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APPENDIX A —MINIMUM PERFORMANCE STANDARDS FOR AIRCRAFT CARGO COMPARTMENT GASEOUS FIRE SUPPRESSION SYSTEMS.

A.1. INTRODUCTION.

Federal Aviation Regulations (FARs) and Joint Aviation Regulations (JARs) require fire suppression systems for some classifications of cargo compartments. In the past, the aircraft industry has selected Halon 1301 total flood fire suppression systems as the most effective systems for complying with the regulations. Because of the ban on production of Halon 1301, mandated by the Montreal Protocol and effective January 1994, new fire suppression systems will need to be certified when the use of Halon 1301 is no longer viable. The tests described in this standard are one part of the total FAA/JAA certification process for cargo compartment fire suppression systems. Compliance with other applicable regulations, some of which are listed below, is also required. Applicants attempting to certify replacement systems are encouraged to discuss the required process with regulatory agencies prior to conducting testing.

A.1.1 APPLICABLE REGULATIONS.

The following existing FARs/JARs pertain to cargo compartment fire suppression systems:

25.851. "(b) Built-in fire extinguishers. If a built –in fire extinguisher is provided—

(1) Each built-in fire extinguishing system must be installed so that—
   (i) No extinguishing agent likely to enter personnel compartments will be hazardous to the occupants; and
   (ii) No discharge of the extinguisher can cause structural damage.
(2) The capacity of each required built-in extinguishing system must be adequate for any fire likely to occur in the compartment where used, considering the volume of the compartment and the ventilation rate."

25.855. "(h) Flight tests must be conducted to show compliance with the provisions of Sec. 25.857 concerning—

(1) Compartment accessibility,
(2) The entries of hazardous quantities of smoke or extinguishing agent into compartments occupied by the crew or passengers, and
(3) The dissipation of the extinguishing agent in Class C compartments.
   (i) During the above tests, it must be shown that no inadvertent operation of smoke or fire detectors in any compartment would occur as a result of fire contained in any other compartment, either during or after extinguishment, unless the extinguishing system floods each such compartment simultaneously."

25.857. "(c) Class C. A Class C cargo compartment is one not meeting the requirements for either a Class A or Class B compartment but in which—

(1) There is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station.

(2) There is an approved built-in fire extinguishing system controllable from the pilot or flight engineer stations;
(3) There are means to exclude hazardous quantities of smoke, flames, or extinguishing agent, from any compartment occupied by the crew or passengers;
(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."

In addition to these regulations, the FAA issued Airworthiness Directive 93-07-15 which required, among other things, that after November 2, 1996, the Class B cargo compartments on Boeing Models 707, 727, 737, 747, and 757 and McDonnell Douglas Models DC-8, DC-9, and DC-10 Series airplanes have improved fire protection features. One of three options available to comply with this AD is to modify Class B cargo compartments on these airplanes to comply with the requirements for Class C compartments. This option would require the installation of a fire suppression system.

One other area of rulemaking activity relating to cargo compartment suppression system requirements is the "Revised Standards for Cargo or Baggage Compartments in Transport Category Airplanes, Final Rule," effective March 19, 1998. This rule eliminates Class D cargo compartments on newly certified aircraft under Part 25 and requires existing Class D compartments on Part 121 certified passenger aircraft to comply with the detection and suppression/extinguishing system aspects of Class C cargo compartment requirements by March 19, 2001. This rule was issued by the FAA and at this time applies only to aircraft operated by U.S.-based airlines.

A.2. SCOPE.

This document establishes the minimum performance standards (MPS) that a cargo compartment fire suppression system must meet. It describes the tests that should be performed to demonstrate that the performance of the replacement agent/systems equals the performance of the currently approved Halon 1301 systems.

A.3. AGENT SELECTION GUIDANCE.

A.3.1 ENVIRONMENTAL.

The replacement agent must be approved under the Environmental Protection Agency (EPA), Clean Air Act, Significant New Alternatives Policy (SNAP) program, or other international governmental approving program. The primary environmental characteristics to be considered in assessing a new agent are Ozone Depletion Potential (ODP), Global Warming Potential (GWP), and Atmospheric Lifetime. The agent selected should have environmental characteristics in harmony with international laws and agreements, as well as applicable local laws. This MPS sets out the means of assessing the technical performance of potential alternatives. In selecting a new agent, it should be noted that an agent which does not have a zero or near zero ODP and the lowest practical GWP and Atmospheric Lifetime may have problems of international availability and commercial longevity.

A.3.2 TOXICOLOGY.

The toxicological acceptability of an agent is dependent on its use pattern. As a general rule, the agent must not pose an unacceptable health hazard for workers during installation and maintenance of the suppression system. At no time should the concentration present an unacceptable health hazard in areas where passengers or workers are present or where leakage could cause an agent to enter an occupied area. Following the release of the agent during fire suppression, the cumulative effect of the agent, its pyrolytic breakdown products, and the by-products of combustion must not pose an unacceptable health hazard.

FAR Parts 25.851, 25.855, and 25.857 all address the issue of hazardous quantities of smoke, gas, or extinguishing agent in occupied compartments. Conducting the fire tests described in this MPS does not address those issues. The FAA William J. Hughes Technical Center has conducted tests in an aircraft fuselage with in-flight airflow conditions. Data on the level of smoke, gases, and extinguishing agent in the normally occupied sections of the fuselage are available for some suppression agents and systems.

A.4. TEST REQUIREMENTS.

A.4.1 TEST ARTICLE.

The fire tests are to be conducted inside a simulated below floor cargo compartment of a wide-body aircraft. The volume of the compartment should be 2000 ± 100 cubic feet (56.6 ± 2.8 m^3). See figure A-1. The leakage rate from the compartment should be 50 ± 5 cubic feet per minute (1.4 ± 0.14 cubic meter per minute). The leakage from the compartment should be configured to simulate the “U”" shape of the cargo door seals that would exist on an actual aircraft. This can be done by installing perforated ducts inside the compartment in the shape of the perimeter of a cargo door and then venting those ducts outside the test article. A variable speed fan installed in the exit of the duct should be used to draw air out of the compartment. One-inch-diameter holes spaced at one hole every 5 inches (12.7 cm) in a round, 4-inch-diameter-steel duct has been shown to be effective. The perforated ducts should be installed on the opposite side of the cargo compartment from where the ignited box for the bulk-load and containerized-load fire scenarios are located. The return air back into the compartment should be evenly distributed and not from any one location.

A.4.2 INSTRUMENTATION.

Temperature measurements should be taken throughout the cargo compartment. Type K chromel/alumel 22 gauge thermocouples have been found to be effective at measuring temperatures in the range these fire scenarios produce. Ceiling thermocouples should be evenly spaced along the compartment ceiling with a maximum of 5 feet between adjacent thermocouples. One of the ceiling thermocouples should be installed directly above the initial ignition location for all fire scenarios. The beads of the ceiling thermocouples shall be 1 inch (2.5 cm) below the compartment ceiling. At least one thermocouple should be placed on the compartment sidewall 1 foot below ceiling level and centered on the fire ignition location. The sidewall thermocouple should be installed on the side of the compartment nearest the ignition location. At least two additional thermocouples should be placed in and above the box containing the igniter for the bulk and containerized fire scenarios. The purpose of these two thermocouples is to monitor and verify the ignition of the boxes. The readings are not part of the acceptance criteria. Care should be taken to prevent these thermocouples from contacting the energized coil of nichrome wire.

A continuous gas analyzer with a real time display of the gas concentration is required for the aerosol can scenario when the suppression system is a gaseous total flood system. A continuous gas analyzer may be required, depending on the suppression system design, for the bulk-load and containerized-load scenarios. Section A.4.4 describes the conditions when this may occur. The accuracy of the analyzer shall be ± 5% of the reading. The gas analyzer is used to measure the concentration of the gaseous suppression agent. The data-sampling rate for all the temperature measurements and the gas concentrations should be at least one data point every 5 seconds.

A pressure transducer is also required for the aerosol can fire scenario. The response time of the transducer should be 0.02 seconds or faster. Omega® manufactures several transducers suitable for this application. The transducer should be mounted on the ceiling in the geometric center of the compartment. The data-sampling rate for the pressure transducer should be at least 50 data points per second.

A.4.3 FIRE SCENARIOS.

The aircraft cargo compartment fire suppression system must successfully control the following four different fire scenarios.

A.4.3.1 Bulk Fire Load.

The fire load for this scenario shall be single-wall corrugated cardboard boxes, with nominal dimensions of 18 × 18 × 18 inches (45.7 × 45.7 × 45.7 cm). The weight per unit area of the cardboard should be 0.11 lbs/ft^2 (0.5417 kg/m^2). The boxes should be filled with 2.5 pounds (1.1 kg) of shredded office paper, loosely packed without compacting. The weight of the filled box should be 4.5 ± 0.4 lbs. (2.0 ± 0.2 kg). The flaps of the boxes should be tucked under each other with no staples or tape used. The boxes should be stacked in two layers into the cargo compartment in a quantity representing 30% of the cargo compartment empty volume. For a 2000 cubic foot (56.6 m^3) compartment, this would require 178 boxes. The boxes shall be touching each other without any significant air gaps between boxes. The test fire is ignited by applying 115 VAC to a 7 foot (2.1 m) length of nichrome wire. The wire is wrapped around four folded (in half) paper towels. The resistance of the nichrome igniter coil should be approximately 7 ohms. The igniter should be placed into the center of a box on the bottom outside row of the stacked boxes. Several ventilation holes should be placed in the side of the box to ensure that the fire does not self extinguish. Ten, 1.0-inch (2.5-cm) -diameter holes have been shown to be effective. See figures A-2 and A-3.

A.4.3.2 Containerized Fire Load.

The same type of cardboard boxes filled with shredded office paper and the same igniter used in the bulk-load fire scenario should be used in this scenario. The boxes should be stacked inside an LD-3 container as shown in figure A-4. The boxes shall be touching each other with no significant air gaps between them. The container shall be constructed of an aluminum top and inboard side, a Lexan (polycarbonate) front, and the remainder of steel. Two rectangular slots for ventilation should be cut into the container in the center of the Lexan front and in the center of the sloping sidewall. The slots should be 12 by 3 ± 1/4 inch (30.5 × 7.6 ± 0.6 cm). See figure A-5. The igniter is placed in a box on the bottom row, in the corner nearest the sloping side of the container and the Lexan. Ventilation holes should be placed in the sides of the box. Ten, 1.0-inch (2.5-cm) -diameter holes have been shown to be effective. Two additional, empty LD-3 containers are placed adjacent to the first container. See figure A-6.

A.4.3.3 Surface Burning Fire.

One-half U.S. gallon (1.9 liters) of Jet A fuel in a square pan should be used for this scenario. The pan should be constructed of 1/8-inch (0.3-cm) steel and measure 2 feet by 2 feet by 4 inches high (60.9 cm × 60.9 cm × 10.2 cm). Approximately 13 fluid ounces (385 ml.) of gasoline should be added to the pan to make ignition easier. Two and one-half gallons (9.5 liters) of water placed in the pan has been found to be useful in keeping the pan cooler and minimizing warping. This quantity of fuel and pan size is sufficient to burn vigorously for approximately 4 minutes if not suppressed. The position of the pan in the cargo compartment should be in the most difficult location for the particular suppression system being tested. The pan should be located 12 inches below the cargo compartment ceiling if the suppression system uses a gaseous agent with a density at standard pressure and temperature (14.7 psia (101.3 kPa), 59.0°F (15°C)) greater than air. The pan should be 12 inches (30.5 cm) above the floor of the compartment if the suppression system uses a gaseous agent with a density less than air at standard pressure and temperature. The pan should be at the compartment mid height when the suppression agent has a density equal to that of air. The pan should be located at the maximum horizontal distance from any discharge nozzles for all tests, regardless of the suppression agent used. See figure A-7.

A.4.3.4 Exploding Aerosol Can Fire.

This scenario addresses the overpressure and bursting of an aerosol can involved in a cargo fire and the potential for the ignition of the released hydrocarbon propellant used in these cans. The FAA William J. Hughes Technical Center has developed an aerosol can simulator that releases a mixture of propane and alcohol through a large area valve and across sparking electrodes.

The aerosol explosion simulator must utilize a cylindrical pressure vessel for the storage of flammable base product and propellant. The pressure vessel must be capable of withstanding a minimum pressure of 300 psi (2068.5 KPa). The pressure vessel must be mated to a ball valve capable of withstanding a minimum pressure of 300 psi (2068.5 KPa). The port diameter of the ball must be 1.5 inches (3.8 cm) (note: a ball valve is typically classified according to the diameter of the pipe that it connects to, but this is not necessarily the size of the ball port). The ball valve must be capable of rotating from the fully closed position to the fully open position in less than 0.1 second to allow the formation of a vapor cloud. Longer opening durations will significantly affect the vapor cloud formation and, hence, the explosive force yielded. The ball valve can be activated by any suitable means, including pneumatic or hydraulic actuators or manually via the appropriate linkage. The pressure vessel must be mounted vertically above the ball valve to allow for complete expulsion of the liquid contents. A discharge elbow located vertically under the ball valve will direct the contents horizontally (figure A-8).

Pressure Vessel. A steel 2-inch (5.1-cm) diameter, 11-inch (27.9-cm) -long schedule 80 pipe welded or capped at one end has been found suitable for storage of the pressurized mix.

Ball Valve. The 2-inch (5.1-cm) valve must be constructed of a material capable of withstanding interaction with ethanol and propane. A DynaQuip® stainless steel valve has been found suitable for this application.

Ball-Valve Actuator. A pneumatic rotary actuator has been found suitable for quickly and reliably rotating the ball valve from closed to fully open. A Speedaire® 90-degree actuator with a 2-inch (5.1-cm) bore performs well.

Propellant Heater. A system for heating the pressurized propellant mix after transfer to the pressure vessel must be provided. This would include a hot-air gun directed toward the pressure vessel, a hot-wire wrap, or other suitable means.

Pressure Gauge. A suitable device for measuring the pressure of the contents must be installed on the simulator pressure vessel. The device must be capable of measuring the pressure to within ± 5 psi (34.5 KPa).

Propellant Mix. The base product/propellant mix should consist of 20% liquid propane (C_3H_8, 3.2 ounces [0.09 kg]), 60% ethanol (denatured alcohol, 9.6 ounces [0.27 kg]), and 20% water (3.2 ounces [0.09 kg]). The total weight of the base product/propellant mix should be 16 ounces.

Spark Igniters. A set of direct current (DC) spark igniters must be used to ignite the propellant/base product mix as it is discharged from the pressure vessel. An ignition transformer capable of providing 10,000 volts output has been found to be suitable for powering the igniters, which should be placed 36 inches (91.4 cm) from the point of discharge. The spark igniter gap should be set at 0.25 inch (0.64 cm).

The procedure for conducting the aerosol simulator test is as follows:

Weight the empty simulator device on a suitable scale. Place the 9.6 ounces (0.27 kg) of ethanol (denatured alcohol) and 3.2 ounces (0.09 kg) of water into the pressure vessel. Transfer 3.2 ounces (0.09 kg) of liquid propane from a storage tank into the pressure vessel. Remove all transfer lines and check final mass. Mount the simulator device in either the forward or aft compartment bulkhead such that discharge is directed into the compartment, across spark igniters. Simulator discharge port and the spark igniter must be 2 feet (60.9 cm) above the compartment floor. Begin heating the pressure vessel to raise the pressure of the contents to 210

± 5 psi (1448 ± 34.4 KPa). Activate the suppression agent/system. Activate the spark igniters. Release the charged contents into the compartment when the concentration of agent is within ± 0.1% of the minimum design concentration.

A.4.4 SUPPRESSION SYSTEM DESIGN.

The suppression system design used for these fire tests should be similar to the design intended for use in aircraft. For a gaseous total flood system, the quantity of agent used should be that quantity that will produce the same initial concentration by volume in an empty 2000 cubic foot (56.6-m^3) compartment as the initial design concentration that will be demonstrated in the required flight test in the actual aircraft cargo compartment. Some aircraft total flood system designs consist of single-bottle discharges, multiple-bottle discharges at staggered intervals, and single-bottle discharges followed by metered systems that bleed smaller quantities of agent into the compartment to maintain the desired concentration. The compartment volume, leakage rate, and diversion time for the aircraft determines the type of system necessary. There may be situations when the volume, leakage rate, and 30-minute test duration required by these fire tests would not allow for the use of the same system design as is intended for installation in an aircraft. One possible situation could be when the leakage from the actual aircraft cargo compartment is much lower than what is required for the fire test and a single-bottle discharge is sufficient to maintain adequate concentration in the aircraft but not in the fire test article. For this and other situations that require changing the system design, a metered system may be used to maintain adequate concentration of agent. The concentration that should be maintained for the fire test should be the minimum design concentration that the system will demonstrate can be maintained by the required flight test. If a metered system is used in the fire test, the concentration in the compartment after the metered system is started should not be allowed to go higher than 10% above the minimum design concentration. The concentration should be measured at heights of 16″ (40.6 cm), 32.5″ (82.5 cm), and 49″ (124.4 cm) in the middle of the compartment. The design and initial concentrations referenced in this paragraph for the fire test refer to the arithmetic average of the three different probe heights. The method of measuring the concentration of agent in the required flight test might not use the arithmetic average of three probes. The certification authority that requires the flight test will specify the number and location of the probes that should be used to determine the concentration of agent in the compartment.

For a nongaseous suppression system, parameters such as activation set points, operating pressures, nozzle spacing and direction, etc. should be the same as the system intended to be installed in the actual aircraft. Other factors that are cargo compartment size dependent such as agent quantity, number of nozzles, zone sizes, etc. should be scaled up or down as appropriate when the volume and/or shape of the compartment in the actual aircraft is different than the 2000-cubic foot (56.6-m^3) compartment required for these tests.

A.4.5 SUPPRESSION SYSTEM ACTIVATION.

Bulk-load, containerized-load and surface-burning fire scenarios: The suppression system should be activated 60 seconds after any one of the ceiling mounted thermocouples equals or exceeds 200°F (93.3°C).

Aerosol can scenario: For a gaseous total flood suppression system, the aerosol can simulator should be activated when the agent concentration 2 feet (60.9 cm) above the compartment floor is at the minimum volumetric design concentration ± 0.1%. The agent concentration must be actually measured during this test. Calculation of agent concentration based on the leakage rate is not permitted. The sampling probe for measuring agent concentration should be 36 inches (91.4 cm) from the exit of the aerosol simulator and less than 18 inches (45.7 cm) from the spark igniters. For a suppression system that is not a total flood gaseous system, the aerosol simulator should be positioned at the most difficult location for that particular system.

A.4.6 TEST DURATION.

The duration of the bulk-load and containerized-load fire scenario tests shall be for 30 minutes after the activation of the suppression system. The surface-burning fire test shall be conducted for 5 minutes from the time the suppression system is activated or until the fire is extinguished, whichever occurs first. The exploding aerosol can test scenario is complete 15 seconds after the release of the aerosol simulator contents.

A.5 ACCEPTANCE CRITERIA.

The acceptance criterion for the bulk load fire scenario is that none of the ceiling or sidewall thermocouples exceed 730°F (387.8°C) starting 30 seconds after the suppression system is initially activated until the end of the test. In addition, the area under the time-temperature curve for the ceiling thermocouple that recorded the highest temperature starting 30 seconds after the suppression system was activated cannot exceed 11900°F-min (6593°C-min). The area should be computed from the time of initial suppression system activation until the end of the 30-minute test duration.

The criteria for the containerized-load fire scenario is that none of the ceiling or sidewall thermocouples exceed 670°F (354.4°C), starting 30 seconds after the suppression system is initially activated. The area under the time-temperature curve cannot exceed 15.400°F-min (8538°C-min). These values for the bulk, containerized, and surface burn fires are based on an approximate 10% increase over the maximum values obtained in a series of tests conducted under the requirements of this MPS using Halon 1301 as the suppression agent. Figure A-9 shows the critical times during a test for computing the acceptance criteria for the bulk and containerized fire scenarios.

The acceptance criteria for the surface-burning fire scenario is that none of the ceiling or sidewall temperatures exceed 1250°F (677°C) starting 30 seconds after the suppression system is initially activated until the end of the test. In addition, the area under the time-temperature curve cannot exceed 3.270°F-min (1799°C-min).

The criteria for the aerosol can scenario is that no overpressure should be present in the compartment at the time the simulator is activated.

Five tests must be conducted for each scenario. The suppression system must successfully meet the acceptance criteria for all five tests. Table A-1 summarizes the acceptance criteria for the four fire tests.

TABLE A-1. ACCEPTANCE CRITERIA

Fire Scenario	Maximum Temp. °F (°C)	Maximum Pressure psi (KPa)	Maximum Temp-Time Area °F-min. (°C-min)	Comments
Bulk Load	730 (387.8)	Not applicable	11,900 (6,593)	Temperature limit starting 30 seconds after suppression system activation. Temp.-Time area for 30 minutes starting with suppression system activation.
Containerized Load	670 (354.4)	Not applicable	15,400 (8538)	Temperature limit starting 30 seconds after suppression system activation. Temp.-Time area for 30 minutes starting with suppression system activation.
Surface Fire	1250 (676.7)	Not applicable	3,270 (1799)	Temperature limit starting 30 seconds after suppression system activation. Temp.-Time area for 5 minutes starting with suppression system activation.
Aerosol Can	Not Applicable	0	Not applicable	There shall be no explosion

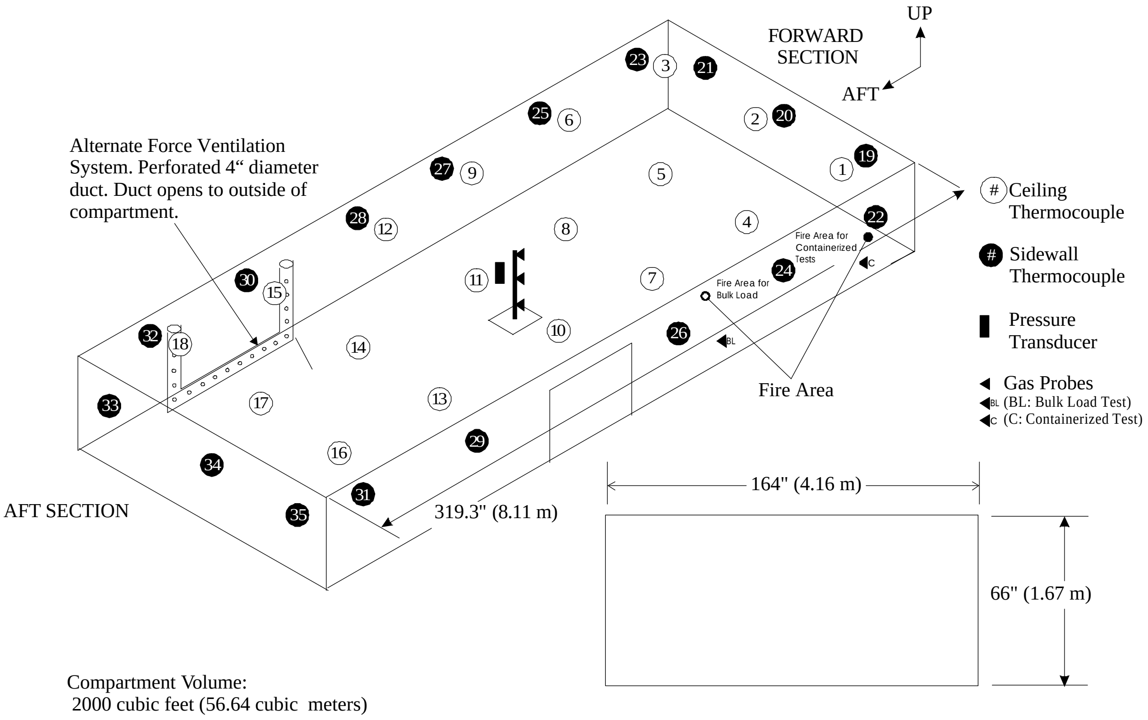


FIGURE A-1. CARGO COMPARTMENT LAYOUT AND INSTRUMENTATION LOCATIONS

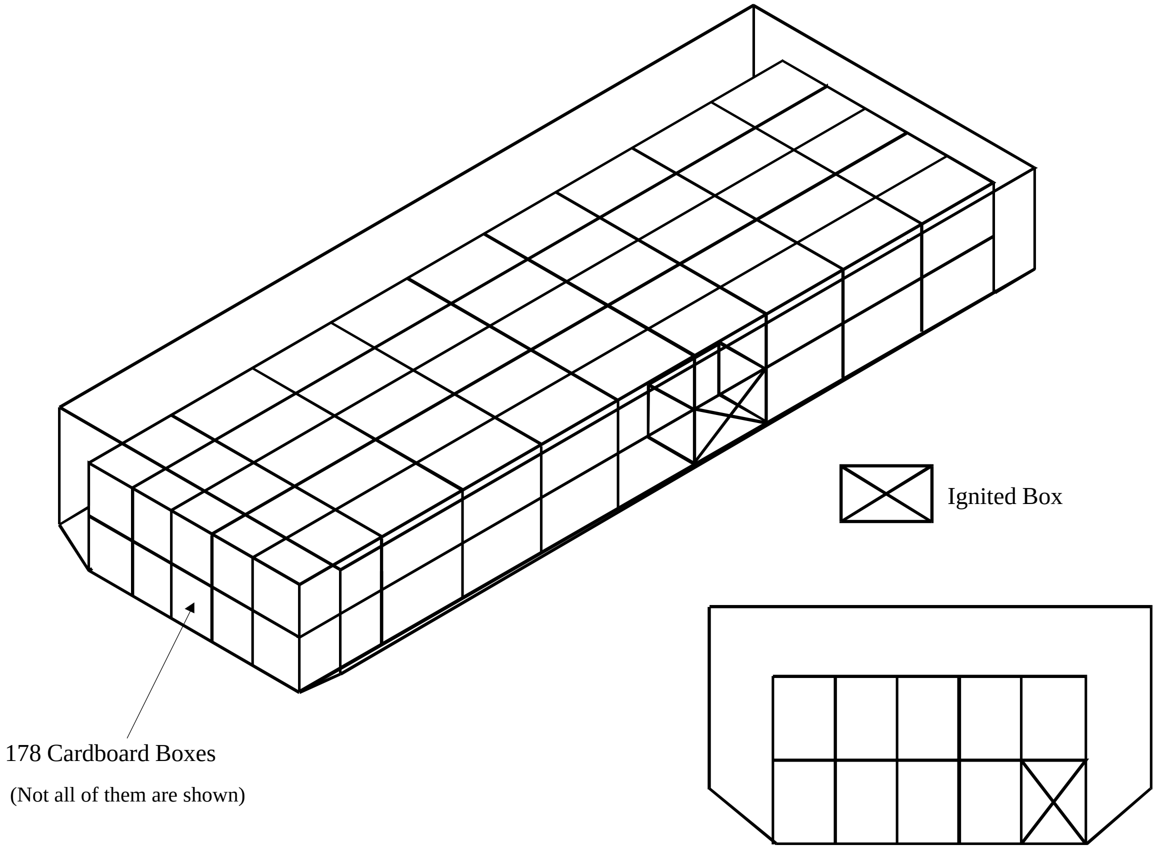
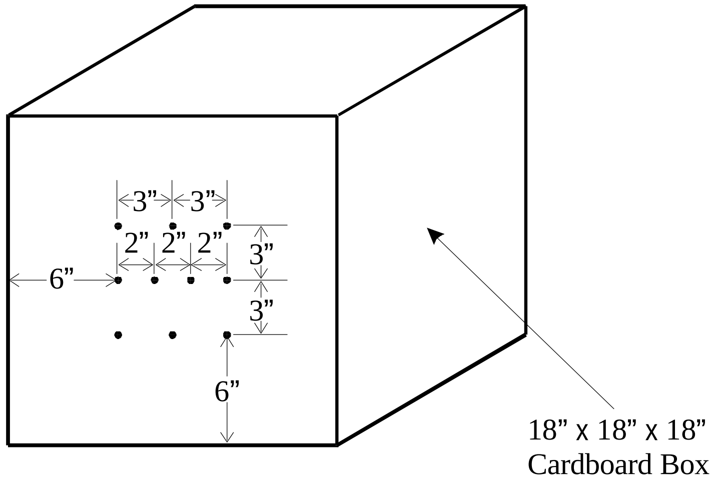


FIGURE A-2. BULK FIRE LOAD TEST SET-UP



6 inch (15.2 cm)
3 inch (7.6 cm)
2 inch (5.0 cm)

- 1.0-inch (2.54-cm) diameter holes

FIGURE A-3. IGNITER BOX

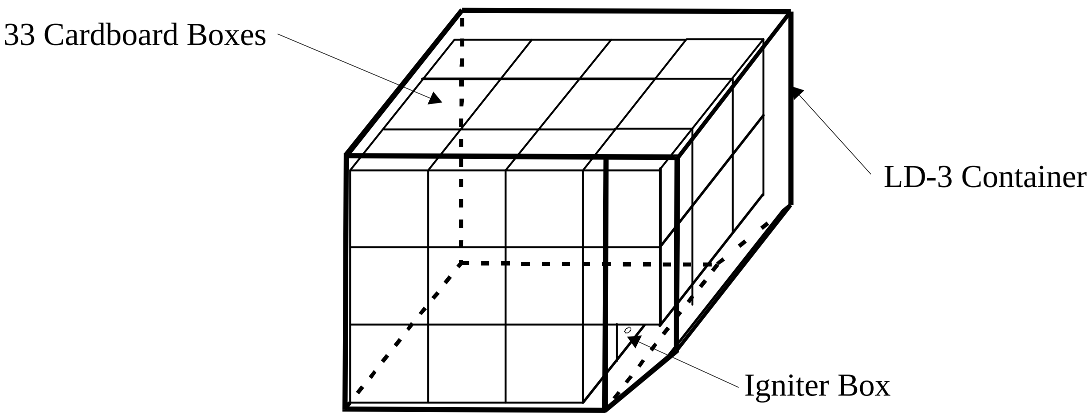


FIGURE A-4. CONTAINERIZED FIRE TEST SET-UP

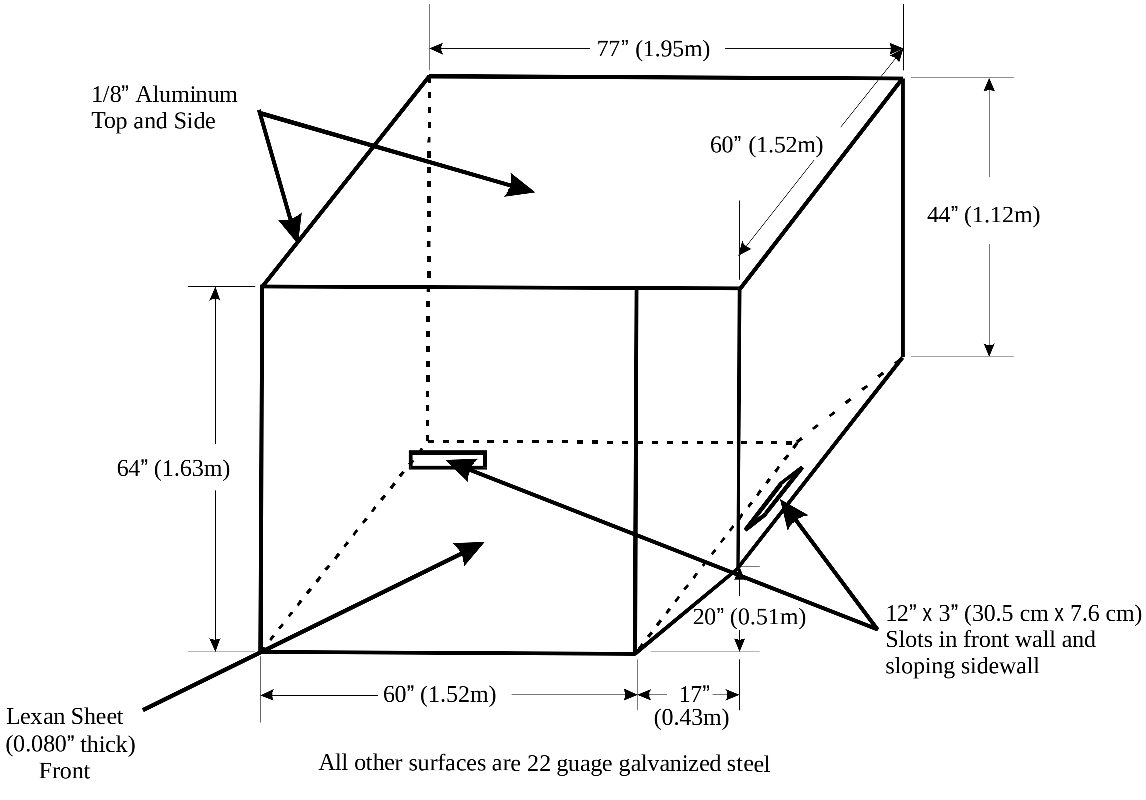


FIGURE A-5. LD-3 CONTAINER

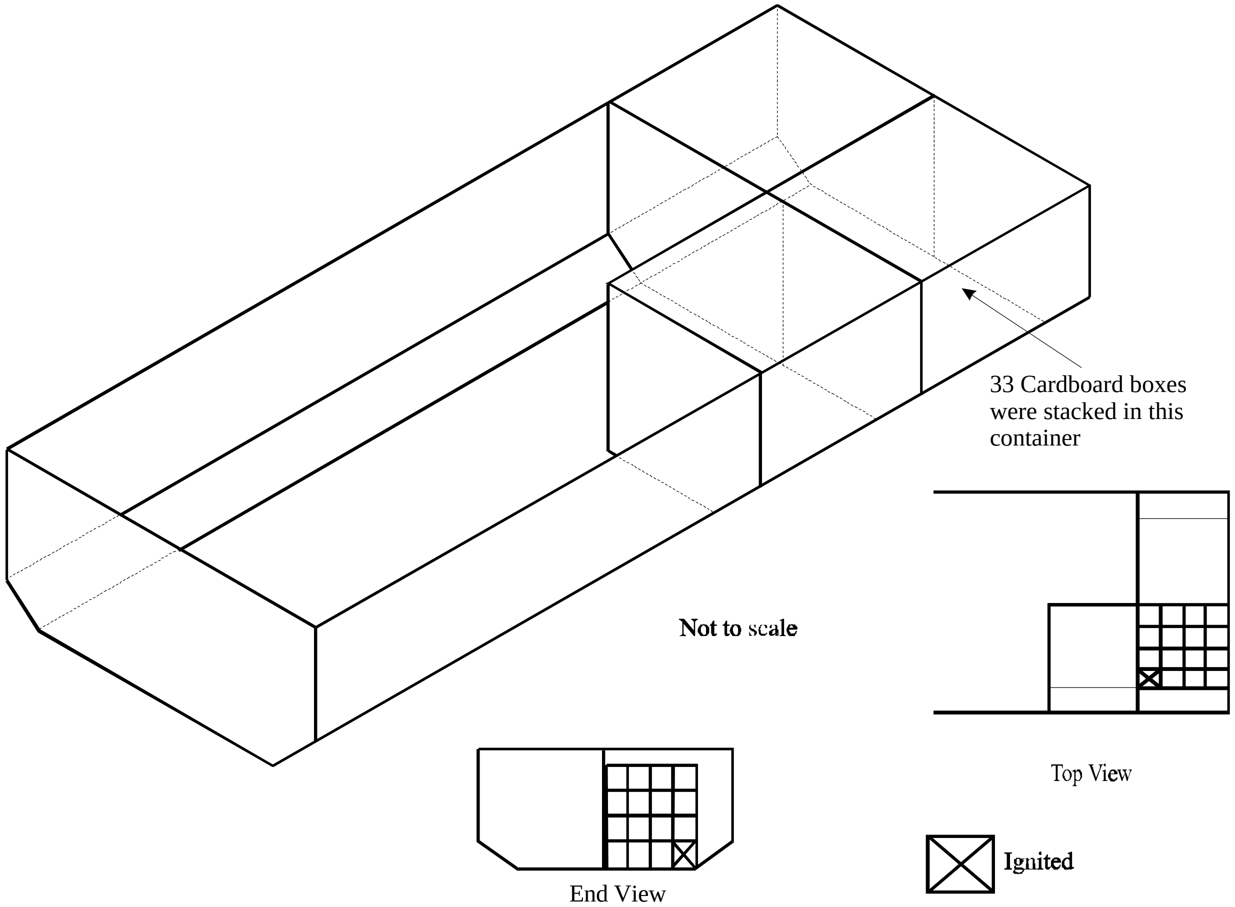


FIGURE A-6. LD-3 CONTAINERS ARRANGEMENT

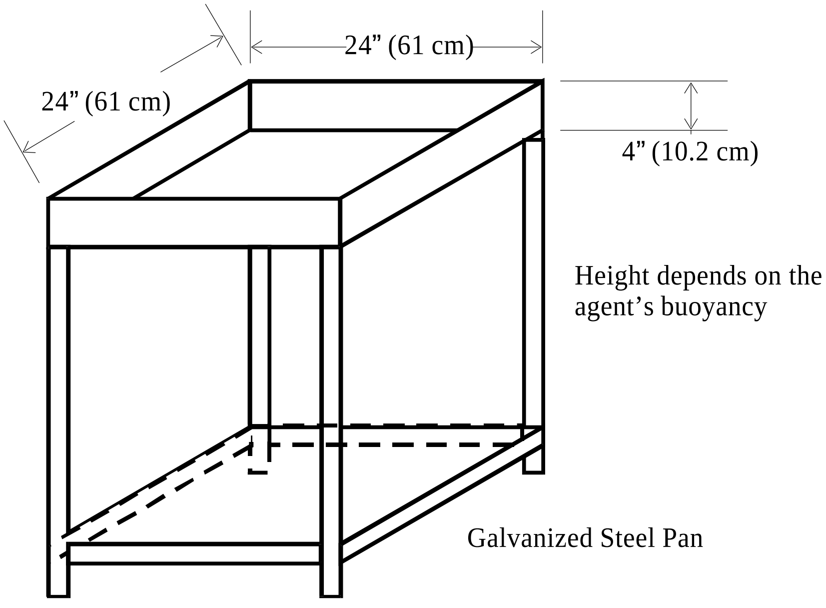


FIGURE A-7. SURFACE BURNING FIRE PAN

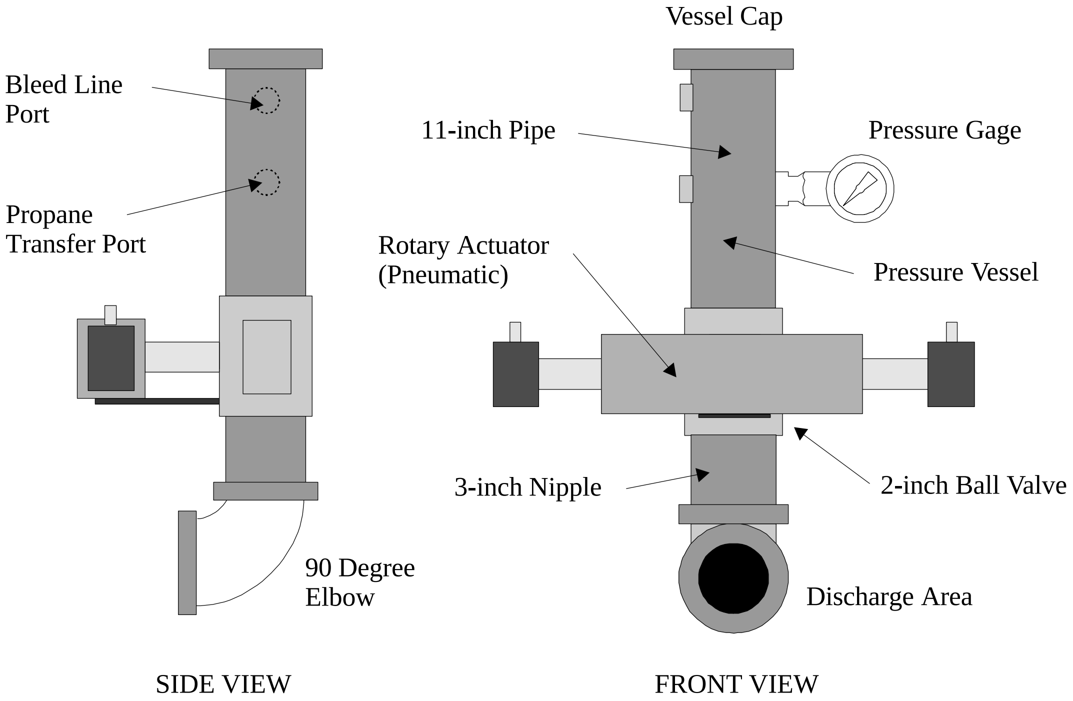


FIGURE A-8. SCHEMATIC OF AEROSOL EXPLOSION SIMULATOR

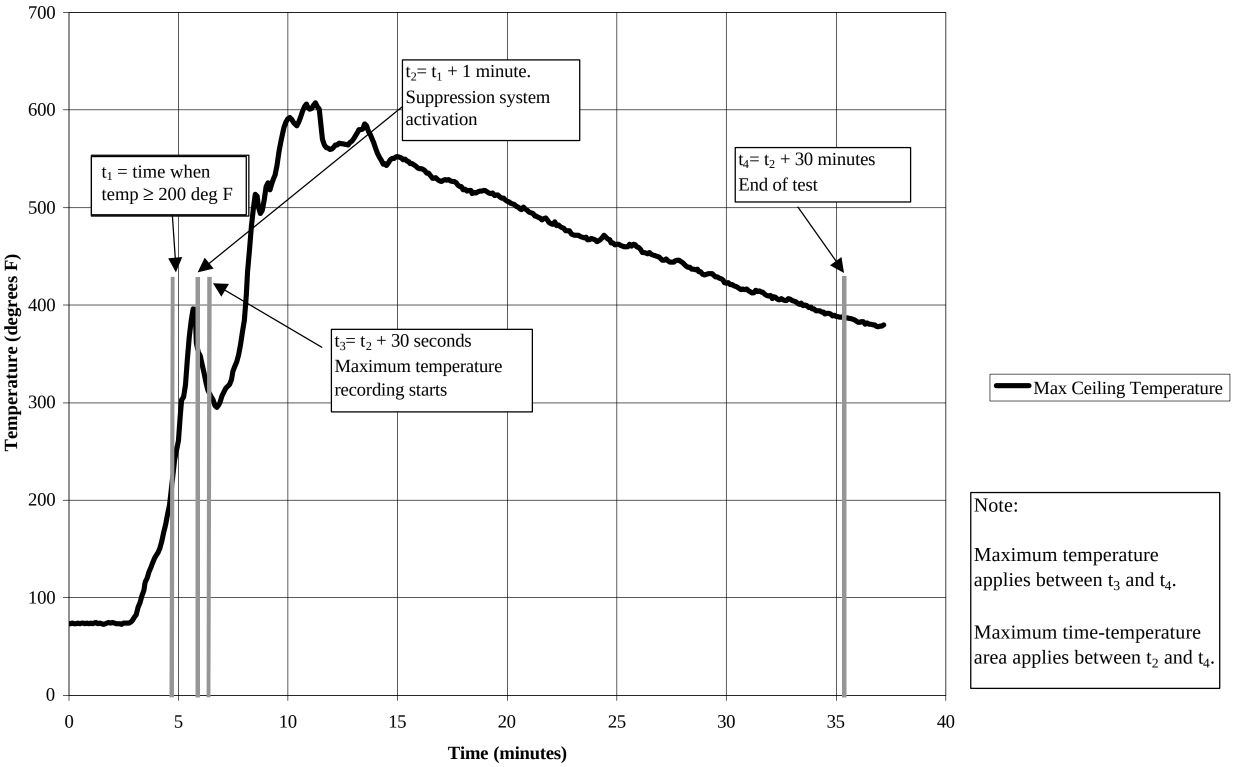


FIGURE A-9. ACCEPTANCE CRITERIA BOUNDARIES