

# Guidance for Handheld Extinguishers for Use in Aircraft



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The Fifth Triennial International Fire & Cabin Safety Research Conference  
Atlantic City, New Jersey  
October 29- November 1, 2007



# OUTLINE

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- Background
- Purpose of the FAA handheld advisory circular (AC 20-42D)
- FAR requirements for hand-held extinguishers
- Halon equivalency guidance
- Fire fighting guidance
- Toxicity guidance
- Safe use of hand extinguishers
  - Ventilated and unventilated compartments
  - Accessible cargo compartments in passenger/cargo & cargo aircraft
- Recent changes to the Draft FAA Advisory Circular AC20-42D



## BACKGROUND

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- Since **1994**, Halon 1211 has no longer been produced in the US.
- By **2010**, Halon 1211 will no longer be produced anywhere in the world .  
Remaining users of halons are dependent on existing, potentially uncertain, supplies and their ability to gain access to these remaining stockpiles.
- Halon replacement hand extinguishers are available meeting FAA safe-use guidelines: **HCFC Blend B, HFC-236fa and HFC-227ea.**



## BACKGROUND

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- Current A/C 20-42C for hand extinguishers will be cancelled. Can continue to be used for existing installations
- New A/C 20-42D for hand extinguishers– New installations
- The FAA will provide safe use guidance for agents introduced after the publication of this Advisory Circular.



# PURPOSE OF ADVISORY CIRCULAR

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- Provides a method of showing compliance with the applicable airworthiness requirements for new installations of hand extinguishers. ***This AC is not mandatory.***
  - Provide safety guidance for hand extinguishers.
    - ☐ Effectiveness in fighting onboard fires.
    - ☐ Toxicity
    - ☐ Provides updated general information.
- Applies to aircraft and rotorcraft.
- Refers to outside documents:
  - ASTM specifications
  - UL Standards
  - MPS for hand fire extinguisher for transport category aircraft
  - Federal Aviation Regulations (FARS)
  - CFR Title 40: Protection of the Environment

# FEDERAL AVIATION REGULATIONS (FARs) FOR HAND FIRE EXTINGUISHERS

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- Specifies the minimum number of Halon 1211 *or equivalent* extinguishers for various size aircraft.
- Specifies the location and distribution of extinguishers on an aircraft.
- Each extinguisher must be approved.
- Each extinguisher intended for use in a personnel compartment must be designed to minimize the hazard of toxic gas concentrations.
- The type and quantity of extinguishing agent, if other than Halon 1211, must be appropriate for the kinds of fires likely to occur.
- The FAR does not give extinguisher ratings. This is done in the AC.



# HALON EQUIVALENCY GUIDANCE

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- UL rated 5B:C *and equivalent hand extinguishers* replacing required 2½ lb 5B:C Halon 1211 extinguishers must meet the Minimum Performance Standard for Hand Extinguishers.

DOT/FAA/AR-01/37 Development of a Minimum Performance Standard (MPS) for Hand-Held Fire Extinguishers as a Replacement for Halon 1211 on Civilian Transport Category Aircraft.

➤ Hidden Fire Test

➤ Seat Fire/Toxicity Test (The toxicity test is for decomposition products of the agent). Guidance for *agent* toxicity can be found in the advisory circular.

# EXTINGUISHER PERFORMANCE AND SAFETY GUIDANCE

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## Aircraft Cabin:

- Recommends a minimum 5B:C UL or equivalent listing.
- Small aircraft can use 2 B:C extinguishers
  - Aircraft with a maximum certificated occupant capacity of one to 4 persons including the pilot.
  - Aircraft with volumes up to 200 ft<sup>3</sup>
  - The agent must be predominantly gaseous upon discharge one foot from the extinguisher nozzle.
- Select an extinguisher that does not exceed the maximum safe W/V.
- If no extinguisher meets this safe-use guidance, select the safest agent.



# EXTINGUISHER PERFORMANCE AND SAFETY GUIDANCE

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## Aircraft Cabin:

- Always provide the recommended number of hand held extinguishers with the proper UL listing, **even in spaces where the toxicity guidelines are exceeded.**
- If the safe-use guidelines are exceeded, select the **safest** extinguisher of the required UL listing and **use only the amount necessary to extinguish the fire.**
- Halon replacement extinguishers with a minimum listing of 5B:C can be used in place of required TSO'd water extinguishers if it can be shown that the replacement extinguisher has comparable or better class A extinguishing performance than the TSO'd water extinguisher and an acceptable throw range for that installation.
- Two required TSO'd water extinguishers in close proximity may be replaced by one Halon replacement extinguisher if the extinguisher has been shown to have comparable or better class A fire extinguishing capability than both water extinguishers and an acceptable throw range for that installation.

# EXTINGUISHER PERFORMANCE AND SAFETY GUIDANCE

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## **Cargo Compartments: Passenger/Cargo & Cargo Aircraft:**

- Recommends a minimum extinguisher listing of 2A:10B:C for compartments less than 200 ft<sup>3</sup>
- Compartments 200 ft<sup>3</sup> and larger should meet the requirements of the FAA Airworthiness Directive AD 93-07-15. This AD provides options to the use of hand extinguishers:
  - Conversion to meet Class C cargo compartment requirements
  - Use fire containment containers or covers.



# ACCESSIBLE CARGO COMPARTMENTS

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## Cabin Safety Guidance:

- Cargo extinguishers should be available to fight cabin fires
- Select a cargo extinguisher that meets the safe use guidance for the aircraft cabin.
- If no cargo extinguisher meets the safe use guidance for the aircraft cabin:
  - Consider installing a class C fire flooding suppression system in the cargo compartment or alternatives to handheld extinguishers that would provide effective fire protection.
  - Use the required UL rated extinguisher.
    - ❖ Select the least toxic agent of the required rating. Place a placard alongside the bottle stating: *“Discharge of the entire contents of this size bottle into the occupied cabin area exceeds safe exposure limits. Use only the amount necessary to extinguish a fire”*



# TOXICITY CONSIDERATIONS

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- **Toxicity of the halocarbon itself**
  - Cardiotoxicity
  - Anesthetic Effects
- **Toxicity of halocarbon decomposition products**
  - Guidelines set in the Minimum Performance Standard for Handheld Extinguishers
- **Low oxygen hypoxia: Very small aircraft**



## SAFE-USE GUIDANCE

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- Use science-based approach published in peer-reviewed literature.
  - Conservative
  - More accurate than approach used for Halons in AC 20-42C
- The safe-use guidance is based on an assessment of the relationship between halocarbons in the blood and any adverse toxicological or physiological effect.
- States the maximum weight that **all** extinguishers in a compartment should not exceed, based on agent toxicity, size of compartment, and maximum FAA certificated cabin altitude.
- Separate guidance provided to avoid low oxygen hypoxia.
- Includes guidance for general aviation as well as transport category aircraft and rotorcraft.

# AGENT TOXICITY : MAXIMUM SAFE CONCENTRATIONS

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Total agent available from all extinguishers should not be capable (assuming perfect mixing) of producing concentrations in the compartment by volume, at **70°F (21.1°C)** **when discharged at the maximum certificated altitude** that exceeds the agent's safe exposure guidelines.

## Nonventilated passenger or crew compartments:

- PBPK derived 5 minute safe human exposure concentration, if known.
- If PBPK data is not available, the agent No Observable Adverse Effect Level (**NOAEL**) is to be used. *(Note: UL 2129 allows use of a (sometimes higher) LOAEL Concentration)*
- **Ventilated Compartments:** (Higher agent concentrations can be used)
  - Use ventilation selector graphs to obtain the maximum agent weight per unit volume allowed in the cabin.
  - Graphs are based on Physiologically-based Pharmacokinetic (PBPK) modeling of theoretical blood concentration decay curves & perfect mixing.
  - If graphs are not available, follow concentration guidelines for nonventilated compartments.

# MAXIMUM SAFE WEIGHT OF AGENT WITH NO VENTILATION



*Perfect mixing assumed*

*Solve equation or use table:*

$$\left(\frac{W}{V}\right)_{Safe} = \frac{1}{(S \times A)} \times \frac{C_{Altitude}}{(100 - C_{Altitude})}$$

S = Specific volume of the agent at sea level:  
At 70°F (21.1°C): S= \_\_\_\_\_ ft<sup>3</sup>/lb

A = Altitude correction factor for S:

8000 ft:	A= 760/ 564.59 = 1.346
12,500 ft:	A= 760/ 474.09 = 1.604
14,000 ft:	A= 760/ 446.63 = 1.702
18,000 ft:	A= 760/ 397.77 = 2.003
25,000 ft:	A= 760/ 282.40 = 2.695

*Air is half as dense at 18,000 ft. than at sea level*

C<sub>Altitude</sub> is the maximum safe clean agent concentration (%)

*C<sub>Altitude</sub> is not altitude dependent.*

(W/V)<sub>Safe</sub> is based on *all* hand extinguishers in the compartment

(The cabin is a compartment)

# MAXIMUM SAFE WEIGHT/VOLUME

## (NO VENTILATION, 70°F, 21.1°C)



**Total agent weight from all extinguishers in compartment, released at 70°F: (21.1°C)**

Agent	Maximum Safe W/V (pounds/ft <sup>3</sup> ) <sup>a,b,c</sup>					
	Sea Level (For info only)	8,000 ft P Altitude (Pressurized Cabin) <sup>d</sup>	12,500 ft P Altitude <sup>d,e</sup>	14,000 ft P Altitude <sup>d,e,f</sup>	18,000 ft P Altitude <sup>d,e,f</sup> Nasal Cannula Oxygen Supply	25,000 ft P Altitude <sup>d,e,f</sup> Diluter-Demand Oxygen Mask
HCFC Blend B <sup>g</sup>	0.00389	0.00289	0.00243	0.00229	0.00194	0.00145
HFC-227ea	0.0551	0.0409	0.0344	0.0324	0.0275	0.0205
HFC-236fa	0.0595	0.0442	0.0371	0.0349	0.0297	0.0221
Halon 1211 <sup>h</sup>	0.00449	0.00334	0.00281	0.00264	0.00225	0.00167
Halon 1301 <sup>h</sup>	0.0260	0.0193	0.0162	0.0153	0.0130	0.00968

*See footnotes on next slide*



# MAXIMUM SAFE WEIGHT/VOLUME (NO VENTILATION, FOOTNOTES)



- a. Use this table if air change time is unknown or exceeds 6 minutes.
- b. Maximum safe W/V ratios represent total weight of agent from **all extinguishers in the aircraft compartment.**
- c. W/V multiplication factors can be applied to the data in this table for unventilated compartments if an egress analysis is preformed and approved and escape time < 30 seconds:
  - $MF_{HFC-227ea, 30sec} = 11.6/10.84 = 1.07$
  - $MF_{HFC-236fa, 30sec} = 14.84/12.75 = 1.16$
  - $MF_{Halon\ 1211, 30sec} = 1.73/1.0 = 1.73,$
  - $MF_{Halon\ 1301, 30sec} = 7.13/6.25 = 1.14$
- d. If the maximum safe W/V is exceeded, use the safest extinguisher of the required rating.
- e. If possible, ventilate immediately, preferably overboard after successfully extinguishing the fire. Increase ventilation to the highest possible rate, and turn off any air recirculation systems, if equipped.
- f. Descend immediately at the maximum safe rate to an altitude of 8,000 feet or an altitude that is as low as practicable.
- g. At pressure altitudes above 12,500 feet follow precautions to prevent hypoxia. See paragraph 12h of this AC.
- h. Values are based on the NOAEL. All other agents are based on PBPK safe use concentrations for a 5 minute exposure. HCFC Blend B values will be made available when PBPK data is provided to the FAA.
- i. The maximum safe Weight/ Volume for blends of Halon 1211 and Halon 1301 can be found by assuming the total weight of the blend is Halon 1211 .



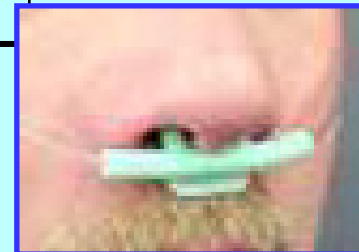
# MINIMUM SAFE COMPARTMENT VOLUME NO VENTILATION

## Appendix

For the following 5 B:C extinguishers, released at 70°F: (21.1°C)

Agent	Agent Weight <sup>1</sup> (lbs)	Minimum Safe Volume (ft <sup>3</sup> ) <sup>2, 3</sup>				
		Sea Level (For info only)	8,000 ft P Altitude (Pressurized Cabin)	14,000 ft P Altitude	18,000 ft <sup>4</sup> 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	5.75	104	141	178	209	281
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, 70°F)



Aircraft/ Helicopter	Vol (ft³)	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



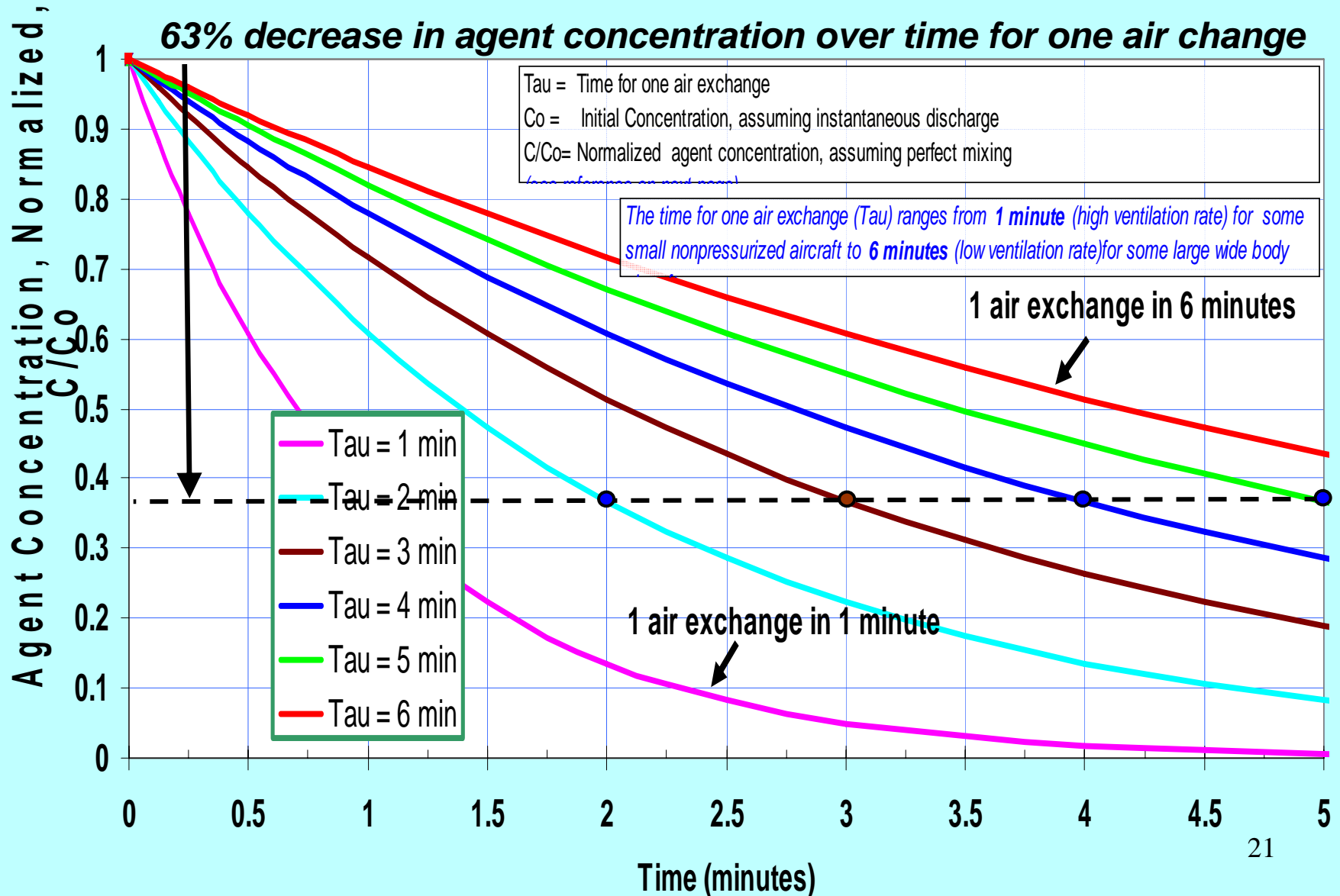
# VENTILATION SELECTOR CURVES

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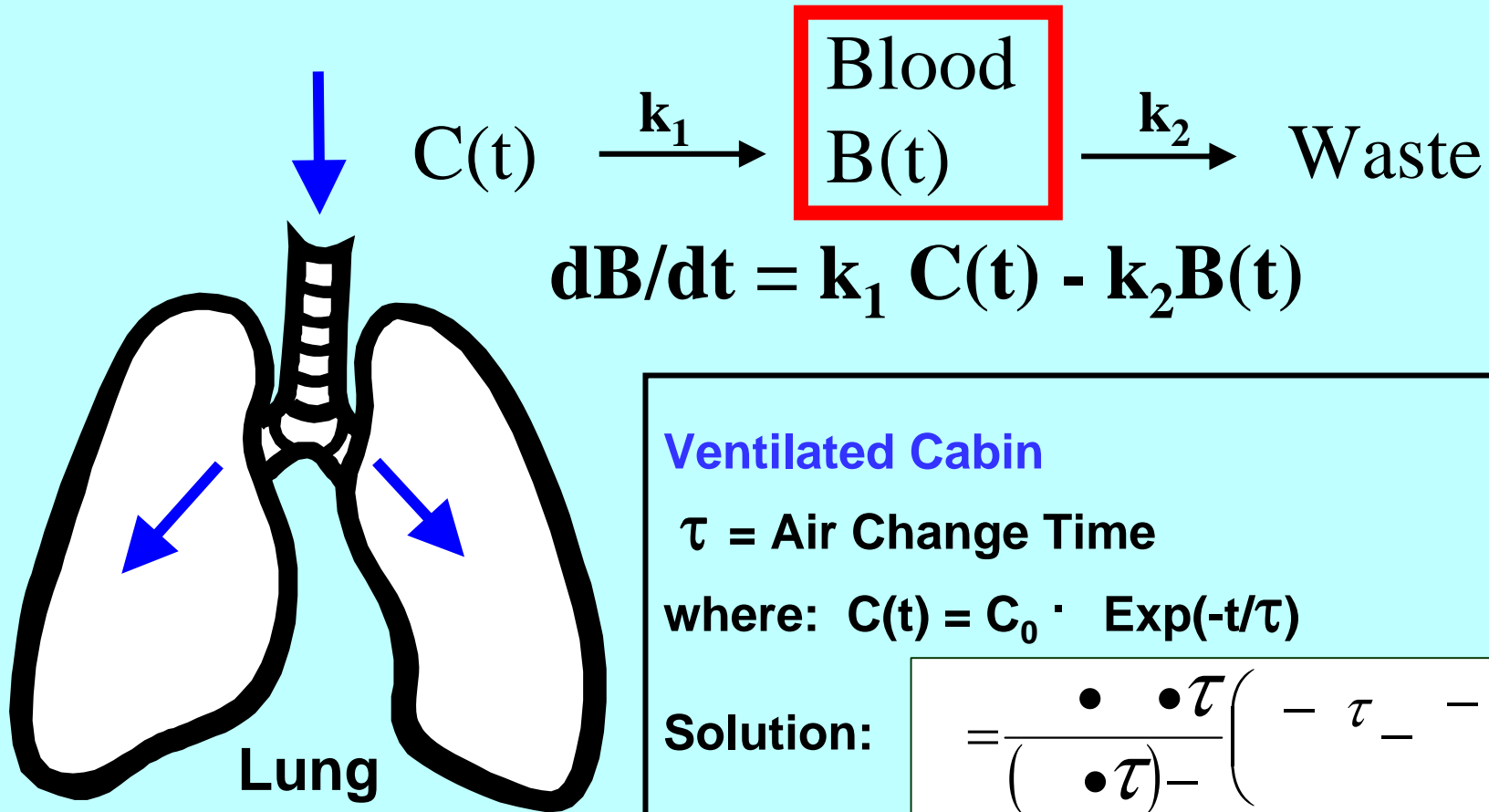
- Based on total weight of agent for *all* extinguishers in compartment.
- Based on pharmacokinetic modeling of blood concentration data to perfect mixing agent decay concentration curves.
- Stratification of agents is a realistic expectation. It can be a safety benefit or disbenefit. Perfect mixing is assumed.
- Selector curves provide the maximum agent weight per unit cabin volume allowed in a compartment for any known air change time.

# Effect of Air Exchange Time (Tau) on Normalized Agent Concentration-Time Profiles

$$C/Co = \exp(-t / \text{Tau}) \quad (\text{assuming perfect mixing})$$



# MODELING ARTERIAL BLOOD CONCENTRATIONS OF HALOCARBONS USING 1<sup>st</sup> ORDER KINETICS



## Ventilated Cabin

$\tau$  = Air Change Time

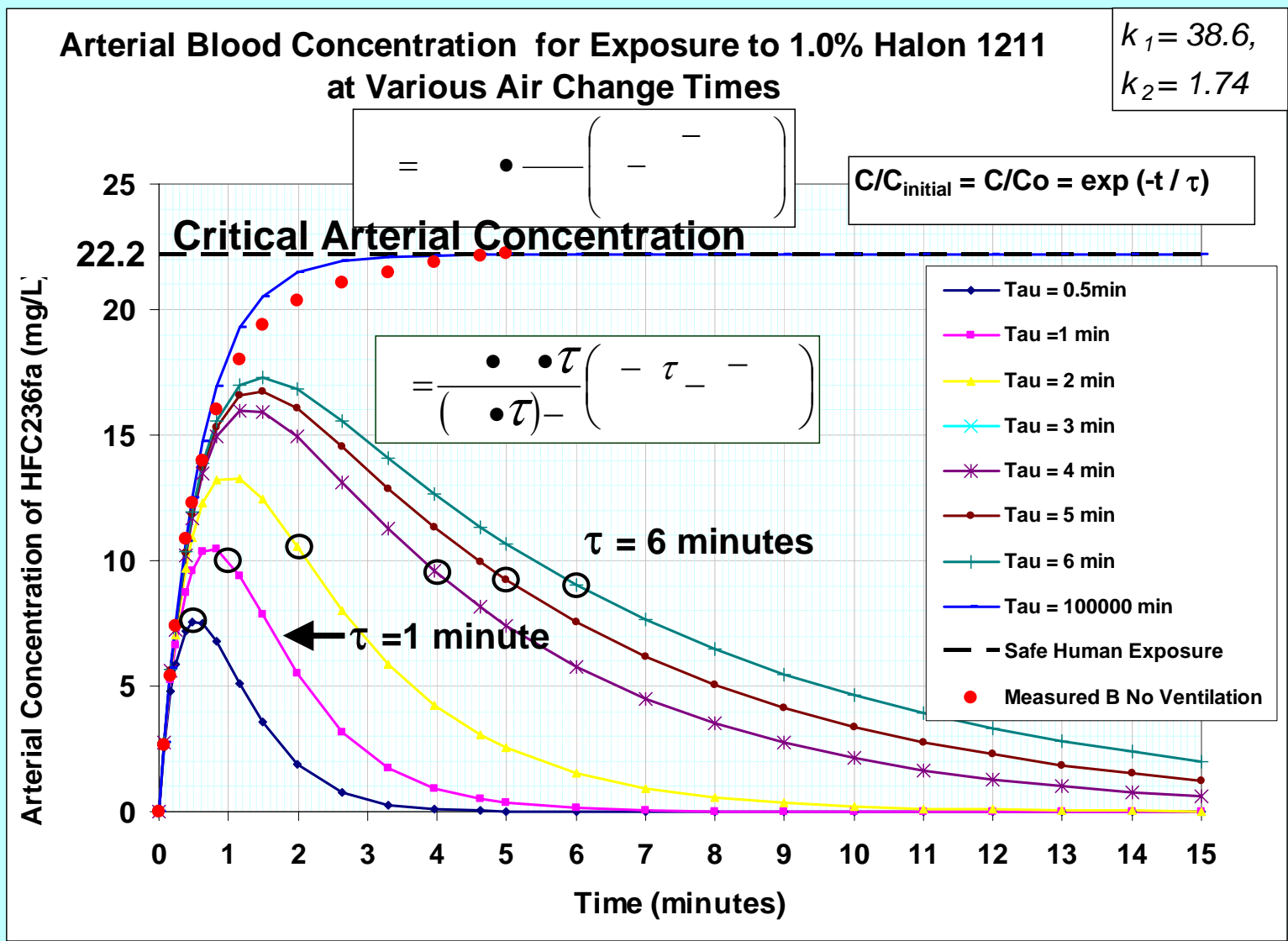
where:  $C(t) = C_0 \cdot \text{Exp}(-t/\tau)$

Solution:

$$= \frac{\bullet \bullet \tau}{(\bullet \tau) -} \left( - \tau - - \right)$$

Speitel, Louise C. "Setting Safe Acute Exposure Limits for Gaseous Halocarbon Extinguishing Agents in Ventilated Compartments",  
FAA Report to be published

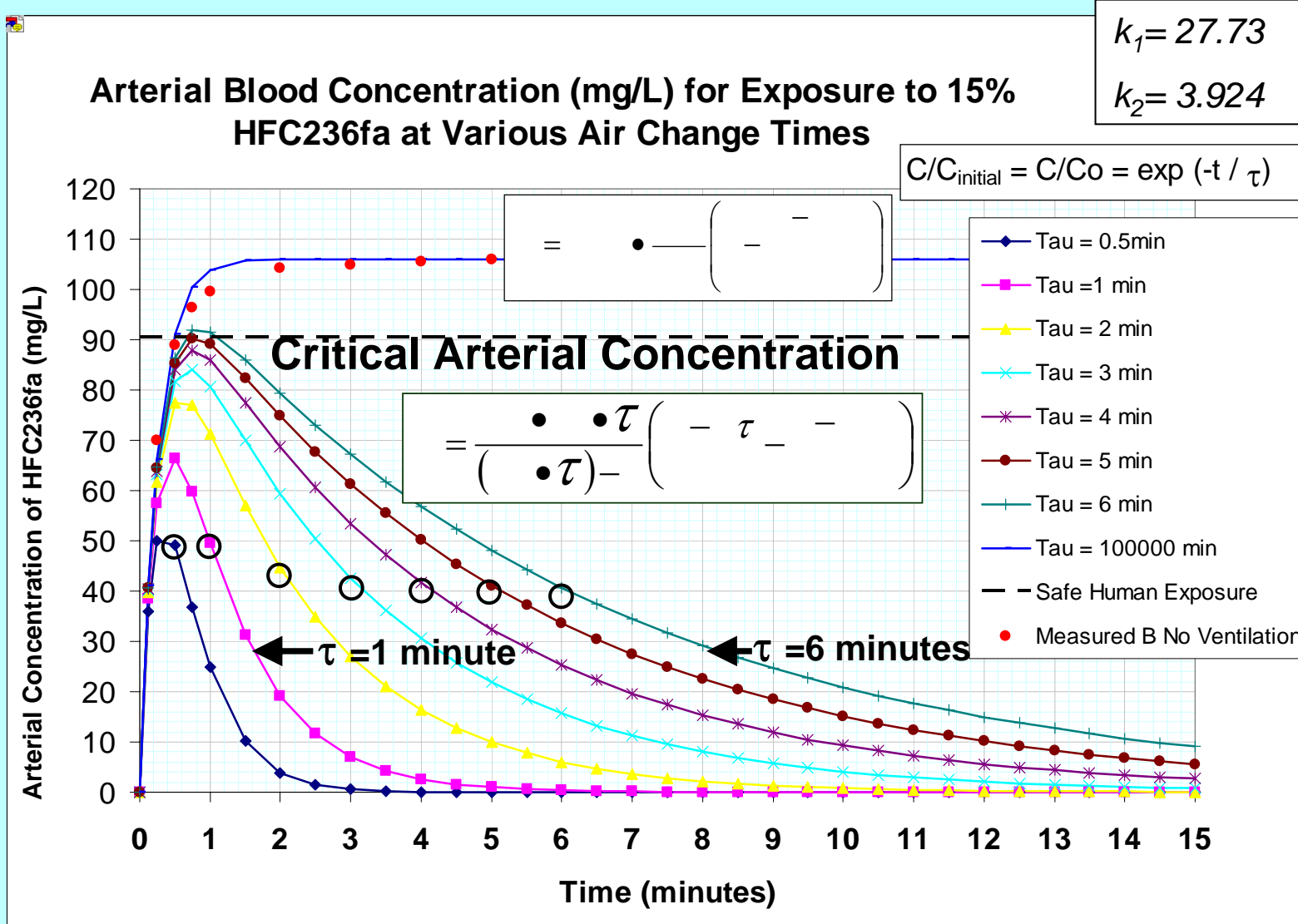
# KINETIC MODELING OF ARTERIAL HALON 1211 BLOOD CONCENTRATION IN VENTILATED AIRCRAFT



$\tau$  = Air Change Time

The peak arterial concentrations are used to develop the selector curves

# KINETIC MODELING OF ARTERIAL HFC236fa BLOOD CONCENTRATION IN VENTILATED AIRCRAFT



$\tau$  = Air Change Time

The peak arterial concentrations are used to develop the selector curves



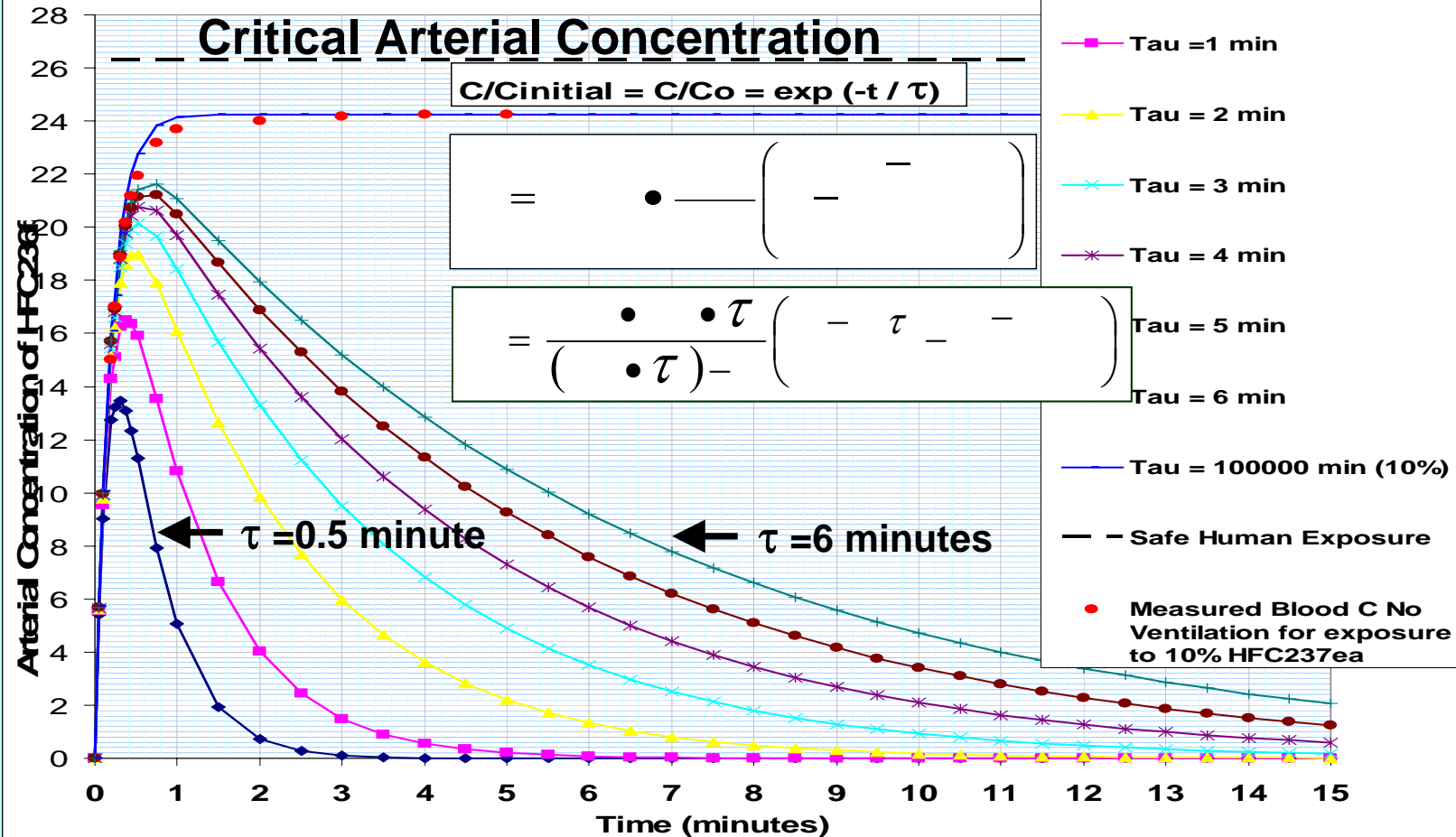
# KINETIC MODELING OF ARTERIAL HFC237ea BLOOD CONCENTRATION IN VENTILATED AIRCRAFT



$$k_1 = 13.0$$

$$k_2 = 5.36$$

Arterial Blood Concentration (mg/L) for Exposure to 10% HFC227ea at Various Air Change Times



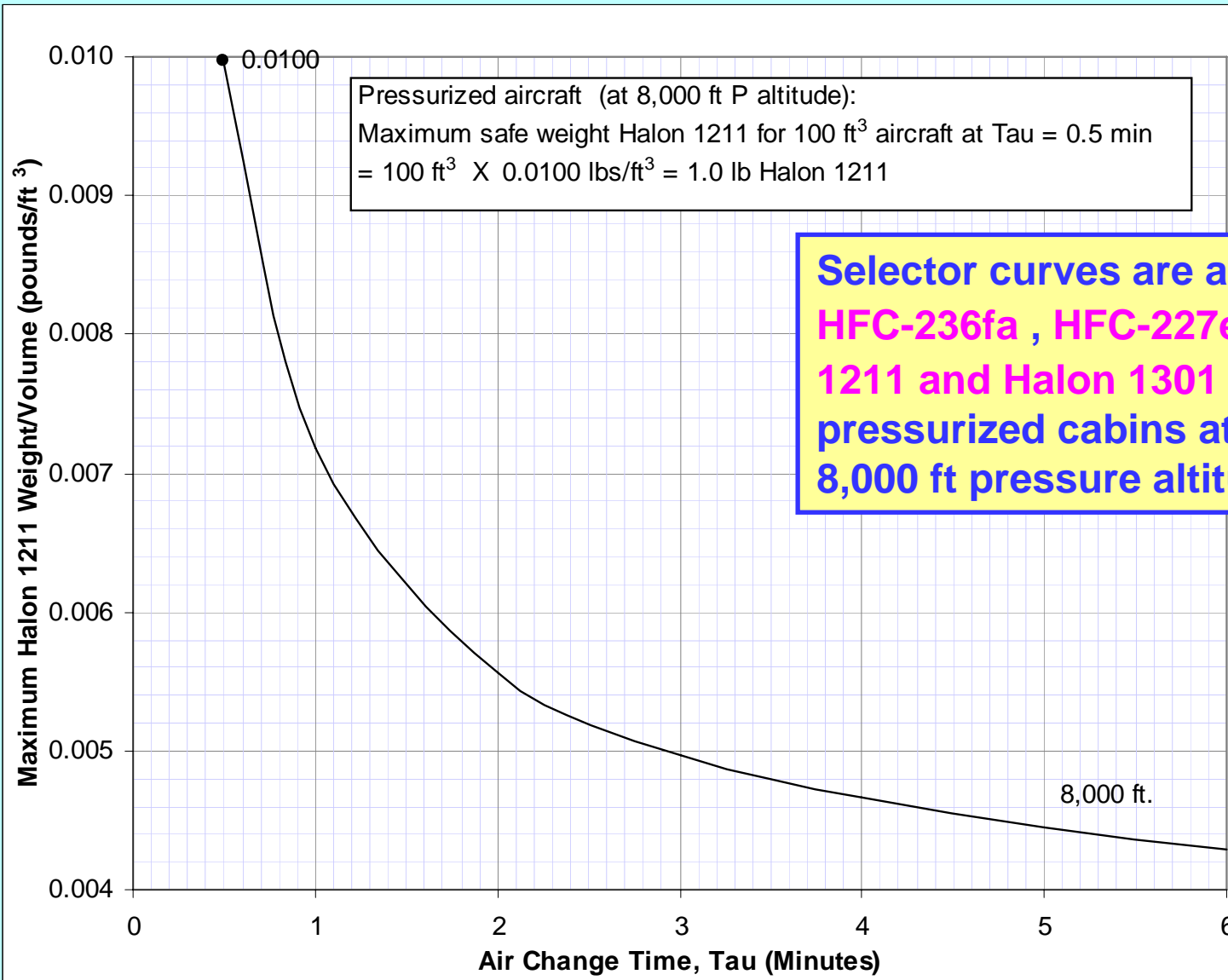
$\tau$  = Air Change Time

The peak arterial concentrations are used to develop the selector curves

# Halon 1211 SELECTOR FOR PRESSURIZED VENTILATED COMPARTMENTS



*Perfect  
mixing  
assumed*



Selector curves are available for:  
**HFC-236fa , HFC-227ea , Halon  
1211 and Halon 1301** for  
pressurized cabins at:  
**8,000 ft pressure altitude**

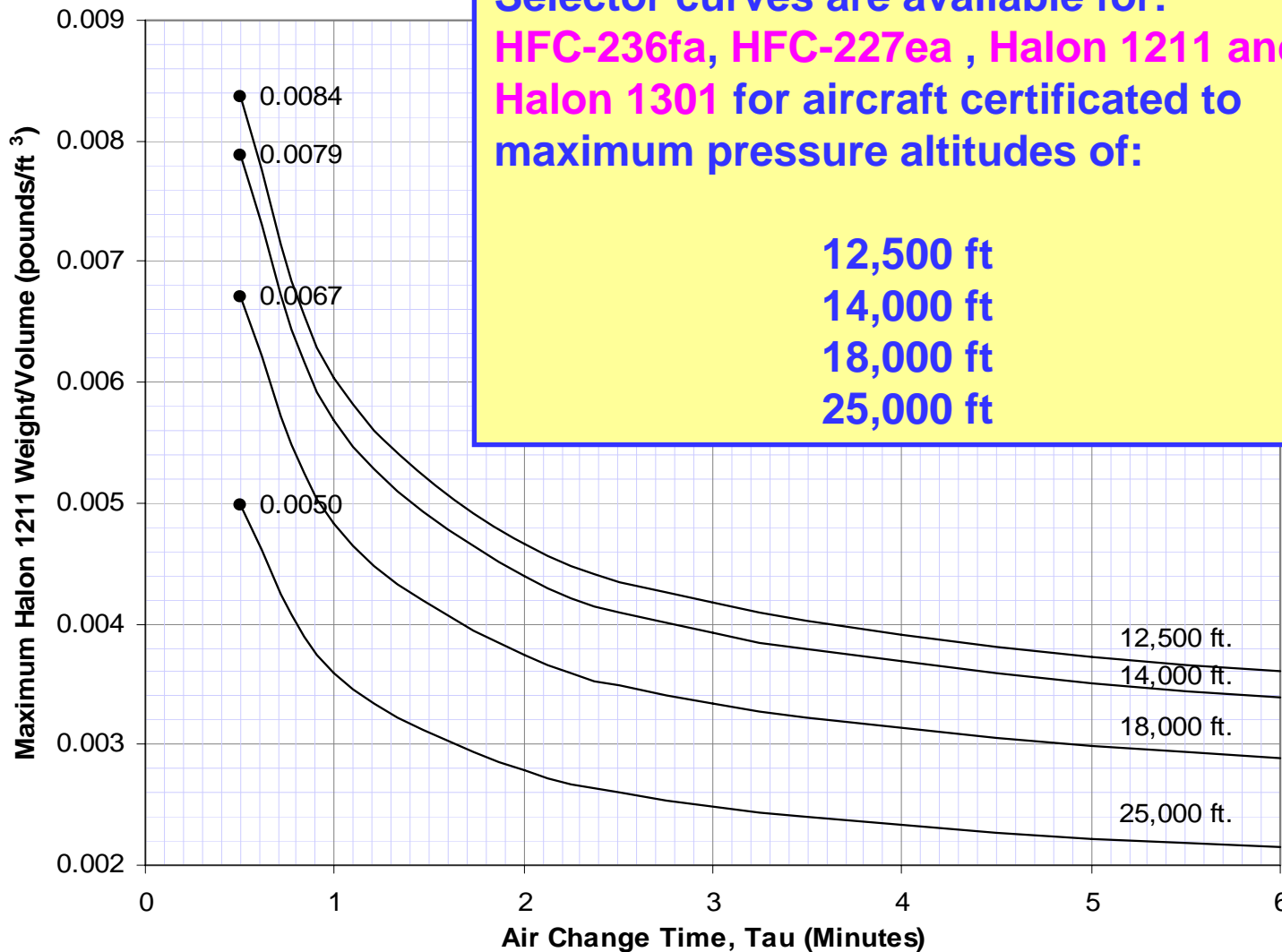
# Halon 1211 SELECTOR FOR UNPRESSURIZED VENTILATED COMPARTMENTS



Selector curves are available for:  
**HFC-236fa, HFC-227ea, Halon 1211 and Halon 1301** for aircraft certificated to maximum pressure altitudes of:

**12,500 ft**  
**14,000 ft**  
**18,000 ft**  
**25,000 ft**

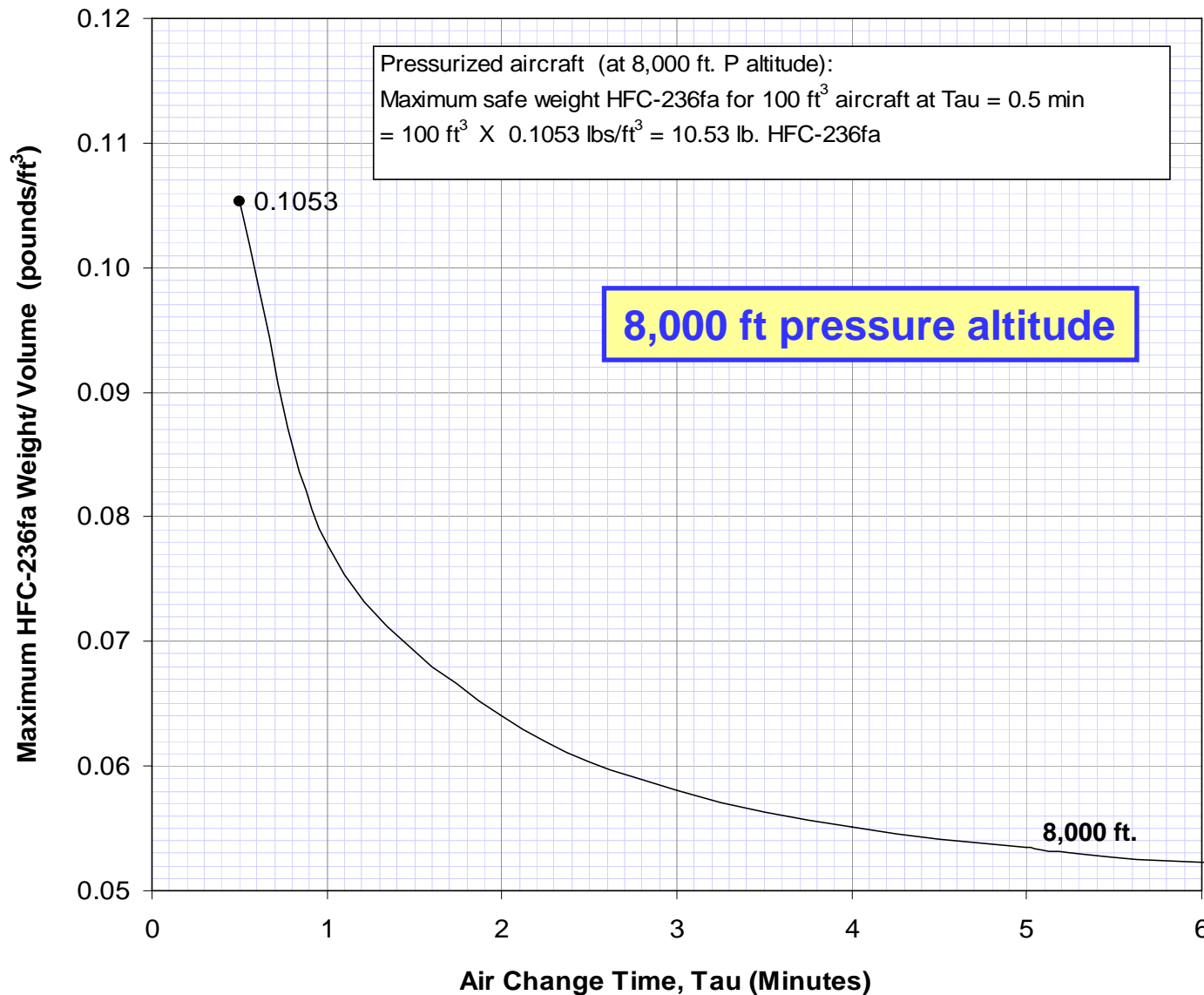
***Perfect mixing assumed***



# HFC-236fa SELECTOR FOR PRESSURIZED VENTILATED COMPARTMENTS



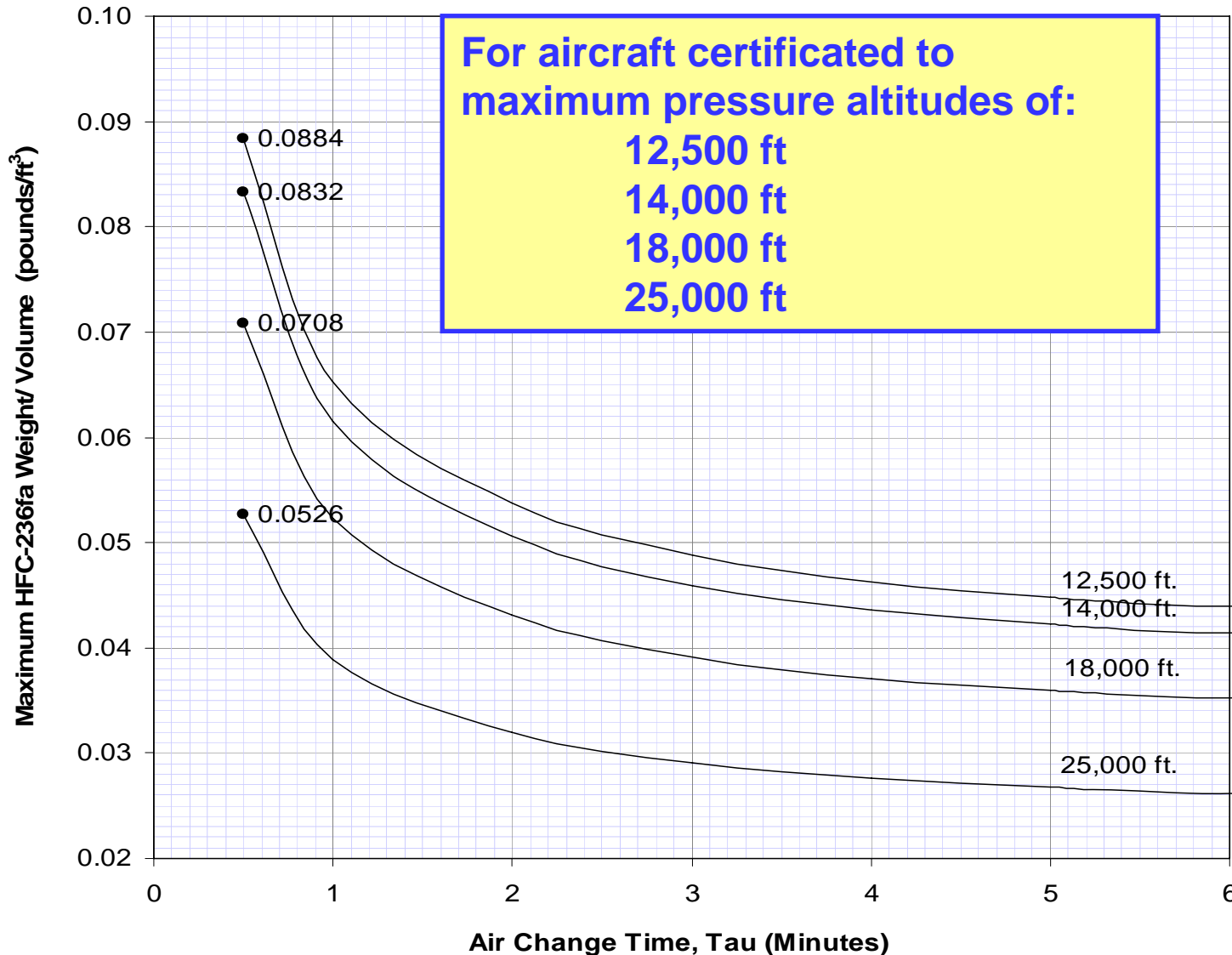
*Perfect  
mixing  
assumed*



# HFC-236fa SELECTOR FOR UNPRESSURIZED VENTILATED COMPARTMENTS



*Perfect  
mixing  
assumed*



# HFC236fa SELECTOR FOR VENTILATED COMPARTMENTS

*Perfect  
mixing  
assumed*



Ventilate immediately after fire extinguished. Increase ventilation to the highest possible rate.

If air change time is unknown or exceeds 6 minutes, use unventilated data (Prolonged exposure to these agents may be hazardous):

- $W/V = 0.0442$  pounds/ft<sup>3</sup> for Pressurized Cabins at 8,000 ft. P altitude
- $W/V = 0.0371$  pounds/ft<sup>3</sup> for Nonpressurized Cabins at 12,500 ft.
- $W/V = 0.0349$  pounds/ft<sup>3</sup> for Nonpressurized Cabins at 14,000 ft.
- $W/V = 0.0297$  pounds/ft<sup>3</sup> for Nonpressurized Cabins at 18,000 ft.
- $W/V = 0.0221$  pounds/ft<sup>3</sup> for Nonpressurized Cabins at 25,000 ft.

Unpressurized aircraft should descend **at the maximum safe rate to 8000 feet or the minimum practicable altitude** to avoid the life threatening hazards of hypoxia resulting from the agent displacing oxygen from the air and to minimize exposure to halogenated agents. This guidance should be followed regardless of ventilation rate.

# RECENT CHANGES

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- The Halons in new installations are to use same guidance as other FAA approved Halon replacement extinguishers.
- Do not recommend the use of dry chemical or CO2 extinguishers.
- Consider throw ranges for replacing water extinguishers with Halon replacement extinguishers for cargo use.
- The maximum safe Weight/ Volume for blends of Halon 1211 and Halon 1301 can be found by assuming the total weight of the blend is Halon 1211.

# RECENT CHANGES

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- Dry Chemical Extinguishers are not recommended due to
  - a. The potential for damage to electronic equipment
  - b. The possibility of visual obscuration if the agent were discharged into the flight deck area
  - c. The cleanup problems from their use.
- Guidance for UL 2B:C extinguishers
- Label “ For aircraft use refer to AC20-42D”



# RECENT CHANGES

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- Fires involving up to 4 small AA-sized Lithium Batteries or equivalent bulk
  - Lithium primary (non-rechargeable) cells are constructed with metallic lithium.
    - ❑ Isolate the burning appliance and use a Halon 1211 or equivalent extinguisher.
    - ❑ Water or Halon 1211 equivalent extinguishers are effective in preventing the spread of fire to adjacent materials
    - ❑ Do not use water for larger lithium fires.
  - Lithium-ion (rechargeable) cells are not constructed with metallic lithium and do not have the same fire hazard as primary cells.
    - ❑ Water or Halon equivalent extinguishers are effective.
- Fires involving a laptop computer (battery pack contains multiple larger lithium-ion cells)
  - Water extinguisher is the first choice for initial knockdown and cooling
  - Halocarbon extinguishers will knock the fire down. Must be immediately doused with water to prevent the spread of fire to adjacent cells.

# REVIEW SCHEDULE

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- Internal FAA Review, Directorates, Flight Standards: 2 months
- Public Comment: 2 months
- Total: 4-6 months



## HANDHELD EXTINGUISHER WEB PAGE

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