Handheld Extinguisher Toxicity Update

Presented to: International Aircraft Systems Fire Protection Forum Meeting

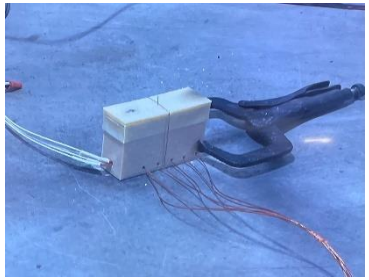
By: Natallia Safronava, Robert Morrison, Timothy Marker

Date: FAATC, October 18-19, 2023

Federal Aviation Administration

Outline

- Project motivation and the timeline.
- Instrumentation and test compartment setup.
- Test details.
- General toxicity guidelines.
- TC data for recent water pour tests.
- Toxicity data (HF) for 18650 tests (all 4 agents).
- Summary



Motivation

Evaluate the difference in thermal and toxic hazards of handheld extinguishing agents used on Lithium-Ion battery fires in small compartments.

Agents:

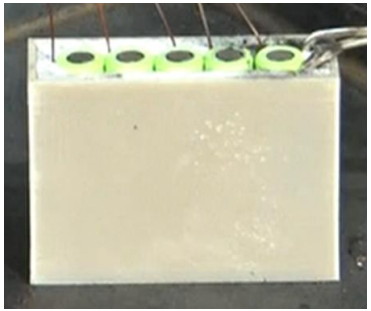
- Halon 1211
- Halotron BrX (stabilized 2-BTP)
- Water (2 x 0.5L bottles)
- Water Extinguisher

Batteries:

- 18650
- Pouch cells

Testing timeline

- Phase 1- Summer 2022, 18650 5 cells pack
  - No agent/baseline -3 tests
  - Halon 1211-3 tests
  - 2-BTP- **5** tests
- Phase 2- December 2022, Pouch 3 cells pack
  - No agent/baseline -3 tests
  - Halon 1211-3 tests
  - 2-BTP- **7** tests

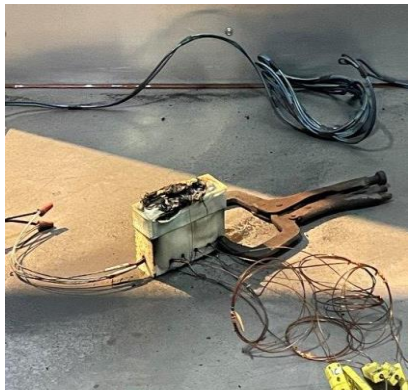


****Novec 1230 was considered until December 2022 when 3M announced they were pulling forever chemicals off the market.*

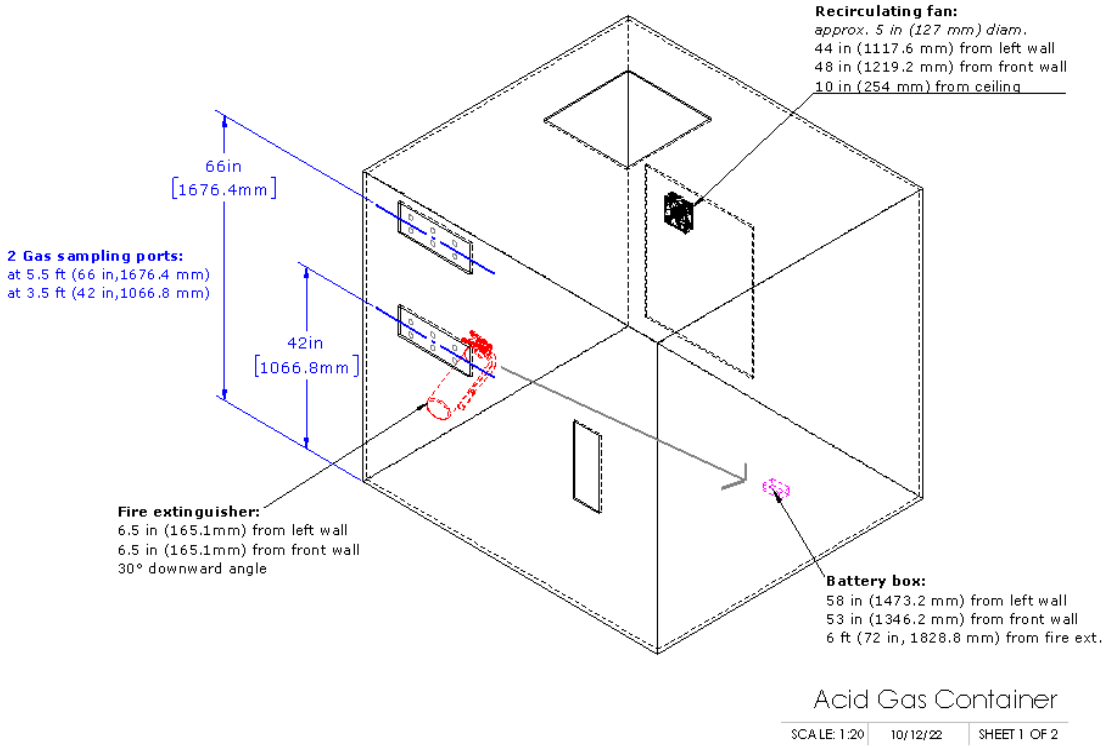
- Phase 3- Summer/Fall **2023**, Additional agents (water/ water extinguisher)
  - Pouch, baseline – 2 tests
  - Pouch, water pour- 3 tests
  - Pouch, water extinguisher- 3 tests (* still in progress)
  - 18650, water pour – 6 tests
  - 18650, water extinguisher- 3 tests

Instrumentation

- Multiple TC
- NDIR gas analyzers: CO, CO_2, O_2 and Halocarbon.
- Acid gas sampling assembly
- Dionex Integrion Ion Chromatograph (IC) with AS15 column. Ion chromatography (IC) method described in FAA report https://www.fire.tc.faa.gov/pdf/dot_66039_DS1.pdf

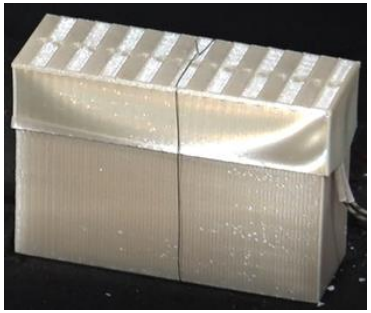


Test Compartment



- ❑ 240 ft^3 volume (flight deck)
- ❑ NO air exchange
- ❑ Battery box on the floor
- ❑ Fire extinguisher 5 feet away from battery box
- ❑ Small fan on the ceiling
- ❑ Two (2) heights form gas sampling/ Temp
- ❑ Temp, CO, CO_2, Agent data collection started @ heater initiation
- ❑ Acid gases data collection @ fire extinguisher discharge

Test details



- 3D printed battery case **+ lid** using thermoplastic material
- **Five (5)** 18650 Li-ion batteries were each fitted with a type-K thermocouple.
- The right most cell was fitted with the cartridge heater, rate **15°C/minute**
- Agent introduced after thermal runaway propagated to the **3rd cell**.

- 3D printed battery case using thermoplastic material
- **Three (3)** pouch Li-ion batteries were each fitted with a type-K thermocouple.
- The right most cell was fitted with the cartridge heater, rate **15°C/minute.**
- Agent introduced when the **1st cell** ignited.

** For water/ water extinguisher test series (2023) agent was introduced when **2nd** pouch cell ignited to ensure propagation.*

Hazard Levels for Gases

Acute Exposure Guideline Levels (AEGLs) 10 minute (CO, HF, HBr, HCl)

- **AEGL 2**: Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- **AEGL 3**: Life-threatening health effects or death

Cardiac Arrhythmias: (Halon 1211 & 2-BTP) 5-minute exposures.

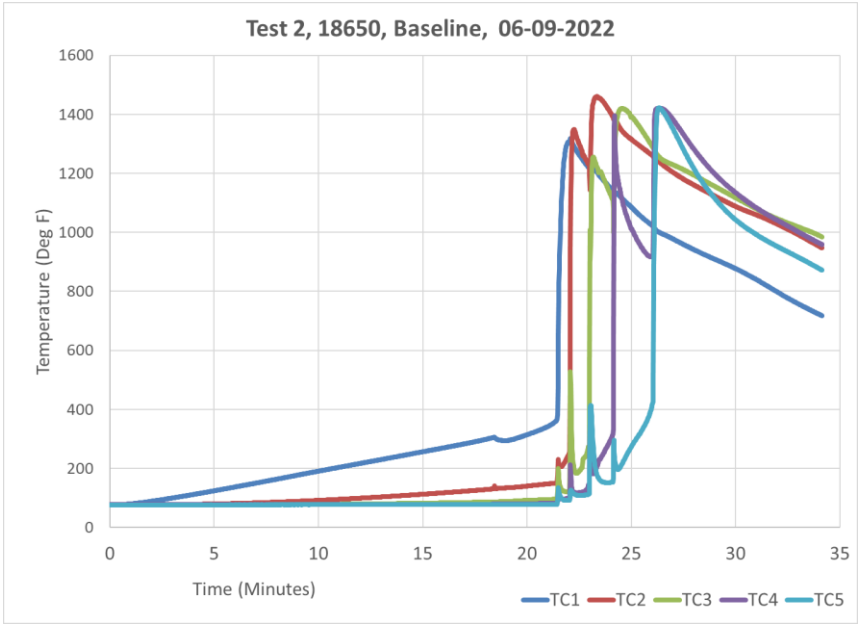
- No Observable Adverse Effect Level (NOAEL)
- Safe-use concentrations
- Lowest Observable Adverse Effect Level (**LOAEL**)

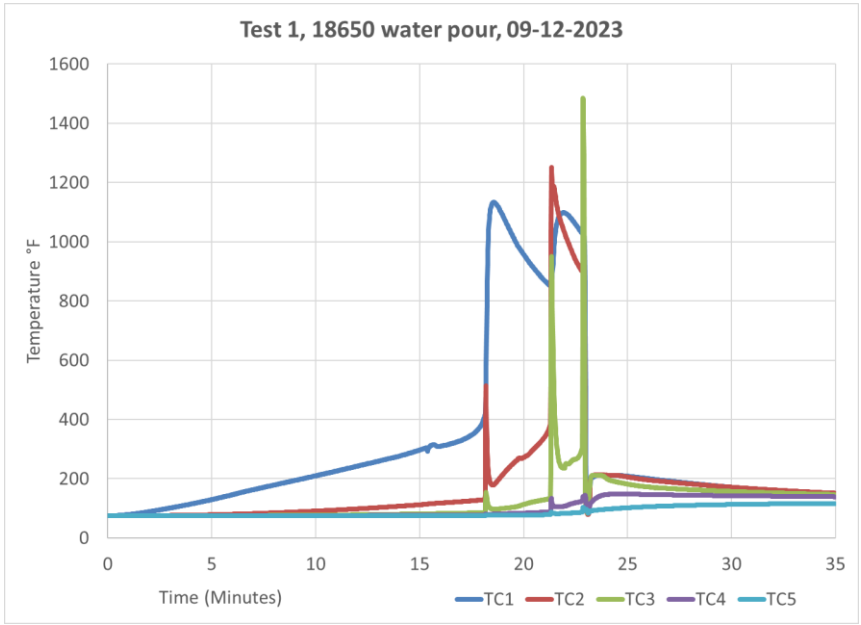
Toxicity assessment

Hazard Level (10 min.)	**HF** (ppmv)	**HCl** (ppmv)	**HBr** (ppmv)	**CO** (ppmv)	**Effect**
AEGL2	95	100	250	400	Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
AEGL3	170	620	740	1,700	Life-threatening health effects or death

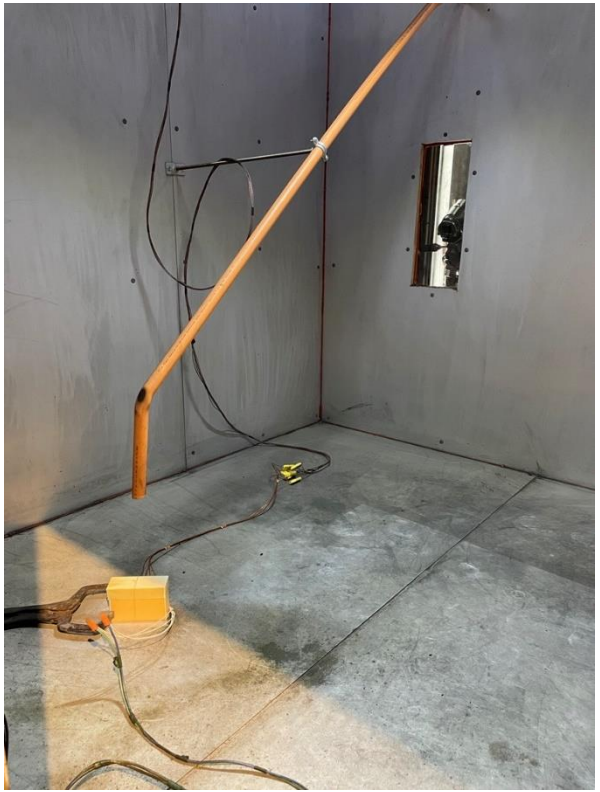
Hazard Level (5 min.)	**Halon 1211** (percent)	**2-BTP** (percent)	**Effect: Atypical heartbeats**
NOAEL	0.5	0.5	No dogs affected
Safe Use	___	0.95	No effect is predicted for humans
LOAEL	1.0	1.0	Lowest observed number of dogs affected

Water pour results (18650 cells)

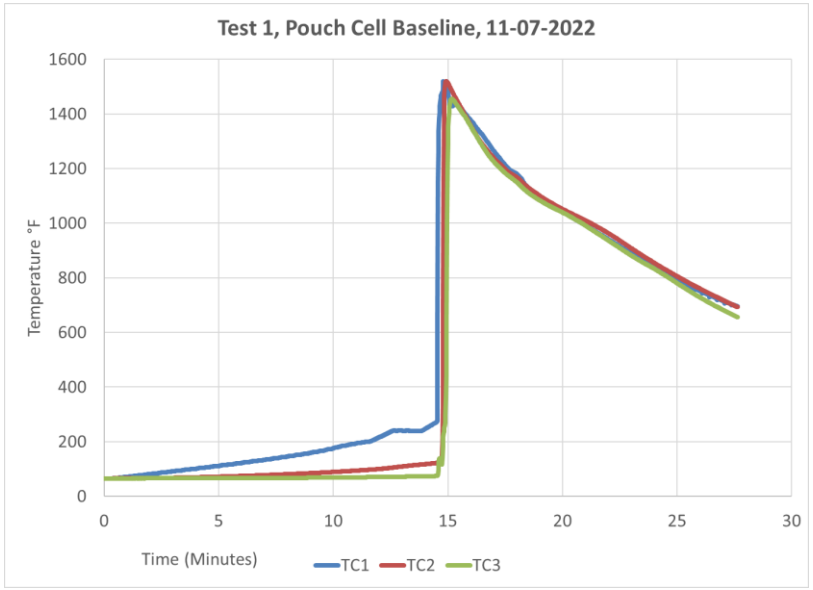


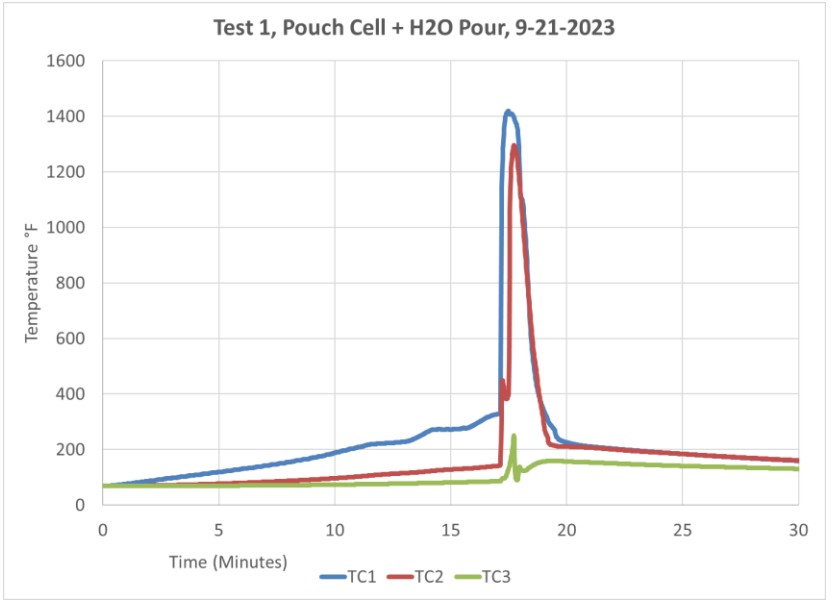


Cells propagation stops immediately @ water pour



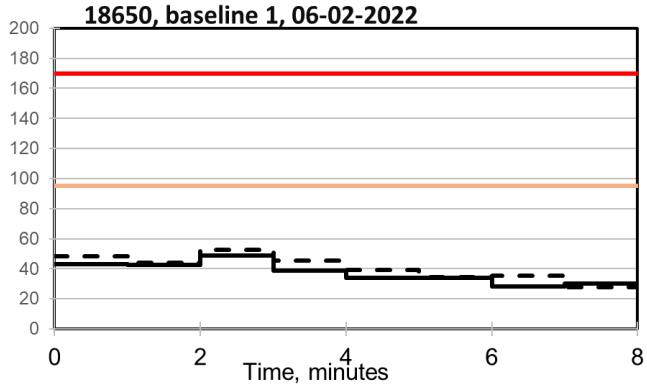
Water pour results (pouch cells)

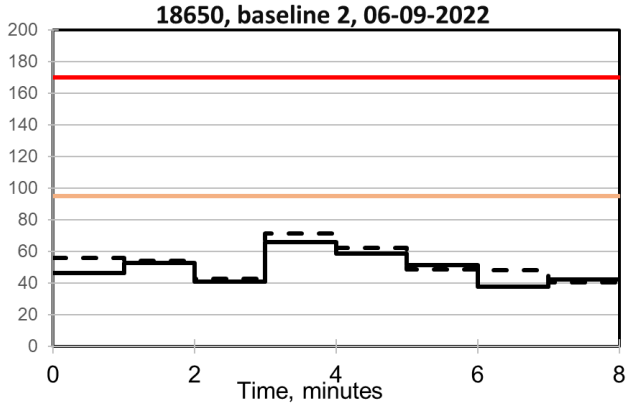


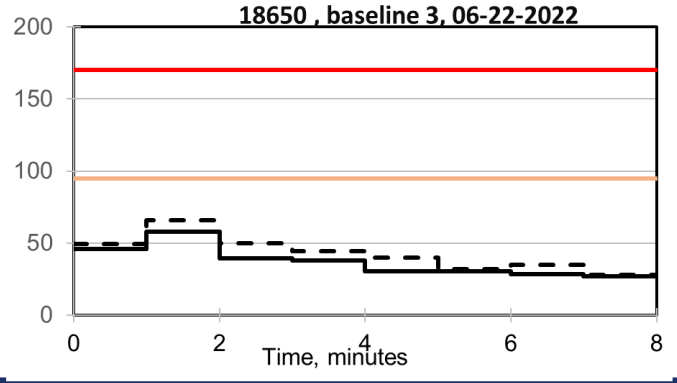


Cells propagation stops immediately @ water pour (^{2nd} cell)

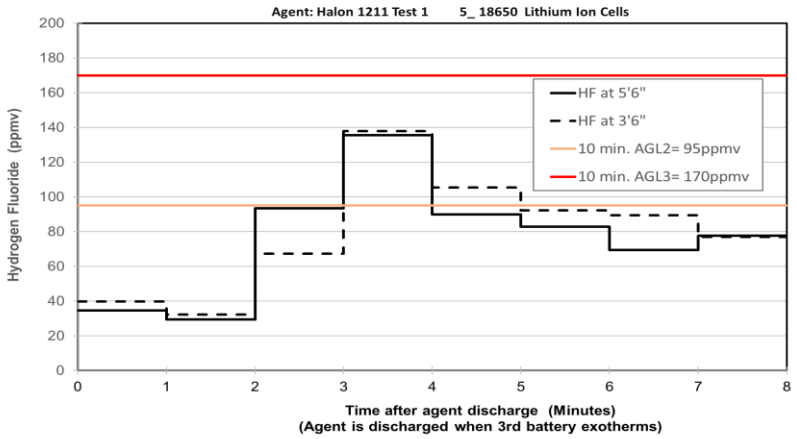
HF values, 18650 cells, baseline

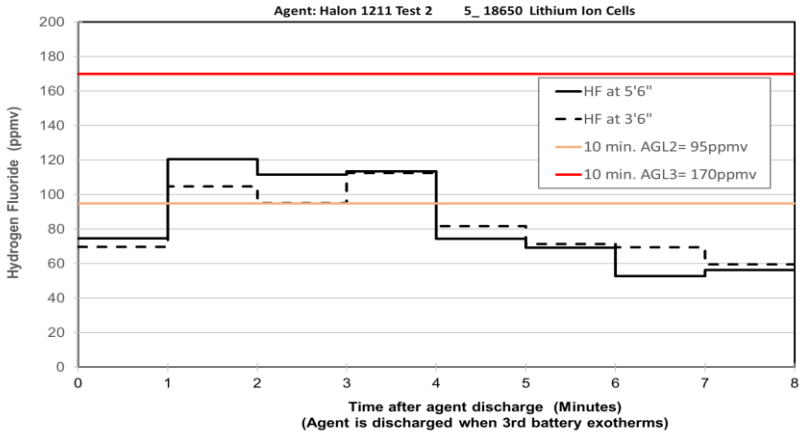


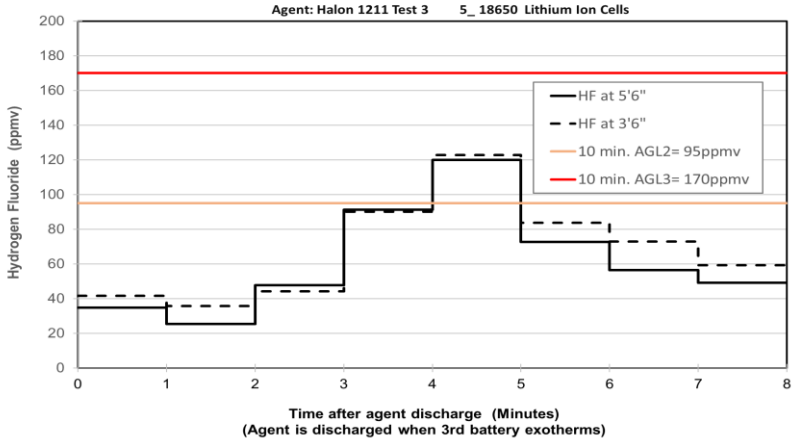




Average values for HF were in the range of **40-65 ppmv** for 5 pack 18650 cells

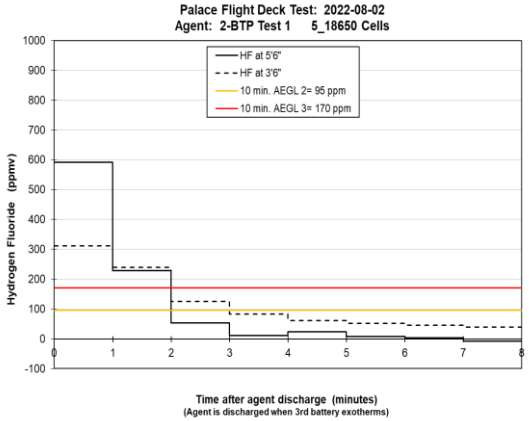


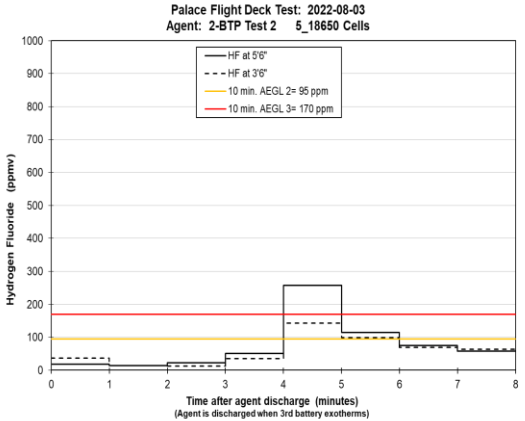


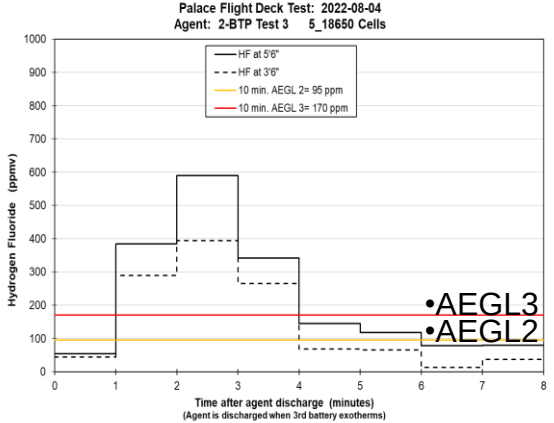


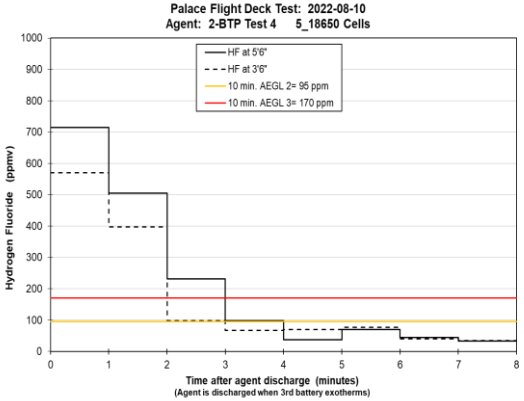
HF, Halon 1211

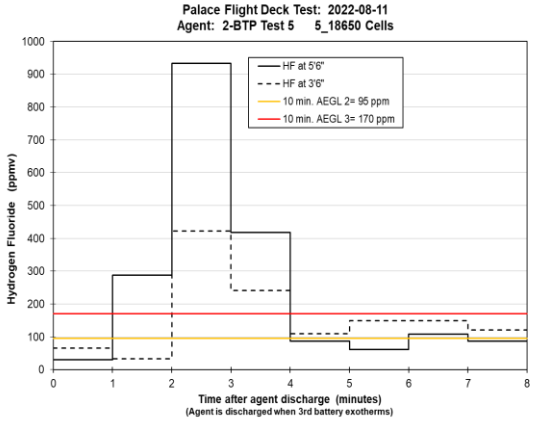
Peak concentrations HF exceed AEGL2 for a few minutes during the tests





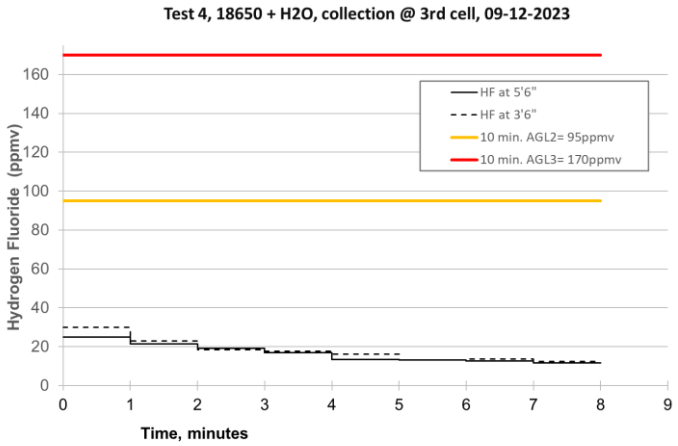


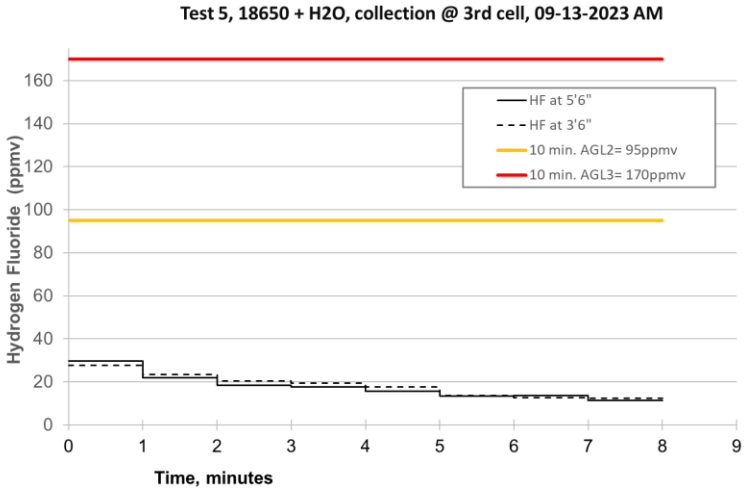


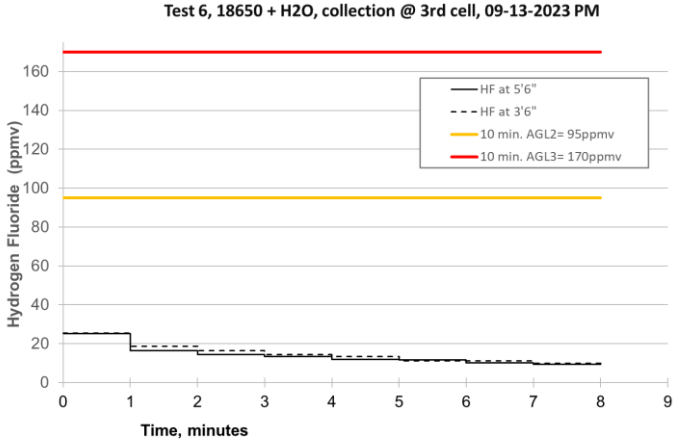


HF, 2-BTP

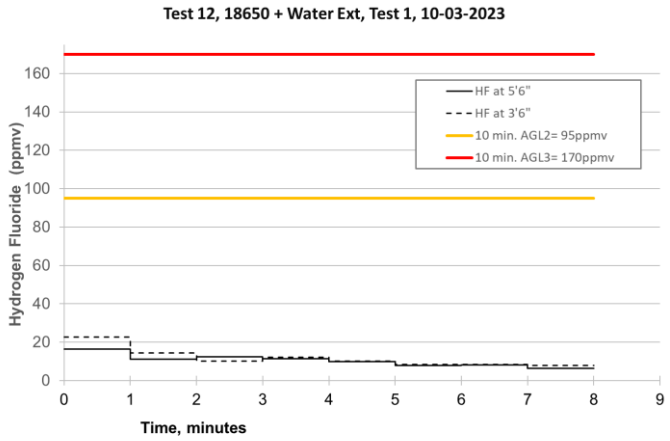
- Note scale
- Peak concentrations HF exceed AEGL3 for a few minutes

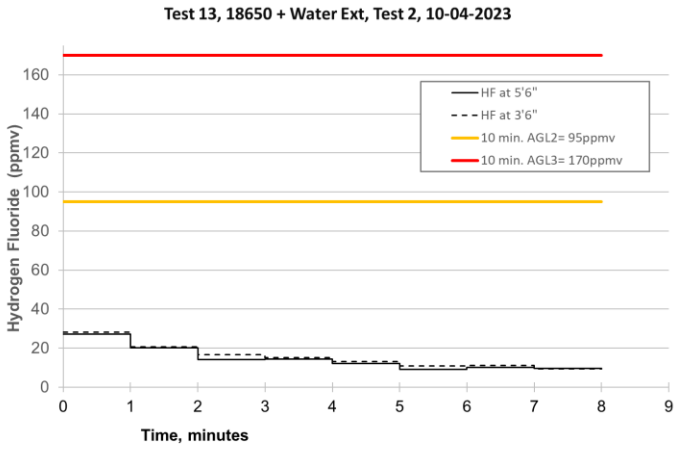


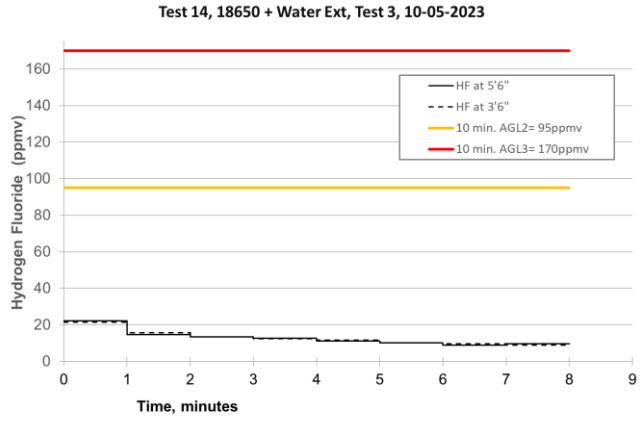




HF values (max = 30 pppv) @ the start of acid gas collection for 18650 5 pack cells Water pour tests.







HF values (max = 28 pppv) @ the start of acid gas collection for 18650 5 pack cells Water Extinguisher tests.

Summary

- Project scope was expanded by including the water pour (2 x 0.5L bottles) and water extinguisher to compare to Halon 1211 and Halotron BrX applied for 18650 and pouch cells.
- Water and water extinguisher were effective in stopping the cells propagation. Toxicity numbers were lower comparing to the previous agents.
- **Next steps:** complete final FAA report to summarize all the testing for different agents and 2 types of cells (pouch and 18650).

Contact info

Natallia Safronava

Natallia.i.safronava@faa.gov

FAATC reports:
https://www.fire.tc.faa.gov/Reports/reports.asp