting. The mass flow will be set using a mass flow controller.
6. Start and adjust leakage pump settings to compensate the overpressure build up inside the test cell. The pressure in the cargo bay should now be the same as the ambient pressure.
7. The leakage rate is now calibrated.

Unsuppressed MFF



Boeing test data are taken from the report published on the FAA Fire Safety Branch website “A Comparison of Suppressed and Unsuppressed Multiple Fuel Fires with Verdagent and Halon”.

Unsuppressed MFF

Boeing	unsuppressed	MFF
	TTI [°C*min] 3-31min	PeakT [°C]
	4462,222	569

AirPed Data	unsuppressed	MFF
run	TTI [°C*min] 3-31min	PeakT [°C]
1	3305,105	175,517
2	3232,599	184,149
3	4736,228	753,473

Boeing test data are taken from the report published on the FAA Fire Safety Branch website "A Comparison of Suppressed and Unsuppressed Multiple Fuel Fires with Verdagent and Halon".

Project Status

- Task 1 is pending finalization of unsuppressed fire test scenarios

- Task 2 and Task 3 are on-going. Activities performed since January 2024:
  - unsuppressed fire test scenarios (issues with the Multiple Fuel Fire scenario)
  - Halon 1301 fire suppression system calibration tests

- Fire scenario 6 (replacement agent): test with N2 only the MFF scenario

- All fire test scenarios to be run by 12 November 2024

- Final report and project deliverables due by the end of Q4 2024

MPS update

- Impact on the MPS (to be further discussed with the MPS Task Group):
  - Conducting unsuppressed tests should be required by the MPS
  - Define minimum conditions for the acceptance of the results of unsuppressed fire tests
  - allow testing in conditions that are more severe than the ones specified in the MPS to increase the level of severity of the unsuppressed fire events

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Any Questions ?

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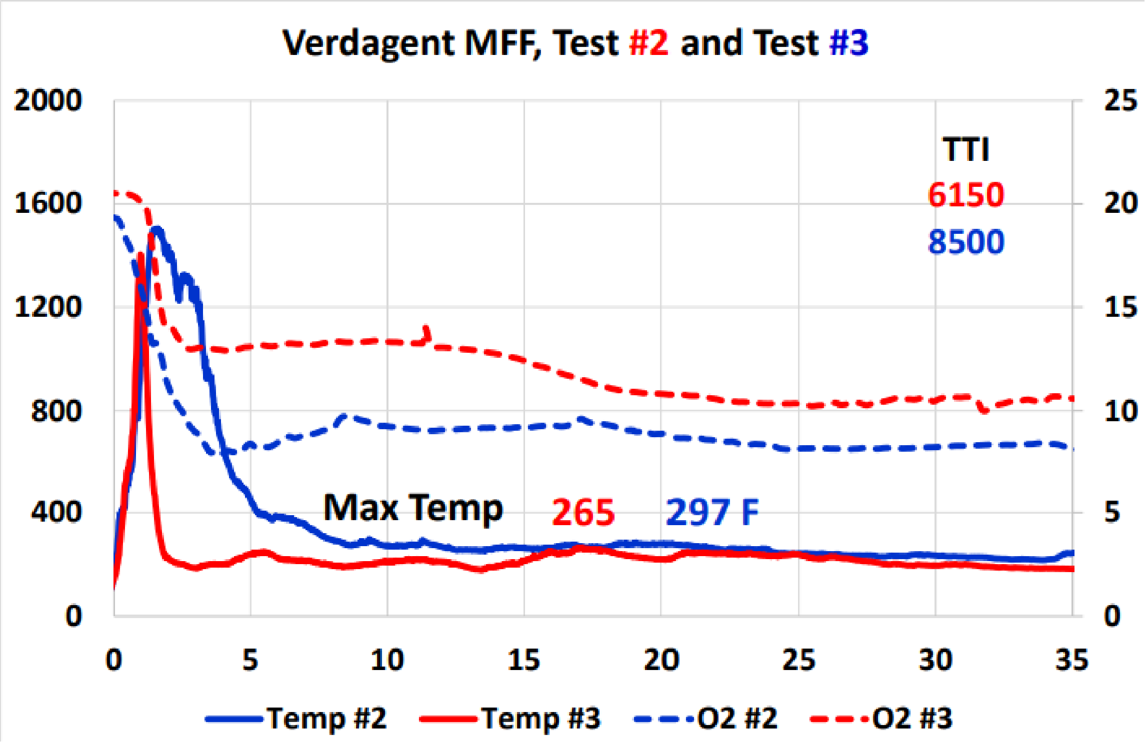
AirPED Unsuppressed fire test scenarios

→ MFF test performed by Boeing

Suppressed
And
Unsuppressed
Multiple Fuel Fire



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