U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Hand Fire Extinguishers for use in Aircraft **Date:** 5/xx/10 **AC No:** 20-42D
Initiated by: AIR-120 **Change:**

This advisory circular (AC) gives you guidance for the fire-fighting effectiveness, selection and safe-use of hand fire extinguishers in airplanes and rotorcraft. In it we will also show you how to gain Federal Aviation Administration (FAA) approval of hand fire extinguishers for aircraft.

David W. Hempe
Manager, Aircraft Engineering Division
Aircraft Certification Service

Table of Contents

Paragraph *Page*

Paragraph *Page*

Table of Figures

Chapter 1. General Information about this Advisory Circular (AC)

1. What is the Purpose of this Advisory Circular (AC)?

a. We provide guidance for fire-fighting effectiveness, selection, location and mounting of hand fire extinguishers.

b. We establish the halocarbons hydrochlorofluorocarbon (HCFC) Blend B, hydrofluorocarbon (HFC)-227ea, and HFC-236fa as FAA approved replacement agents to Halon 1211 and Halon 1301.

c. This AC recommends that you transition to using these new halocarbon clean agents in fire extinguishers kept onboard aircraft and rotorcraft. We explain how to gain certification for halocarbon clean agent extinguishers intended to replace Halon 1211 hand-held extinguishers.

d. This AC recommends that dry chemical, dry powder, and carbon dioxide hand extinguishers, in general, should not be used in aircraft.

e. We also explain how to gain Federal Aviation Administration (FAA) certification for replacement agent fire extinguishers, given you comply with Title 14 of the Code of Federal Regulations (14 CFR) Parts 23, 25, 29, 91, 121, 125, 127 and 135.

f. This AC establishes an FAA approved minimum performance standard (MPS) for halon replacement agents which includes a hidden fire test and a seat fire/toxicity test.

g. This AC provides guidance for safe-use, and marking of halocarbon extinguishers.

h. We show how to reduce the health and safety risk of exposure to halocarbon clean agents and how to use halocarbon clean agent fire extinguishers.

i. We offer updated guidance on the continued safe-use of Halon 1211, Halon 1301, and Halon 1211/1301 Halon blend extinguishers.

j. We set new maximum safe weight per unit volume (W/V) guidance for each approved agent.

k. This AC recognizes that while toxicity of halocarbon agents and their decomposition products is a concern and should be a consideration for extinguisher selection, it is far less of a concern than an unextinguished in-flight fire.

l. This AC is not mandatory and does not constitute a regulation. It is not intended to require you to do anything beyond what is specifically required by the regulations. In it, we describe an acceptable means, though not the only means, to gain certification for fire extinguishers kept onboard aircraft and rotorcraft. However, if you use the means described, you must follow it entirely.

2. Who is this AC for?

a. We wrote this AC for those responsible for selecting, approving, purchasing and maintaining hand fire extinguishers. The guidance in this AC is also for manufacturers, installers, modifiers, owners and operators of airplanes and rotorcraft.

b. Existing halon handheld fire extinguisher installations are not affected by the updated guidance in this AC. The guidance in prior revisions of this AC apply to specific extinguisher installations on existing approved type design aircraft. These extinguishers remain suitable for continued use based on a history of safe use of halon extinguishers on aircraft. However, although not required, we encourage owners and operators to consider replacing discharged halon handheld fire extinguishers with FAA approved halon replacement extinguishers.

3. What has Changed in this AC from the Previous AC?

a. Replacement halocarbon clean agents were developed in response to restrictions on the production of ozone-depleting halon fire extinguishing agents. The restrictions were introduced under the Clean Air Act Amendments of 1990 which implemented the Montreal Protocol signed September 16, 1987, as amended. In addition, the International Civil Aviation Organization is considering further mandated limits on halon use in aircraft.

b. Since 1994, Halon 1211 has not been produced in the US. By 2010, Halon 1211 will no longer be produced anywhere in the world. Halocarbon clean agent extinguishers hydrochlorofluorocarbon HCFC Blend B and hydrofluorocarbons HFC-227ea, and HFC-236fa are now commercially available. These halocarbon hand fire extinguishers have been evaluated and found to be effective fire-fighting agents. If properly used, these agents are safe to human health. While the HFCs are greenhouse gases, the U.S. Environmental Protection Agency (EPA) is allowing their limited use for aviation applications. The EPA considers the HFCs to be safer to the environment than the halons they are replacing.

c. Safe-use guidance is provided for Halon 1211 and Halon 1301 and blends of these agents. Safe-use concentrations of Halon 1211 are lower than in the previous AC. The safe-use guidance in this AC is more conservative. The standard for safety is higher than the previous AC, and is based on a better understanding of the toxicology of halocarbons.

4. Does This AC Cancel Any Prior ACs? This AC cancels AC 20-42C, dated March 7, 1984.

5. Where Can I find This AC and Other FAA Publications? You can find this AC on the Regulatory and Guidance Library (RGL) website: http://rgl.faa.gov/. See appendix **3** in this AC for additional information and related documentation.

Chapter 2. Gaining FAA Approval for Fire Extinguishers

1. How are Hand Fire Extinguishers Approved?

a. Federal Regulations for Hand Fire Extinguishers. Hand fire extinguishers are required under 14 CFR §§ 23.851, 25.851(a)(1), 29.851(a)(1), 29.853(e) & (f), 91.513(c), 119.25, 121.309(c), and 135.155. We approve hand fire extinguishers to be used on aircraft under the provisions of 14 CFR § 21.305(d). Accordingly, this AC is provided as one means acceptable to us for the approval of hand fire extinguishers.

> **Note:** Although 14 CFR parts 91 and 125 don't require our approval of hand fire extinguishers, we consider the information in this AC acceptable for use by Part 91 and 125 operators.

b. Extinguishers Approved Under Industry Standards Organizations. We approve hand fire extinguishers for use in aircraft when they meet industry standards. Extinguishers approved in this manner should also meet the safe-use guidance provided in this AC. In addition, replacement agents must meet additional requirements specified in paragraph **2.** below. We accept hand fire extinguishers approved by:

(1) U.S. - Underwriters Laboratory (U.S. - UL) according to U.S. - UL Standard 711, *Rating and Fire Testing of Fire Extinguishers*, and U.S. - UL construction and performance requirements for specific agent extinguishers with a U.S. - UL Listing mark (See paragraph **3.c.** below.) or equivalent such as:

(2) Factory Mutual Research Corporation (FM),

(3) The British Standards Institution (BSI) European standard BS EN 4649-E: 2009, *Portable Fire Extinguishers*, (if demonstrated to be equivalent to U.S. - UL 711) or

(4) The U.S. Coast Guard (USCG) under 49 CFR.

c. Safe-Use Guidance. Although this AC is a method of compliance for transport category aircraft, operators of non-transport category airplanes or rotorcraft should become familiar with the information, precautions and the safe-use guidance in chapter **4** of this AC**.** Also follow the recommendations of the extinguisher manufacturer unless their guidance conflicts with the guidance in this AC.

d. Minimum Rating. Your hand fire extinguisher should be rated per the requirements of U.S. - UL 711 or equivalent, as noted in paragraph **1.b.** above. Hand extinguishers produced in the U.S. or those used on airplanes and/or rotorcraft operated within the U.S. should meet U.S. – UL fire rating standards.

(1) **Large Aircraft.** The required hand extinguishers should be listed and have a minimum U.S - UL 5B:C rating or the equivalent. Exception: See chapter **4**, paragraph **6.** for minimum extinguisher ratings for use in accessible cargo compartments.

(2) **Small Airplanes or Rotorcraft**. You may use an extinguisher with a minimum rating of U.S. - UL 2B:C or equivalent on aircraft with maximum compartment volumes of up to 200 ft^3.

2. How are Halon 1211 Replacement Extinguishers Approved? Hand extinguisher replacement agents, such as the halocarbon clean agents intended to replace the required 2 ½ pound U.S. - UL 5B:C Halon 1211 extinguishers, may be approved for use on aircraft if the agent complies with the following requirements:

a. Replacement Agent Health and Environment Approval.

(1) Evaluate any halon replacement agent using the EPA significant new alternatives policy (SNAP) program according to 40 CFR part 82, Subpart G. This process characterizes the health and environmental risk of a proposed replacement agent.

(2) The three halon replacement agents covered by this AC have been evaluated under the SNAP program. Halocarbon clean agents HCFC-Blend B, HFC-227ea, and HFC-236fa have been approved for environmental and toxicological acceptability.

b. Replacement Agent Hand Extinguisher MPS. Evaluate the replacement agent/extinguisher using the following two fire tests specified in technical report DOT/FAA/AR-01/37, *Development of a Minimum Performance Standard for Hand-Held Fire Extinguishers as a Replacement for Halon 1211 on Civilian Transport Category Aircraft.* These fire tests ensure that the replacement agent extinguishers provide equivalent fire fighting performance to Halon 1211. Clean agent extinguishers designed to replace the required 2½ pound Halon 1211 extinguisher onboard aircraft should comply with the following MPS provisions:

(1) **Hidden Fire Test.** The hidden fire test evaluates the "flooding" characteristics of the replacement agent against a hidden in-flight fire and determines the ability of a streaming agent to function as a flooding agent. This is a hardware-specific test and the extinguisher design affects it's performance. Each required 5B:C extinguisher model should pass this test to be certified as a Halon 1211 replacement on aircraft.

(2) **Seat Fire/Toxicity Test.** The seat fire test is a baseline test that evaluates the effectiveness of the replacement agent in fighting a flammable fluid seat fire scenario and the associated toxicity hazard of the decomposition products of that agent. This test measures the agent's ability to extinguish a triple-seat fire in an aircraft under in-flight conditions and ensures an acceptable level of toxicity for the thermal decomposition products of the replacement agent. If a particular required 5B:C extinguisher model passes the seat fire/toxicity test, other models of extinguishers do not need to be tested, if the same agent is used.

> **Note 1:** Select a replacement agent or halocarbon extinguisher for your aircraft compartment according to the fire rating per its U.S - UL listing, not the agent weight.

> **Note 2:** The effectiveness of a hand fire extinguisher relies upon the training, expertise and capabilities of the crew member utilizing the device. See **Figure 15**.

c. National Certification. U.S. - UL 2129, *Halocarbon Clean Agent Fire Extinguishers,* with a required rating of U.S. - UL 5B:C or equivalent per U.S. - UL 711 or equivalent (see paragraph **1.e.** above).

> **Note:** Use the FAA approval marking label, (see paragraph **2.e.** below) and the U.S - UL numeric rating listing, not the agent weight to select extinguishers for an aircraft compartment.

d. Specifications for Approved Halocarbon Clean Agents to Replace Halon 1211. For hand fire extinguishers employing halocarbon clean agents replacing Halon 1211, the following American Society of Testing and Materials (ASTM) specifications apply:

(1) HCFC Blend B must meet ASTM D 7122-05, *Standard Specifications for HCFC Blend B*;

(2) HFC-227ea must meet ASTM D 6064-03, *Standard Specifications for HFC-227ea, 1,1,1,2,3,3,3-Heptaflouropropane (CF_3CHFCF_3);*

(3) HFC-236fa must meet ASTM D 6541-05, *Standard Specification for HFC-236a, 1,1,1,3,3,3-Hexafluoropropane ($CF_3CH_2CF_3$)*; or

(4) New Halon 1211 replacement agents must have and meet an applicable ASTM or equivalent specification.

(5) Fire extinguisher manufacturers are responsible for the validation of agent purity whether using new or recycled agent.

e. Marking. If you are a manufacturer, each of your models of U.S. – UL 5B:C Halon 1211 replacement extinguishers that have passed the test specified in paragraph **2.b.(1)** and **2.b.(2)** above should be permanently and legibly marked with the following:

(1) "Meets FAA approved MPS per DOT/FAA/AR-01/37"

(2) The name of the listing agency and rating according to U.S. - UL 711 or equivalent. U.S. - UL extinguishers must have the UL listing mark (include UL copyright logo) with the four required elements: UL in circle mark; word "listed;" product or company name; and issue/serial number or control number.

f. New Technologies and Extinguishers Containing Replacement Agents Introduced After the Effective Date of This AC. Nothing in this AC is intended to restrict new technologies or use of new replacement agents provided they meet the regulations and the guidance prescribed in paragraph **2.a.** through **2.e.** above.

(1) The FAA Technical Center (FAATC) intends to publish future guidance on handheld extinguishers. This guidance will cover maximum safe W/V for FAA approved fire extinguishers containing halon replacement agents introduced after the effective date of this AC.

(2) New replacement agents will require FAA approval of a specific maximum safe W/V. For agents that have not established an approved W/V, use the guidance provided in appendix **4,** paragraph **2.c.** of this AC to propose a maximum safe W/V for unventilated compartments.

(3) The provisions in this AC also apply to new agents.

3. How are Halon Extinguishers Approved?

a. National Certification. Required halon hand-held fire extinguishers approved for use on aircraft should have a minimum rating of UL 5B:C. Halon 1301 and Halon 1211/1301 blends are also used. Halogenated fire extinguishers must comply with U.S. - UL 1093, *Halogenated Agent Fire Extinguishers*, or equivalent, for Halon 1211, Halon 1301 and Halon 1211/1301 blends per U.S. - UL 711 or equivalent (see paragraph **1.e.** above). It should be noted that on March 12, 2009, UL announced the withdrawal of US – UL 1093 and the continuance of existing certifications to the withdrawn US - UL 1093. UL will no longer accept the submittal of new or revised products, but all current compliant products covered under US – UL 1093 will continue to be authorized to bear the classification mark of Underwriters Laboratories Inc. until October 1, 2014.

b. Specifications for Approved Halon Agents. For hand fire extinguishers that still employ halogenated agents, only Halon 1211, Halon l301, or blends of the two have been previously approved and used aboard aircraft. The following specifications cover the requirements for halogenated agents:

(1) Halon 1211 should meet the requirements of ASTM Dxxxx , *Standard Specification for Halon 1211-Bromochlorodifluoromethane (CF_2ClBr)*,or ISO 7201-1:1989, *Fire protection -- Fire extinguishing media -- Halogenated Hydrocarbons -- Part 1: Specifications for Halon 1211 and Halon 1301.*

(2) Halon l301 should meet the requirements of ASTM D5632-08, *Standard Specification for Halon 1301-Bromotrifluoromethane (CF_3Br))*, or ISO 7201-1:1989.

(3) Hand fire extinguishers with halon agents may continue to be used on aircraft as long as recycled halon of proven acceptable quality is available. Recycled agents are still available for purchase, but the duration of their availability is unknown. Therefore, we encourage operators to consider replacing halon extinguishers after discharge with approved halon replacement extinguishers.

(4) An EPA exemption allows the production of halon blends from recycled halon for aircraft use.

(5) Fire extinguisher manufacturers are responsible for the validation of agent purity whether using new or recycled agent.

c. Marking. If you are a manufacturer, mark your halon extinguishers permanently and legibly with the name of the listing agency and rating according to U.S. - UL 711 or equivalent. U.S. - UL extinguishers must have the UL listing mark (include UL copyright logo) with the four required elements: UL in circle mark; word "listed;" product or company name; and issue/serial number or control number.

Chapter 3. Selecting the Correct Hand Fire Extinguisher

1. What are the Different Types of Fires?

a. Classes of Fires. To properly select an appropriate hand fire extinguisher for use in an aircraft, you should consider the following classes of fires that are likely to occur onboard your aircraft, as defined in the U.S. National Fire Protection Association (NFPA) Standard 10, *Standard for Portable Fire Extinguishers, 2007 Edition*:

(1) **Class A.** Fires involving ordinary combustible materials, such as wood, cloth, paper, rubber, and plastics.

(2) **Class B.** Fires involving flammable liquids, petroleum oils, greases, tars, oil base paints, lacquers, solvents, alcohols, and flammable gases.

(3) **Class C.** Fires involving energized electrical equipment where the use of an extinguishing media that is electrically nonconductive is important.

(4) **Class D.** Fires involving combustible metals, such as magnesium, titanium, zirconium, sodium, lithium, and potassium.

b. Lithium Battery Fires. Do not treat a fire involving a small number of lithium batteries as a Class D fire. Halon, Halon replacement, or water extinguishers can be used to control fires involving a small number of rechargeable lithium batteries as found in portable electronic devices (PED) e.g. laptop computers, cell phones, pagers, audio/video/data recording or playback devices, messaging devices, personal digital assistants (PDAs), and two-way radios. Water from any available source should be poured over the cells immediately after fire knockdown or extinguishment, since only water can provide sufficient cooling to prevent re-ignition and/or propagation of the fire to adjacent cells of the battery pack. A water extinguisher, by itself, can be used to safely (from a distance) to extinguish a lithium battery fire and cool it sufficiently to end the event.

(1) Do not use fire resistant burn bags to isolate burning Lithium batteries. Transferring a burning appliance into a burn bag may be extremely hazardous.

(2) In addition, a training video, which demonstrates effective techniques for fighting lithium battery fires, is available from the FAA. The video, *"Extinguishing In-flight Laptop Computer Fires,"* is available for viewing at http://www.fire.tc.faa.gov/2007Conference/session_details.asp?sessionID=26

(3) See SAFO 09013 for further guidance on how to fight Lithium battery fires.

2. What Extinguishing Agents are Appropriate for the Different Types of Fires?

Make every effort to consider the effects of agent toxicity, ventilation, stratification and hypoxia when selecting and sizing the necessary fire protection. The following extinguishing agents are appropriate for use on the types of fires specified in paragraph **1.a.** above:

a. Water. Class A type fires are best controlled with water by cooling the material below its ignition temperature and soaking the material to prevent re-ignition.

b. Carbon Dioxide. Class B or C fires are effectively controlled by carbon dioxide as a blanketing agent.

> **Note:** Carbon dioxide is **not recommended** for hand-held extinguishers for internal aircraft use.

c. Dry Chemicals. Class A, B, or C fires are best controlled by dry chemicals. The only "all purpose" (Class A, B, C rating) dry chemical powder extinguishers contain mono-ammonium phosphate. All other dry chemical powders have a Class B, C U.S – UL fire rating only.

> **Note 1:** In general, dry chemicals are **not recommended** for hand extinguishers for internal aircraft use, due to the potential for corrosion damage to electronic equipment, the possibility of visual obscuration if the agent were discharged into the flight deck area, and the cleanup problems from their use.

> **Note 2:** When approving a non-gaseous agent for installation on aircraft, evaluate the contamination impact to the structure, wiring and surrounding systems, and consider potential mixing of the agent residue with water. Using such extinguishers may require specific maintenance procedures addressing cleanup.

d. Halons. Class A, B, or C fires are appropriately controlled with halons. However, do not use halons on a class D fire. Halon agents may react vigorously with the burning metal.

> **Note:** While halons are still in service and are appropriate agents for these classes of fires, the production of these ozone depleting agents has been restricted. Although not required, consider replacing halon extinguishers with halon replacement extinguishers when discharged.

e. Halocarbon Clean Agents. *(Halons are a subcategory of halocarbons.)* Class A, B, or C fires are appropriately controlled with the use of halocarbon clean agents. Never discharge halocarbon clean agents or water on a Class D (burning metal) fire. Halocarbon agents may react vigorously with the burning metal.

f. Specialized Dry Powder. Class D fires are best controlled by dry powder. Follow the recommendations of the extinguisher manufacturer because of the possible chemical reaction between the burning metal and the extinguishing agent.

> **Note 1:** Specialized dry powder is **not recommended** for hand extinguishers for internal aircraft use.

Note 2: Fires involving a small number of Lithium primary batteries (containing molten Lithium) should not be treated as class D fires and specialized dry powder should not be used. See paragraph **1.b.** above for a discussion of appropriate extinguishing agents for Lithium battery fires.

3. What Do the Numeral Ratings Mean? Numerals are used with identifying letters for extinguishers labeled for Class A and Class B fires. The "numeral," which precedes the letter, indicates the relative extinguishing effectiveness of the device on a given size fire. This is dependent on the agent, the capacity of the device, discharge times, and design features. For example, an extinguisher rated as U.S. - UL 4A should extinguish about twice as much Class A fire as a U.S. - UL 2A rated extinguisher. Numeral ratings are not used for extinguishers labeled for Class C or D fires. Extinguishers that are effective on more than one class of fires have multiple "numeral-letter" and "letter" classifications and ratings; for example, U.S. - UL 5B:C.

4. What Extinguishing Agents are Compatible with Aircraft Materials?

a. Corrosion by Extinguishing Agents. Halocarbon clean agents are not corrosive, but review the material compatibility properties for acceptability to aircraft materials. Water itself is not corrosive, but may be rendered corrosive by the addition of antifreeze solutions. Specialized dry powder is corrosive to most sensitive electronic components and instruments.

b. Material Compatibility. Halocarbon clean agents can be used in numerous aircraft applications and it is important to review the materials of construction for compatibility when designing new equipment, retrofitting existing equipment, or preparing storage and handling equipment to incorporate halocarbon clean agents. Materials that should be considered include metals, elastomers, and plastics. Halocarbon clean agents or water should never be discharged on Class D (burning metal) fires. These agents may react vigorously with the burning metal. See paragraph **1.b.** above for the exception: Lithium battery fires involving carry-on appliances.

c. Corrosivity of Decomposition Products. The thermal decomposition products of halocarbon extinguishing agents are corrosive, particularly the acid halides: HF, HCl and HBr. The decomposition products of burning aircraft materials are also corrosive, Decomposition products are minimized by quickly extinguishing the fire. Acid halide production is also based on the agent used and the size of the fire.

5. What are the Operating Temperature Tolerances?

a. Halocarbon clean agent hand fire extinguishers should operate properly after being conditioned at -40ºF (-40ºC) or -65ºF (-54ºC) as applicable and 120ºF (49ºC) for 16 hours as specified in U.S. - UL 2129 or U.S. - UL 1093 as applicable. Hand fire extinguishers containing water should be protected to temperatures as low as -40°F (-40°C) by adding antifreeze and stipulated on the extinguisher nameplate.

b. Cold operation may require additional consideration in the selection of an extinguisher to install. This is particularly true for general aviation aircraft in extremely cold climates. The hidden fire extinguishment tests in the MPS were conducted on halocarbon extinguishers equilibrated to 70°F. More agent, a lower boiling point agent, or an extinguisher design change, may be needed to extinguish hidden fires. Testing may be needed to select an appropriate extinguisher. The boiling points of the halocarbons (at 1 atmosphere) listed in this AC are:

(1) HCFC Blend B = 80.6°F (27.0°C),

(2) HFC-227ea = 1.9°F (-16.4°C),

(3) HFC-236fa = 29.5°F (-1.4°C),

(4) Halon 1211 = 26.0°F (-3.4°C), and

(5) Halon 1301 = -72.0°F (-57.8°C).

6. What is the Fire Fighting Effectiveness of the Different Hand Fire Extinguishers?

a. General Guidelines for Hand Fire Extinguishers:

(1) Consider the effects of agent toxicity, ventilation, stratification and hypoxia when selecting and sizing the necessary fire extinguisher.

(2) Provide the required/recommended number of hand held extinguishers, as indicated in chapter **5,** paragraph **4.** of this AC. All extinguishers must have the proper U.S. - UL rating, even in spaces where the safe use guidelines, as outlined in chapter **4** paragraphs **2**., **4**., **5**., and **6**., are exceeded. The failure to extinguish a fire has catastrophic consequences for all aircraft occupants. Agent toxicity concerns are secondary to the immediate need to extinguish the fire.

(3) Follow the maximum safe W/V guidance in chapter **4** of this AC for selecting extinguishers for aircraft compartments.

(4) Do not substitute two smaller extinguishers for one extinguisher of the proper UL rating, except as provided for accessible cargo compartments, as noted in chapter **4**, paragraph **6.c**. The fire can grow quickly prior to the discharge of the second extinguisher.

(5) The minimum discharge time of a U.S. - UL 5B rated extinguisher is approximately 8 seconds, 12 seconds for a U.S. - UL 1A:10B:C extinguisher, and 13 seconds for a U.S. - UL 2A:10B:C extinguisher. Due to this relatively short effective time span, proper training and use of the fire extinguishers is important.

(6) For access to under seat, overhead, and other difficult to reach locations, hand extinguishers equipped with a discharge hose or adjustable wand mounted directly to the extinguisher are highly recommended. A discharge hose or adjustable wand is preferred because it is likely to result in the extinguisher being properly held in an upright position during use and provides a means of directing a stream of agent to more inaccessible areas. Adjustable wand or fixed nozzle extinguishers allow for one-handed use. See AC 120-80 for more details and guidance on in-flight fire fighting. A video for flight crew training is available from the FAA. The title of the video is *"Aircraft In-flight Fire Fighting."* The tape version of the video is referenced as "MST 730" and the DVD version is referenced as "MST 730.01." It can be obtained from Dale Dingler, FAA William J. Hughes Technical Center, Advanced Imaging Division, AJP-7960, Atlantic City International Airport, NJ 08405. phone: 609.485.6646, email:dale.dingler@faa.gov. The in-flight training video is also available at the following public website: http://www.fire.tc.faa.gov/2007Conference/session_details.asp?sessionID=26

b. General Guidelines for Halocarbon Extinguishers:

(1) For occupied spaces on transport category aircraft, extinguishers employing halocarbon clean agents, replacing required Halon 1211, should have a minimum U.S. - UL 5B:C or an equivalent rating. These extinguishers should have a discharge time that is not less than 8 seconds effective discharge time, and not less than an 8 foot (3 m) throw range (passing the MPS seat tests assures a 8 foot throw range). Longer throw ranges of 10 feet and greater provide a significant advantage in fighting fires in large transport category aircraft. See appendix **4,** paragraph **1.** of this AC for more information on replacement agent throw ranges.

(2) Halocarbons that are gaseous upon discharge have a more limited throw range. Halocarbons have discharge characteristics dependent on the halocarbon, nozzle design, extinguisher super pressurization, cold soak times, and operational temperatures. Throw ranges of 10 feet and higher provide significant advantages in fighting fires in large aircraft cabins.

(3) Halocarbon extinguishers are most effective on Class B and C fires. Extinguishers with greater capacity are also rated for Class A fires. Extinguishers with a 2B:C or 5B:C U.S. - UL rating, although not rated for use on Class A fires, have been shown to be effective in extinguishing surface Class A fires. In addition to this circular, detailed information on halocarbon agent characteristics, concentration requirements, health hazards, and extinguishing limitations can be found in:

(a) ISO 7201-1:1989, *Fire Protection -- Fire Extinguishing Media -- Halogenated Hydrocarbons -- Part 1: Specifications for Halon 1211 and Halon 1301,*

(b) NFPA Standard 12A, *Halon 1301 Fire Extinguishing Systems*, and

(c) NFPA *2001 Standard on Clean Agent Fire Extinguishing Systems.*

c. General Guidelines for Halon Replacement Extinguishers:

(1) Halon replacement extinguishers with a minimum rating of 5B:C can be used in place of required technical standard order (TSO) C19 water extinguishers, if you can show that the replacement extinguisher has comparable or better Class A extinguishing performance than the TSO'd water extinguisher. A TSO C19 water extinguisher can fight small Class A fires but are not large enough to have a 1A rating. The halon replacement extinguisher must have a sufficient throw range to extinguish fires likely to occur.

(2) Two required 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 and a sufficient throw range to extinguish fires likely to occur.

Chapter 4. Safe Use of Hand Fire Extinguisher

1. What Basic Fire Fighting Training Should be Provided?

a. Flight crewmembers should be trained on the urgency of immediate and aggressive extinguishment of an onboard fire. As fires can grow exponentially with time, the risks of exceeding the recommended levels of extinguishant are considered minimal compared to the risks of an in-flight fire.

(1) Quickly extinguish the fire.

(2) Immediately turn off all air circulation systems, if so equipped

b. Train flight crewmembers on the proper use of hand extinguishers. See AC120-80, *In-Flight Fires*, for additional guidance. A training video on the use of hand extinguishers to fight on-board fires is available at the following website: http://www.fire.tc.faa.gov/2007Conference/session_details.asp?sessionID=26.

c. Operators should ensure that all crew members receive proper training in the appropriate use of hand fire extinguishers onboard their aircraft

d. Attack the base of the fire at the near edge of the fire and then move the fire extinguisher nozzle rapidly with a side-to-side sweeping motion, progressing toward the back of the fire. The optimum firefighting technique differs for each approved extinguisher.

e. Do not direct the initial discharge at the burning surface at close range, if the extinguisher has an initial high velocity stream that could splash and/or scatter the burning material.

2. What are Some General Guidelines for the Safe-Use of Halocarbon Extinguishers?

Although exposure to halocarbon agents and their decomposition products are a concern, it is far less of a concern than the consequences of an unextinguished in-flight fire. It is critically important to quickly extinguish an in-flight fire. The consequences of an unextinguished in-flight fire include the loss of the aircraft and its occupants and immediate toxic hazards from exposure to thermal decomposition products of the burning materials, including carbon monoxide, hydrogen cyanide, smoke, heat, and subsequent oxygen depletion.

a. Control Exposure to Halocarbon Vapors and Combustion Gases. Halocarbon agents are much heavier than air and stratify with time. Agent stratification may provide a safety benefit or a disbenefit depending on the height of an occupant's head above the floor of the compartment and the attitude of the aircraft. In addition, this lower stratified agent may be re-circulated and redirected into the breathing zone of passengers.

(1) Avoid exposure to concentrations of halocarbon vapors that exceed the amounts and/or duration allowed in this AC. Exposure may result in dizziness, impaired coordination, reduced mental acuity, and heart arrhythmias. Halocarbon agents also decompose when they contact open flames or hot surfaces and the decomposition products have a characteristic sharp, acrid odor, and an eye irritating effect, even in concentrations of only a few parts per million. See appendix A, paragraph 1.5.1.2 and 1.5.2.1 of NFPA *Standard 2001 on Clean Agent Fire Extinguishing Systems*, 2008 edition, or the most current revision, for more detailed information on the effects of neat agent and hydrogen fluoride (HF) respectively.

(2) Quickly extinguish the fire.

(3) Turn off all air recirculation systems immediately, if so equipped. Halocarbon concentrations stratify and are more concentrated at lower levels. Turning off the recirculation allows all the agent entering the low level air returns to be directed to the air outflow valves and out of the aircraft. Some aircraft have up to 50% recirculation, so it is important to turn off the air recirculation quickly.

b. Use Portable Protective Breathing Equipment (PBE). In compartments where extinguisher(s) do not or can not meet the safe-use guidance in this AC, flight crewmembers should use portable PBE, if available. Full extinguisher discharge into these compartments would result in high concentrations of agent that exceed toxicity levels or acceptable exposure limits identified herein. Unprotected personnel should not enter a protected space during or after agent discharge, until ventilated. Crewmembers should follow fire fighting procedures when using portable PBE. See paragraph **6.b.** below for additional information on portable PBE use in cargo compartments.

c. Ventilate the Compartment.

(1) When you are absolutely sure the fire is extinguished, ventilate the compartment overboard at the highest possible rate allowed by established crew procedures for your particular aircraft to rid the cabin and flight deck of hazardous gases and smoke. *(If the fire is not completely extinguished, or a smoldering fire exists, increasing airflow could promote fire growth.)*

(2) Small aircraft lack the distinct safety advantages available to the large transport category aircraft. Large aircraft with small volume occupied spaces (flight decks) have a forced ventilation system, availability of oxygen masks, and a co-pilot available. Small aircraft usually do not have these advantages.

3. How to Prevent Hypoxia in an Unpressurized Aircraft. You can avoid life-threatening hypoxia (low oxygen) hazards, resulting from the halocarbon agent displacing air in unpressurized aircraft, by following the descent, ventilation, and supplemental oxygen guidance below. See FAA Report No. DOT/FAA/AR-08/3, *"Guidelines for Safe Use of Gaseous Halocarbon Extinguishing Agents in Aircraft"* for further information.

a. When you are absolutely sure the fire is extinguished, all unpressurized aircraft compartments should be ventilated overboard at the highest possible rate allowed by established crew procedures for your particular aircraft to rid the cabin and flight deck of hazardous gases and smoke. If the fire is not completely extinguished, or a smoldering fire exists, increasing airflow could promote fire growth

b. Descend to Lower Altitudes. Immediately descend at the maximum safe rate to 8,000 ft. or to an altitude that is as low as practicable. Descent dilutes the agent concentration, lowering exposure to the halocarbon agent and combustion gases, while increasing the oxygen concentration. We recommend descending regardless of the amount of agent used, and regardless of the ventilation rate.

(1) Aircraft with a maximum flying altitude of 12,500 ft. are protected from the hazards of hypoxia by immediately following the descent guidance in paragraph **3.b.** above, without the need for supplemental oxygen.

c. Use Supplemental Oxygen. If used, supplemental diluter demand personal oxygen systems used at CPAs above 12,500 ft. nasal cannula up to and including 18,000 ft CPA and oral-nasal masks above 18,000 ft. up to 25,000 ft. CPA do not fully protect the user from the hazards of hypoxia resulting from the displacement of air by the agent, since the oxygen flow control is based on pressure altitude, not oxygen partial pressure.

(1) Occupants flying at altitudes above 12,500 ft. should immediately switch their masks or nasal cannula to the maximum flow of oxygen, if so equipped, to get additional protection during the time it would take to exchange the air in the compartment three times.

(2) We recommend using fingertip probe oxygen sensors for users of oxygen systems in unpressurized aircraft with maximum flying altitudes above 12,500 ft. These devices provide user feedback on the effects of hypoxia after halocarbon agents are discharged in the aircraft compartment and feedback to dial up the oxygen flow to their breathing device to compensate for the hypoxia.

(3) Unpressurized aircraft are allowed to use nasal cannula supplementary oxygen systems up to 18,000 ft. altitude. These systems provide no protection to a wearer when he or she breaths through the mouth, which can occur at times of stress.

4. What are the Guidelines on the Selection of Halocarbon Extinguishers?

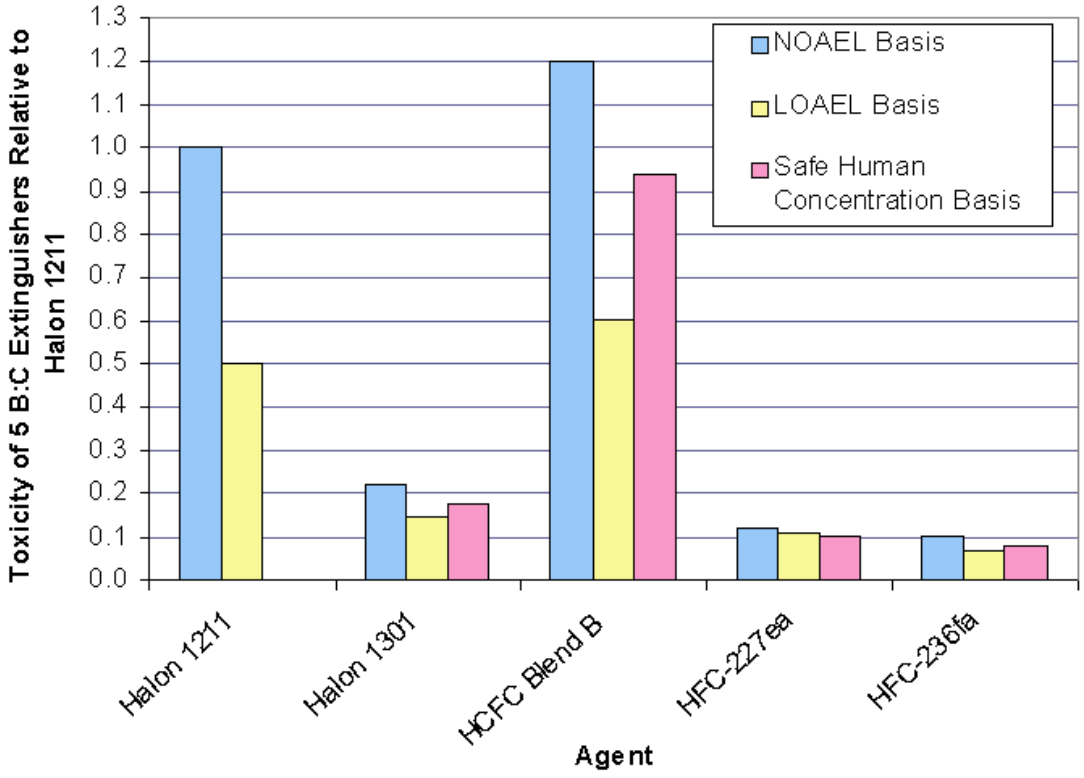
a. You should not exceed the maximum safe W/V found in the tables in the figures of this AC. The maximum safe W/V guidance is based on agent discharge at 70^{o} F at the aircraft certificated cabin pressure altitude (CPA).

b. For unpressurized aircraft, follow the safe-use guidance for the highest altitude for which the aircraft is certified.

c. Maximum Safe W/V Guidance. Maximum safe W/V guidance is based on the assumption of perfect mixing. The passenger cabin is considered and referred to as a compartment. For aircraft compartments with 2 or more required extinguishers, the maximum safe W/V is based on the total charge weight of the 2 largest extinguishers in that compartment volume. The total charge weight of the 2 largest extinguishers divided by the compartment volume should not exceed the maximum safe W/V.

d. If it is not possible to select a hand extinguisher that meets the maximum safe W/V guidance for your compartment, it is best to select a commercially available extinguisher of the required fire rating with the lowest toxicity per **Figure 1** or the lowest minimum safe volume. **Figure 1** shows the normalized toxicities of 5B:C extinguishers relative to the NOAEL-based toxicity of a 5B:C Halon 1211 extinguisher. These normalized toxicities are based on 3 different measures: LOAEL, NOAEL, and Safe Human Concentration. The minimum safe volume of one extinguisher is obtained by dividing the extinguisher charge weight by the maximum safe-use agent W/V for the appropriate altitude and ventilation (See appendix **4,** paragraph **3.** and **Figures 13** and **14.**). Do not use the minimum safe volumes stamped on U.S. - UL rated extinguishers. They are not applicable for aircraft because they are based on sea level discharge at 120°F.

Figure 1. Relative Toxicity of 5 B:C Halocarbon Extinguishers



e. In a pressurized aircraft (6000 to 8,000 ft CPA), the hypoxic hazard is minimal for the maximum safe concentrations for the halocarbon agents in this AC. Immediate descent is not necessary. Pressurized aircraft benefit (increased oxygen and decreased agent concentrations) only from descent to altitudes below the CPA. The worst case oxygen equivalent CPA for pressurized aircraft using the maximum safe W/V guidance provided in this AC is 10,000 ft at 2 minutes after discharge when 8,000 ft CPA is maintained. However, landing as quickly as possible is always recommended when an onboard fire is suspected.

5. How to Safely Use Halocarbon Extinguishers (including the halons) in Unventilated Passenger and Crew Compartments. Unventilated use guidance applies to compartments where the air change time of the compartment is not known, or exceeds 6 minutes. Also use unventilated guidance if the ventilated guidance is not available for that agent in this AC or in any subsequent guidance published by the FAA after the effective date of this AC.

a. If halocarbon clean agent extinguishers are installed in an unventilated passenger or crew compartment, and the compartment cannot be vented, then the total agent charge weight for the 2 largest hand held extinguishers in that compartment should not produce concentrations in that compartment at 70ºF (21ºC) at the stated pressure altitude, assuming perfect mixing, that exceed the agent's safe exposure guidelines, as indicated by the safe W/V guidance in **Figure 2** below. The total agent charge weight of the 2 largest required extinguishers in a compartment divided by the compartment volume should not exceed the maximum safe W/V in **Figure 2**.

Figure 2. Maximum Safe Agent W/V for Halocarbon Extinguishers in Unventilated Passenger and Crew Compartments

Agent	Maximum Safe W/V (lbs/ft^3) [a,b]					
	Sea Level (For info only)	Pressurized Aircraft (8k ft. CPA)	Unpressurized Aircraft [c]			
			12.5k ft.[d]	14k ft.[d]	18k ft.[d]	25k [e]
HCFC Blend B	0.00499	0.00371	0.00311	0.00293	0.00249	0.00185
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 [f]	0.00224	0.00166	0.00139	0.00131	0.00112	0.000829
Halon 1301	0.0260	0.0193	0.0162	0.0153	0.0130	0.00968

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

b *Extinguish the fire and immediately turn off air recirculation systems, if so equipped. When you are absolutely sure the fire is extinguished, ventilate the compartment overboard at the highest possible rate allowed by established crew procedures for your particular aircraft to rid the cabin and flight deck of hazardous gases and smoke and raise the oxygen concentration in the compartment. See chapter **4**, paragraph **2.c.** of this AC. Unpressurized aircraft should descend immediately at the maximum safe rate to an altitude of 8,000 ft or an altitude that is as low as practicable.*

c *Unpressurized aircraft should follow precautions to prevent hypoxia. (See chapter **4,** paragraph **3.** of this AC.)*

d *Using nasal cannula oxygen & fingertip-probe oxygen sensor*
e *Using diluter-demand oxygen mask & fingertip-probe oxygen sensor*
f *This value is based on the NOAEL Halon 1211 concentration of 0.5%.*

(1) The maximum safe agent W/V in unventilated compartments obtained from **Figure 2** may be increased using multiplication factors ($MF_{30\ sec\ egress}$) under certain circumstances**.** These multiplication factors would allow higher concentrations of agent in unventilated compartments, such as flight deck or crew rest areas where egress into a halocarbon-free environment can be completed within 30 seconds. Use of 30 second egress MF_s is based on the ability of any occupants of the compartment to quickly egress into a halocarbon-free compartment or to don PBE which provides breathable air/oxygen that is not diluted with the cabin air. Egress should be demonstrated or analyzed to be less than 30 seconds. Then, the maximum safe W/V may be increased by the following 30 second egress MF_s:

Figure 3. MF_s for Maximum Safe Agent W/V if Egress is Less Than 30 Seconds

Agent	$MF_{30sec\ egress}$
HCFC Blend B	1.53
HFC227ea	1.10
HFC236fa	1.19
Halon 1211	N/A
Halon 1301	1.15

Where $MF_{30\ sec\ egress}$ for an agent is the ratio of maximum safe-use 30 second agent concentration to the maximum safe-use 5 minute agent concentration. The derivation of the 30 second egress MF_s can be found in appendix **4**, paragraph **4.** Egress multiplication factors must not be used for ventilated compartments.

b. If the safe-use guidelines are exceeded in an unventilated cabin or crew compartment (If the required W/V exceeds the maximum safe agent W/V in **Figure 2**), select extinguishers of the required UL rating that does not exceed the maximum safe agent W/V. See chapter **4,** paragraph **2.d.** above. If no extinguisher of the required rating meets the safe use guidance, it is best to select the commercially available extinguisher having the lowest toxicity per **Figure 1** or the smallest minimum safe volume for the required rating. The exposure hazard for exceeding the maximum safe W/V values is low when following the safe use guidelines outlined in this AC. A conservative methodology was employed to determine the maximum safe W/V.

c. Refer to the safe-use guidance in chapter **4,** paragraphs **2.** and **3.** above for actions those personnel should take to limit exposure and to prevent hypoxia.

d. In the absence of EPA SNAP approved NOAEL toxicity data for a particular blend of two or more halocarbon agents, use the procedures outlined in appendix **4,** paragraph **2.d.** to calculate the maximum safe W/V for that blend. The individual agents must be SNAP approved with the exception of Halon 1211 and Halon 1301.

6. How to Safely Use Halocarbon Extinguishers in Ventilated Passenger and Crew Compartments. Ventilated guidance applies to compartments where both the compartment volume and the air change time is known and the air change time is greater than 0.5 minutes and less than or equal to 6 minutes. The air change time τ, is the time it takes for a volume of fresh air to enter the compartment that is equal to the volume of that compartment. For ventilated passenger or crew compartments, apply the multiplication factors for ventilated aircraft (**$MF_{Ventilated}$**) in **Figure 4** to the maximum safe W/V in **Figure 2** to find ventilation-corrected maximum safe W/Vs. Use the ventilated maximum safe W/Vs to determine acceptable extinguisher charge weights, when compartment volume and ventilation rates are controllable and known. Otherwise use **Figure 2**. The basis for these $MF_{Ventilated}$ is discussed in appendix **4**, paragraph **2.** of this AC.

a. The total agent charge weight of the 2 largest required extinguishers in a compartment divided by the compartment volume should not exceed the maximum safe W/V.

b. Do not use these $MF_{Ventilated}$ if compartment volumes and ventilation rates are not known (as for most unpressurized aircraft). However, these MFs for unpressurized aircraft serve to give perspective and background for extinguisher selection if air change times can be estimated.

c. If $MF_{Ventillated}$ are applied, $MF_{30\ second\ egress}$ can not be applied

d. If the maximum safe W/V guidelines are exceeded, select extinguishers of the required UL rating with the appropriate agent that would meet these maximum safe W/V guidelines. If no extinguisher meets the safe use guidance, select the safest extinguisher of the required rating. See chapter **4,** paragraph **2.** above.

e. Refer to the safe-use guidance in chapter **4,** paragraph **2. and 3.** above to limit exposure and to prevent hypoxia.

f. These selector graphs, for ventilated aircraft, are based on the assumption of perfect agent mixing, when an extinguisher is discharged.

g. Use the procedures outlined in appendix **4,** paragraph **2.d.** to calculate the maximum safe W/V for a blend of 2 or more halocarbons.

Figure 4. Multiplication Factors ($MF_{Ventilated}$) for Maximum Safe W/V for Ventilated Compartments

Agent	Air Change Time, τ (minutes)								
	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0	>6[a]
Halon 1211[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Halon 1301	1.96	1.57	1.42	1.34	1.25	1.21	1.17	1.15	1
HFC-236fa	1.98	1.58	1.42	1.34	1.25	1.20	1.17	1.15	1
HFC-227ea	1.90	1.53	1.39	1.32	1.24	1.19	1.16	1.14	1
HCFC-123	2.80	2.33	2.14	2.02	1.89	1.79	1.70	1.62	1

a *No ventilation benefit is applied if air change time is greater than 6.*
b *Halon 1211 was assigned no ventilation benefit as suitable PBPK modeling data was not available for this agent.*
c *The total charge weight of the 2 largest extinguishers in the aircraft compartment is the basis for these maximum safe W/V guidelines.*

7. How to Safely Use Halocarbon Extinguishers in Accessible Cargo Compartments.

a. Unsafe Concentrations of Extinguishing Agent. 14 CFR § 25.857 and § 29.855(d) require aircraft systems to be designed to prevent unsafe concentrations of extinguishing agent from entering occupied areas. Airplane Flight Manual (AFM) fire fighting procedures should state that the crew member should close the Class B cargo compartment door after extinguishing a fire.

b. When to Use Portable Protective Breathing Equipment (PBE). Portable PBE should be worn before entering the cargo compartment and attempting to extinguish a fire, as outlined in 14 CFR § 25.1439. Note that AFM and/or Crew Operations Manual are required to have the appropriate procedure including calling out the use of portable PBE and other emergency equipment necessary to fight a fire.

c. Compartments Under 200 Cubic Feet. Halon replacement extinguishers should have a minimum fire rating classification of U.S. - UL 2A:10B:C for accessible Class B cargo compartments, combination passenger/cargo (combi) and cargo airplane/rotorcraft. The fire threat for accessible cargo compartments is primarily from Class A fires. Usually, one extinguisher with a U.S. - UL 2A:10B:C rating is sufficient to fight most fires likely to occur.

(1) Multiple hand-held fire extinguishers may be shared to comply with the cabin and accessible Class B cargo compartment regulations, if they are located where a person fighting a fire in the compartment could quickly retrieve them and continue fighting the fire with minimal delay between the discharges. It must be demonstrated that the extinguishers, as installed, can extinguish 2A and 10B:C rated fires. The combined rating is to be determined by

performing the UL 711 fire tests by discharging the extinguishers with a delay between the end of each extinguisher's discharge and the start of the discharge of the next extinguisher based on the location of each extinguisher and an assessment of factors such as:

(a) The manpower available to fight the fire. If two trained crew members are available to fight the fire, it may be possible to avoid a delay between discharges of the extinguishers.

(b) The time to recognize the completion of the discharge, to walk to the location of the next bottle, remove it from it's mounting bracket, pull the pin, return to the cargo compartment, position the extinguisher to continue to fight the fire and initiate discharge.

(2) The rating is based on UL 711 performance tests, not agent weight, as the agent weight is not sufficient to predict performance. Nozzle design, super pressurization and other factors affect performance. The UL fire tests can be preformed by the applicant or an approved test laboratory such as UL.

> **Note:** The recommended extinguisher rating of 2A:10B:C is lower than the 2A:40B:C rating in AC 20-42C. This is because the fire threat for accessible cargo compartments is primarily from Class A fires. The prior guidance in AC 20-42C was based on the need for at least a 2A rating for class A fires using a Halon 1211 extinguisher to extinguish a fire. Halon 1211 extinguishers that have a class A rating of 2A also have a 40B:C rating. It has been determined that a 10B:C rating is more then adequate for the type and size of class B and C fires likely to occur in a Class B cargo compartment.

d. Compartments Over 200 Cubic Feet. Accessible cargo compartments of 200 ft^3 and larger, in combination passenger/cargo and cargo aircraft/rotorcraft, should comply with the requirements of the FAA Airworthiness Directive (AD) 93-07-15. This AD specifies acceptable forms of fire protection equipment and operational procedures. The options provided include converting the compartment to meet the requirements of a Class C cargo compartment, use of hand-held fire extinguishers, or the use of fire containment containers or covers, fire extinguishing systems and smoke or fire detectors.

(1) If you elect to use hand fire extinguishers provide the following:

(a) A minimum of three U.S. - UL listed Halon 1211 or its equivalent 2A:10B:C hand held fire extinguishers (equivalent to the AD's requirement of 48 lbs. of Halon 1211) readily available for use in the cargo compartment.

(b) At least two U.S. - UL 2A (2-1/2 gallon) listed water portable fire extinguishers, or its equivalent, adjacent to the cargo compartment entrance for use in the compartment.

(c) Protective garments stored adjacent to the cargo compartment entrance.

(d) Portable PBE with a minimum of 15 minutes of protective breathing, per 14 CFR § 25.1439(b)(5). This portable PBE should be TSO C-116 approved or equivalent, and be stored adjacent to the cargo compartment entrance.

(2) If no extinguisher is available that meets the safe-use criteria for the aircraft/rotorcraft cabin, consider converting that cargo compartment to a class C compartment with a built-in fire suppression system, or any other technology that would provide effective fire protection. Restrict personnel from entering the cargo compartment for the duration of the flight.

8. How to Inspect and Maintain the Hand Fire Extinguisher for Continued Safe-Use. Maintain and inspect hand fire extinguishers in accordance with the manufacturer's nameplate instructions. Follow the maintenance procedures, inspections and testing specified in the applicable NFPA and U.S. - UL standards**.**

a. Non-refillable, disposable fire extinguishers may have plastic discharge heads installed. Locate this type of fire extinguisher in a safe area to assure there will be no damage to the plastic discharge heads.

b. Non-refillable, disposable fire extinguishers are exempt from periodic hydrostatic testing. However, replace these extinguishers with a serviceable unit upon reaching:

(1) The service life where hydrostatic testing would normally be required for a similar extinguisher, or

(2) The service life guidelines established by the manufacturer if sooner.

c. Recommended procedures for the inspection, hydrostatic test and life limits of pressure cylinders are outlined in:

(1) Specification of cylinders is in 49 CFR, part 178, Subpart C.

(2) Inspection and maintenance of cylinders is in 49 CFR, Part 180, Subpart B.

(3) Fire extinguishers are addressed in 49 CFR § 173.309 and in 29 CFR § 1910.157.

d. Manufacturers of fire extinguishers containing halon replacement agents approved for use on FAA certified aircraft should take immediate action through the appropriate channel(s) to have their retest requirements included in the aforementioned regulatory guidelines.

Chapter 5. Locating and Mounting Hand Fire Extinguishers

1. Where to Locate and Mount Hand Fire Extinguishers in Passenger Compartments. Install fire extinguishers in passenger compartments according to 14 CFR §§ 23.851, 25.851 and 29.853 and the following criteria:

a. Locate hand fire extinguishers adjacent to hazardous areas (for example, galleys, accessible baggage or cargo compartments, electrical equipment racks, etc.) to be protected.

b. If there are no defined hazardous areas, locate the hand fire extinguishers as follows:

(1) When one extinguisher is used, locate it at the flight attendant's station.

(2) When no flight attendant is required, locate the extinguisher at the passenger entrance door.

(3) When two or more extinguishers are used, locate one at each end of the passenger compartment and space the remainder uniformly within the cabin area.

c. Mount hand fire extinguishers for ready accessibility. If they are not visible in their mounted position, use a placard to indicate their location.

(1) Aircraft structure and mounting brackets are required to withstand the applicable inertia forces required in 14 CFR §§ 23.561, 25.561, 27.561, and 29.561, with the hand fire extinguisher installed. Replacement of halon extinguishers with halocarbon extinguishers will require an evaluation of the mounting system strength. The mounting structure may need to be strengthened. Halocarbon clean agent extinguishers of the same listing can be 2-3 times the weight of the halon extinguishers they are replacing.

(2) Installation of an extinguisher should include vertical reach combined with horizontal (offset) reach to ensure ease of retrieval from overhead compartments. The vertical reach should not exceed 74.5 in. (189.23 cm) combined with an offset reach of 7.87 in. (20cm) to permit a 5 percentile female, 60.5 in. (153.67 cm.) tall to quickly access the extinguisher. Consideration should be allowed for assist steps (or seats) or other factors.

(3) Add the weight of the hand fire extinguisher and its mounting bracket to the aircraft empty weight and a compute a new empty weight center of gravity.

d. Consider the type of fire hazard (Class A, B, C or D) expected to be encountered when you select a hand fire extinguisher. If extinguishers intended for different classes of fire are grouped together, consider marking their intended use conspicuously via a placard or other means (near the extinguisher) to aid in the choice of the proper extinguisher at the time of the fire.

2. How to Locate and Mount Hand Fire Extinguishers in Flight Deck Compartments. Consider using the following criteria if you install a fire extinguisher in the flight deck compartment:

a. Each hand fire extinguisher should be conveniently located, readily accessible, and it's location obvious.

b. Hand fire extinguishers should be mounted for easy release and removal by seated crewmember(s) as follows:

(1) Secure the extinguisher(s) in mounting bracket(s) such that it requires a deliberate action to release the extinguisher from its primary restraint for removal from its mounting. Design the mounting bracket so that upon release from their primary restraint, the extinguisher remains in position until removed from its mounting by the user.

(2) Aircraft structure and extinguisher mounting brackets must be capable of withstanding the inertia forces specified in paragraph **1.c.** above.

c. Fire extinguishers for the flight deck compartment should be able to extinguish Class B and C fires.

3. How to Locate and Mount Hand Fire Extinguishers in Small Single Engine and Multiengine Aircraft.

a. Locate hand fire extinguishers so that they are easily accessible to the flight crew and the passengers.

b. Do not allow hand fire extinguishers to lie loose on shelves, seat back pockets or seats. Properly mount the hand fire extinguisher to the airframe structure.

c. Aircraft structure and extinguisher mounting brackets should be capable of withstanding the inertia forces specified in paragraph **1.c.** above.

4. How Many Hand Extinguishers Must I Install?

a. Transport Category Airplanes. 14 CFR §§ 25.851(a) and 121.309(c) requires a minimum number of hand extinguishers to be installed on transport category airplanes.

(1) The minimum number of hand fire extinguishers that must be conveniently located and evenly distributed in passenger compartments are as shown in **Figure 5** below.

Figure 5. Minimum Number of Hand Fire Extinguishers Required for Transport Category Aircraft Passenger Compartments

Passenger Capacity	No. of Extinguishers
7 through 30	1
31 through 60	2
61 through 200	3
201 through 300	4
301 through 400	5
401 through 500	6
501 through 600	7
601 through 700	8

(2) At least one hand fire extinguisher must be conveniently located in the pilot compartment.

(3) At least one readily accessible hand fire extinguisher must be available for use in each Class A or Class B cargo or baggage compartment and in each Class E cargo or baggage compartment that is accessible to crewmembers in flight, per 14 CFR § 25.851(a)(3).

(4) At least one of the required fire extinguishers located in the passenger compartment of an airplane with a passenger capacity of at least 31 and not more than 60, and at least two of the fire extinguishers located in the passenger compartment of an airplane with a passenger capacity of 61 or more must contain Halon 1211, or equivalent, as the extinguishing agent.

(5) The quantity of extinguishing agent used in each extinguisher required by this section must be appropriate for the kinds of fires likely to occur where used.

b. Transport Category Rotorcraft. 14 CFR § 29.853 requires a minimum number of hand extinguishers to be installed in passenger compartments:

(1) See **Figure 6** below for the minimum number of hand fire extinguishers that must be conveniently located in passenger compartments.

Figure 6. Minimum Number of Hand Fire Extinguishers required for Transport Category Rotorcraft Passenger Compartments

Passenger Capacity	No. of Extinguishers
7 through 30	1
31 through 60	2
61 or more	3

(2) There must be a hand fire extinguisher for the flight crewmembers.

(3) There are no requirements for extinguishing systems or hand extinguishers for accessible cargo or baggage compartments in transport category rotorcraft. Use the hand extinguisher guidance provided in chapter **4,** paragraph **6.** of this AC for these compartments.

c. Small Airplanes. 14 CFR §§ 23.851 and 91.513(c) requires a minimum number of hand extinguishers to be installed on small part 23 airplanes.

(1) At least one hand fire extinguisher must be located within easy access of the seated pilot.

(2) At least one hand fire extinguisher must be in the passenger compartment of an airplane that accommodates more than six passengers. The extinguisher must minimize the hazard of toxic gas concentration.

Appendix 1. List of Acronyms

14 CFR	Title 14, Code of Federal Regulations
AC	Advisory Circular
ACO	Aircraft Certification Office
AD	Airworthiness Directive
AHJ	Authority Having Jurisdiction
AIR	Aircraft Certification Service
ALS	Airworthiness Limitation Section
AMOC	Alternate Means of Compliance
ASTM	American Society of Testing and Materials
CAA	Civil Aviation Authority
CFR	Code of Federal Regulations
CMM	Component Maintenance Manual
COS	Continued Operational Safety
CPA	Cabin Pressure Altitude
DOT	Department of Transportation
ELOS	Equivalent Level of Safety
EPA	U.S. Environmental Protection Agency
ETSO	European TSO
FAA	Federal Aviation Administration
FC	Fluorocarbon
FIC	Fluoroiodocarbon
FK	Fluoroketone
FM	Factory Mutual Research Corp.
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
ICA	Instructions for Continued Airworthiness
IM	Installation Manual
IPC	Illustrated Parts Catalog
ISO	International Organization for Standardization
LODA	Letter of TSO Design Approval
LOAEL	Lowest Observable Adverse Effect Level
MF	Multiplication Factor
MIDO	Manufacturing Inspection District Office
MISO	Manufacturing Inspection Satellite Office
MPS	Minimum Performance Standard
MW	Molecular Weight
NAA	National Aviation Authority
NOAEL	No Observable Adverse Effect Level
NFPA	National Fire Protection Association
OEM	Original Equipment Manufacturer
OPR	Office of Primary Responsibility
PFC	Perfluorocarbon
PAH	Production Approval Holder

PBE	Protective breathing equipment
PBPK	Physiologically Based Pharmacokinetic
PC	Production Certificate
PED	Portable Electronic Device
PI	Principal Inspector
P/N	Part Number
QCS	Quality Control System
QMS	Quality Management System
RGL	Regulatory Guidance Library
RTCA	Radio Technical Corporation of America
SAE	Society of Automotive Engineers
SNAP	Significant New Alternatives Policy
STC	Supplemental Type Certificate
τ, Tau	Air Change Time
TC	Type Certificate
TSO	Technical Standard Order
TSOA	Technical Standard Order Authorization
UL	Underwriters Laboratory
W/V	Weight per Unit Volume (W/V) ratio
%v/v	Volume Percent

Appendix 2. Definitions and Terms

The following definitions and terms apply when following the procedures outlined in this AC:

1. Air Change Time, τ, is the time in minutes, it takes for the inflow of fresh air into a compartment, with a volume equivalent to the volume of the compartment.

2. Authority Having Jurisdiction is the organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

3. Cabin Pressure Altitude is specified for transport aircraft by regulation to be the air pressure in the cabin or compartment of a commercial airliner and it must not be lower than that found at an altitude of 8,000 ft (2,438 m) under normal operating conditions, per § 25.841(a)

4. Cargo Aircraft are aircraft configured solely to carry cargo and no personnel other than the flight crew and any additional crew required for the care of the cargo.

5. Clean Agent is electrically nonconducting, volatile or gaseous fire extinguishant that does not leave a residue upon evaporation. The word *agent* as used in this circular means clean agent unless otherwise indicated.

6. Combi Aircraft are aircraft designed/configured to transport both passengers and cargo on the same level within the fuselage.

7. Compartment is an enclosed space on an aircraft. Examples of compartments are a flight deck, a crew rest, and a cabin. The aircraft cabin is considered one compartment.

8. Dry Chemical is a mixture of finely divided solid particles, usually sodium bicarbonate, potassium bicarbonate, or ammonium phosphate-based with added particulate material supplemented by special treatment to provide resistance to packing, and moisture absorption (caking) and to promote proper flow characteristics.

9. Dry Powder is solid materials in powder granular form designed to extinguish class D combustible metal fires by crusting, smothering, or heat transferring means.

10. Flight Crew are the aircraft crew whose responsibilities include the operations and management of the aircraft flight controls, engines, and systems, including, but not limited to, pilot in command (captain), first officer (copilot), second officer (flight engineer).

11. Flight Deck is the compartment of the aircraft arranged for use by the flight crew in operating the aircraft.

12. Galley is the area of the aircraft for storing, refrigerating, heating and dispensing of food and beverages.

13. Halocarbon Agent is comprised primarily of one or more organic compounds containing one or more of the elements fluorine, chlorine, bromine, or iodine. Halocarbon agents are electrically non-conducting, volatile liquids, or gaseous fire extinguishants. As "clean agents", they do not leave a residue on evaporation. These agents are pressurized with inert gases. Halocarbon agents include the halons and halon replacements. Halocarbon agents that are currently commercialized include the hydrochlorofluorocarbons (HCFCs), perfluorocarbons (FCs or PFCs), hydrofluorocarbons (HFCs), fluoroiodocarbons (FICs), and fluoroketones (FKs), as well as the completely halogenated halocarbons (halons). Halocarbon agents are multipurpose class A, B, C rated agents. They are most effective on Class B and C fires. Extinguishers with greater capacity are also UL listed for Class A fires. To achieve the minimum 1A U.S. - UL rating, one of the tests required is the extinguishment of an eight feet wide by eight feet tall wood panel. (See **Figure 15** for the other U.S. - UL tests that must be passed to obtain a 1A U.S. - UL rating.) Smaller extinguishers do not contain a sufficient amount of agent to extinguish this size of fire. However, they have been shown to be effective against smaller Class A fires, such as seat fires onboard aircraft. Consult the agent manufacturers to obtain detailed information on agent characteristics, concentration requirements, health hazards, and extinguishing limitations. Halocarbon agents that are SNAP and FAA approved for use on aircraft to replace Halon 1211 in hand fire extinguishers include HCFC Blend B, HFC-227ea, and HFC-236fa. Advantages of halocarbon agents include low cold shock characteristics on electronic equipment, no degradation of visual acuity, and low pressure.

14. Halocarbon Blend is a mixture of 2 or more halocarbon agents in a portable extinguisher.

15. Halon is a short derivation for "halogenated hydrocarbon." The chemical structure is identified as a four digit number representing, respectively, the number of carbon, fluorine, chlorine, and bromine atoms present in one molecule. Halon fire extinguishing agents approved for use include Halon 1211, Halon 1301, and a combination of the two. Both are liquefied gases and typified as "clean agents." Halons primarily extinguish fire by chemically interrupting the combustion chain reaction rather than by heat removal or physically smothering.

16. Halon Equivalent Extinguisher is an extinguisher containing a clean agent which meets the MPS for hand-held fire extinguishers (see appendix **3** reference paragraph **7.s.**). Equivalency does not refer to the weight of the agent. Agent weights for 5B:C listed halon replacement extinguishers listed in this circular may be more than twice the weight of agent in a 5B:C listed halon extinguisher.

17. Halon 1211 has the chemical name bromochlorodifluoromethane, $CBrC1F_2$. Halon 1211 is a multipurpose, Class A, B, C rated agent effective against flammable liquid fires. Due to its relatively high boiling point of +26ºF (-4ºC), Halon 1211 discharges as an 85 percent liquid stream offering a long agent throw range.

18. Halon 1301 has the chemical name bromotrifluoromethane, $CBrF_3$. Halon 1301 is recognized as a multipurpose agent having Class A, B, C capability in total flooding systems. However, Halon 1301 offers limited Class A capability when used in portable fire extinguishers. The boiling point for this agent is -72°F (-57.8ºC). Halon 1301 discharges as a gas.

19. Halon Replacement Agents are any clean agents which can be either a non-halon (halocarbon agent) or halon alternative (all other substitute agents) that have SNAP approval by the U.S. EPA and meet the MPS for hand fire extinguishers.

20. Hand Fire Extinguisher is an approved, aircraft portable fire extinguisher which can be used by aircraft occupants to combat accessible, incipient, on-board fires.

21. HCFC Blend B is an extinguishing agent that is a tertiary blend comprised primarily of the chemical 2,2-dichloro-1,1,1-trifluoroethane HCFC-123, (CF_3CHCl_2). Two inert gases are blended with the HCFC-123 to enhance flow distribution and fire extinguishing performance. The boiling point of the blend is 80.6ºF (27ºC). Due to its high boiling point, HCFC Blend B discharges primarily as a liquid stream which readily evaporates. It is a multipurpose agent with class A, B and C capability.

23. HFC-227ea is an extinguishing agent that is comprised of the chemical 1,1,1,2,3,3,3-heptafluoropropane (CF_3CHFCF_3). The boiling point of the agent is 2.5ºF (-16.4ºC). Due to this boiling point, HFC-227ea is discharged as a mixed liquid and vapor stream which readily evaporates. It is a multipurpose agent with class A, B and C capability.

24. HFC-236fa is an extinguishing agent that is comprised of the chemical 1,1,1,3,3,3 hexafluoropropane ($CF_3CH_2CF_3$). The boiling point of the agent is +29.5ºF (-1.4ºC). Due to its relatively high boiling point, HFC-236fa discharges predominately as a liquid stream which readily evaporates. It is a multipurpose agent with class A, B and C capability.

25. Labeled equipment or materials have an attached label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

26. Listed refers to equipment, materials or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services. The organization maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and who's listing states that the equipment, material or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

27. Lithium Ion Battery is a rechargeable battery that has an anode made from a metal oxide composite containing lithium ion, and a cathode made from a specialized carbon material. Charge and discharge of the battery is facilitated by the movement of lithium ions in electrolytic solutions. Lithium ion batteries are used in small electronic devices such as pagers, portable computers, camcorders, and portable telephones.

28. Lithium Primary Battery is a rechargeable battery that has a lithium anode and a cathode system consisting of carbon and either thionyl chloride or sulfuryl chloride.

29. Lowest Observable Adverse Effect Level (LOAEL) is the lowest concentration at which an adverse physiological or toxicological effect has been observed.

30. Maximum Certificated Occupant Capacity is the maximum number of persons that can be carried for each specific aircraft model as certified by the authority having jurisdiction.

31. Minimum Performance Standard (MPS) for Hand Extinguishers refers specifically to two tests that hand extinguishers containing halon replacement agents must pass. See appendix **3** reference paragraph **7.s.** These fire tests demonstrate equivalent fire extinguishing performance currently used in aircraft and assess the toxicity of the decomposition products.

32. Minimum Safe Volume refers to the smallest volume into which an extinguisher in a compartment could be discharged without posing a toxicity hazard. The minimum safe volumes are dependent on the agent, the agent weight, ventilation, and pressure altitude of the discharge. Perfect mixing is assumed. Safety increases as the minimum safe volume decreases. The minimum safe volumes marked on U.S. - UL listed extinguishers are not applicable for aircraft, as they are based on sea level discharge at 120°F. Aircraft minimum safe volumes can be calculated as shown in appendix **4,** paragraph **3.** Guidance on the use of minimum safe volumes can be found in chapter **4** of this AC.

33. No Observable Adverse Effect Level (NOAEL) is the highest concentration at which no adverse physiological or toxicological effect has been observed.

34. Physiologically Based Pharmacokinetic (PBPK) Model is a mathematical modeling technique for human health risk assessment and investigation of toxicity. The human health concern for halocarbons, including halons, is cardiac sensitization which occurs at a fixed arterial concentration specific to the agent. The PBPK model estimates the allowable human arterial blood concentration for each halocarbon as a function of agent exposure time to establish both the concentration of agent and duration to which personnel could be safely exposed. The PBPK modeling approach is endorsed by the U.S. EPA and the NFPA.

35. Rated/Rating is a numerical value assigned to an extinguisher based on its fire extinguishing capability.

36. Safe-Use Rankings of Extinguishers are based on the minimum safe volumes of extinguishers of the same U.S. - UL rating (for the same level of fire protection). See chapter **4,** paragraph **2.d.** of this AC**.**

37. Small Aircraft are defined by part 23.

38. SNAP Program is EPA's significant new alternatives policy (SNAP) program to evaluate and regulate substitutes for ozone depleting chemicals that are being phased out under the stratospheric ozone protection provisions of the Clean Air Act.

39. Time of Useful Consciousness is the time available to don an oxygen mask without assistance.

40. Unventilated Compartment for the purposes of the AC is a compartment where the air change time is not known or exceeds 6 minutes.

41. Ventilated Compartment is a compartment where the air change time is known and does not exceed 6 minutes.

42. Volume Percent (% v/v) is the volume of a gas in liters per 100 liters of the resulting gas mixture. For example, a 2% v/v Halon 1211 mixture contains 2 liters Halon 1211 per 100 liters volume.

Appendix 3. Related Publications and How to Get Them

1. Code of Federal Regulations (CFR). You can get copies of Title 14, 40, 46, and 49 of the Code of Federal Regulations, parts from the Superintendent of Documents, Government Printing Office, P.O. Box 37154, Pittsburgh, PA 15250-7954. Telephone (202) 512-1800; fax (202) 512-2250. You can order copies Title 14 through the FAA website at http://rgl.faa.gov/. Select "Access" then "Online Bookstore." Select "Aviation," then "Code of Federal Regulations." You can also get copies of 14 CFR sections on-line at www.gpoaccess.gov/cfr/ and copies of 40 CFR sections on-line at www.epa.gov/epahome/cfr40.htm. The following is a list of applicable Federal Regulations used for this AC:

a. 14 CFR §§ 21.305, 23.561, 23.851, 23.1441, 23.1443-1449, 25.561, 25.851, 25.857, 25.1439, 27.561, 27.861, 29.561, 29.851, 29.853(e) and (f), 91.122, 91.211, 91.193, 121.309(c), 125.119(b) and (c), 127.107(c), 135.155.

b. Title 40 of the Code of Federal Regulations (40 CFR), Chapter I--Environmental Protection Agency, Part 82-Protection of Stratospheric Ozone, Subpart G-Significant New Alternatives Policy Program and Subpart H-Halon Emissions Reduction (40 CFR Part 82).

c. Title 46 of the Code of Federal Regulations (46 CFR), Chapter I—Coast Guard, Department of Transportation, Part 34-Fire Fighting Equipment.

d. Title 49 of the Code of Federal Regulations (49 CFR), Transportation.

2. FAA Airworthiness Directive (AD). You can get copies of the following AD from the FAA's website at www.airweb.faa.gov/rgl.

a. AD 93-07-15, *Boeing And McDonnell Douglas Models 707, 727, 737,747, and 757 and McDonnell Douglas Models DC-8, DC-9, and DC-10 Series Airplanes*

3. FAA Advisory Circulars (AC). Order copies of Advisory Circulars (AC) from the U.S. Department of Transportation, Subsequent Distribution Office, M-30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20795. Telephone (301) 322-5377, fax (301) 386-5394. To be placed on FAA's mailing list for free ACs contact, U.S. Department of Transportation, Distribution Requirements, Section, M-494.1, Washington, D.C. 20590.

You can also get copies at www.airweb.faa.gov/rgl. On the website, select "Advisory Circulars," then select "By Number."

a. AC 120-80, *In-Flight Fires*

b. AC 20-42C, *Hand Fire Extinguishers for Use in Aircraft*

c. AC 25-17, *Transport Airplane Cabin Interiors Crashworthiness Handbook*

d. AC 25-18, *Transport Category Airplanes Modified for Cargo Service*

e. AC 25-22, *Certification of Transport Airplane Mechanical Systems*

f. AC 25-869-1, *Fire Protection Systems*

g. AC 65-9A, *[Large AC] Airframe and Powerplant Mechanics General Handbook*

h. AC 65-12A, *[Large AC] Airframe and Powerplant Mechanics Powerplant Handbook*

4. FAA Technical Standard Order (TSO). You can find the following technical standard orders on the FAA website at http://rgl.faa.gov/ or at www.airweb.faa.gov/rgl. You will also find the TSO Index of Articles at the same site.

a. TSO-C19, *Portable Water-Solution Type Fire Extinguisher*

b. TSO-C116, *Crewmember Portable Protective Breathing Equipment*

5. FAA Safety Alerts for Operators (SAFOS) and Information for Operators (InFOs)

a. SAFO 09013 Fighting Fires Caused by Lithium Type Batteries in Portable Electronic Devices, June 23, 2009, www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/safo/all_safos/media/2009/SAFO09013.pdf

b. InFO 09010 Availability of a Federal Aviation Administration (FAA) In-flight Firefighting Training Video, June 23, 2009, www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/info/all_infos/media/2009/info09010.pdf

6. FAA Training Videos:

a. "*Extinguishing In-flight Laptop Computer Fires*" and "Cabin Crew Firefighting Training Video," a training video on the use of hand extinguishers to fight on-board fires are available for viewing at www.fire.tc.faa.gov/2007Conference/session_details.asp?sessionID=26

7. Reports and Papers. Order copies of the following reports and papers from the National Technical Information Service, Springfield, Va. 22161. FAA publications can also be found on the following Web Site of the FAA Fire Safety Branch: http://www.fire.tc.faa.gov/reports/reports.asp. Journal articles can be obtained directly from the publisher. Printed copies of Civil Aviation Authority documents are available from Documedia Solutions Ltd., 37 Windsor Street, Cheltenham, Glos., GL522DG, United Kingdom

a. Abramowitz, A., Neese, W., Slusher, G, *Smoke and Extinguisher Agent Dissipation in a Small Pressurized Fuselage*, Federal Aviation Administration, Report No. DOT/FAA/CT-89/31, 1990.

b. Blake, D.R., *Effectiveness of Flight Attendants Attempting to Extinguish Fires in an Accessible Cargo Compartment,* Federal Aviation Administration Technical Note DOT/FAA/AR-TN99/29, 1999.

c. Chattaway,A., *The Development of A Hidden Fire Test for Aircraft Hand Extinguisher Applications*, Civil Aviation Authority Paper No. 95013, London, 1995.

d. Cherry, R.G. W. et al, *A benefit Analysis for Enhanced Protection from Fires in Hidden Areas on Transport Aircraft*, Federal Aviation Administration Report No. DOT/FAA/AR-02/50, CAA Paper 2002/01.

e. Colton, B., Gargas, M., Sweeney, L., "Setting Acute Exposure Limits for the Halotron 1 Clean Agent Onboard Aircraft Using Physiologically Based Pharmacokinetic Modeling, Submitted to Louise Speitel, Federal Aviation Administration, July 16, 2008.

f. Eklund, Thor I., *Analysis of Dissipation of Gaseous Extinguishing Agents in Ventilated Compartments*, Federal Aviation Administration Report No. DOT/FAA/CT-83/1, 1993.

g. Hill, R.G., and Speitel, L., *In-Flight Aircraft Seat Fire Extinguishing Tests (Cabin Hazard Measurement*, Federal Aviation Administration Report No. DOT/FAA/CT-82/111, December 1982.

h. Krasner, L.M., *Study of Hand-held Fire Extinguishers aboard Civil Aviation Aircraft, Factory Mutual Research Corporation,* Federal Aviation Administration Report No. DOT/FAA/CT-82/42, 1982.

i. Lain, M.J.,Teagle, D.A., Cullen, J., Dass,V., *Dealing with In-Flight Lithium Battery Fires in Portable Electronic Devices*, Civil Aviation Authority Paper No. 2003/4, London, 2003 , ©Civil Aviation Authority 2003.

j. Slusher, G.R., Wright, J.A., and Speitel, L.C., *Halon Extinguishment of Small Aircraft Instrument Panel Fires*, DOT/FAA/CT-86/26, December 1986.

k. Slusher, Gerald R., Wright, Joseph, Demaree, James, *Halon Extinguisher Agent Behavior in a Ventilated Small Aircraft*, Federal Aviation Administration Report No. DOT/FAA/CT-86/5, 1986.

l. Slusher, G.R., Wright, J., Demaree, J.E., Neese, W.E., *Extinguisher Agent Behavior in a Vantilated Small Aircraft*, Federal Aviation Administration Report No. DOT/FAA/CT-83/30, 1984.

m. Speitel, Louise C., Lyon, Richard E., *Guidelines for Safe Use of Gaseous Halocarbon Extinguishing Agents in Aircraft,* Federal Aviation Administration: Report No. DOT/FAA/AR-08/3.

n. Tabscott, R.E. and Speitel, L.C. eds., "Options to the Use of Halons for Aircraft Fire Protection Systems- 2002 Update", Federal Aviation Administration Report No. DOT/FAA/AR-99/63, Task Group on Halon Options, International Halon Replacement Working Group, U.S. Department of Transportation, FAA William J. Hughes Technical Center, February, 2002.

o. Vinegar, A., Jepson, G.W. and Overton, J.H (1998), *PBPK Modeling of Short-term (0-5 min) Human Inhalation Exposures to Halogenated Hydrocarbons, Inhalation Toxicology*, 10:411-429.

p. Vinegar, A., Jepson, G.W., Cisneros, M., Rubenstein, R. and Brock, W.J. (2000), *Setting Safe Acute Exposure Limits for Halon Replacement Chemicals Using Physiologically Based Pharmacokinetic Modeling, Inhalation Toxicology*, 12:751-763.

q. Vinegar, A (2001), *Modeling Cardiac Sensitization Potential of Humans Exposed to Halon 1301 or Halon 1211 Aboard Aircraft, Aviation, Space and Environmental Medicine,* Vol. 72, No. 10.

r. Vinegar, A., Jepson, G.W., Hammann, S.J., Harper, G., Dierdorf, D.S. and Overton, J.H.(1999), *Simulated Blood Levels of CF_3I in Personnel Exposed During Its Release from an F-15 Jet Engine Nacelle and During Intentional Inhalation*, AIHA Journal, 60:403-408.

s. Webster, Harry, *Development of a Minimum Performance Standard (MPS) for Hand-Held Fire Extinguishers as a replacement for Halon 1211 on Civilian Transport Category Aircraft*, Federal Aviation Administration Report No. DOT/FAA/AR-01/37, 2002.

t. Webster, Harry, *Flammability Assessment of Bulk—Packed, Nonchargeable, Lithium Primary Batteries in Transport Category Aircraft,* Federal Aviation Administration Report No. DOT/FAA/AR-04/26, 2004.

u. Webster, Harry, *Flammability Assessment of Bulk—Packed, Rechargeable, Lithium-Ion Cells in Transport Category Aircraft,* Federal Aviation Administration Report No. DOT/FAA/AR-06/38, 2006.

8. American Society of Testing and Materials (ASTM) Standards. You can get copies of the following ASTM standards from ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. Telephone (610) 832-9585. You can also order on-line at www.astm.org , or contact ASTM Customer Service at service@astm.org.

a. ASTM Dxxxx-10 Standard Specification for Halon 1211, Bromochlorodifluoromethane (CF_2ClBr)

b. ASTM D5632-08 Standard Specification for Halon 1301, Bromotrifluoromethane (CF_3Br)

c. ASTM D5631-08 Standard Practice for Handling, Transportation and Storage of Halon 1301, Bromotrifluoromethane (CF_3Br)

d. ASTM D 7122-05, Standard Specification for HCFC Blend B (CF_3CCl_2H, Ar, and CF_4)

e. ASTM D 7123-04, Standard Practice for Handling, Transportation, and Storage of HCFC Blend B (CF_3CCl_2H, Ar, and CF_4)

f. ASTM 6064-03 Standard Specification for HFC-227ea 1,1,1,2,3,3,3-Heptafluoropropane (CF_3CHFCF_3)

g. ASTM D6065-05 Standard Practice for Handling, Transportation, and Storage of HFC-227ea 1,1,1,2,3,3,3-Heptafluoropropane (CF_3CHFCF_3)

h. ASTM D6541-05 Standard Specification for HFC-236fa, 1,1,1,3,3,3-Hexafluoropropane ($CF_3CH_2CF_3$)

i. ASTM D6427-04 Standard Practice for Handling, Transportation, and Storage of HFC-236fa, 1,1,1,3,3,3-Hexafluoropropane ($CF_3CH_2CF_3$)

9. Factory Mutual Research Corp. (FM). Order copies of the FM approval standards from FM Corporate Headquarters 1151 Boston-Providence Turnpike, P.O. Box 9102, Norwood, MA 02062 USA. Telephone +1-781-762-4300. You can also order on-line at www.fmglobal.com:

10. International Organization for Standardization (ISO). Order copies of the following ISO standards from ISO, 1, rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland. Telephone +41-22-749-01-11. You can also order on-line at www.iso.org:

a. ISO 7201-1:1989, *Fire Protection -- Fire Extinguishing Media -- Halogenated Hydrocarbons -- Part 1: Specifications for Halon 1211 and Halon 1301*.

11. National Fire Protection Association (NFPA). Order copies of the following NFPA standards from NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471. Telephone +1 800 344-3555 or +1 617 770-3000. You can also order on-line at www.nfpa.org:

a. NFPA 10, *Standard for Portable Fire Extinguishers*, 2007 Edition

b. NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 2009 Edition

c. NFPA 12B, *Standard on Halon 1211 Fire Extinguishing Systems,* 1990 Edition **(No longer an active standard)**

d. NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2008 Edition

12. RTCA Inc. Documents. Order copies of the following RTCA Inc. documents from RTCA Inc., 1828 L Street NW, Suite 805, Washington, D.C. 20036. Telephone (202) 833-9339, fax (202) 833-9434. You can also order copies online at www.rtca.org.

a. RTCA/DO-160F, *Environmental Conditions and Test Procedures for Airborne Equipment*

13. SAE Documents. Order copies of SAE Aerospace Standards from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001. Telephone (724) 776-4970, fax (724) 776-0790. You can also order copies online at www.sae.org.

14. Underwriters Laboratories, Inc (UL). You can get copies of the following U.S. - UL standards from UL Corporate Headquarters, 333 Pfingsten Road, Northbrook, IL 60062-2096 USA. Telephone Customer Service +1-877-ULHELPS (1-877-854-3577). You can also order on-line at: www.ULStandards.com.

a. U.S. - UL 154, *Standard for Safety Carbon-Dioxide Fire Extinguishers-Ninth Edition*, Reprint with revisions through and including January 31, 2007.

b. U.S. - UL 299, *Standard for Safety Dry Chemical Fire Extinguishers-Tenth Edition*, Revisions through and including 1/31/2007

c. U.S. - UL 626, *Standard for Safety Water Fire Extinguishers-Eighth Edition*, Reprint with revisions through and including January 31, 2007.

d. U.S. - UL 711, *Standard for Fire Extinguishers, Rating and Fire Testing*, Copyright 2004.

e. U.S. - UL 1093, *Halogenated Agent Fire Extinguishers*, ISBN 1-55989-840-2, Copyright 2000. (UL intends to withdraw this standard effective October 2014)

f. U.S. - UL 2129, *Halocarbon Clean Agent Fire Extinguishers*, ISBN 0-7629-0408-9, Copyright 2000.

15. The British Standards Institution (BSI). You can order copies of BSI standards on line at www.bsigroup.com.

Appendix 4. Explanatory Material

1. Effective Throw Ranges. Typical throw ranges for halocarbon and water extinguishers are listed in **Figure 7** below.

Figure 7. Effective Throw Ranges for Halocarbon Halon Replacement and Water Extinguishers

Agent	Effective Throw Ranges for UL/ULC Rated Extinguishers[a,b.] (ft.)					
	2-B:C	5-B:C	1A-10B:C	2A	2A-10B:C	2A-40B:C
HCFC Blend B	6-10	9-15	9-15	N/A	12-18	N/A
HFC-236fa	8-10	10-12	14-16	N/A	14-16	N/A
HFC-227ea	N/A	8-10	N/A	N/A	N/A	N/A
Halon 1211	N/A	9-15	12-18	N/A	N/A	12-18
Halon 1301	N/A	N/A	N/A	N/A	N/A	N/A
Water	N/A	N/A	N/A	30-40	N/A	N/A

a. *The throw range is extinguisher dependant. It may be substantially different from these tabulated values.*

b. *Check the manufacturer's literature for the throw ranges of their extinguishers.*

2. Basis for the Maximum Safe Halocarbon Weight to Volume (W/V). The maximum safe W/V is based on the combined weight of agent contained in all hand extinguishers in that aircraft compartment. See FAA report DOT/FAA/AR-08/3. A brief summary is provided below.

a. Agent Toxicity Guidance. The maximum safe W/V guidance cited in this AC protects against the agent toxicity which includes both cardiotoxicity and anesthetic effects (not hypoxia).

(1) Exposures to halocarbon agents must be limited to less than 5 minutes (to protect against potential anesthetic effects which can result from prolonged exposure to halocarbon agents).

(2) Cardiac sensitization occurs before anesthetic effects are observed for Halon 1211, Halon 1301, HCFC Blend B, HFC-227ea and HFC-236fa.

(3) The maximum safe agent W/V does not protect against hypoxia. Descent at the recommended rates, combined with the other safe-use guidance, provides protection against hypoxia.

(4) Hypoxia caused by the agent displacing oxygen, is of greatest concern for small unpressurized aircraft compartments. It is far less of a concern for small pressurized aircraft compartments, and of little concern for large pressurized aircraft compartments in transport category aircraft.

(5) Immediate descent at the maximum safe rate to the lowest practicable altitude or 8,000 feet is recommended for all unpressurized aircraft to minimize exposure to halocarbon gases and reduces the hazards of hypoxia resulting from the agent displacing oxygen from the air in the compartment. This holds for ventilated and unventilated compartments.

b. Cardiotoxicity. Physiologically based pharmacokinetic (PBPK) modeling is used to evaluate cardiotoxicity. Each halocarbon agent has a threshold arterial blood concentration at which cardiac sensitization occurs. Safe human exposure concentrations are based on this target arterial concentration being common for both the human and the dog. PBPK modeling simulates the human arterial blood halocarbon concentration histories from given human inhaled halocarbon concentration histories. Safe human exposures are exceeded when the simulated arterial blood concentration exceeds the target or "critical" arterial concentration.

The selector graphs were developed by applying pharmacokinetic modeling of canine blood concentration data to perfect mixing agent decay curves. The scientific basis for the development of the selector graphs for ventilated aircraft compartments used in this AC can be found in appendix **3** reference report paragraph **7.m.**

(1) The total agent available from the 2 largest extinguishers in an aircraft compartment should not capable of producing concentrations in that compartment by volume, at 70ºF (21ºC) assuming perfect mixing, that exceed the agent's safe human exposure. Safe human exposure concentrations are derived by PBPK + 2σ modeling. Monte Carlo Simulations should be applied to the PBPK arterial concentration data to account for human variability, accounting for 95 % of the simulated population. If PBPK + 2σ modeling data is not available, the agent no observable adverse effect level (NOAEL) is to be used. The maximum safe exposure concentration is designated A_{Safe} (see **Figure 8** and **9** below**)** and is to be used in the calculation of the maximum safe W/V for ventilated and unventilated compartments, per the equation in paragraph **2.c.** below. This guidance is sufficiently conservative to ensure safe-use of halocarbon agents.

(2) NOAEL values for halocarbon agents approved under the U.S. EPA SNAP program can be obtained from the SNAP Program Coordinator at the U.S. EPA Office of Air and Radiation or on the public docket for that office.

(3) The maximum safe W/V for unventilated compartments obtained from **Figure 2** can be increased by the multiplication factors ($MF_{\mathbf{30\ second\ egress}}$) from **Figure 3** only if an egress analysis is performed and approved by the aircraft certification office showing that the escape time into a halocarbon-free environment is less than 30 seconds. Donning oxygen masks which do not use diluent cabin air is considered an acceptable escape into a halocarbon free environment. Multiplication factors are not available for Halon 1211, since the required PBPK

modeling input data is not available for this agent. These MFs were derived per appendix **4**, paragraph **4.**

Figure 8. Maximum Safe Exposure Concentrations (A_{Safe}) for Unventilated Compartments and Compartments where the Ventilation is not known.

Agent[a]	NOAEL[a] (%v/v)	Max Safe 5 Minute Human Exposure Concentration[b] (%v/v)	A_{Safe}[b] (%v/v)
HCFC Blend B	1.0	1.28[c]	1.28
HFC-227ea	9.0[d]	10.84[d]	10.84
HFC-236fa	10.0[d]	12.75[d]	12.75
Halon 1211	0.5	N/A	0.5
Halon 1301	5.0	6.25[d]	6.25

a *NOAEL values for agents approved under the EPA SNAP program can be obtained from the SNAP program coordinator, US EPA's Office of Air and Radiation, or from the public docket for that office.*

b *Appendix **3** reference paragraph **7.m.***

c *Derived from the FAA approved PBPK Model found in: Setting Acute Exposure Limits for the Halotron® 1 Clean Agent Onboard Aircraft Using Physiologically Based Pharmacokinetic Modeling, Submitted to the FAA July 2008.*

d *Derived from the EPA-approved and peer reviewed PBPK model or it's equivalent found in appendix **3** reference paragraph **7.p.** Based on constant exposure level for duration of exposure.*

Figure 9. Maximum Safe Initial Discarge Concentrations for Ventilated Compartments, $A_{0\ Safe}$ (%v/v)

Agent	Air Change Time, τ (Minutes)								
	0.5	**1.0**	**1.5**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**> 6.0[a]**
HCFC Blend B	3.58	2.98	2.73	2.59	2.42	2.29	2.18	2.07	1.26
HFC-227ea	20.6	16.6	15.1	14.3	13.4	12.9	12.6	12.4	10.84
HFC-236fa	25.2	19.5	18.1	17.1	15.9	15.3	14.9	14.7	12.75
Halon 1211[b]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Halon 1301	12.3	9.81	8.88	8.38	7.81	7.56	7.31	7.19	6.25

a *Unventilated value, A_{safe} from **Figure 8** above.*

b *Halon 1211 was assigned no ventilation benefit, as suitable PBPK modeling data was not available for this agent.*

c. Calculation of Maximum Safe W/V. The maximum safe W/V for any agent is based on the combined weight of agent contained in all hand extinguishers in that aircraft compartment. Use the following equation to find the maximum safe weight to compartment volume ratio, $\left(\frac{W}{V}\right)_{Safe}$ (lb/ft^3) for any halocarbon extinguisher to be used on an aircraft:

Equation 1 includes an allowance for the normal leakage from a "tight" enclosure due to agent expansion. Instantaneous discharge and perfect mixing are assumed.

$$\left(\frac{W}{V}\right)_{Safe} = \left(\frac{1}{S \bullet H}\right) \bullet \frac{(A_{0_{Saf\ e}})}{(100 - A_{0_{Safe}})}$$

Where A_{0Safe} is the maximum safe initial discharge concentration (%v/v) per **Figure 8** and **9**. *H* is the altitude correction factor, which is the ratio of sea level pressure to the pressure at a stated altitude, as shown in **Figure 10.** These pressures were obtained from the ICAO International Standard Atmosphere.

Figure 10. Altitude Correction Factors.

Altitude (ft)	*H*
0	1.000
8,000	1.346
12,500	1.604
14,000	1.702
18,000	2.003[a]
25,000	2.695

a *Note the air is half as dense at 18,000 ft. as at sea level*

For pressurized aircraft, use *H*=1.346 (for 8,000 ft CPA). For unpressurized aircraft, use the *H* value for the maximum certificated altitude.

S is the specific volume of the superheated agent vapor at 70ºF (21ºC), ft^3/lb; as shown in **Figure 11** below**.**

V is the net volume of the space: gross volume minus volume of fixed structures, ft^3.

W is the maximum safe weight of the clean agent, lb (for *V*, if the largest 2 extinguishers in a compartment are discharged).

Figure 11. Specific Volume of Halocarbon Agents.

Agent	Specific Volume of Agent (ft^3/lb @ 1 atm and 70ºF)
HCFC Blend B	2.597[a]
HFC-227ea	2.2075[a,b]
HFC-236fa	2.4591 [a,b]
Halon 1211	2.248[c,d]
Halon 1301	2.5605[c,e]

a *Manufacturer's data.*
b *NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems, 2008 Edition.*
c *US manufacturer's data. Halons no longer manufactured in US.*
d *NFPA 12B, Standard on Halon 1211 Fire Extinguishing Systems, 1990 Edition (No longer an active standard).*
e *NFPA 12A, Standard on Halon 1301 Fire Extinguishing Systems, 2009 Edition.*

The maximum safe W/V for a ventilated aircraft compartment with a particular air change time can be calculated by applying the appropriate $MF_{Ventilated}$ from **Figure 4** to the nonventilated maximum safe W/V from **Figure 2**.

d. Maximum Safe W/V for Blends.

(1) The maximum safe W/V for a blend of halocarbon agents A and B, the can be calculated from the maximum safe W/V of halocarbon A and the maximum safe W/V of halocarbon B as follows:

$$\left(\frac{W_{A+B}}{V}\right)_{Safe} = \chi_A \times \left(\frac{W_A}{V}\right)_{Safe} + \chi_B \times \left(\frac{W_B}{V}\right)_{Safe}$$

where χ_A and χ_B are the mole fractions of halocarbons A and B in the extinguisher and $\chi_A + \chi_B = 1$ regardless of the presence of inert gases in the extinguisher. By definition:

$$\chi_A = \frac{n_A}{n_A + n_B} \text{ and } \chi_B = \frac{n_B}{n_A + n_B}$$

where n_A and n_B are the number of moles of *A* and *B* in the extinguisher. n_A and n_B can be expressed in terms of the mass and molecular weight of the agent.

$$n_A = \frac{m_A}{MW_A} \text{ and } n_B = \frac{m_B}{MW_B}$$

where MW_A and MW_B are the molecular weights of A and B in g/mole and m_A and m_B are the mass of A and B in grams.

The molecular weights of the halocarbons agents and blends are shown in **Figure 12** below.

Figure 12. Molecular Weights of Halocarbon Agents and Blends

Halocarbon	MW (g/mole)
HCFC Blend B	151
HFC-227ea	170
HFC-236fa	152
Halon 1211	165
Halon 1301	149

The maximum safe W/V for agents A, $\left(\frac{W_A}{V}\right)_{Safe}$ and B, $\left(\frac{W_B}{V}\right)_{Safe}$ are shown in **Figure 2** for unventilated compartments. Apply the multiplication factor for ventilated compartments, $MF_{\mathbf{Ventilated}}$ from Figure 4 to the maximum safe W/Vin n figure 2 to obtain the maximum safe W/V for ventilated compartments.

(2) Alternately, in the absence of EPA SNAP approved NOAEL toxicity data (see appendix **4**, paragraph **2.b**. above) for a particular blend of halocarbon agents A and B, the maximum safe W/V can be based on the more toxic agent, using the total blend weight. For example, the maximum safe W/V for a blend of Halon 1211 and Halon 1301 can be found by assuming the total weight of the blend is Halon 1211 and using the maximum safe W/V for Halon 1211. This is a conservative method that overestimates the maximum safe W/V of the blend. The extinguisher manufacturer may choose to use this method if they do not wish to disclose the chemical composition of the blend to the public.

3. Selection of Safest Extinguishers for a Compartment of a Given Volume. An installer should select the safest extinguisher of the required rating for a compartment when the toxicity of all FAA approved extinguishers exceeds safe W/V guidance.

a. Minimum Safe Volume. As used in this AC, the minimum safe volume is a tool for comparing the toxicity of hand extinguishers with the same fire fighting performance, i.e. the same U.S. - UL rating. The lower the minimum safe volume used, the comparatively less toxic the agent. Therefore, the safest extinguisher of a given rating has the lowest minimum safe volume. The minimum safe volume for one extinguisher of a given rating is based on the weight of agent in that extinguisher, as shown in equation below. Obtain the minimum safe volume of an extinguisher by dividing the total agent weight in the 2 largest extinguishers in an aircraft compartment by the maximum safe agent *W/V* for the appropriate altitude and ventilation.

$$MinimumSafeVolume = \frac{Charge\ Weight_{Agent}}{\left(\frac{W}{V}\right)_{MaxSafe}}$$

Where, $\left(\frac{W}{V}\right)_{MaxSafe}$ is the maximum safe *W/V* obtained from **Figure 2** of this AC, which can be used alone or with the applicable multiplication factors from **Figure 3** ($MF_{30\ sec\ egress}$) or Figure 4 ($MF_{Ventilated}$) applied to the maximum safe W/V determined from **Figure 2**. The minimum safe volume for 2 or more bottles is expressed as:

$$MinimumSafeVolume_{2+Bottles} = MinimumSafeVolume_{1Bottle} \times 2$$

(1) **Extinguishers in Unventilated Compartments.** The minimum safe volume for unventilated aircraft is to be used when the air change time is unknown or exceeds 6 minutes, and when selector graphs for ventilated aircraft are not available for a particular agent. The minimum safe volumes of various single 5B:C extinguishers when used in unventilated compartments, and assuming perfect mixing, is shown in **Figure 13**. The minimum safe volumes in **Figure 13** below are based on the agent weights for particular extinguishers, and should be corrected if the agent weight differs. The volume of the compartment must be larger than the sum of the minimum safe volumes of the 2 largest extinguishers in that compartment. If this criterion is not met, or if the maximum safe W/V can not be met for any of the agents, it is best to select an agent that provides the lowest minimum safe volume.

(2) **Extinguishers in Ventilated Compartments.** The minimum safe volumes of various single 5B:C extinguishers when used in ventilated compartments, and assuming perfect mixing can be obtained by applying the applicable multiplication factors from **Figure 4** as a divisor to the minimum safe volume obtained in the above paragraph.

Figure 13. Minimum Safe Compartment Volume for One Extinguisher in Unventilated Compartments.

Agent	Agent Weight[a] (lbs)	Minimum Safe Volume For One 5 B:C Extinguisher (ft^3)[b,c]					
		Sea Level (info only)	Pressurized Aircraft 8,000 ft CPA	Non-Pressurized Aircraft			
				12,500 ft[d]	14,000 ft[d]	18,000 ft[d,e]	25,000 ft[e]
HCFC Blend B	5.5	1102	1482	1768	1877	2209	2973
HFC-227ea	5.75	104	141	167	177	209	280
HFC-236fa	4.75	79.8	107	128	136	159	214
Halon 1211[f]	2.5	1116	1502	1790	1908	2232	3016
Halon 1301	5.0	192	258	308	327	385	517

a *The weight of agent for a 5B:C extinguisher is extinguisher dependent. Nozzle design, pressurization differences and other factors can result in different agent weights for extinguishers using the same agent. The tabulated minimum safe volumes should be corrected for the actual agent weight if different from* ***Figure 13*** *above.*
b *Use this table if air change time is unknown or exceeds 6 minutes.*
c *The minimum safe volume for a ventilated compartment can be obtained by dividing the value obtained from this figure by the* $MF_{Ventilated}$ *from* ***Figure 4***
d *Nasal Cannula Oxygen Supply*
e *Diluter-Demand Oxygen Mask*
f *Values are based on the NOAEL*

c. Number of Extinguishers. The number of 5B:C extinguishers that can be safely discharged into a given sized unventilated aircraft compartment can be calculated by dividing the compartment volume by the sum of the minimum safe volumes of the two largest extinguishers in that compartment. If the resultant value is greater than 2, any number of extinguishers can be used. The number of extinguishers from **Figure 13** above that can installed in various sized unventilated aircraft volumes are shown in **Figure 14** below. **Figure 14** is provided for general guidance only.

(1) Since compartment volumes may vary for aircraft of the same type, use the cabin volume for your aircraft and the maximum safe W/V guidance in **Figures 2 to 4 t**o determine what extinguishers to install in that aircraft compartment.

(2) Large transports have ventilation systems, enabling higher weights of agent to be safely used.

Figure 14. Number of 5B:C Extinguishers that can be Safely Discharged in Range of Aircraft at 8,000 ft. CPA (Assuming 70°F (21°C), and Unventilated)

Aircraft	Volume[c] (ft^3)	Max No. Seats[c]	Allowable Number of 5B:C Extinguishers [a,b]					
			Halon 1211 AC 20-42C[d] and U.S. - UL1093	Halon 1211	Halon 1301	HCFC Blend B	HFC-227ea	HFC-236fa
C 152	77	2	0.3[e]	0.05[e]	0.3[e]	0.05[e]	0.5[e]	0.7[e]
C 210C	140	6	0.5[e]	0.09[e]	0.5[e]	0.09[e]	1.0	1.3
C 421B	217	10	0.7[e]	0.1[e]	0.8[e]	0.1[e]	1.5	2.0
S76	204	14	0.7[e]	0.1[e]	0.8[e]	0.1[e]	1.4	1.9
ERJ135	968	37	2+	0.6[e]	2+	0.7[e]	2+	2+
CRJ200	2015	50	2+	1.3	2+	1.4	2+	2+
B727-100	5,333	131	2+	2+	2+	2+	2+	2+
B767-200	11,265	255	2+	2+	2+	2+	2+	2+
B 747	27,899	500	2+	2+	2+	2+	2+	2+

a *Actual number of extinguishers may be greater as many of these aircraft have fixed ventilation systems.*

b *The number of 5B:C extinguishers that can be safely discharged into a given sized* ***unventilated*** *aircraft compartment can be calculated by dividing the compartment volume by the sum of the minimum safe volumes of the two largest extinguishers in that compartment. Based on minimum safe volumes for unventilated compartments from figure 13. For* ***ventilated*** *compartments follow the same procedure, select the minimum safe volume from the same figure, dividing the value obtained from this figure by* $MF_{Ventilated}$ *from* ***Figure 4***

c *Compartment volume and number of seats can vary for aircraft of the same type.*

d *For information only, see canceled AC20-42C.*

e *Less than one 5B:C extinguisher can be safely discharged into that volume.*

4. Basis for the Multiplication Factors for Unventilated Compartments Allowing Higher Concentrations if Egress can be Performed Within 30 Seconds. An exposure to the PBPK-derived maximum safe 5-minute human exposure concentration results in a critical arterial concentration being reached at 5 minutes into the exposure. A brief 30 second exposure to that same constant halocarbon concentration results in a 30 second arterial concentration which is a fraction of the critical arterial concentration. Since arterial concentration increases linearly with exposure concentration, the 30 second multiplication factor brings the 30 second blood concentration up to the critical arterial concentration. Therefore, the multiplication factor equals the 5 minute arterial concentration/30 second arterial concentration. Note that the 30 second multiplication factors are not much greater than one for most agents covered in this AC. The use

of multiplication factors would allow higher concentrations if escape leads to a halocarbon free environment within 30 seconds. Examples of aircraft compartments where these 30 second egress multiplication factors would be applicable include small unventilated compartments, in very large aircraft and compartments where protective breathing equipment that provides halocarbon-free air can be donned within 30 seconds. Egress should be determined by the authority having jurisdiction to be less than or equal to 30 seconds, and escape should lead to a halocarbon-free environment. See referenced report by Speitel/Lyon for a detailed derivation of 30 second multiplication factors for each halocarbon.

5. Extinguisher Weights. Figure 15 below illustrates the fire fighting performance, agent and gross extinguisher weights of some halocarbon and water extinguishers.

Figure 15. Fire Extinguisher Performance and Gross Weights

UL Listing	Class A Panel Fire	Class A Crib Fire	Class B Novice	Class B Experienced	Agent and Extinguishers Weights[a]					
					Halon 1211	Halon 1301	HCFC Blend B	HFC-227ea	HFC-236fa	Water
2-B:C	N/A	N/A	2 ft^2	5 ft^2	Agent 1.3 lb Gross Wt. 2.3 lb	N/A	Agent 2.5 lb Gross Wt. 5.3 lb	Agent 2.75 lb	Agent 2.5 lb Gross Wt. 5.0 lb	N/A
5-B:C	N/A	N/A	5 ft^2	12.5 ft^2	Agent 2.5 lb Gross Wt. 3.7 lb[b]	Agent 2.5 lb[b]	Agent 5.2 lb Gross Wt. 9.6 lb	Agent 5.75 lb Gross Wt. 9.12 lb	Agent 4.75 lb Gross Wt. 9.5 lb	N/A
1-A: 5-B:C	8 ft x 8 ft	(72) 12 layers 6-2x2x20 in.	5 ft^2	12.5 ft^2	Agent 3.5 lb Gross Wt. 4.4 lb	N/A	N/A	N/A	N/A	N/A
1-A: 10-B:C	8 ft x 8 ft	(72) 12 layers 6-2x2x20 in.	10 ft^2	25 ft^2	Agent 9 lb Gross Wt. 15.7 lb	N/A	Agent 11 lb Gross Wt. 22 lb	N/A	Agent 9.5 lb. Gross Wt. 21.81 lb	N/A
2A	10 ft x 10 ft	(112) 16 layers 7-2x2x25 in.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Agent 22 lb (2.5gal) Gross Wt. 28 lb
2-A: 10-B:C	10 ft x 10 ft	(112) 16 layers 7-2x2x25 in.	10 ft^2	25 ft^2	N/A	N/A	Agent 15.5 lb Gross Wt. 27 lb	N/A	Agent 13.3 lb. Gross Wt. 25.6 lb	N/A
2A-40 B:C	10 ft x 10 ft	(112) 16 layers 7-2x2x25 in.	40 ft^2	100 ft^2	Agent 16 lb Gross Wt. 33 lb	N/A	N/A	N/A	N/A	N/A

a *Weights are extinguisher dependent. Extinguishing effectiveness is determined by test.*

b *Halon 1211 is no longer in production. However, Halon 1211 extinguishers are still in production using recycled agent.*

7. Aircraft Volumes and Ventilation. Figure 16 below provides general information on various size aircraft, i.e. number of seats, volumes and ventilation. Use this table as general guidance. The accuracy of this data has not been verified. Check aircraft manual for accurate guidance for your aircraft. The information in this table is taken in part from: Hocking, M.B. (1998). Indoor Air Quality: Recommendations Relevant to Aircraft Passenger Cabins. American Industrial Hygiene Association Journal. 59:446-454.

Figure 16. Aircraft Volumes and Ventilation

Transport Category Aircraft	Air Changes Per Hour Minimum Reported	Air Change, Minutes	Number of Seats	Cabin Volume, $ft^3(m^3)$
Airbus A310 (53)	9.7	6.19		11795(334)
Boeing 727-100	22.9	2.62		5333(151)
Boeing 727-200	18.8	3.19		5827(165)
Boeing 737-100	26.1	2.30		4238(120)
Boeing 737-200	17.7	3.39		4626(131)
Boeing 737-300 (42)	14.2	4.23		5262(149)
Boeing 747 (26)	14.7	4.08		27899(790)
Boeing 757 (48)	15.6	3.85		9747(276)
Boeing 767-200 (52)	10.3	5.83		11265(319)
Boeing 767-300 (-)	11.1	5.41		15115(428)
Lockheed L1011-1/100	17.8	3.37		18964(537)
Lockheed L1011-50	19.3	3.11		17445(494)
McDonald Douglas DC9-30	27.3	2.20		4379(124)
McDonald Douglas DC9-50	18.8	3.19		5227(148)
McDonald Douglas DC9-80/MD80 (22)	19.7	3.05		6109(173)
McDonald Douglas DC10-10	22.8	2.63		
Donald Douglas DC10-40 (35)	14.9	4.03		14797(419)
Average		**3.68**		
Smaller Commercial Aircraft				
Bombardier CRJ200			50	2015(57.1)
Bombardier CRJ700			70	2682(76)
Bombardier DASH-8, Q100 & Q200			37	1328(37.6)
Bombardier DASH-8, Q400			70-80	2740(77.7)
Embraer Brasilia EMB-120			30	968(27.4)
Embraer ERJ-135			37	968(27.4)
Embraer ERJ-145			50	1872(53.1)
Fairchild Dornier 328			32	1183(33.5)
Saab 340A & 340B			33	1180(33.5)
Saab 2000			50	1860(52.7)

Rotorcraft			Number of Seats	Cabin Volume, $ft^3(m^3)$
Sikorsky S76			10-14	204(5.8)
Sikorsky S92				700(19.8)
Bell 206B3			5	40(1.1)
Bell 407			7	85(2.4)
Bell 412			8	220(6.2)
Small Aircraft				
Cessna Caravan II			6-8	152(4.3)
Cessna Citation CJ1			4	300(8.5)
Cessna Citation CJ2			6	350(9.9)
Cessna Corsair, Conquest I			6-8	193(5.5)
Cessna 152			2	77(2.2)
Cessna 210C			6	140(3.9)
Cessna 414			6-8	226(6.4)
Cessna 421B			6-8	217(6.2)
Cessna Caravan 675			6-8	254(7.2)
Cessna Caravan Amphibian			6-8	254(7.2)
Cessna Grand Caravan			6-12	340(9.6)
Gulfstream Turbo Commander			6	184(5.2)
Gulfstream Jetprop				184(5.2)
Gulfstream G100				367(10.4)
Gulfstream G150			6-8	465(13.2)
Gulfstream G200			6-8	868(24.6)
Gulfstream G350/450			12-16	1,525(43.2)
Gulfstream G550			14-18	1669(47.3)
Gulfstream G650			11-18	2138(60.5)
LearJet 31A				271(7.7)
LearJet 40			6	363(10.3)
LearJet 45/45XR			6-8	410(11.6)
LearJet 60/60XR			6-8	453(12.8)
Pilatus PC12				330(9.4)
Piper PA31T Cheyenne				151(4.3)
Raytheon Beechcraft King Air 200			7	358(10.1)[a]
Raytheon Beechcraft King Air 300/350			9	440(12.5)[a]
Raytheon Beechjet 400/Hawker 400XP			8	305(8.6)[a]
Raytheon Premier I			6	315(8.9)[a]
Rockwell Gulfstream Commander GC-1000				249(7.1)
Socata TBM-700		estimated by Pilatus		155(4.4)
Sino Swearingen SJ30-2				190(5.4)
VisionAire Vantage				310(8.8)

a *Includes lavatory and internal baggage compartment.*