Aircraft Cargo MPS Test of FK-5-1-12

The Evaluation of FK-5-1-12 as a Halon 1301 Replacement for Aircraft Cargo Compartment Fire Protection Application

Presented to: International Aircraft Systems Fire Protection Working Group Meeting

By: John Reinhardt, Aerospace Engineer

Date: October 25-26, 2006

Federal Aviation Administration

Outline

- Agent & System Information
- MPS Tests & Results
  - Status
  - Aerosol Can Simulation Explosion Test
  - Surface Burn Test
  - Containerized Fire Test
  - Bulk-Load Fire Test
- Final Remarks

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Agent Information

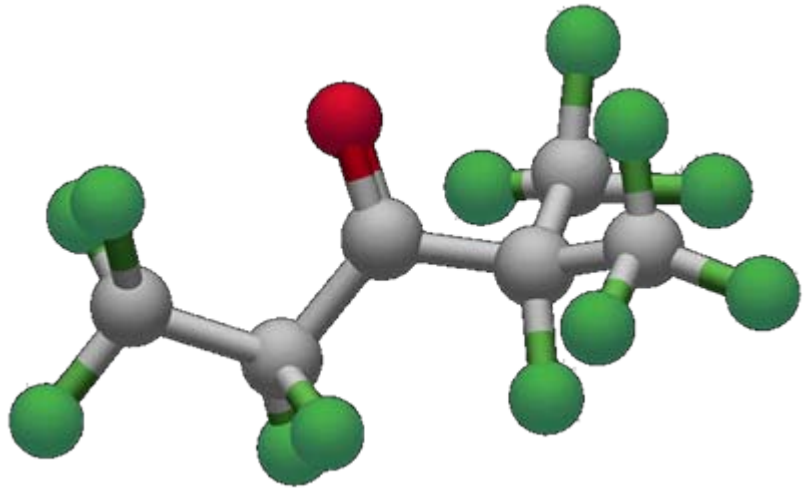
Compound	Atmospheric Lifetime (yrs)	ODP	GWP_{100}
Halon 1301 (CF_3Br)	**65**	**12**	**6,900**
HFC-125 (CF_3CF_2H)	**29**	**0**	**3,400**
2-BTP (CH_2CBrCF_3)	**0.008**	**0**	**N/A**
FK-5-1-12 ($CF_3CF_2C(O)CF(CF_3)_2$)	**0.014**	**0**	**1**

Agent Information

Property	Value	Unit
Molecular Weight	316.05	
Boiling Point	49.0	°C
Freezing Point	-108	°C
Liquid density @ 25°C	1600	kg/m^3
Vapor density @ 25°C	13.65	kg/m^3
Vapor Specific volume @ 1bar & 25°C	0.0733	kg/m^3
Vapor pressure@ 25°C	0.404	bar
Specific Heat, vapor @ 1bar & 25°C	0.891	kJ/kg°C
Heat of vaporization @ bp	88.1	kJ/kg
Solubility of water in agent @ 21°C	<0.001	wt%
Dielectric strength rel. to N_2 @25 °C	2.3	

Agent Information

- EPA SNAP Listed
- Agent disperses as a gas
- No residue
- High density
- Water Insoluble
- High dielectric strength
- Liquid at room temperature



Information provided is courtesy of 3M

Agent Information

AGENT	USE CONC.	NOAEL*	SAFETY MARGIN
FK-5-1-12	4.2 - 6%	10%	67 - 138%
Halon 1301	5%	5%	---
HFC-125	11.3%	7.5%	No
2-BTP	6%	0.5%	No
Inert Gases	38 - 40%	43%	7 - 13%

*** No Observable Adverse Effect Level**

Information provided is courtesy of 3M

Agent Information

Currently, FK-5-1-12 Successfully Protecting:

- Telecommunication Switch Rooms
- Computer and Electronic Control Rooms
- Hazards Aboard Ships
- Military Engine and Crew Bay
- Flight Line Protection

Information and photographs provided is courtesy of 3M

System Information

PRESSURE VESSEL

- 20 lb Fenwal Protection Systems Cylinder (93-100020-001)
- Fenwal Protection Systems Electric Control Head (486500-01)
- ½” NPT black iron pipe
- Single ½” NPT Nozzle (designed for FK-5-1-12)

FAA TC-10 AIRCRAFT

- 70 lb Fenwal Protection Systems Cylinder (93-100020-001)
- Fenwal Protection Systems Electric Control Head (486500-01)
- 1-½” NPT black iron pipe
- Single 1-½” NPT Nozzle (designed for FK-5-1-12)

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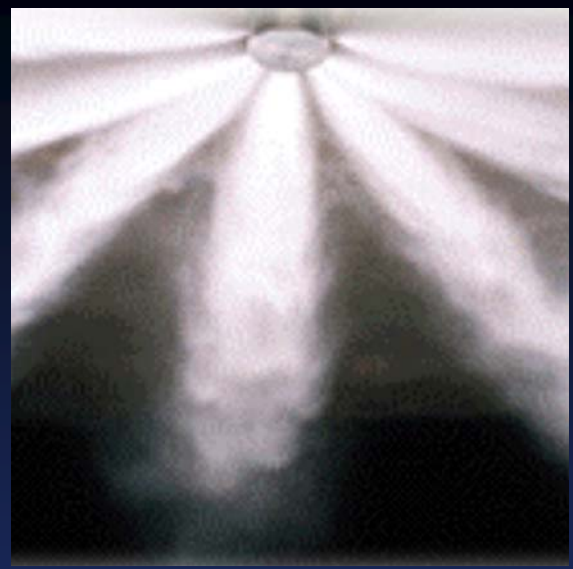
MPS Tests & Results



CARGO MPS TESTING OF FK-5-1-12 STATUS

- Conducted 13 Aerosol Can Simulation Explosions in the 11.4 m^3 pressure vessel.
- Conducted 3 Surface Burn Tests (TC-10)
- Conducted 2 Containerized Fire Tests (TC-10)
- Conducted 3 Bulk-Load Tests (TC-10)

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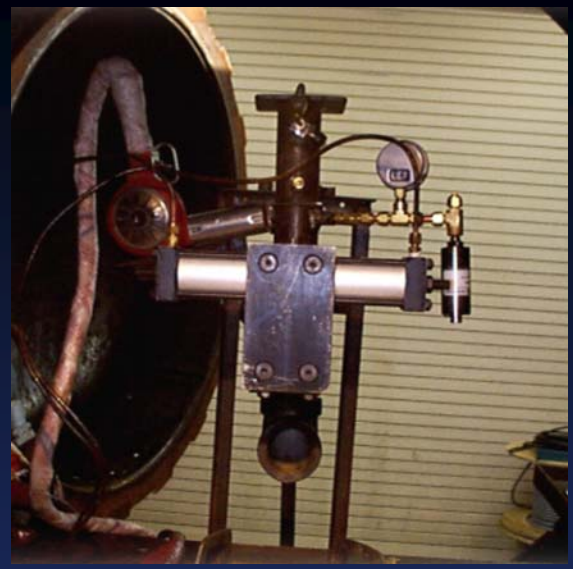
MPS Tests & Results



AEROSOL CAN EXPLOSION SIMULATION TEST (11.4 m^3 VESSEL)

Fire Load:
Simulator - 0.2 lb. Propane, 0.6 lb. of denatured alcohol, 0.2 lb of water

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Ignition Sources = arcing electrodes (3' away from the simulator)

Heat up simulator to increase pressure in content chamber to 240 psig

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FK-5-1-12 FSS Activation = after simulator reached 240 psig

MPS Tests & Results

AEROSOL CAN EXPLOSION SIMULATION TEST (11.4 m^3 VESSEL)

Aerosol Can Simulator Activation = after agent concentration stabilizes and simulator pressure is at 240 psig.

Test Duration = until the simulator is activated

MPS Tests & Results

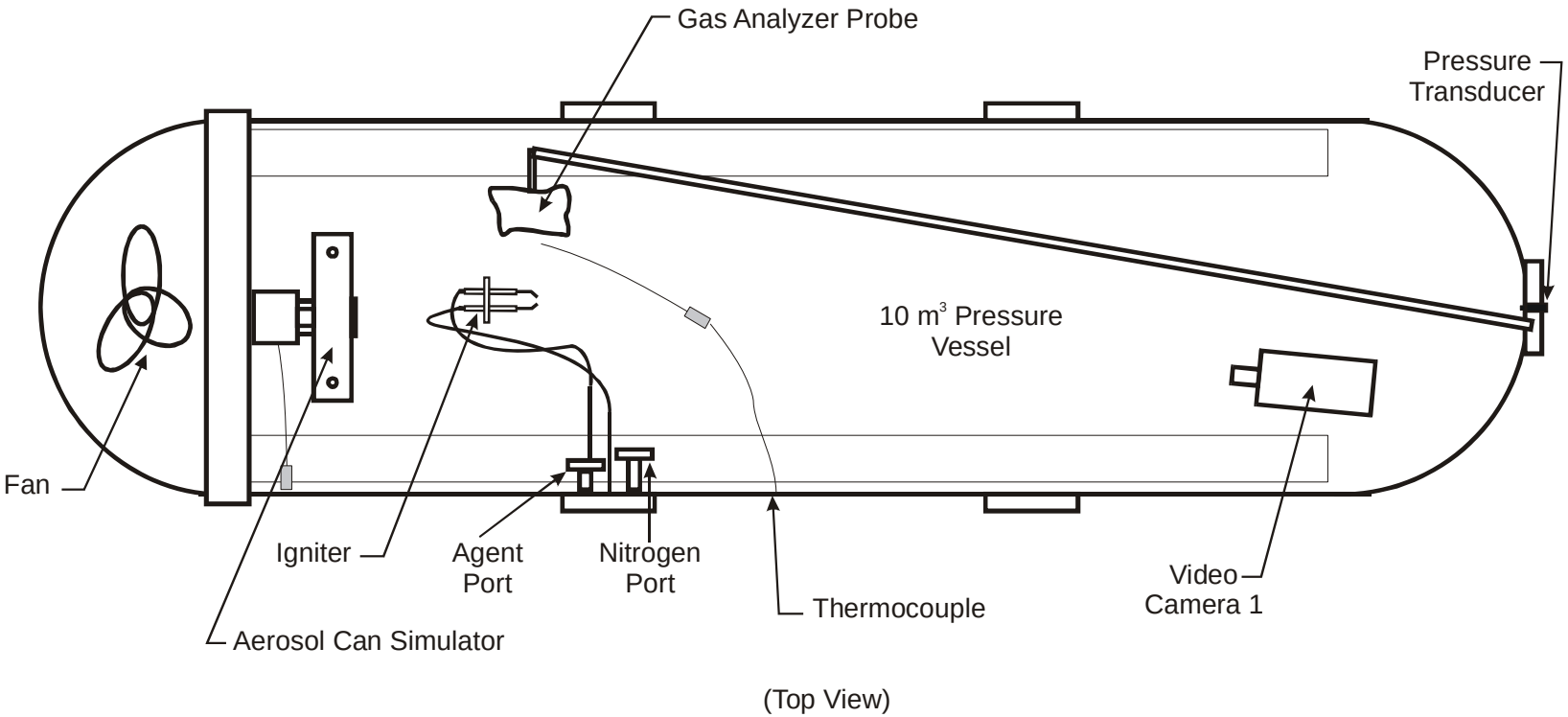
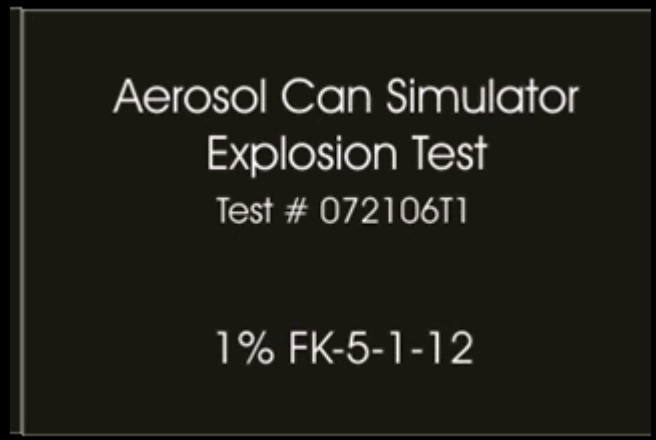


FIGURE 1. PRESSURE VESSEL SETUP

MPS Tests & Results

Test No.	Concentration Desired (Vol %)	Agent Quantity (lbs)	Result	Comments
050806T1	4.2	14	No Explosion	Agent filled by OEM. Arc electrodes did not spark.
050806T2	8.1	28	No Explosion	Agent filled by OEM. Arc electrodes did not spark.
071906T1	4.2	14.95	No Explosion	Fill to 14.8 -15.0 lbs with 460 psig N2. Air added to electrodes.
071906T2	8.1	29.96	No Explosion	Fill to 30 lbs with 460 psig N2. Air added to electrodes.
071906T3	2	6.92	No Explosion	Fill to 7.0 lbs with 460 psig N2. Air added to electrodes.
071906T4	0	0	20 psig	Baseline - No agent
07/20/06T1	8.1	30.12	No Explosion	Fill to 30.0 lbs with 460 psig N2. Air added to electrodes.
07/20/06T2	4.2	14.98	No Explosion	Fill to 15.0 lbs with 460 psig N2. Air added to electrodes.
07/20/06T3	2	6.94	No Explosion	Fill to 7.0 lbs with 460 psig N2. Air added to electrodes.
072106T1	1	3.44	33 psig	Fill to 3.4 lbs with 460 psig N2. Air added to electrodes. Explosion same as baseline.
072106T2	2	6.94	34 psig	Fill to 7.0 lbs with 460 psig N2. Air added to electrodes. Explosion same as baseline.
072106T3	4.2	14.8	66 psig	Fill to 15.0 lbs with 460 psig N2. Air added to electrodes. Agent enhanced explosion.
081006T1	4.2	14.8	67 psig	Fill to 15.0 lbs with 460 psig N2. Air added to electrodes. Agent enhanced explosion.

MPS Tests & Results



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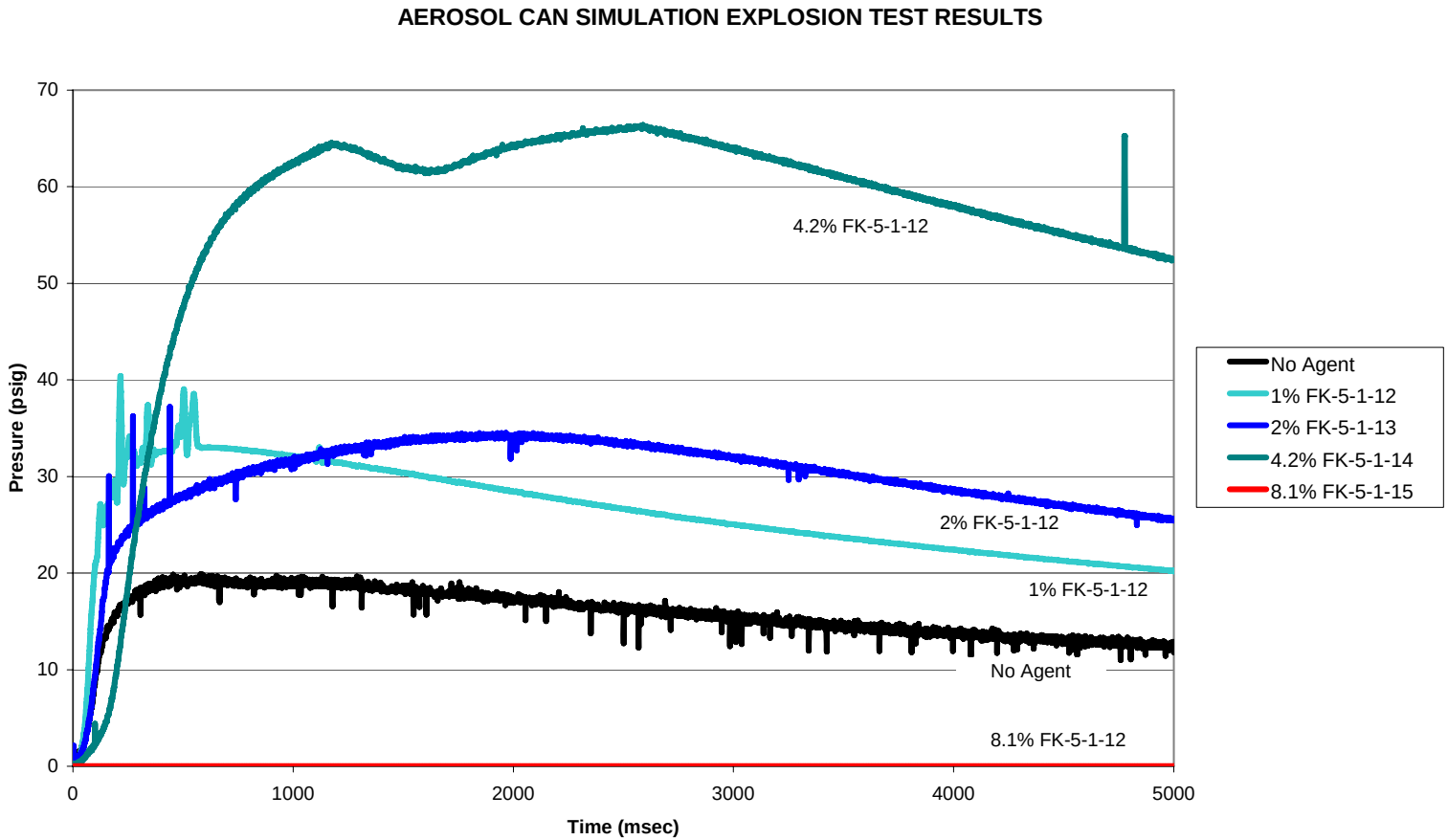

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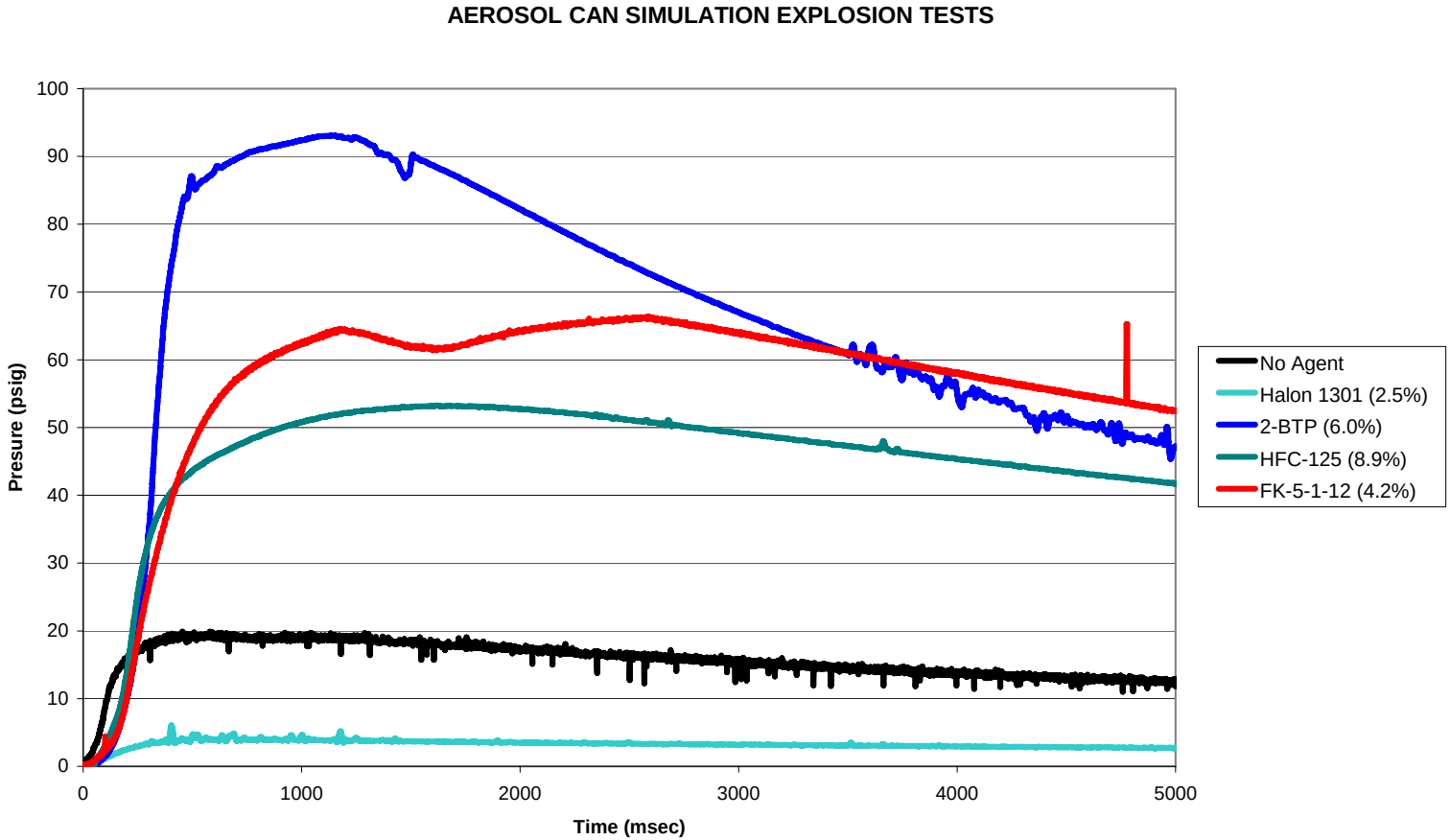
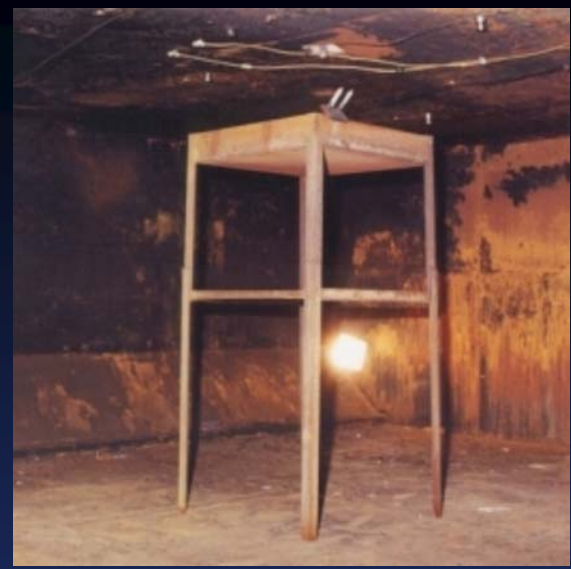


COMPARISON OF OVERPRESSURE HISTORIES OF VARIOUS AGENTS

Outline



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MPS Tests & Results

SURFACE BURN FIRE TEST

Fire Load = 0.5 U.S. Gallon of Jet A fuel (with 13 oz of gasoline) inside A 2 ft x 2 ft x 0.33 ft pan

Add 13 oz of gasoline to make ignition easier; add 2.5 gallons of water to reduce pan warping.

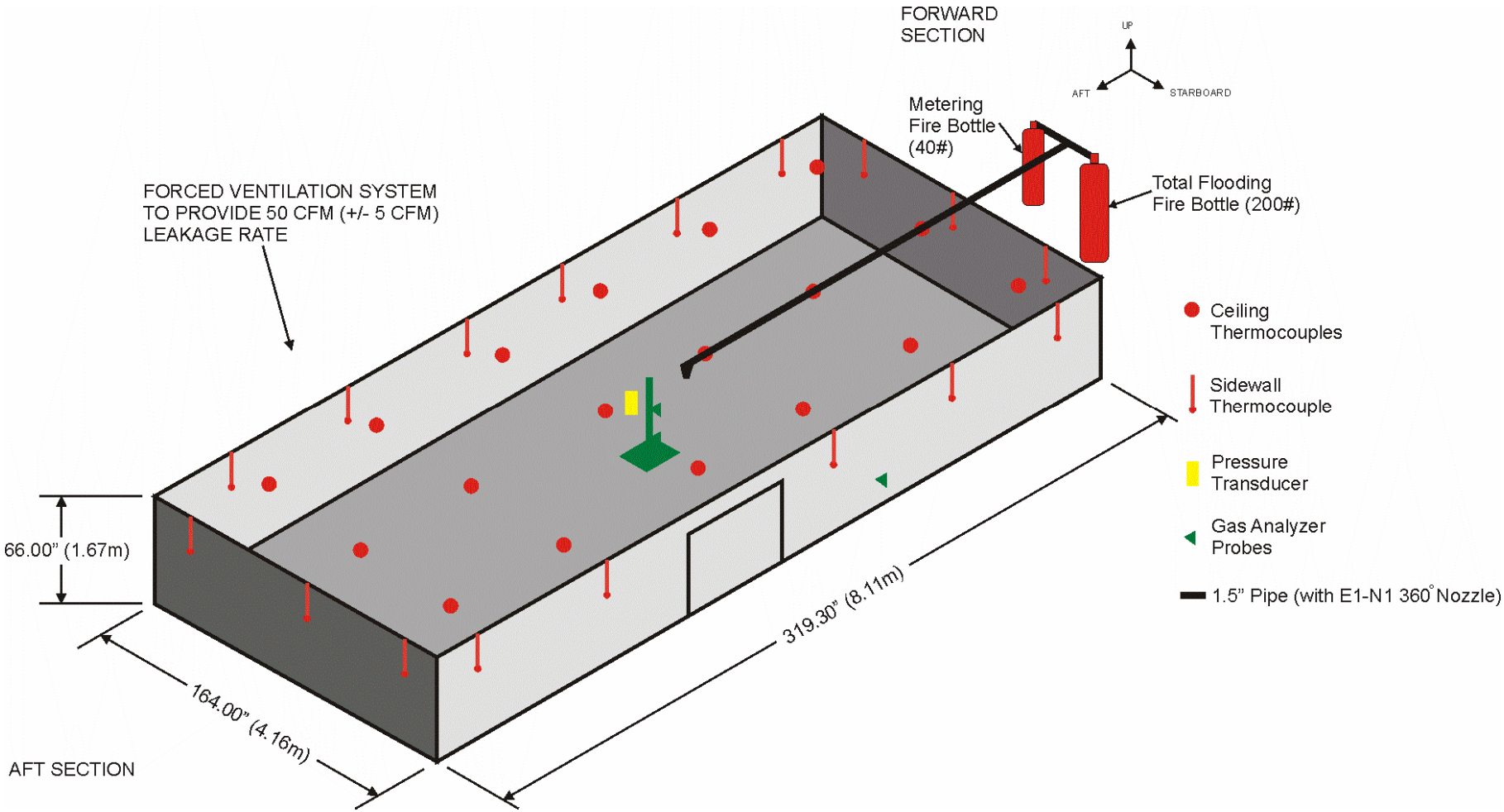
Place pan in most difficult location (1 ft)

Fire Ignition = Arc created by two electrodes

FSS Activation = 1 min. after one of the ceiling T/C reaches 200 ^{o}F

Test Duration = 5 minutes after agent discharge

MPS Tests & Results

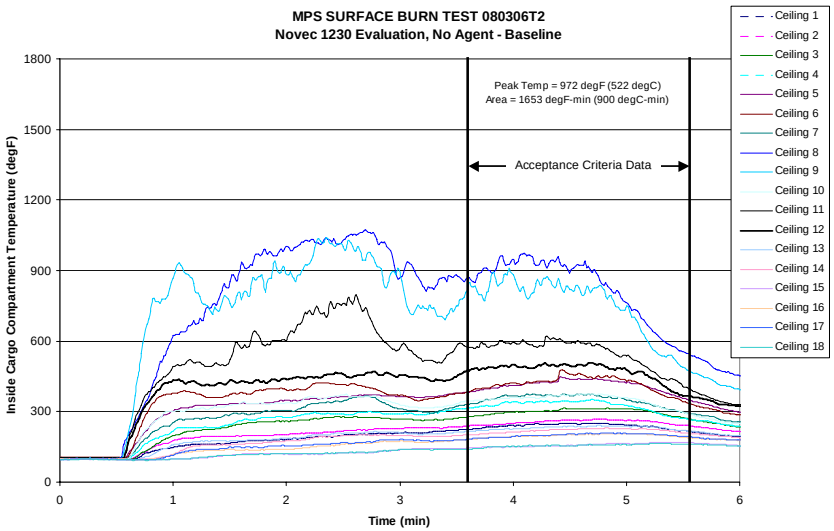


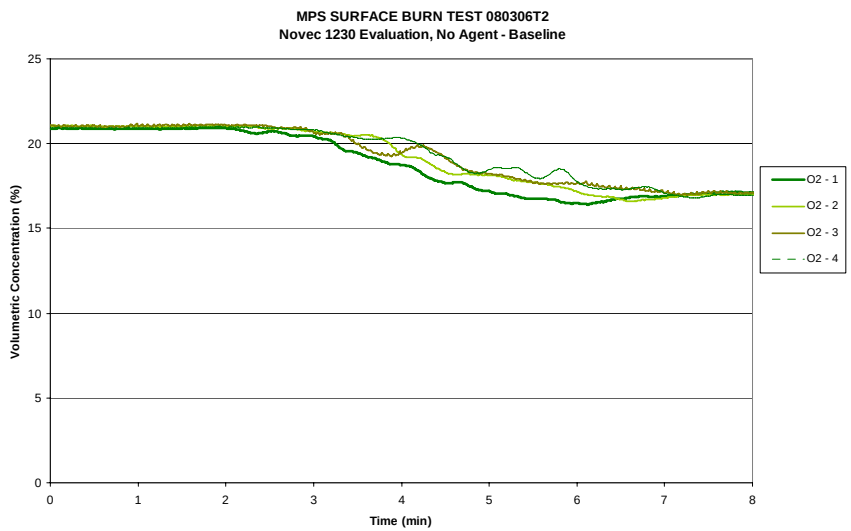
MPS Tests & Results

SURFACE BURN TEST RESULTS (56.6 m^3 COMPARTMENT)

Test No.	Concentration Desired (Vol %)	Agent Quantity (lbs)	Result	Comments
080106T1	0	0	Fire Peak = 953 F, Area = 1631 F*min	Surface Burn Baseline
080306T1	4.2	74.41	Fire Peak = 294 F, Area = 540 F*min	Filled to 74.4 lbs with 360 psig N2. Test temperature was 95 degF, atm. pressure 29.83", 50% relative humidity
080306T2	0	0	Fire Peak = 972 F, Area = 1653 F*min	Surface Burn baseline

MPS Tests & Results





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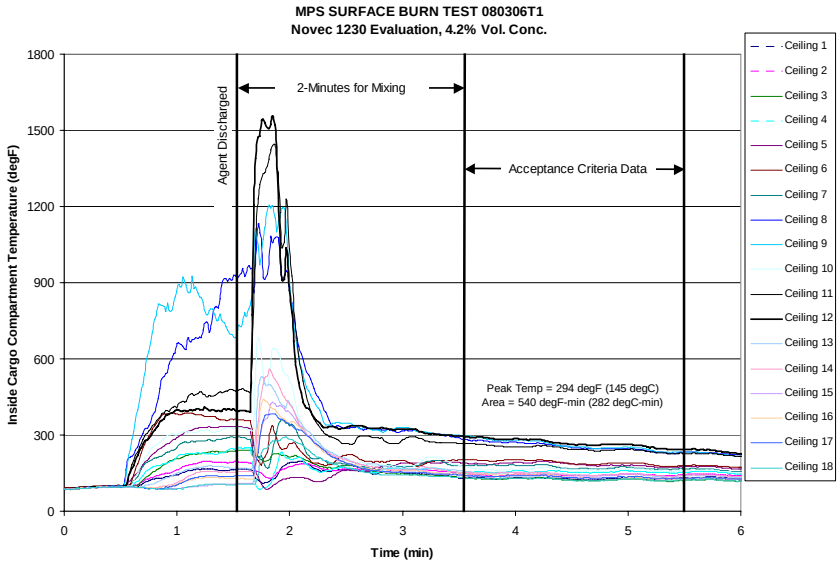

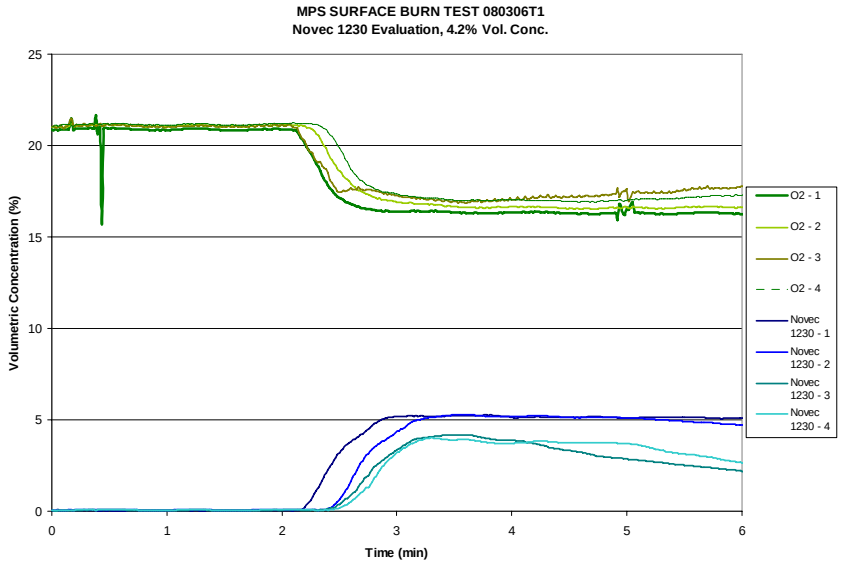

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MPS Tests & Results

CONTAINERIZED FIRE TEST

Fire Load = 33 card board boxes inside an LD3. 3 LD3 in Compartment

Two ventilation slots in main LD3 container size 12” x 3” +/-1/4 (access panel, and lower right panel)

The LD3 access panel is made out of 0.08” polycarbonate sheet

Fire Ignition = 7 ft of nichrome wire wrapped around four folded paper towels (Energized with 120 Vac)

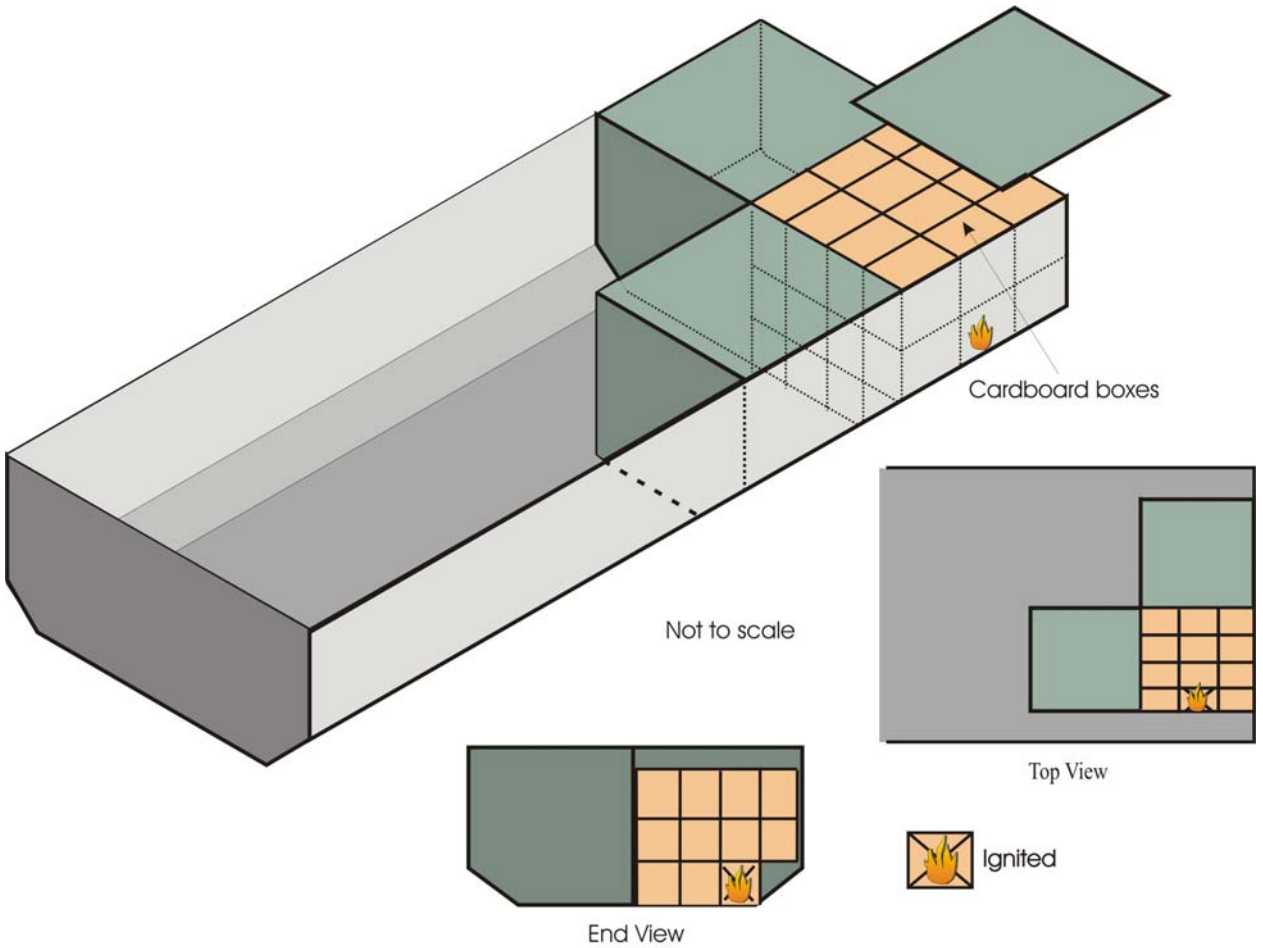
MPS Tests & Results

CONTAINERIZED FIRE TEST (CONT.)

FSS Activation = 1 min. after one of the ceiling T/C reaches 200 ^{o}F

Test Duration = Four tests @ 30 minutes each; fifth test shall
for at least 180 minutes. Hybrid systems shall run for 180 min.

MPS Tests & Results



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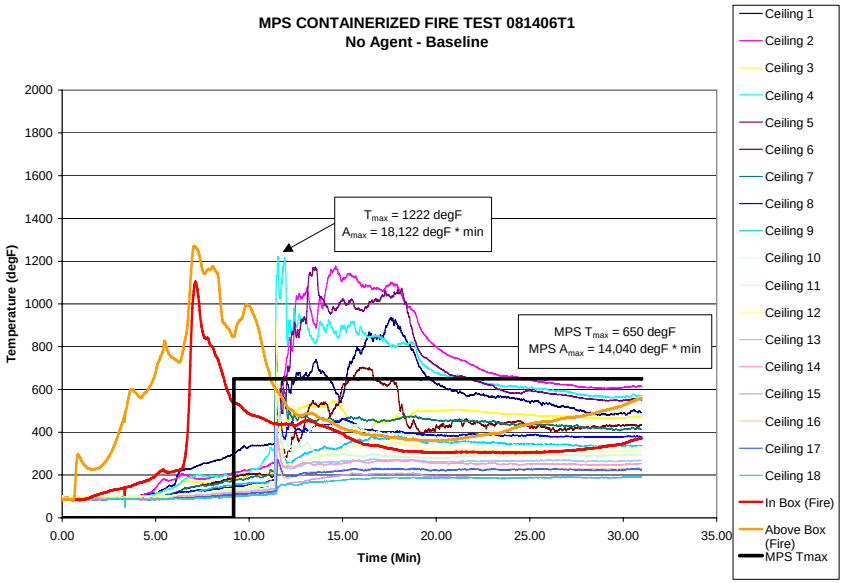

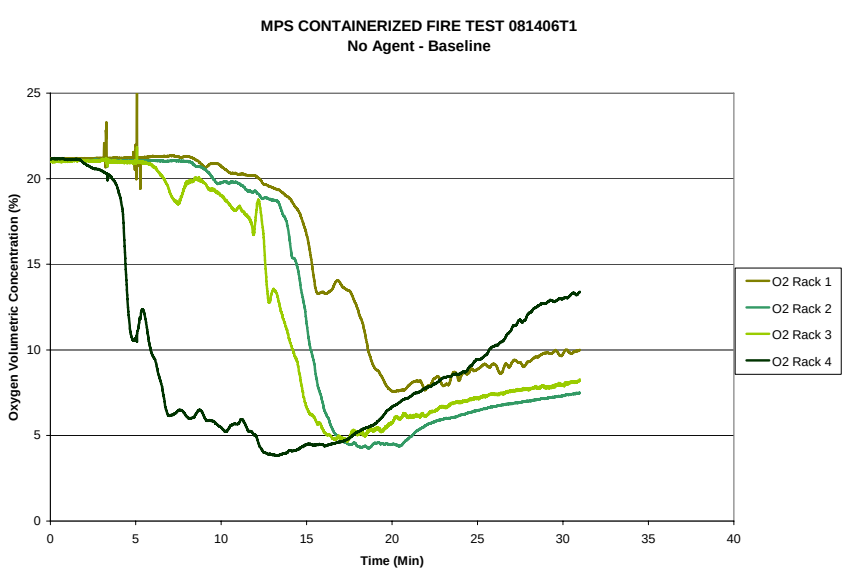

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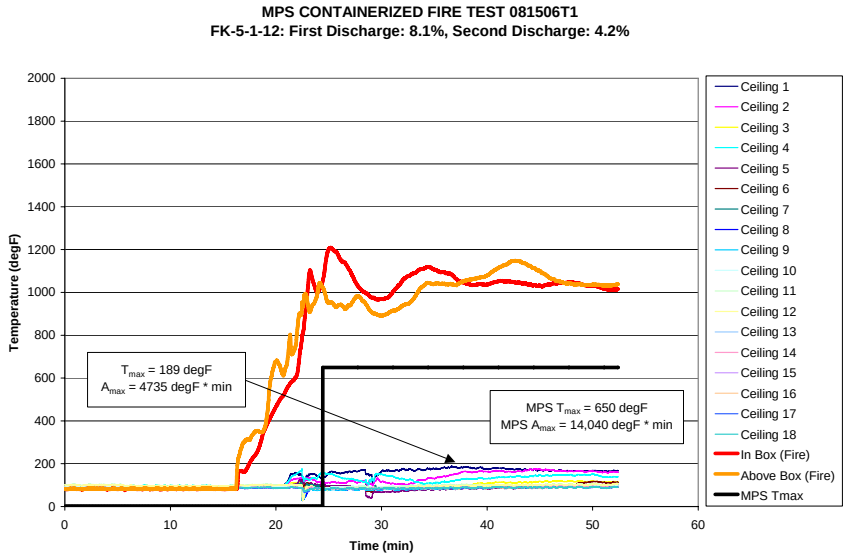

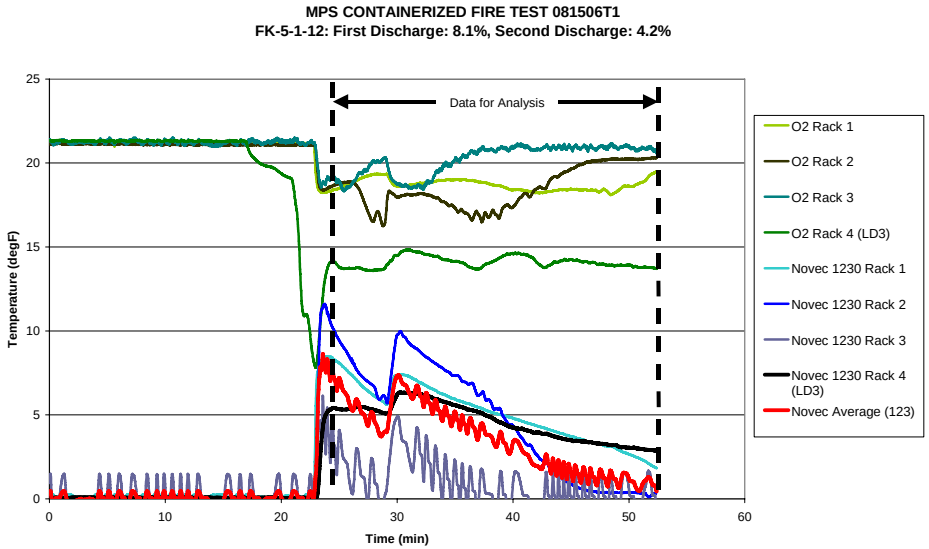

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BULK-LOAD FIRE TEST

Fire Load = 178 card board boxes (30% of Vol.) containing 2.5 lbs of shredded office paper (strips, not confetti) at standard room temp.

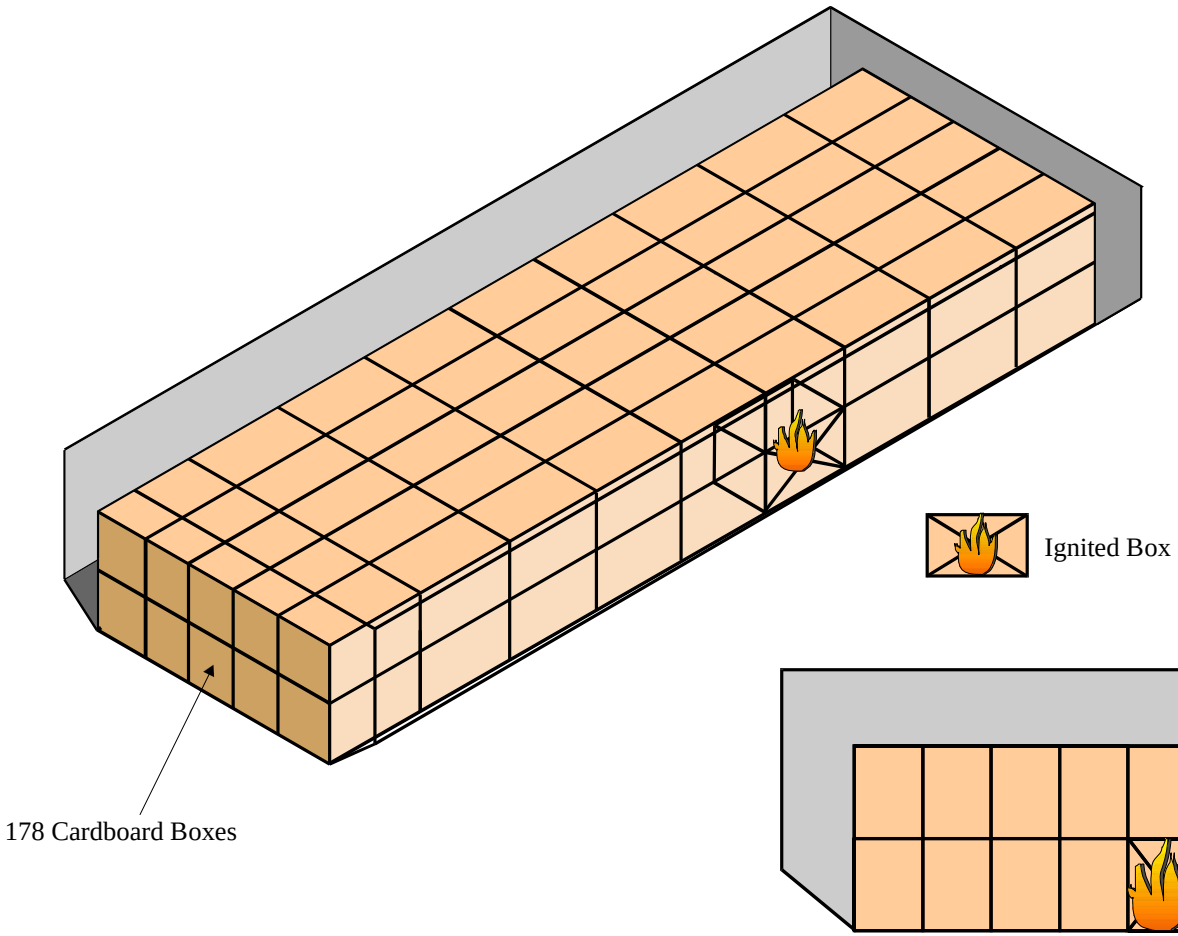
Boxes nominal dimensions: 18'x18"x18"

Fire Ignition = 7 ft of nichrome wire wrapped around four folded paper towels (Energized with 120 Vac) inside box (with 1" holes).

Fire Suppression System Activation = 1 minute after one of the ceiling T/C reaches 200 ^{o}F

Test Duration = Four tests @ 30 minutes each; fifth test shall for at least 180 minutes. Hybrid systems shall run for 180 min.

MPS Tests & Results



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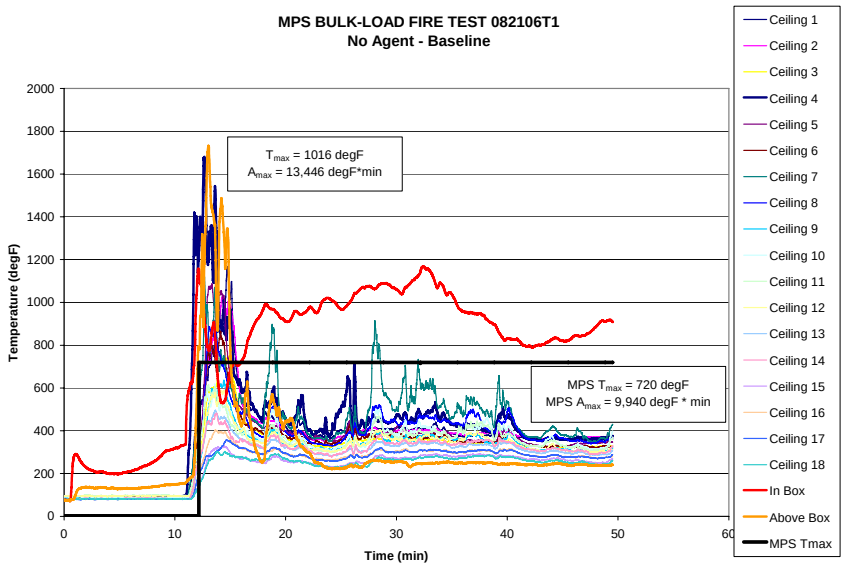

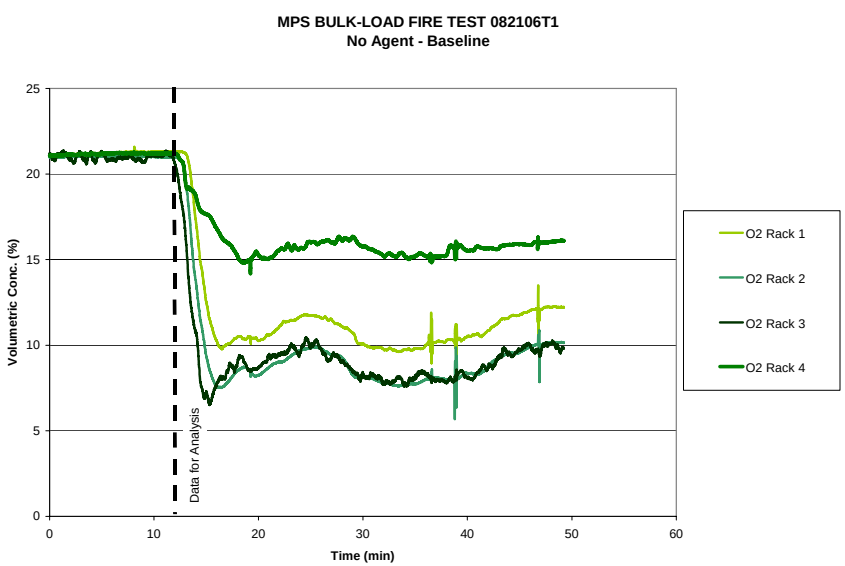

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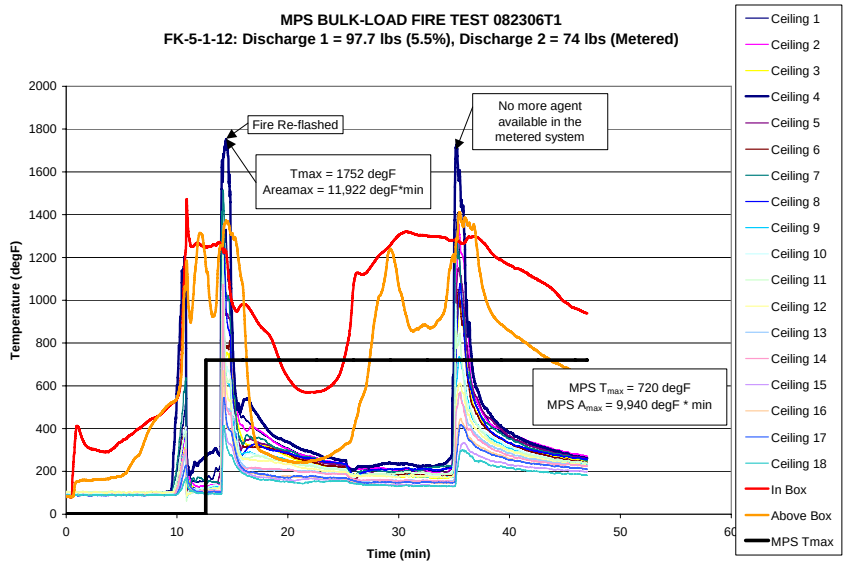

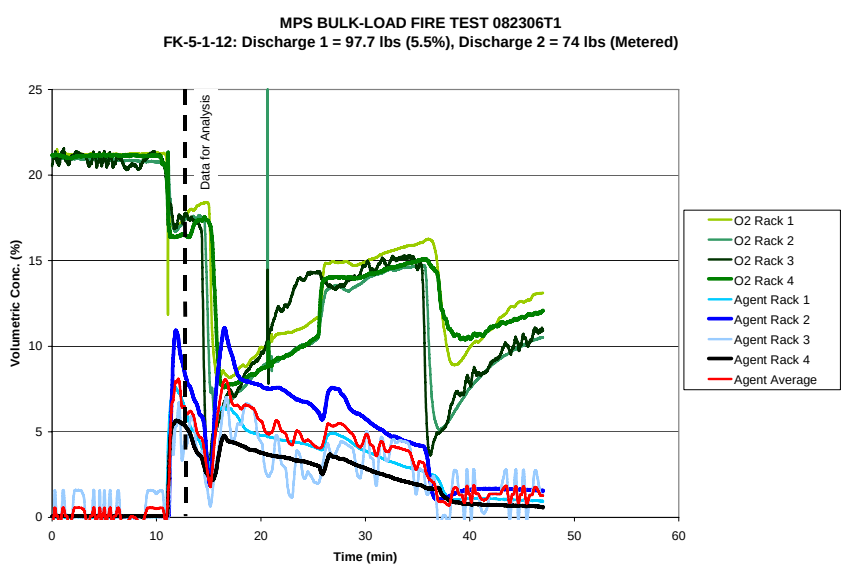

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Final Remarks

FK-5-1-12: AIRCRAFT CARGO COMPARTMENT MPS TEST RESULTS

MPS TEST	PASS	FAIL	COMMENTS
Aerosol Can Explosion Simulation Test		**X**	Modified Test: added air to electrodes to make them arc. Explosion enhancement at below inert concentration. 13 tests conducted.
Surface Burn Test	**X**		1 out of 5 tests conducted
Containerized Test	**X**		1 out of 5 tests conducted
Bulk-Load Test		**X**	Fire re-ignited ~ 3 minutes after the agent was discharged. It reflashed for a second time after the metering agent was consumed. 1 out of 5 tests conducted

For this fire protection application, FK-5-1-12 (as configured and tested) is not effective because it did not meet the FAA acceptance criteria in its entirety.

Final Remarks

Suggestion on solutions to meet Aircraft Cargo Compartment MPS acceptance criteria:

Aerosol Can Simulation Explosion & Bulk-Load Tests:

- Maintain agent at inert concentration at all times
- Or, maintain oxygen level in cargo compartment below 12% using inert gas
- Or, combine agent and inert gas system (three-stage discharge):

  FK-5-1-12 HRD → Inert Gas HRD → Inert Gas LRD

  (Knockdown Flames → Prevent Re-ignition → Suppress for long period of time)