Handheld Extinguisher Draft Advisory Circular Summary

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OUTLINE OF TALK

- Background
- Purpose of the handheld advisory circular (AC)
- FAR requirements for hand-held extinguishers
- Minimum performance standard (MPS) for transport category aircraft
- Fire fighting guidance
- Toxicity: decomposition products, agent, low oxygen hypoxia
- Safe use of hand extinguishers
  - ➢ Ventilated and unventilated compatments
  - ➢ Accessible Cargo Compartments in Passenger/Cargo & Cargo Aircraft
- AC language for halocarbon fire extinguishers

BACKGROUND

- The Montreal Protocol and U.S. Clean Air Act requires phase out of ozone depleting halons and transition to available alternatives.
- Halon replacement hand extinguishers are available meeting UL and MPS requirements and FAA safe-use guidelines:
  - HCFC Blend B
  - HFC-236fa
  - HFC-227ea.
- A draft halon replacement hand extinguisher advisory circular has been submitted to The FAA Aircraft Certification Office.
- A FAA Technical Report “Halocarbon Handheld Extinguisher Handbook” will include safe use guidance for agents introduced after the publication of this Advisory Circular.
- Shortages of Halon 1211 expected within the next few years
- Current A/C 20-42C for halons will be revised later.

PURPOSE OF ADVISORY CIRCULAR

- Provides a method of showing compliance with the applicable airworthiness requirements for each hand fire extinguisher. ***This AC is not mandatory.***
  - Provide safety guidance for halon replacement agents.
    - Effectiveness in fighting onboard fires.
    - Toxicity
    - Provides updated general information.
- Applies to aircraft and rotorcraft.
- Refers to outside documents:
  - ASTM specifications
  - MPS for hand fire extinguisher for transport category aircraft
  - Federal Aviation Regulations (FARS)
  - CFR Title 40: Protection of the Environment, Part 82- Protection of Stratospheric Ozone, Subpart G, Significant New Alternatives Program and Subpart H- Halon Emissions Program.
  - FAA Policy Letter

FEDERAL AVIATION REGULATION (FAR) REQUIREMENTS FOR HAND FIRE EXTINGUISHERS

- 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 concentration.
- 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.

THE MINIMUM PERFORMANCE STANDARD (MPS) FOR HAND-HELD EXTINGUISHERS

- Provides specifications for equivalency to required Halon 1211 5 B:C extinguishers to satisfy FARS citing “Halon 1211 or equivalent”:

- UL rated 5 B:C Halocarbon extinguishers that will be replacing required 2 ½ lb. Halon 1211 lb extinguishers in transport category aircraft must pass 2 tests identified in 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 (for decomposition products of the agent). Guidance for agent toxicity can be found in the advisory circular.

FAA POLICY LETTER

- UL listed 5B:C and equivalent EN3 listed hand extinguishers replacing required 2½ lb. extinguishers must meet the MPS for hand extinguishers.
  - Hidden Fire Test
  - Seat Fire/Toxicity Test
- A permanent label must be affixed to the extinguisher :
  - Label identifies FAA approval for UL listed 5B:C extinguishers for use onboard transport category aircraft based on meeting the MPS test requirements.

EXTINGUISHER LISTINGS FOR HALON REPACEMENT HALOCARBONS

Aircraft Cabin:

- Recommends a minimum 5B:C UL or equivalent listing.
- Always provide the recommended number of hand held extinguishers with the proper UL rating, 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 rating 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.
- Two required TSOd 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 as both water extinguishers.

DRAFT ADVISORY CIRCULAR

Accessible Cargo Compartments: Passenger/Cargo & Cargo Aircraft:

- Recommends a minimum extinguisher listing of 2A:10B:C for compartments less than 200 ft^3

- Compartments 200 ft^3 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

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 listed extinguisher.
    - ❖ Select the least toxic agent of the required UL listing. 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”

THROW RANGE

- The MPS requires a minimum throw range of 6-8 feet
- A longer throw range of 10 feet or greater provides significant advantages in fighting fires in large aircraft cabins
- A shorter throw range with a lower velocity discharge is less likely to cause splashing &/ or splattering of the burning material. Consider a shorter throw range for very small aircraft
- Select a range that would allow the firefighter to effectively fight fires likely to occur.

FIXED NOZZLE/HOSE/ ADJUSTABLE WAND

- For access to underseat, overhead and difficult to reach locations, it is recommended that extinguishers be equipped with a discharge hose or adjustable wand.

- An extinguisher with a discharge hose or adjustable wand is more likely to result in the extinguisher being properly held during use.

- Provides a means of directing a stream of agent to more inaccessible areas.

- Fixed nozzle and adjustable wand allows one-handed use.

TOXICITY CONSIDERATIONS

- **Toxicity of the halocarbon itself**
  - ➢ Cardiotoxicity
  - ➢ Anesthetic Effects
  - ➢ Guidelines in the proposed circular are stricter than UL 2129 “Halocarbon Clean Agent Fire Extinguishers”. Immediate egress is assumed in the UL 2129 standard.
- **Low oxygen hypoxia: Very small aircraft**
- **Toxicity of halocarbon decomposition products**
  - ➢ Guidelines set in the Minimum Performance Standard for Handheld Extinguishers

SAFE-USE GUIDANCE

- Use science-based safe-use approach published in peer-reviewed literature.
  - Conservative
  - More accurate than approach used for halons
- The safe-use guidance is based on an assessment of the relationship between halocarbons in the blood and any adverse toxicological or physiological effect.
- Separate guidance provided to avoid low oxygen hypoxia.
- Includes guidance for general aviation as well as transport category aircraft.
- Operators of non-transport category aircraft should become familiar with the information in this AC

SAFE-USE GUIDANCE

- **Safe human exposure limits, up to 5 minutes are derived using a Physiologically-based Pharmacokinetic (PBPK) modeling of measured agent levels in blood .**
- **Assume 70F (21.1C) cabin temperature, perfect mixing, and the maximum cirtificated cabin P altitudes:**
  - **8,000 ft- Pressurized Aircraft .**
  - **12,500 ft- Nonpressurized aircraft with no supplemental oxygen.**
  - **14,000 ft- Nonpressurized aircraft with no supplemental oxygen.**
  - **18,000 ft- Nonpressurized aircraft with nasal cannula oxygen supply.**
  - **25,000 ft- Nonpressurized aircraft with oxygen masks (diluter demand).**
- **Non-ventilated aircraft:**
  - **The allowed concentration would be based on the 5-minute PBPK safe human concentration if available. Otherwise, the "No Observable Adverse Effect Level" (NOAEL) may be used.**
  - **Table provides maximum safe weight/volume ratios for the aircraft cabin.**
- **Ventilated aircraft: Selector graphs will be included if PBPK data is available for that agent.**

AGENT TOXICITY : MAXIMUM SAFE CONCENTRATIONS

Total agent available from all extinguishers should not be capable (assuming perfect mixing) of producing concentrations in the compartment by volume, at **70ºF (21.1ºC) when discharged at altitude** (for the appropriate pressure altitude), that exceeds the agent's safe exposure guidelines. *(Note: Designing for altitude provides a large safety factor for ground use. No need for 120ºF correction)*

- **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:**
  - ➢ Use ventilation selector graphs to obtain the maximum agent weight per unit volume allowed in the cabin. Graphs are based on PBPK modeling of theoretical 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:

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

$(W/V)_{Safe}$ is based on ***all*** hand extinguishers in the compartment

(The cabin is a compartment)

S = Specific volume of the agent at sea level:
At 70ºF (21.1ºC): S= _____ ft^3/lb

A = Altitude correction factor for S:

8000 ft:	A= 760/ 564.59 = 1.346
12,500 ft:	A= 760/ 474.09 = 1.603
14,000 ft:	A= 760/ 446.63 = 1.702
18,000 ft:	A= 760/ 397.77 = 1.911
25,000 ft:	A= 760/ 282.40 = 2.691

$C_{Altitude}$ is the maximum safe clean agent concentration (%)
$C_{Altitude}$ is not altitude dependent.

AGENT TOXICITY: MINIMUM SAFE COMPARTMENT WEIGHT/VOLUME (NO VENTILATION, 70ºF, 21.1ºC)

Total agent from all extinguishers in compartment, released at 70ºF: (21.1ºC)

Agent	Minimum Safe W/V (pounds/ft^3) [1,2,3]					
	Sea Level (For info only)	8,000 ft P Altitude (Pressurized Cabin)	12,500 ft Cabin P Altitude	14,000 ft Cabin P Altitude	18,000 ft Cabin P Altitude Nasal Cannula Oxygen Supply	25,000 ft Cabin P Altitude Diluter-Demand Oxygen Mask
HCFC Blend B	0.00389	0.00289	0.00245	0.00229	0.00195	0.00145
HFC-236fa	0.0579	0.0432	0.0365	0.0342	0.0292	0.0216
HFC-227ea	0.0532	0.0394	0.0335	0.0313	0.0266	0.0197
Halon 1211[4]	0.00450	0.0034	0.00284	0.00264	0.00225	0.00167

1. *Use this table if air change time is unknown, or exceeds 6 minutes.*
2. *Multiply W/V by the compartment volume to get the maximum safe weight.*
3. *Divide total agent weight from all ext. in compartment by W/V to get the min. safe volume. Safety improves as min. safe volume decreases for extinguishers of same ul rating.*
4. *If the proposed halocarbon extinguisher AC was applied to Halon 1211.*
5. *Table footnotes provide W/V multiplication factors if egress analysis is preformed and approved and escape time < 30 seconds. Data not available yet for HCFC Blend B.*

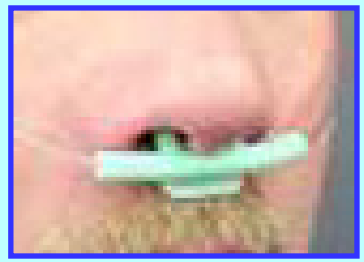
Appendix

MINIMUM SAFE COMPARTMENT VOLUME (NO VENTILATION, 70ºF, 21.1ºC)

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 cabin	18,000 ft [4] P Altitude Cabin Nasal Cannula Oxygen Supply	25,000 P altitude cabin Diluter-Demand Oxygen Mask
HCFC Blend B	5.2	1337	1799	2276	2533	3586
HFC-236fa	4.75	85	115	145	163	220
HFC-227ea	5.75	108	146	184	2161	292
Halon 1211[5]	2.5	556	749	947	1111	1497

1. *The agent weight fo 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*
5. *(If the proposed halocarbon extinguisher AC was applied to the Halons)*



nasal cannula

AGENT TOXICITY: MINIMUM SAFE COMPARTMENT WEIGHT/VOLUME (NO VENTILATION, 70ºF, 21.1ºC)

Total agent from all extinguishers in compartment, released at 70ºF: (21.1ºC)

1. *Use this table if air change time is unknown, or exceeds 6 minutes.*

2. *Multiply W/V by the compartment volume to get the maximum safe weight.*

3. *Divide total agent weight from all ext. in compartment by W/V to get the min. safe volume. Safety improves as min. safe volume decreases for a given number of extinguishers of same UL rating.*

4. *If the proposed halocarbon extinguisher AC was applied to Halon 1211.*

5. *W/V multiplication factors if egress analysis is preformed and approved and escape time < 30 seconds.* $MF_{HFC236fa30sec} = 15/12.5 = 1.20$
   $MF_{HFC227ea30sec} = 12/10.5 = 1.14$

6. *PBPK data is not available yet for HCFC Blend B. PBPK data is needed to determine multiplication factor.*

AGENT TOXICITY: NO. OF 5BC BOTTLES ALLOWED
(NO VENTILATION, 8000 FT ALTITUDE, 70ºF)

Appendix

Aircraft/ Helicopter	Vol (ft^3)	Max No. Seats	Halon 1211			HFC-236fa	Halotron 1	HFC-227ea
			AC20-42C & UL1093	AC20-42C 1 air-change /min	New AC	New AC	New AC	New AC
Cessna 152-	77	2	0.3	0.4	0.1	0.6	0.04	0.5
Cessna 210C	140	6	0.5	0.7	0.2	1.2	0.08	1.0
Cessna C421B	217	10	0.7	1.1	0.3	1.9	0.1	1.5
Sikorsky S76	204	14	0.7	___	0.2	1.8	0.1	1.4
B727-100	5,333	131	17	___	6.4	47	3.1	37
B767-200	11,265	255	36	___	14	98	6.5	77
B 747	27,899	500	90	___	34	243	16	192

Less than one 5 B:C extinguisher allowed

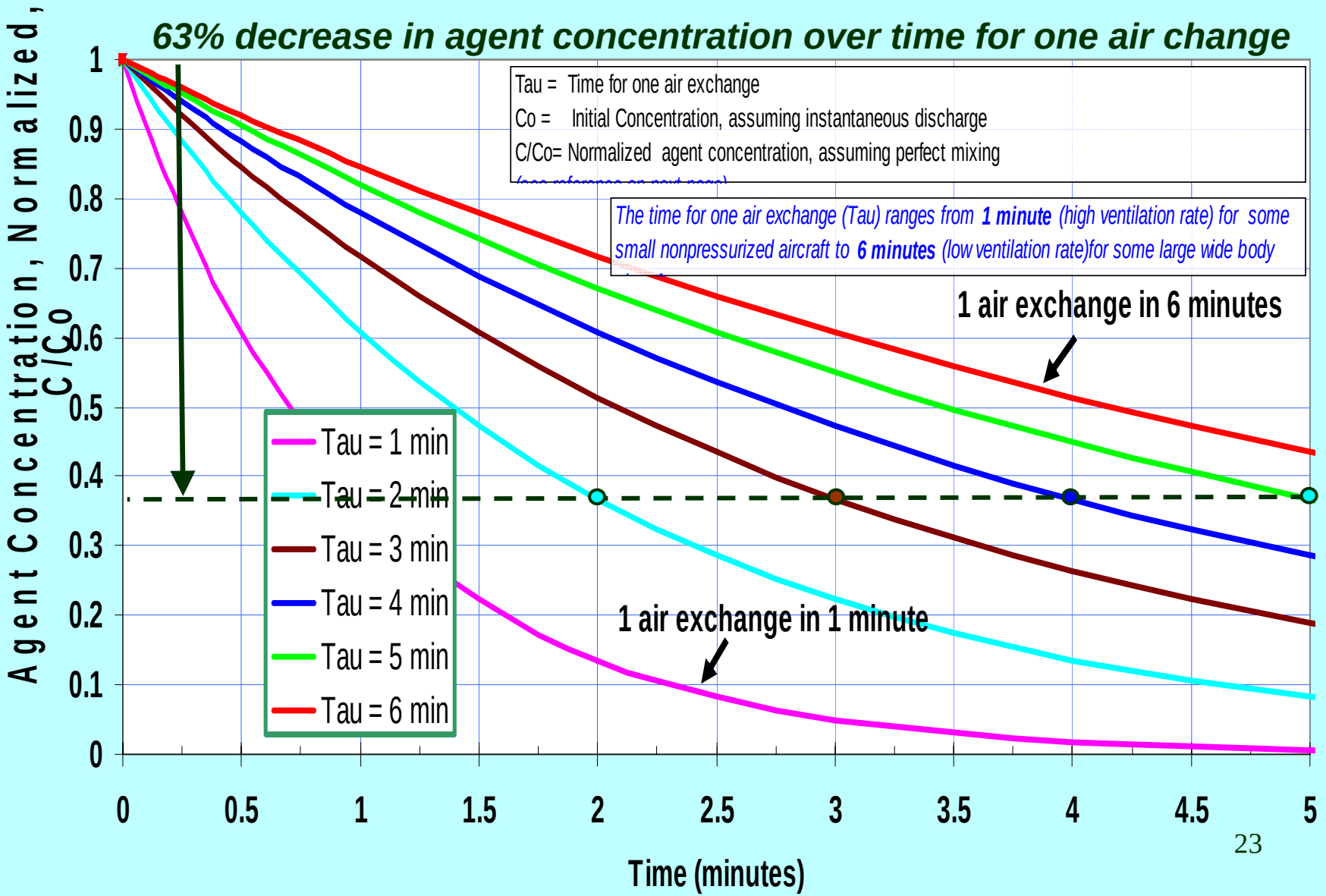
VENTILATION

- ***WARNING***: Small increase in concentration above the Maximum Safe 5 Minute Exposure Concentration results in a much shorter time to effect: Safe human exposure to constant concentration:
  - HFC 236fa : 12.5% for 5 min, 15% for 30 sec.
  - HFC 227ea: 10.5% for 5 min, 12.0% for 30 sec.,

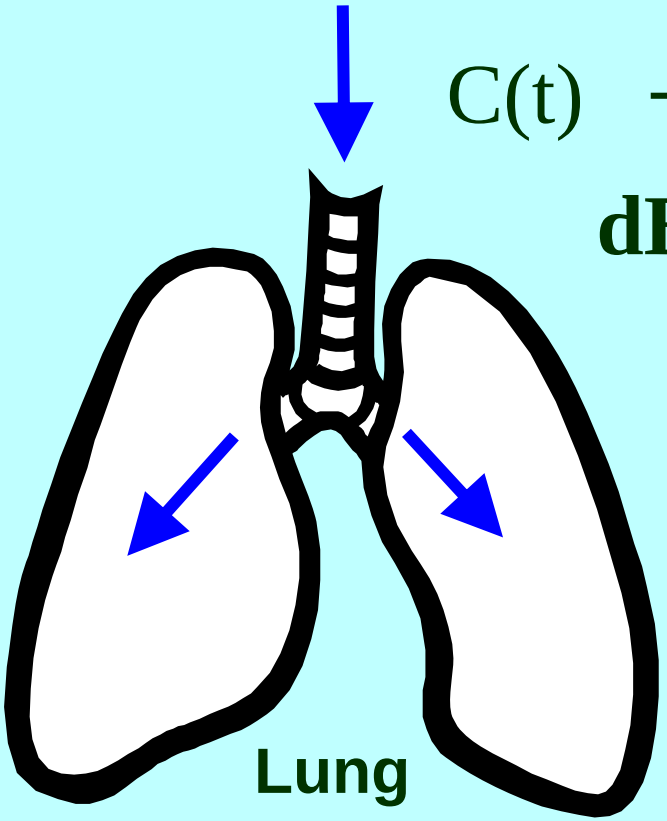
- Development of Ventilation Tables:
  - Based on total weight of agent for ***all*** extinguishers in compartment.
  - Stratification of agents is a realistic expectation. It can be a safety benefit or disbenefit. Perfect mixing is assumed.
  - Agent manufacturers apply pharmacokinetic modeling of blood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

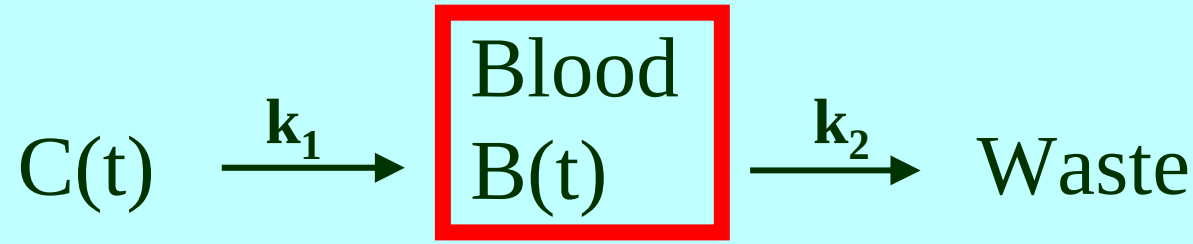
Effect of Air Exchange Time (Tau) on Normalized Agent Concentration-Time Profiles

C/Co = exp (-t / Tau) (assuming perfect mixing)



MODELING ARTERIAL BLOOD CONCENTRATIONS OF HALOCARBONS USING 1st ORDER KINETICS





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

Ventilated Cabin

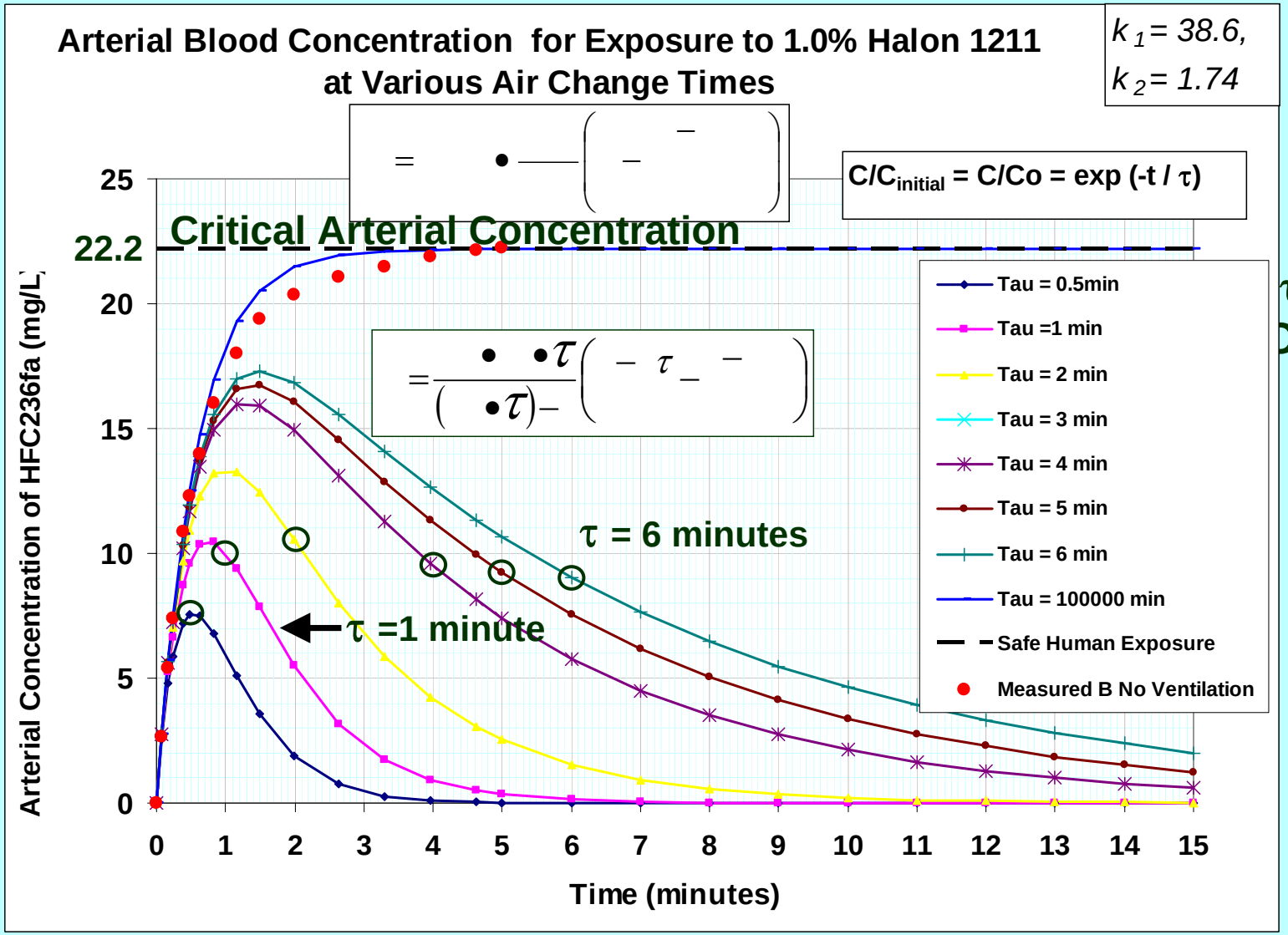
τ = Air Change Time

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

Solution:

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

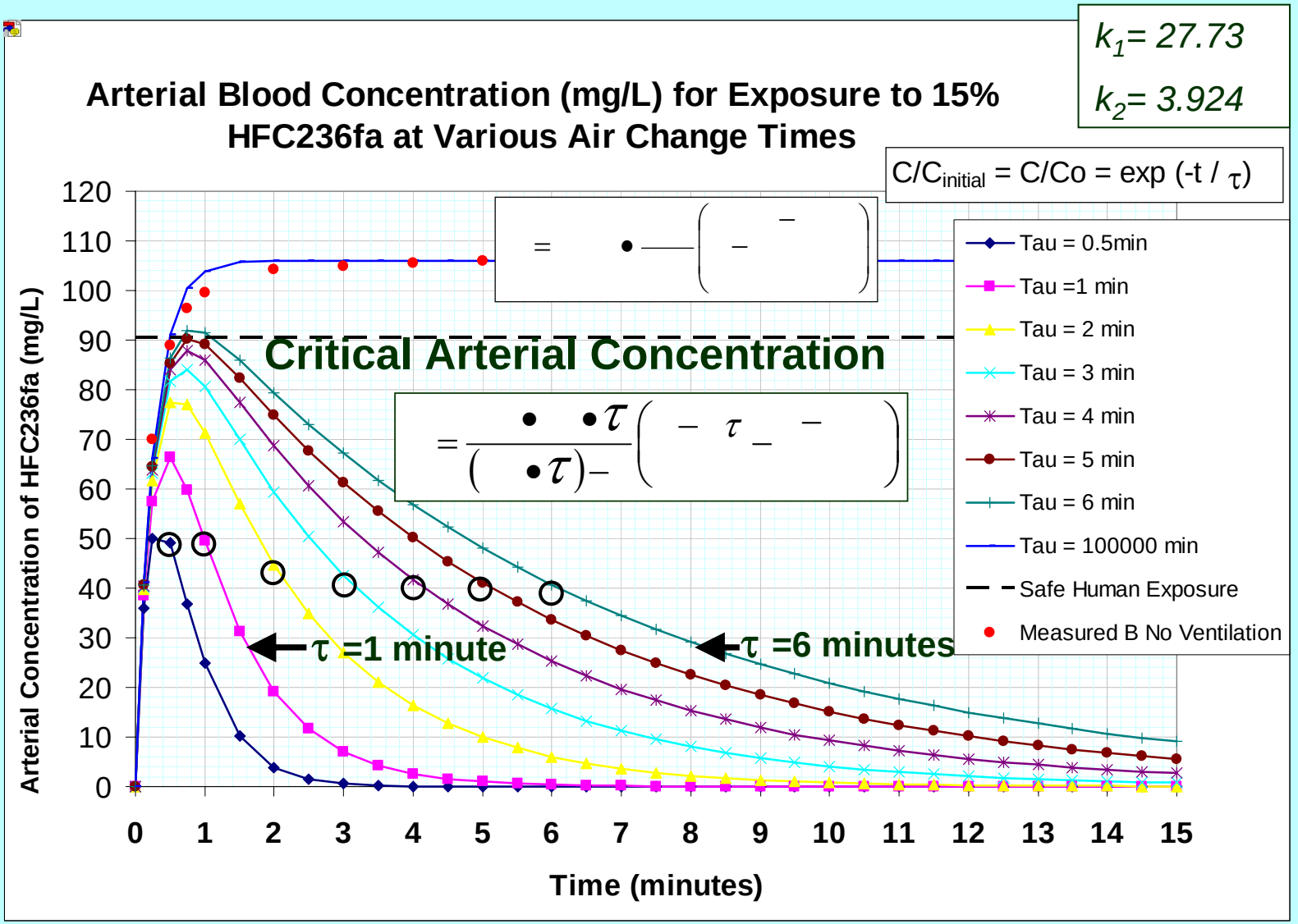
KINETIC MODELING OF ARTERIAL HALON 1211 BLOOD CONCENTRATION IN VENTILATED AIRCRAFT



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



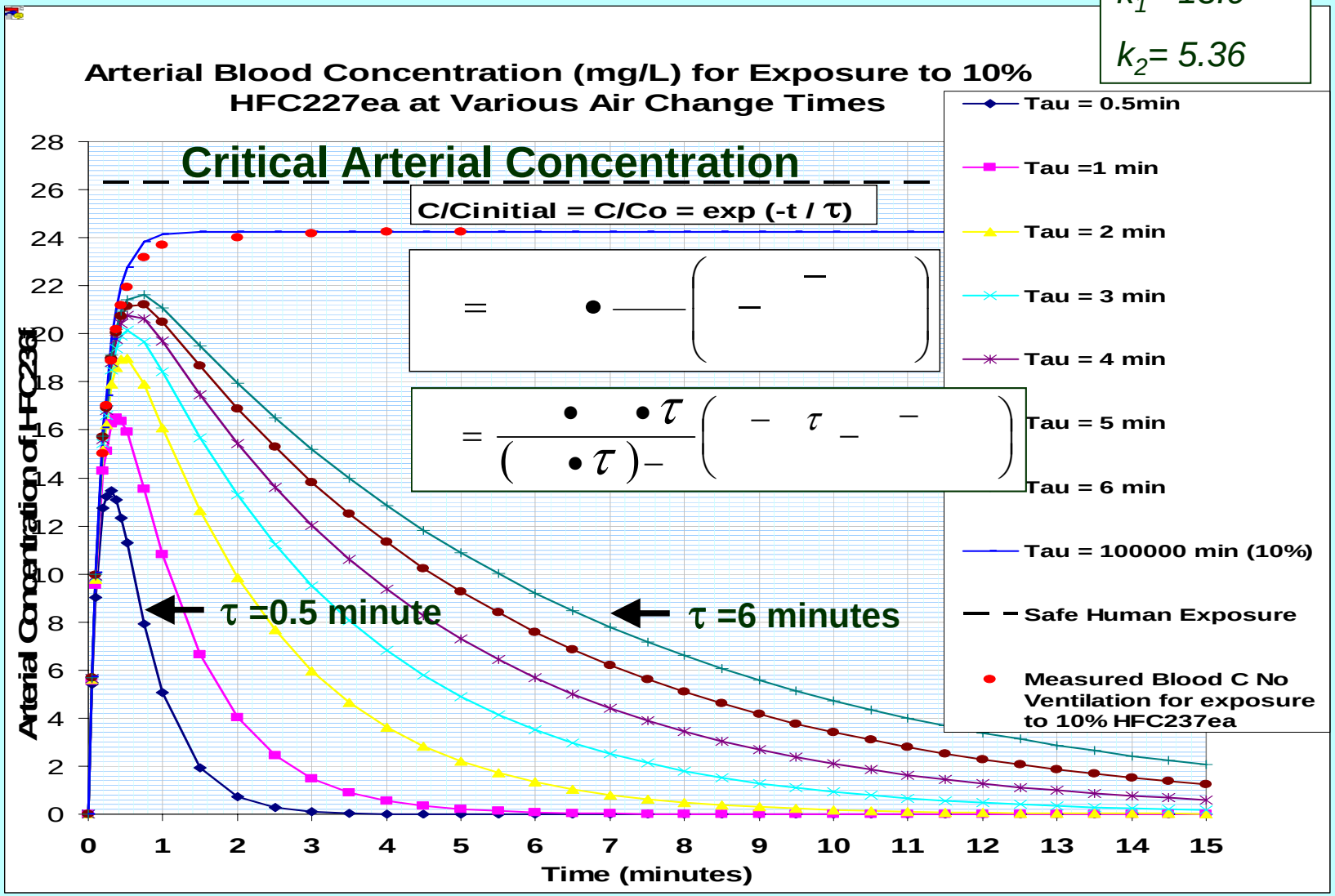
τ = Air Change Time

The peak arterial concentrations are used to develop the selector curves

KINETIC MODELING OF ARTERIAL HFC237ea BLOOD CONCENTRATION IN VENTILATED AIRCRAFT

$k_1 = 13.0$

$k_2 = 5.36$

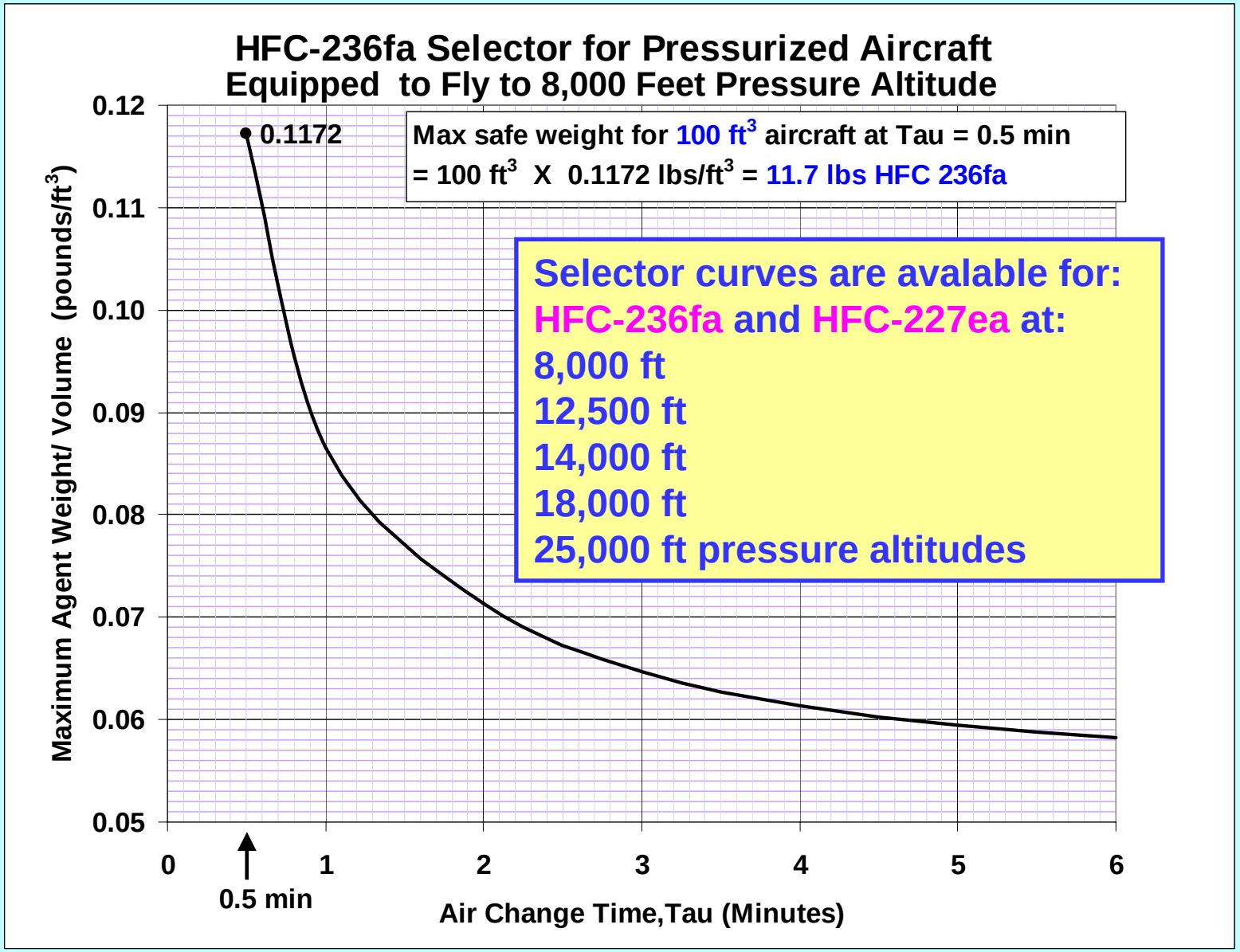


τ = Air Change Time

The peak arterial concentrations are used to develop the selector curves

HFC-236fa SELECTOR FOR VENTILATED COMPARTMENTS

Perfect mixing assumed



HFC236fa SELECTOR FOR VENTILATED COMPARTMENTS

Perfect mixing assumed

- **If the air change time is unknown, or exceeds 6 minutes, do not exceed the maximum safe HFC-236fa W/V ratio for unventilated aircraft: W/V= 0.0361 pounds/ft^3 for unpressurized cabins at 12,500 ft. Pressure Altitude.**

- ***The total weight of agent for all extinguishers in the aircraft cabin is the basis for these maximum safe weight/volume ratios.***

- **Ventilate <u>immediately</u>, preferably overboard after successfully extinguishing the fire. Increase ventilation to the highest possible rate, and turn off any air recirculation systems, if equipped.**

- ***All Unpressurized aircraft should descend immediately at the maximum safe rate to an altitude that is as low as practicable.***

- ***Unpressurized aircraft equipped to fly above 12,500 feet should also follow additional precautions in 8.3.2 to prevent the hazards of low oxygen hypoxia (oxygen masks or nasal cannula as applicable).***

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):

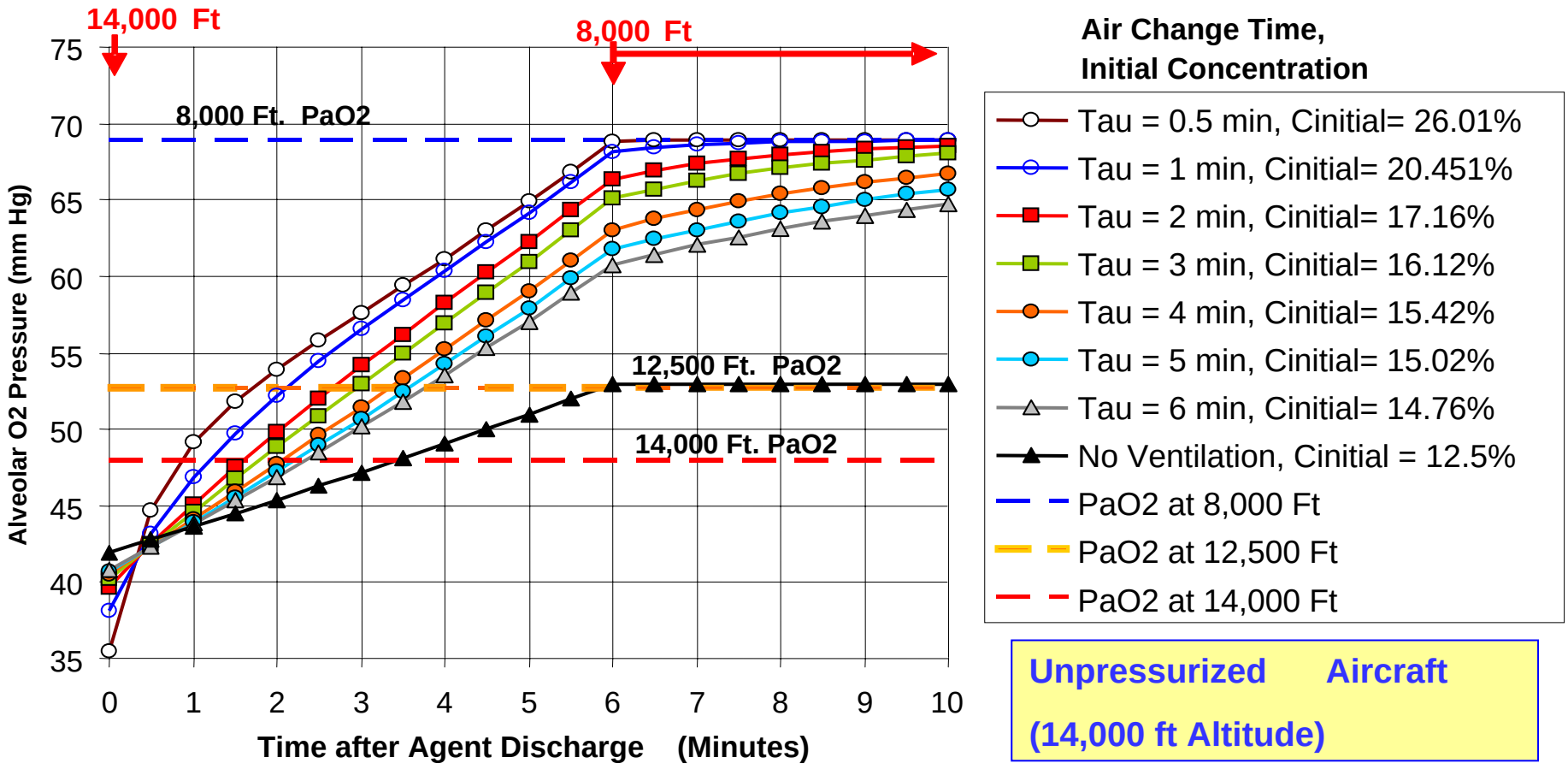
- W/V = 0.0432 pounds/ft^3 for Pressurized Cabins at 8,000 ft. P altitude
- W/V = 0.0361 pounds/ft^3 for Nonpressurized Cabins at 12,500 ft.
- W/V = 0.0342 pounds/ft^3 for Nonpressurized Cabins at 14,000 ft.
- W/V = 0.0292 pounds/ft^3 for Nonpressurized Cabins at 18,000 ft.
- W/V = 0.0216 pounds/ft^3 for Nonpressurized Cabins at 25,000 ft.

Unpressurized aircraft should descend at the maximum safe rate to 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.

1st ORDER KINETIC MODELING OF ARTERIAL BLOOD CONCENTRATION HISTORIES

- Provides a ***simple mathematical solution*** to obtain data needed to develop perfect mixing ventilation tables which will provide maximum safe extinguishing agent weights for a range of compartment volumes and air change times.
- Monte Carlo simulations of arterial blood concentration histories for 5 minute exposures to constant agent concentrations are used as input data for developing equations (95% confidence) for each extinguishing agent.
- PBPK arterial blood data has been published for HFC 236fa and HFC 227fa which accounts for 95% (two standard deviations) of the simulated population having 5 minute arterial blood concentrations below the target concentration.
- Equations can be developed for each agent, which transform agent concentration histories to arterial blood concentration histories in ventilated spaces.
- Demonstrated to work for predicting blood concentration histories for exposures to a constant concentration of agent.
- Has been validated for predicting blood concentration histories for exposures to changing concentrations of agent.

LOW OXYGEN HYPOXIA AT ALTITUDE: Unpressurized Small Aircraft



Unpressurized Aircraft

(14,000 ft Altitude)

Unpressurized aircraft currently allowed to fly at: 14,000 ft. for 30 minutes
12,500 ft. indefinitely

A/C LANGUAGE FOR HALOCARBON FIRE EXTINGUISHERS

- Provide safety guidance for halocarbon extinguishers.
- Recommends a minimum UL listed 5 B:C extinguisher for occupied spaces
- The proposed A/C references requirements for hand extinguishers.
- Recommends throw ranges for various sized aircraft
- Recommends a discharge hose or adjustable wand.
- Provides guidance for minimizing risk of low oxygen hypoxia when agent is released at altitude.
- States the maximum weight that ***all*** extinguishers in a compartment should not exceed, based on agent toxicity, size of compartment, and maximum FAA-allowed altitude of the cabin.

A/C LANGUAGE FOR HALOCARBON FIRE EXTINGUISHERS

- May allow increased halocarbon clean agent concentrations in ventilated compartments:
  - ➢ Selector graphs can be developed if PBPK data is available.
  - ➢ Selector graphs provide the maximum safe weight of agent based on safe concentration at altitude, compartment volume, time for an air change.
  - ➢ Provides updated safe handling guidelines based on adverse toxicological or cardiac sensitization events, PBPK modeling, and hypoxia considerations.
  - ➢ Operators of non-transport category aircraft should become familiar with the information in this A/C.
- The proposed AC is subject to change/ rewrite by the FAA Aircraft Certification Office.

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HANDHELD EXTINGUISHER WEB PAGE

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