Status of Research & Testing to Replace Halon Extinguishing Agents in Civil Aviation

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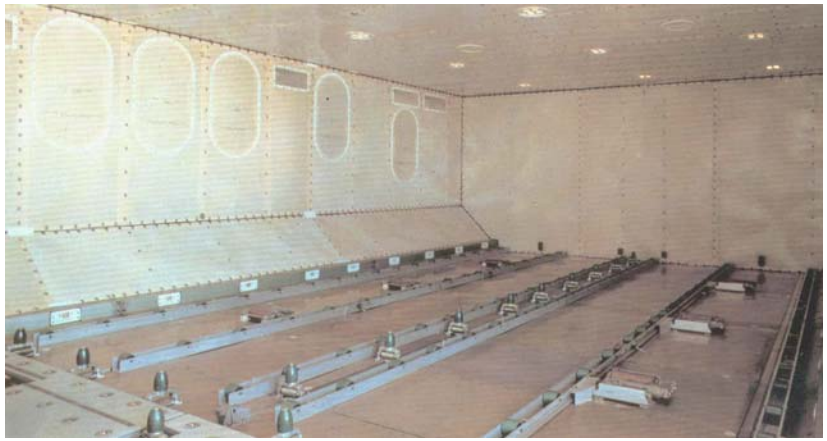
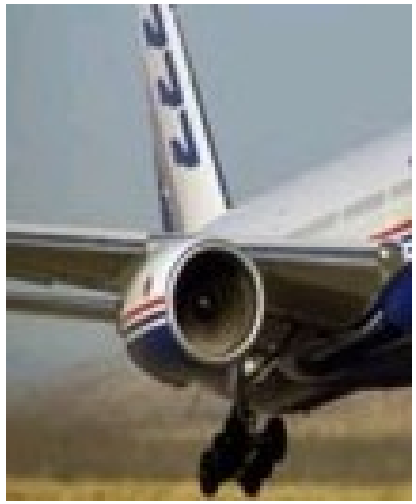
Federal Aviation Administration

Current Usage of Halon 1301/1211



Cargo Compartments



Engine Nacelles

Hand Held Extinguishers

Lavatory Trash Receptacles

Halon Replacement in Civil Aviation

- **Halon Fire Extinguisher Used in Civil Aviation for Over 45 Years**
- **Montreal Protocol Banned Halon Production (*Not Use*) on January 1, 1994**
- **Example of Relative Agent Weights (B777): Lavs (1.5 to 3.0 lbs), Hand-Held (10 to 17.5 lbs), Engine/APU (58 lbs), Cargo (377 lbs)**
- **FAA Established International Halon Replacement Working Group (Now Called International Systems Fire Protection Working Group) to Develop Minimum Performance Standards (MPS) for Each Application**
- **Purpose of Each MPS is to Define Full-Scale Fire Tests to Demonstrate Equivalency**
- **Tests Developed at FAA Technical Center**

Agents Tested

Agent	Chemical Formula	Name
Halon 1301	**$CBrF_3$**	
Halon 1211	**$CBrClF_2$**	
HFC-227ea	**CF_3CHFCF_3**	**FM-200**
HFC-125	**CHF_2CF_3**	**FE-25**
FIC-13I1	**CF_3I**	**Triodide**
2-BTP	**CH_2CBrCF_3**	
HCFC Blend B	**$CF_4/CHCl_2CF_3$**	**Halotron I**
HFC-236fa	**$CF_3CH_2CF_3$**	**FE-36**
FK-5-1-12	**$CF_3CF_3COCF(CF_3)_2$**	**Novec 1230**
Water Mist	**H_20**	
Water Mist/Nitrogen	**H_20/N_2**	

Lavatory Trash Receptacle Summary

- **FM-200 and FE-36 Passed MPS Test**
- **Airbus and Boeing Offer Lavatory Extinguishers**
- **MPS Report: DOT/FAA/AR-96/122**

Lavatory Trash Receptacle Extinguishers

Hand-Held Extinguishers Summary

- **Two Fire Tests Required in MPS**
- **Hidden Fire Test Standard (Effectiveness)**
  - Developed by IASFPWG
  - U.L. Offers Test Approval
- **Seat Fire Extinguishing Test (Toxicity)**
  - Full-Scale Tests at Tech Center
  - Measure Agent Decomposition Products
- **Draft AC 20-42D: “Hand Fire Extinguishers for Use in Aircraft”**
  - Safe Agent Discharge for Wide Range Aircraft/Compartment Volumes
- **Know Agents Listed by U.L. (Hidden Fire Test)**
  - HCFC Blend B (Halotron 1)
  - HFC-227ea (FM-200)
  - HFC-236fa (FE-26)
- **MPS Report: DOT/FAA/AR-01/37**

Hidden Fire Test Apparatus

Seat Fire Extinguishing Test (Toxicity)

FAA Advisory Circular AC 20-42D

- Guidance for New Installations of Required Hand-Held Extinguishers
- Lists FAA-Approved Replacement Agents
  - HCFC Blend B
  - HFC-227ea
  - HFC-236fa
- Would replace AC 20-42C
- Developed with Experts in IASFPWG
- Publish in Federal Register in 2008 for Public Comment

Appendix

MINIMUM SAFE COMPARTMENT VOLUME
NO VENTILATION

For the following 5 B:C extinguishers, released at 70ºF: (21.1ºC)

Agent	Agent Weight[1] (lbs)	Minimum Safe Volume (ft^3) [2, 3]				
		Sea Level (For info only)	8,000 ft P Altitude (Pressurized Cabin)	14,000 ft P Altitude	18,000 ft [4] P Altitude Nasal Cannula Oxygen Supply	25,000 P Altitude Diluter-Demand Oxygen Mask
HCFC Blend B	5.2	1337	1799	2276	2678	3586
HFC-227ea	5.5	99	135	170	200	269
HFC-236fa	4.75	80	107	128	159	214
Halon 1211	2.5	556	749	947	1111	1497
Halon 1301	5.0	192	259	327	385	517

1. *The agent weight for a 5 B:C extinguisher is extinguisher dependent.*
2. *Use this table if air change time is unknown or exceeds 6 minutes*
3. *Multiply this number by the number of extinguishers in the aircraft*
4. *If nasal cannula oxygen on-board*

nasal cannula

AGENT TOXICITY: NO. OF 5BC BOTTLES ALLOWED

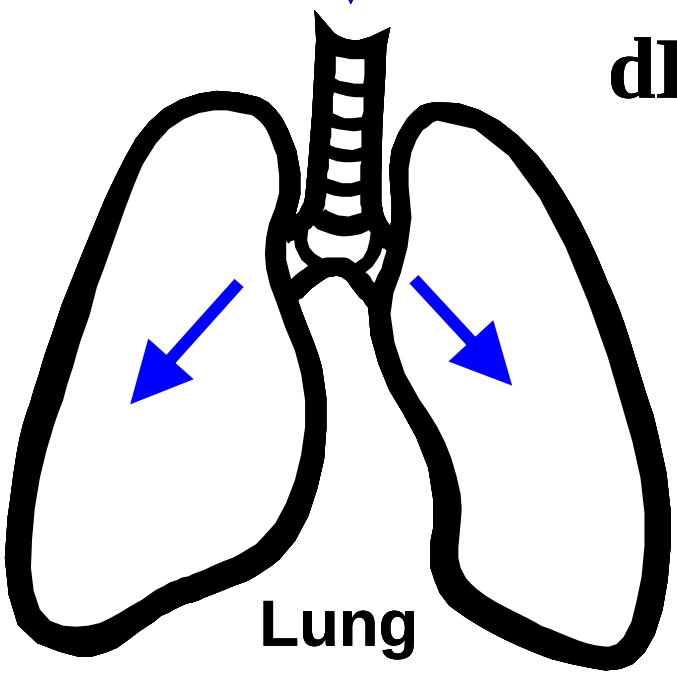
Appendix

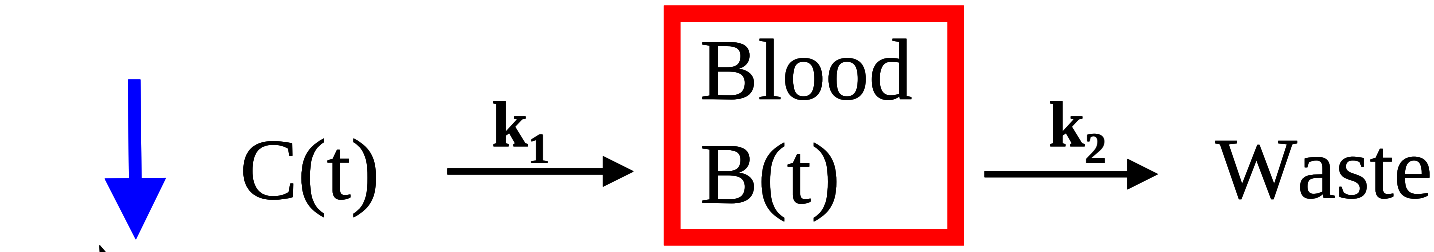
(NO VENTILATION, 8000 FT ALTITUDE, 70ºF)

Aircraft/ Helicopter	Vol (ft^3)	Max No. Seats	AC20-42C & UL1093	AC40-22D				
			Halon 1211	Halon 1211	Halon 1301	HCFC Blend B	HFC-227ea	HFC-236fa
Cessna 152	77	2	0.3	0.1	0.3	0.04	0.5	0.7
Cessna 210C	140	6	0.5	0.2	0.5	0.08	1.0	1.3
Cessna C421B	217	10	0.7	0.3	0.8	0.1	1.5	2.0
Sikorsky S76	204	14	0.7	0.3	0.8	0.1	1.5	1.9
B727-100	5,333	131	17	7.1	21	3.0	38	50
B767-200	11,265	255	36	15	43	6.3	80	105
B 747	27,899	500	90	37	108	16	198	260

Less than one 5 B:C extinguisher allowed

MODELING ARTERIAL BLOOD CONCENTRATIONS OF HALOCARBONS USING 1st ORDER KINETICS





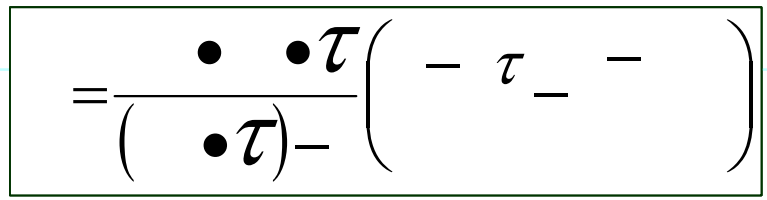
$$dB/dt = k_1 C(t) - k_2 B(t)$$

Ventilated Cabin

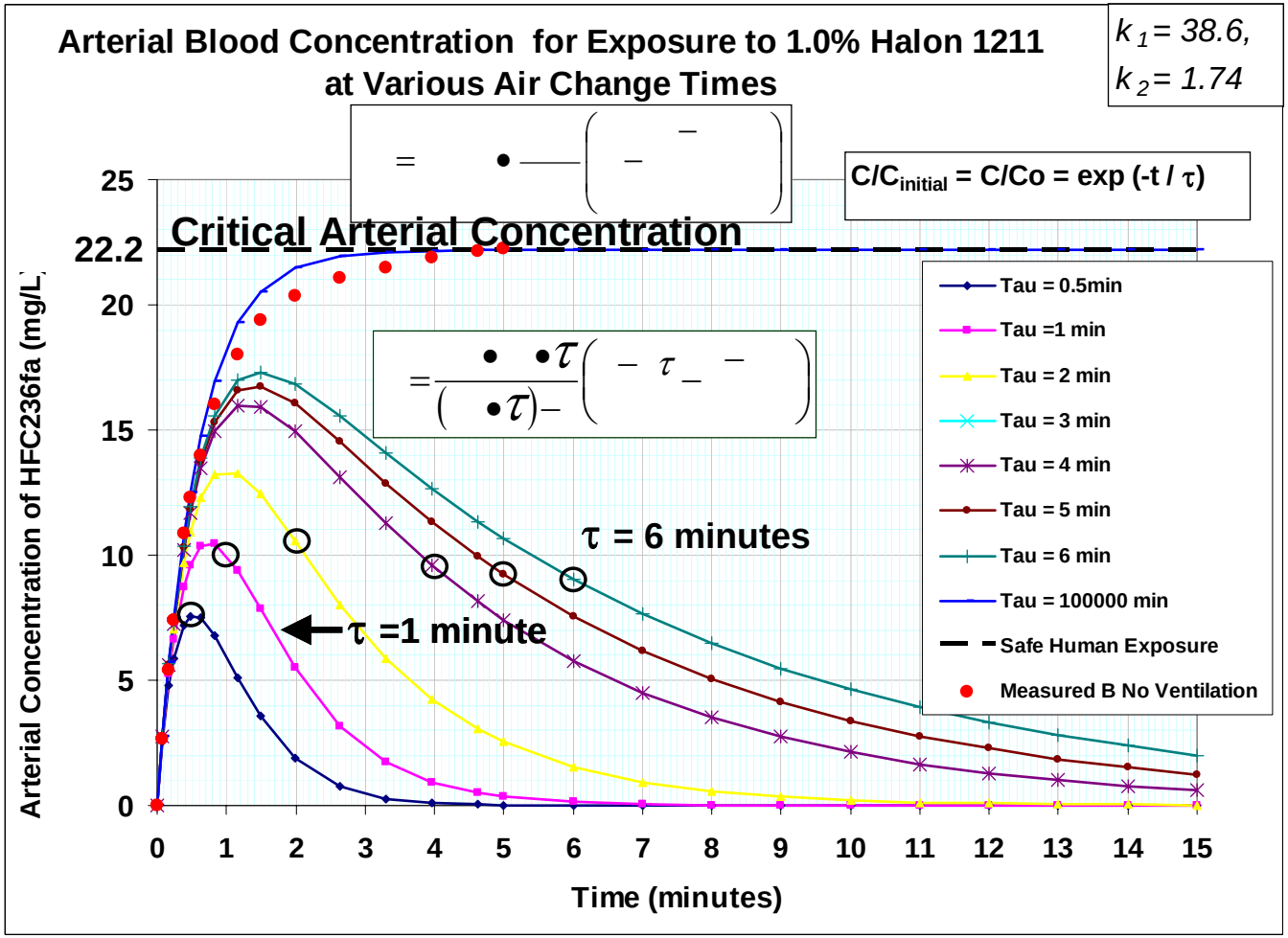
τ = Air Change Time

where: $C(t) = C_0 \cdot \text{Exp}(-t/\tau)$

Solution:



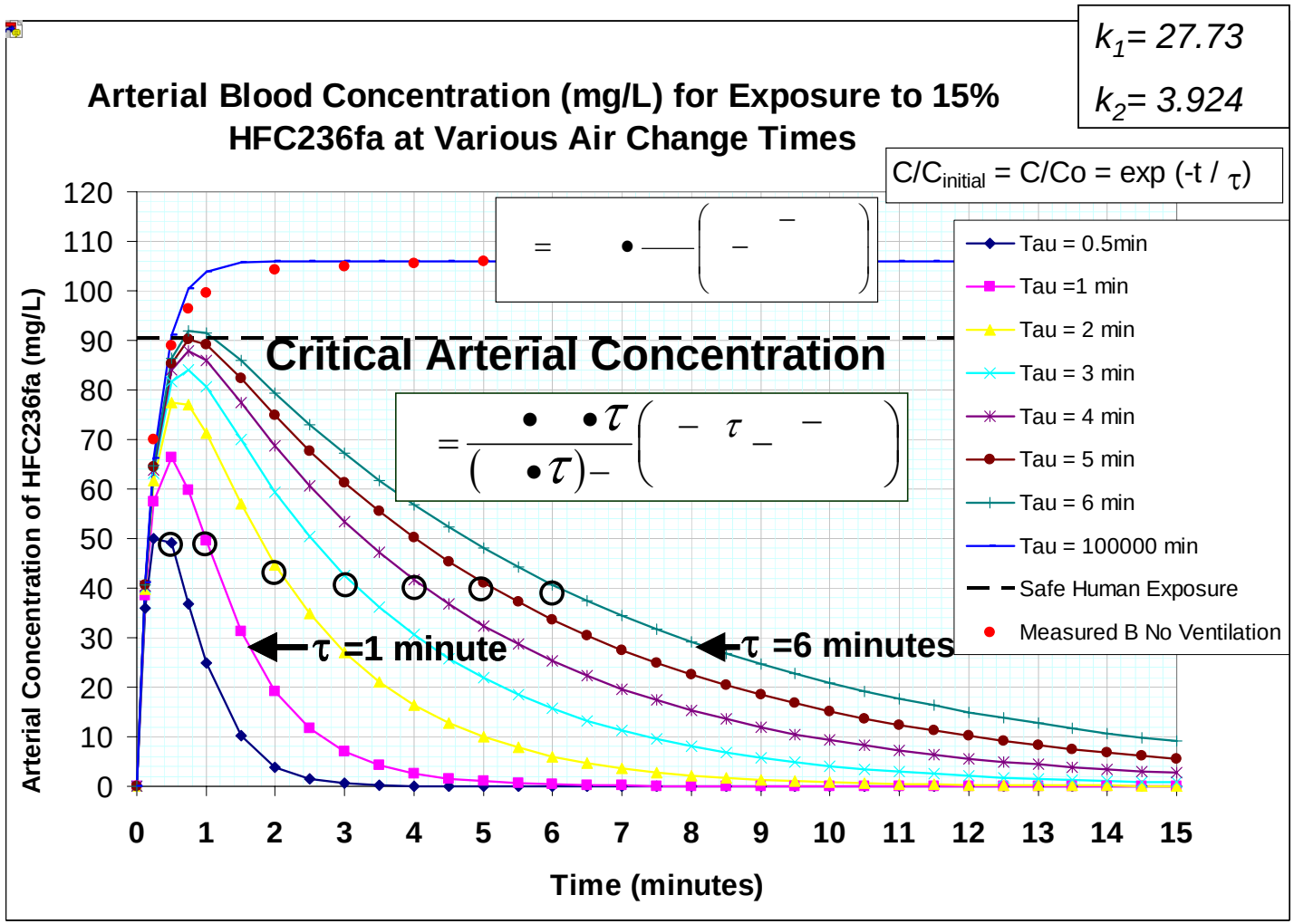
KINETIC MODELING OF ARTERIAL HALON 1211 BLOOD CONCENTRATION IN VENTILATED AIRCRAFT



τ = Air Change Time

The peak arterial concentrations are used to develop the selector curves

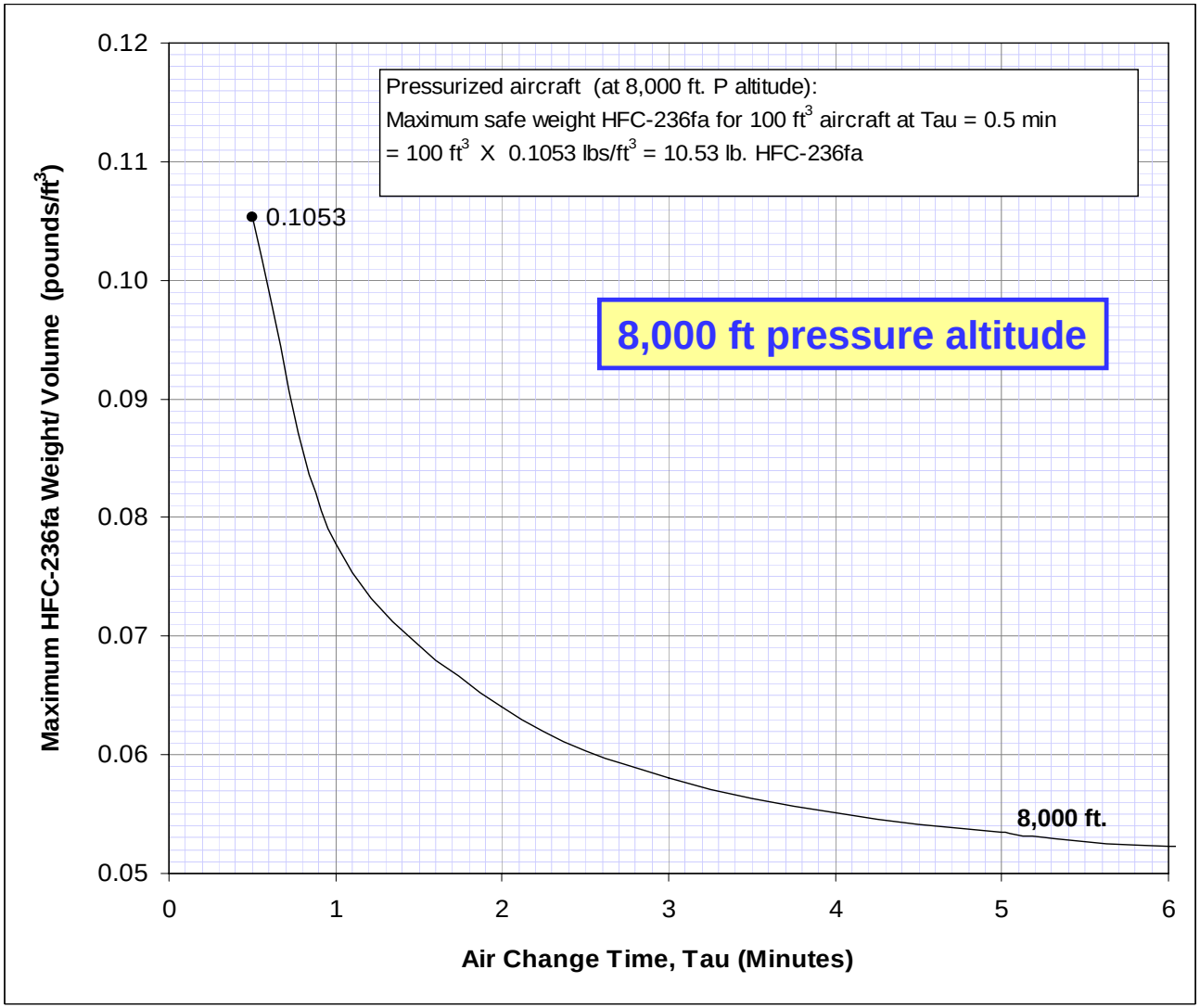
KINETIC MODELING OF ARTERIAL HFC236fa BLOOD CONCENTRATION IN VENTILATED AIRCRAFT



τ = Air Change Time

The peak arterial concentrations are used to develop the selector curves

HFC-236fa SELECTOR FOR PRESSURIZED VENTILATED COMPARTMENTS

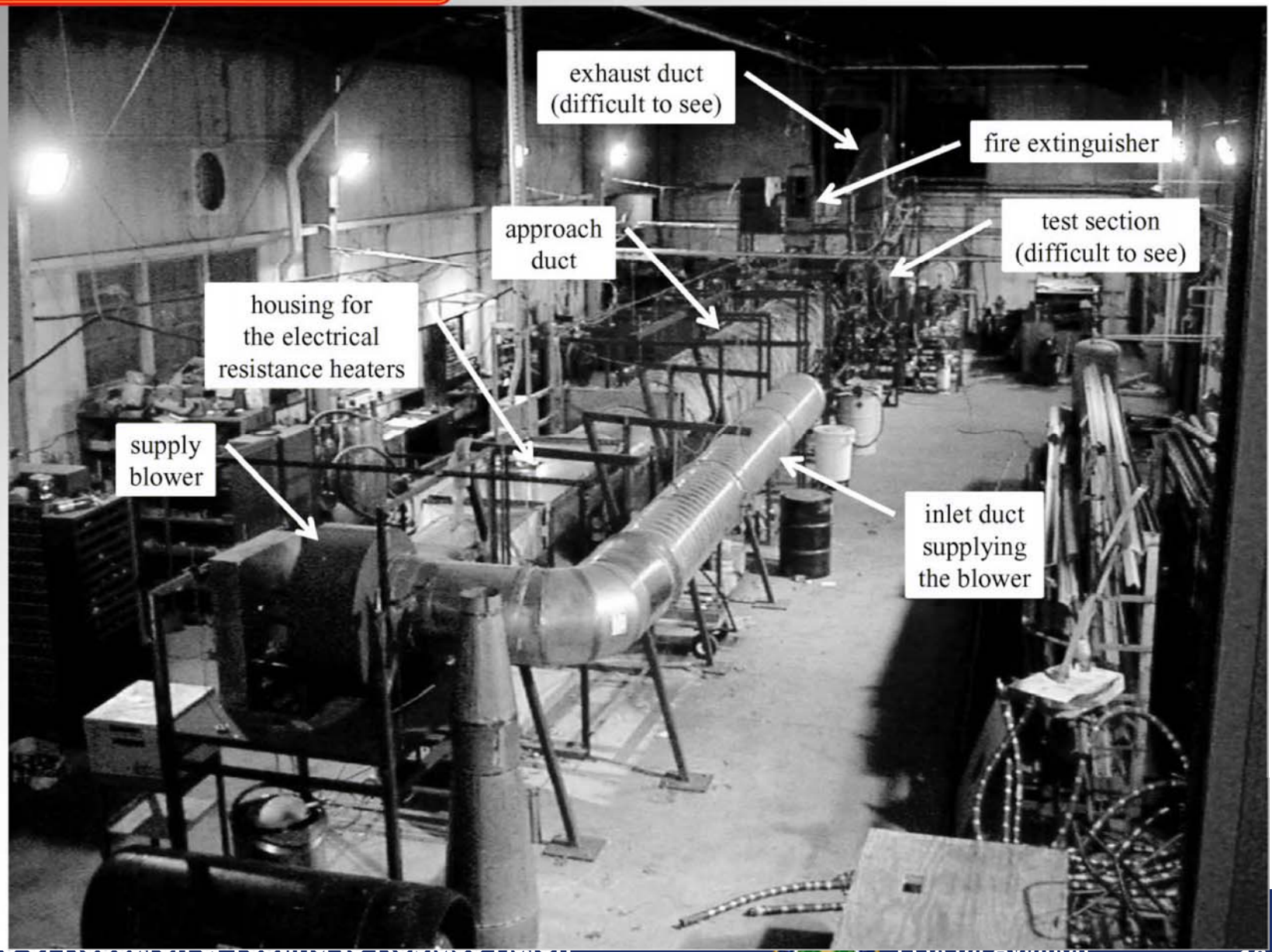


Perfect mixing assumed

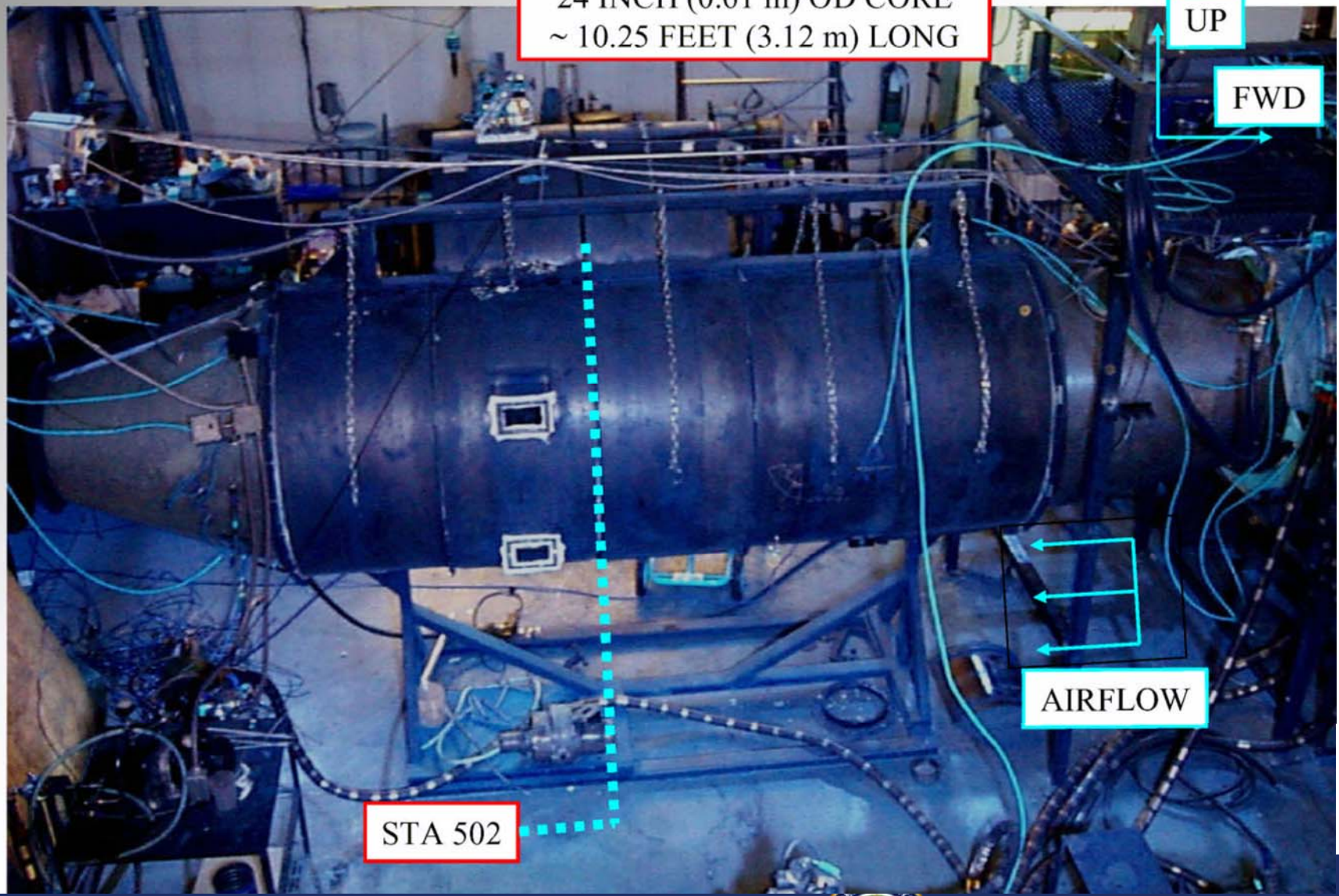
Engine Nacelle/APU Summary

- **Full-Scale Engine Nacelle Fire Simulator Only Exists at Tech Center**
- **Spray and Residual (Pan) Fires/Jet Fuel, Hydraulic Fluid, Engine Oil**
- **Two Mass Flow Rates/Two Temperatures**
- **Equivalency Determinations (Halon 1301 = 6%)**
  - HCF-125 = 17.6%
  - CF_3I = 7.1%
  - FK-5-1-12 = 6.1%
- **FAA/Airbus Tests in ENFS**
  - Proprietary Agent Equivalency/Certification Criteria Determined
  - Agent/System Will be Made Available for Production Airplanes
- **FAA/Walter Kidde/Boeing Began Testing New Agent in ENFS in 2007**
- **MPS Report: Draft (Available)**

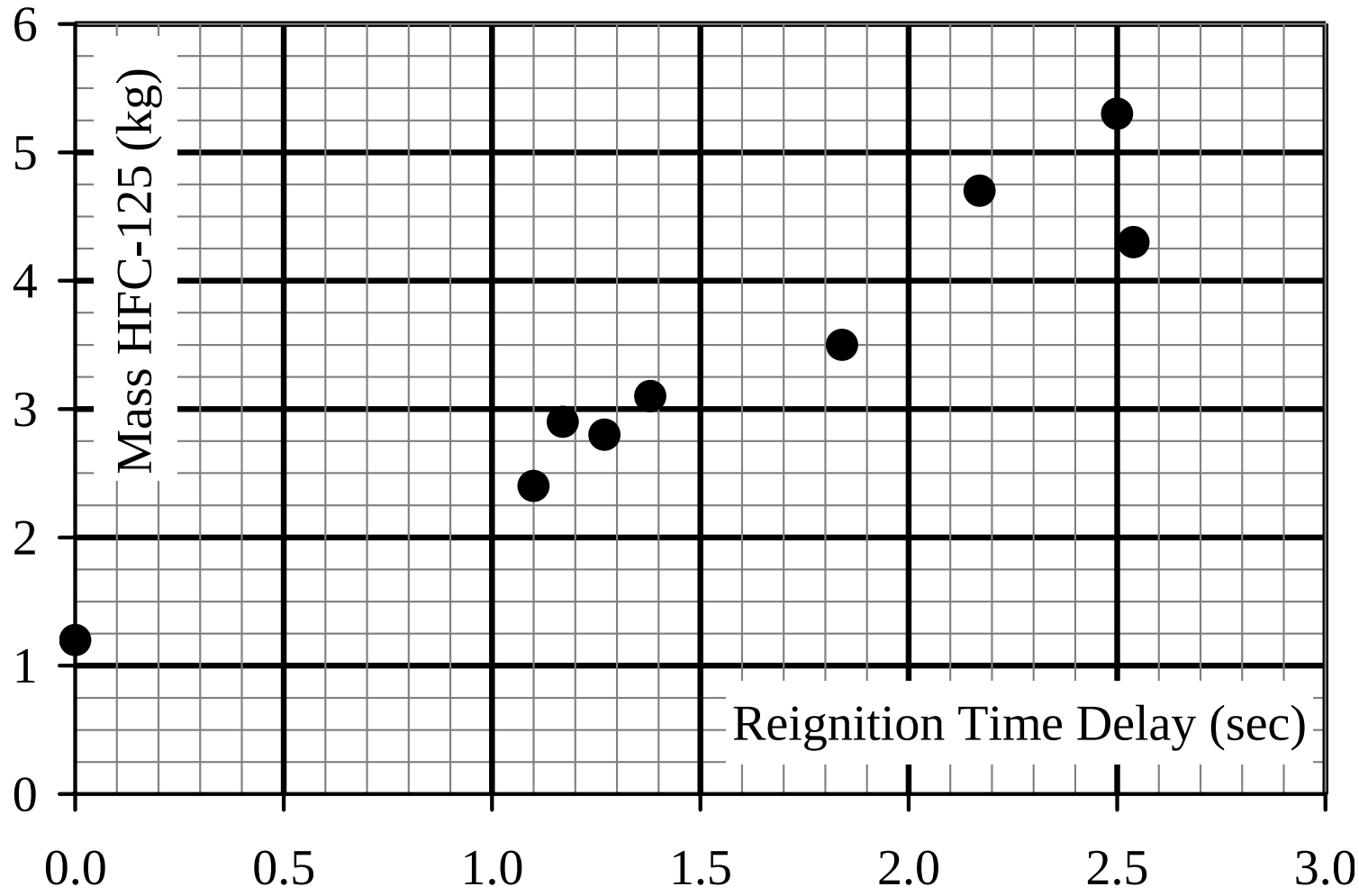
IMAGERY - TEST FIXTURE



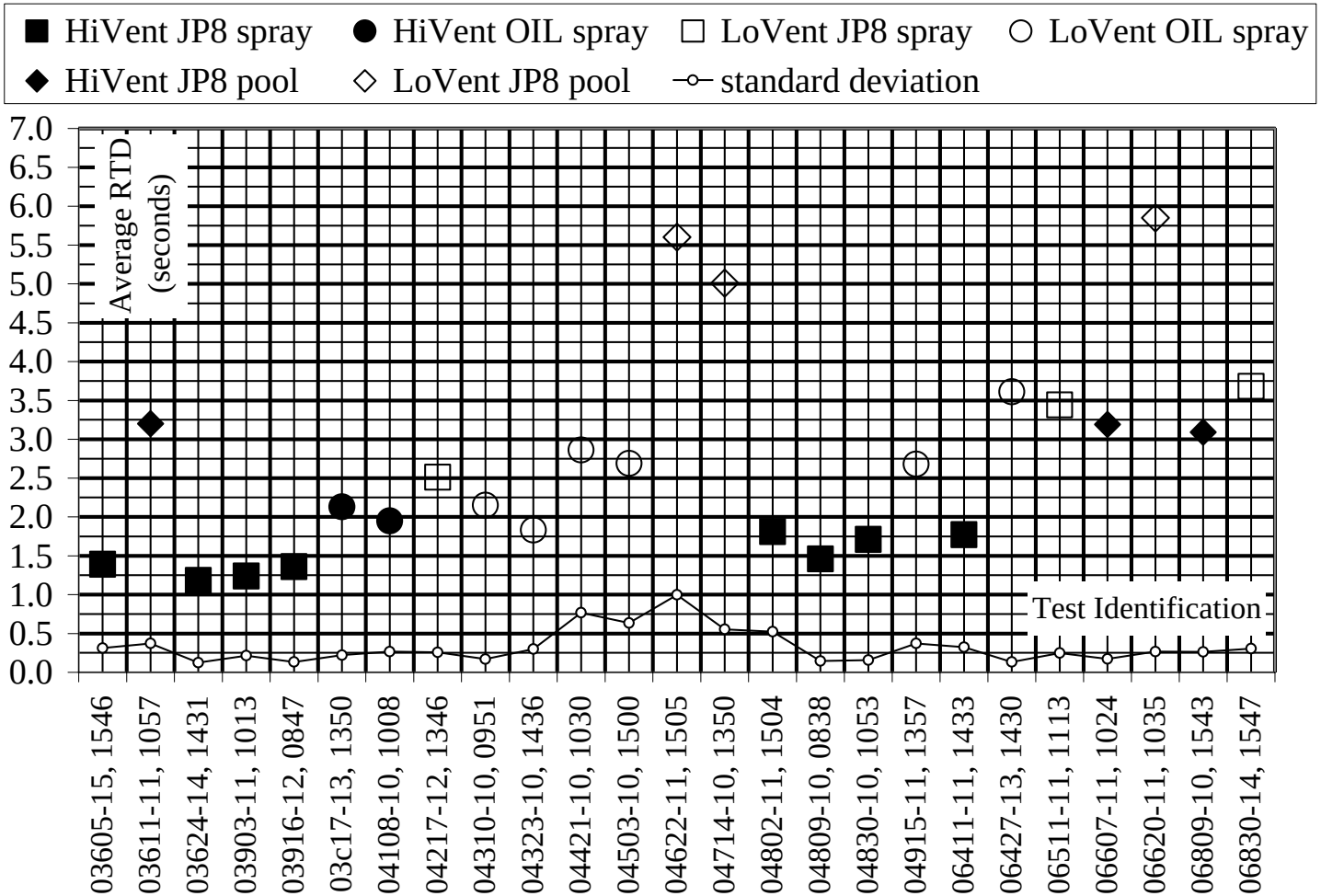
IMAGERY - TEST SECTION



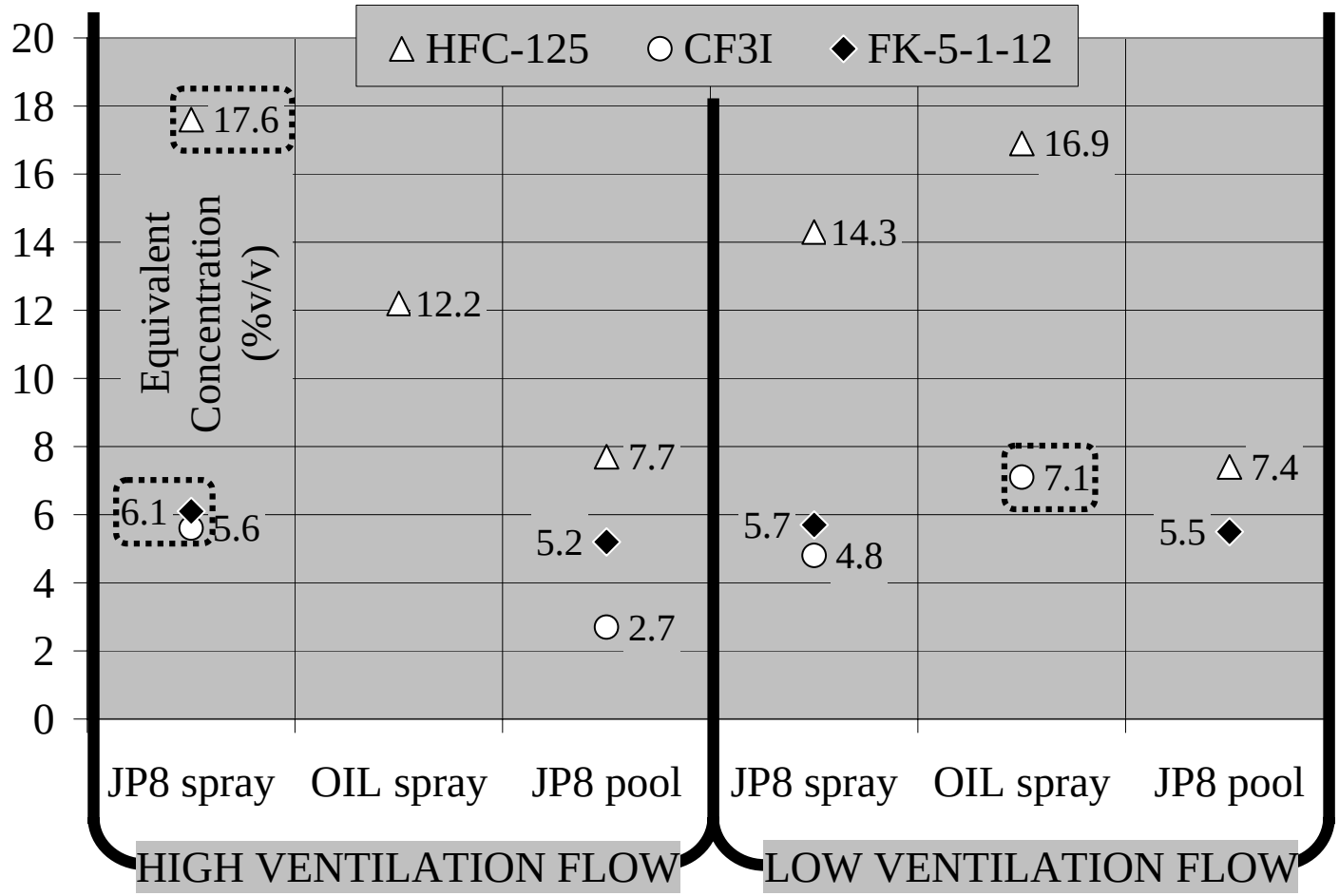
Effect of Mass of HFC-125 on Reignition Time Delay



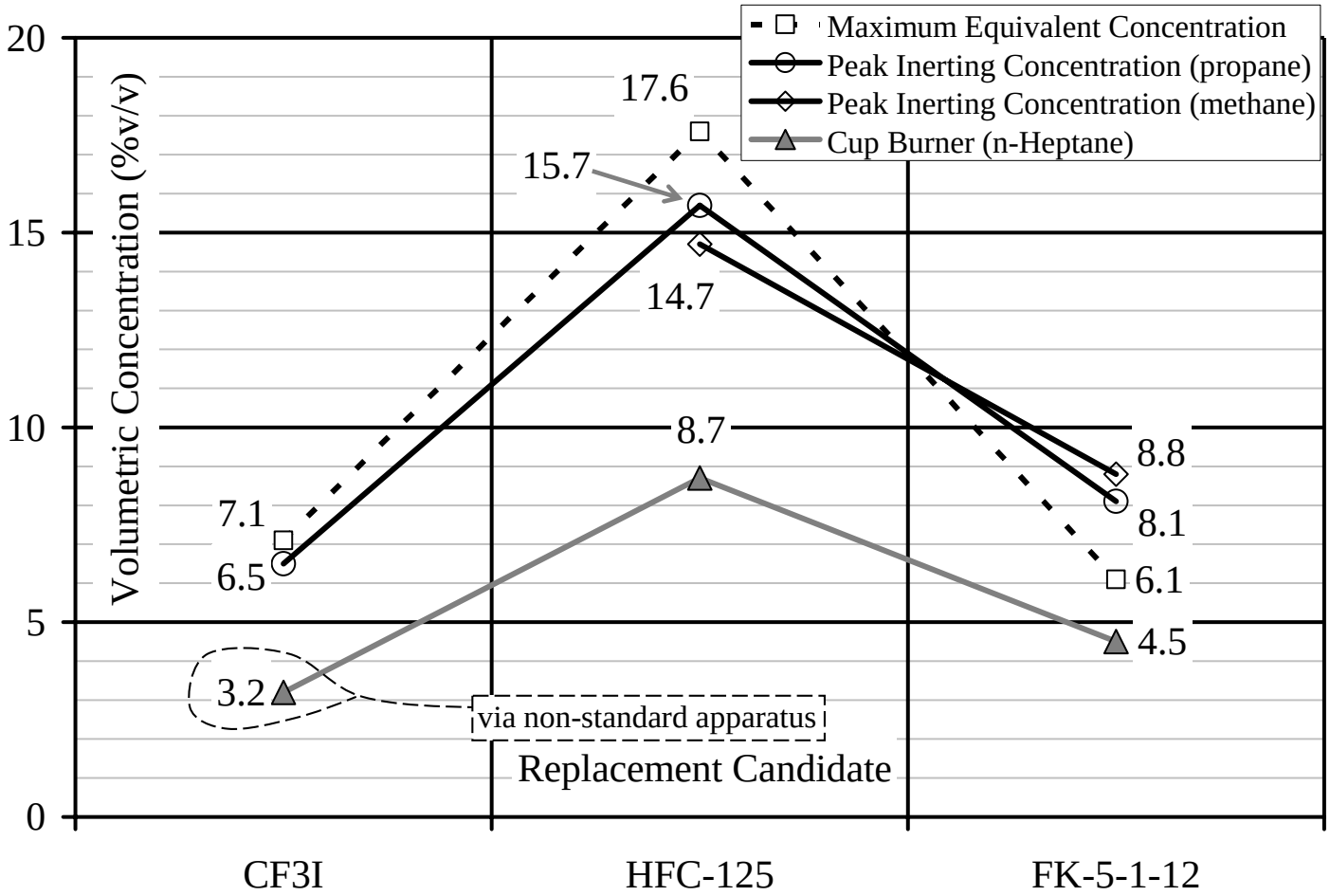
Three Year Variation of Ignition Time Delays



Equivalent Concentration of HFC-125, CF3I, and FK-5-1-12 at Different Fire Scenarios



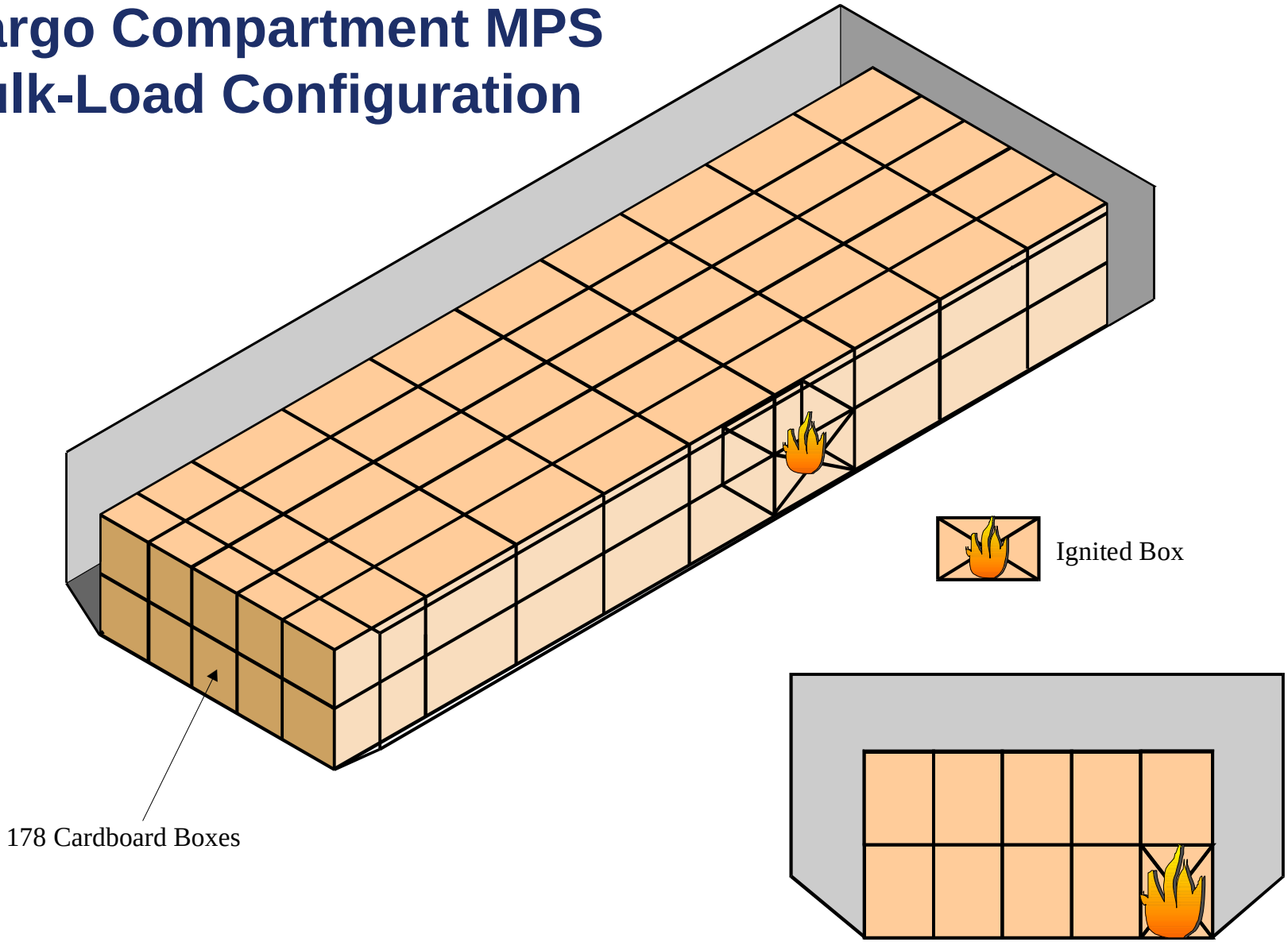
Comparison of Maximum Equivalent Concentrations of CF31 HFC-125, and FK-5-1-12 with NFPA 2001 Inerting and Cup Burner Data



Cargo Compartment Summary

- **Full-Scale 2000 ft^3 Test Article Specified in MPS**
- **Four Fire Scenarios**
  - Bulk-Loaded Cargo
  - Containerized Cargo
  - Surface Burning Fire
  - Exploding Aerosol Can
- **Much Activity but Each Approach has Shortcomings**
  - HFC-125/FM-200: High Weight Penalty, High HF Concentrations, Ignition of Smoke Layer
  - CF_3I: Toxicity Concerns
  - 2-BTP/Novec 1230: Overpressures at Below Inerting Concentrations During Aerosol Can Scenario
- **Water Mist/Nitrogen System Concept**
  - Promising but Requires Significant Development and Acceptance
- **MPS Report: DOT/FAA/AR-TN05/20**

Cargo Compartment MPS Bulk-Load Configuration



Status Summary on Halon Replacement in Civil Aviation

- **Lavatory:** Replacement Agents (2) Identified and Are Being Installed in Newly Manufactured Aircraft
- **Hand-Held Extinguishers:** Replacement Agents/Extinguishers (3) Identified But Are Not Being Installed By Manufacturers Because of Increased Weight and Volume
- **Engines:**
  - Significant and Promising Activity last Several Years
  - One Manufacturer has Selected a Replacement Agent for a New Aircraft Design and Possibly Current Manufactured Aircraft
  - Another Manufacturer having New Agent Tested at FAA
- **Cargo Compartments:**
  - No Substantive Activity in Recent Years
  - Previous Agents Tested Unsuitable or Require Significant Development
  - Most Challenging and Most Important (Largest Halon Usage) Application
  - FAA will Conduct Tests in Cooperation with the Aircraft Manufacturers