U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: Built-in Fire Extinguishing/Suppression Systems in Class C and Class F Cargo Compartments

Date: 02/03/16
Initiated By: ANM-112

AC No: 25.851-1

This advisory circular (AC) provides guidance concerning compliance with the airworthiness standards for transport category airplanes pertaining to Class C and Class F cargo compartments that incorporate built-in fire extinguishing/suppression systems. This guidance is applicable to transport category airplanes for which a new, amended, or supplemental type certificate is requested.

If you have any suggestions for improving this AC, you may use the Advisory Circular Feedback form at the end of this AC.

Jeffrey E. Duven
Manager, Transport Airplane Directorate
Aircraft Certification Service

Contents

Paragraph **Page**

Figures

Tables

1 PURPOSE.

This AC provides guidance concerning compliance with the airworthiness standards for transport category airplanes pertaining to Class C and Class F cargo compartments that incorporate built-in fire extinguishing/suppression systems. This guidance applies to Class C cargo compartments with built-in fire extinguishing/suppression systems regardless of their location (lower deck, main deck, or upper deck) and to Class F cargo compartments with built-in fire extinguishing/suppression systems, which must be located on the main deck.

Note: The terms "extinguishing system," "suppression system," and "extinguishing/suppression system" are used interchangeably in this AC. Systems that are located in remote (e.g., inaccessible or distant) areas are not required to extinguish a fire in its entirety, because the crew would not be able to confirm that the fire is extinguished. These systems are intended, instead, to suppress a fire until it can be completely extinguished by ground personnel following a safe landing.

2 APPLICABILITY.

2.1 The guidance in this AC is applicable to transport category airplanes for which a new, amended, or supplemental type certificate is requested. This guidance is for airplane manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration (FAA) transport airplane type-certification engineers and their designees.

2.2 The material in this AC is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. If, however, we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation as a basis for finding compliance.

2.3 The material in this AC does not change or create any additional regulatory requirements, nor does it authorize changes in, or permit deviations from, existing regulatory requirements.

3 CANCELLATION.

The following FAA policy memoranda are cancelled by this AC:

- Memorandum TAD 95-008, *Guidance on Protection Afforded by Halon Fire Extinguishing Systems in Class C Cargo Compartments,* dated August 11, 1995.

- Memorandum 98-112-24, *Halon Concentration Levels,* dated March 9, 1998.
- Memorandum 98-113-143, *Standards for Cargo or Baggage Compartments,* dated October 29, 1997.

4 RELATED DOCUMENTS.

4.1 Sections of Title 14, Code of Federal Regulations (14 CFR):

- § 25.851, *Fire extinguishers.*
- § 25.855, *Cargo or baggage compartments.*
- § 25.857, *Cargo compartment classification.*
- § 25.858, *Cargo or baggage compartment smoke or fire detection systems.*
- § 121.314, *Cargo and baggage compartments.*

4.2 FAA ACs.

The following ACs were current at the time of publication of this AC. You should use the latest version for guidance. You can view and download the latest version at the FAA website.

- AC 20-42D, *Hand Fire Extinguishers for use in Aircraft*, issued January 14, 2011.
- AC 25-9A, *Smoke Detection, Penetration, and Evacuation Tests and related Flight Manual Emergency Procedures*, issued January 6, 1994.
- AC 25-17A, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, issued May 18, 2009.
- AC 25-18, *Transport Category Airplanes Modified for Cargo Service*, issued January 6, 1994.
- AC 25-22, *Certification of Transport Airplane Mechanical Systems*, issued March 14, 2000.
- AC 25.857-1, *Class B and F Cargo Compartments*, issued February 3, 2016.
- AC 120-42B, *Extended Operations (ETOPS and Polar Operations)*, issued June 13, 2008.
- AC 135-42, *Extended Operations (ETOPS) and Operations in the North Polar Area*, issued June 10, 2008.

4.3 FAA Orders.

- FAA Order 8150.4, *Certification of Cargo Containers with Self-Contained Temperature Control Systems (Active ULDs)*, dated August 29, 2007.

4.4 References.

The following documents are referenced in this AC:

4.4.1 Gassmann, J., Hill, R., *Fire Extinguishing Methods for New Passenger/Cargo Aircraft*, Federal Aviation Administration, Final Report FAA-RD-71-68, November 1971.

4.4.2 Blake, D., *Evaluation of Large Class B Cargo Compartment's Fire Protection*, Federal Aviation Administration, Final Report DOT/FAA/AR-96/5, June 1996.

4.4.3 Reinhardt, J., Blake, D., Marker, T., *Development of a Minimum Performance Standard for Aircraft Cargo Compartment Gaseous Fire Suppression Systems*, Federal Aviation Administration, Final Report DOT/FAA/AR-00/28, September 2000.

4.4.4 Marker, T., Reinhardt, J., *Water Spray as a Fire Suppression Agent for Aircraft Cargo Compartment Fires*, Federal Aviation Administration, Technical Note DOT/FAA/AR-TN01/1, June 2001.

4.4.5 Ingerson, Douglas A., *Simulating the Distribution of Halon 1301 in an Aircraft Engine Nacelle With HFC-125*, Federal Aviation Administration, Technical Note DOT/FAA/AR-TN99/64, August 1999.

4.4.6 Blake, D., Marker, T., Hill, R., Reinhardt, J., Sarkos, C., *Cargo Compartment Fire Protection in Large Commercial Transport Aircraft*, Federal Aviation Administration, Technical Note DOT/FAA/AR-TN98/32, July 1998.

5 BACKGROUND.

5.1 Paragraphs (c) and (f) of § 25.857 provide standards for certification of two classes of cargo compartments, Class C and Class F. A Class C cargo compartment is configured in a manner that incorporates a built-in fire extinguishing/suppression system to extinguish or suppress any fire likely to occur in the cargo compartment. The means to extinguish or suppress a fire applies to bulk-loaded cargo, cargo loaded on pallets, cargo within unit load devices, and other means of carrying cargo. Both Class C and Class F cargo compartments have fire or smoke detection systems to alert the crew to the presence of the fire anywhere within the cargo compartment (i.e., anywhere cargo is designed to be carried).

5.2 A Class F cargo compartment that uses a built-in fire suppression system should meet the same requirements as a Class C cargo compartment. For example, per §§ 25.851, 25.855, and 25.857, an applicant for a Class F cargo compartment with a built-in fire extinguishing/suppression system must ensure that:

5.2.1 No discharge of the extinguisher can cause structural damage;

5.2.2 The capacity of each required built-in extinguishing/suppression system is adequate for any fire likely to occur in the compartment where used, considering the volume of the compartment and the ventilation rate;

5.2.3 There are means to exclude hazardous quantities of smoke, flames, or extinguishing agent from any compartment occupied by the crew or passengers; and

5.2.4 There are means to control ventilation and drafts within the compartment so that the extinguishing agent used can control any fire that may start within the compartment.

Note: Flight tests are conducted to ensure compliance with the provisions in §§ 25.855(h), 25.857(f), 25.858, and 25.1301(a).

5.3 Cargo fire extinguishing systems installed in airplanes today primarily use Halon 1301 as the fire suppression agent. One widely used method to certify Halon 1301 cargo fire suppression systems requires an initial concentration of 5 percent by volume in order to knock down (i.e., flames are no longer visible from the source of the fire) a cargo fire. Subsequent concentration levels should not drop below 3 percent by volume for the remainder of the flight in order to suppress a cargo fire until it can be completely extinguished by ground personnel following a safe landing.

5.3.1 Since Halon 1301 is approximately five times heavier than air, it tends to stratify and settle after it is released into the cargo compartment. Also, due to temperature differences and ventilation patterns in a ventilated compartment, Halon 1301 starts to stratify shortly after discharge and the concentration level decays faster in the upper locations of the compartment than in the lower locations. Halon 1301 also has a tendency to move aft due to any upward pitch, or forward in any downward pitch, of the airplane in flight. For some airplane certification programs, the concentration levels of Halon 1301 have been measured at various locations throughout the cargo compartment, and an arithmetic average of the individual sampling locations has been used to determine an overall concentration level for the cargo compartment. This averaging technique may allow the concentration level to drop below 3 percent by volume at individual sampling locations near the top of the cargo compartment.

5.3.2 Testing data from the FAA William J. Hughes Technical Center (see paragraph 4.4 of this AC) and other data from standardized fire extinguishing evaluation tests indicate that the use of averaging techniques may not substantiate that there are adequate concentration levels of fire extinguishing agent throughout the compartment to effectively suppress a cargo fire. If a cargo fire occurred and was subsequently suppressed by Halon 1301, the core of the fire could remain hot for a period of time. If the local concentration of Halon 1301 in the vicinity of the fire core dropped below 3 percent by volume, and sufficient oxygen is available, re-ignition could occur. FAA tests have shown that when the Halon 1301 concentration level drops below 3 percent by volume and the cargo fire reignites, the convective stirring caused by the heat of the fire may be insufficient to raise the local concentration of Halon in the vicinity of the fire. Therefore, compliance testing should involve the use of point concentration data from each probe. Additionally, the probes closest to the cargo compartment ceiling should be at least at the highest level that cargo and baggage can be loaded as specified by the manufacturer and certified by the appropriate airworthiness authority. In addition, compliance demonstration should include data acquired after landing at a time representative of the completion of an evacuation of all occupants; as with the transient flight phases, if real-time data cannot be acquired using approved instrumentation, applicants may submit the results of analysis.

Note: Due to the ozone depleting characteristics of halon, the U.S. Environmental Protection Agency (EPA) has established restrictions on using halon for testing. Applicants should instead use a halon simulant, such as pentafluoroethane (HFC-125), for tests. Applicants will find useful information and technical reports on HFC-125 at the FAA William J. Hughes Technical Center Fire Safety Branch website.

6 COMPARTMENT CLASSIFICATION REGULATIONS.

In order to establish appropriate requirements for fire protection, a system for classification of cargo or baggage compartments was developed and adopted for transport category airplanes. Classes A, B, and C were initially established; Classes D, E, and F were added later. Class D has since been eliminated from the regulations. The classification is based on the means by which a fire can be detected and the means available to control a fire. All cargo compartments must be properly classified in accordance with § 25.857 and meet the requirements of §§ 25.851, 25.855, 25.857, and 25.858 pertaining to the particular class involved.

6.1 A Class A compartment (see § 25.857(a)) is located so close to the station of a crewmember that the crewmember would easily discover the presence of a fire. In addition, each part of the compartment is easily accessible so that the crewmember could quickly extinguish a fire with a portable fire extinguisher. A Class A compartment is not required to have a liner.

6.2 A Class B compartment (see § 25.857(b)) is accessible in flight but more remote from the crewmember's station than a Class A compartment and must, therefore, incorporate a smoke or fire detection system to give warning at the pilot or flight engineer station. Because a fire would not be detected and extinguished as quickly as in a Class A compartment, a Class B compartment must have a liner that meets the requirements of § 25.855(b). In flight, a crewmember must have sufficient access to a Class B compartment to effectively fight a fire in any part of the compartment with a hand fire extinguisher when standing at the compartment's one designated access point, without stepping into the compartment. Therefore, Class B cargo compartments are limited to the main deck. There must be means to ensure that, while the access provisions are being used, no hazardous quantity of smoke, flames, or extinguishing agent will enter areas occupied by the crew or passengers.

6.3 A Class C compartment (see § 25.857(c)) differs from a Class B compartment in that it is not required to be accessible in flight and must, therefore, have a built-in fire extinguishing or suppression system that is controllable from the flight deck. A Class C compartment must have a liner and a smoke or fire detection system that meets the requirements of §§ 25.855(b) and 25.857(c)(1). There must also be means to exclude hazardous quantities of extinguishant and products of combustion from occupied areas (see § 25.857(c)(3)).

6.4 A Class D compartment was one in which a fire would be completely contained without endangering the safety of the airplane or the occupants. A Class D compartment was not accessible to a crewmember in flight, and instead of providing smoke or fire detection and extinguishment, Class D compartments were designed to control a fire by severely restricting the supply of available oxygen. Due to several uncontrollable fires in Class D compartments, they were eliminated by Amendment 25-93, effective March 19, 1998. As explained in Amendment 25-93, Class D cargo compartment standards pre-dating Amendment 25-93 are inadequate. Therefore, the FAA does not approve new Class D cargo compartments even in airplanes with a certification basis pre-dating Amendment 25-93.

6.5 A Class E compartment (see § 25.857(e)) is found only on an all-cargo airplane. Typically, a Class E compartment is the entire cabin of an all-cargo airplane; however, other compartments (e.g., lower–deck, inaccessible cargo compartments) of such airplanes may be classified as Class E compartments. Shutting off the ventilating airflow to or within the compartment controls a fire in a Class E compartment. A Class E compartment must have a liner and a smoke or fire detection system installed in accordance with § 25.857(e)(2). It is not required to have a built-in fire suppression system.

6.6 A Class F compartment (see § 25.857(f)) must be located on the main deck of the airplane. Class F compartments must have means to control or extinguish a fire without requiring a crewmember to enter the compartment. Class F compartments that include a built-in fire extinguishing/suppression system or require the use of fire containment covers (FCCs) or fire resistant containers (FRCs) meeting the criteria identified for these components in paragraph 6.3.3 of AC 25.857-1 may meet these requirements.

6.6.1 We introduced the Class F cargo compartment as a practicable and safe alternative to the previous practice of providing large Class B cargo compartments. Class B compartments are limited to the main deck for accessibility reasons. Likewise, Class F cargo compartments must be limited to the main deck for accessibility. Lower-deck cargo compartments should not be approved as Class F cargo compartments. All lower-deck or remote cargo compartments in airplanes carrying passengers need to comply with the Class C cargo compartment requirements of § 25.857(c).

6.6.2 The Class F compartment must have a smoke or fire detection system installed in accordance with § 25.857(f)(1). Unless there are other means of containing the fire and protecting critical systems and structure, a Class F compartment must have a liner meeting the requirements of part III of appendix F to part 25 or other approved equivalent methods (see § 25.855(b)). For example, the FAA would accept a Class F cargo compartment requiring the use of FCCs, FRCs, or other means meeting the liner requirements (i.e., part 25, appendix F, part III flame penetration resistant means) as equivalent to installation of a fixed liner.

7 TESTING VOLUMETRIC CONCENTRATION LEVELS.

7.1 The applicant must demonstrate that the cargo fire extinguishing system provides adequate concentration levels of extinguishing agent to combat a fire anywhere baggage and cargo is placed within the cargo compartment for the time duration required to land

and evacuate the airplane. A combination of flight testing and analysis may be used. If Halon 1301 is used, an initial minimum concentration of 5 percent by volume is required to knock down a cargo fire. Subsequent gaseous extinguishing agent , if required for the duration of the flight, should be introduced via a metering or other appropriate system to ensure that point concentration levels do not drop below the minimum level appropriate for the agent (e.g., for Halon 1301, the minimum level is 3 percent by volume) for the remainder of the flight. The duration of agent application should be determined from route analysis (i.e., the time to travel from the farthest distance expected en route to the nearest adequate airport for landing according to applicable operational rules. For extended operation (ETOPS) with two-engine airplanes, appendix K to part 25, AC 120-42B, and AC-135-42 provide regulatory requirements and guidance. These references specify that an analysis or tests should be conducted to show, considering approved maximum diversion in still air (including an allowance for 15-minute holding and/or approach and landing), that the ability of the system to suppress or extinguish fires is adequate to ensure safe flight and landing at a suitable airport (e.g., a flight test simulated landing may be used in lieu of an actual landing). The minimum extinguishing agent concentration levels should be maintained for the required duration throughout the cargo compartment where cargo will be carried, including side to side, end to end, and top to bottom. However, flight-test measurements do not have to be made in compartment areas that are designated empty and will not contain cargo.

7.2 The fire extinguishing agent concentration levels should be measured at sufficient vertical, horizontal, and longitudinal locations to ensure that sufficient resolution exists to define the variations in fire extinguishing agent concentration levels throughout the cargo compartment in these planes. Averaging techniques should not be used in compliance demonstrations for § 25.851(b)(2). An exception to this would be in the event of a probe failure, where interpolation of probe concentration data from other nearby probes to yield an estimate of missing agent concentration data may be allowed by the FAA. In the event such interpolation is necessary, then a linear interpolation of the data will provide an acceptable means of approximating the missing data. The applicant should coordinate such situations closely with the FAA.

7.3 Sampling locations should also be placed as close as practical to potential leakage or ventilation flow areas (e.g., door seals, vents, etc.), which can disrupt the local concentration levels. The concentration levels should not be less than the minimum established for that fire extinguishing agent at any point within the compartment. Arithmetic averaging of individual sampling locations to determine the concentration levels is not acceptable, except where a sensor probe failure occurs and the use of interpolation from adjacent sensor probes is warranted. If the FAA finds the use of the adjacent sensors is not warranted, then the flight test must be repeated. Compliance with § 25.851(b) requires the use of point-concentration data from each sensor and that the sensors closest to the cargo compartment ceiling be at least at the highest level that cargo and baggage can be loaded as specified by the manufacturer and certified by the FAA. Other placement of concentration sensors within the cargo compartment should be sufficient to substantiate that there are adequate concentration levels of fire extinguishing agent throughout the compartment to effectively control a cargo compartment fire. The sampling rate should be sufficient to establish a concentration level versus time decay curve. In the event that a single sensor displays a suspect time history, the use of an interpolated time-averaged value may be acceptable. If fire extinguishing agent concentration levels at a probe drop below the minimum requirement, it should be a temporary anomaly of short duration and not observed in adjacent probes. If the applicant can demonstrate that the temporary anomaly is associated with normal airplane maneuvers, then the data should be acceptable. The applicant should coordinate such situations closely with the FAA.

7.4 Cargo airplane designs typically use two types of built-in fire suppression systems. The first type, known as a “flood,” “dump,” or “quick discharge” system, rapidly introduces extinguishing agent throughout the cargo compartment upon initial indication of fire. These systems often discharge once more, after a set amount of time. After these initial discharges, a second type of system, known as a “metered” or “slow-discharge” system, maintains the concentration of agent needed to suppress the fire until the airplane can safely land and be evacuated. Regardless of the type of system, compliance with §§ 25.855(h) and 25.857 requires demonstration flight tests.

7.4.1 Applicants whose flood or dump systems use Halon 1301 fire extinguishing agent should demonstrate an initial concentration of 5 percent of agent by volume. After any second discharge by the dump system, as the concentration approaches the minimum sustaining level (3 percent for Halon 1301) the metered system should maintain that minimum sustaining level for the time necessary for a safe landing and evacuation.

7.4.2 Certification flight test demonstrations are required for demonstrating compliance for built-in systems for the duration of the intended diversion profile. If the built-in fire suppression system includes a metering system, then the metering system’s acceptability may be demonstrated through a limited flight test, in which a portion of the system is actually tested, and the full capability of the system is demonstrated via analysis. This type of testing and analysis should be documented in the applicant’s certification plan. A sufficient portion of the metering system capability should be demonstrated to provide enough data to establish fire extinguishing agent concentration and behavior for the remaining flight. Airplane climb flight phase and the descent flight phase represent dynamic environments and historically have represented a challenge for accurate data acquisition. While real-time data should be acquired during all phases of airplane flight, applicants may submit the results of analysis for these transient flight phases if the intended instrumentation would preclude accurate data acquisition during these flight phases and the FAA agrees with the use of the instrumentation. In addition, compliance demonstration should include data acquired after landing at a time representative of the completion of an evacuation of all occupants; as with the transient flight phases, if real-time data cannot be acquired using approved instrumentation, applicants may submit the results of analysis. If a fire extinguishing agent other than Halon 1301 is proposed, the method of compliance will need to be documented in an issue paper.

Note 1: Due to EPA restrictions, an FAA-accepted halon simulant, such as HFC-125, should be used for testing (see section 11 of this AC).

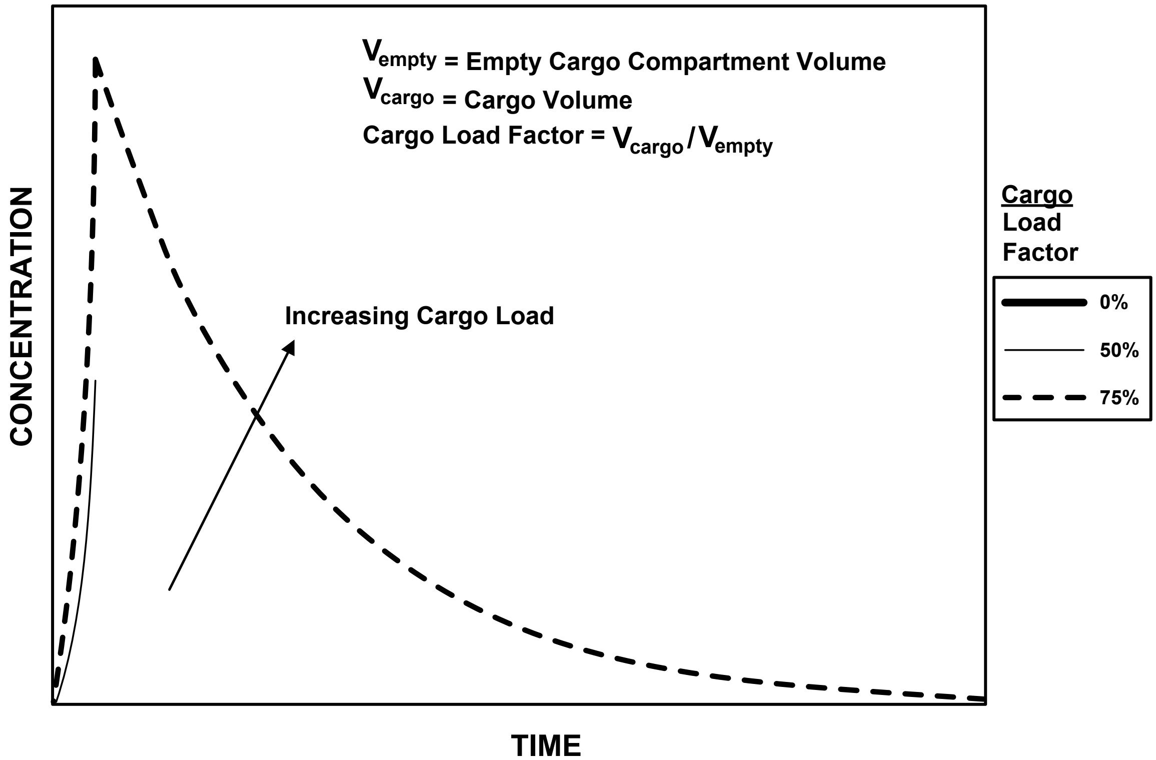
Note 2: Future fire extinguishing systems may be adaptive in providing superior control of a fire by zonal fire control in lieu of the flooding control provided by today's Class C cargo compartment fire suppression systems. Such systems will require development of an issue paper and may result in special conditions or other regulatory means to obtain FAA approval.

8 AIRPLANE TEST CONDITIONS.

8.1 Flight tests are required per § 25.855(h) to demonstrate function and dissipation of the fire extinguishing agent in a cargo compartment. For certification tests, the airplane and relevant systems should be in the type design configuration.

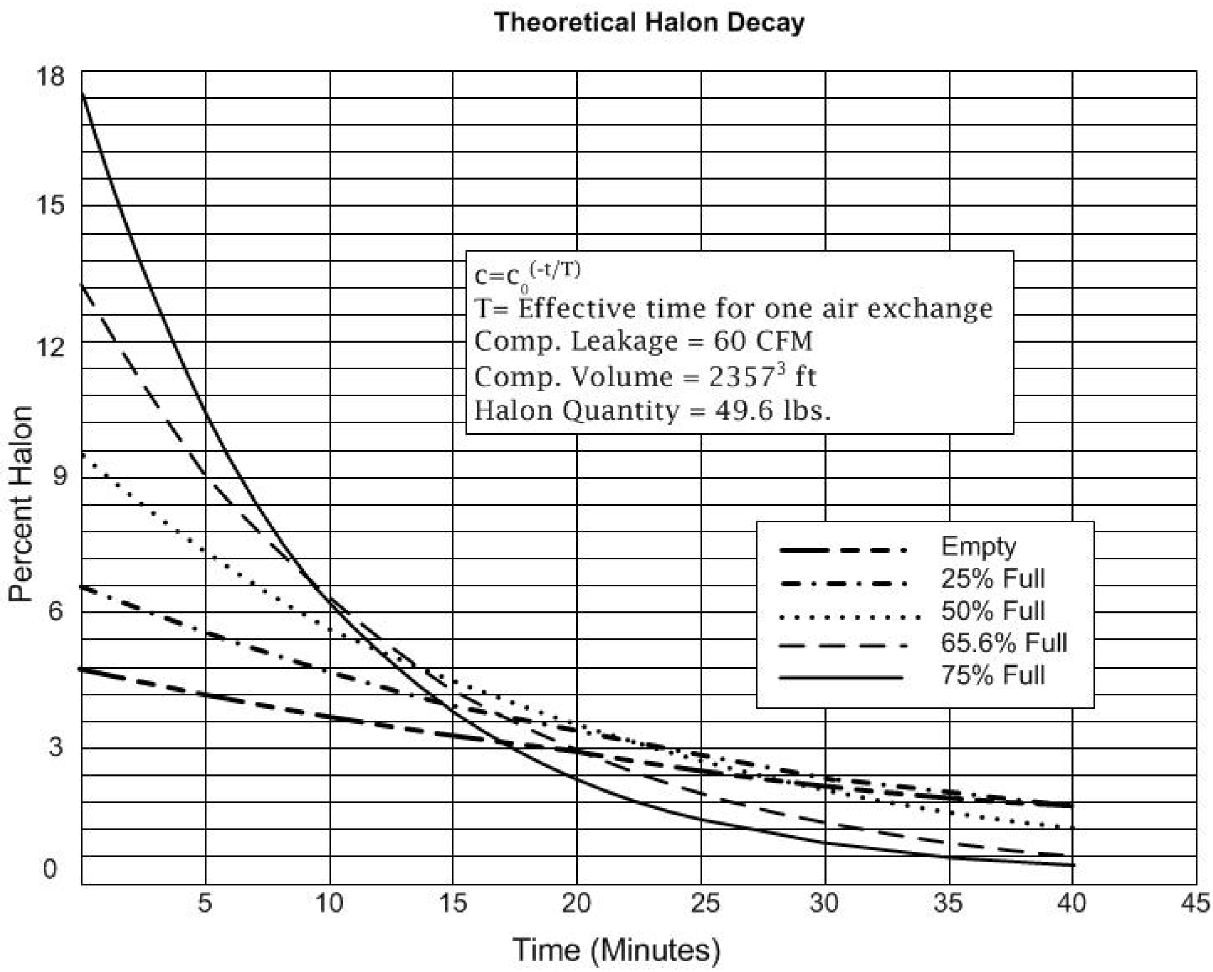
8.2 The cargo compartment should be empty for the above tests. However, as shown in figure 1 of this AC, the fire extinguishing agent concentration level decreases more quickly in a compartment with cargo than it would in the same compartment without cargo. This is because discharging the same quantity of fire extinguishing agent into a smaller volume results in a larger percentage of extinguishing agent by volume. For a cargo compartment with a constant leakage rate, the result of the smaller volume and constant leakage rate will be that the fire extinguishing agent concentration level decreases more quickly. The duration that the concentration is maintained (or conversely, how quickly it decreases) depends on several factors (e.g., cargo load factor, location of leakage within the cargo compartment such as seals around cargo loading door and light fixtures, etc.). Rather than requiring numerous flight tests with varying load factors to demonstrate compliance, applicants may conduct analysis to account for these effects as shown in figure 2 of this AC.

Figure 1. Effect of Cargo Load on Halon 1301 Concentration Levels



8.3 A specific example of the effect of cargo compartment loading is shown in figure 2 of this AC, using the simulation in appendix A of this AC. If the volume of the compartment is decreased to represent increasing cargo load percentages and the leakage rate and initial Halon 1301 quantity are kept constant, then the initial Halon 1301 concentrations increase and the concentration decay rates also increase. Using this approach, the concentration in an empty compartment will decay to 3 percent faster than a loaded compartment up to a load percentage of about 65.6 percent. With compartments loaded to a higher percentage than 65.6 percent, the concentration will fall below 3 percent faster than an empty compartment.

Figure 2. Halon Concentration Time History



8.4 This simulation of cargo loading assumes that the Halon 1301 concentration is homogeneous throughout the compartment, and that the volume taken up by the loaded cargo is uniformly distributed throughout the compartment. Both of these assumptions are not true in an actual loaded compartment, so caution should be exercised to relate the measurements taken to an actual loaded compartment in flight. Figure 2 shows a time history of the volumetric concentration of a fire extinguishing agent (Halon 1301) in a cargo compartment with various percentages of cargo loaded. Historically, the time that it takes for the airplane ventilation system to completely replace the volume of air in a cabin or cargo compartment has been called the air exchange rate. The effective time used in figure 2 of this AC refers to the time that it would take to completely remove the entire quantity of fire suppression agent once it is discharged. This depends on the specific design of the cargo compartment (e.g., volume of the compartment, the amount of cargo present, sources of air entry, and sources of air and suppression agent leakage).

8.5 Analysis should be provided to ensure that the suppression agent will not fall below the minimum concentration levels with a cargo load factor as follows:

8.5.1 For cargo compartments using only standard cargo containers, the maximum possible volume occupied by containerized cargo should be determined, and this value should be used as the cargo load factor. This maximum volume becomes an airplane operating limitation.

8.5.2 For all other configurations, a minimum cargo load factor of 75 percent by volume should be used in the analysis.

8.6 Appendix A to this AC provides guidance on analyzing Halon 1301 concentration levels.

8.7 The suppression system certification test should be conducted, at a minimum, during steady-state cruise with a maximum cabin-to-ambient pressure differential. The ventilation system should be configured according to the airplane flight manual (AFM) procedures for a cargo compartment fire. The system should also be demonstrated acceptable for unpressurized flight conditions unless there is a limitation on unpressurized flight for the airplane.

8.8 Cargo compartment leakage rates will vary between airplanes. This is especially significant for changes introduced by a supplemental type certificate modifying airplanes that have been in service. Some preliminary testing should be done to determine the maximum leakage rates seen to date and expected in service. For new type designs, the issue of wear and tear on the compartment (e.g., cargo compartment door seals, fire resistant tape used on adjacent liner material, etc.) should also be addressed when establishing the decay rate in a brand new airplane at the factory. For example, cargo compartment door seals present during the flight test should reflect the worn state prior to replacement according to instructions for continued airworthiness. Prior to flight testing and during the conformance inspection of the airplane, it should be confirmed that the cargo compartment door seals represent a worn state per maintenance instructions provided by the airplane manufacturer for seal replacement.

Note: Due to EPA restrictions, an FAA-accepted halon simulant, such as HFC-125, should be used for testing (see section 11 of this AC).

9 EVALUATION OF ALTERNATIVE GASEOUS EXTINGUISHING/SUPPRESSION SYSTEMS AND ALTERNATIVE AGENTS.

9.1 The Montreal Protocol, in existence since 1987, is an international agreement to phase out production of ozone-depleting substances, including halogenated hydrocarbons, also known as halon. The Montreal Protocol prohibits the manufacture or import of new halon in all developed countries as of January 1, 1994, and will extend this prohibition to developing countries in the future. The U.S. EPA has subsequently released a regulation banning the intentional release of halons during repair, testing, and disposal of equipment containing halons and during technician training. However, the EPA has provided the aviation industry an exemption from their ban on the intentional release of halons in determining compliance with airworthiness standards. A European Union (EU) regulation[1] also contains provisions that allow exemptions for critical uses of halon, including fire extinguishing in aviation. The EPA/EU exemption is predicated on the basis that there is currently no suitable alternative agent or system available for use on commercial transport category airplanes. It is the understanding of the FAA and the European Aviation Safety Agency that once a suitable replacement extinguishing agent or system has been found, the EPA/EU will remove the exemption.

9.2 To date, the FAA Technical Center testing of alternative gaseous extinguishing/suppression agents has not yielded any acceptable alternative halon replacement agents for use in cargo compartments. For example, testing at the Technical Center using HFC-125 demonstrated the need for large concentrations of this agent, which would carry weight penalty and toxicity concerns. In addition, HFC-125 may exhibit significant over-pressure events when sub-inerting concentrations of the agent are introduced into a fire under certain environmental conditions (e.g., small amount of agent, intense fire, low ventilation rate, etc.). The Technical Center will continue to pursue this line of research to identify alternative gaseous, liquid, and other fire extinguishing/suppression agent systems. Acceptable means of compliance for these immature systems are beyond the scope of this AC. We will revise this AC when suitable standards are developed for these systems.

9.3 If the proposed design will use an alternative agent or alternative gaseous fire extinguishing system in lieu of a Halon 1301 system, then the recommended approach would be to (1) perform testing that meets the minimum performance standards for that application as developed by the International Halon Replacement Working Group, and (2) address installation issues. The International Halon Replacement Working Group was established in October 1993. This group was tasked to work towards the development of minimum performance standards and test methodologies for non-halon aircraft fire suppression agents/systems in cargo compartments, engine nacelles, hand fire extinguishers, and lavatory trash receptacles. The International Halon Replacement Working Group has been expanded to include all system fire protection research and development for aircraft and now carries the name International Aircraft Systems Fire Protection Working Group. Completion of the testing according to the minimum performance standards does not mean that an agent is approved for use on an airplane. Concentration testing should be conducted to ensure the installation provides acceptable concentration levels anywhere within the cargo compartment where cargo can be carried. Additional testing, including full scale fire extinguishing testing within an actual cargo compartment or high-fidelity model simulator, may be necessary. An applicant proposing to use a non-halon fire extinguishing agent should contact the FAA as soon as possible to enable the FAA to consider their design, determine what testing is required, and to propose any additional testing to ensure the applicant’s design is acceptable.

[1] Regulation (EC) No. 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer.

9.4 To ensure compliance when using the guidance in this AC, the following should be provided for gaseous agent systems:

9.4.1 The test data and gaseous agent distribution profiles that meet the certification criteria and in the minimum performance standards as developed by the FAA Technical Center as part of the International Halon Replacement program (see paragraph 4.4 of this AC);

9.4.2 A system description document that includes a description of the distribution of the gaseous agent under the test conditions in the cargo compartment;

9.4.3 A detailed test plan; and

9.4.4 Chemical data that describes the agent and any toxicity data.

9.5 **Pre-Test Considerations.**

9.5.1 An analyzer (e.g., Halonizer, Statham-derivative analyzer) capable of measuring the agent distribution profile in the form of volumetric concentration is required.

9.5.2 An analyzer (e.g., Halonizer, Statham-derivative analyzer) and associated hardware should be configured for the particular application.

9.5.3 The fire suppression system should be completely conformed prior to the test.

9.5.4 The fire extinguisher bottle(s) should be serviced and prepared for the prescribed test(s).

9.6 **Test Procedures.**

9.6.1 Perform the prescribed distribution test in accordance with the test plan. See section 7 of this AC for guidance on probe placement.

9.6.2 An analyzer (e.g., Halonizer, Statham-derivative analyzer) should record the distribution profile as volumetric concentration for the agent.

9.7 **Test Result Evaluation.**

9.7.1 Produce the data from the analyzer (e.g., Halonizer, Statham-derivative analyzer) in graphical format. This format should be the volumetric concentration of the agent versus time. A specific percent volumetric initial concentration and a specific percent volumetric metered concentration for the length of the test duration, as determined by previous testing conducted according to the established minimum performance standards, is required for airworthiness approval of cargo compartment systems.

9.7.2 Using the appropriate minimum performance standards evaluation criteria, evaluate the distribution profile of the agent for acceptable performance. The acceptability of the test data would be dependent on the distribution profile and duration exhibited by each probe according to section 7 and paragraph 9.7.1 of this AC for cargo compartment fire extinguishing systems.

10 EVALUATION OF ALTERNATIVE LIQUID AGENT AND FIRE EXTINGUISHING/SUPPRESSION SYSTEMS.

10.1 The FAA Technical Center released a technical note (see paragraph 4.4.4 of this AC) that represents the latest minimum performance standards for a water spray system. However, as mentioned within the body of the report, additional developmental testing may be needed for such a system. Additional testing would be required to demonstrate compliance with an aerosol spray-can fire threat. The Technical Center continues to perform research towards identifying alternative liquid and other fire extinguishing/suppression systems. Acceptable means of compliance for these immature systems are beyond the scope of this AC. We will revise this AC when suitable standards are developed for these systems.

10.2 If the proposed design will use a liquid fire extinguishing agent or system, or any non-halon agent, the applicant should contact the FAA. The FAA may initiate an issue paper addressing the use of an alternative fire extinguishing agent or system.

11 USE OF SIMULANTS FOR CERTIFICATION TESTING.

11.1 The aviation industry may continue to use halon in cargo fire suppression applications as long as acceptable alternatives have not been identified and shown to provide an equivalent level of safety. The EPA/EU is allowing the aviation industry to use halon to demonstrate system functionality as long as a simulant or alternative extinguishing agent or alternative fire extinguishing system cannot be used in place of the halon during system or equipment testing for technical reasons. However, certain U.S. states continue to ban the release of halon for testing. The FAA Technical Center and the International Aircraft Systems Fire Protection Working Group are concentrating efforts on evaluating alternative fire extinguishing agents and the use of simulants during certification testing. An effective simulant (HFC-125) has been used in place of Halon 1301 during certification tests of engine nacelle fire extinguishing systems to predict actual Halon 1301 volumetric concentration levels. The FAA recommends that all applicants consider use of a simulant in lieu of discharging Halon 1301.

11.2 Testing at the FAA Technical Center successfully demonstrated that there is a suitable simulant (HFC-125) for cargo compartment and engine nacelle gaseous fire extinguishing systems (see paragraphs 4.4.5 and 4.4.6 of this AC). It appears that HFC-125 can be used as a simulant for Halon 1301 provided that suitable conversion equations are used to correlate the concentrations of Halon 1301 and HFC-125. To ensure acceptable, successful means of compliance, the same information as outlined in section 7 of this AC should be provided.

11.3 A simulant is defined in this AC as a chemical agent that adequately imitates the discharge and distribution characteristics of a given extinguishing agent. It need not be an actual fire suppressant. For certain cases due to, for example, cost of the extinguishing agent, problems with supply of the extinguishing agent, impact to the environment from discharge of the agent, etc., it may be more appropriate to use a simulant in the application. If an applicant proposes a simulant, they should complete adequate analysis and testing to establish the validity of the simulant across the operating environment of the airplane application. As a minimum, corroborating information would need to be provided as to the detailed chemical analysis of the simulant and evaluation testing of the fire extinguishing system operated with the simulant that demonstrates the equivalent behavior. To ensure compliance when using the guidance in this AC, the following should be provided to the FAA to corroborate the applicant's findings:

11.3.1 Test data and distribution profiles using the simulant that meet the approved certification criteria and meet the minimum performance standards as developed by FAA Technical Center as part of the International Aircraft Systems Fire Protection Working Group (see paragraph 4.4 of this AC);

11.3.2 A system description document that includes a description of the distribution of the simulant under the test conditions in the cargo compartment;

11.3.3 A detailed test plan; and

11.3.4 Chemical data that describes the simulant and any toxicity data.

Note: Any unique observances during development testing or minimum performance standards testing will need to be addressed appropriately prior to the start of airplane certification testing.

11.4 The distribution of the simulant in the application should be compared with Halon 1301 under the following conditions:

11.4.1 Given the same filling conditions, the simulant is loaded into the fire extinguisher bottle based on an equivalent liquid fraction to the Halon 1301 charge weight required. This is an equivalent statement to the mass of the simulant being a specific percentage of the Halon 1301 charge weight required.

11.4.2 The fire extinguisher bottle containing the simulant is pressurized with nitrogen in an identical manner required by the Halon 1301 charge weight.

11.4.3 The simulant is discharged into the test environment (i.e., cargo compartment).

11.5 **Pre-Test Considerations.**

11.5.1 An analyzer (e.g., Halonizer, Statham-derivative analyzer) capable of measuring the simulant distribution profile in the form of volumetric concentration is required.

11.5.2 An analyzer (e.g., Halonizer, Statham-derivative analyzer) and associated hardware should be configured for the particular application.

11.5.3 The fire suppression system should be completely conformed for Halon 1301.

11.5.4 The fire extinguisher bottle(s) should be serviced and prepared for the prescribed test(s).

11.6 **Test Procedures.**

11.6.1 Perform the prescribed distribution test in accordance with the test plan. See section 7 of this AC for guidance on probe placement.

11.6.2 An analyzer (e.g., Halonizer, Statham-derivative analyzer) should record the distribution profile as volumetric concentration for the simulant.

11.7 **Test Result Evaluation.**

11.7.1 Produce the data from the analyzer (e.g., Halonizer, Statham-derivative analyzer) in graphical format. This format should be the volumetric concentration of the simulant versus time. A specific percent volumetric initial concentration and a specific percent volumetric metered concentration for the length of the test duration as determined by previous testing conducted according to the established minimum performance standards should be included.

11.7.2 Using the Halon 1301 certification criteria, evaluate the distribution profile of the simulant for acceptable performance. The acceptability of the test data would be dependent on the distribution profile and duration exhibited by each probe.

12 ESTABLISHING DURATION FOR THE SUPPRESSION SYSTEM.

12.1 The adequacy of the capacity of the "built-in system" means that there is sufficient quantity of agent to extinguish or suppress the fire anywhere baggage and cargo is placed within the cargo compartment for the duration required to land and evacuate the airplane. Current built-in cargo fire extinguishing systems use Halon 1301 as the fire extinguishing agent where protection is afforded as long as the minimum concentration levels in the cargo compartment do not drop below 3 percent by volume. The time for which a suppression system will maintain the minimum required concentration levels should be identified as a certificate limitation.

12.2 The applicant should work with the airplane owner/operator and the civil aviation authority providing operational approval to ensure that the cargo compartment fire extinguishing system is sized adequately to provide the required protection for the specific route structure. Protection time should account for some holding time to allow for weather and other possible delays, and may specify the speeds and altitudes used to calculate airplane diversion times based on one-engine-out considerations.

12.3 Operational approval for the airplane should include the maximum allowable time, following the discovery of a fire or other emergency situation, required to divert the airplane to an alternative landing site. The maximum allowable time should include a 15-minute allowance for holding and/or approach and landing in addition to the actual time required to reach the alternative landing site and account for the completion of an evacuation of all occupants.

12.4 AC 120-42B and AC 135-42 provide guidance on an acceptable means for obtaining approval under applicable operational rules for two-engine airplanes operating over a route that contains a point farther than one hour's flying time at the normal one-engine inoperative cruise speed (in still air) from an adequate airport. The ACs include specific criteria for deviations of 75 minutes, 120 minutes, 180 minutes, and other authorized operations from an adequate airport plus an allowance for 15-minute holding and/or approach and landing.

12.5 Flight-test data, supplemented by analysis for cargo load factors and additional metering system bottles as applicable, determines the maximum protection time provided by the cargo fire extinguishing system. This maximum protection time may not be the same as the maximum allowable time required to divert the airplane. The certificate limitation for total time, including the 15-minute allowance for holding and/or approach and landing as applicable, should never be greater than the maximum protection time provided by the cargo fire extinguishing system.

12.6 The following examples illustrate these issues:

12.6.1 Example 1:

Maximum Protection Time Provided

By cargo fire extinguishing system	= 127 minutes
Maximum planned diversion time	= 112 minutes + 15 minutes
Certificate limitation for total time	= 127 minutes

Note: This example includes an allowance of 15 minutes for holding and/or approach and landing.

12.6.2 Example 2:

Maximum Protection Time Provided

By cargo fire extinguishing system	= 68 minutes
Maximum planned diversion time	= 60 minutes + 15 minutes
Certificate limitation for total time	= 68 minutes (less than the maximum planned diversion time)

Note: In this example, the system would not support the planned route. The FAA could approve the route if additional suppression agent was provided that would extend the suppression time to 75 minutes.

13 AIRPLANE MANUAL CONSIDERATIONS.

To ensure fire extinguishing/suppression system effectiveness and continued safe flight and landing, the applicable airplane manuals should contain appropriate directives, for example:

13.1 Any procedures related to fighting a cargo compartment fire should be clearly defined in the AFM.

13.2 AFMs should contain instructions to land at the nearest adequate airport (or suitable airport for ETOPS) following detection of a cargo fire.

13.3 Cargo loading restrictions (certified type of loading according to compartment, limits for loading heights and width, etc.) should be clearly described in the weight and balance manual or any other appropriate airplane manual.

13.4 Where the use of airplane manuals is considered to be impractical during cargo loading activities, all necessary information may be introduced in crew operating manuals or part of dedicated instructions for cargo loading personnel.

14 PLACARDS AND MARKINGS IN CARGO COMPARTMENTS.

14.1 Experience has shown that under certain circumstances and despite clear instructions in the applicable airplane documentation, cargo loading personnel may not follow loading restrictions. Pallets have been loaded higher than certified, or bulk cargo may be stowed up to the ceiling, adversely affecting smoke detection and fire protection/fire suppression system effectiveness. To visually indicate the applicable loading restrictions to each person responsible for cargo-loading activities in a compartment, placards and markings indicating the maximum loading height and widths for the approved configuration should be installed in that compartment. The airplane’s weight and balance manual should describe these loading restrictions.

14.2 For the design (shape, size, color, and brightness) of these indications, illumination conditions in the compartment should be considered. Markings and placards should not be easily erased, removed, disfigured, or obscured. Further guidance may be derived from compliance demonstrations for part 25 paragraphs regulating other internal markings and placards, for example, in the cockpit or passenger compartment.

Appendix A. Analytical Methods for Determining Halon 1301 Concentration Levels

A.1 PURPOSE.

This appendix contains analytical methods for determining Halon 1301 fire extinguishing agent concentration levels in empty or loaded cargo compartments as a function of time.

A.2 EXPLANATION OF TERMS AND SYMBOLS.

Table A-1. Terms and Symbols

SYMBOL	DESCRIPTION	UNITS CONSISTENT WITH EQUATIONS
C(t)	Halon 1301 concentration by volume at time (t). $= \frac{V_{Halon\ 1301}}{V}$	Dimensionless
$V_{Halon\ 1301}$	Volume of Halon 1301 in cargo compartment.	Cubic feet (ft^3) Cubic meters (m^3)
V	Cargo compartment free volume (i.e., volume not occupied by cargo). $= -\left(\frac{V_{cargo}}{V_{empty}}\right)$	Cubic feet (ft^3) Cubic meters (m^3)
V_{cargo}	Cargo volume.	Cubic feet (ft^3) Cubic meters (m^3)
V_{empty}	Empty cargo compartment volume.	Cubic feet (ft^3) Cubic meters (m^3)
T	Time.	Minutes (min)
E	Cargo compartment leakage rate.	Cubic feet per minute (ft^3/min) Cubic meter per minute (m^3/min)
S	Specific volume of Halon 1301.	Cubic feet per pounds (mass) (ft^3/lbm) Cubic meters per kilogram (m^3/kg)
R	Halon 1301 flow rate.	Pounds (mass) per minute (lbm/min) Kilogram per minute (kg/min)

A.3 HALON 1301 CONCENTRATION LEVEL MODEL.

A.3.1 Cargo compartment fire extinguishing systems generally use a combination of one or two types of Halon 1301 discharge methods. One type rapidly releases all of the fire extinguishing agent from one or more pressurized bottles into the cargo compartment. This type of discharge method is commonly known as a high-rate discharge or ‘dump’ system.

A.3.2 The second type of Halon 1301 discharge method slowly releases the fire extinguishing agent from one or more pressurized bottles into the cargo compartment. This type of discharge method is commonly known as a metering system.

A.3.3 The following list provides some examples, not all-inclusive, of different combinations of these Halon 1301 discharge methods:

A.3.3.1 One high-rate discharge.

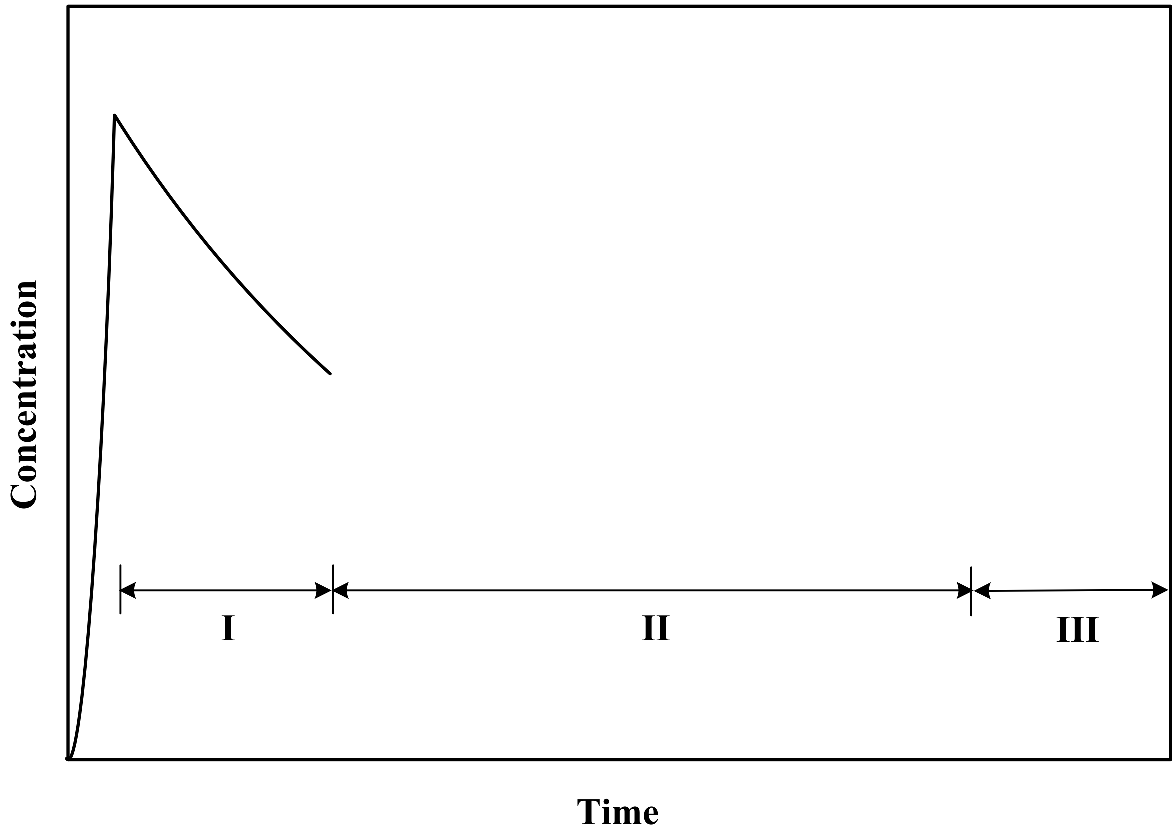
A.3.3.2 One high-rate discharge followed by a second high-rate discharge at a specified later time.

A.3.3.3 One high-rate discharge followed by a metered discharge at a specified later time.

A.3.3.4 Simultaneous high-rate and metered discharges.

A.3.4 The Halon 1301 fire extinguishing system that incorporates both high-rate and metered discharges, as in paragraph A.3.3.4, is illustrated in figure A-1 of this AC.

Figure A-1. Example – Halon 1301 Model



A.3.5 **Prior to Phase I: Initial High-Rate Discharge of Halon 1301.**

This portion of the extinguishing process illustrates the high-rate discharge method of releasing all of the fire extinguishing agent from one or more pressurized bottles into the cargo compartment.

A.3.6 **Phase I: Exponential "Decay" of Halon 1301.**

A.3.6.1 The beginning of Phase I represents the initial concentration of Halon 1301 used to knock down a cargo fire. Since no more Halon 1301 is introduced into the cargo compartment during Phase I, the concentration of Halon 1301 undergoes an exponential "decay" versus time.

A.3.6.2 The governing equation for exponential "decay" during Phase I is the following:

$$C(t) = C(0)e^{-\frac{Et}{V}}$$

Note: "C(0)" is the initial concentration of Halon 1301 used to knock down a cargo fire at the beginning of Phase I, and "t" is the time elapsed since the beginning of Phase I.

A.3.7 **Phase II: Metered Discharge of Halon 1301.**

A.3.7.1 The metered discharge of Halon 1301 starts at the beginning of Phase II. The example in figure A-1 of this AC shows that the metering rate is set to release Halon 1301 into the cargo compartment at a rate that is slightly greater than the rate Halon 1301 is lost through cargo compartment leakage.

A.3.7.2 The governing equation for metering during Phase II is the following:

$$C(t) = \left[C(0) - \left\{\frac{RS}{E}\right\}\right] e^{-\frac{Et}{V}} + \left\{\frac{RS}{E}\right\}$$

Note: "C(0)" is the concentration of Halon 1301 at the end of Phase I, and "t" is the time elapsed since the end of Phase I.

A.3.8 **Phase III: Exponential "Decay" of Halon 1301.**

The beginning of Phase III marks the end of Halon 1301 metering. As in Phase I, since no more Halon 1301 is introduced into the cargo compartment, the concentration of Halon 1301 undergoes an exponential "decay" versus time. The governing equation for exponential "decay" during Phase III is the same as during Phase I with one exception: "C(0)" is the concentration of Halon 1301 at the end of Phase II, and "t" is the time since the end of Phase II.

Advisory Circular Feedback

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by (1) emailing this form to 9-AWA-AVS-AIR500-Coord@faa.gov or (2) faxing it to the attention of the Aircraft Certification Service Directives Management Officer at (202) 267-3983.

Subject: ______________________________ Date: ____________________

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph __________ on page ____________ .

☐ Recommend paragraph __________ on page _________ be changed as follows:

☐ In a future change to this AC, please cover the following subject:
(Briefly describe what you want added.)

☐ Other comments:

☐ I would like to discuss the above. Please contact me.

Submitted by: ______________________________ Date: ____________________