

The background of the slide features the official seal of the Federal Aviation Administration (FAA). The seal is circular, with a blue outer ring containing the words "FEDERAL AVIATION ADMINISTRATION" in white. Inside the ring is a green globe with a white grid of latitude and longitude lines. A white eagle with its wings spread is superimposed over the globe, facing right. The eagle's body is white, and its wings are detailed with feather patterns.

Toxic Hazards of Hand Extinguishants used on Lithium Battery Fires in Flight Decks

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<http://www.fire.tc.faa.gov>

***10th Triennial International Aircraft Fire and Safety
Research Conference***

***Atlantic City, New Jersey
October 20, 2022***



Motivation

Evaluate the [difference](#) in thermal and toxic hazards for Lithium Ion battery fires using [Halon 1211](#) and [Halotron BrX](#) (stabilized 2-BTP) hand extinguishers in flight decks.

Gases of concern:

- CO, CO₂
- HF, HCl, HBr
- Halon 1211, 2-BTP



Hazard Levels for Gases

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

(Includes sensitive populations)

- **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.

HF > 200ppm:

- **Mouth breathing starts:** More direct path to the lung. Toxicity of all acid gases is enhanced

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

(Includes sensitive populations)

- **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

The AEGL Technical support document for each gas describes the data-driven basis for these levels: <https://www.epa.gov/aegl>

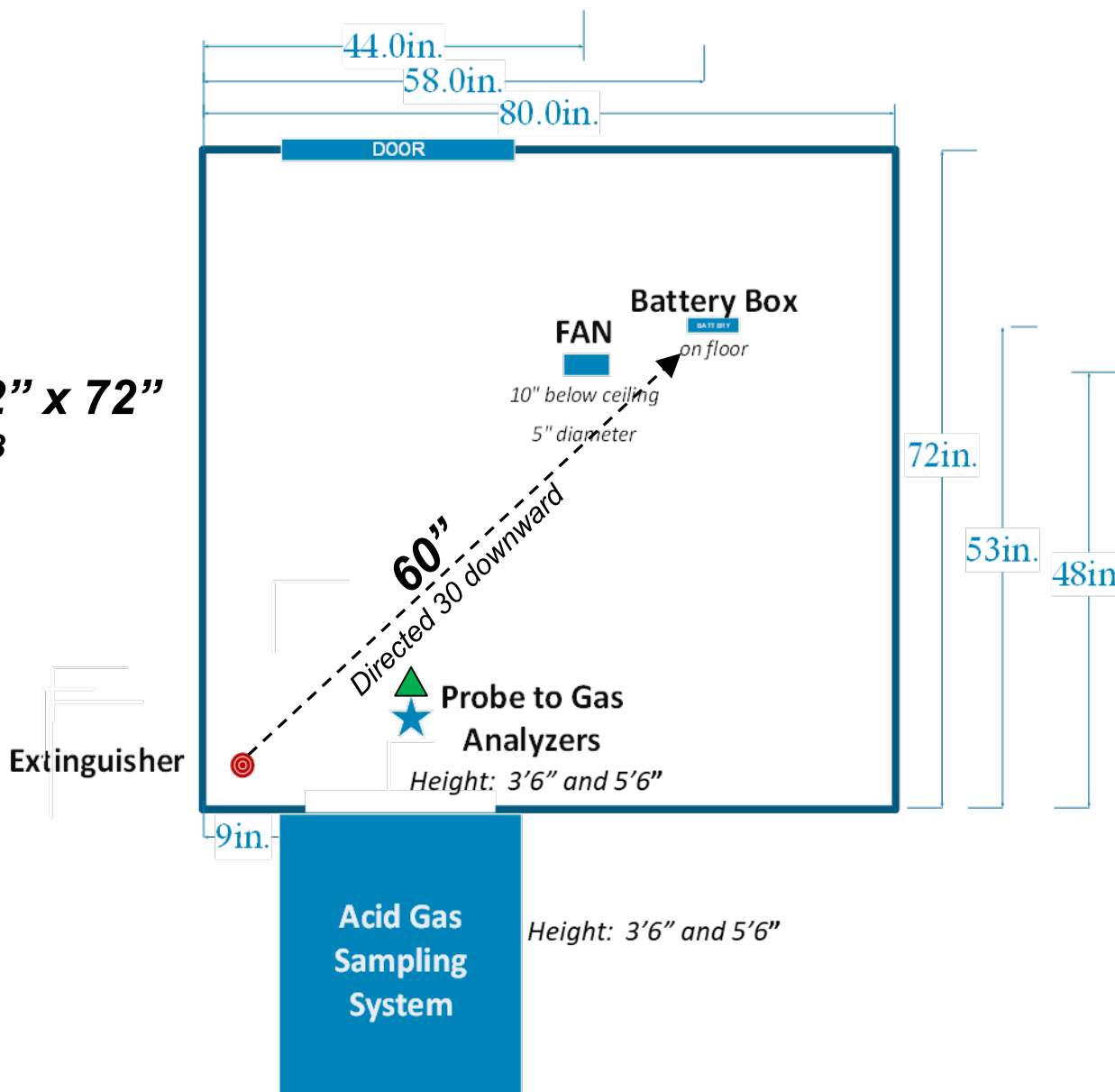
Hazard Level (5 min.)	Halon 1211 (percent)	2-BTP (percent)	Effect: Atypical heartbeats
NOAEL	0.5	0.5	No dogs affected
Safe Use Limit	_____	0.95	No effect is predicted for humans
LOAEL	1.0	1.0	Lowest observed number of dogs affected

The FAA report: “Guidelines for safe use of gaseous halocarbon extinguishing agents in aircraft” Speitel, L.C and Lyon R.E.: <https://www.fire.tc.faa.gov/pdf/08-3.pdf> describes the data-driven basis for FAA safe-use guidance for halocarbon agents



Test Article: Top View

80" x 72" x 72"
= 240 ft³



▲ Temp. at 5'6"

5 Batteries and Case

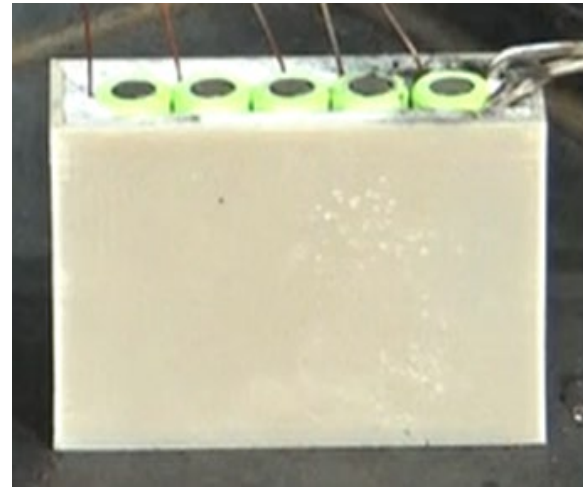


***18650 Lithium Ion Battery
3.7Volts, 2600 Milliamp Hr.***

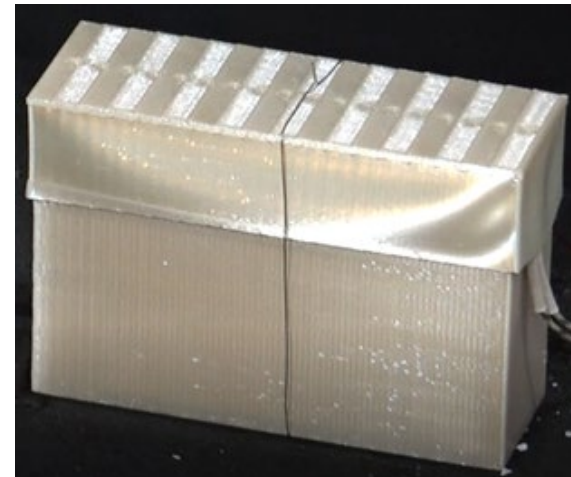
Five 18650 Lithium ion batteries were each fitted with a type-K thermocouple.

The five cells were tightly packed into the 3D printed case lined with ceramic micro board

- **The right most cell was fitted with the cartridge heater.**
- **The first cell is heated at a rate of 15 C/minute**
- **3-5 Tests run per condition.**



***3D printed battery case and lid
using ULTEM polyetherimide (PEI)
thermoplastic material***





Test Plan

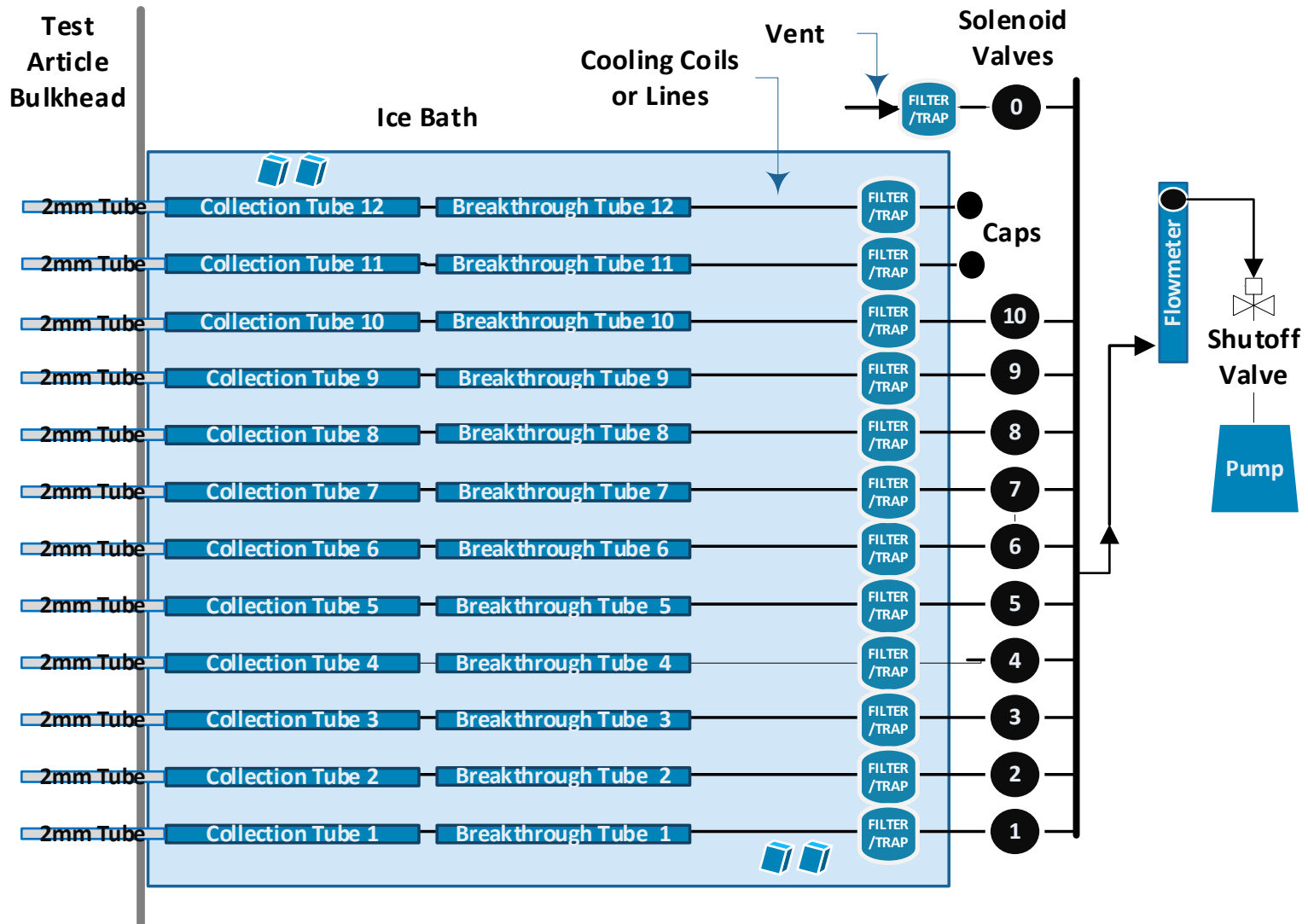
- **No air changes**
- **Small 5" fan set to highest speed clipped to ceiling in middle of the room facing opposite top corner of the room.**
- **5 B:C Fire Extinguisher is 5 feet from battery box. 30 degree downward angle**
- **Agent introduced after thermal runaway propagated to the third cell.**
- **Background tests run with no agent (since HF and other gases are decomposition products of Lithium Ion battery fires).**



Instrumentation

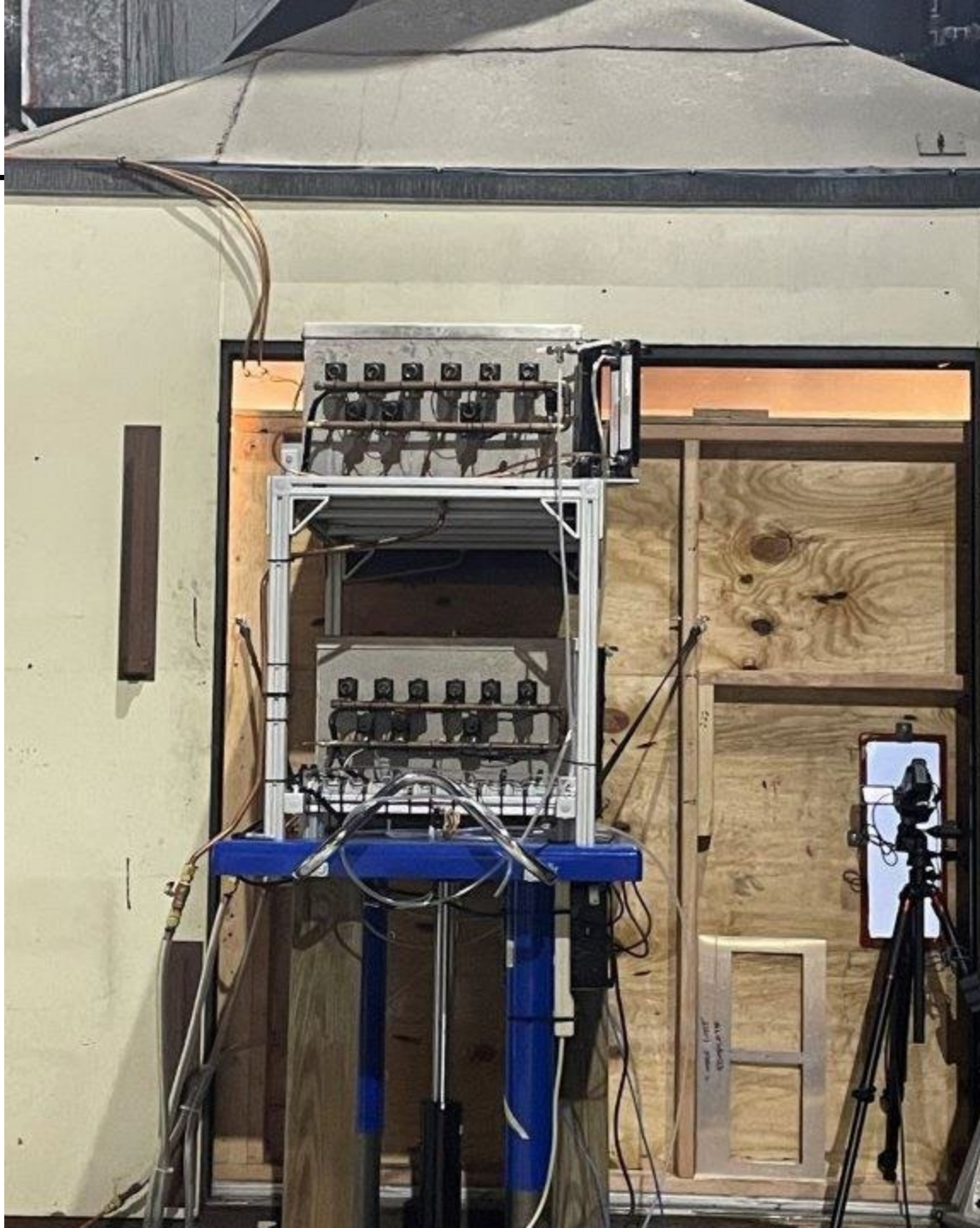
- **NDIR gas analyzers: CO, CO₂, O₂ and Halocarbon.**
- **Acid gas sampling assembly**
- **Dionex Integrion Ion Chromatograph (IC) with AS15 column**
- **This IC method described in FAA report (to be published)**
DOT/FAA/TC-22/34

Acid Gas Sampling System



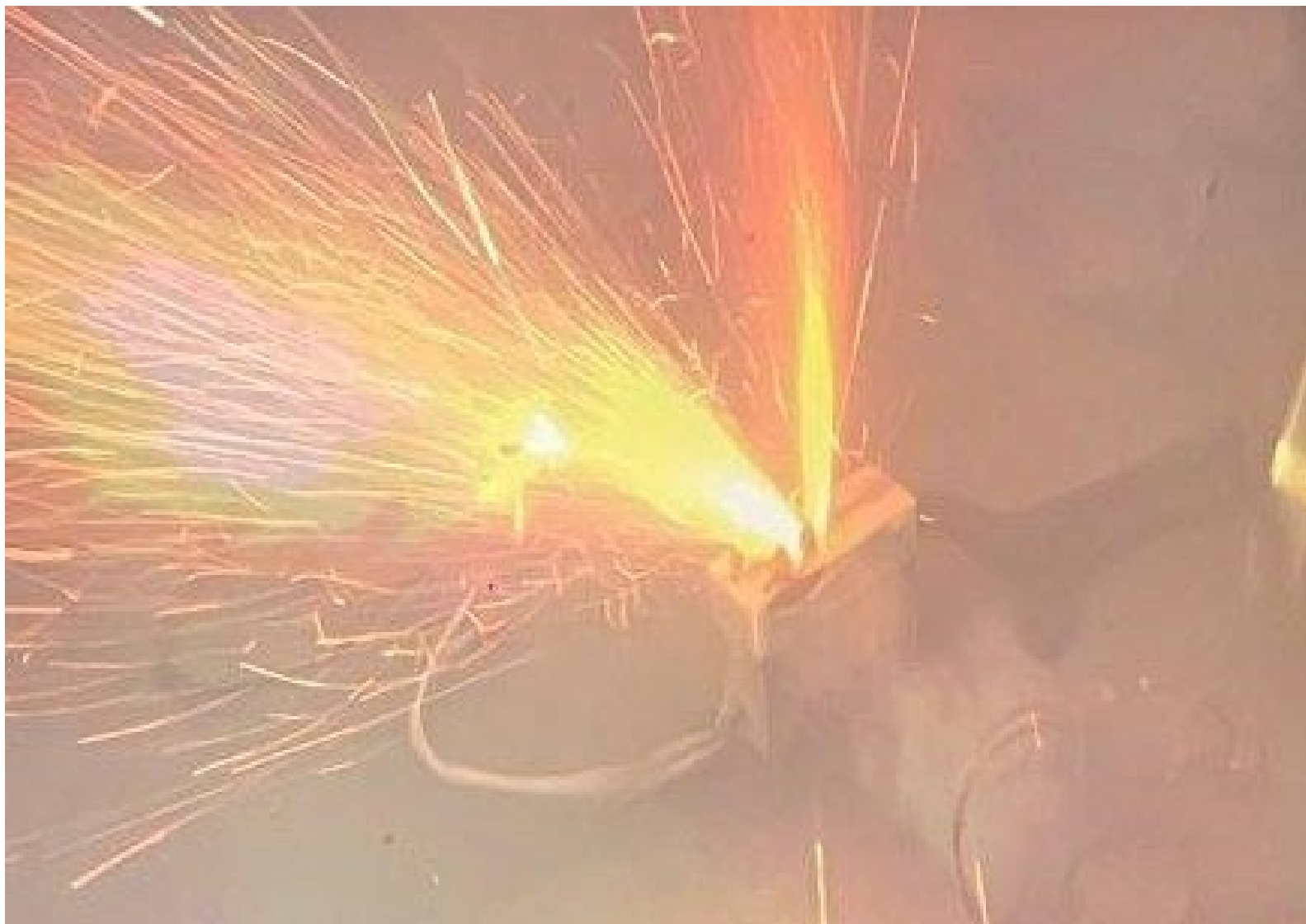
Acid Gas Collection Tubes







Before Agent Discharge

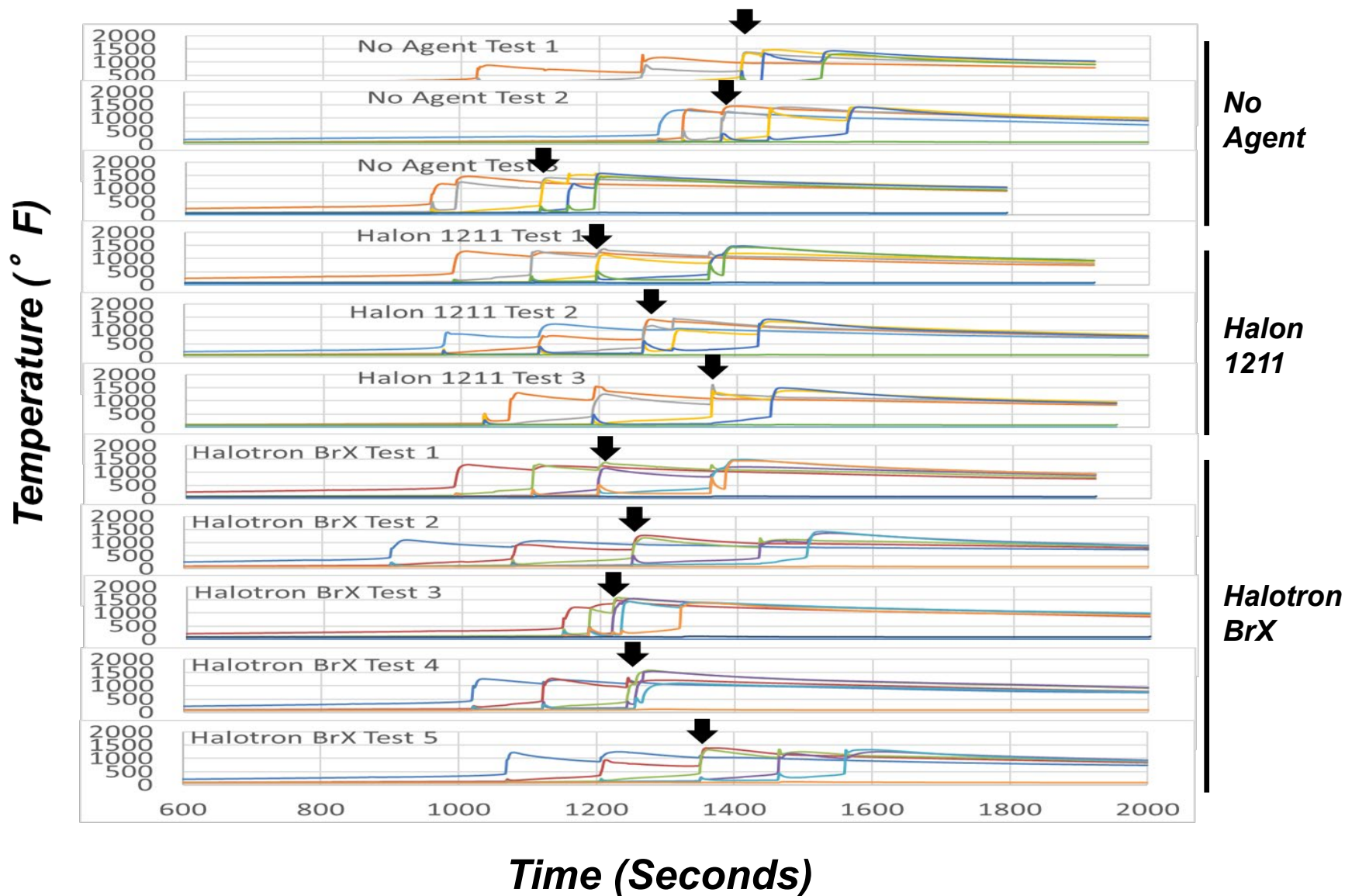


After Test





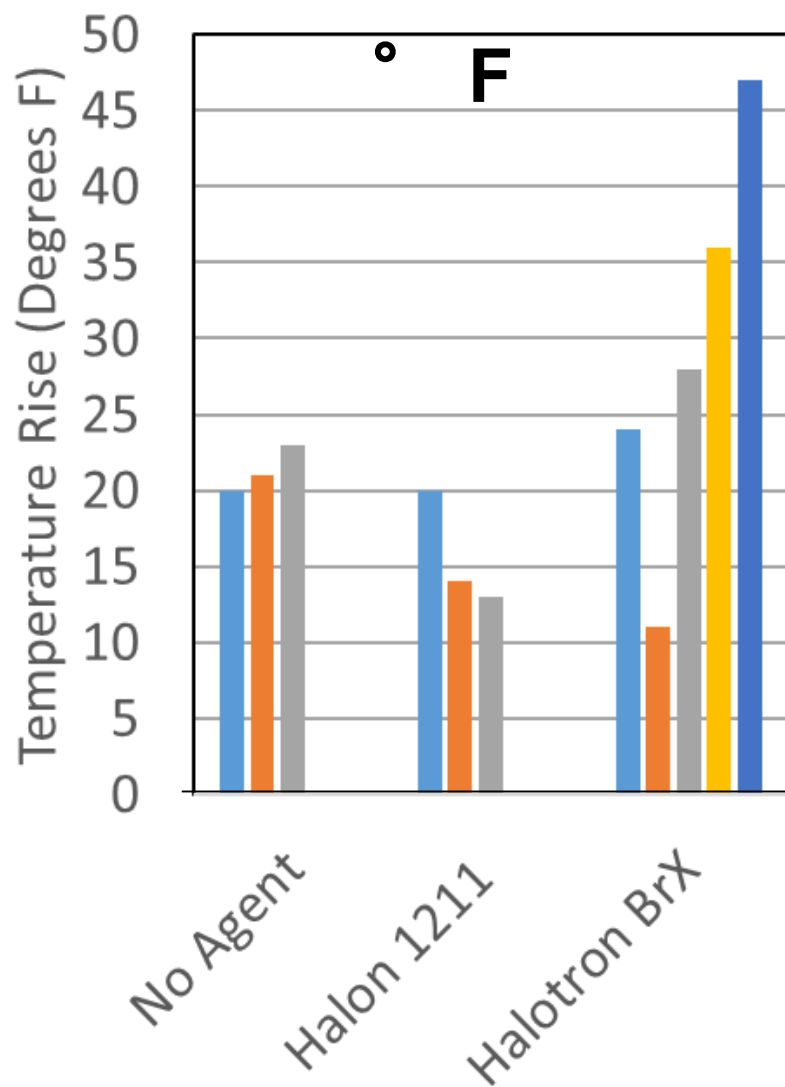
Comparison of Temperature Profiles



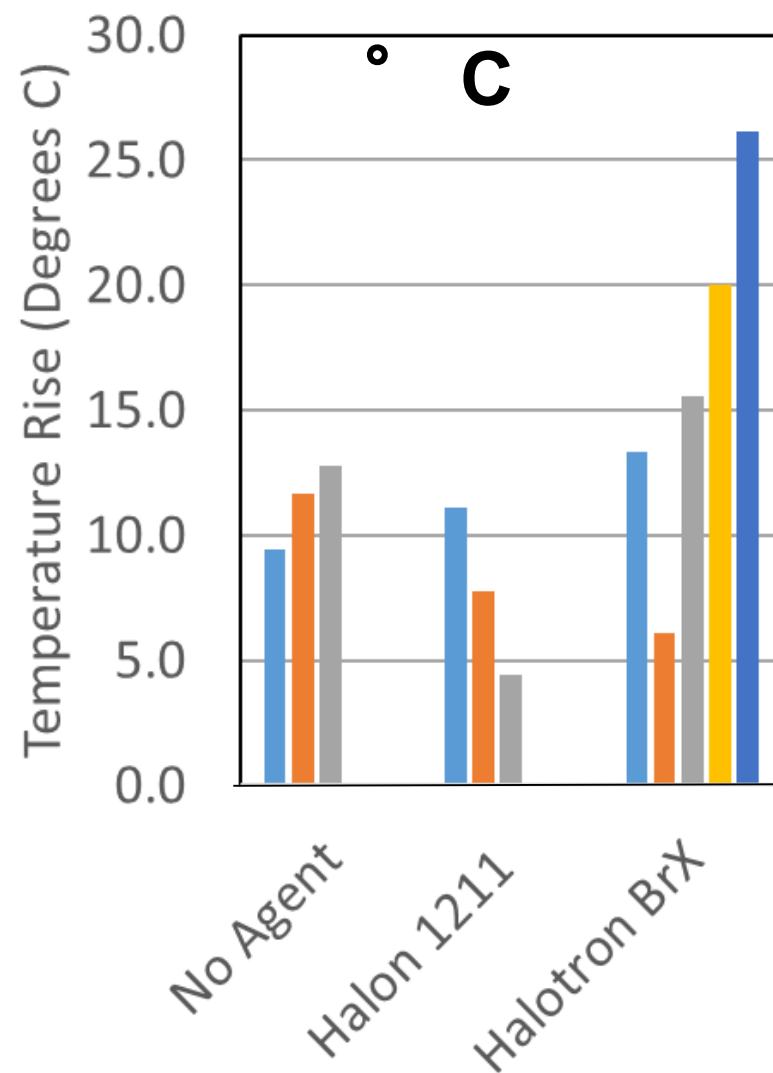


Peak Temperature Increase at 5'6" Nose

Temperature Increases at 5'6" (Degrees F)



Temperature Increases at 5'6" (Degrees C)



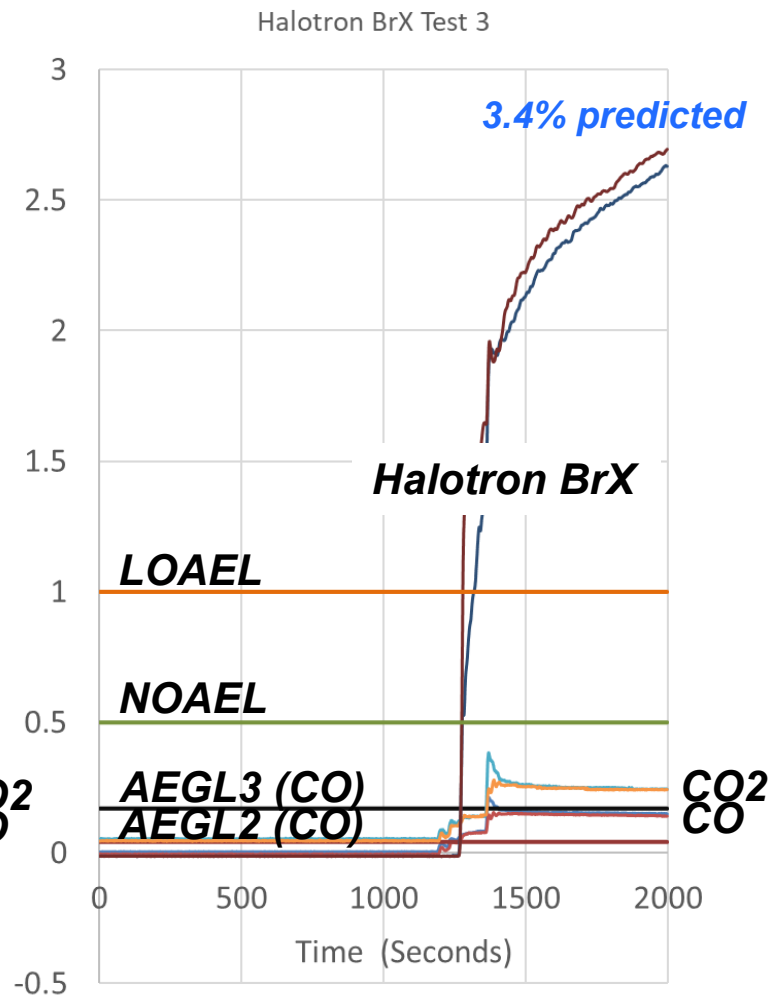
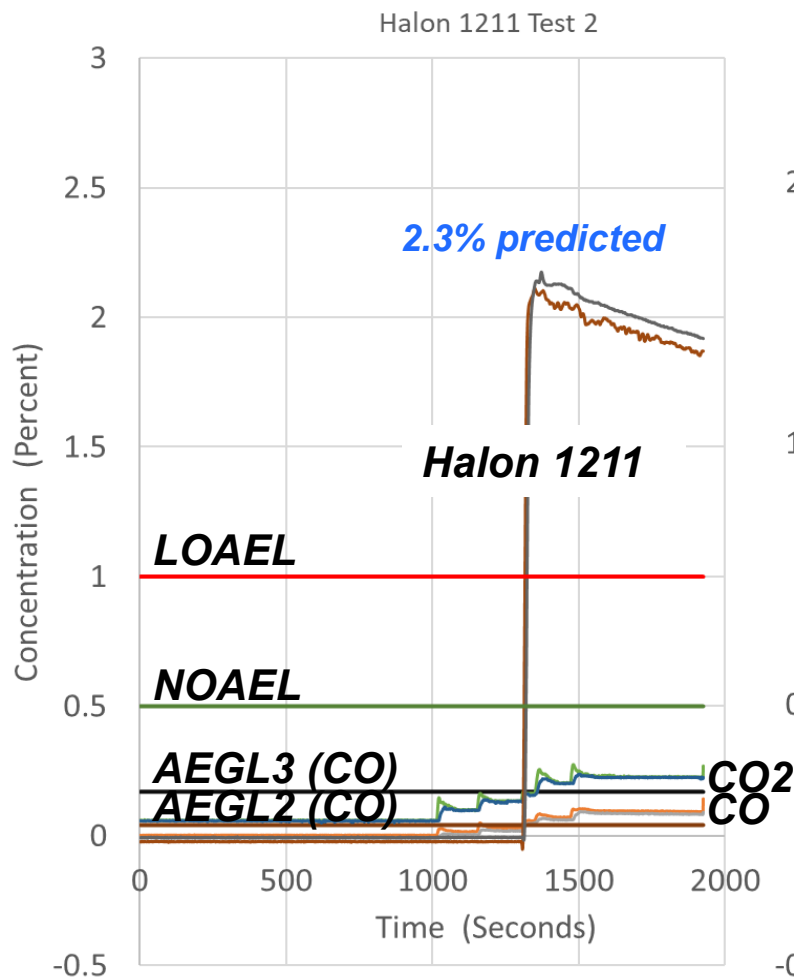


Comparison of Tests

Halon 1211 Test 2 (2.4lb)

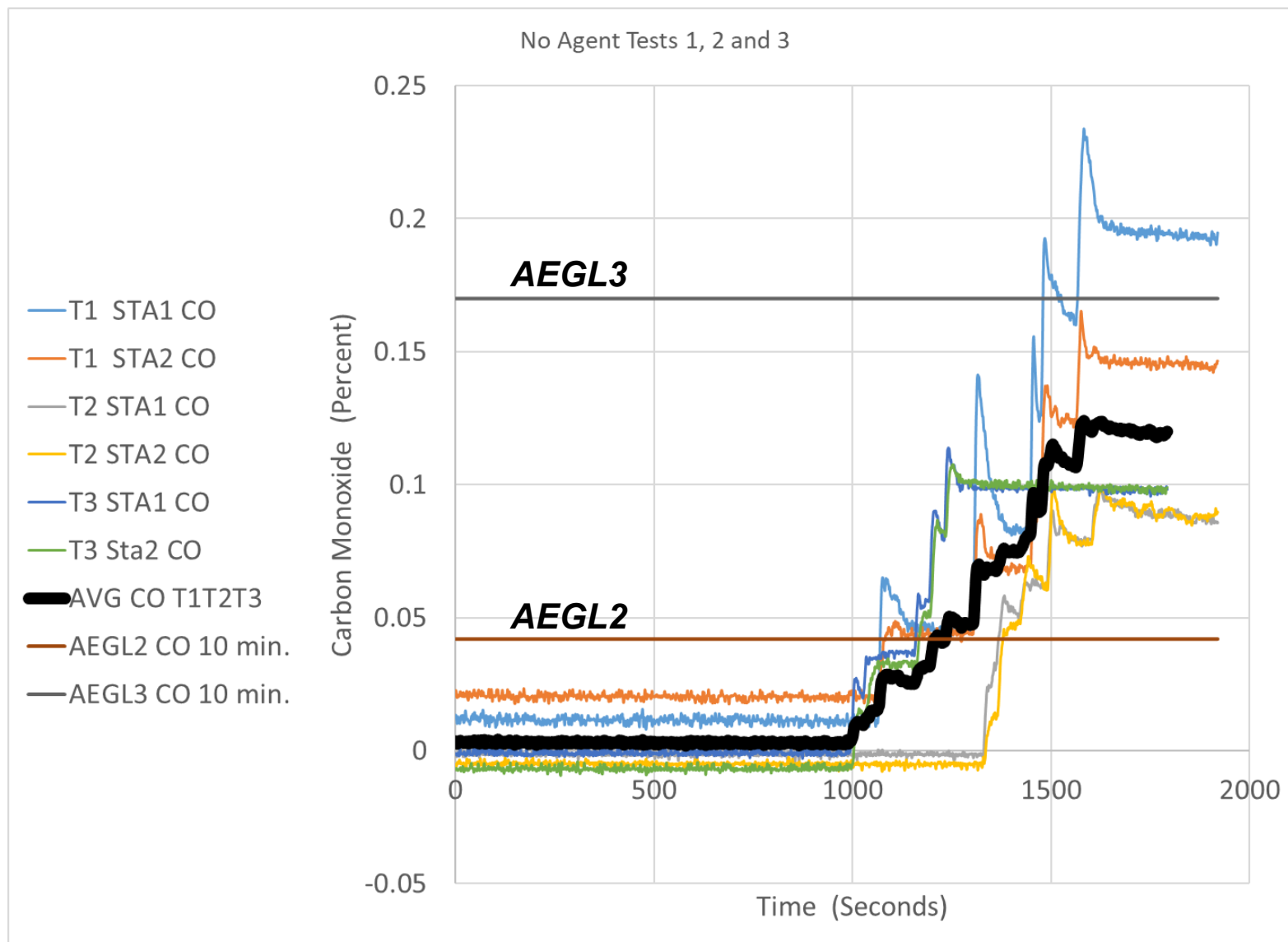
Halotron BrX Test 3 (3.65lb)

- STA1 CO
- STA2 CO
- AEGL2 CO 10 min.
- AEGL3 CO 10 min.
- STA1 CO₂
- STA2 CO₂
- STA1 AGENT
- STA2 AGENT
- NOAEL Agent
- LOAEL Agent



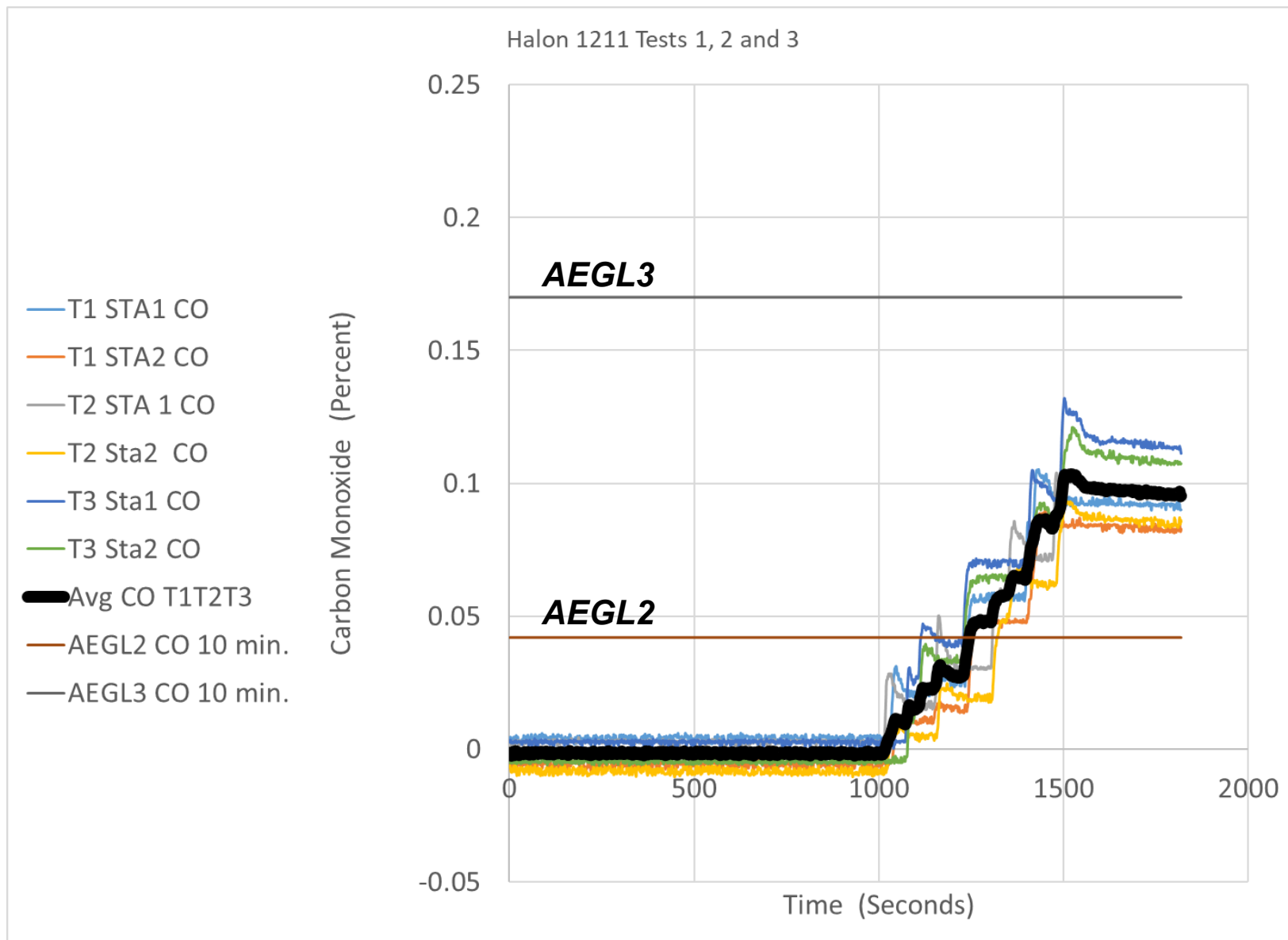


No Agent CO: Tests 1,2,3





Halon 1211 CO: Tests 1,2,3

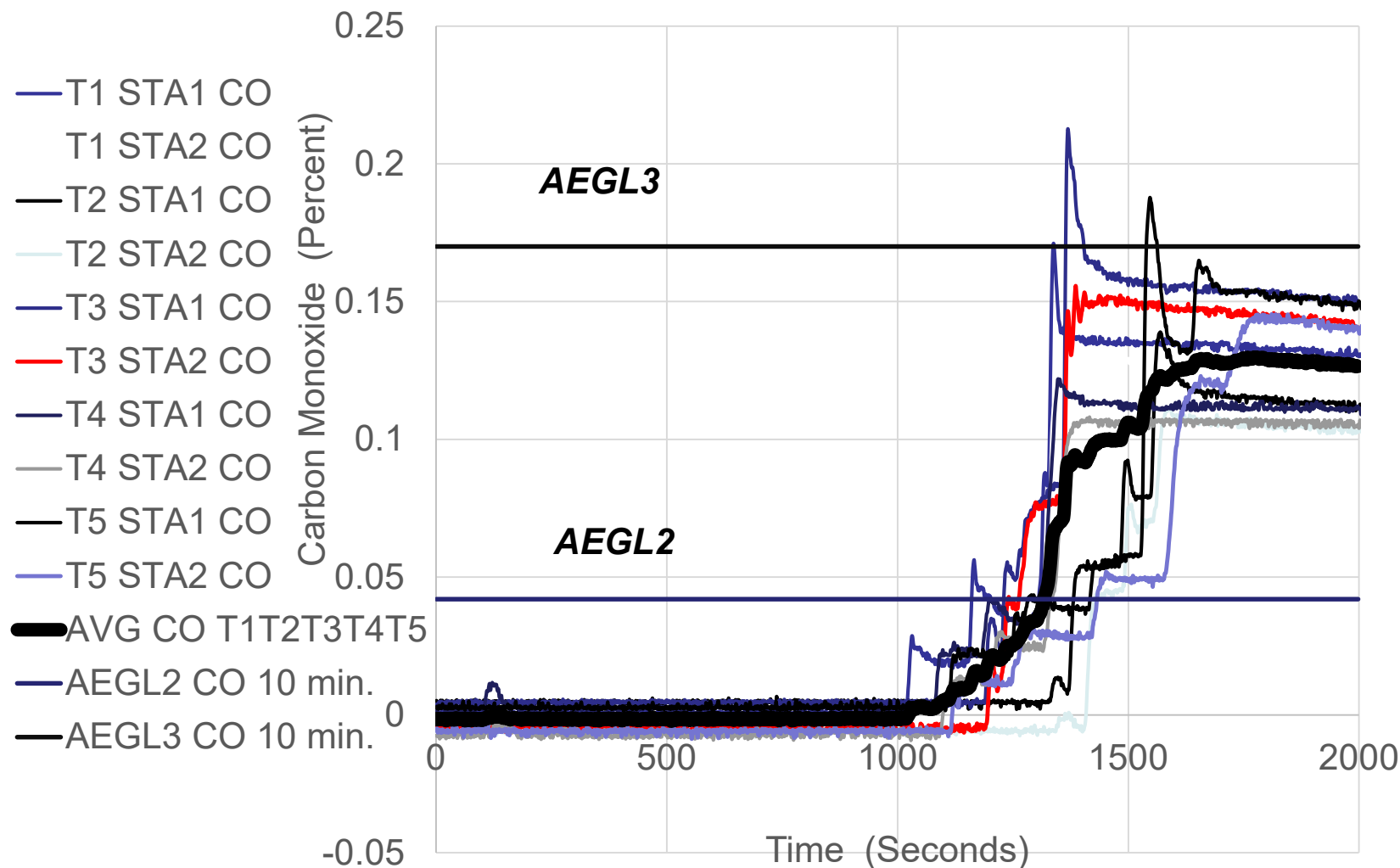




Halotron BrX CO: Tests 1,2,3,4,5

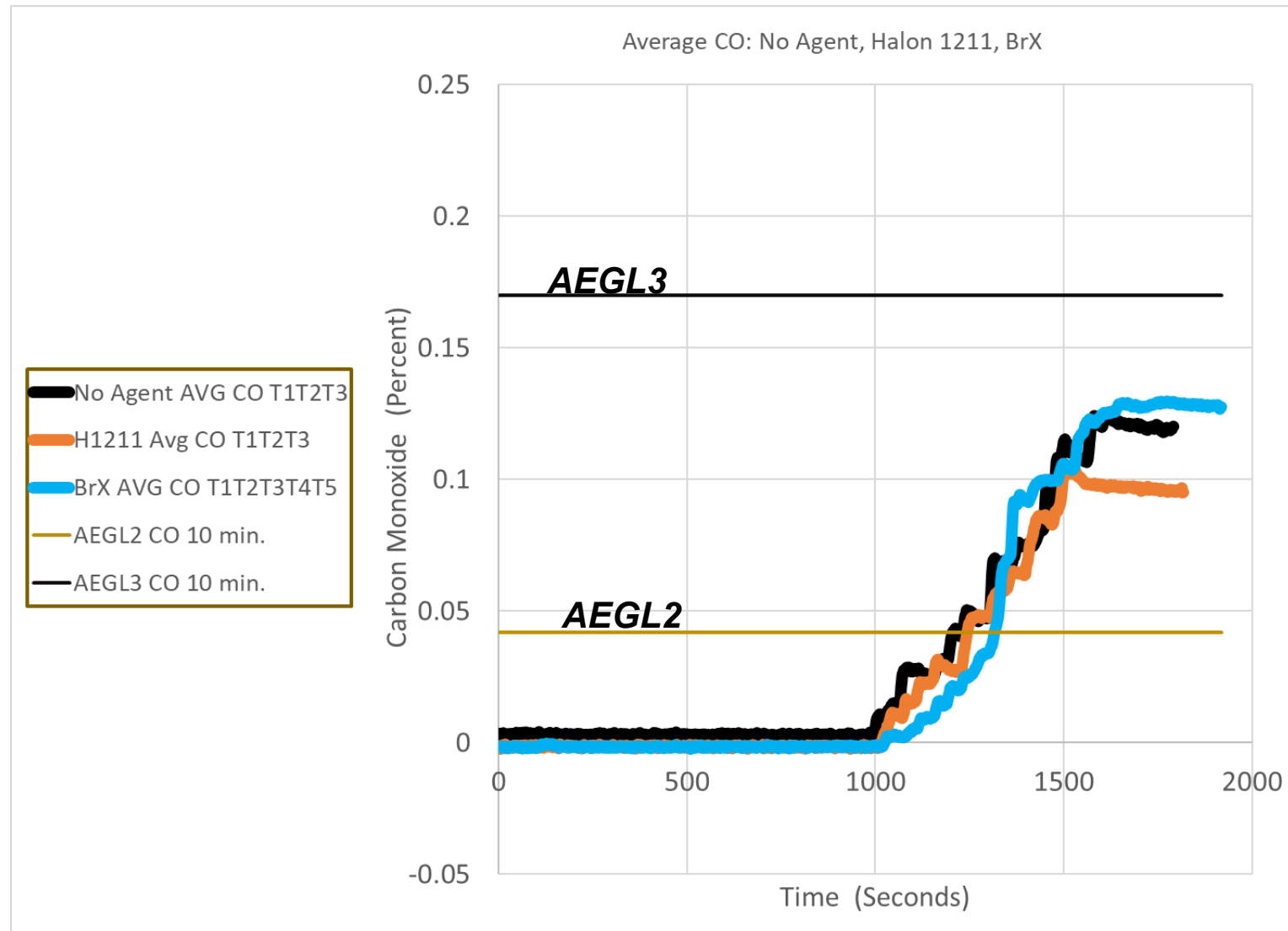


Halatron BrX Tests 1, 2, 3, 4 and 5

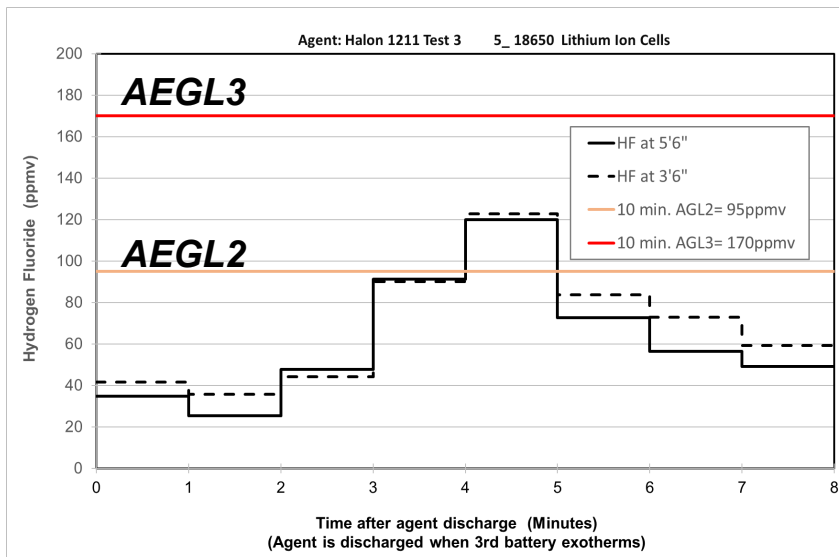
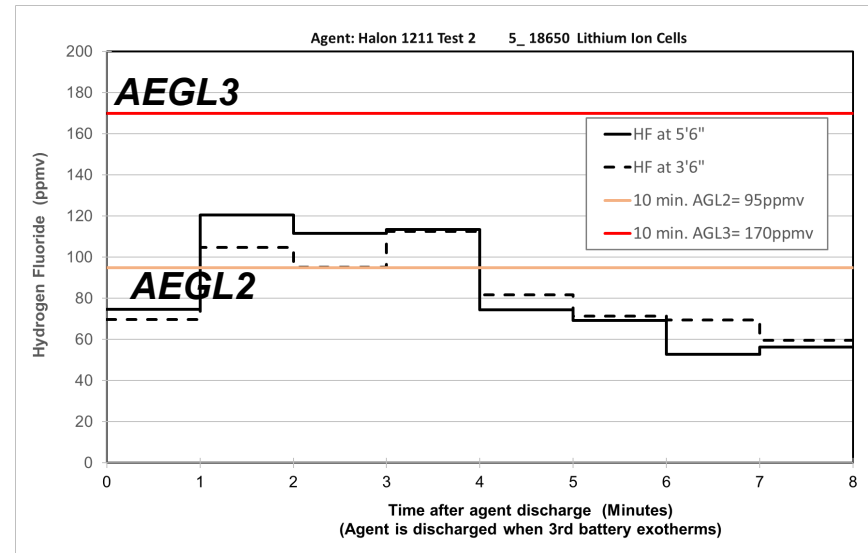
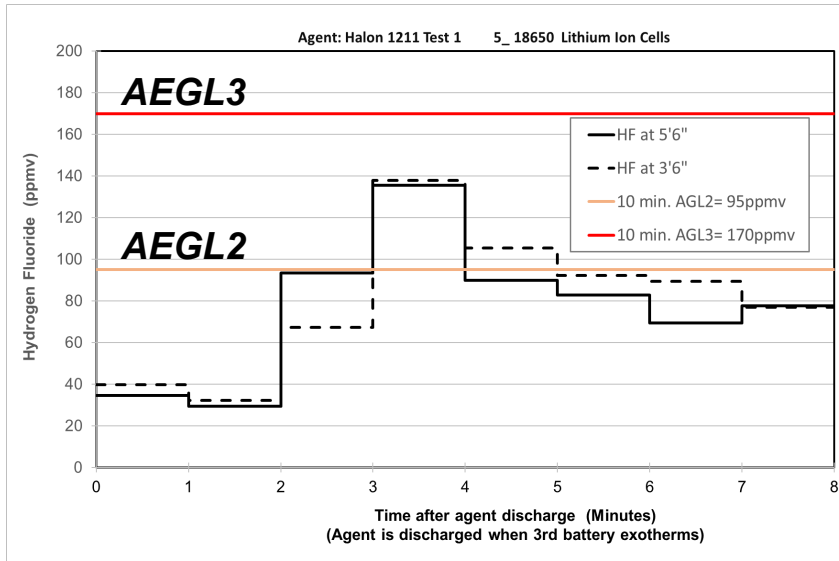




CO Averages for each Agent

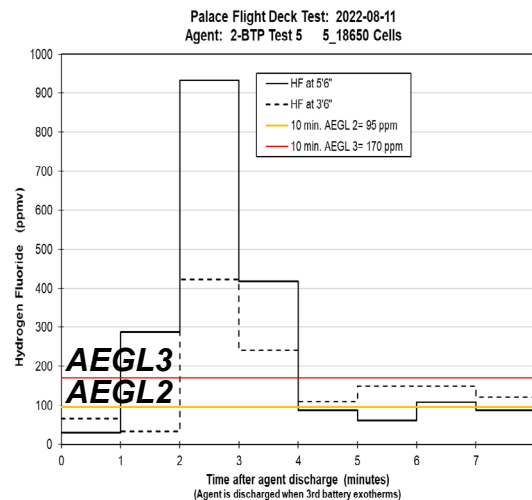
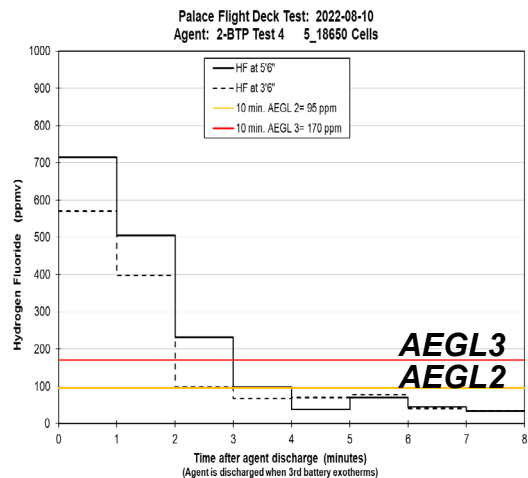
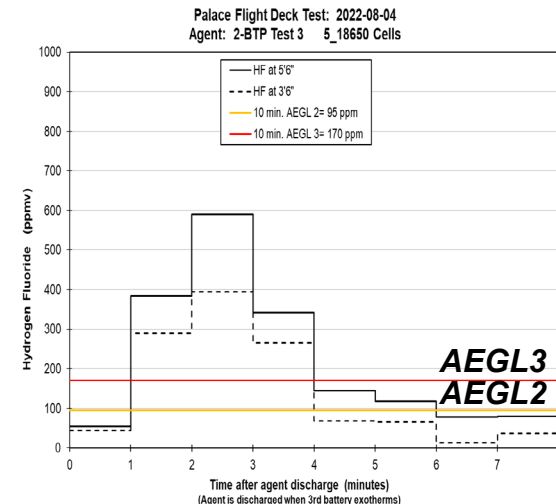
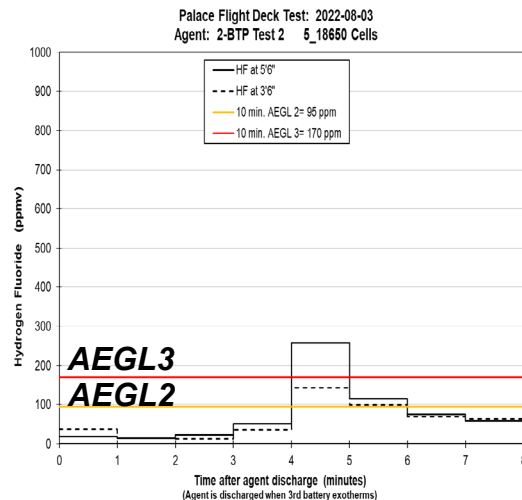
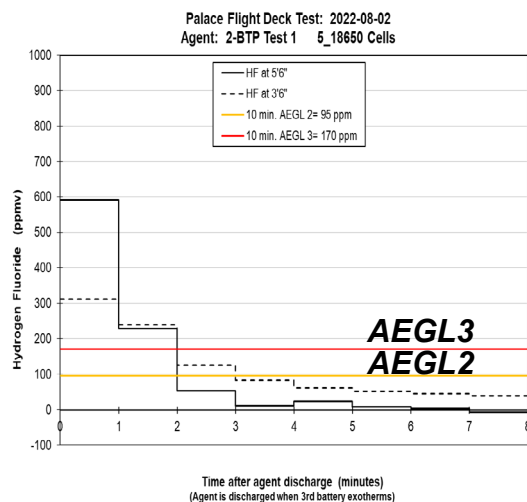


Halon 1211 Tests 1- 3: Hydrogen Fluoride



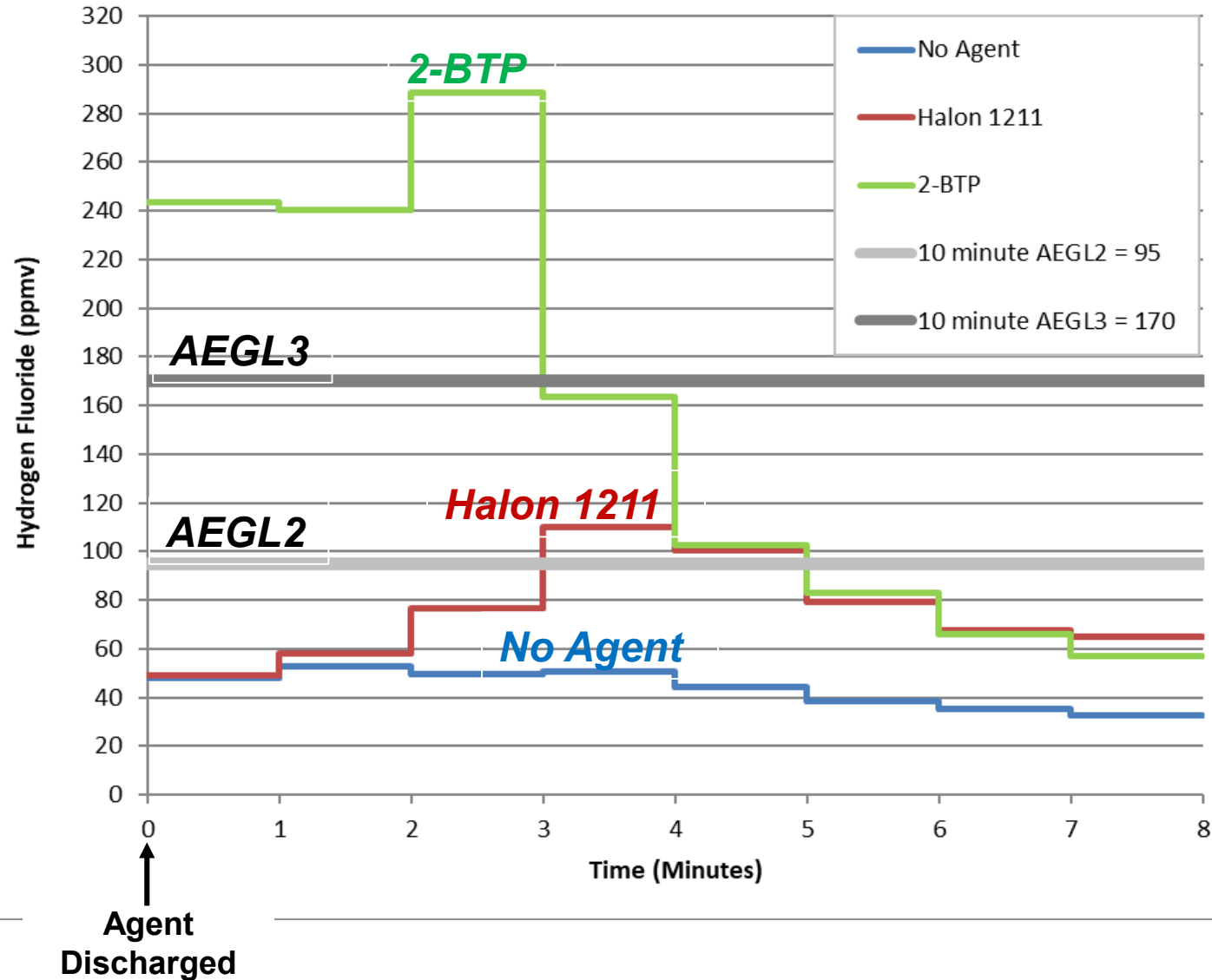


Halotron BrX Tests 1-5: Hydrogen Fluoride



Hydrogen Fluoride

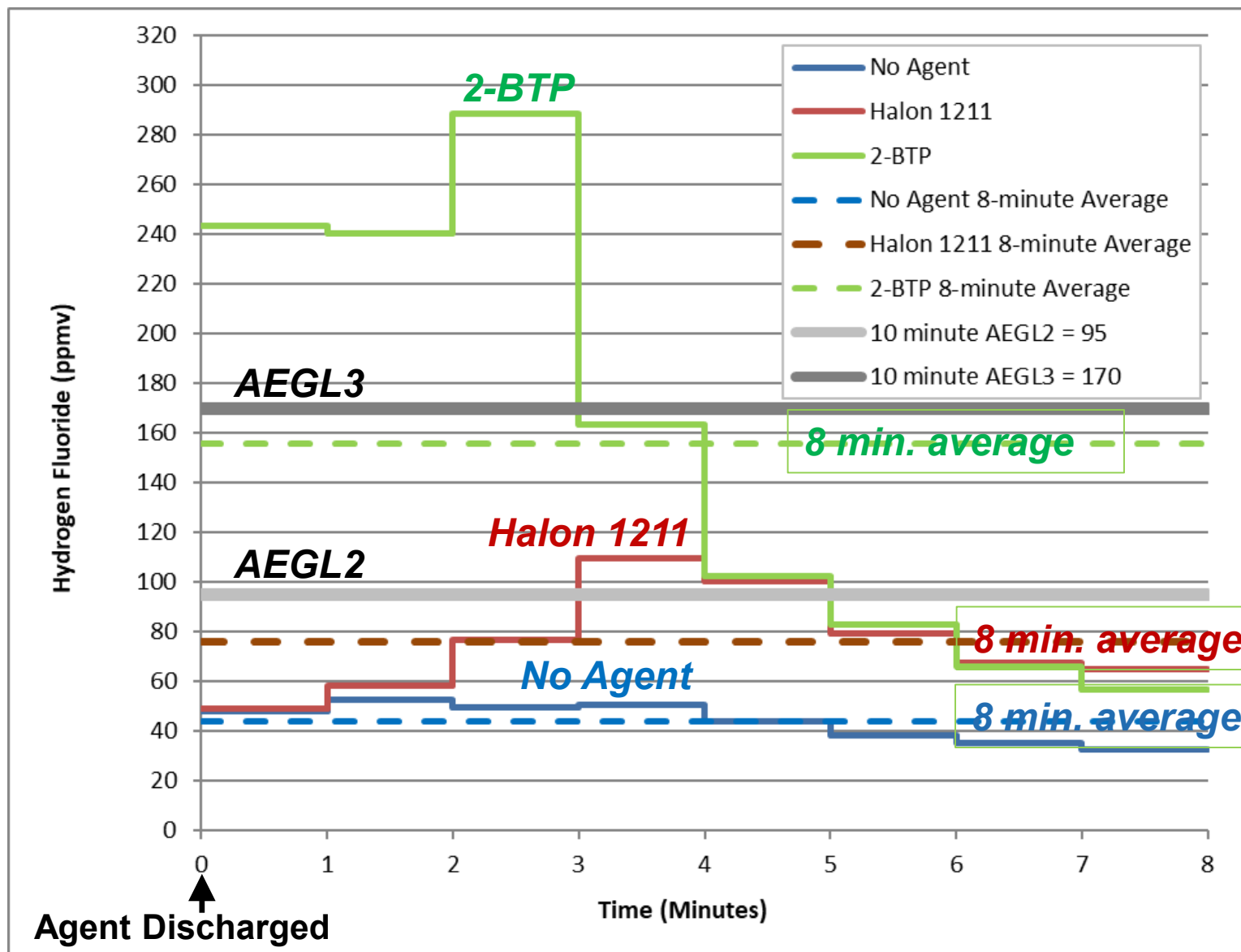
Averages for each Agent





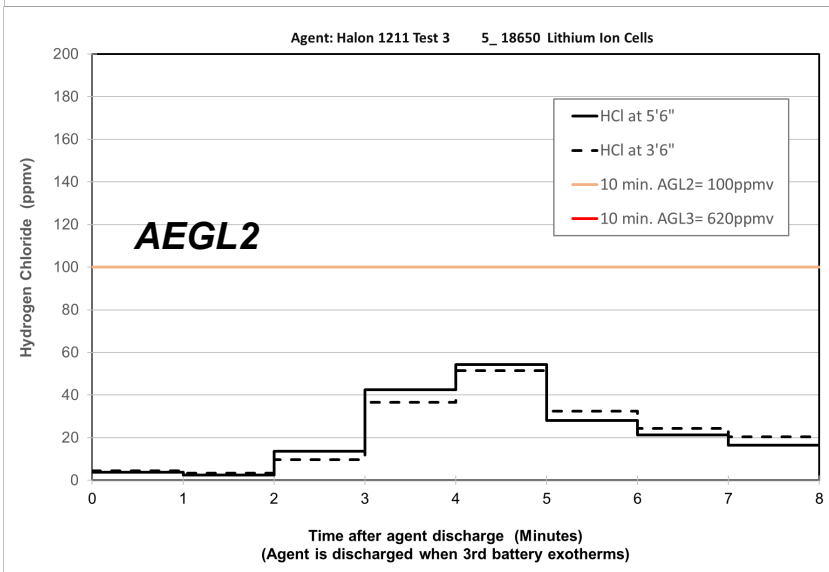
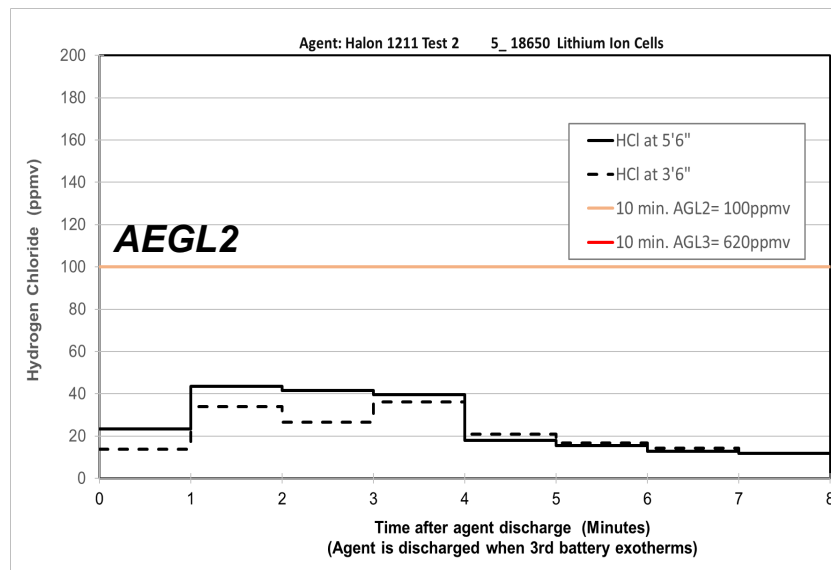
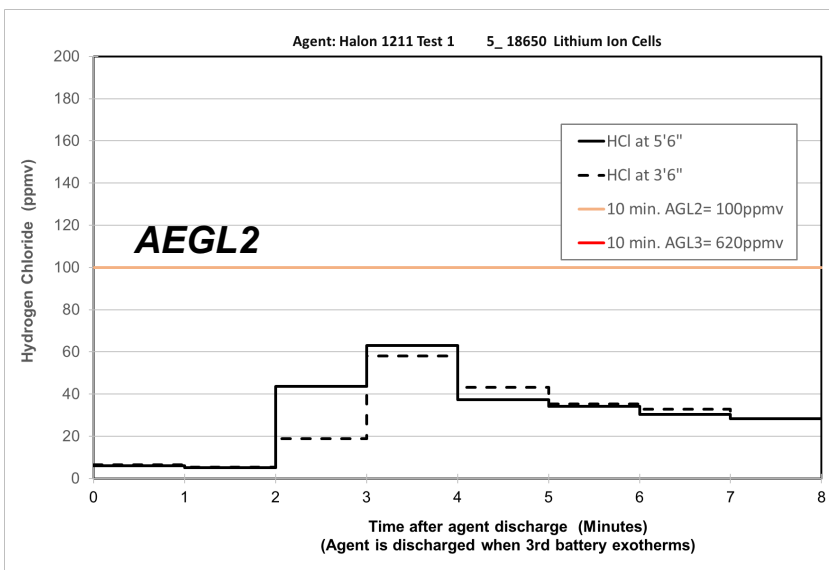
Hydrogen Fluoride

Averages for each Agent



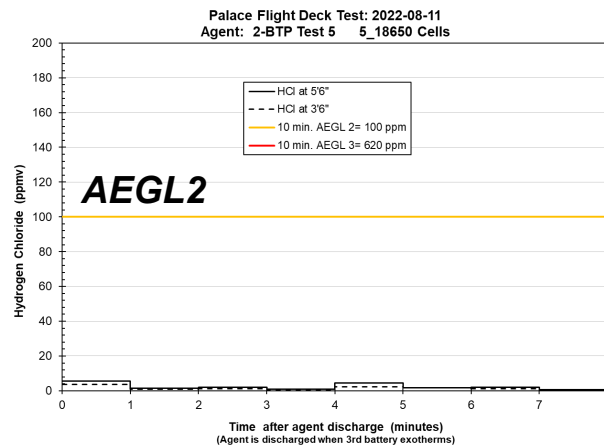
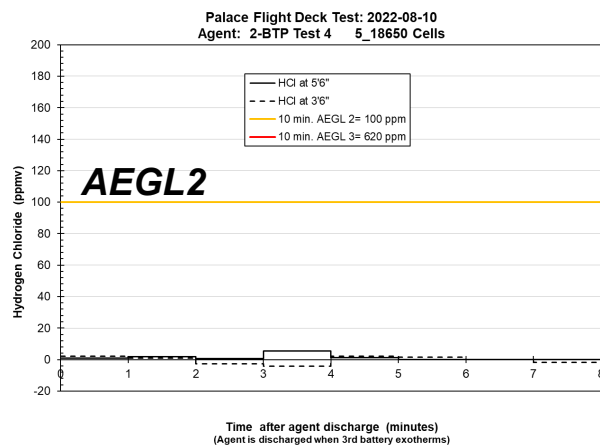
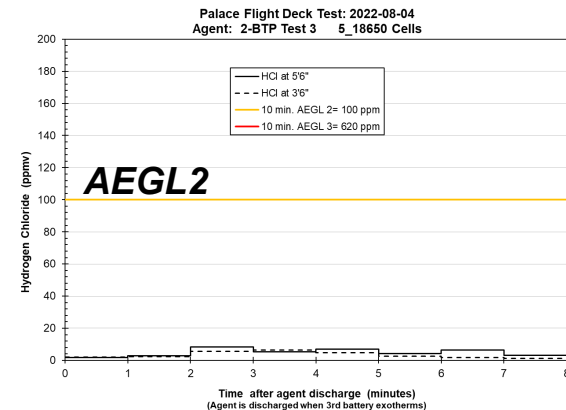
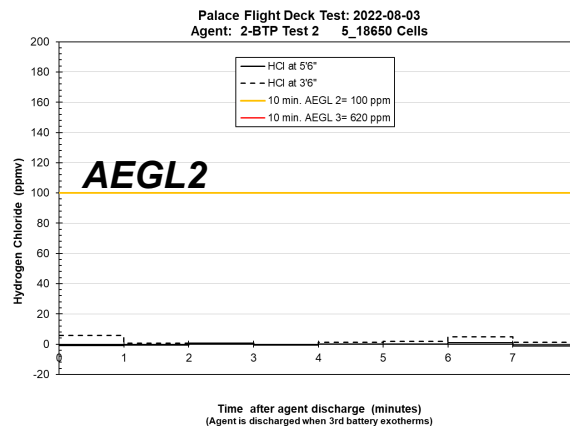
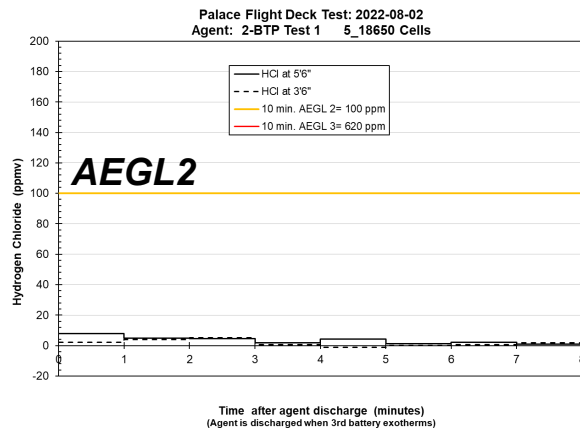


Halon 1211 Tests 1- 3 Hydrogen Chloride





Halotron BrX: Hydrogen Chloride





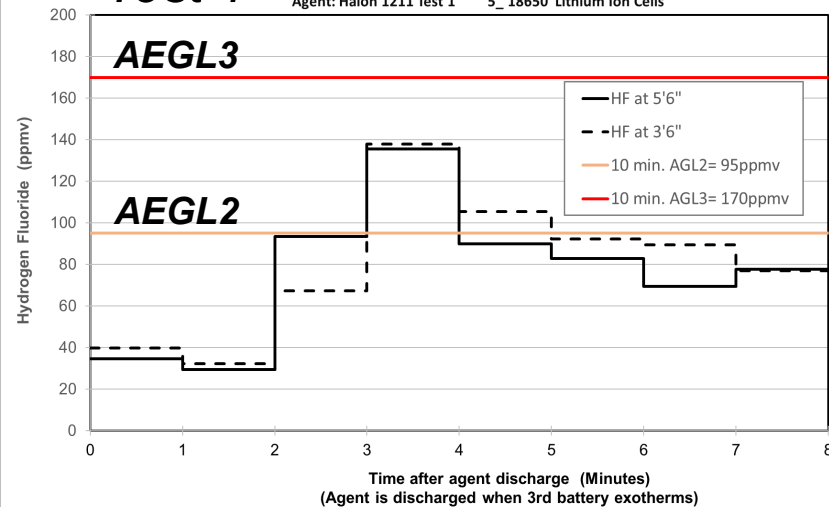
Halon 1211 Tests 1, 2: HF & HCl

HBr: None seen



Test 1

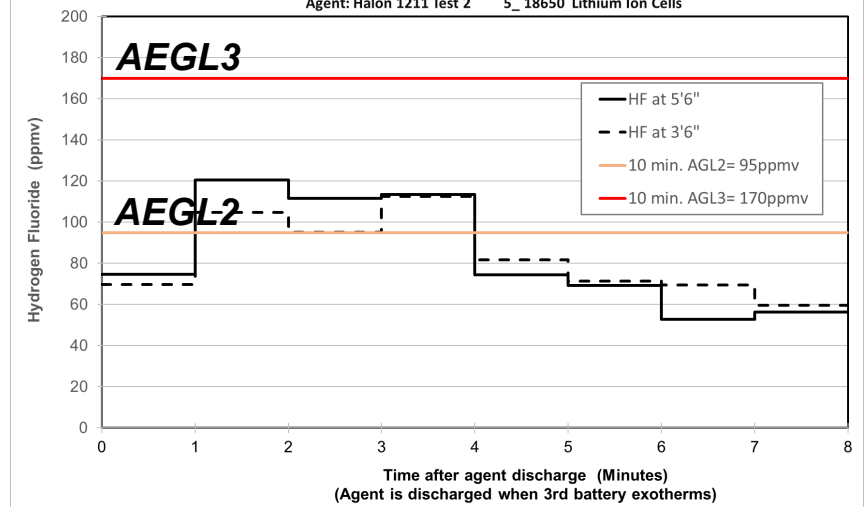
Agent: Halon 1211 Test 1 5_18650 Lithium Ion Cells



HF

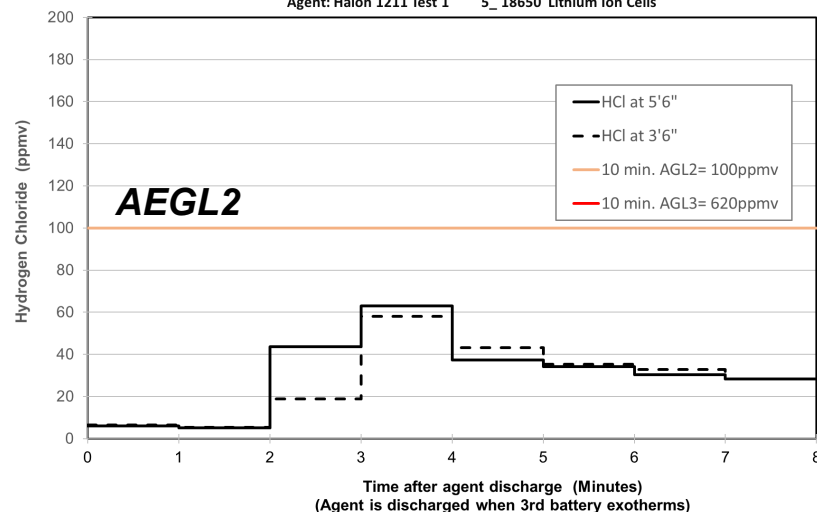
Test 2

Agent: Halon 1211 Test 2 5_18650 Lithium Ion Cells



Test 1

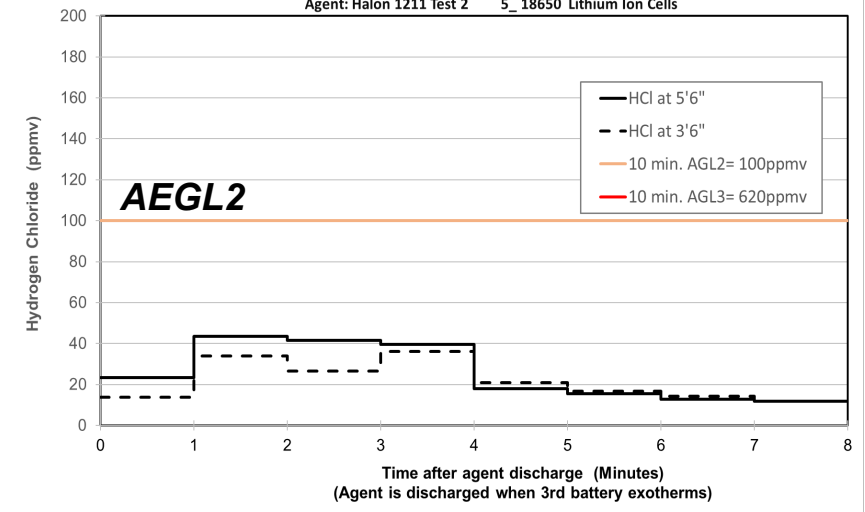
Agent: Halon 1211 Test 1 5_18650 Lithium Ion Cells



HCl

Test 2

Agent: Halon 1211 Test 2 5_18650 Lithium Ion Cells





Conclusions

Carbon Monoxide

- The battery fire alone produces hazardous CO concentrations exceeding the 10 minute AEGL2.
- CO produced by Halon 1211 and Halotron BrX does not pose a significant hazard relative to the CO produced by the battery fire alone.

Agent Stratification

- There is a clear stratification benefit for Halotron BrX relative to Halon 1211.
- There is a slow buildup of Halotron BrX at breathing zone of sitting and standing person. This slow buildup will improve the air change benefit.



Conclusions

Acid Gases

- No HBr was observed for the Halon 1211 or Halotron BrX tests.
- HCl contributes to the toxicity of Halon 1211 use.
- Peak HF concentrations do not exceed the AEGL2 for the battery fires with no agent.
- Peak HF concentrations exceeded the AEGL2 for the battery fires with Halon 1211
- Peak HF Concentrations significantly exceeded the AEGL3 for the battery fires with Halotron BrX
- Peak 1 minute HF levels are 6.7 times higher for Halotron BrX (930ppmv) relative to Halon 1211 (139 ppmv).
- Halotron BrX stratifies more than Halon 1211 despite mixing.